Samuel Neaman Institute
FOR ADVANCED STUDIES IN SCIENCE AND TECHNOLOGY

Technion
Israel Institute of Technology

Bioethanol in Israel: Global Context, Research, Planning and Policy

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THE SAMUEL NEAMAN INSTITUTE
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FOREWORD

The ongoing efforts to advance the research and promote the introduction of biofuels into world markets have elicited a heated emotional debate regarding their perceived negative effects. Notwithstanding this debate, the push to introduce biofuels into the market continues in full swing and is due to three key drivers: energy security, rural development, and climate change. The importance of each of these drivers is different in different countries. Most countries embrace the need for energy security and rural development and encourage the increased use of biofuels for diversifying their energy portfolio, especially for transportation fuels. Additionally, in many countries biofuels are also touted for their environmental benefits and global warming mitigation potential.

The goal of this report is to examine the rapid advances in the bioethanol field in recent years and to provide the global context for examining its implications for the State of Israel. The report is organized in two parts. Part I provides a global perspective of state-of-the-art techniques for bioethanol feedstock production and the emergence of advanced processing technologies. The study also examines results from "well-to-wheels" analyses in order to ascertain the key factors contributing to a positive energy balance and greenhouse gas emission reductions. Part I also includes a summary of statutory frameworks in selected countries in order to highlight "best practices" that could be emulated in Israel.

In Part II, the study provides an 'Israeli specific' perspective by analyzing scenarios for bioethanol demand in Israel and by investigating the availability of agricultural and/or cellulosic feedstock in Israel along with their respective economic viability for bioethanol production. The study also reverts to the basic premise that not all biofuels are created alike, which makes it necessary to consider key sustainability tenets when undertaking to develop policy measures and implementation strategies.

The concluding sections of the report highlight the role of advanced research and development and the need for technological breakthroughs in several areas.

The project team wishes to thank the GM Foundation Israel for supporting this study and hopes that it will contribute to the development of a technically viable and sustainable Israeli national bioethanol strategy.

EXECUTIVE SUMMARY

The Samuel Neaman Institute (SNI) was requested by the GM Israel Foundation to assess the role that Israel can play in the global bioethanol market.

The current report examines the global trends in the bioethanol market and evaluates the potential advantages and the anticipated shortcomings of Israel adopting a national bioethanol strategy and the planning it would require. An overarching objective of this assessment is to evaluate whether bioethanol could be used as a relatively significant substitution for fossil fuel, as well as a pollution mitigation strategy, in the near term, when compared to other policy options.

GLOBAL PERSPECTIVE

The benefits of introducing biofuels stem from their contribution to energy security and rural development as well as their potential contribution towards mitigating global climate change and other environmental benefits. The main advantages of biofuels are attributable to the plants used to produce them. Plants absorb carbon dioxide from the atmosphere, but it takes land - and in most cases water as well - to grow these plants. It is these aspects of biofuels production that may lead to scarcity of land and water for other uses, eclipsing other benefits that could be derived from these alternative liquid transportation fuels.

Biofuels are typically classified as either “first generation” – referring to current production techniques that utilize the sugar or starch content of the plants - or “second generation”, which include advanced processing techniques that produce ethanol from the whole plant, including its cellulosic content.

In reviewing the plethora of recent studies on the different facets of these first and second-generation bioethanol pathways and related issues, the report has tried to address several key questions:

- ***What are the major findings when comparing biofuels by lifecycle analysis?***

  Lifecycle analyses studies are useful for comparing both the energy balance and the emissions of greenhouse gases from all the different stages of producing or using a fuel. Carbon dioxide (CO_2) is the largest contributor to global warming, hence by growing plant feedstock, such as sugar cane, sugar beets, corn, soybeans or switch-grass for biofuels, they absorb CO_2 from the atmosphere in their growing process and when cars and trucks burn biofuels, they return that CO_2 to the air resulting in zero net emissions. However, when analyzing the full “well to wheel” lifecycle of fuel production, blending and distribution, biofuels may lose the initial edge of atmospheric CO_2 absorption due to the energy balance associated with their production and processing steps.

An early consensus emerged that corn-based ethanol modestly reduces greenhouse gases, while producing bioethanol from sugarcane or switch-grass provides the most benefits. New studies are now emerging that show that only limited categories of biofuels are likely to reduce greenhouse gases as well as have a positive energy balance. This newer generation of analyses is showing that the loss of greenhouse gases from direct and indirect land use changes could exceed the other benefits of biofuels in the long run. The ultimate results indicate that some biofuels, such as those produced from municipal, industrial and agricultural waste, remain viable biofuel feedstocks and provide processing pathways that may reduce greenhouse gases, while contributing to diversification of energy supply.

Conclusion # 1: **New policies ought to focus on biofuels feedstocks that do not require the use of productive land or scarce water resources.**

- ***What are the advantages/disadvantages of “second-generation” biofuels?***

“Second-generation” biofuels that are produced from cellulosic feedstock are more beneficial than current “first generation” biofuels. Cellulosic feedstock may also come from a variety of sources, and if it utilizes productive land it could still have substantial impacts due to land use changes and water usage.

Notably, biofuels that use waste products will not trigger land use changes. Potentially significant sources for such feedstock include municipal, industrial and agricultural wastes, and the report identifies large potential sources of such waste products. Using agricultural wastes, however, needs to proceed with care. Many of the crop residues are left on the soil and are eventually plowed into it, limiting soil erosion and contributing to organic matter and nutrients. Their removal and use for biofuels has potential carbon costs as well as other environmental effects. Forest wastes could also contribute to the production of biofuels if they are true waste products.

Conclusion # 2: **Policies ought to incentivize the use of feedstocks based on cellulosic waste products in order to maximize the advantage of "second generation" biofuels.**

- ***What is the role of production process efficiency?***

Sugarcane, grown under careful conditions, may be a source of biofuel that provides both energy and greenhouse gas benefits. In Brazil, sugarcane is grown with remarkable productivity. Part of the high productivity of the Brazilian production is due to the fact that they use the whole plant in the process. Sugarcane ethanol refineries in Brazil use the waste 'bagasse' as a fuel for producing combined heat and power that provides the needed steam for processing and the electricity to run the plant.

It is evident from the energy balance studies reviewed, and supported by the IEA findings, that much of the positive energy balance of biofuel production is dependent on the design of the production process, i.e. the slate of commercial co-products generated, and the use of process biomass waste for combined generation of heat and power.

Conclusion # 3: **Policies should incentivize – and expedite permitting –biofuels production processes that are based on combined heat and power generation from the biomass residual of the feedstock.**

- ***How could Biofuels' sustainability be ascertained?***

Due to some of the potential drawbacks of biofuels it has become essential to distinguish between biofuels production pathways and create a way to ascertain their sustainability. Many call upon governments, the private sector, and other relevant stakeholders to take concerted, collaborative and coordinated action to ensure sustainable trade, use and production of biofuels. These steps are needed to assure that biofuels may play their key role in the transformation of the energy sector, contribute to climate stabilization and result in a worldwide renaissance of rural areas, all of which are needed urgently.

In order to accomplish these aims, there is an urgent need to Integrate and better coordinate policy frameworks and assess benefits and impacts of biofuels on land use, water resource needs, international trade, feedstocks used and production pathways.

Conclusion # 4: **Policies should comprise of "Sustainability Principles" that will encourage research, development and demonstration, and reward investments leading to positive impacts of biofuels production and use.**

ISRAELI PERSPECTIVE

Israel has the advantage of learning from the experience of the high-income (OECD) countries, before adopting her own biofuel policy framework. Within this context the report deals with two major questions:

- ***Should Israel aim to be a bioethanol producer?***

The findings indicate that the vast majority of grain as well as finished sugar-products that could comprise feedstock for bioethanol production are imported into Israel. Additional production of grain in Israel at present conditions would be designed to substitute imports for food and feed purposes rather than be used for bioethanol production.

The analysis has revealed that Israel is at a fundamental disadvantage in production of agricultural commodities that presently constitute "first generation" feedstock for bioethanol production. Additionally, future production of cellulose (timber, switchgrass, kenaf etc.) via conventional agricultural methods is probably unsuitable as well.

<u>Conclusion # 5:</u> **Israel should not aim to be a conventional – "first generation" - bioethanol producer, unless it serves a deliberate, short-term, energy security policy objective. Such a policy should be strictly time-limited and require offsetting energy inefficiency and environmental impacts.**

This report also indicates that approximately 885,000 MT of cellulose from origins of agricultural by-products, forest and garden waste and municipal solid waste (MSW) could be made available for bioethanol production. The majority (70%) of this amount will originate from MSW and a quarter from forest and municipal pruning. As technologies to efficiently convert cellulose develop these figures are expected to grow. Theoretically, sources currently suffice to provide about 265 million liters (200,000 MT) of bioethanol if utilized efficiently.

Assuming present consumption of about 2.2 million MT of gasoline in Israel and a growth forecast estimated at 1.5% per annum to 2.8 million MT by 2025. The total potential production volume of bioethanol based on feedstocks that originates in unutilized agricultural by-products and waste, could amount to over 9% of the total gasoline demand and could be used as a possible fuel blend.

<u>Conclusion # 6:</u> **Israel could supply almost 10% of gasoline demand by utilizing agricultural and municipal wastes as feedstock for bioethanol production, provided energy efficient processes are utilized including full utilization of process residual for combined heat and power production.**

- ***Should Israel aim to become a leading technologies developer?***

Israel has gained a worldwide reputation as a provider of ingenious solutions in agricultural production, and was recently praised at a special meeting of the Economic and Social Council of the United Nations: “Though Israel had not suffered social tensions because of the global food crisis…Israel had developed agricultural technologies allowing the country to increase yields over 27 times” (United Nations Headquarters, N.Y, 20 May 2008).

Israel has also demonstrated capabilities in biotechnology techniques that are essential for designing efficient processes for cellulosic bioethanol conversion methods, including the ability to efficiently produce key enzymes, algae and other applicable microorganisms.

The development and demonstration of such novel technologies has the potential of having a global impact on the biofuels field while concurrently helping Israel achieve its goal of introducing more sustainable transportation fuels domestically.

Conclusion # 7: **Israel should focus on research, development and demonstration of advanced agricultural technologies and biotechnology including a multi-faceted R&D effort of using cellulosic by-products from agricultural operations and municipal waste as feedstock for bioethanol**

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ISSUES AT-A-GLANCE

The world faces an energy challenge of historic proportions that is at the nexus of three global trends. The world population is increasing resulting in wide spread migration in search for income. Improving economic conditions and elevation of standards of living, especially in Asia, put a strain on providing food and energy resources. Concurrently, concerns over environmental degradation and climate change demand strategies that would constrain the use of fossil fuels in order to stabilize the concentration of greenhouse gases in the atmosphere.

World oil demand is expected to increase by more than 50% in the next two decades while its cost, which has recently surpassed $ 130/ barrel, might continue to rise due to the following risk factors:

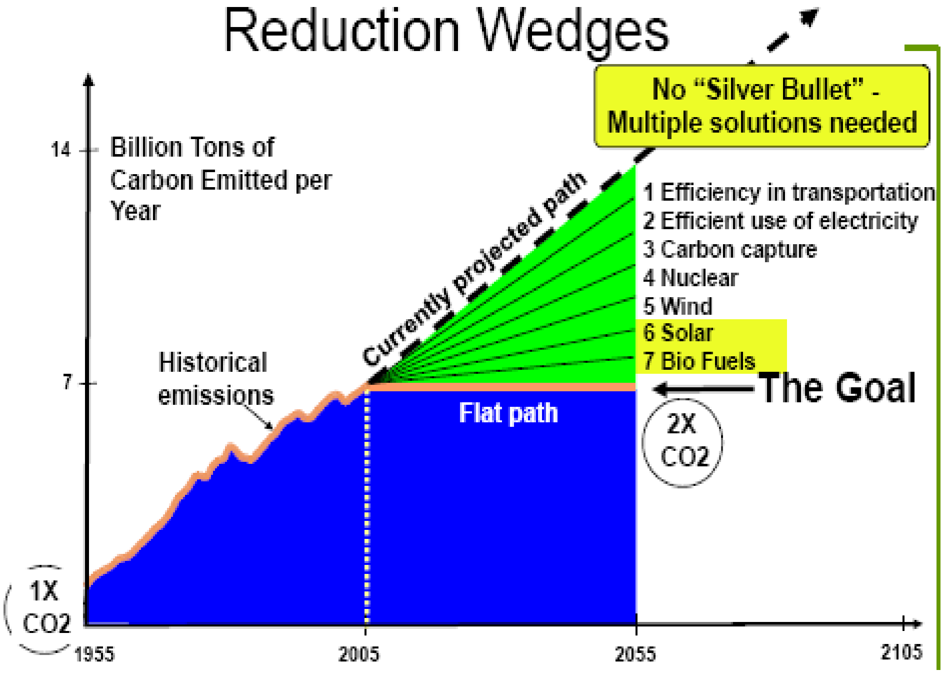
- Excessive dependence on a number of potentially unstable foreign oil suppliers;
- Conventional petroleum supplies that are not meeting the current and anticipated dramatic increases in world oil demand, particularly from emerging economies such as China and India;
- Possible supply disruptions due to natural disasters, political causes, regional wars and terrorism.

Rising fossil fuel prices and policies to tackle global climate change have created an environment where research, development and investment in renewable energy sources have gained new momentum. Among renewable energy sources, bio-energy derived from plant materials is one of the most rapidly growing sectors. However, it is becoming exceedingly clear that no single option could resolve these challenges alone: we must deploy every resource and technology at our disposal to meet the needs of an ever growing world population while protecting the environment and potentially reversing the trend of increased greenhouse gas emissions to the atmosphere.

Limiting atmospheric CO2 emissions

Proposals to limit atmospheric CO_2 to a concentration that would prevent most damaging climate change have focused on a goal of stabilizing the atmospheric concentration of CO_2 at 500 ± 50 ppm (parts per million), or less, double the pre-industrial concentration of 280 ppm. With the current concentration standing at 375 ppm, stabilization at 500 ppm requires that emissions will be held near the present level of 7 billion tons of carbon per year (GtC/year) for the next 50 years, even though they are currently on a course to more than double if no actions are taken.

Figure A- CO_2 Stabilization Wedges



According to the "Carbon Mitigation Initiative" at the Princeton Environmental Institute (PEI)[1] a "stabilization triangle" (Figure A) concept has been conceived in which different approaches and technologies could contribute to the reduction in emissions and dependency on fossil fuels. Investigating technologies that have the potential to produce a material difference over the next 50 years, the researchers at Princeton have envisioned equal "wedges", where each wedge represents an activity that has the potential to account for 1 GtC/year of reduced carbon emissions in 50 years. Looking at it cumulatively it can represent a total of 25 GtC of reduced emissions over 50 years[2]. According to this approach, substituting biomass fuel for fossil fuel would comprise one such "wedge".

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[1] Princeton Environmental Institute, 2007, "CMI in Brief- Building the Stabilization Triangle" , at: http://www.princeton.edu/~cmi/news/CMIinBrief.pdf

[2] Pacala, S., Socolow, R., 2004, "Stabilization Wedges: Solving the Climate Problem with Current Technologies for the Next 50 Years", Science, **305 (5686):** 968-972.

The role of advanced biofuels

According to the “wedge” strategy, fossil-carbon fuels can be replaced by bio-fuels such as ethanol. A wedge of bio-fuel would be achieved if in 50 years we reach a production of about 34 million barrels of ethanol per day to displace gasoline, provided the ethanol itself is fossil-carbon free. This ethanol production rate would be about 50 times larger than the current global production rate that is mostly attributed to Brazilian sugarcane and United States corn. Under today’s technologies, an ethanol wedge would require 250 million hectares committed to high-yield (15 dry tons/ hectare) plantations by 2054, an area equal to about one-sixth of the world's cropland.

This scenario does not take into account advances in biofuels production and feedstocks. Although most bioenergy production currently comes from agricultural crops such as grains, oilseeds and sugar, research is increasingly focused on cellulosic sources of biomass such as wood and perennial grasses, use of which would expand the range of potential feedstocks. Such advances in biofuel technology may ultimately lead to increasing the share of biofuels in the transportation fuel mix, which currently accounts for roughly 3% globally. Emerging biofuel technologies offer a great energy promise in conjunction with improved rural economic prosperity and overall standard of living. Hence, in developing sustainable biofuels, we could:

- Facilitate the emergence of new technologies
- Enhance economic growth by creating new jobs
- Lower trade and budget deficits
- Ensure energy availability and affordability
- Contribute to environmental protection and the potential of substantially reducing total atmospheric emissions.

The role of national policies

Biofuels, although useful in replacing fossil fuels, also present technical and economic constraints. Even though they could contribute to lowering the carbon content of fuels they require proper policies which are critical for markets to get on the right path. Some notable and unintended consequences of current policies are:

- They may lead to increased imports of fuels in the short-term (as stated by the EU directive: *'encourage the import of fuels from abroad and the domestic production of crops and fuels with low* CO_2*-equivalent savings');*
- They fail to recognize that low carbon technologies require more support at earlier phases of development, otherwise investments will flow to established technologies, especially in the absence of wider awareness of carbon pricing;
- The current approach is short on environmental and social co-benefits, may lead to detrimental land-use changes and is lacking in flood management and proper assessment of terrestrial carbon sequestration.

Report Objectives

The aim of this report is to investigate Israel's national biofuels policy and present recommendations as the nation enters the global biofuels market. In order to accomplish this goal the discussions and analysis have been divided into two parts: ***Part I*** provides a focused summary of the global perspectives of the issues raised, and ***Part II*** addresses the Israeli perspective. Since the overall focus of this report is on issues relating to bioethanol, it is that while other biofuels may be mentioned, neither was analyzed in detail.

In general, the report has been structured to attempt and answer the following questions:

1. How did the biofuels market emerge?
2. What are the latest processes and technologies for producing bioethanol?
3. What is the regulatory framework used in other countries?
4. What are the Israeli strengths and weaknesses regarding biofuels?
5. What should the Israeli government and legislature do next?

Part I – GLOBAL PERSPECTIVE

1 Definition of the Biofuels Market

The use of biofuels as a source of energy is not new. For many generations oils from coconut, palm and other species have been used to light lamps and heat stoves. Biogas made from animal manure has also been utilized as an energy source. Biofuels can be produced from just about any organic source that is rich in sugar and carbon. All forms of fuel, whether they occur in the form of a bale of hay, a bundle of wood, propane gas or petroleum, are fundamentally related. Their molecular structure contains carbon and hydrogen, the fundamental building blocks of energy.

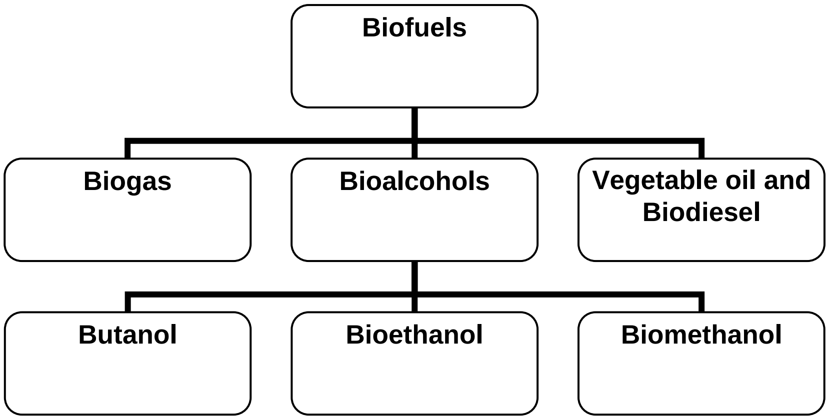
Biofuel can be broadly defined as solid, liquid, or gas fuel consisting of, or derived from biomass**.** Since biomass such as wood has been used directly for heating or power, a narrower, more relevant definition for biofuel is ***liquid or gaseous fuel derived from biomass***.

1.1 Emergence of Gasoline Blending Stocks

Different biofuels constitute alternatives for gasoline or diesel fuel (Figure 1.1). Although both types are generated via natural or chemical processes activated on natural carbohydrates, ***bioalcohols***, a fermentation product made from sugar, starch and cellulose comprise the basis for gasoline substitutes and triglycerides (oil) act as feedstock for ***bio ester*** production, an alternative for diesel.

At present, agricultural products specifically grown for biofuel production include sugar cane (in Brazil), corn (primarily in the USA), wheat and sugar beet (primarily in Europe) and sorghum and cassava (in China) - all grown for bioethanol production as alternatives for gasoline. Soybeans, primarily in the United States; rapeseed in Europe; palm oil in South-East Asia; and jatropha in India are feedstocks for bio-ester production as diesel substitutes. The two main types of biofuels currently used commercially are ***bioethanol and bio-esters***.

Figure 1.1- Biofules Production and Products



Bioalcohols are a group of organic compounds where a hydroxyl group (-OH) substitutes for one of the hydrogens of an alkyl group. Several of the bioalcohols of interest as blending stocks for transport fuel are summarized in Table 1.1.

Table 1.1- Typical Bioalcohols Used as Blending Stocks for Gasoline

TYPE OF BIOALCOHOL	SOURCE OR PRODUCTION PATHWAY	PROPERTIES AND USEAGE
Bioethanol	– Fermentation of sugars and starches – Produced by plants such as sugar cane and corn – Requires the presence of certain yeasts.	– Main gasoline alternative or blend stock, blended typically in mixtures up to 10% – In 2005, ethanol production: 3.9 Million gallons (or 2.9% of the gasoline pool)[3]
Biomethanol	– Known as methyl alcohol, carbinol, wood alcohol, wood naphtha or wood spirits.	– Used on a limited basis in fuel – Not nearly as flammable as gasoline – Corrosive and toxic and thus only a minor blending component
Biobutanol	– Produced by fermentation of biomass, – Butanol production inhibits microbial growth even at low concentrations, – Results in a fermentation product that is < 2% butanol – Research on this aspect might lead to wider use for gasoline blending.	– May be used as a fuel in internal combustion engines – Demonstrated to work in vehicles designed for use with gasoline without any modification – Considered as a 2nd generation biofuel

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[3] Energy Information Administration, 2007, "Biofuels in the U.S. Transportation Sector" at: http://www.eia.doe.gov/oiaf/analysispaper/biomass.html

Ethanol has a similar density - and is fully miscible - with gasoline. The early attraction to ethanol use in motorcars was its high-octane value. Low petroleum prices have essentially kept ethanol out the gasoline market until the oil crisis of the mid-1970. Demand for ethanol as a gasoline extender increased significantly in the U.S. after the passage of the 1990 Clean Air Act Amendments that mandated blending of oxygenates into gasoline to improve combustion efficiency and lower air pollution. Several ethanol blends and products are used in the motor fuels market, as shown in Text Boxes 1-2.

Text Box no.1- Types of Alcohols Blends Used For Transport Fuels

- **Hydrous ethanol** (95% ethanol, 5% water), can be used as a full substitute for gasoline in automobile engines, but requires special engine modifications. Standard spark-ignition gasoline cars cannot utilize such blends.
- **Anhydrous ethanol** (at least 99% ethanol, at most 1% water) can be used as a partial gasoline substitute, blended with conventional fuel between ratios of 5% and 85% (E85) ethanol. Cars with standard spark-ignition engines can utilize up to a 10% ethanol substitute (E10) without modification. Higher blends require modified engines and vehicles containing these engines are known as “flexible fuel” vehicles (FFVs).
- **Ethanol** is used as an oxygenate additive to gasoline in concentrations of 5-10%, promoting a more complete gasoline fuel combustion. It is used for local air pollution control aiming to reduce local emissions of CO and ozone precursors. It is increasingly replacing MTBE (methyl t-butyl ether) as the most popular oxygenate additive.
- **ETBE** (Ethyl t- Butyl Ether) can be manufactured from bioethanol. This is a fuel additive for conventional gasoline that can be blended instead of direct ethanol blends.

Source: American Coalition for Ethanol, 2008

Text Box no.2-
E85 Fuel & Vehicles Facts

- E85 is an alcohol fuel mixture that typically contains a mixture of up to 85% denatured fuel ethanol and gasoline or other hydrocarbon.
- On a non-denatured basis, the ethanol component ranges from 70% to 83%.
- E85 has the highest oxygen content of any transportation fuel currently available.
- E85 is used in engines modified to accept higher concentrations of ethanol, known as flexible-fuel vehicles (FFV) that are designed to run on any mixture of gasoline with up to 85% ethanol.
- Vehicles fueled by E85 typically have fewer exhaust emissions resulting in lower air emissions, including CO2, the main contributor to global warming, by as much as 39 to 46% when compared to conventional unleaded gasoline.
- E85 contains approximately 27% less energy per gallon than conventional unleaded gasoline, although ethanol typically burns more efficiently. These results in a fuel economy loss of less than the energy content would imply.

Source: National Ethanol Vehicles Coalition, 2008

With the increased worldwide interest in Renewable Energy, bioethanol has risen in prominence as a renewable transportation fuel. Bioethanol is derived from agricultural sources and the carbon dioxide produced during its combustion can be recycled as its feedstock is “renewable”, thus it is the essence of the Renewable Fuel Standard (RFS). The U. S. has made it a center of its Energy legislation in 2005 and had extended it in December 2007 by increasing the mandate for using bioethanol.

Text Box no.3- Ethanol Quick Facts

- In 2005, the U.S. produced about 4 billion gallons of ethanol from corn grain, equaling approximately 2% of the 140 billion gallons of gasoline consumed.
- Ethanol is widely used as a fuel additive. The oxygen contained in ethanol improves gasoline combustibility.
- The U.S. Energy Policy Act of 2005 has established a renewable fuels standard that requires using 7.5 billion gallons of ethanol by 2012.
- The U.S. Energy Independence and Security Act of 2007 has extended the renewable fuel standard to at least 36 billion gallons of ethanol to be used nationwide by 2022.
- E85 (85% ethanol and 15% gasoline blend) can be used as a substitute for gasoline in vehicles that have been modified to use E85.
- Energy content of E85 is 70% that of gasoline, so about 1.4 gallons of E85 are needed to displace one gallon of gasoline.
- An acre of corn generates about 4.5 tons of grain; 66% (3 tons) is starch that can be converted to 400 gallons of ethanol.
- Ethanol yield could be increased to roughly 700 gallons per acre by using corn stover (stalks and leaves) in addition to corn grain.
- Potential energy crops include perennial grasses like switchgrass or woody crops such as fast growing poplar. For these crops, average annual yield per acre is about 5 dry tons of cellulosic biomass.
- At a current conversion rate of 65 gallons per dry ton, an acre generates about 325 gallons of ethanol.
- Goals include increasing biomass yield to 10-15 dry tons per acre and ethanol yield to 80-100 gallons per dry ton of biomass.

Source: U.S. DOE, 2006

The demand for biofuels particularly in Europe and North America is spurred by legislation, mandates and economic incentives that come to address issues such as energy security, sustainable income for rural/farming communities and lessening of environmental impacts - especially greenhouse gas emissions that lead to climate change.

Despite initial development challenges and controversies about the exact benefits of biofuels, the biofuels industry is poised for significant growth over the next decade or so, and is viewed as one in a menu of solutions to address energy diversification and sustainability.

Due to both environmental reasons and the need to consider future energy requirements, the transition to bioethanol has been very rapid over the last few years. Table 1.2 below provides a brief summary of the advantages and disadvantages that ought to be considered when evaluating the widespread use of bioethanol.

Table 1.2- Bioethanol: Comparative Advantages and Disadvantages

ADVANTAGES OF BIOETHANOL	DISADVANTAGES OF BIOETHANOL
Fossil fuel replacement: Crops used for ethanol production absorb CO2 released by the combustion of ethanol, thus maintaining a CO2 balance.	**Infrastructure conversion:** The move from gasoline to Ethanol will require a new infrastructure of pipelines, fuel storage, and transportation facilities.
Sustainable fuel supply: Bioethanol can be produced from nearly any type of crop—corn and sugar or even trees and straw—especially with improved processing technologies	**Flexible-fuel vehicles (FFVs):** New vehicles will be needed to be able to utilize both gasoline and ethanol fuels of any concentration. Today’s automobile engines can only tolerate ethanol mixtures up to 10%.
Energy security: For many countries producing ethanol from their homegrown feedstocks will increase energy security and governments will become less reliant on foreign petroleum exports.	**Contamination of ethanol-blended gasoline:** Ethanol is highly miscible with water and it can cause phase separation, and thus destruction of the fuel. Transporting ethanol and gasoline separately and mixing them at the fueling station, is costly energetically and economically.
Higher fuel quality: Ethanol, by itself, has a much higher octane rating than gasoline and thus improves the compression ratio of an internal combustion engine, allowing for increased thermal efficiency.	**“Food vs. Fuel” dilemma:** The use of food crops for producing bioethanol is leading to an unprecedented increase in crops – particularly grains – prices all over the world. The outcome might be rationing of one or the other or both unless new processing technologies are developed for extracting ethanol from non-edible feedstocks.

1.2 Market Overview

1.2.1 Historical Review

The use of ethanol as a transportation fuel started in 1876 when a combustion engine was designed to use alcohol and gasoline.

In 1908, Henry Ford designed his Model T to run on ethanol, gasoline, or a combination of these fuels. However, as the cost of gasoline became much lower than ethanol, it lost popularity despite federal and state legislation and efforts by Henry Ford and others to promote it. The mid - 1940's saw the end of ethanol production for fuel, until the oil embargo[4] of 1973.

The first major world oil crisis began in October 1973, following The Yom Kippur War between Israel Syria and Egypt. OPEC (the Organization of Petroleum Exporting Countries) imposed an oil embargo on countries supporting Israel with the United States and the Netherlands being specifically targeted. OPEC members were determined to use their leverage over the world price-setting mechanism of oil to raise world oil prices. The market price for crude oil rose substantially, from $3.00/barrel in 1972 to over $12.00 by the end of 1974.

The dependence of the western world on Middle Eastern oil was further intensified as a result of internal events in Iran and Iraq during 1978-1980. The Iranian revolution resulted in the loss of 2-2.5 million barrels per day of oil production between November 1978 and June 1979. The combination of the Iranian revolution and the Iraq-Iran War caused crude oil prices to more than double, increasing from $14/barrel in 1978 to $35 in 1981[5]. Figure 1.2 shows the crude oil price changes that resulted from these and other historical events between 1970 and August 2007.

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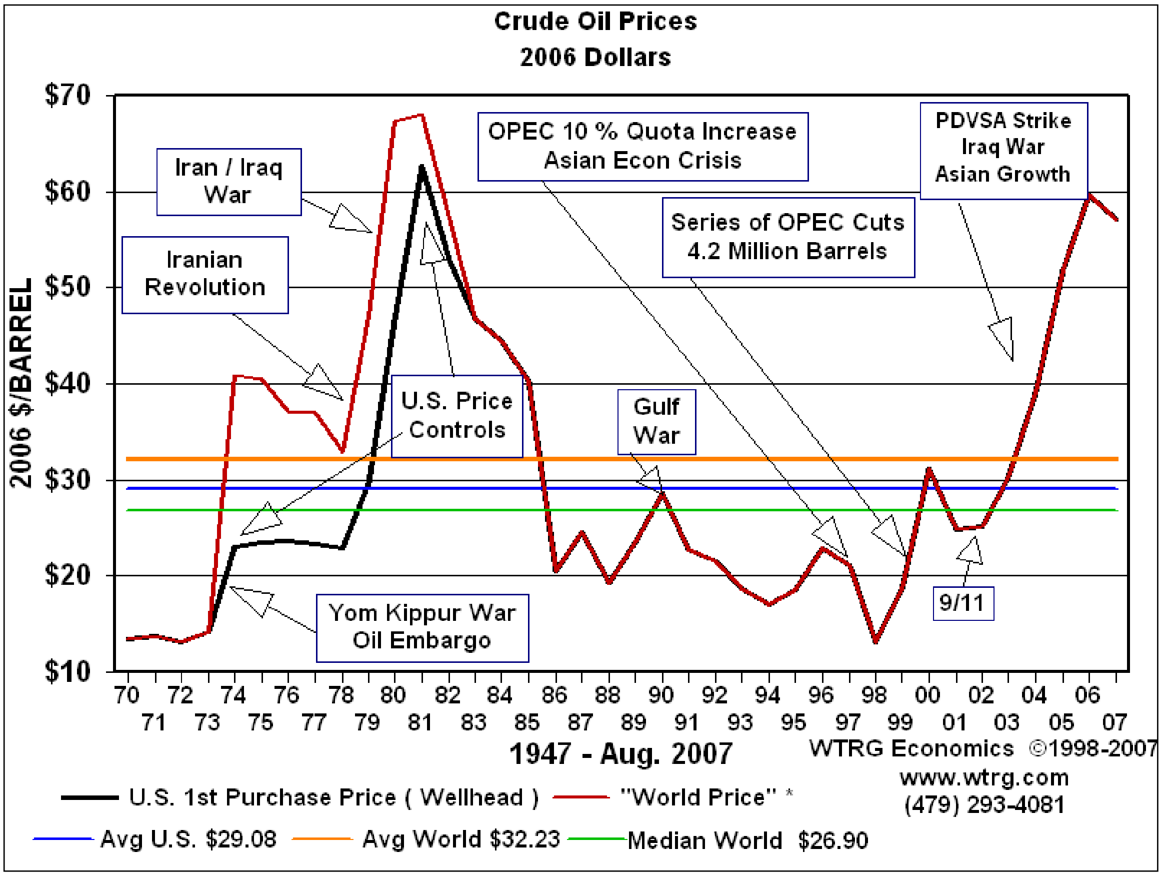
[4] Frost & Sullivan Market Research, 2002, "Biofuels: Emerging Developments and Existing Opportunities", at: http://www.frost.com/prod/servlet/frost-home.pag

[5] WTRG Economics, 2008, "Oil Price History and Analysis", at: http://www.wtrg.com/prices.htm

Figure 1.2– Crude Oil Prices, 1970-2007



Following the two oil crises, the western countries responded with a wide variety of new initiatives to contain their oil dependency. Policies in the West has led to increased off-shore and deep water oil exploration, intensified measures for energy conservation, and implementation of restrictive monetary policy. The increased burden of the ‘petroleum bill’ drove new enterprises to concentrate on finding substitutes to the Middle East oil resulting in a plethora of research and development and the revival of production and utilization of biomass energy.

1.2.2 Market Forecast and Expectations

The total bioethanol market is very difficult to forecast as consumption and production levels depend on decisions made by individual governments. As bioethanol is blended with gasoline the consumption also depends to a large extent on the policies the oil majors adopt and the political or social pressures put on them.

The European Market

The Biofuels Directive[6] sets a “reference value” of a 5.75% (v/v) market share for biofuels in 2010 (See section 4.1.3). According to Frost & Sullivan[7], it is likely that the first steps in the development of the European bioethanol market will be the conversion of existing MTBE (Methyl t-butyl ether) capacity to ETBE (Ethyl t-butyl ether) production. This will probably happen due to three factors: (1) bioethanol subsidies; (2) concerns over the environmental effects of MTBE (See Text Box no.4); and (3) reduced toxicity risk and cost of handling ethanol as compared to methanol (For further discussion on environmental factors see section 1.3.3).

Text Box no.4- Concern over MTBE

MTBE is a volatile, flammable and colorless liquid that is immiscible, yet reasonably soluble in water and has a very unique and strong terpine-like smell. MTBE is a gasoline additive, used as an oxygenate and to raise the octane number. MTBE makes drinking water unpalatable in extremely low concentrations. While many studies have shown MTBE not to be carcinogenic and to be safe in low concentrations, concern still arises about MTBE. In the USA, MTBE has been banned in certain States and is in the process of being completely phased out in favor of ethanol. MTBE is still allowed in Europe although oil majors are looking for ways to replace it.

Bioethanol, and ETBE are both oxygenatesand have similar effects on fuel combustion, hence they are natural alternatives to MTBE. Bioethanol is odorless when mixed with water, even in relatively large concentrations, and is fully biodegradable if it leaks.. One of the main drivers for the adoption of ETBE to replace MTBE as the oxygenate additive for gasoline is the ability to use existing MTBE production facilities to produce ETBE. The process can be run using the same equipment with very minor changes to the process, using ethanol as the feedstock instead of methanol. Onsite blending with gasoline as usual then becomes a very facile process as the infrastructure is already in place.

Source: Frost & Sullivan Market Research, 2005

Independent fuel producers and distributors would probably initiate the market of directly blending ethanol, after which the oil majors will start to play an increasing role in it.

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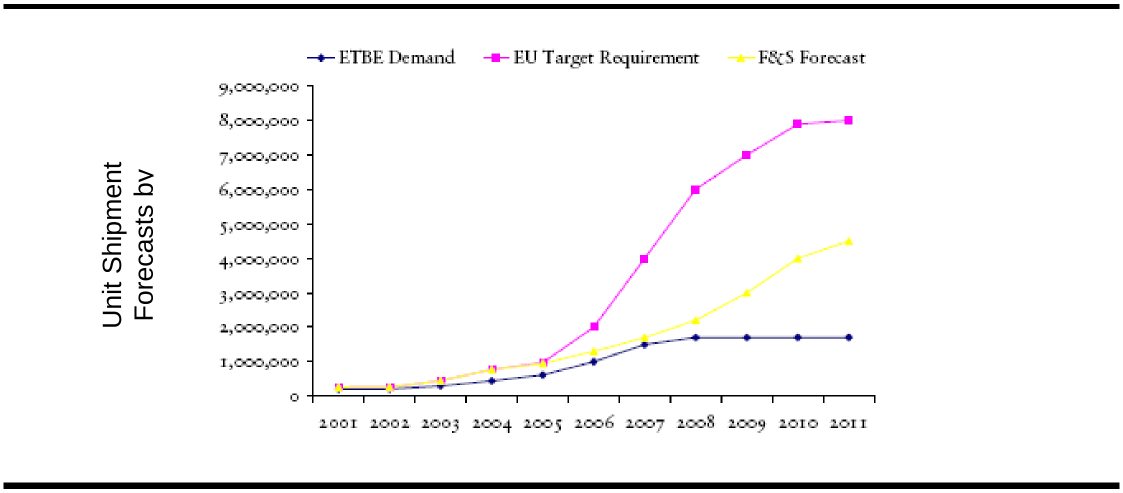
[6] Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport (17.5.2003), at: http://ec.europa.eu/energy/res/legislation/doc/biofuels/en_final.pdf

[7] Frost & Sullivan Market research, 2005, “European Biofuels - Market and Opportunity Analysis”, at: http://www.frost.com/prod/servlet/frost-home.pag

Figure 1.3 shows the volume forecasts for the total EU bioethanol market for the period 2001 to 2011. The chart depicts 3 likely scenarios:

- ✓ *First scenario*: The ETBE requirement is met and the market stalls due to no splash blending.
- ✓ *Second scenario*: The market grows in line with the EU Directive targets (See section 4.1.3).
- ✓ *Third scenario*: Feedstock demand for ETBE production fulfillment is followed by a steady growth of the market due to splash blending, first from independents and then from the oil majors.

Figure 1.3– Volume Forecasts for the Total EU Bioethanol Market, 2001-2011



Note: All figures are rounded. Source: Frost & Sullivan

The U.S Market

In August 2005, The Energy Bill was enacted, aiming to double the use of ethanol and biodiesel by 2012 (See section 4.1.1). According to Frost & Sullivan[8], the ethanol market in the United States is greatly driven by world oil prices notwithstanding the various government programs at both the federal and state levels. Three scenarios have been offered on how the ethanol market might be driven:

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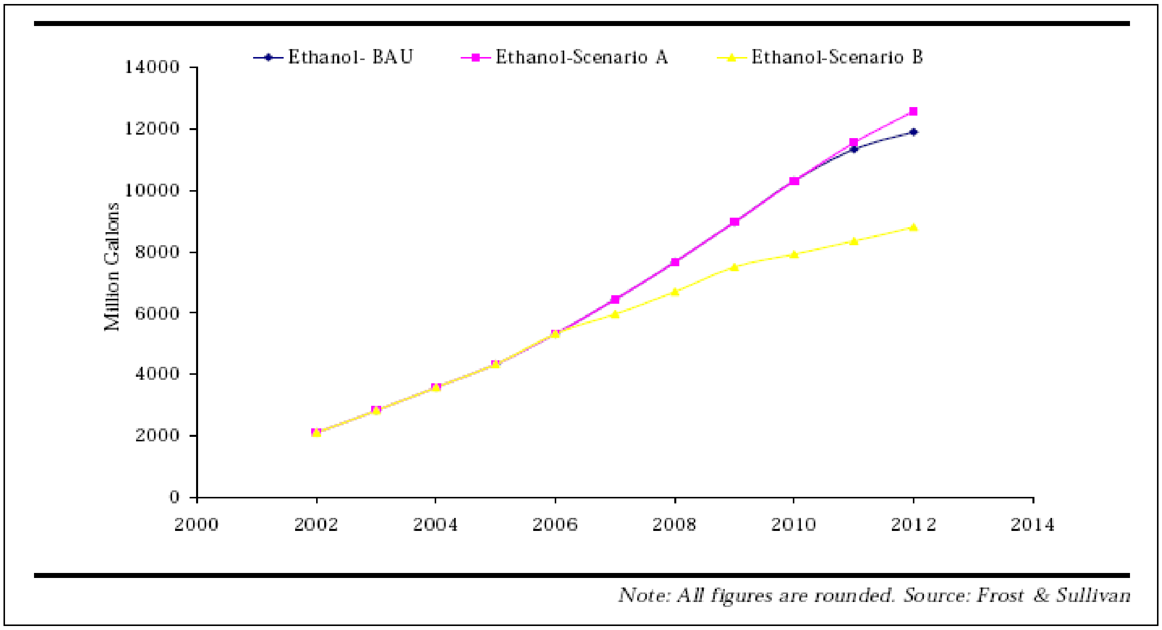
[8] Frost & Sullivan Market research, 2006, “North American Ethanol Market Assessment”, at: http://www.frost.com/prod/servlet/frost-home.pag

- ✓ *BAU (Business as Usual):* No improvement in feedstock conversion efficiency; same share of dry mills; no increase in net feedstock cost; constant proportion of feedstock i.e., corn and sorghum; no decrease in oil prices.
- ✓ *Scenario A (Positive):* Continuation of tax incentives; improved feedstock conversion efficiency; increased share of dry mills; decrease in net feedstock cost from 0.72¢/ gallon to 0.60¢/ gallon; constant proportion of feedstock, i.e., corn and sorghum; no decrease in oil prices.
- ✓ *Scenario B (Negative):* Falling oil prices - RFS standard; discontinuation of tax incentives from 2010; no improvement in feedstock conversion; increased or same share of wet mills; increase in net feedstock cost from 2009-2010 from 0.72 ¢/ gallon to 0.80 ¢/ gallon in 2012.

Figure 1.4 illustrates the estimated ethanol production in the United States (North America) between 2002 and 2012.

Figure 1.4– Estimated Ethanol Production in the United States (North America), 2002-2012



Note: All figures are rounded. Source: Frost & Sullivan

1.3 Market Drivers

1.3.1 Geopolitical and Policy Factors

Energy self-sufficiency has historically been a strong driver for the biofuels industry.

Increased Asian demand and Middle Eastern turmoil have highlighted the fact that fossil fuels are a finite commodity and that supply can be precarious. This has rekindled interest in alternative fuels. Biofuels offer the attraction of enhanced self-sufficiency and reduced reliance on oil producing countries. The political stability in oil producing Middle Eastern countries continues to be uncertain and reliance on other oil producing countries such as Venezuela and Russia is also quite precarious. Dependency on fossil fuels, from strategic and economic viewpoints, has a major impact on the biofuels markets. Since the price of oil is one of the key factors driving the market for ethanol in North America high oil prices will be a huge boost for the ethanol industry. Hence it is extremely important that any ethanol market assessment will take into account the high volatility of oil prices and the large uncertainties associated with it.

In Europe, geopolitical factors have been second to environmental public awareness and political pressures to comply with environmental requirements. International agreements such as the Kyoto protocol (aimed at reducing GHG emissions) have driven EU directives (See section 4.1.3) and individual countries legislations. Table 1.3 outlines the political and geopolitical drivers in the EU for the adoption of biofuels usage, as outlined by Frost & Sullivan[9].

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[9] Frost & Sullivan Market Research, 2005, "European Biofuels - Market and Opportunity", at: http://www.frost.com/prod/servlet/frost-home.pag

Table 1.3- Biofuels Market: Market Drivers Ranked in Order of Impact (Europe), 2005-2011

RANK	DRIVER	1-2 YEARS	3-4 YEARS	5-7 YEARS
1	EU Directives promote biofuels use	High	High	Medium
2	Biofuels can use existing infrastructure	High	High	High
3	High mineral oil price makes biofuels profitable	High	High	High
4	Greater energy self sufficiency	Medium	Medium	Medium
5	Lower environmental pollutants	Medium	Medium	Medium

Source: Frost& Sullivan, 2005

An additional political driver promoting the usage of biofuels has been the perceived opportunity biofuels could bring to agricultural production. As part of the Common Agricultural Policy (CAP), the European Union has guaranteed minimum prices paid for sugar for nearly 40 years. Subsidies to European sugar farmers are to be cut back by 39% by 2008, under plans unveiled by the European commission. The reforms of the current system were necessary after the world trade organization ruled in 2004 that European Union sugar subsidies were illegal following complaints from Brazil, the world's biggest sugar exporter, and Asian producers. Sugar producers in Europe must now decide whether to claim compensation and leave the market, or continue producing sugar with reduced subsidies. Only the most efficient producers will be able to survive in the food market while competing with exporting developing countries and as a consequence the bioethanol feedstock market will become very attractive due to the subsidies energy crop cultivation could bring. Most major sugar producers in Europe: Tereos, Suedzucker, Cristal Union, Tate & Lyle and British Sugar, are now active in the bioethanol market. The bioethanol industry is likely to benefit from the new sugar reform as governments will probably encourage sugar production for bioethanol so compensation will not have to be paid to farmers who would have otherwise gone out of business[10].

In the USA, a national Renewable Fuel Standard was created following the enactment of the Energy Policy Act of 2005[11]. This watershed legislation (See section 4.2.1)

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[10] Frost and Sullivan Market Research, 2007, "European Bioethanol and Feedstock Markets", at: http://www.frost.com/prod/servlet/frost-home.pag

[11] EPA, 2005, "Energy Policy Act of 2005", at: http://www.epa.gov/OUST/fedlaws/publ_109-058.pdf

established a mandated threshold for the use of renewable fuels, albeit it maintained the 10% limit for the renewable fuel content, as is appropriate to the existing vehicle fleet. Most of the renewable fuel demand will be met by ethanol, and this legislation is a driver for the industry and is likely to result in more than a threefold increase in the domestic ethanol industry[12].

Another major advantage of using ethanol as a transport fuel is the associated advantage, which spill over to other sectors and segments in the economy, owing to the 'multiplier' effect. For instance, in 2005 in the USA, the ethanol industry strengthened the economy by contributing $30 billion to the gross output, supported the creation of over 150,000 jobs, increased household income by about $6 billion, and added $1.5-2 billion in tax revenue to the federal and the local governments. In addition, ethanol production increases the price the farmer gets for corn by 30-45¢ /bushel. It is evident, therefore, that the associated benefits provided by ethanol, as an alternative fuel, are enabling it to obtain acceptance and adoption by the governments at the state and federal levels[13].

1.3.2 Economic Factors

Increasing oil prices are a growing concern among all the economies of the world. As has already been indicated, oil prices are extremely volatile and if it was the supply shocks in the United States, caused by the hurricanes that hit the country that sent the prices spiraling in 2005, it is the stand off over Iran's nuclear program that has sent oil prices spiraling higher. Oil prices have reached an all-time high of over $120/ barrel in early 2008 and there is no indication that this trend will slow down any time soon. The US administration has taken steps in an attempt to reduce oil imports by setting a goal of reducing gasoline consumption in the US by 10% by the year 2020 through increased production and consumption of Biofuels.

In Europe the focus has been on biodiesel production given the large proportion of vehicles that run on diesel fuel. With biofuels production benefiting from tax relief and thus proving profitable, higher fuel prices increase further the profit margin biofuels

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[12] Frost and Sullivan Market Research, 2006, "North American Ethanol Market Assessment", at: http://www.frost.com/prod/servlet/frost-home.pag

[13] Frost and Sullivan Market Analysis, 2006, "North American Ethanol Market Assessment", at: http://www.frost.com/prod/servlet/frost-home.pag

producers can expect to receive. Indeed, the price paid for biodiesel in large contracts, for example, is often linked to the Platts price of fossil diesel minus an agreed amount for transport and blending costs.

When introducing an alternative fuel to the market there are major technical aspects to be considered to allow for a streamlined implementation into the existing market system. The key considerations to the ability of biofuels to penetrate global markets are summarized in Table 1.4. As noted below liquid biofuels have an advantage over other alternative fuels since their distribution does not impose major technological barriers or require specialized handling equipment. Hence, biofuels can achieve rapid market penetration given that other market conditions are favorable. It is, therefore, that with a sound regulatory program and clear product specifications, market penetration aimed at reaching the overall goal (such as in the EU Directive) of 5.75% of all fuel consumed, could be very rapid indeed.

Table 1.4- Key Contributors to the Ability of Biofuels to Penetrate the Fuels Market

CONSIDERATION	RATIONALE
Fuel Distribution	– Low concentration blends of bioethanol and bio-ETBE can all be handled and distributed from the refinery and/or major wholesale distribution terminals using existing network systems and standard fuel pumps – Low concentration biofuel blends have a distinct advantage over fuels, such as Liquid petroleum gas (LPG) or compressed natural gas (CNG) that require elaborate dispensing and storage equipment.
Increased Vehicle Power	– Ethanol is an important Octane booster to be blended into neat gasoline, and in many parts of the world it is used to attain the required Octane levels in lieu of more complex refining processes. – For higher ethanol blends, it is significantly easier to tune an engine to perform optimally on ethanol fuel than if a range of different combustible materials have to be considered. – This increased performance is a valuable marketing tool for those that desire improved performance, – It ought to be recognized that this increased power performance can lead to increased fuel consumption,
Flexi-Fuel Vehicles	– Flexi-fuel vehicles give end users great versatility in the fuel used, as they can run on most ethanol-gasoline blends up to E85 (85% ethanol and 15% gasoline) – This is of great benefit to the emerging bioethanol market as standard gasoline can be used even in the absence of E85 at the pump. – Fuel versatility also gives the end-user options on the fuel used, should adverse economics impact the price of a particular fuel, say neat gasoline.
Feedstock Diversity	– Bioethanol can be produced from any carbohydrate feedstock crops such as fruits, wheat, barley, sugarcane, sugar beet, maize and even sap from pine trees. – Due to the diversity of potential feedstock, countries in many parts of the world could produce bioethanol domestically. – Introduction of ligno-cellulosic production technologies would greatly expand the suitable feedstock, as cellulosic sources do not include the edible part of the crop. – The technologies for production of cellulosic ethanol are in the demonstration stages and are not yet fully commercially viable.

It is quite certain that with oil prices being high (and climbing steadily higher) that governments will continue to incentivize renewable fuels, primarily bioethanol and biodiesel. The trend towards increased use of renewable fuel blends and the new requirements for improved average fuel efficiencies, have led to renewed commitment by major automobile manufacturers, such as General Motors Corporation and the Ford Motor Company, to re-introduce to the market dual-fuel or flexi-fuel vehicles. The move towards flexible fuel vehicles is also coupled with a tendency to tune such vehicles for higher performance. For example, the standard Saab 95 gasoline powered car produces 150bhp (brake horsepower) while the Saab 95 flexi-fuel car produces 180bhp with the same size engine and basic technology. However, this would lead to higher fuel consumption especially since ethanol has lower heat content per volume and its use leads to a deterioration of vehicle fuel economy.

1.3.3 Environmental Factors

The European biofuels market has enjoyed excellent European Commission (EC) support by way of the Kyoto agreement and Directives 2003/30/EC and 2003/96/EC which specifically aim to promote the increased use of biofuels and set indicative targets for their use in the transport industry. It is felt that biofuels will enjoy continued support for many years to come. As part of the Kyoto Agreement, the European Union (EU) committed to reducing its emissions of CO_2 by 8 percent by between 2008 and 2012.

Bioethanol is regarded as a CO_2 neutral fuel while Ethanol significantly reduces emission from both automobiles and off-road vehicles that contribute to local air pollution.

It is estimated that a 10% blend of ethanol will help in reducing tailpipe particular matter emission by about 45-50%, reducing toxic content (mass) by around 15%.

Using ethanol will also help to reduce the potency of toxic content by 18-20%. It should also be noted that apart from reducing air pollution at a local level, ethanol also helps to reduce global warming[14].

1.4 Market Restraints

A number of significant restraints impede the development of the biofuels industry, as addressed briefly below:

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[14] Frost and Sullivan Market Research, 2006, "North American Ethanol Market Assessment", at: http://www.frost.com/prod/servlet/frost-home.pag

1.4.1 Geopolitical and Policy Factors

Current fuel specification caps on ethanol content could put a limit on the market. The European gasoline standard EN228 only permits the blending of bioethanol up to a maximum of 5% and ETBE up to 15%. The use of blends above this threshold will invalidate the engine warranty of almost all standard cars. Use of blends above 5% is only allowed in specially adapted flexi-fuel vehicles (FFVs) if the engine warranty is to remain valid. For higher ethanol blends, there is no real fuel standard as yet. It should be noted though that the Swedish car manufacturer Saab produces an engine which uses E85 fuel based on a European Committee for Standardization (CEN) workshop agreement. In the U.S. blending of ethanol up to 10% is permitted with no engine modification requirements.

The percentage of FFVs on the road in Europe is almost negligible and thus the market for bioethanol is effectively capped at approximately 5% of the total gasoline market. Higher concentrations of ethanol, above 10%, would require engine modification or the use of flexi-fuel vehicles (such as the Ford Taurus). Although FFVs were introduced originally into the U.S. market in the late 1980s, their manufacture and further development has essentially stopped, with the only exception of their manufacture and usage being Brazil. Automobile manufacturers are now starting to reintroduce FFVs into the marketplace yet it will take several years for them to be available to the mass market in most countries.

1.4.2 Economic Factors

Some of the key economic factors that impede the biofuels market include:

- *Biofuels cannot compete with fossil fuels without providing tax relief or subsidies*- The price of producing biodiesel is 1.5 to 3 times a much as for mineral diesel, depending on the feedstock used and the production process. Since this price differential is not expected to change significantly in the near future, biofuels will still require tax incentives in order to be competitive in most countries.
- *Oil majors need regulatory certainty*- Oil companies may be reluctant to blend ethanol into gasoline unless they have regulatory certainty and ensure that the "playing field is level" otherwise they could be losing a share of the fuel market. The main argument from oil majors regarding the lack of incentive to blending ethanol is

the additional costs involved in producing a lower vapor pressure fuel to which ethanol could be added. As seen in Spain, where there is a vapor pressure waiver, the oil majors are still reluctant to blend ethanol directly into the fuel since splash blending is costly and technically will lead to a higher Octane product than is required in the market. Therefore strict gasoline specifications with Ethanol subsidies (or tax incentives) remain an option to rectify this deterrent.

- *The increasing price of natural gas*- Natural gas is a major source of energy for ethanol plants, either for the power used or for process heat. However, natural gas prices have been constantly increasing over the last few years, thus increasing the cost of producing ethanol. The price of natural gas has increased from about $4/ million BTU to about $11/million BTU. The steep increase in the price of natural gas is compelling the ethanol plant owners to look at coal as an alternative source of energy. The silver lining in this is that with higher natural gas prices companies are adopting more sustainable energy practices such as combined heat and power units that rely on the combustion of residual biomass from the ethanol production phase to produce power and steam for processing.
- *Threat from competing alternative fuels*- There is strong political support for ethanol in North America as well as renewed interest in Biodiesel. This increased focus on biodiesel could result in potential investors turning away from ethanol and looking toward biodiesel, which could limit the increase of ethanol production capacity. Other vehicle technology breakthroughs such as plug-in hybrids, electric cars and fuel cell technology cars are potentially major factors that can stunt the growth of the ethanol industry.

1.4.3 Technical Factors

When introducing ethanol into the fuels market there are several technical factors that ought to be addressed in order to minimize their negative impact on market penetration:

- *Bioethanol and blends of bioethanol require careful storage and handling*- Ethanol is bipolar in nature, which makes it hygroscopic, namely it readily picks up, and is miscible with water. Care is therefore needed when handling or storing bioethanol or bioethanol blends. Standard gasoline is not miscible with water and thus can be distributed in "wet" pipelines, and any water accumulated during transit can be easily separated off. The presence of ethanol in gasoline means water will be solvated into the fuel and could cause contamination problems, which makes pipeline transport of ethanol-blended gasoline almost impossible over long distances. Similarly, long term storage of the final gasoline/ethanol blend is not stable. ETBE on the other hand can be distributed with none of the aforementioned effects and is, therefore, the oxygenate of choice as far as distributors are concerned.

- <u>*Low concentration blends of bioethanol raise the vapor pressure of gasoline making attaining the fuel volatility specifications difficult*</u>- Both the EU and US fuel standards require ethanol to be blended at no more than 5-10% to maintain specific vapor pressure, as applicable under either winter or summer conditions. The summer vapor limit, in particular, serves to limit evaporative emissions that are a precursor to the formation of ozone under hot bright sunlight conditions. Ethanol forms an azeotrope with petroleum causing an increase of the vapor pressure of the ethanol-gasoline mixture until the ethanol reaches 40% after which the vapor pressure starts to drop. Thus, blending 5% ethanol in gasoline typically raises the vapor pressure by 7 KPa (or ~0.8 RVP) requiring that the base blending stock have lower vapor pressure, requiring more processing to remove the light ends.

Additionally, if the vapor pressure exceeds the design point of the vehicles emission management system, it may not be able to cope with the excess vapor resulting in evaporative emissions above the allowed limit. Such higher evaporative emissions- from the vehicles fuel system- could lead to the formation of higher concentrations of ozone in the lower troposphere thus affecting urban air quality. ETBE has no drastic effect on fuel blend vapor pressure and as such fuel producers and vehicle manufacturers prefer it.

2 Bioethanol Production- Feedstocks and Process Technologies

2.1 Overview of Feedstocks

2.1.1 First and Second Generation Biofuels

Biofuels are categorized into “first” and “second” generation products because of their different levels of economic and energetic efficiency and the feedstocks and types of processes from which they originate.

“First generation” fuels refer to biofuels made from sugar, starch, vegetable oil or animal fats using conventional technologies.

“Second generation” biofuels are made from lignocellulosic biomass using advanced technical processes[15].

First generation biofuels

These biofuels can currently be produced at commercial scales. The most important first generation biofuels are:

- Bioethanol (from sugar and starch crops)
- Biodiesel
- Pure Vegetable Oil

First-generation bioethanol, made from food crops, can offer some CO_2 benefits and can help to improve domestic energy security. But concerns exist about the sourcing of feedstocks, including the impact they may have on biodiversity, land use and competition with food crops.

At present, agricultural products specifically grown for bioethanol production include sugar cane (Brazil) corn (primarily in the USA), wheat and sugar beet (primarily in Europe) and sorghum and cassava (in China).

Second generation biofuels

Second-generation biofuels are made from non-food feedstocks, such as waste from agriculture and forestry. They could significantly reduce CO_2 production, do not compete with food crops and some types can offer better engine performance. When commercialized, the cost of second-generation biofuels has the potential to be more comparable with standard fuels. Used at 100% concentration, second- generation biofuels could reduce well-to-wheels CO_2 production by up to 90%. Second- generation biofuels offer the potential to be the most cost-effective route to renewable, low-carbon energy for road transport.

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[15] United Nations, 2007, “Sustainable Bioenergy; A Framework for Decision Makers”, UN-Energy, at: http://esa.un.org/un-energy/pdf/susdev.Biofuels.FAO.pdf

Second generation biofuels use biomass to liquid (BTL) technology, including conversion of biomass from lignocellulosic sources to biofuels from non food plant parts and crops. While first generation biodiesel and bioethanol use only parts of a plant (i.e. oil, sugar, or starch), second generation BTL production uses the whole plant including lignocellulosic parts.

Cellulosic ethanol production is a new approach that may alleviate land use and related concerns. It can be produced from any plant material, potentially doubling yields, in an effort to minimize the conflict between food demands and fuel needs. Instead of utilizing only the starch by-products from grinding corn, wheat and other crops, cellulosic ethanol production maximizes the use of all plant materials, including gluten. This approach would have a smaller carbon footprint because the amount of energy-intensive fertilizers and fungicides remain the same for a higher output of usable material. The result is that less land area is required per unit of energy produced compared with first generation biofuels. *Second-generation biofuels however, will not be available in significant commercial quantities for 5-10 years.*

2.1.2 Sugar Feedstock

These feedstocks include sugarcane juice, sugar beet juice, sugarcane or sugar beet molasses, raw sugar and refined sugar. Ethanol is produced in many countries around the world. Over one-half of world ethanol production uses sugarcane, sugar beets or molasses, as a feedstock, while the remainder is produced from grain feedstocks[16].

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[16] USDA, 2006, "The Economic Feasibility of Ethanol Production from Sugar in the United States", at: http://www.usda.gov/oce/EthanolSugarFeasibilityReport3.pdf

Text Box no.5- Sugar Cane

Brazil is the world’s largest producer of sugar. In 2007/08, Brazil is expected to produce 32.1 million metric tons of sugar, accounting for nearly 20% of total production and nearly 40% percent of total world exports. Brazil is also the world leader in the production of ethanol from sugarcane. Sugarcane now provides approximately 13 percent of Brazil’s energy, replacing fossil fuels for motor vehicles and bagasse for heat and power. Ethanol production from sugarcane is very economical in Brazil because of two primary reasons. Brazil dropped support of sugar prices to support the ethanol industry with government established mandates for the blending of ethanol with gasoline. This drastically lowered the cost of the feedstock, sugarcane, and created a demand for and supported the price of ethanol. In addition, Brazil’s vast land area of cultivatable area means that land devoted to sugarcane production for ethanol is not in competition with land devoted for food production. As a result, the cost of producing ethanol in Brazil is in the $0.68 to $0.95 per gallon ($0.18 - $0.25 per liter) range.

The primary factor influencing the dominance of Brazilian sugarcane for ethanol production has been government policies affecting the production and use of ethanol. About one-half of the sugarcane produced in Brazil is used for ethanol production, which has no government limits on production. The amount of alcohol blended into gasoline is dictated to the market by law or decree, which directly affects Brazilian producer prices of sugarcane, consumer prices for sugar and ethanol, and sugar quantities both produced and consumed in Brazil, as well as world prices for raw and refined sugar.

Brazil produces two types of ethyl alcohol or ethanol from sugarcane: hydrated and anhydrous. Hydrated ethanol (with a 4 percent water addition) is used to power alcohol and “flex fuel” vehicles while anhydrous ethanol is used as a gasoline oxygenate and a substitute for tetraethyl lead and MTBE. Ethanol in Brazil is produced at sugarcane mills with adjoining distillery plants, producing both sugar and ethanol, and at independent distilleries, producing only ethanol.

The sugar and ethanol industry in Brazil has invested approximately $40 million per year in research and development since 1979. This research has contributed to the dramatic increase in sugar and ethanol productivity in Brazil over the past thirty or so years. In 1975, sugarcane production in Brazil averaged 16 tons per acre. By 2004, sugarcane yields were averaging over 32 tons per acre. Ethanol production from sugarcane increased from 305 gallons per acre (2.85 m^3/Ha) to about 590 gallons per acre (5.52 m^3/Ha) over this same period.

Source: USDA Foreign Agricultural Service, 2007; Poppe et al, 2006; Coelho, 2005.

Text Box no.6- Sugar Beet

Production of bioethanol in the EU is from sugar beets and wheat. A recent GAIN publication reveals that sugar beets prove to be a good feedstock for European bioethanol production. Because sugar beets have a much larger yield per hectare than wheat, the EU currently produces 2 million more tons of sugar beet than wheat on 20 million less hectares of land. Additionally, sugar beets produce more ethanol per hectare: a hectare of sugar beets can produce 30 hectoliters more ethanol, on average, than wheat. Also, sugar beet ethanol is shown to have a more energy-efficient production process than wheat ethanol and promises greater greenhouse gas reductions.

Source: USDA Foreign Agricultural Service, 2006.

2.1.3 Starch Feedstock

Starch is a polymer made up of simple sugars. Plants store sugar (energy) in the form of starch and it is this chemical component of the feedstock that is utilized in the production of ethanol. Most grain crops are high in starch which is stored in the seed or grain component of the plant. It is thus the food portion of the plant that is used for bioethanol production, rather than the stems, as the stem contains no starch. Typical starch feedstocks are wheat, barley, maize, rye, corn and triticale.

Wheat has the highest starch content per unit price in many European countries and is thus the most economic crop from which to produce bioethanol at current market prices. Indeed, UK wheat has the highest starch content in Europe and as such is ideal for bioethanol production. Rye is more commonly grown in Germany and thus makes up a larger portion of feedstock use than in other European countries[17].

The starch in grains must be broken down into simple sugars by a process called saccharification before the yeast is able to ferment the sugars into ethanol. Saccharification is usually done by adding an enzyme, normally an amylase, to the mashed grain and heating it. Saccharification may also be done using acids but this poses a waste disposal and treatment problem, resulting in higher production costs. Corn and sorghum are the major feedstock used in the production of ethanol in the

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[17] Frost and Sullivan Market Research, 2007, "European Bioethanol and Feedstock Markets", at: http://www.frost.com/prod/servlet/frost-home.pag

United States[18]. The following are the key trends of feedstock in terms of production, price, and ethanol use.

Text Box no. 7- Sorghum

Sorghum is one of the other major feedstock used in ethanol production in the USA, but it accounts only for about 5 percent to 8 percent of ethanol production. However, with the recent initiatives by the government to set up ethanol plants outside traditional corn-producing states and the expected increase in the consumption of ethanol over the next few years, an increase in the share of sorghum with regard to ethanol production is envisaged. Sorghum production is expected to increase slowly, equaling use, reaching about 380-400 million bushels by 2012. Sorghum yield is also expected to increase- by about 3.0-0.5 bushels per hectare each year. As the use of sorghum strengthens over the next few years, the price is expected to increase. However, the use of sorghum in ethanol production is anticipated to increase on account of the US government focusing on other feedstock, apart from corn.

Source: Frost & Sullivan, 2006.

Text Box no. 8- Corn

Corn is the major feedstock for ethanol production in the United States. About 90 percent to 95 percent of the ethanol in the country is processed from corn. It is therefore likely that any change in the trends of key parameters related to the crop will impact the market for ethanol in the country. The corn acreage in 2005 was about 80 million hectares. This area is poised to increase, albeit slowly, over the coming period, to about 85 million hectares by 2012. The area under corn is anticipated to expand owing to the increased use of the grain and the competitive price. Corn basically competes with soybean for land area and is often used in rotation with soybean. Corn areas are expected to grow relative to soybean as net returns are expected to favor corn over the coming period. In addition, the yield per unit area for corn is also expected to increase during the forecast period, largely due to genetic improvements. The yield is expected to increase from 145 bushels/acre to about 170 bushels/acre (9.1-10.7 metric tons/Ha).

The price of corn is expected to increase slowly, and this rise is expected to be largely on account of the increasing use of corn. With increasing ethanol production going up, the utilization of corn for production has also risen. In 2005, about 1.4 billion bushels of corn were used for ethanol production. The use of corn for ethanol production is expected to increase, to about 2 billion bushels by 2012. In particular, the increased use of ethanol is likely to be largely due to the various government initiatives at both the federal and the state levels. In particular, the ban of MTBE by an increasing number of states is expected to give a major fillip to the industry in the near future.

Source: USDA/ ERS, 2005

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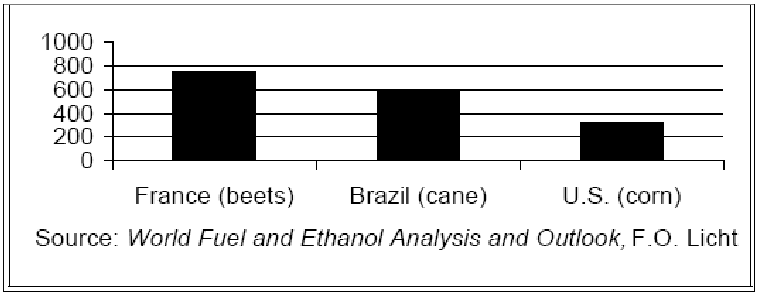
[18] Frost and Sullivan Market Research, 2006, "North American Ethanol Market Assessment", at: http://www.frost.com/prod/servlet/frost-home.pag

A Sugar– Starch feedstock comparison[19]

The most critical factors that determine the economic feasibility of ethanol production from agricultural product feedstocks are ethanol yields per unit of feedstock and the cost of the feedstock. Figure 2.1 presents the relationship between estimated ethanol yields per acre for three ethanol feedstocks: France- sugar beets, Brazil- sugarcane and the United States- corn.

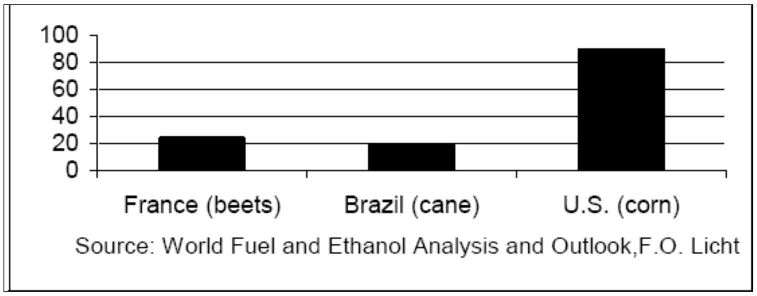
Figure 2.1- Ethanol Yields (gallons) Per Acre (2004)



Source: *World Fuel and Ethanol Analysis and Outlook,* F.O. Licht

Based on sugar beet yields in France, one acre of sugar beets could produce approximately 750 gallons of ethanol per acre and an acre of sugarcane in Brazil could produce 590 gallons of ethanol per acre. U.S. corn production produces roughly 370 to 430 gallons of ethanol per acre, depending upon corn yields. When the ethanol yield per ton of feedstock is compared, corn is by far the leader (Figure 2.2).

Figure 2.2- Ethanol Yields (gallons) Per Ton of Feedstock (2004)



Source: World Fuel and Ethanol Analysis and Outlook,F.O. Licht

A ton of U.S. corn can yield approximately 100 gallons of ethanol, compared with 25 gallons from a ton of French sugar beets and 20 gallons from a ton of Brazilian sugarcane. However, it is the cost of producing that feedstock which ultimately

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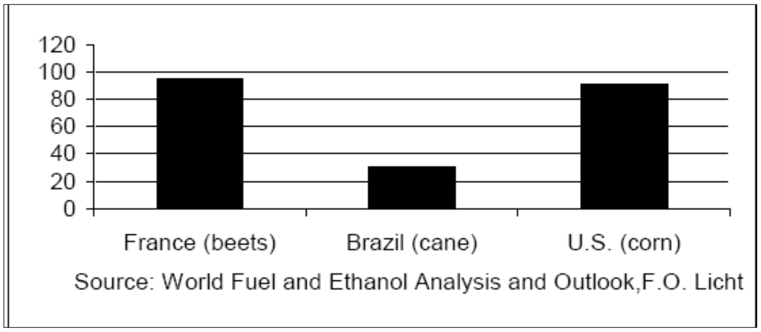
[19] Berg, C., 2004, "World Fuel and Ethanol Analysis and Outlook". F.O Licht (Eds), at: http://www.distill.com/World-Fuel-Ethanol-A&O-2004.html

determines the relative economic feasibility of various feedstocks. In this regard, Brazil has a significant comparative advantage, with estimated gross feedstock costs of about 30¢/ gallon of ethanol produced (Figure 2.3), compared to 97¢/ gallon for sugar beets in France and 80-85¢/ gallon for corn in the U.S.

Figure 2.3- Gross Feedstock Cost (cents) Per Gallon of Ethanol (2004)



Source: World Fuel and Ethanol Analysis and Outlook,F.O. Licht

2.1.4 Cellulosic Feedstock

Cellulosic ethanol is a type of biofuel produced from lignocellulose, a structural material that comprises much of the mass of plants. It is composed mainly of cellulose, hemicellulose and lignin. Cellulosic ethanol is chemically identical to ethanol from other sources, such as corn starch or sugar, but has the advantage that the lignocellulose raw material is highly abundant and diverse. However, it differs in that it requires a greater amount of processing to make the sugar monomers available to the microorganisms that are typically used to produce ethanol by fermentation.

As of 2007, ethanol is produced mostly from sugars or starches, obtained from fruits and grains. In contrast, cellulosic ethanol is obtained from cellulose, the main component of wood, straw and much of the plants. Since cellulose cannot be digested by humans, the production of cellulose does not compete with the production of food.

Most of these "bio-mass" products are currently discarded. Transforming them into ethanol using efficient and cost effective hemi (cellulose) enzymes or other processes might provide as much as 30% of the current fuel consumption in the United States- and probably similar figures in other oil-importing regions like China or Europe. Moreover, even land marginal for agriculture could be planted with cellulose-producing crops, resulting in enough production to substitute for significant mounts of fossil fuels. Corn stover, switchgrass, miscanthus and woodchip are some of the more popular cellulosic materials for ethanol production. The price per ton of the raw material is thus much less than grains or fruits. Moreover, since cellulose is the main component of plants, the whole plant can be harvested. This results in much better yields per unit area- up to 10 tons per hectare for example, instead of 4-5 tons per hectare for the best crops of grain.

According to the US Department of Energy studies conducted by the Argonne Laboratories of the University of Chicago[20], one of the benefits of cellulosic ethanol is that it reduces greenhouse gas emissions (GHG) by 85% over reformulated gasoline. By contrast, starch ethanol (e.g., from corn), which most frequently uses natural gas to provide energy for the process, reduces GHG emissions by 18% to 29% over gasoline. Sugar ethanol is cheaper than corn ethanol. Cellulosic ethanol from sugarcane bagasse, reduces greenhouse gas emissions by as much as cellulosic ethanol. In both cases the waste lignin becomes fuel to provide the energy for the process with some excess to provide electricity for the grid. Ethanol, if made from cellulose, emits 80% less global warming pollution than gasoline[21].

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[20] Argonne National Laboratory, 2004, "Energy and Emission Benefits From Fuel Ethanol", at: http://www.transportation.anl.gov/research/systems_analysis/fuel_ethanol.html

[21] Environment California, 2007, "Clean Cars, Cool Fuels", at: https://www.environmentcalifornia.org/newsletter/fall07/clean-cars-cool-fuels

Text Box no.9- Switchgrass

Switchgrass is the major biomass material being studied today in the USA, due to its high levels of cellulose. Switchgrass is a native prairie grass that is known for its hardiness and rapid growth. This perennial grows during the warm season of the year and grows to 2-6 feet tall. Switchgrass can be grown in most parts of the United States, including swamplands, plains, streams, and along the shores. It is resistant to many diseases and pests and can produce high yields with low applications of fertilizer and other chemicals. It is also tolerant to poor soils, flooding, and drought and improves soil quality and prevents erosion1.

Switchgrass is an approved cover crop for land protected under the federal Conservation Reserve Program (CRP). CRP is land where crops recently grew, and now the producer gets paid a fee to stop growing crops on this land. This program reduces soil erosion, enhances water quality, and increases wildlife habitat. CRP land serves as a habitat for upland game, such as pheasants and ducks, and a number of insects.

CRP land has been considered for growing switchgrass for biofuel production, which could increase ecological sustainability and lower the cost of the CRP program. However, CRP rules would have to be modified to allow this economic use of the CRP land. Other sources include agricultural production by-products such as hay, plant remains and thinned forest logs and pruned branches. Economic feasibility of exploitation of these feedstocks for bioethanol production will depend on the cost associated with collecting and shipping them to production facilities in addition to production costs as soon as these become economically feasible.

Source: Rinehart, 2006.

2.2 Ethanol Production

The production of ethanol (or ethyl alcohol) from starch or sugar-based feedstocks is among man's earliest ventures into value-added processing. While the basic steps remain the same, the process has been considerably refined in recent years, leading to a very efficient process.

Fermentation is the chemical process at the basis of bioethanol production, where sugars are the common substrate. Yeasts carry out fermentation in a process of deriving energy from the oxidation of organic compounds, such as carbohydrates, using an endogenous electron acceptor, which is usually an organic compound.

Straight fermentation of sugar (e.g. from sugar cane, bagasse or sugar beet) at an industrial level is a well developed procedure.

The processing of starchy grains is enabled using two industrial production processes: wet milling and dry milling (See Text Box no.10-11). The main difference between the two is in the initial treatment of the grain. As of January 2007, dry mill facilities account for 82% of ethanol production and wet mills account for 18% in the USA[22].

Dry mill processing plants are usually much smaller than wet mill plants, they are easier and simpler to build and operate. They typically only sell ethanol and distillers dried grains for animal feed. Some dry mill plants also capture and sell CO2 as a byproduct, but most do not.

Text Box no.10- Dry Milling

In dry milling, the entire corn kernel or other starchy grain is first ground into flour ("meal"), and processed without separating out the various component parts of the grain. The meal is slurried with water to form a "mash." Enzymes are added to the mash to convert the starch to dextrose, a simple sugar. Ammonia is added for pH control and as a nutrient to the yeast. The mash is processed in a high-temperature cooker to reduce bacteria levels ahead of fermentation.

The anhydrous ethanol produced is blended with about 5% denaturant (such as natural gasoline) to render it undrinkable and thus not subject to beverage alcohol tax. It is then ready for shipment to gasoline terminals or retailers.

The stillage is sent through a centrifuge that separates the coarse grain from the solubles. The solubles are then concentrated to about 30% solids by evaporation, resulting in Condensed Distillers Solubles (CDS) or "syrup." The coarse grain and the syrup are then dried together to produce dried distillers grains with solubles (DDGS), a high quality, and nutritious livestock feed. The CO_2 released during fermentation is captured and sold for use in carbonating soft drinks and beverages and the manufacture of dry ice.

Source: University of Kentucky, 2008

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[22] Renewable Fuels Association, 2007, "How Ethanol is Made", at: http://www.ethanolrfa.org/resource/made/

Text Box no.11- Wet Milling

In wet milling, the grain is soaked or "steeped" in water and dilute sulfurous acid for 24 to 48 hours. This steeping facilitates the separation of the grain into its many component parts. After steeping, the corn slurry is processed through a series of grinders to separate the corn germ. The corn oil from the germ is either extracted on-site or sold to crushers who extract the corn oil. The remaining fiber, gluten and starch components are further segregated using centrifugal, screen and hydroclonic separators. The steeping liquor is concentrated in an evaporator.

This concentrated product, heavy steep water, is co-dried with the fiber component and is then sold as corn gluten feed to the livestock industry. Heavy steep water is also sold by itself as a feed ingredient and is used as a component in Ice Ban, an environmentally friendly alternative to salt for removing ice from roads. The gluten component (protein) is filtered and dried to produce the corn gluten meal co-product. This product is highly sought after as a feed ingredient in poultry broiler operations. The starch and any remaining water from the mash can then be processed in one of three ways: fermented into ethanol, dried and sold as dried or modified corn starch, or processed into corn syrup. The fermentation process for ethanol is very similar to the dry mill process described above.

Source: University of Kentucky, 2008

2.2.1 Conventional Bioethanol Production

Conventional bioethanol production starts once crops have been harvested, the cellulosic parts removed, and the starches collected. Typically it is the starchy grains or sugary feedstocks that are processed. The processing entails conversion into glucose that ferments with the help of yeast and amylase, which is a specified enzyme for digesting carbohydrates (sugars). Low concentration Ethanol will result directly from the fermentation steps, resulting in concentrations between 8 and 12%, which are further distilled and dried to produce bioethanol and other important byproducts.

The general processing steps listed in Text Box no.12 have been perfected over the years for conventional bioethanol productions, sometimes referred to as 1st generation bioethanol. Care needs to be taken with each step of the process to ensure efficient conversion, particularly as it is a biological process where stray reactions can occur causing loss in yield and also since different grains have different process requirements.

In all, there are four products from the conversion of grain to conventional bioethanol.

Text Box no.12- Ethanol process steps

- **Slurry Preparation**- The feed grain is milled to sufficient fineness to allow water access to all the starch inside each grain. Steeping, grinding, and germ separation are techniques that can be used to fully convert grain into pure starch. The “meal” is then slurried with warm water to a concentration that balances maximum take up without generating excessive viscosities downstream.
- **Hydrolysis-** The slurry temperature is raised to between 80 and 100 °C to accelerate the hydrolysis of the grain’s starch into solution. Again there is an optimum depending on the grain type- if the slurry is too hot, the viscosity is excessive and if too cool, the required residence time for effective hydrolysis is too long.
- **Saccharification**- The dissolved starch is enzymatically converted to sugars by saccharification, but at a reduced temperature approaching 60 °C which again is selected to achieve a balance between a satisfactory reaction rate, while avoiding the promotion of spurious side reactions and a subsequent loss in yield.
- **Fermentation-** The slurry is then further cooled to a fermentation temperature of around 32 °C and held in large batch fermentation tanks for 40-50 hours. Fresh yeast is prepared in parallel and added at the beginning of each batch fermentation cycle. The fermenting slurry is agitated and also circulated through external exchangers to remove the heat generated by the fermentation process. On completion of fermentation the batch is transferred to the ‘Beer Well’ and the particular fermentation tank and associated equipment are thoroughly cleaned. **Distillation**- The ‘beer’ produced contains about 8 – 12% ethanol. It is continuously pumped to the two-stage distillation unit, which produces an overhead stream of 90+% ethanol and water. Ethanol and water form a 95% azeotrope so it is not possible to reach 100% by simple distillation.
- **Dehydration-** The 90+ % overhead stream is passed through an absorber containing a molecular sieve that traps the ethanol while letting the water pass through. Once the bed in the absorber is full, the feed is switched to a parallel absorber and the ethanol is desorbed to yield a near pure ethanol product, which is sent to product storage. The cycle is then repeated and the result is a nearly 100% anhydrous ethanol product. Typically three absorbers are used.
- **Centrifuge-** The residual slurry left after distillation is called ‘Whole Stillage’ and it contains all the insoluble and soluble non-starch components from the feed grain, as well as the yeast that has grown during fermentation. The bulk of the solids, termed ‘Wet Distillers Grains’ (WDG) are removed by centrifuge leaving a ‘Thin Stillage’.
- **Evaporation**- To minimize water consumption, a large portion of the ‘Thin Stillage’ is recycled to the front of the process. The remainder is concentrated by multiple effect evaporation to recover further water for recycle. The residual ‘syrup’ contains typically 30 – 35% solids and it is either blended with the WDG or sold off separately as animal feed.
- **Drying**- WDG has a shelf life of about 3 days, so it is commonly dried as a mixture with the ‘syrup’ by gas fired rotary kiln or pneumatic entrainment dryer down to about 10% moisture. This by-product, called ‘Dried Distillers Grains and Solubles’ (DDGS) is sold to animal feed lots.
- **CO_2 Recovery-** Fermentation simultaneously generates carbon dioxide that is collected, and scrubbed to recover any ethanol, and it can either be processed into a byproduct or released to the atmosphere. Per Table 1 above, this process adds no net carbon dioxide to the air.

Source: Northewest Iowa Community College, 2008

Typically from 1,000 kg of wheat containing 65% starch, on a dry basis, and 12.5% moisture, on a wet basis, the ethanol yield is 293 kg, the CO_2 yield is 283 kg and the DDGS yield is 458 kg. It is worth noting that the conventional bioethanol process only removes the starch from the feed grain, leaving the protein, fiber, mineral matter, etc. with the DDGS. Consequently DDGS is an important byproduct for use as a high protein animal food.

Bioethanol manufacture is a sequence of relatively straightforward process steps, but there are important issues to consider for achieving reliable and continuous commercial production.

Text Box no.13- The Importance of Water

Bioethanol manufacture involves a variety of chemical processes and water plays a major role in them. The overall process can be depicted as one large water loop, which has a number of effects:

- The slurry concentration fed to hydrolysis is about the same irrespective of feed grain;
- Feed grains richer in starch, such as corn (70% starch), require less water than poorer varieties such as barley (60% starch);
- Corn bioethanol plants require less process volume, less process power, and are on the whole more cost effective;
- Most modern bioethanol plants are designed for zero water effluent, however, as the DDGS drying stage reduces moisture content from around 30-35% to 10-15% through evaporation to the atmosphere, the plant has a significant demand for process water;
- The second largest demand for water is evaporative cooling, primarily to keep fermentation temperatures down at 32-33 ºC.

Source: Cardona and Sánchez, 2007

Text Box no.14- The Importance of Feed Grain

As noted above it is possible to convert most starch containing feed grains to bioethanol. A few important considerations:

- All the non-starch material, such as protein, fiber, etc. in the feed grain, reports to the byproduct DDGS;
- The economics of bioethanol manufacture depend on achieving adequate quality and good market prices for this solid material;
- Protein content, palatability, shelf life, transport logistics are all part of the price equation;
- Care needs to be taken in handling these components through the process- particularly thermal treatment, such as drying.

Source: Cardona and Sánchez, 2007

Text Box no.15- The Importance of Cleanliness

Most biological processes involving food material, water and warm temperatures risk spurious reactions, and therefore the following ought to be considered:

- Minimization of infection in the water loop of the bioethanol process is critical as it can lead to loss in yield and a decline in throughput;
- Select enzymes guide the process reactions in the preferred direction, but regular service by a “Clean-In-Place” system is mandatory to ensure positive control;
- Careful plant design can minimize dead spots in the system and close monitoring during plant operation can achieve trouble free operation.

Source: Cardona and Sánchez, 2007

Text Box no.16- The Importance of Energy

A significant operating cost, and emissions, will be due to the consumption of energy, such as:

- Consumption of natural gas, liquefied petroleum gas (LPG), or distillate fuel oil to run the process;
- Several integrated energy balances ought to be carefully controlled;
- Especially important for the support of the whole process is the multiple effect relationship between distillation, dehydration and evaporation, and the utilization of dryer waste heat for steam generation.

Source: Cardona and Sánchez, 2007

2.2.2 Cellulosic Ethanol Production

Ethanol from cellulosic biomass- the most abundant biological material on the planet- has the potential to revolutionize the bioethanol industry and change gasoline production patterns worldwide. Despite its abundance, cellulosic biomass is a complex feedstock that requires more extensive processing than grain, and several scientific breakthroughs are needed to make cellulosic bioethanol production cost efficient enough to operate at a commercial scale.

Cellulosic ethanol can be produced from a wide variety of cellulosic biomass feedstocks material including: agricultural plant wastes (corn stover, cereal straws, sugarcane bagasse); plant wastes from industrial processes (sawdust, paper pulp); and energy crops grown specifically for fuel production, such as switchgrass.

Cellulosic biomass is generally composed of cellulose (about 44%), hemicellulose (around 30%) and lignin (around 26%), with smaller amounts of proteins, lipids (fats, waxes and oils) and ash. Roughly, two-thirds of the dry mass of cellulosic materials is present as cellulose and hemicellulose. Lignin makes up the bulk of the remaining dry mass.

As with grains, processing cellulosic biomass aims to extract fermentable sugars from the feedstock. But the sugars in the cellulose and hemicellulose are locked in complex carbohydrates called polysaccharides (long chains of monosaccharides or simple sugars). Separating these complex polymeric structures into fermentable sugars is essential to the efficient and economic production of cellulosic ethanol.

Two processing options are employed to pre-treat cellulosic biomass:

1. **Acid hydrolysis:** uses acids to break down the complex carbohydrates in the cellulosic feedstock into simple sugars;
2. **Enzymatic hydrolysis:** utilizes pretreatment processes to first reduce the size of the material to make it more accessible to hydrolysis. Once pretreated, enzymes are employed to convert the cellulosic biomass to fermentable sugars.

In the future, large-scale, cellulosic bioethanol production facility may include the following steps:

a) Cellulosic biomass from trees, grasses, or agricultural wastes is harvested and delivered to the Biorefinery;

b) Biomass is ground into small, uniform particles. Thermal or chemical pretreatment separates cellulose from other biomass materials and opens up the cellulose surface to enzymatic attack;

c) A mix of enzymes is added to break down cellulose into simple sugars;

d) Microbes produce ethanol by fermenting sugars from cellulose and other biomass carbohydrates;

e) Ethanol is separated from water and other components of the fermentation broth and purified through distillation.

To bring down costs, continued progress is needed in the development of energy crops dedicated to Biofuels production, biomass-collection technologies, pretreatment methods that minimize the release of inhibitory by-products, and more efficient enzymes and microbes robust enough to withstand the stresses of industrial processing.

2.2.3 Cellulose Degradation and Conversion

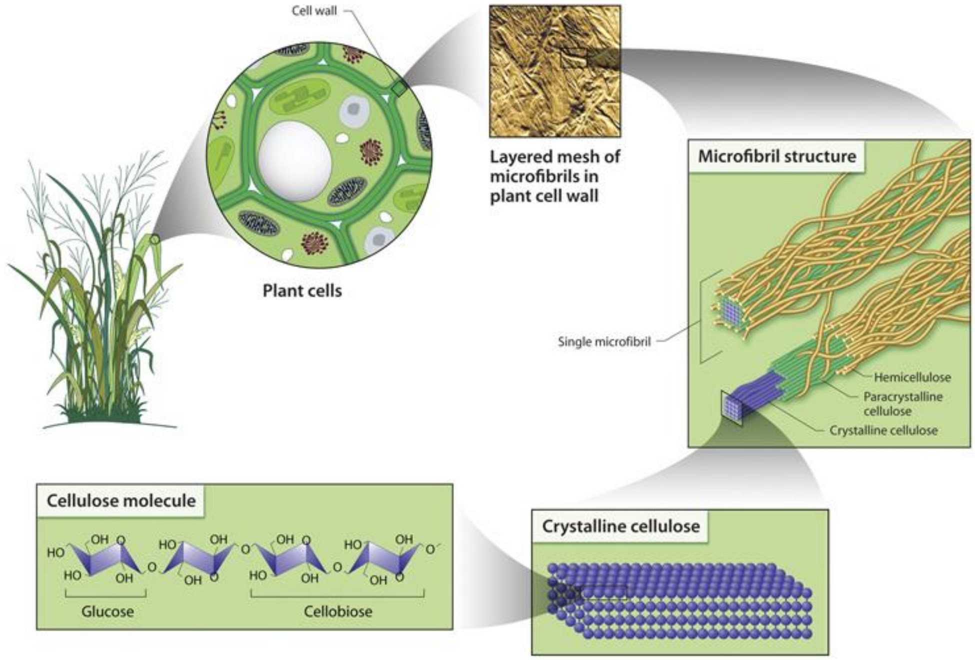
Each cellulose molecule is a linear polymer of glucose residues, and depending on the degree of hydrogen bonding within and between cellulose molecules, this polysaccharide can be found as either crystalline or paracrystalline (amorphous) forms. Cellulose exists within a matrix of other polymers, primarily hemicellulose and lignin. Hemicellulose is a branched sugar polymer composed of mostly pentoses (five-carbon sugars) and some hexoses (six-carbon sugars). Lignin is a complex, highly cross-linked aromatic polymer that is covalently linked to hemicellulose, thus stabilizing the mature cell wall. These polymers provide plant cell walls with strength and resistance to degradation, which also makes these materials a challenge to use as substrates for bioethanol production.

A mix of enzymes is required to break down cellulose into simple sugars that can be fermented by microorganisms to bioethanol. These include enzymes such as *cellulases*, *hemicellulases*, and other *glycosyl hydrolases* that work together in a synergistic fashion to degrade the structural polysaccharides in biomass. These enzyme systems, however, are as complex as the plant cell-wall substrates they attack.

As discussed above, the biomass feedstock needs to be pretreated prior to its processing. For enzymatic hydrolysis three general classes of cellulases- endoglucanases, exoglucanases, and cellobiases- work together in a coordinated fashion to hydrolyze cellulose. Endoglucanases internally cleave a cellulose chain, and

exoglucanases bind the cleaved ends of the cellulose chain and feed the chain into its active site where it is broken down into double glucose molecules called cellobiose. Cellobiases split cellobiose to yield two glucose molecules. Figure 2.4 depicts schematically the chain of processes that make up the enzymatic conversion pathway.

Figure 2.4- Enzymatic Biomass Conversion



Source: U.S DOE

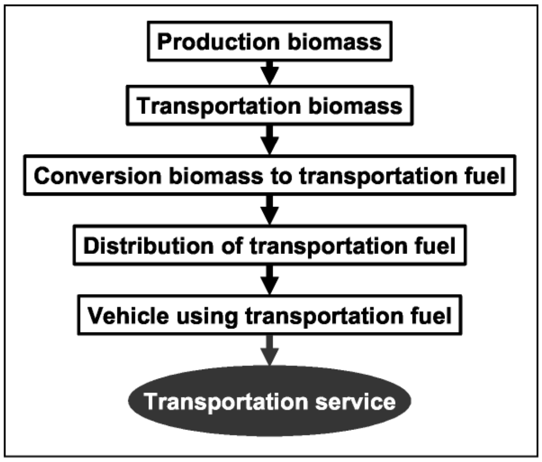
Despite our basic understanding of the steps involved in the biochemical conversion of biomass to bioethanol, a more complete understanding of enzymes and microbes involved in the biomass conversion to bioethanol is needed in order to overcome current inefficiencies in the production process. Moreover, optimization of these enzymes- and enzymatic processes- will require a more detailed understanding of their regulation and activity as a tightly controlled, highly organized system.

3 Bioethanol Production- Energy, Environmental and Economic Considerations

The political popularity of biofuels has increased over the past few years due to the notion that domestic production will reduce countries' dependence on foreign sources of energy, particularly oil from the Middle East. Thus 'security of supply' and potential environmental benefits- in terms of reducing GHG emissions- are the pillars of energy policies worldwide. The IEA estimates that roughly 65 billion liters of biofuels were consumed in 2006 and they displaced around 32 billion liters of fossil fuels (or approximately 1% of energy demand in the transport sector). Governments want to keep prices of energy carriers low, minimize volatility while reducing their environmental impacts.

The attractiveness of using bioethanol is that it is produced from plants and is a renewable resource. This means that the CO_2 produced when the fuel is burned is equivalent to the amount taken up by the growing plants. Theoretically the net contribution to GHG emissions is thus zero. In reality this cycle is never 100% efficient since we are not able to utilize all of the energy content of the crops, and we consume energy in growing the crop, processing it to produce the applicable biofuels and transporting it for distribution to consumers. Hence, when comparing biofuels as displacement for fossil fuels we ought to evaluate a comparable cycle of operations, which in the case of fossil fuels will include the extraction and processing of crude oil for the production of conventional transportation fuel, as describe in figure 3.1.

Figure 3.1- The Chain of Transportation Service



The heat content of different fuels, either fossil fuels or biomass, varies considerably among locations, fuels, the car fleet, and vehicle miles traveled. Therefore, in order to compare the relative benefits of different transportation fuels the whole cycle must be considered, from the Production to the provision of Transportation services.

Table 3.1 provides a comparison of the heat content of various fuels without taking into account how they are produced. This is an important baseline for further analysis of emerging alternative fuels, including bioethanol.

Table 3.1- Heat Content for Various Fuels

FUEL	HEATING VALUES (GROSS)	HEATING VALUES (NET)
Automotive gasoline	125,000 Btu/gal	115,400 Btu/gal
Hydrogen	134,200 Btu/kg	113,400 Btu/kg
Diesel motor fuel	138,700 Btu/gal	128,700 Btu/gal
Biodiesel	126,206 Btu/gal	117,093 Btu/gal
Methanol	64,600 Btu/gal	56,560 Btu/gal
Ethanol	84,600 Btu/gal	75,670 Btu/gal
Propane	91,300 Btu/gal	83,500 Btu/gal
Butane	103,000 Btu/gal	93,000 Btu/gal
Jet fuel (naphtha)	127,500 Btu/gal	118,700 Btu/gal
Jet fuel (kerosene)	135,000 Btu/gal	128,100 Btu/gal
Petroleum coke	143,400 Btu/gal	
Natural gas		
- Wet	1,109 Btu/ft^3	
- Dry	1,027 Btu/ft^3	
- Compressed	20,551 Btu/Lb	960 Btu/ft^3
- Liquid	90,800 Btu/gal	87,600 Btu/gal
Crude petroleum	138,100 Btu/gal	131,800 Btu/gal
Fuel Oils		
- Residual	149,700 Btu/gal	138,400 Btu/gal
- Distillate	138,700 Btu/gal	131,800 Btu/gal
Coal		
- Anthracite - Consumption	21.711 x 10^6 Btu/short ton	
- Bituminous and lignite - Consumption	21.012 x 10^6 Btu/short ton	
- Production average	21.352 x 10^6 Btu/short ton	
- Consumption average	21.015 x 10^6 Btu/short ton	

The heat content values provided above are using the U.S. convention of fuel specification, providing in most entries both the “gross” (higher heating values- HHV), and the “net” (lower heating value- LHV) energy content of the fuels. Gross heat content rates are commonly used in energy calculations in the United States; net (or lower) heat content rates are typically used in European energy calculations. The difference between the two rates is the amount of energy that is consumed to vaporize water that is created during the combustion process. Generally, the difference ranges from 2% to 10%, depending on the specific fuel and its hydrogen content. Some fuels, such as unseasoned wood, could exhibit more than a 40 percent difference between their gross and net heat content rates.

The degree to which the use of biofuels displaces fossil fuel as an energy source varies fairly widely across estimates by different researchers and across production technologies and regions. In general, displacement factors for fossil fuels overall are considerably worse for starch-based ethanol than for cellulosic ethanol. This is due to a fossil-intensive fuel cycle of the former, including feedstock production and high consumption of natural gas within the plants themselves. Unfortunately, natural gas markets are also volatile, or subject to the same supply insecurities as exist with imported oil. Coal can also be used to fuel ethanol refineries, as is becoming commonplace in the United States; but its use worsens the environmental profile of ethanol substantially. Furthermore, the energy content of a liter of ethanol is typically only two-thirds of the energy content of a liter of gasoline, as is shown in Table 3.1 above.

3.1 Energy Input and GHG Emissions Considerations

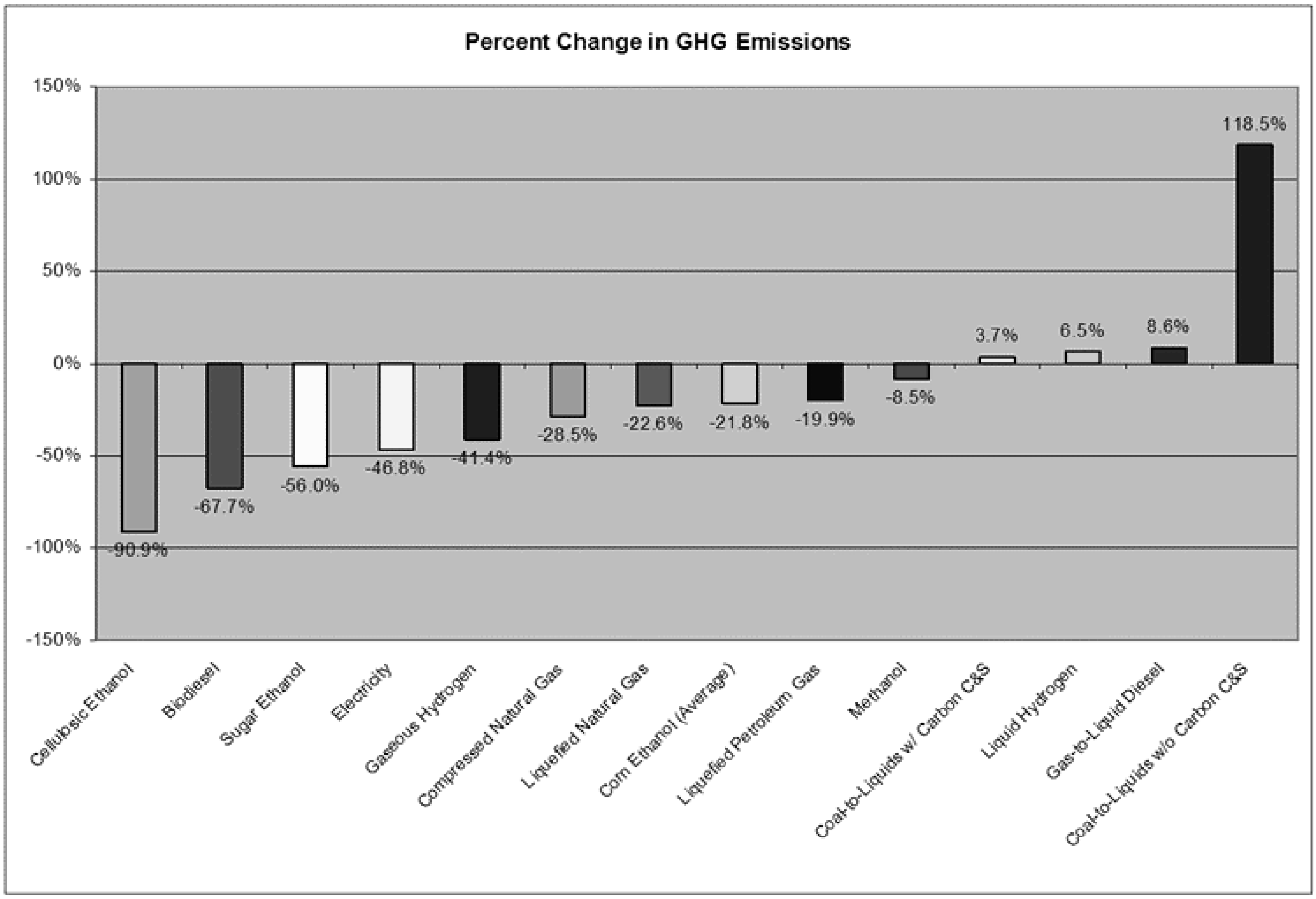
Fossil energy inputs and emissions levels from bioethanol fuel production are sensitive to the specific processes and feedstocks utilized; to the energy embedded in fertilizers consumed for growing the feedstock; and to other local conditions. The diversity of feedstocks and processes, make it difficult to identify indicative values for energy input and emissions, however some general observations from studies performed to-date are:

- *Sugar-cane ethanol-* the fossil fuel input is about 10%-12% of the final energy, and one can anticipate up to 90% CO_2 reduction as compared with gasoline;

- *Corn ethanol*- requires a much higher energy input and much smaller potential reduction of CO_2 emissions (15-25%).
- *Cellulosic ethanol*- the total energy input is high but with the utilization of the biomass itself, CO_2 emission reductions of up to 70% could be attained, or even up to100% with power co-generation.

Figure 3.2 below presents a recent compilation produced by the U.S. EPA about the relative GHG reduction potentials for different transportation fuels.

Figure 3.2- Percent Change in GHG Emissions



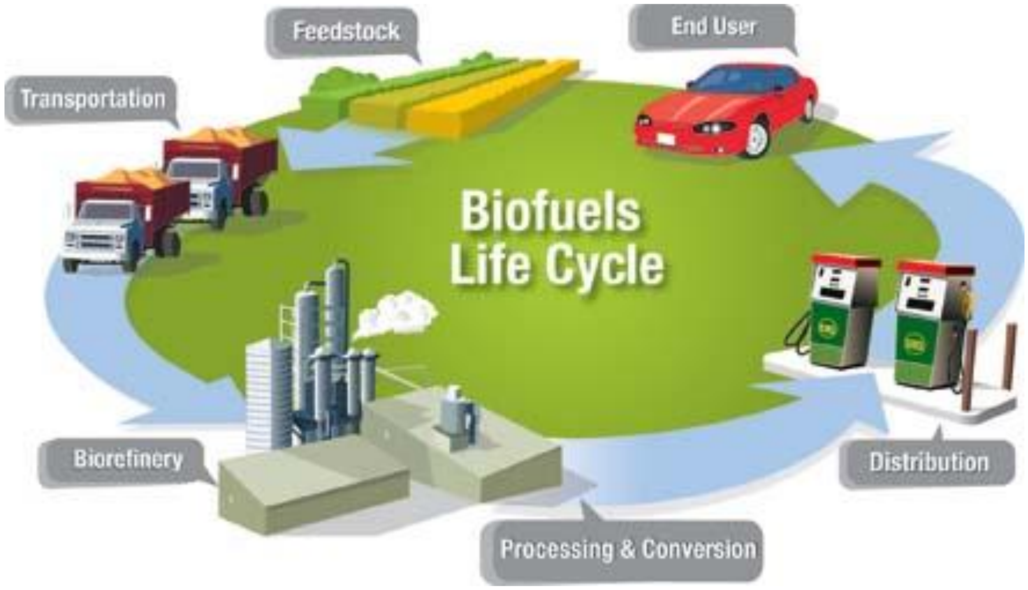
Source: U.S EPA

The data presented in this figure indicate that cellulosic ethanol has the potential of reducing GHG emissions by over 90%, as compared to 56% for sugar ethanol, or 22% on average for corn ethanol. In Brazil, for example, the production of sugar ethanol is energy-efficient since the crop produces high yields per hectare and the sugar is relatively easy to extract, and bagasse is used to provide the heat and power for the process.

3.2 "Well-to-Wheel" Life Cycle Analyses

In order to compare the energy and environmental balances of the myriad of processes, feedstock and local conditions, a "Well-to-Wheel (WTW)" life cycle analysis models are typically used to calculate and compare the relative benefits of different transportation fuels[23]. Figure 3.3 shows schematically the various phases of the transportation fuels lifecycle that needs to be addressed in a complete analysis. This way the analysis will account properly for the energy and environmental impact of a product from its inception to the point in which it is delivered to the end user.

Figure 3.3- Biofuels Lifecycle



Source: U.S. DOE

Several WTW analyses have been conducted in different regions of the world, and the results could vary with local cultivation and operating practices and the transportation of the final products. For example, IEA assessments show that in Brazil sugarcane ethanol might emit as low as 0.2-0.3kg CO_2 per liter of ethanol, on a WTW basis, as compared with 2.8kg CO_2/liter for conventional gasoline. Although this amounts for an

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[23] Wu, Y., Wang, M.Q., Sharer, P.B., Rousseau, A., 2007, "Well-to-Wheels Results of Energy Use, Greenhouse Gas Emissions, and Criteria Air Pollutant Emissions of Selected Vehicle/Fuel Systems", SAE 2006 Transactions (Journal of Engines), Paper No. 2006-01-0377.

apparent 90% reduction, it is not the whole picture since it does not account for the lower heat content of ethanol which necessitates more litters per km of travel.

Ethanol from sugar beet requires more energy input and could provide only 50%-60% emission reduction on a WTW basis as compared with gasoline. Ethanol production from cereals and corn (maize) can be even more energy-intensive and the debate is still raging as to the net energy gain of the process[24]. The results obtained vary due to the sensitivity of the estimates to the process used. Although corn-ethanol may displace petroleum use by up to 95%, the total fossil energy input currently amounts to some 60%-80% of the energy contained in the final fuel (20% diesel fuel, the rest being coal and natural gas) and hence the CO_2 emissions reduction may be as low as 15%-25% vs. gasoline.

For ethanol production from ligno-cellulosic feedstock, the total energy input needed may be even higher as compared to bioethanol from corn, but in some cases most of such energy could be provided by the biomass feedstock itself. Hence, net CO_2 emissions reduction from ligno-cellulosic ethanol can be close to 70% as compared to gasoline, and could approach 100% if electricity co-generation is used instead of fossil fuel generated electricity. Current R&D aims to exploit the large potential anticipated from improving efficiency in enzymatic hydrolysis.

The U.S. Argonne National Laboratory GREET Model[25] shows that for cellulosic ethanol an 80% GHG emission reductions can be expected, as compared to gasoline, while corn ethanol shows only 20-30% reductions. The conclusions from these studies are that the benefit of using cellulosic ethanol stems from the fact that lignin, which is a biomass by-product of the conversion operation, is used to fuel the process. In that case there are “no net GHG emissions”, since as a renewable fuel the GHG produced by the combustion of the biomass is offset by the CO_2 absorbed by the biomass as it grows.

More recent studies are drawing attention to the fact that existing WTW analyses might not present the whole picture since most of them do not take into account the indirect impact of the large amounts of CO_2 that are stored in a variety of ecosystems and which

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[24] IEA Energy Technology Essentials, 2007, “Biofuels Production”, at: http://www.iea.org/textbase/techno/essentials2.pdf

[25] Argonne National laboratory, 2008, “The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model”, at: http://www.transportation.anl.gov/software/GREET/

could be released as a consequence of the land-use changes caused by the demand for, and the resultant intensive cultivation of, fuel crops[26].

An expanded WTW analysis of various bioethanol pathways was conducted in a collaborative study supported by the European Commission[27]. This study evaluates not just the fuel production pathway until it is dispensed for use, but also looks at the "Fuel-Vehicle" system in order to evaluate the expected GHG emissions from a gasoline powered car fleet utilizing 2010 model year and newer cars. The results of this analysis are shown in Figure 3.4 and demonstrate the importance of studying the GHG reduction potential in the whole transport system, i.e. from the very origin of the crops that are used to produce the fuel, all the way through production and distribution to using the fuel while driving.

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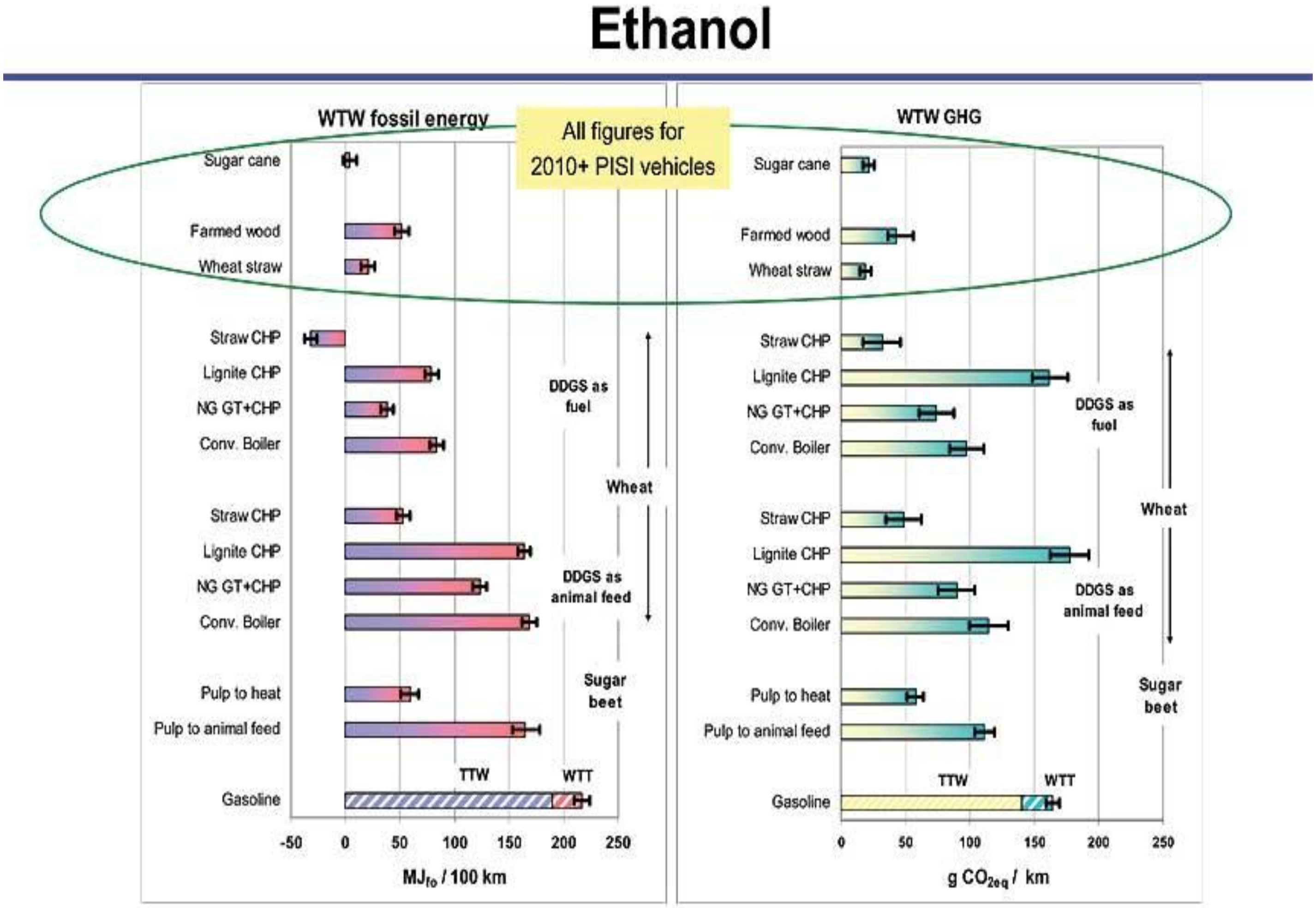
[26] Farrell, A., O'Hare, M., 2008, "Memo to California Air Resources on Greenhouse Gas Emissions from Indirect Land-Use Changes", Berkeley, California, 12 January 2008, at: http://www.its.berkeley.edu/sustainabilitycenter/lcfs/011608ucb_luc.pdf

[27] EUCAR/ JRC/ CONCAWE, 2007. Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. At: http://ies.jrc.ec.europa.eu/wtw.html

Figure 3.4- Savings in GHG Emissions (right box) and Fossil Energy (left box) for Different Feedstocks, Production Methods and Different Use of Products Compared to Gasoline



Source: EUCAR/ JRC/ CONCAWE, 2007

The main conclusion from the analysis shown in Figure 3.4 is that the energy used for the ethanol plant is of key importance. The extent of fossil energy input into the production process influences the GHG emission reduction potential to a high extent. Hence, advanced processes (from wood or straw) can give very high savings of greenhouse gas emissions, mostly because these processes use part of the biomass intake as fuel and therefore involve little fossil energy.

Using the by-products from the bioethanol production for energy production rather than animal feed (which is the most common use today) has a very large impact on the GHG emissions in the WTW perspective. If the sugar beet pulp is used for heat production, the sugar beet pathway can deliver high savings of energy and GHG emissions. Similar reduction can be achieved with wheat when the “distiller’s dried grain with solubles” (DDGS) residues from the conventional production of ethanol are used for heat. Production of bioethanol from sugar beet and wheat, as currently practiced in Europe, (using gas-fired boilers for steam and electricity from the grid) gives a modest fossil energy/GHG savings compared with gasoline.

With conventional energy production scheme, and the currently most economic way of using by-products (as cattle fodder), the schemes save about 20% of the fossil energy required for gasoline and just over 30% of the GHG emissions. Use of co-generation, particularly in combination with a gas-fired gas turbine, could significantly improve these figures to over 40% of energy savings and GHG emissions. Combined heat and power production (CHP), also improves the environmental profile of the produced ethanol, yet the wrong choice of energy for the production plant, like brown coal, wipes out most of these gains and can even result in increased GHG emissions.

Similar studies were also part of the Viewls project[28]. It compared around 600 LCA studies and resulted in the following overall picture:

- From a WTW perspective, bioethanol produced from starch crops can be both better and worse than petrol when it comes to GHG emissions.
- For bioethanol production from sugar crops, the results exhibited less or much less, GHG emissions.
- For bioethanol production from lignocellulose residuals the results looked even more promising.
- The costs of GHG reduction are more favorable for 2nd generation biofuels, which is attributed to the higher greenhouse gas reductions due to the use of lignocellulose-based biomass.

The Swiss Institute[29], performed a full LCA of a large number of biofuels and compared the environmental footprint with those of transport fuels derived from petroleum and natural gas in different European countries, as shown in Figure 3.5.

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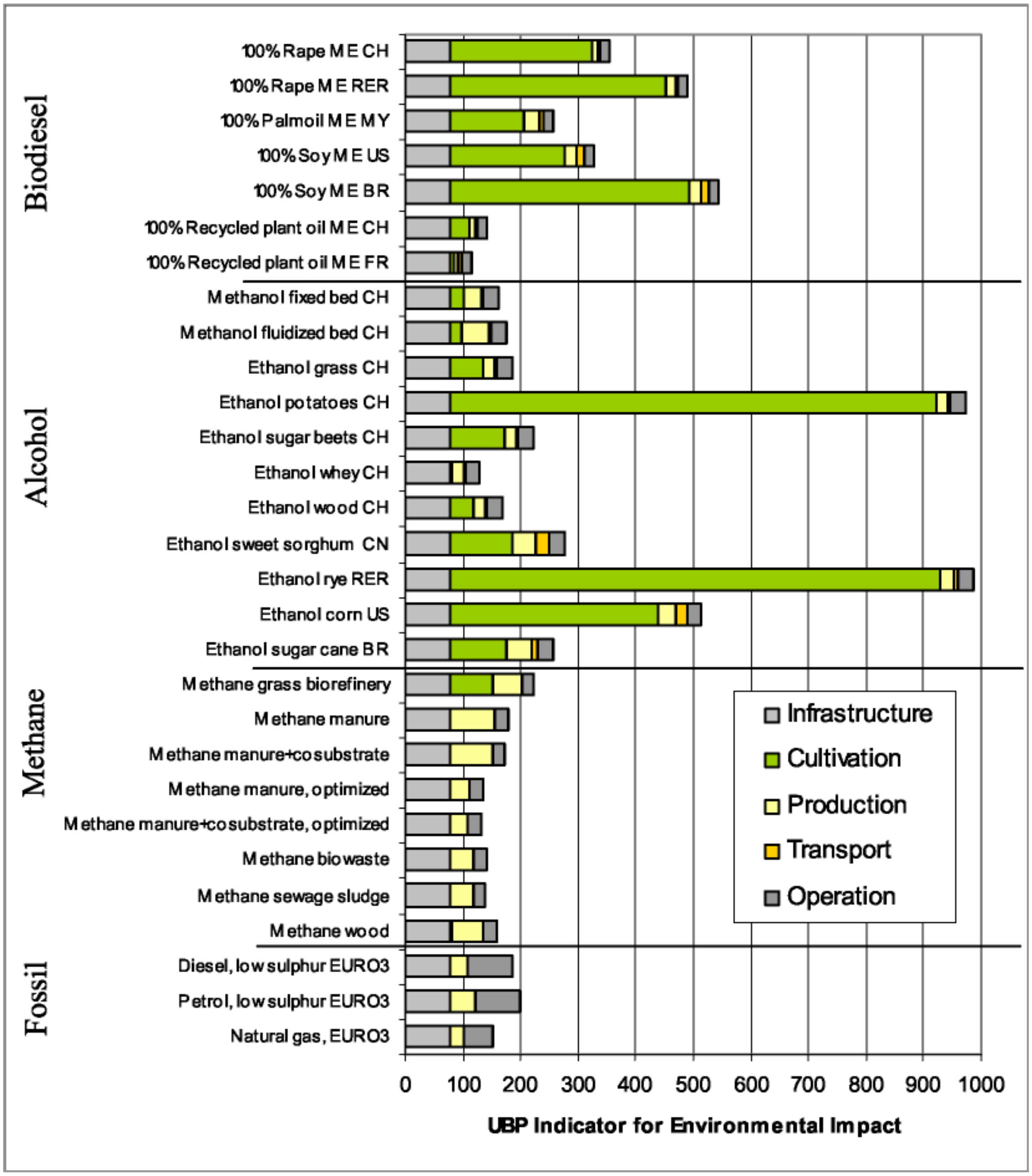
[28] VIEWLS project, 2005, “Shift Gear to Biofuels: Results and Recommendations from the VIEWLS project”, at: http://www.refuel.eu/fileadmin/refuel/user/docs/Final_report_-_Shift_Gear_to_Biofuels.pdf

[29] Zah, R., Heinz, B., Gauch, M., Hischier, R., Lehmann, M., Wäger, P., 2007, “Life Cycle Assessment of Energy Products: Environmental Assessment of Biofuels- Executive Summary”, EMPA- Materials Science & Technology,

Figure 3.5- The Environmental Footprint of Different Fuels in Different European Countries



Source: The Swiss Institute

Federal Office for Energy (BFE), Bern, at: www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=en&name=en_667574407.pdf

In its methodology the Swiss Institute calculated environmental impact using multiple indicators including damage to human health and ecosystems and the depletion of natural resources, aggregated into a single indictor (UBP -UmweltBelastungsPunkte). The indicators also reveal the relative contribution of the infrastructure, cultivation, production, transport and operation. Although their study shows that environmental impacts of vehicle operation are much higher when fossil fuels are used, this may be offset in many cases by the very high environmental impacts from agricultural production in terms of soil acidification and excessive fertilizer use, biodiversity loss, air pollution caused by slash-and-burn and the toxicity of pesticides.

3.3 Other Environmental Considerations

As shown in figure 3.5 above, comparisons between fossil fuels and biofuels should not be limited to GHG emissions. Biofuels have a more positive record in respect to their end-of-pipe emissions, but those made from grains and oilseeds are generally more damaging to the environment up-stream. Production of biomass for biofuels can therefore have widely differing impacts on biodiversity, water quality (through the use of fertilizers and pesticides), water use and soil erosion.

Benefits of Wastes as Feedstock

Agricultural wastes are a low cost feedstock that is quite abundant and contains greater potential energy than simple starches and sugars. Currently, agricultural residues are plowed back into the soil, composted, burned or disposed in landfills. Thus, using agricultural wastes as a feedstock could have added benefits by offering farmers a new resource of income from their land. Large benefits could also be attained by using perennial grasses, such as switchgrass, and other forage crops as feedstocks for ethanol production. The perennial grass has a deep root system, anchoring soils to prevent erosion and helping to build soil fertility.

Industrial wastes and municipal solid waste (MSW) can also be used to produce ethanol.

From an environmental standpoint, any process that can reduce or eliminate landfilling with wastes could have an added environmental benefit.

Biodiversity Loss

Large sugarcane, oil palm and soy plantations are already supplanting forests and grasslands in Brazil, Argentina, Colombia, Ecuador, Malaysia, Mali and Indonesia. When land is transformed from primary or secondary forest to farmland, the loss of forest species within the deforested areas can be immediate and permanent. Wide-scale destruction of forests can alter local and global climates through the disruption of the carbon cycle and the hydrological cycle. Affects of deforestation include:

- Extinction of species: Forests contain more than half of all species on the planet, many of which depend on forests for survival;
- Fragmentation of existing habitat: Smaller habitat areas generally support fewer species, and for species requiring undisturbed core habitat, fragmentation can cause local and even general extinction;
- Spread of exotic species: Species invasion by non-native plants, animals and diseases can occur more readily in deforested areas;
- Silting of water courses, lakes and dams: This occurs as a result of soil erosion and impacts aquatic biodiversity;
- Soil erosion: Without the protective cover of vegetation, more soil is lost, negatively impacting soil biodiversity and increasing vulnerability to desertification. The maintenance of soil fertility is one of the most vital ecological services provided by the ecosystem. The replenishment of minerals and organic content must be constant as plants consume soil content and pass it up the food chain.

The above issues are not particularly relevant to Israel and will be further discussed in section 6.2.

Climate Impacts

As stated above, energy crops around the world are sometimes grown on land that was previously rainforest, savannah, peat land, old-growth forest or wetlands. As fuel crop plantations are created or expanded, the land-use change is sending huge amounts of carbon emissions into the air.

By some estimates, agriculture and deforestation together account for at least one-third of man-made emissions of greenhouse gases[30]. Land use changes impact the global climate through an increase or decrease in net carbon emissions and sequestration. Sequestration is the process through which green plants made of cellulose remove CO_2 from the atmosphere and accumulate it in their biomass. When this biomass is burned, carbon in the plant rejoins with oxygen to release CO_2. The rate of carbon sequestration varies by source; rainforests on peat soils in particular are one of the world's most important carbon sinks and play a vital role in helping to regulate the global climate.

As discussed above, very few assessments in "wells-to-wheels" analysis include carbon emissions all the way to origin, taking into account land use change brought on by energy crop production. In particular, the Global Environmental Facility notes: "Two striking features of existing LCA studies are important: the wide range of results in terms of net energy balances and net GHG emissions, and their apparent lack of focus on evaluating GHG impacts on a per-hectare basis, which is surprising since land is the primary resource for biofuels production"[31].

This is an information gap that requires further study; particularly as researchers at the World Land Trust estimate that forestation of an equivalent area of land would sequester two to nine times more carbon over a 30-year period than the emissions avoided by the use of the biofuels. Additionally, some studies show values of as much as 200 metric tons of CO_2 sequestered per hectare of tropical forest, with about half of this forest capacity located at mid and high latitudes. Taken together, these gaps of information mean that we might not be able to accurately compare the consumption of fossil fuels against the consumption of biofuels and derive accurate GHG reductions and associated environmental impacts.

Water Consumption & Quality

Just as climate impacts vary by feedstock, water consumption and degradation also depend on which crop is being substituted and where it is being grown. Corn crops have

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[30] Stern Review Report, 2006, "The Economics of Climate Change", at: http://www.hm-treasury.gov.uk/media/3/2/Summary_of_Conclusions.pdf

[31] Global Environment Facility, 2006, "Report of the GEF-STAP Workshop on Liquid Biofuels", at: http://www.gefweb.org/documents/council_documents/GEF_30/documents/C.30.Inf.9.Rev.1ReportoftheGEFSTAPWorkshoponLiquidBiofuels.pdf.

been shown to have a negative impact on the water cycle because of the high volumes of water required for irrigation and for ethanol refinery plants[32,33].

Sugarcane production also requires enormous amounts of water, because of the large amounts required to remove soil attached to the stalks. By some estimates (e.g., Business for Social Responsibility[34]), the total water consumption for ethanol production in Brazil is enough to supply water for approximately 13,800 people in Brazil for 42 years. Water use for sugarcane production will likely increase, as Brazilian pasturelands is increasingly being planted with sugarcane.

Many agricultural practices rely extensively on pesticides for crop production. Corn crops in particular require large usage of herbicides. Many herbicides dissolve in water and are mobile, so they can be transported in surface runoffs from agricultural fields to water streams. In the United States, 70% of corn for ethanol production is grown in four states: Illinois, Iowa, Minnesota and Nebraska. All of this corn production is located in the upper Mississippi River basin. Studies conducted by the U.S. Geological Survey have documented the presence of herbicides in the Mississippi River and its tributaries, which eventually flow to the Gulf of Mexico[35]. The excess of nitrogen in the Mississippi River system is a major cause of the oxygen-starved "dead zone" in the Gulf of Mexico, an area that cannot support marine life.

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[32] Institute for Agriculture and Trade Policy, 2006, "Water Use by Ethanol Plants: Potential Challenges", at: http://www.agobservatory.org/library.cfm?refid=89449.

[33] Roberts, M.G., Male, T.D., Toombs, T.P., 2007, "Potential Impacts of Biofuels Expansion on Natural Resources", at: http://www.environmentaldefense.org/documents/7011_Potential%20Impacts%20of%20Biofuels%20Expansion.pdf

[34] Business for Social Responsibility. 2007, "Biofuels for Transportation: The next energy revolution or a fix that fails", at: http://www.bsr.org/reports/bsr_biofuels-transportation.pdf

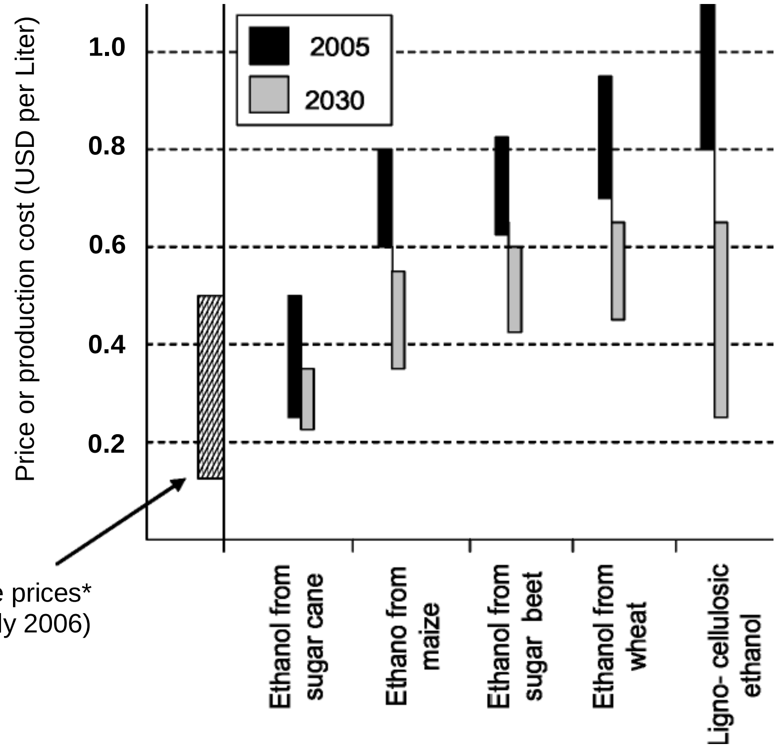
[35] U.S. Geological Survey- Kansas Water Science Center, 1998, "Discharge of Herbicides from the Mississippi River Basin to the Gulf of Mexico, 1991-97", at: http://ks.water.usgs.gov/Kansas/pubs/fact-sheets/fs.163-98.html.

3.4 Economic Considerations

Based on current commercial technologies, biofuels are not competitive when oil prices are around 70$/ barrel without extensive government support. More than half of the production cost of biofuels is determined by the price of the feedstock. Given the enormous requirements for land and the competition with food and fiber, feedstock prices may not decline as much as is often assumed.

The IEA[36] has evaluated current and projected future costs of producing ethanol from different feedstocks, as shown in Figure 3.6. Brazil's costs, at $0.20/liter (or $0.30/ liter of gasoline equivalent) for ethanol produced in new plants, are the lowest in the world. Corn based ethanol costs about 50% more to produce, even before the recent rise in prices in the U.S. and 100% more than in the EU. These costs do not include the costs of transporting, splash blending and distributing ethanol, however, which can easily add another $0.20/ liter at the pump.

Figure 3.6- Current and Projected Future Ethanol Production Costs, Compared with Recent (pre-tax) Gasoline Prices / Liter of Gasoline Equivalet



Pre-tax gasoline prices*
(Jan. 2000 – July 2006)

Source: The IEA

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[36] IEA, 2006, "World Energy Outlook", OECD Publications, Paris, at: http://www.iea.org/Textbase/npsum/WEO2006SUM.pdf

The IEA foresee that technological improvements will help to reduce costs by one third between 2005 and 2030, in part driven by reductions in the costs of feedstocks. They project that feedstocks costs will decline by one-half in the U.S., one-third in Brazil and one-quarter in Europe; all this under the assumption that the current rates of subsidies and incentives will remain in place.

Yet some unknown factors remain, including the pressure on commodities to feed a growing world population, uncertain changes in yields caused by global climate change, and increased demand for biomass for fuels. All these might lead to rising feedstock prices, as was already seen between 2005 and May 2007 when prices for key ethanol feedstocks rose by between 6% and 68%, with the proportional increase being observed for corn. Certainly spot prices can be expected to remain volatile, as was evident in February 2006, for example, when the reference price for sugar was more than twice its lowest value only nine months earlier.

Second-generation biofuels

It is expected that expanding biofuels availability will hit a limit within the next decade unless 2nd generation technologies and feedstock become available.

Existing demonstration plants that produce ethanol from ligno-cellulosic materials typically have production costs around $1.00/ liter, on a gasoline-equivalent basis, as was shown in Figure 3.6 above. Most of the efforts to bring down costs are focusing on enzymatic or microbial breaking down of the lignin, cellulose or hemi-cellulose into a form that can be fermented. This is the critical front end of the process that with increased ethanol content in the fermented broth, the energy needed in the distillation stage is reduced and the whole process becomes more efficient. The rapid pace of technological developments, and uncertainty over the long-run costs of feedstock, may lead in the long run to production costs around $0.50/ liter of gasoline equivalent.

Some of this cost reduction may be due to lower costs of enhanced enzymes (resulting from biotechnological research) and improved separation techniques, in addition to front-end hydrolysis of the biomass. All of these advances need technological breakthroughs, as well as improved process integration in biorefineries of lingo-cellulosic feedstock that will produce an associated array of valuable co-products, and self generated power that could reduce overall costs.

4 The Statutory Framework

4.1 Legislative & Regulatory Overview

4.1.1 U.S.A

In March 2008, President George W. Bush Attended the Washington International Renewable Energy Conference and presented the formal stand of the U.S government toward biofuels and energy security: “Ethanol production in the U.S has quadrupled from 1.6 billion gallons in 2000 to a little over 6.4 billion gallons in 2007.The vast majority of that ethanol is coming from corn, and that is good. That is good if you are a corn-grower. And it is good if you are worried about national security. I would rather have our corn farmers growing energy than relying upon some nation overseas that may not like us”.

This policy has been implemented since 1990 by The Clean Air Act Amendments, which established the Oxygenated Fuels Program and the Reformulated Gasoline (RFG) Program. As a result, a new demand for ethanol blended with gasoline was created. The RFG program was aimed to reduce vehicle emissions in areas that did not succeed in attaining the National Ambient Air Quality Standards for ground-level ozone.

A decade later, in August 2005, The Energy Bill was enacted. The Energy Bill is a comprehensive energy legislation, which includes a nationwide renewable fuels standard (RFS) that aims to double the use of ethanol and biodiesel by 2012. According to this program, a small share of the oil supply of the country will be provided by renewable fuels such as ethanol and biodiesel with a view to providing reduced consumer prices, increased energy security, and growth in rural areas.

The key provisions of the Renewable Fuels Standard are[37,38,39]:

- Establishes an RFS that starts at 4 billion gallons in 2006 and increases to 7.5 billion gallons in 2012.
- For calendar year 2013 and each year thereafter, the minimum required volume of renewable fuels would be equal to the same percentage of the amount of

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[37] Tokgoz, S., Elobeid, A., 2006, “An Analysis of the Link between Ethanol, Energy, and Crop Markets”, Working Paper 06-WP 435, Center for Agricultural and Rural Development, Iowa State University.

[38] Renewable Fuels Association, 2005, “Federal Regulations: Renewable Fuels Standard”, at: www.ethanolrfa.org/policy/regulations/federal/standard/.

[39] Frost & Sullivan Market Research, 2006, “North American Ethanol Market Assessment”, at: http://www.frost.com/prod/servlet/frost-home.pag

renewable fuels in 2012 (7.5 billion gallons) in the total gasoline sold in the U.S. in that year. In addition, starting in 2013, the required amount of renewable fuels must include a minimum of 250 million gallons derived from cellulosic biomass.

- Provides for 2.78% by volume renewable fuel use in 2006 if federal regulations have not yet been promulgated by the U.S. Environmental Protection Agency.
- Provides flexibility for refiners through a credit-trading program that allows the usage of renewable fuel where and when it is most efficient and cost-effective. RFS credits have a life span of 12 months. Under this program, ethanol produced from cellulosic feedstocks is granted extra credit: a gallon of cellulosic ethanol counts as 2.5 gallons of renewable fuel.
- Exemption of small refineries from the RFS program until January 1, 2011.
- Requires regulations to ensure that at least 25 percent of the annual renewable fuel obligation be met in each season, should seasonal variations exist. California is an exception, but refiners in the state must still use the requisite amount of renewable fuel in any given year.
- Elimination of re-formulated gasoline (RFG) 2.0 wt. percent oxygenate standard under the Clean Air Act, 270 days after enactment.
- Creation of grant and loan guarantee programs for cellulose ethanol and ethanol production from sugar.

In February 2007, the US expanded the scope of its RFS in order to reduce gasoline use in the country by 15% during the next 10 years. The main objective is to stimulate the consumption of renewable and alternative fuels, especially ethanol, aiming at increasing alternative fuel consumption from the present level of 5 billion gallons of ethanol to 35 billion gallons of any alternative fuel in 10 years time. However, for the U.S, the short-term objective is clearly one of replacing MTBE, rather than base gasoline, by ethanol. MTBE is a fossil-based fuel, the substitution of which is advantageous from the perspectives of both human health and GHG emission problems[40].

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[40] Szklo, A., Schaeffera, R., Delgado, F., 2007, “Can One Say Ethanol is a Real Threat to Gasoline?”, Energy Policy, **35:** 5411–5421.

4.1.2 Brazil

The decline in international sugar prices and the increased burden of the petroleum bill after the first oil crisis led the Brazilian government to launch the Proálcool Program in 1975. The government mandated a blending ratio of ethanol for all gasoline sold in Brazil depending on market conditions. In 1973, Brazil was importing 34% of its total energy consumption in the form of crude oil. The Pro-Alcohol program was sought to reduce the country's dependence on oil imports and the trade deficit that came about as a result. The program also relied on the fact that Brazil produced about one quarter of the world's sugar (over 300 million tons of sugarcane a year).

The fuel ethanol used in Brazil was at first a blend of 1-16% that could be used without engine modification. With government incentives the technology was developed to produce vehicles that could run exclusively on hydrated ethanol, or on a blend of anhydrous ethanol and gasoline[41].

In Brazil all petrol is still sold with an ethanol component of 20–26%. In economic terms, investments in agriculture and industry for the production of transport ethanol during the period 1975–89 has been estimated at close to US$ 5 bn, triggering benefits in terms of import savings with a value of over US$ 52 bn for the period 1975–2002.

Although the program lost some of its impact in the 1990s due to a slump in world oil prices and the phasing-out of government incentives, it is seeing a resurgence related to current high oil prices, the competitiveness of ethanol as a transport fuel and the emergence of new export markets.

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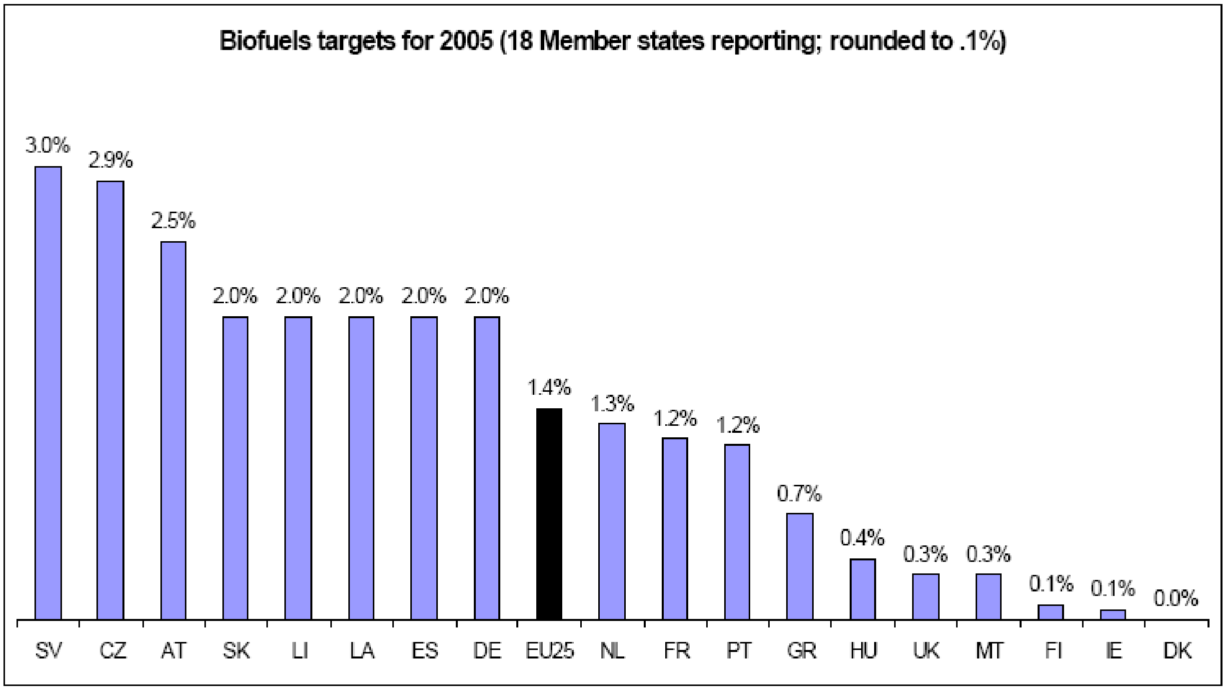
[41] Frost & Sullivan Market Research, 2002, "Biofuels: Emerging Developments and Existing Opportunities", at: http://www.frost.com/prod/servlet/frost-home.pag

4.1.3 The European Union

In 2003 directives 2003/30/EC and 2003/96/EC were formally adopted by the European Parliament. The Biofuels Directive[42] sets “reference values” of a 2% (v/v) market share for biofuels in 2005 and a 5.75% (v/v) share in 2010. To implement the directive, many Member States are relying on fuel tax exemptions, facilitated by the Energy Taxation Directive[43]. A number of Member States have recently turned to biofuels obligations, requiring fuel supply companies to incorporate a given percentage of biofuels in the fuel they place on the national market. The 2005 target share of 2% biofuels has not been achieved. With the objectives set by the Member States, the share of biofuels would have attained, at most, only 1.4%[44], as describe at figure 4.1.

Figure 4.1- Biofuels Targets for 2005 (EU25)[45]



Source: European Commission

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[42] Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport (17.5.2003), at: http://ec.europa.eu/energy/res/legislation/doc/biofuels/en_final.pdf

[43] Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity (31.10.2003), at: http://ec.europa.eu/energy/res/legislation/doc/biofuels/taxation_energy_products_and_electricity.pdf

[44] European commission, 2006, “An EU Strategy for Biofuels”, Commission of the European communities, Brussels, at: http://ec.europa.eu/agriculture/biomass/biofuel/com2006_34_en.pdf

[45] European Commission, 2006, “Biofuels in the European Union”, Biofuels Research Advisory Council, Final draft report of the Biofuels Research Advisory Council, at: http://ec.europa.eu/research/energy/pdf/draft_vision_report_en.pdf

EU heads of state and government officials committed to set a binding target of 20% of the EU's total energy supply to come from renewables by 2020. Biofuels included are ethanol and biodiesel[46].

According to Frost & Sullivan[47] analysis it is highly likely that the European commission will renew the biofuels directives and the targets for further years. Moreover, it is also likely that the limits set will continue to be non-mandatory, although the penalties for not following the guidelines will probably increase. On the other hand, there is an increasing effort calling upon the EU to abandon its biofuels targets. A recent report[48] of The Environmental Audit Committee (EAC) of the UK Parliament concludes that the UK Government and EU should not have pursued targets to increase the use of biofuels in the absence of robust sustainability standards and mechanisms to prevent damaging land use change. The report also concludes that biofuels are generally an expensive and ineffective way to cut greenhouse gas emissions when compared to other policies.

4.2 Governmental Incentives

4.2.1 U.S.A

Subsidization of ethanol production at the federal level began with the Energy Tax Act of 1978. That Act reduced the motor fuels excise tax for ethanol-gasoline blends. Initially set at 4¢/ gallon of gasohol- a blend of 10% ethanol and 90% gasoline, also called E10- equivalent to 40¢/ gallon of pure ethanol. The exemption level thereafter changed frequently over the years, as described at figure 4.2.

The Energy Tax Act of 1978 was finally replaced by the Volumetric Ethanol Excise Tax Credit (VEETC) in 2004[49].

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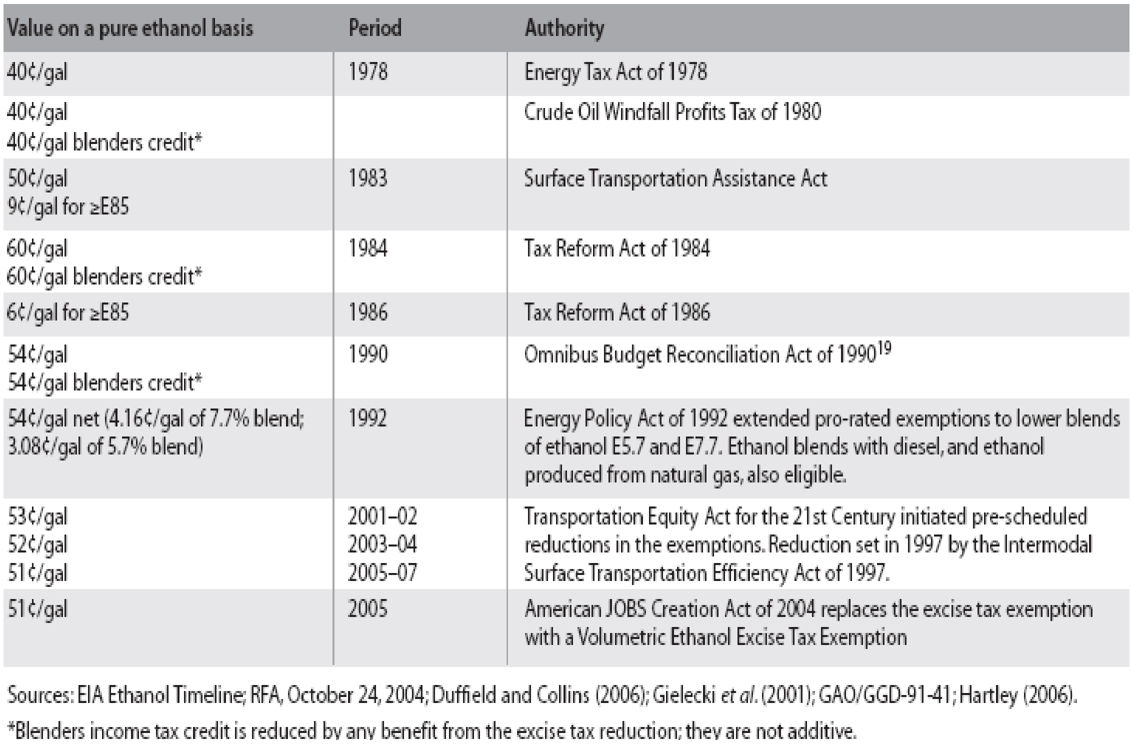
[46] Szklo, A., Schaeffera, R., Delgado, F., 2007, "Can One Say Ethanol is a Real Threat to Gasoline?", Energy Policy, **35:** 5411–5421.

[47] Frost & Sullivan Market Research, 2007, "European Bioethanol and Feedstock Markets", at: http://www.frost.com/prod/servlet/frost-home.pag

[48] The Environmental Audit Committee, 2008, "Are Biofuels Sustainable?", The UK Parliament, at: http://www.publications.parliament.uk/pa/cm/cmenvaud.htm

[49] Koplow, D., 2006, "Biofuels – At What Cost ?: Government Support for Ethanol and Biodiesel in the United States", International Institute for Sustainable Development, at: www.globalsubsidies.org/IMG/pdf/**biofuels**_subsidies_us.pdf

Figure 4.2- Exemption from Motor Fuels Excise Tax for Alcohol Blends



Value on a pure ethanol basis	Period	Authority
40¢/gal	1978	Energy Tax Act of 1978
40¢/gal 40¢/gal blenders credit*		Crude Oil Windfall Profits Tax of 1980
50¢/gal 9¢/gal for ≥E85	1983	Surface Transportation Assistance Act
60¢/gal 60¢/gal blenders credit*	1984	Tax Reform Act of 1984
6¢/gal for ≥E85	1986	Tax Reform Act of 1986
54¢/gal 54¢/gal blenders credit*	1990	Omnibus Budget Reconciliation Act of 1990[19]
54¢/gal net (4.16¢/gal of 7.7% blend; 3.08¢/gal of 5.7% blend)	1992	Energy Policy Act of 1992 extended pro-rated exemptions to lower blends of ethanol E5.7 and E7.7. Ethanol blends with diesel, and ethanol produced from natural gas, also eligible.
53¢/gal 52¢/gal 51¢/gal	2001–02 2003–04 2005–07	Transportation Equity Act for the 21st Century initiated pre-scheduled reductions in the exemptions. Reduction set in 1997 by the Intermodal Surface Transportation Efficiency Act of 1997.
51¢/gal	2005	American JOBS Creation Act of 2004 replaces the excise tax exemption with a Volumetric Ethanol Excise Tax Exemption

Sources: EIA Ethanol Timeline; RFA, October 24, 2004; Duffield and Collins (2006); Gielecki *et al.* (2001); GAO/GGD-91-41; Hartley (2006).
*Blenders income tax credit is reduced by any benefit from the excise tax reduction; they are not additive.

Volumetric Ethanol Excise Tax Credit (VEETC)

The American Job Creation Act of 2004 developed a new system of federal taxation of ethanol blends. The salient features of the new system of taxation, Volumetric Ethanol Excise Tax Credit, are:

- Modification of gasohol blends containing 10 percent, 7.7 percent, and 5.7 percent ethanol by providing a 0.51¢ /gallon excise tax credit for each gallon of ethanol blended with gasoline rather than providing a reduced tax rate.
- Extension of 0.51¢ /gallon tax credit for ethanol through December 2010. Requires payment of full tax on each gallon of gasoline-blended ethanol by blenders, but provides a 0.51¢ /gallon tax credit or refund for each gallon of ethanol used in the mixture.
- Deposit all gasohol excise tax into the Highway Trust Fund, and pay out for the credit of the General Fund.

Small Ethanol Producer Tax Credit

This program provides small ethanol producers with 10¢ /gallon production income tax credit on up to 15 million gallons of production annually. The credit is limited to $1.5 million per year per producer. Small ethanol producers are defined as those who produce 60 million gallons of ethanol per year or less.

RFG Required Areas

In the Clean Air Act, the U.S. Congress specified that RFG must contain oxygen— two percent by weight. Ethanol and MTBE are two of the most commonly used substances that add oxygen to gasoline. Since the banning of MTBE by the states, ethanol has become the oxygenate of choice in the RFG program. The Energy Policy Act of 2005 (H.R. 6) removes the oxygenate requirement of 270 days after enactment, instead of a nationwide renewable fuels standard. Currently, about 30 percent of the nation's gasoline is RFG; helping about close to 80 million people breathe cleaner air.

Winter Oxygenated Fuel Areas

The federal Clean Air Act Amendments of 1990 established a winter oxygenated fuels program to combat carbon monoxide emission from vehicles. Beginning in 1992, the gasoline sold during the winter months in areas designated as non-attainment areas for carbon monoxide pollution has to contain 2.7 percent oxygen by weight. In fact, several areas have increased the minimum oxygen content to 3 percent to 3.5 percent by weight. Ethanol is the oxygenate of choice in this program. It is a tremendous success that many areas are demonstrating attainment of carbon monoxide, and are including the continued use of oxygenated fuel in their maintenance plan.

CCC Bioenergy Program

The Commodity Credit Corporation (CCC) was established by the United States Department of Agriculture in 2001. Under this program, the CCC makes payments to eligible bioenergy producers to encourage increased purchases of agricultural commodities for the purpose of expanding the production of bioenergy (ethanol and biodiesel) and to encourage the construction of new production capacity. The 2002

Farm Bill is continuing the program through fiscal year 2006, thus providing $150 million annually[50].

State Policies

Each state embraces different incentives in order to enlarge the ethanol production or consumption, for example[51]:

- New York State grants subsidy for 50 Million gallons per year dry mill ethanol plant. The subsidy rate is $3.1m for rail access; $2.5m in economic development funding; $25m in additional federal support through USDA; and $0.4m through the NY DOT.
- The State of Minnesota grants an exemption from environmental impact assessment requirements to any ethanol plant with a production capacity of less than 125 Million gallons per year.

4.2.2 Brazil

Brazil has become the world's largest producer and consumer of ethanol, largely thanks to the targeted subsidies under the Pro`alcool program. It provided incentives for ethanol producers, as well as price subsidies for consumers through tax reductions. Initially, the program was very successful: in 1986, 90% of all new cars sold ran solely on ethanol, while ethanol production costs and prices gradually decreased due to economies of scale and gains in yield.

Between 1973 and 1990, the Pro-Alcohol program was made up of the following components:

- A guaranteed volume of ethanol purchased by the national oil company Petrobras.
- A guaranteed price for ethanol.
- Incentives, in the form of preferential interest rates, to invest in new production units.

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[50] Frost & Sullivan Market Research, 2006, “North American Ethanol Market Assessment”, at: http://www.frost.com/prod/servlet/frost-home.pag

[51] Koplow, D., 2006, “Biofuels – At What Cost ?: Government Support for Ethanol and Biodiesel in the United States”, International Institute for Sustainable Development, at: www.globalsubsidies.org/IMG/pdf/biofuels_subsidies_us.pdf

- A subsidy for the purchase of vehicles running on pure ethanol.

The 1986 rebound from the oil crisis and the discovery of oil deposits by “Petrobras” weakened the main argument for developing the bioethanol sector, namely independence from oil imports. The drop in oil prices in 1986 meant that the public purse was no longer able to subsidize ethanol purchase prices, owing to the excessive differential between the price of petrol and that of ethanol, which was borne by the Brazilian state. Developments on the sugar market, which had become more attractive for sugar cane producers, also played a significant role. Each year, sugar cane producers played off sugar against ethanol, depending on the price of sugar on the world market.

During the 1990s, the program underwent a radical reform. Since 1999 the ethanol market has been opened up, with an end to guaranteed prices. The main changes in the ProAlcool program have been:

- A shift towards the fuel mixture option by withdrawing specific aid for the purchase of vehicles running on pure ethanol.
- A tax break for ethanol. For example, in the states of Mato Grosso and Sao Paulo, the tax relief is equivalent to the cost price of ethanol, which means that ethanol sales are almost wholly exempted from tax.
- Compulsory minimum ethanol content for petrol (22 to 24% set by the government).
- In order to stabilize the price of alcohol (and indirectly that of sugar), the Brazilian agriculture minister has introduced an aid mechanism for the storage of alcohol in factories (public aid in the form of subsidized-interest loans, amounting to USD 170 million in 2004). [52].

Nowadays, there are no subsidies for ethanol production and the product is very competitive on the domestic market: hydrated ethanol is sold for 60–70% of the price of gasohol (a blend of 90% petrol and 10% ethanol) at the pump. The Brazilian

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[52] European Parliament, 2007, “Biofuels in Brazil”, Directorate General for External Policies of the Union Directorate B- Policy Department, Brussels, at: http://www.europarl.europa.eu/meetdocs/2004_2009/documents/nt/692/692070/692070en.pdf

government continues to pay close attention to the biofuels sector, however, by encouraging the sugar cane industry and the provision of "flexible-fuel" vehicles[53].

4.2.3 The European Union

A recent report of the IISD[54] (International Institute for Sustainable Development) estimates that the total support for ethanol used as a fuel has grown rapidly, from roughly € 800 million in 2005 to around € 1,300 million in 2006. This estimation does not include the value of support for investment in fixed capital used in ethanol production, which in some countries accounts for up to 30 percent of total investment costs. The largest of the identified elements of incentives is support provided through exemptions from excise taxes, and market price support. On a per-liter basis, this support (including support for R&D) works out to at least € 0.74/ liter.

Import Duties

The European Union has set two levels of import duty on ethanol, determined by whether the ethanol is undenatured, and can thus enter the food chain, or whether it is denatured and thus is limited to use as a solvent or other industrial application. Table 4.1 describes the import duty structure in the EU.

Table 4.1- European Bioethanol Market (2006)- Import Duty Structure

PRODUCT	EU IMPORT DUTY	VAT[55]
Undenatured Bioethanol	€ 19.2/ HL[56]	Standard (17.5% in UK)
Denatured Bioethanol	€ 10.2/ HL	Standard (17.5% in UK)

Source: Frost & Sullivan

The European Union import duty applies to all countries in the European Union; however each individual member state then has its own specific excise duty that is levied on the fuel. In most Union member states only denatured ethanol will qualify for

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[53] European commission, 2006, "An EU Strategy for Biofuels", Commission of the European communities, Brussels, at: http://ec.europa.eu/agriculture/biomass/biofuel/com2006_34_en.pdf

[54] Kutas, G., Lindberg, C., Steenblik, R., 2007, "Biofuels: At What Cost? Government Support for Ethanol and Biodiesel in the European Union", International Institute for Sustainable Development, at: http://www.globalsubsidies.org/IMG/pdf/Global_Subsidies_Initiative_European_Report_on_support_to_Biofuels.pdf

[55] VAT- Value Added Tax

[56] HL- hectoliter- metric unit of measure (capacity) equal to 100 liters.

fuel tax exemption. On top of these payments VAT is also charged on the fuel at the standard rate. The VAT also varies by European Union member state[57].

Incentivization Models

There is no unilateral way European Union member states have incentivized the use of biofuels in their respective countries. The European Union directives merely provide the political and legal framework for countries to implement their own policies. As a result a number of different models has been used to promote the development of national biofuel industries:

Tax Relief

The traditional way of encouraging biofuels production and usage is to subsidize biofuels by way of tax relief. Most countries in the European Union started their biofuels programs using this approach. The majority of countries lifted the tax completely, such as Germany and Austria. However some gave partial tax relief, such as the UK. France has a more sophisticated system in which the tax relief level changes depending on mineral fuel and feedstock prices. Some countries, such as France and Italy, have put a quota system in place to cap the amount of biofuel that would be free of tax, in order to limit the government revenue lost.

Renewable Transport Fuel Obligation (RTFO)

The RTFO obliges oil companies to use a set amount of renewable fuel a year, but does not specify which biofuels must be used and at what levels they must be blended. The oil company can then decide how it wants to distribute this biofuel component in its standard petrochemical fuels. It has the choice of using all biodiesel or all bioethanol or a proportion of each fuel. It also has the choice of blending biofuels at low levels in all fuel or making smaller volumes of a more concentrated blend.

In November 2005, The United Kingdom introduced the Renewable Transport Fuel Obligation (RTFO) as the country's primary mechanism to deliver the objectives set forth in the Biofuels Directive. The RFTO set out the levels of obligation (i.e. the percentages of vehicle fuels that must come from biofuels, on a volume basis): 2.5 percent in fiscal year 2008–2009, 3.75 percent in fiscal year 2009–2010 and 5 percent in fiscal year

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[57] Frost & Sullivan Market Research, 2007, "European Bioethanol and Feedstock Markets", at: http://www.frost.com/prod/servlet/frost-home.pag

2010–2011. Once an oil company does not meet the RFTO, it must pay a “buy-out price”, which is set at € 21.7/ liter.

Blending Mandate

A blending mandate requires oil companies to blend a set percentage of biofuel in all its fuels. The levels are normally set quite low, such as 2%, but there is little freedom for the oil companies. Bioethanol must be included in gasoline. Blending biofuels in all fuel sold presents a huge logistical challenge for the oil companies as a constant supply of biofuel must be sourced and blending performed in all fuel sold. The advantage of this model is that it enforces oil majors to use bioethanol and, while percentage levels are usually low, large volumes of biofuel need to be used to meet the mandated levels. Blending mandates mean oil companies require a reliable supply of biofuel which means they are likely to team up with biofuel producers in long term agreements or even invest in their own plants. Luxembourg, for example, introduced a mandatory blending of 2 percent beginning on 1 January 2007. In case of noncompliance with this target, a tax is mandated. The amount of the tax is equal to € 120/ hectoliter that the oil retail companies failed to supply.

Optional Buy Outs and Fines

In France and the UK there is a fine or an optional buy-out for oil majors not using biofuels, as required by legislation. The details and logistics of this system are still being sorted out in the UK, but it is postulated that the money recovered from optional buy-outs will be given back to oil companies using biofuels in order to make them cost competitive with those which are not. This system should encourage all oil companies to use biofuels.

Further Models and Trends

Individual member states have been very innovative with regard to encouraging biofuel use by way of legislation. Each country has tailored and implemented legislation to fit their own requirements. It is likely that variations in the above models will be seen across Europe, although the trend is almost certainly towards RTFO's and mandates as governments cannot provide unlimited tax relief while the industry grows[58-59].

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[58] Kutas, G., Lindberg, C., Steenblik, R., 2007, "Biofuels: At What Cost? Government Support for Ethanol and Biodiesel in the European Union", International Institute for Sustainable Development, at: http://www.globalsubsidies.org/IMG/pdf/Global_Subsidies_Initiative_European_Report_on_support_to_Biofuels.pdf

[59] Frost & Sullivan Market Research, 2007, "European Bioethanol and Feedstock Markets", at: http://www.frost.com/prod/servlet/frost-home.pag

PART II – ISRAELI PERSPECTIVE

5 Potential for Bioethanol Demand in the Israeli Market

As discussed above many countries are proposing to use bioethanol as a blend in their gasoline in order to incorporate a renewable energy component into their fuel mix. In this chapter we will examine the anticipated gasoline demand in Israel in view of the current requirements of the gasoline standards which necessitate the incorporation of an oxygenated component into the gasoline in order to enhance combustion.

5.1 Israel Gasoline Standards

The Israel fuel standard for unleaded gasoline has been updated in November 2007[60]. This standard is an adoption of the European Standard EN 228 of January 2004, with applicable deviations as specified in the body of the Israeli Standard. The standard specifies requirements and test methods for unleaded gasoline (petrol) that is used in gasoline engine vehicles designed to run on unleaded gasoline.

Table 5.1 is an excerpt from the Israel Standard 90 Part II exhibiting the requirements for regular grade unleaded gasoline (Octane 95) including limits on various gasoline properties and content of additives, such as oxygenates. The table also lists the applicable test methods for the determination of each specified limit. A similar set of specification is available also for premium grade unleaded gasoline (Octane 98).

The standard specifies a 2.7% limit for the overall oxygenate content. For ethanol this would translate to either a 10% or 15% blends for ethanol or MTBE, respectively. However, in view of the potential for increased volatility with alcohol blends, and other fuel quality considerations, the standard also specifies the following limits for individual oxygenated compounds: methanol (3%), ethanol (5%), isopropyl alcohol (10%), isobutyl alcohol (10%), t-butyl alcohol (7%), ethers with 5 carbons or more (15%), and other oxygenates (10%).

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[60] Israel Standard 90 (2007), Part B: Unleaded Gasoline

Table 5.1- European Gasoline Standard EN 228:2004 as Adopted into Israel Standard 90 Part II: Unleaded Gasoline

Property	**Units**	**Limits** **Min.**	 **Max.**	**Test Method** [a] (See 2. Normative references)
Research octane number, RON		[k]	--	prEN ISO 5164 [b]
Motor octane number, MON		[k]	--	prEN ISO 5163 [b]
Lead content	**mg/l**	**--**	**5**	prEN 237
Density (at 15 °C) [c]	kg/m^3	720	775	EN ISO 3675 EN ISO 12185
Sulfur content [c]	**mg/kg**	--	**150** **or** **50,0**	EN ISO 20846 EN ISO 20847 EN ISO 20884
		--	**10,0**	EN ISO 20846 EN ISO 20884
Oxidation stability	minutes	360	--	EN ISO 7536
Existent gum content (solvent washed)	mg/100 ml	--	5	EN ISO 6246
Copper strip corrosion (3 h at 50 °C)	rating	class 1		EN ISO 2160
Appearance		clear and bright		visual inspection
Hydrocarbon type content [c]	**% (*V/V*)**			ASTM D 1319 [d, e, f] prEN 14517
- olefins		**--**	**21,0**	
- aromatics		**--**	**42,0** **or** **35,0**	
Benzene content [c]	**% (*V/V*)**	--	**1,00**	EN 12177 EN 238 prEN 14517
Oxygen content [c]	**% (*m/m*)**	**--**	**2,7**	EN 1601 EN 13132
Oxygenates content [c]	**% (*V/V*)**			EN 1601 EN 13132
- methanol [g]		--	**3,0**	
- ethanol [h]		--	**5,0**	
- iso-propyl alcohol		--	**10,0**	
- iso-butyl alcohol		--	**10,0**	
- tert-butyl alcohol		--	**7,0**	
- ethers (5 or more C atoms)		--	**15,0**	
- other oxygenates [i]		--	**10,0**	

NOTE Requirements in bold refer to the European Fuels Directive 98/70/EC [1], including Amendment 2003/17/EC [2]

[a] See also 5.7.1

[b] A correction factor of 0,2 for MON and RON shall be subtracted for the calculation of the final result, before reporting according to the requirement of the European Fuels Directive 98/70/EC [1], including Amendment 2003/17/EC [2]

[c] See also 5.7.2

[d] The content of oxygenate compounds shall be determined as prescribed in Table 2 in order to make the corrections when necessary according to clause 13.2 of ASTM D 1319

[e] When Ethyl-tert-butyl ether (ETBE) is present in the sample, the aromatic zone shall be determined from the pink brown ring downstream of the red ring normally used in the absence of ETBE. The presence or absence of ETBE can be concluded from the analysis as required in footnote d

[f] For the purpose of this standard ASTM D 1319 shall be applied without the optional depentanisation step. Therefore clauses 6.1, 10.1 and 14.1.1 shall not be applied

[g] Stabilising agents shall be added

[h] Stabilising agents may be necessary

[i] Other mono-alcohols and ethers with a final boiling point no higher than prescribed in Table 3

[k] When regular grade is marketed, RON and MON shall be specified in a national annex to this European Standard, **but not lower than 81,0 MON and 91,0 RON**

5.2 Israel Gasoline Demand- Current Status and Forecast

Israel consumes today about 11 million tons of crude oil per year that are distilled into a variety of products, with about 50% of which used for manufacturing of transportation fuels. Table 5.2 below depicts total consumption of gasoline in Israel for the years 2003 to 2006, as provided by the Central Bureau of Statistics (CBS). Overall gasoline demand increased by 1.85% from 2003 to 2004, by 1.36% from 2004 to 2005 and then by almost 3% from 2005 to 2006. Hence overall consumption increased by 6.3% in the four years, from 2003 to 2006, where at the same time the demand for Unleaded gasoline went up by over 20%. This is in line with increased penetration of catalyst-equipped vehicles, requiring Unleaded gasoline, and the government decision to phase out Leaded (96 octane) gasoline, consumption of which went down by as much as 55% over the same period - from 2003 to 2006.

Table 5.2- Israel Transportation Gasoline Consumption, 2003-2006[61]

YEAR	GASOLINE (MILLION LITERS)			GASOLINE (1,000 TONS)
	Unleaded	96 Octane	Total	Total
2003	2,069.1	606.0	2,675.1	2,004.8
2004	2,207.3	517.2	2,724.5	2,042.1
2005	2,333.7	427.9	2,761.6	2,070.1
2006	2,511.1	333.3	2,844.3	2,132.3

The Israel gasoline market is dominated by consumption of unleaded gasoline, where the combined grades of unleaded gasoline (95 and 98 Octane) increased their share of the gasoline market from about 80% in 2004 to 87% in 2006, as shown in Figure 5.1 below. The data in the figure also demonstrate that the higher grade unleaded gasoline, i.e. 98 Octane, is only about 2% of the total unleaded gasoline in the market. In order to meet the gasoline consumption demands, including supplying gasoline to the Palestinian Authority, Israel had to import some of its 95 Octane gasoline. This import

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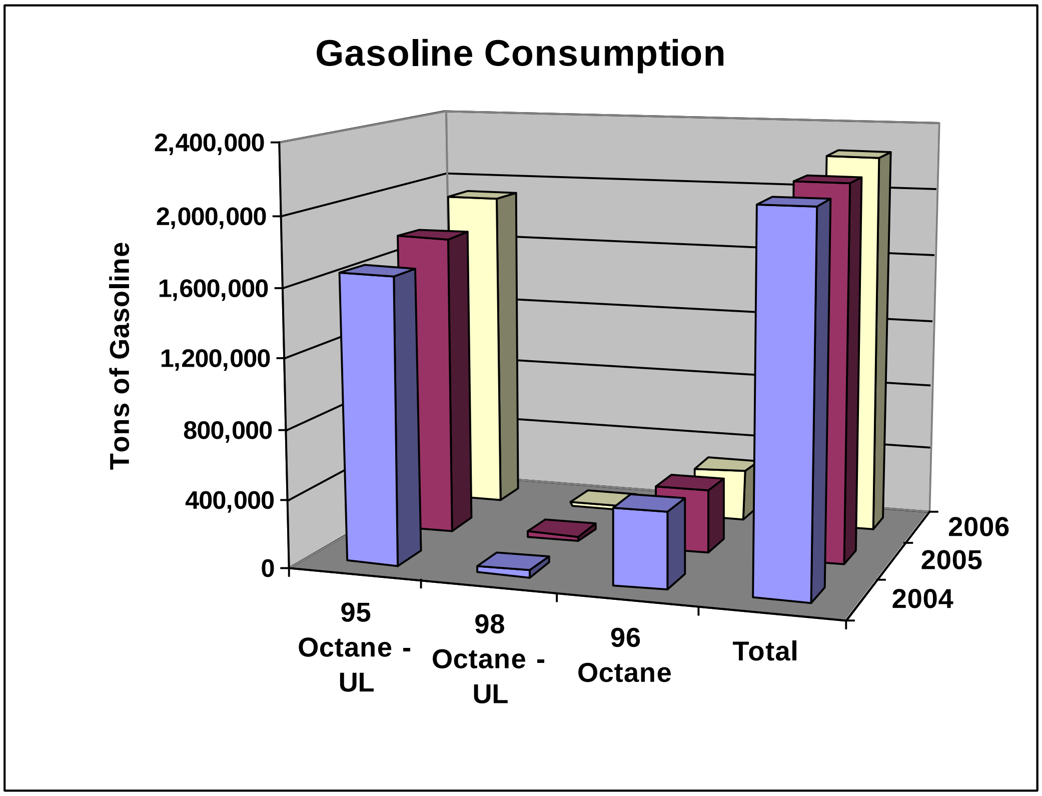
[61] CBS, 2007, "Supply of Gasoline and Fuel Oil for Transportation", Transport Statistics Quarterly No. 4, Table 36, at: www.cbs.gov.il/transport_q/**t36**.pdf

amounted to about 25% in 2004 and decreased to about 13-15% for 2005 and 2006, as Israeli refineries increased their capacity to produce it.

Figure 5.1- Consumption of Gasoline by Grade in 2004-2006 (including gasoline distributed in the Palestinian Authority)



Source: Analysis by Israel MNI, Fuels Administration

5.3 Scenarios for Ethanol Blending

The sections below will address various scenarios for introducing bioethanol into the Israeli gasoline market (It should be noted that ethanol could be produced in or imported to Israel- each alternative has environmental and economic impacts- See Chapter 6 and Section 9.2). The demand for bioethanol to be considered will be consistent with three scenarios:

- ***Blending 5% ethanol in all the unleaded gasoline distributed in the market-*** can be implemented immediately with no change in Israel fuel standards or vehicle technology;
- ***Meeting all the demand for Oxygenates in unleaded gasoline by blending 10% ethanol into the gasoline-*** would require an exception to be incorporated

into the current fuel standard that limits ethanol to 5%. Otherwise no change will be required in vehicle technology;

- ***Introducing E85 as a new fuel grade in the market-*** this would require a new fuel standard for this new fuel as well as the introduction of new Flexible Fuel Vehicles (FFVs) that could be operated by different blends of ethanol and gasoline up to 85% Ethanol that is blended with 15% Unleaded gasoline.

These scenarios can be put into context by comparing them with current targets in selected countries, as detailed in Table 5.3 below.

The data presented include targets set by the listed countries and a preliminary forecast of their ethanol production capacity in 2008. Many countries are looking more closely at the Brazil example and are evaluating, in addition to the use of low concentration blends of ethanol in the range of 5-10%, the possibility of introducing higher concentration ethanol blends, pending a wider availability of compatible vehicle technologies and other infrastructure storage, distribution and dispensing considerations. With the growing recognition that higher alcohol blends have certain distinct benefits, E85 is becoming more widely used primarily in Sweden and is becoming increasingly common in the United States and Canada.

Table 5.3- U.S. Department of Agriculture Overview: Bioethanol blending targets in selected countries (November 2007)

COUNTRY	BIOETHANOL FEEDSTOCK	ETHANOL PRODUCTION FORECAST (Million Gallons)	BLENDING TARGETS
Brazil	Sugarcane	4,966.5	25% blending ratio of ethanol with gasoline (E25) in 2007;
Canada	Corn, wheat, straw	264.2	5% ethanol content in gasoline by 2010;
China	Corn, wheat, cassava, sweet sorghum	422.7	10% ethanol blend for gasoline in five provinces; five more provinces targeted for expanded use.
EU	Wheat, other grains, sugar beets	608.4	5.75% Biofuel share of transportation fuel by 2010; 10% by 2020.
India	Molasses, sugarcane	105.7	10% blending of ethanol in gasoline by late 2008,
Thailand	Molasses, cassava, sugarcane	79.3	Plans call for E10 consumption to double by 2011 through use of price incentives;
United States	Primarily corn	6,498.7	Use of 7.5 billion gallons of biofuels by 2012; new legislation raised renewable fuel standard to 36 billion gallons (mostly from corn and cellulose) by 2022.

5.4 Forecast for Bioethanol Demand

In order to analyze the potential bioethanol demand in Israel under the three scenarios discussed above we have used the current forecasts available from the Ministry of National Infrastructure for overall energy demand in Israel to the year 2025[62]. An excerpt from this forecast listing only the forecast for transportation fuels is provided in Table 5.4 below.

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[62] Ministry of National Infrastructure, 2003, "Forecast of Energy Demand for the years 2002-2025", at: http://www.mni.gov.il/NR/rdonlyres/4A4ACE57-7063-424D-BF01-A0DF4694E272/0/tachazit_bikush_01_05.rtf

Table 5.4- Forecast of Increase in the Consumption of Transportation Fuel Products in Israel (MNI, 2003 Report)

FUEL PRODUCT	PERCENT INCREASE PER YEAR			AVERAGE FORECAST (1,000 TONNES)	
	High Estimate	**Low Estimate**	**Average Estimate**	**2001**	**2025**
Diesel	3.4%	2.4%	2.6%	2,541	4,809
Gasoline	2.4%	1.3%	1.5%	1,954	2,851
Naphtha	1.4%	-0.6%	-0.1%	968	946
Kerosene / Jet Fuel	3.9%	-0.2%	2.8%	1,027	2,061
LPG	5.6%	1.0%	2.6%	444	858

For gasoline, the average estimated rate of annual increase of 1.5% is probably on the low side, based on the analysis presented above for the years 2003 to 2006, with the increase from 2005 to 2006 reaching almost 3%. More data is needed in order to asses whether this accelerated level of increased demand will persist.

Based on this forecast the bioethanol demand in Israel in 2025 may be:

- ***Scenario 1 (5% blend in all gasoline)-*** 107 to 113 million liters of ethanol,
- ***Scenario 2 (10% blend in all gasoline)-*** 214 to 225 million liters of ethanol,
- ***Scenario 3 (penetration of 5% E85)-*** A stand-alone E85 scenario would require 91 to 96 million litters of ethanol. If the scenario is to be introduced in conjunction with scenario 1, namely 5% ethanol to be blended in 95% of all gasoline with an incremental penetration of E85 to cover the additional 5% demand, would require about 197 to 203 million litters of bioethanol to be available for blending the different gasoline products.

5.5 Israel Statutory Framework

Israel has currently no obligatory regulatory system dealing with biofuels and thus there are no formal incentives to encourage the use of bioethanol. However, national authorities have taken several steps towards examining the possible role of bioethanol in the Israeli fuel market:

- The Standards Institution of Israel convened a special committee to develop an Automotive Ethanol fuel standard[63]. The committee (no. 31025) is comprised of members of the Ministry of Environmental Protection, The Ministry of Transport & Road safety, The Israel Institute of Petroleum and Energy and the Oil companies. The committee intends to adopt the European standard for ethanol[64]. The standard is now in Draft form and according to the committee's schedule it is expected to be published at the beginning of 2009.
- The Green tax committee[65] has recently submitted to the Ministry of Finance the following recommendations:
    - To exempt, or to reduce the tax on motor fuels that are derived from renewable energy sources for a period of at least five years.. This provision will be in force as long as there is no renewable fuel standard in the Israel.
    - A full tax exemption, or reduction, at the current fuel consumption levels could theoretically cause up to 5% lost income; meaning a decline of 9 Billion NIS from the current excise tax revenue.
    - Waive taxation on technologies that have proven their efficiency in reducing motor fuel consumption.

The Ministry of Finance is now examining ways of implementing the committee's recommendations.

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[63] The Standards Institution of Israel, 2008, "Ethanol as a motor fuel", at: http://www.sii.org.il

[64] European Standard for Ethanol- PREN15376: "Automotive Fuels - Ethanol as a Blending Component for Petrol- Requirements and Test Methods"

[65] The Tax Authority, 2008, "Governmental Committee on "Green" Taxation", at: http://www.mof.gov.il/taxes/docs/misui150108.pdf

6 Agricultural Feedstock Production in Israel

6.1 Overview of Current status

Israel is far from being self sufficient in staple starch and edible oil sources. The country is at a fundamental disadvantage in the production of these agricultural commodities due to scarcity of land and water resources. The cost of irrigation water coupled with an arid to semi-arid climate forces intensification of agricultural production in Israel and choice of high value crops using advanced technologies to generate superior yields - a condition for profitability. Israel cannot compete with countries that utilize vast swaths of land to efficiently produce commodity crops under rain-fed conditions at minimal cost. Furthermore, a large proportion of commodity producing countries subsidize their agricultural production further disrupting global market competition.

Israel is an importer of starch and oil rich commodity grain for food and animal feed. Corn grain is imported primarily for animal feed (99%)[66] with the small remaining amounts processed for edible starch (corn-flour) consumption. Israel imports approximately two thirds of its wheat consumption, whereas nearly 25% of agricultural land in Israel is used to produce the remaining one third. Most of Israel’s barley is imported as is all of the grain for oil production and finished oil for human consumption.

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[66] Yigal Flash, Head of Field Crops Department, Israel Ministry of Agriculture, Extension Service, Per Comm.

Table 6.1- Typical Annual Grain Imports to Israel 1995 - 2007[67,68]

	ANNUAL IMPORTS (Thousands MT)	% OF DOMESTIC CONSUMPTION	PRICE (2007 prices) ($/MT CIF)	IMPORT VALUE (2007 prices) ($ M - CIF)	COMMENTS
Corn	1,000	100%	200	200	
Wheat	700 - 900	60% - 70%	300	225	
Barley	400 - 500	~100%	230	100	
Soybean	550 - 600	100%	390	215	120 K MT imported for protein production
Rapeseed	cake only	100%	N/A		Finished oil for human consumption imported separately
Sunflower	cake only	100%	N/A		
Total	**2,000**			**~750**	**(excluding cake)**

2007 price sources: CBOT (corn, soybean), KCBT (wheat), WCE (barley) CIF prices assume $50 - $70 / MT shipping costs

The present cost of importation (2007 prices- CIF[69] Israel) reached ~$750 million excluding importation of oil grain cake for animal feed and separate importation of finished edible oils for human consumption (see Table 6.1 above).

Theoretical bioethanol feedstock production in Israel, should such a policy be promoted, would presently be based on field crops such as wheat and corn as sources for starch, or in the future crops such as sorghum or kenaf for cellulose production. In addition, various forest and agricultural by-products as well as cellulosic waste could comprise raw materials for future bioethanol production.

Sugar production (sugar beet), that flourished in Israel in the 1960’s and 70’s was discontinued since Israel had no competitive advantage in production and was at an economical disadvantage in relation to the relatively low cost of imported refined sugar.

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[67] Rachel Borshack, Economist, Israel Farmers Federation, Per. Comm.

[68] Rachel Borshack, Economist, Israel Farmers Federation, Per. Comm.

[69] CIF- Cost, Insurance and Freight

Potatoes, an additional source of starch, are produced in Israel as a food crop on relatively small areas and would probably not be relevant as a bioethanol feedstock source at current prices.

6.2 Agricultural Production Areas

Agricultural land use has a great value in increasing biodiversity and preventing desertification in Israel. Nevertheless, land allocation in favor of energy crops should not compete with water and land for food crops.

Field crops are produced on 150,000-200,000 hectares of Israel’s nearly 400,000 hectares of cultivated land. A typical breakdown and production volumes are presented in Table 6.2.

Table 6.2- Field Crop Production in Israel[70]

CROP	TYPICAL PLANTED AREA (Ha)			TYPICAL YIELD IRRIGATED (MT/Ha)	TYPICAL YIELD RAINFED (MT/Ha)	PRODUCTION TOTAL (MT)
	Irrigated	**Rain-fed**	**Total**			
Cereals - Grain						
Wheat		55,000	55,000	5.5 – 6.0	2 - 3	140,000
Barley-Wheat mix		20,000	20,000		0.70	14,000
Cereals - Grain Total		**75,000**	**75,000**			**154,000**
Forage						
Silage Wheat	3,000	17,000	20,000	18.00	10.00	176,000
Other cereals		6,000	6,000		8.00	47,000
Legumes		13,000	13,000		6.00	76,000
Alfalfa	1,000		1,000	15.00		15,000
Silage Corn	3,500		3,500	18.00		63,000
Silage Sorghum	2,000	500	2,500	15.00		31,000
Summer cereals	500		500	8.00		4,000
Forage Total	**10,000**	**36,500**	**46,500**			**412,000**
Edible Corn						
Sweet and Super-sweet	5,000		5,000			81,500
Popcorn	500		500			3,000
Edible Corn Total	**5,500**		**5,500**			**84,500**
Edible Seed Crops						
Chickpea	3,500	3,000	6,500	3.00	1.50	14,000
Sunflower (edible seed)	6,000	1,000	7,000	2.00	1.30	13,500
Watermelon (edible seed)	1,000	10,000	11,000	0.06	0.04	4,500
Groundnut	3,000		3,000	5.00		15,000
Pea	1,500		1,500	4.50		7,000
Bean	1,000		1,000	10.00		10,000
Edible Seed Crops Total	**16,000**	**14,000**	**30,000**			**64,000**
Cotton						
Upland	5,000			5.50		28,000
Pima + Hybrid	5,000			5.00		21,000
Cotton Total	**10,000**					**49,000**
Grand Total	**41,500**	**125,500**	**167,000**			**763,500**

6.2.1 Wheat Production

Presently, wheat grain is one of a few major starch crops produced in Israel. During the current decade wheat production has been produced on approximately 75,000 hectares of land mainly in the Negev region, primarily under rainfed conditions (60%). Israel

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[70] Yigal Flash, Head of Field Crops Department, Israel Ministry of Agriculture, Extension Service, Per Comm.

produces about 155,000 metric tones of wheat grain per year on average (Table 6.3). This volume complements an imported volume of about 700,000 metric tones (Table 6.1) and thus constitutes up to one third of annual consumption. Locally produced wheat is also a portion of a national emergency grain inventory.

Table 6.3- Wheat Production in Israel

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**AVERAGE**
Area Harvested (Ha)	64,151	81,300	83,770	72,810	70,510	71,850	67,000	**73,056**
Yield per hectare (Kg/Ha)	1,465	1,943	2,116	2,531	2,188	2,795	1,958	**2,142**
Production Quantity (MT)	94,000	157,970	177,275	184,300	154,300	200,800	131,200	**157,121**

Source: Israel Ministry of Agriculture; FAOSTAT, 2007

Grain yields vary enormously in Israel. Wheat grain production supplemented with irrigation (40% of production) can yield over 6 MT/Ha of grain, whereas rainfed yields under dry conditions seldom exceed 2 MT/Ha.

6.2.2 Corn Production

A second starch crop presently attracting interest in Israel, following the surge in commodity prices, is corn. Traditionally corn grain production could not economically compete with imports, however, with corn grain prices doubling over the last 1-2 years corn grain production has been reconsidered.

Corn grain is a high temperature summer crop and therefore requires irrigation to produce a reasonable yield under Israeli conditions. As an industrial crop, recycled water for irrigation at a reduced price would suffice for production. However, even under these conditions commodity prices would have to remain extremely high for corn to stay profitable. In addition, this crop would compete for the scarce irrigation water and would probably never gain substantial levels of production that could suffice to satisfy the existing feed market and generate substantial quantities for local bioethanol production.

Thus, despite the present interest generated by high corn market prices, corn production in Israel does not seem to be a long term solution for bioethanol production.

6.3 Economic Analysis of Israel Agricultural Feedstocks for Bioethanol Production

This section analyses the economics of grain production in Israel although it was already shown in Section 7.2 above that from a production standpoint locally grown starchy plants are not a promising pathway for feedstock supply for bioethanol.

Wheat is produced under different production regimes in Israel according to different conditions in different regions. Thus, for purposes of this analysis 3 separate typical profit and loss (P&L) sheets complete with required inputs for production are provided below (Table 6.4).

The data reveals unit production costs in Israel in the range of about $0.26-0.29/ Kg of wheat grain.

Table 6.4- Wheat Production in Israel- Cost and Resource Usage

		NEGEV DRYLAND		ISRAEL RAINFED		IRRIGATED	
Revenues	**Price (NIS/Kg)**	**Yield (Kg/Du)**	**Total (NIS/Du)**	**Yield (Kg/Du)**	**Total (NIS/Du)**	**Yield (Kg/Du)**	**Total (NIS/Du)**
Grain	1.1	300	330	425	468	600	660
Hay	0.2	195	39	298	60	510	102
Total Revenues			**369**		**527**		**762**
Input costs	**Price**	**Amount (Kg/Du)**	**Total (NIS/Du)**	**Amount (Kg/Du)**	**Total (NIS/Du)**	**Amount (Kg/Du)**	**Total (NIS/Du)**
Machinery			42		42		44
Spray contractor			13		23		23
Harvesting and baling			45		66		90
Seed			21		21		21
Irrigation	0.66 /m^3					80	77
Fertilizer	2.67 /Kg	12	32	12	32	12	32
Weed control			27		20		9
Pest control			4		6		6
Marketing and other			55		71		97
Overhead and capital costs			60		63		137
Total working capital			**299**		**344**		**536**
Capital Recovery			18		21		39
Total production cost			**317**		**365**		**575**
Net income before tax			**52**		**162**		**187**

Source: Grain price based on recent quotes of $300/ MT at an exchange rate of 3.6 NIS/$

Typical corn grain production P&L analyses reveal profitability of production at present prices despite utilization of significant amounts of fertilizer and irrigation water. Corn, as a summer crop, does not prove to be economically viable under rain-fed conditions in Israel. Table 6.5 exhibits corn grain production costs and profitability. This data shows that unit production costs in Israel are around $0.25/ Kg of corn grain.

Table 6.5- Corn Grain Production in Israel- Cost and Resource Usage

		IRRIGATED	
Revenues	**Price (NIS/Kg)**	**Yield (Kg/Du)**	**Total (NIS/Du)**
Corn Grain	0.82	1,300	1,066
Corn Hay	0.2	1,000	200
Total Revenues			**1,266**
Input costs	**Price**	**Amount (Kg/Du)**	**Total (NIS/Du)**
Machinery			113
Spray contractor			10
Harvesting and baling			100
Seed			60
Irrigation	0.66	400	332
Fertilizer		60	176
Weed control			20
Pest control			6
Marketing and other			80
Overhead and capital costs			140
Total working capital			**1,037**
Capital Recovery			150
Total production cost			**1,187**
Net income before tax			**79**

Source: Corn grain price based on recent quotes of $230 / MT at an exchange rate of 3.6 NIS/$

Despite high yields under irrigated conditions in Israel, economic efficiency and net profits are not particularly high. The cost of inputs such as water, fertilizer and machinery offset the high revenue attributed to the present price and yield and deem the crop comparable to dryland field crops such as wheat.

Moreover, price volatility determines that corn profitability remains borderline and risks remain extremely high should prices decline back to traditional levels. Higher prices will need to be established for a substantial period of time before growers will be convinced that corn production is an economically safe option under Israeli conditions.

From an economic standpoint commodity field crops are low value and low profit products per unit area of production, with production justified on a large scale only. Allocation of additional land for agricultural production, if found reclaimable, would probably be allocated to higher value crops that would justify such reclamation under Israeli conditions.

Present low profitability of these field crops even at present high prices (see Tables 6.4 and 6.5) reveal that significant support would be required to sustain production of bioethanol feedstock by reclaiming additional swaths of land and returning the capital costs required for that purpose. Alternatively, imported grain as bioethanol feedstock would also require substantial support for the resulting bioethanol product to sell at prices competitive with gasoline.

Table 6.6 reveals the cost of the feedstock component in Israel based on the unit cost of production in terms of $ per Kg, and converted to bioethanol at typical conversion rates. At typical conversion rates of 0.3 and 0.32 liters per Kg grain for wheat and corn, respectively, the cost of feedstock alone produced in Israel amounts to 0.72 $/liter for corn ethanol and $0.89 per liter for wheat ethanol. These costs do not include bioethanol fermentation and processing, storage and transport, blending costs, distribution, retailer's margin and taxation.

In comparison, estimated production costs in Iowa[71], USA based on agricultural costs of $0.15-0.17/ Kg corn grain amount to approximately $0.5/ liter bioethanol.

Gasoline price at the pump before tax in Israel, at the time of this writing, amounts to about $1/ liter, thus there is a difficulty for bioethanol to compete at such a high feedstock cost of production.

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[71] Iowa State University Extension, 2008, "Estimated Costs of Crop Production in Iowa", at: http://www.extension.iastate.edu/AGDM/crops/pdf/a1-20.pdf

Table 6.6- Bioethanol Feedstock Production Costs in Israel

	CORN	WHEAT
Yield (Kg/Du)	1,300	300
Cost of production ($/Du)	300	80
Unit cost of production ($/Kg Grain)	0.23	0.27
Bioethanol conversion rate (Lt/Kg grain)	0.32	0.30
Bioethanol feedstock production cost ($/Lt)	0.72	0.89

In conclusion, agricultural products intended for bioethanol production will primarily need to be sourced overseas and shipped at an economically competitive CIF price to Israel, should an administrative decision in favor of such production be taken. Alternatively, grain production will need to receive a substantial subsidy in order for bioethanol to compete with prices of gasoline at the pump.

7 Availability of Cellulosic Feedstock in Israel

Anticipated "second generation" feedstock for ethanol production originates in nature's most abundant hydrocarbon source- cellulose. Technology for efficient conversion of cellulose to bioethanol is presently under development and is expected to become commercial within the forthcoming decade (see above).

This section surveys the existing sources of cellulose in Israel according to their different origins, the amounts expected to be generated and their cost.

7.1 Cellulosic Agricultural By-Products

Plant production of all types generates significant amounts of cellulosic product or by-products. Pruning and thinning of orchards and plant remains from field crop production and greenhouses comprise organic waste generated during and at the termination of the economic production stage. Dry matter such as branches, leaves, and fruit remains are available for collection and utilization.

Table 7.1 summarizes expected amounts of *presently unutilized* cellulosic product generated in agricultural production. Major crops are considered and potential amounts assessed. According to this assessment approximately 100,000 metric tons of cellulosic matter produced on 800,000 dunams, comprising about 20% of agricultural areas, is generated.

Wheat hay and other dry matter utilized for other purposes such as forage produced specifically as fodder for animal husbandry (Table 6.2) is not available at present as a by-product for biofuel production and is absent from this assessment.

Table 7.1- Unutilized Cellulosic By-Products of Agricultural Production Origin

PLANT CROPS	AREA ('000 Dunam[72])	PLANT REMAINS (Kg/Du)	RAW MATERIAL FOR CELLULOSE PRODUCTION ('000 MT
Vegetables			
Greenhouse tomatoes	7	300	2.1
Curcubits and open field crops	200	50	10.0
Field crops			
Cotton straw	100	300	30.0
Sunflower	70	100	7.0
Tree pruning and wood from agricultural production			
Deciduous	166	150	24.9
Citrus	200	100	20.0
Vineyards (wine)	25	100	2.5
Vineyards (table)	35	150	5.3
Total	**803**		**101.8**

Source: Israel Ministry of Agriculture, Extension Service (Based on production figures)

7.2 Cellulosic Forest By-Products

Forest management includes pruning and logging of considerable amounts of cellulosic matter are thus generated. In Israel, about 50% of the logs are utilized for MDF board, firewood and wooden pallet production.

According to an assessment made by KKL in Israel[73] the amount of unutilized prunings in Israeli forests reaches 125,000 tons annually. Presently, about 60% of this amount is shredded in the forest, 30% is burnt and 10% is transported for disposal in landfills .

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[72] 1 Dunam (Du) = 0.1 hectare

[73] Ministry of Environmental Protection, 2000, “Compost in Israel- Sources and Uses Survey and Economic Profitability Analysis”, at: http://www.sviva.gov.il/Enviroment/Static/Binaries/index_pirsumim/p0227_1.pdf

Ultimately, should this cellulosic matter be deemed valuable, it is assumed that 125,000 metric tons per year could be made available for bioethanol production.

7.3 Cellulosic By-Products and Waste in Israel

Cellulosic waste can be found at a variety of different sources. Municipal garden pruning and organic waste such as clippings, leaves, branches etc. are an abundant source of cellulose. These remains are usually collected separately as a municipal service and thus could be supplied readily to bioethanol production plants at no additional cost to the general public. Municipal solid waste, including paper and cardboard as well as sludge produced at sewage treatment facilities also have cellulosic content.

According to the Israel Ministry of Environmental Protection[74], 500,000 metric tons of pruning for removal are generated in private and public gardens. Although some of this tonnage is utilized for compost production and other purposes, the majority of this amount could be made available as cellulosic feedstock. Put differently, 75 kg dry matter of cellulosic garden waste is produced in Israel per capita per year.

Publications by the Ministry of Environmental Protection reveal that every person in Israel produces 1.6 Kg of domestic waste per day on average[75]. In total about 5.8 million metric tons of solid waste are produced at the domestic institutional and industrial levels. Of this amount about 1.6 million tons originate from industrial sources and are deemed either non-retrievable or too contaminated for recycling. Municipal and institutional waste assessments reveal that waste produced in Israel by these sectors each year amounts to 4.2 million tons potentially available for cellulose retrieval.

According to these publications the components of municipal waste are:

- Organic matter- 40%
- Paper and Cardboard- 24%
- Plastics- 15%
- Textile, nappies, glass and metals- 20%

According to this distribution, significant amounts of municipal waste could be theoretically converted to bioethanol.

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[74] Ministry of Environmental Protection, 2006, “Pruning”, at: http://www.sviva.gov.il/bin/en.jsp?enPage=BlankPage&enDisplay=view&enDispWhat=Object&enDispWho=Articals^l1410&enZone=trimmings

[75] Ministry of Environmental Protection, 2007, “Municipal Waste”, at: http://www.sviva.gov.il/Enviroment/bin/en.jsp?enPage=BlankPage&enDisplay=view&enDispWhat=Zone&enDispWho=reka_clali&enZone=reka_clali

Sludge- the solid fraction of municipal sewage is a by-product of wastewater treatment. According to the latest surveys[76], 98,000 MT of sludge (dry weight) are produced annually in Israel. Presently sludge disposal solutions are only partial. Conversion to fertilizer for usage in agriculture is limited or cost prohibitive. Other solutions are environmentally problematic, as in the case of disposal at landfills or at sea.

Cellulosic by products and waste in Israel can be sourced therefore from three major origins:

- Forest by-products and municipal pruning
- Solid waste
- Sludge

7.3.1 Wood By-Products and Municipal Pruning

The cellulosic and hemi-cellulosic content of wood products is estimated at about 80% of dry weight[77]. Raw plant materials such as garden waste and trimmings collected in municipalities comprise about 40% cellulose[78]. Thus forest products and municipal prunings could be an abundant and readily available source of cellulose for processing. Firstly, they are collected separately and would not require intensive sorting procedures. Secondly, the product itself is rich in cellulose and provides an efficient source of feedstock for conversion. For purposes of this analysis high levels of this source have been deemed retrievable. Should 75% of this product be recycled and allocated for conversion, this component would contribute 225,000 MT of cellulose and hemi-cellulose, comprising about 25% of available feedstock originating from total by-products and waste.

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[76] Ministry of Environmental Protection, 2006, “Sludge Producers- Amounts and Dry Weight by Disposal Sites”, at: http://www.sviva.gov.il/Enviroment/Static/Binaries/ModulKvatzim/rikuz_07_1.pdf

[77] Paperonweb, 2008, “Properties of Wood”, at: http://www.paperonweb.com/wood.htm

[78] Ververis, C., Georghiou, K., Christodoulakis, N., Santas, P., Santas, R., 2004, “Fiber dimensions, lignin and cellulose content of various plant materials and their suitability for paper production”, *Industrial Crops and Products,* **19 (3):** 245-254.

7.3.2 Municipal Solid Waste (MSW)

Organic matter

The dominant contributor of mass to solid waste is the organic matter component which is estimated at about 45% of the total including nappies and other cellulosic sources, amounting to nearly 1.9 million MT per year in Israel today.

However, the cellulose content of this organic fraction has been estimated to be only 10% depending upon the raw material constituents[79].

Paper and cardboard

For purposes of this analysis the paper and cardboard fraction of solid waste, highly rich in cellulose, has been analyzed separately. According to a recent survey[80] this fraction contributes about 24% of total solid waste in Israel and amounts to just over 1 million MT per year. Presently about 170,000 MT are already recycled in Israel, mainly for the paper industry. Thus, about 840 MT are estimated to be available for further recycling and bioethanol production. The cellulose content of paper and cardboard is considered high and has been assigned the value of 80% according to the cellulose content of wood based raw materials.

Paper and cardboard in contrast to organic materials are not equally retrievable. While efforts to collect recycled paper and cardboard are relatively advanced, and while these materials are relatively stable, at least when kept dry, a salvage level of 80% has been determined for paper products while only 50% retrieval of cellulose originating from decaying organic matter is deemed feasible. Therefore, despite large volumes of organic material only 100,000 MT are estimated available for conversion according to this analysis. Paper and cardboard in contrast contribute about 540,000 MT of cellulose for conversion per year. In total MSW contributes nearly 75% of expected available cellulose for conversion to bioethanol in Israel in comparison to forest and garden waste.

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[79] Ververis, C., Georghiou, K., Danielidis, D., Hatzinikolaou, D.G., Santas, P., Santas, R., Corleti, V., 2007, "Cellulose, Hemicelluloses, Lignin and Ash Content of Some Organic Materials and Their Suitability for Use as Paper Pulp Supplements", Bioresource Technology, **98 (2):** 296-301.

[80] Shaldag Company, 2006, "The Composition of Domestic Waste- A National Survey 2005", Ministry of Environmental Protection (Publisher), at: http://www.sviva.gov.il/Enviroment/Static/Binaries/ModulKvatzim/p0423_2.pdf

7.3.3 Sludge

Primary sludge from wastewater treatment plants has been shown to contain a considerable amount of cellulose - about 20%, (based on suspended solids - owing to the discharge of toilet paper[81]). However primary cellulose comprises only 30% - 40% of total sludge, whereas the remaining 60% of secondary sludge does not contain cellulose at all. Based on these figures the total cellulose content in sludge is estimated at 5% only, thus potential cellulose from sludge in Israel is estimated at 5,000 MT per year. Although sludge is generated at central sewage purification facilities and is deemed retrievable at a high level of 75%, the 4,000 MT of cellulose estimated available from this waste product are deemed very small in comparison to alternative sources.

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[81] Honda, S., Miyata, N., Iwahori, K., 2002, “Recovery of Biomass Cellulose from Waste Sewage Sludge”, Journal of Material Cycles and Waste Management, **4(1):** 46-50**.**

Table 7.2- Available Amounts of Cellulose Feedstock in Israel

	RAW WASTE			**CELLULOSE and HEMI-CELLULOSE**		
	Potential amount ('000 MT/Year)	**Retrievable proportion (%)**	**Retrievable amount ('000 MT/Year)**	**Cellulose & hemi-cellulose content (%)**	**Cellulose potential production ('000 MT)**	**Expected available cellulose ('000 MT)**
Agricultural by-products	100					
Sub-total agricultural crop remains	***100***	***60%***	***60***	***40%***	***40***	***24***
Forest and Municipal Pruning						
Wood and branches from forests	125	75%	94	80%	100	75
Municipal prunings	500	75%	375	40%	200	150
Sub-total forest and municipal	***625***	***75%***	***469***	***48%***	***300***	***225***
Municipal Solid Waste						
Total solid waste (100%)	***5,800***					
Unavailable industrial solid waste	***1,600***					
Sub-total municipal and institutional	***4,200***					
Organic matter (45%)	1,890	50%	945	10%	189	95
Total paper and cardboard (24%)	1,008				-	
Utilized paper and cardboard	170				-	
Available paper and cardboard	838	80%	670	80%	670	536
Sub-total retrievable solid waste	***2,728***	***59%***	***1,615***	***32%***	***859***	***631***
Sludge (dry weight)	98				-	
Sub-total sludge	***98***	***75%***	***74***	***5%***	***5***	***4***
Grand Total	**3,551**		**2,218**		**1,204**	**883**

7.4 Economic Analysis of Cellulosic Feedstock in Israel

Developing cost estimates for various cellulosic materials will depend greatly on the origin and alternative uses of the different materials evaluated.

Wheat hay and other cellulosic fodder produced for animal husbandry is presently fully utilized in Israel and thus bears an alternative price per se before collection and baling costs and transport to possible bioethanol conversion facilities.

A second future alternative is production of cellulosic material for industrial utilization such as paper manufacture, the wood industry and bioethanol production. This cellulosic material production industry does not exist at present in Israel and according to considerations discussed herewith, such as land and water availability amongst others, will probably not be established.

The present analysis examines the factory gate prices of possible existing cellulosic materials.

7.4.1 Cost of Agricultural Unutilized Cellulosic By-Products

The advantage of utilizing by-products is that they presently have no alternative use; are valued at low prices; and the main costs for their utilization are collection handling and transportation costs.

Typical costs of collecting, raking and baling of cellulosic plant remains in fields are estimated at $7-$10/ dunam or according to typical yields $20-$30/ metric ton dry matter.

Handling and transportation costs are estimated at an additional $10-$15/ metric ton[82].

It is, therefore, that agricultural cellulosic by-products are expected to be made available at the conversion facility gate at a cost of about $30-$45/ metric ton (0.15$/ liter bioethanol).

The sale price of such a product is estimated to reach about $50/ MT, enabling the grower to obtain a reasonable profit margin and with additional incentives to make the product available for conversion.

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[82] Solomon, A., Gal, B., 2007, "Profit and Loss Calculations for Field Crops", Israel Ministry of Agriculture, Extension Service.

7.4.2 Cost of Forest By-Products

Forest by-products require shredding and compressing in preparation for transport. According to a specific survey undertaken to assess the costs of pruning and solid waste removal[83] and handling costs can reach \$20-\$30/ MT of cellulosic matter and an additional \$30/ MT for transportation costs. The total cost of forest products, therefore, may reach about \$60/ MT (0.2\$/ liter bioethanol) at the bioethanol processing facility.

7.4.3 Cost of Cellulosic By-Products and Waste

Cellulosic by products and waste in Israel can be sourced from three major origins: Forest by-products and municipal pruning; solid waste; and sludge. It is estimated that the actual costs of removal of solid wastes are similar to those of pruning removal[84]. Sludge however, is a by-product of effluent recycling with a different cost structure primarily borne by consumers of water and public funds

Therefore, it is estimated that most waste cellulosic material could be obtained at a cost of \$50-60/ MT at the conversion facility gate or \$0.06/ Kg.

At a conversion rate of 0.3 liter bioethanol per 1 Kg cellulosic material[85], the feedstock component of cellulosic bioethanol can be made available at \$0.18/ liter of bioethanol.

This cost is substantially lower than the cost estimate for feedstock originating in agricultural produce such as grain.

The main issue with this source is availability and recovery efficiency. Extra efforts aimed at improving the recovery rate of waste cellulose could be highly useful as an abundant source of cellulosic feedstock for bioethanol production.

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[83] Ecostar, 2005, "Economic Costs of Collection and Removal of Pruning and Solid Waste Separately in Local Councils", Ministry of Environmental Protection (Publisher), at: www.sviva.gov.il/Enviroment/Static/Binaries/index_pirsumim/p0353_1.pdf

[84] Ecostar, 2005, "Economic Costs of Collection and Removal of Pruning and Solid Waste Separately in Local Councils", Ministry of Environmental Protection (Publisher), at: www.sviva.gov.il/Enviroment/Static/Binaries/index_pirsumim/p0353_1.pdf

[85] Chandel, A.K., Chan, E.S., Rudravaram, R., Narasu, M.L., Rao, L.V., Ravindra, P., 2007, "Economics and Environmental Impact of Bioethanol Production Technologies: an Appraisal", Biotechnology and Molecular Biology Review, **2 (1):** 014-032, at: http://www.academicjournals.org/bmbr/PDF/pdf2007/Feb/Chandel%20et%20al.pdf

7.5 Ethanol Cost Comparisons

In evaluating the costs associated with producing bioethanol as a gasoline blend, one can evaluate three options:

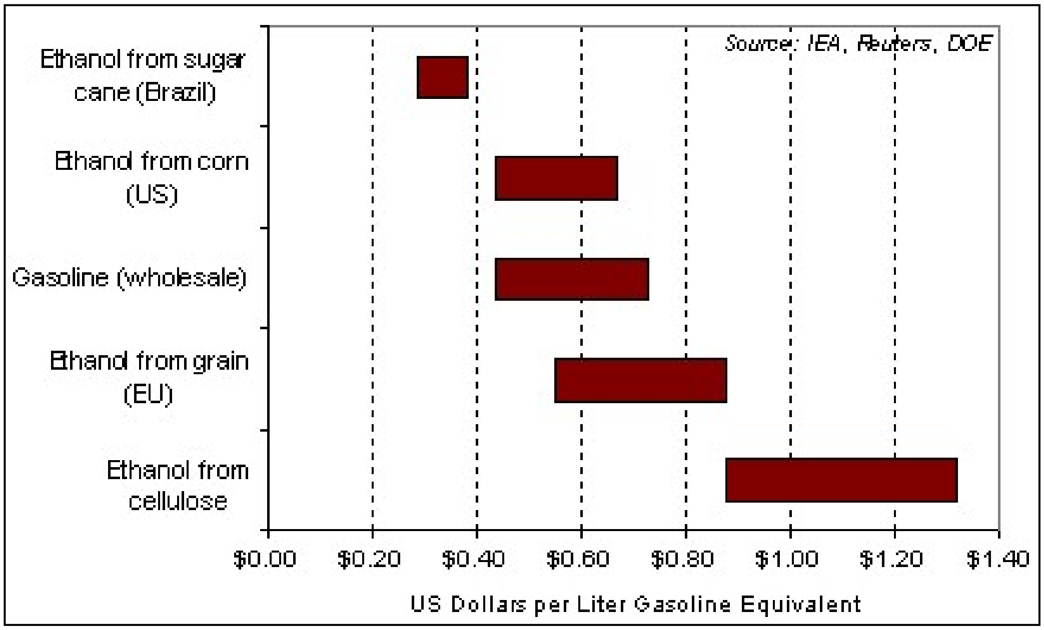
- Cost of growing the feedstock to produce bioethanol,
- Cost of importing the feedstock (grain or sugar) to produce bioethanol, or
- Cost of importing bioethanol for blending into gasoline.

The production cost of various feedstocks in Israel is discussed in section 6.3 and 7.4.

This section deals with the comparative cost of producing ethanol from the various feedstocks with and a brief comparison of the cost of importing ethanol directly as a blend stock.

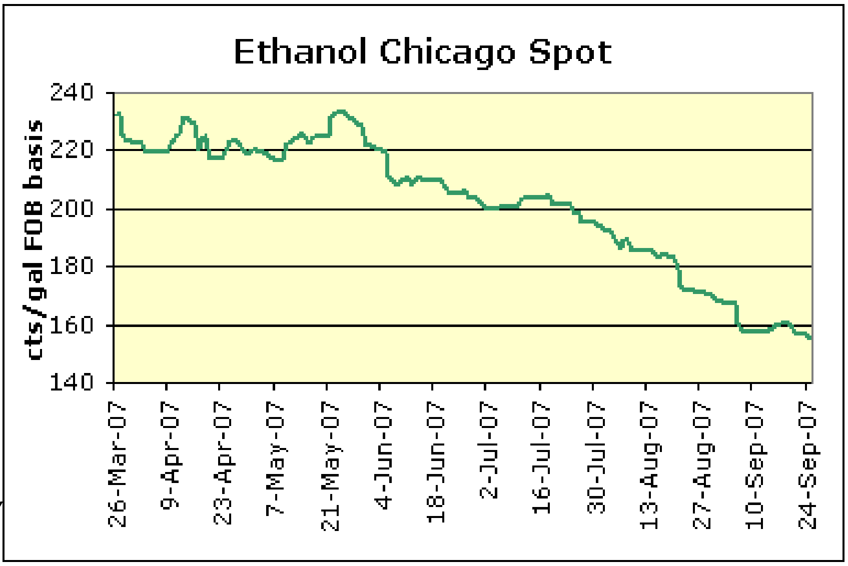
Figure 7.1 depicts the 2004 assessment by the IEA of the cost of ethanol production from various feedstocks. However, the costs reflected in this chart have probably at least doubled since the IEA assessment, although their relative magnitude is probably still valid.

Figure 7.1- Comparative Cost of Ethanol Production from Different Feedstocks (IEA, 2004)



In the U.S. Ethanol is playing an increasing role in the gasoline market, extending its reach beyond reformulated gasoline and reaching into conventional gasoline blends. This is due to the escalating costs of crude oil and the fact that ethanol has become cheap relative to conventional unleaded gasoline. For example, in April 2008 ethanol in Houston was valued at $1.655/gal, compared to $2.03485/gal for regular unleaded gasoline.

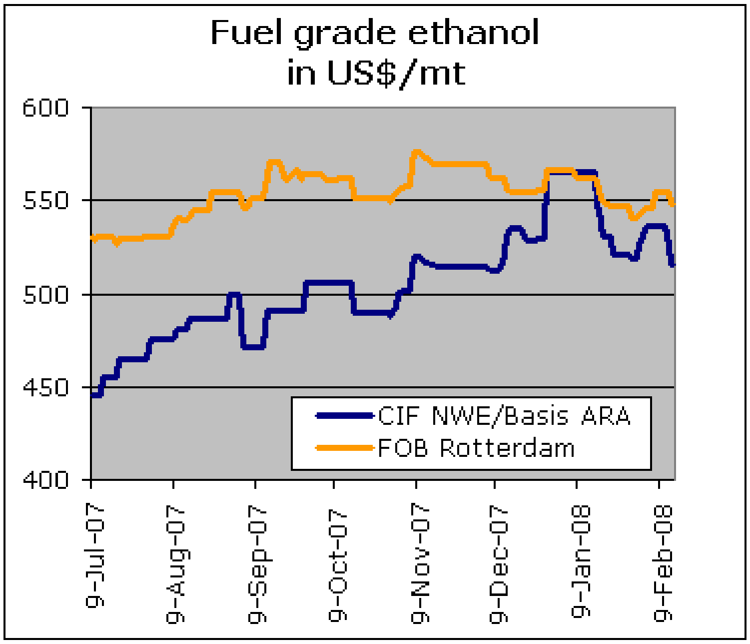
Figure 7.2- Six-Month Trend of Ethanol Prices in 2007 in the U.S.



Platt's Oilgram: Spot Energy Prices, 2007

Figure 7.2 tells part of the story of the declining U.S. ethanol prices, with the trend being the same for the spot market in Chicago, Houston or North Carolina. All this occurred while the costs of grains of corn have gone up from $2/bushel to over $4/bushel.

Figure 7.3- Trend of Fuel Ethanol Cost in Europe



Platt's: European Ethanol Prices, 2007

Ethanol prices in the EU have exhibited a different trend, as depicted in Figure 7.3. In Europe the prices have increased over the last six-month of 2007 and have started to level off in early 2008. So although ethanol is an attractive blending agent for unleaded gasoline due to its high octane and its environmental benefits, the volatility of the market makes it difficult to assess ultimate costs in Israel and also make it perilous to rely on importing it (section 9.2 deals with this issue extensively).

8 The Role of Advanced Technologies

Further development of alternative fuels as substitutes for fossil fuels, particularly bioethanol for transportation, would require a breakthrough in novel technologies that could enable using “second generation” feedstock, reduce competition with food and feed products and significantly improve energetic efficiency and cost effectiveness.

In the U.S. for example, the U.S DOE is supporting fundamental research at the university level and also providing grants for pilot plants to demonstrate market transforming technologies. In early 2007 it has awarded grants totaling $385 million to cover 40% of the capital costs of six cellulosic ethanol refineries. These biorefineries, slated for completion during the next four years, are expected to produce more than 130 million gallons annually of cellulosic ethanol from corn stover, cereal straws, wood chips and other carbonaceous biomass. These six producers would use a variety of means to break down the raw biomass, including enzymes, gasification and acid hydrolysis.

8.1 Research and Development Needs

Israel has gained a worldwide reputation as a provider of ingenious solutions in agricultural production and development in various fields such as agricultural technology, water management and recycling, biotechnology and other high technology and engineering fields based on entrepreneurship and research and development.

Israeli public and private sector institutions and organizations can contribute significantly to the development of alternative biofuels aimed at replacing fossil fuel. New technologies could be applied within Israel and be relevant for worldwide application.

Fields of particular relevance for research into the substitution of gasoline by biofuels, particularly bioethanol include:

- Agricultural technology for the development of alternative feedstocks and their production;
- Biotechnology for efficient enzyme development and other bioethanol conversion technologies;
- Industrial research for improvement in conversion efficiency and reduction in conversion costs;

- Recycling technologies and methods to improve retrieval efficiency and cost-effectiveness of extracting cellulosic feedstock from waste.

Different fields of research relevant to biofuel production and suited to Israel's highly regarded competencies include:

8.1.1 Agriculture

Israel is recognized for her outstanding, internationally acclaimed research and development in the field of agriculture and related technologies.

Arid land conditions and lack of agricultural land have forced Israel into excellence in these fields. Crop yields for various crops are amongst the highest in the world due to R&D investments into varieties development, irrigation technology and precision agronomic management.

Specific fields include breeding of varieties, agricultural biotechnology, irrigation technologies and water use efficiency, plant protection and agronomic methods such as precision management in controlled environments and plant development monitoring.

Although most research and development is performed by academic institutions, agro-industries play an important part in technology development and its application in Israel and worldwide.

Although varieties intended for biofuel production could be developed in Israel by local institutions, collaboration in target producing countries is imperative for correct selection of cultivars and successful outcomes.

Most research and development in the agricultural field, whether breeding and variety development or agronomic management, could be viewed as export of knowledge, based on Israel's highly regarded agricultural background.

8.1.2 Chemical and Biotechnology Research

Chemical and biotechnological processes play a crucial role in conversion of cellulose to ethanol. In comparison to direct sugar sources, the reduction of cellulose to sugars requires a greater amount of processing to make the sugar monomers available to the microorganisms that are typically used to produce ethanol by fermentation.

Improvements in chemical, biotechnological and gasification processes will increase the efficiency of conversion and lower the cost of bioethanol production.

Specific research could include concepts for pretreatment of cellulose, cellulolytic processes such as chemical and enzymatic hydrolysis, fermentation and gasification processing and many more aspects of production.

The Overall objectives are to revolutionize efficiency of conversion and reduce costs.

8.1.3 Industrial Research

Industrial research is focusing on streamlining production processes and improving the efficiency of the overall process chain from the initial preparation of feedstock to the final point of blending into transportation fuels. The main areas of interest include:

- Initial feedstock harvesting and packaging.
- Pretreatment technologies.
- Catalysts, process conditions and material compatibility for required media.
- Storage stability.
- Automating fuel blending and metering.

Elements of these technologies are being researched by different universities and research institutions in Israel. The most advanced technology could be found in the area of computerized control and communication to integrate and automate processing.

8.1.4 Recycling

As it seems from this research, recycling of by-products and waste are a far more promising source of cellulosic material for bioethanol production than direct agricultural products. However, efficiency in retrieval of cellulosic materials from these raw materials still requires further improvements.

Fields for further research and management of recycling could include:

- Source separation
- Waste collection systems and legislation
- Treatment of waste materials and concentration of cellulose for processing

Cellulosic ethanol R&D and commercialization can contribute to a successful renewable fuels future. Many companies are already building refineries that can process biomass and turn it into ethanol, while other companies are producing enzymes and improved yeast strains, which could enable a cellulosic ethanol future. The shift from food crop feedstocks to waste residues offers significant opportunities for a range of players, from farmers to biotechnology firms, and from project developers to investors.

8.2 Status of Bioethanol Research, Development and Technology

Fundamental research and development is essential for achieving a breakthrough in advanced bioethanol production technologies. Although cellulosic ethanol is less polluting than gasoline and, unlike corn ethanol, will not divert massive amounts of agricultural crops into fuel no one company has begun producing cellulosic ethanol commercially yet. There is no doubt, however, that many biofuels companies, government and university researchers will ultimately discover the right formulas. Many discoveries are announced almost daily but scaling up the technologies from the laboratory to full production in order to supply the motor fuel market is still far in the future.

Two recent university discoveries of note, one from the University of Maryland (Text box 17) and the other from the University of Texas at Austin (Text box 18) might offer new avenues for research with the possibility of using a vast array of biotechnology methods that have been previously utilized in other industry sectors.

Text Box no.17- University of Maryland: Chesapeake Bay Bacterium Route to Inexpensive Gasoline Substitute

A Chesapeake Bay bacterium, called Saccharophagus degradans, discovered by chance, was shown to create a mixture of enzymes that break down almost any source of biomass, or plant life, into sugars, which are then converted into ethanol and other biofuels.

This new system can make ethanol and other biofuels from many different types of plants and plant waste (cellulosic sources), potentially making it a viable and inexpensive gasoline substitute.
Key findings:

- This enzyme mixture contains novel, efficient enzymes that are needed to produce biofuels from cellulosic material,
- This enzyme mixture degrades cell walls and breaks down the entire plant material into sugars in one step, creating fermentable sugars faster and at a significantly lower cost, reducing the need for caustic chemicals used by other processes,
- It might be possible to genetically engineer a yeast strain, using genes from the Bay-derived bacterium, to improve the production of ethanol from fermentable sugars by at least one third.
- The enzymes are easy to produce, work well in a water-based environment, are active under industrial conditions and rapidly break down plant material, thus fewer enzymes will be needed to do the work,

These enzymes can avoid the need for a lengthy and expensive multi-step pretreatment process that is currently needed to break down cellulosic materials into biofuel-ready sugars.

The challenge now is to scale up and mass-produce the enzyme and demonstrate its commercial viability with various types of cellulosic material. Although the researchers have been unable to isolate the bacterium in the Bay again, they are producing it in their laboratories through cultured growth.

Source: Ekborg et al, 2006.

Text Box no.18- University of Texas at Austin: **Newly Developed Bacterium as a Source for Biofuels**

Scientists from the University of Texas in Austin have created a microbe that produces cellulose that can be turned into ethanol and other biofuels. They developed cyanobacteria that along with cellulose it secretes glucose and sucrose, which are simple sugars that are the major sources used to produce ethanol.

Key findings:

- The new cyanobacteria (also known as blue-green algae) were developed by inserting a set of cellulose-making genes from a non-photosynthetic "vinegar" bacterium, Acetobacter xylinum, which is well known as a prolific cellulose producer.
- The new cyanobacteria use sunlight as an energy source to produce and excrete sugars and cellulose,
- Glucose, cellulose and sucrose can be continually harvested without harming or destroying the cyanobacteria
- Cyanobacteria that can fix atmospheric nitrogen can be grown without petroleum-based fertilizer input
- The new cyanobacteria produce a relatively pure, gel-like form of cellulose that can be broken down easily into glucose

This approach overcomes a common problem with cellulose harvested from plants that is difficult to break down due to a highly crystalline form and its complex mixture with lignins that are the backbone of the plant structure. Using these bacteria could circumvent the need to use enzymes and mechanical methods to break the cellulose down, which typically make the cellulosic ethanol process very expensive.

The results obtained are very preliminary and a lot more research is needed to scale up production. If a 17-fold increase in productivity can be achieved in large scale in the field, then this technique could yield similar quantities of bioethanol by using only 3.5% of the area required currently for corn-ethanol.

Source: Nobles et al, 2004.

Table 8.1 provides examples of some key research groups in Israel that are investigating enzymes, processes and microorganisms that could be relevant to cellulosic bioethanol research.

Table 8.1- Examples of Biofuel Related Academic Research (in alphabetical order)

ACADEMIC INSTITUTE	FIELD OF RESEARCH
Prof. Bayer Ed Department of Biological Chemistry, Weizmann Institute of Science. Contact details: ed.bayer@weizmann.ac.il	Cellulose and related plant cell wall polysaccharides (biomass) can be potentially utilized as a low-cost renewable source of sugars for conversion to biofuels like ethanol. Since cellulose is pure glucose, its conversion to fuels has remained a romantic and popular notion for weaning ourselves away from dependence on fossil fuels. Perhaps the major bottleneck for conversion of biomass to ethanol is the combined high cost and low efficiency of the celluloses and related enzymes that degrade such polysaccharides to simple sugars. Future research must thus focus on overcoming the natural recalcitrance of biomass. One attractive prospect for biomass conversion relies on the multi-enzyme complex, the cellulosome. In contrast to free enzyme systems, the cellulosome comprises a set of Lego-like multi-modular components — some structural and some enzymatic, contained into a discrete complex. Due to the proximity of the various different enzyme subunits and their common targeting to the cellulose surface, they work with enhanced levels of synergy to degrade the substrate. Rational bioengineering of cellulosomal components for production of tailor-made “designer cellulosomes” is now being developed for improved cellulose degradation. Unlike the native cellulosomes, designer cellulosomes can be produced in large amounts in host cell systems and their enzymatic content can be strictly controlled. The combination of designer cellulosomes with novel production concepts may provide future breakthroughs necessary for economical conversion of cellulosic biomass to biofuels.
Prof. Ben- Asher Jiftah The Jacob Blaustein Institutes for Desert Research, Ben Gurion University of the Negev. Contact details: benasher@bgu.ac.il	*Improving Biofule production Effect of multiplied genotypes on CO2 Sequestration and Water Use Efficiency*- This study was aimed to study the effect of multiplied tomato genotype on its productivity, its ability to sequestrate CO2 and its WUE. It's unique approach was that with the appropriate field instrumentation it provided increased understandings of the complex interactions between crops and their environment. For example, elevated CO2 humidity and temperature changes. From the standpoint of irrigation management the consequences are that we established a tool to control the crops environment under arid conditions. Undoubtedly the models for predicting effect of high temperature are constantly modified as knowledge increases but this study with the understanding of the interactive effects was a step to improve and demonstrate the advantages of multiplied genotypes and the economic benefit that can be obtained.
Prof. Boussiba Sammy The Jacob Blaustein Institutes for Desert Research, Ben Gurion University of the Negev. Contact details: sammy@bgu.ac.il	The group has been instrumental in developing and supporting one of the largest and most advanced tubular photobioreactor facilities (200-300 m3) located at Kibbutz Ketura for the production of astaxanthin-rich Haematococcus biomass. Other current activities in the group involve the production of some unique PUFAs such ARA, DGLA, and developing integrated aquaculture biosystems for efficient water utilization.

ACADEMIC INSTITUTE	FIELD OF RESEARCH
Prof. Eshel Amram Department of Plant Sciences, Faculty of Life Sciences, Tel Aviv University. Contact details: AmramE@ex.tau.ac.il	Developing plant materials in order to produce biofules or benefiting from the CDM mechanism. Focus on growing plants on marginal lands. Main activity: Identification plants with high production ability, as: The Tamarisk tree and other desert plants that can be use as a fuel substitute. Development of agrotechnics methods and determining the production potential in order to initiate economic projects at the third world countries.
Prof. Hadar Yitzhak Department of Plant Pathology and Microbiology, Faculty of Agricultural, Food and Environmental Quality Sciences, The Hebrew University of Jerusalem. Contact details: hadar@agri.huji.ac.il	Prof. Hadar's group works in the area of lignocellulosic waste upgrade and microbial transformation of organic matter. In order to provide access of the cellulolytic enzymes for degradation of cellulose, the crude substrates must undergo a pre-treatment step. One possibility is biological treatment based on developing a process for selective degradation of lignin using white rot fungi (in particular Pleurotus ostreatus in our lab) and elucidation of mechanisms involved. Special attention is given to the ligninolytic enzymes laccase and manganese per-oxidase and to solid state fermentation of these fungi.
Dr. Harlev Eli Ben Gurion University of the Negev. Contact details: harleve@bgu.ac.il	Developing of an infrastructure for economic ethanol production based on energy-rich crops that can grow in the Israeli Arava- The Project, sponsored by General Motors and led by Dr. Elaine Solowey of the Arava Institute for Environmental studies (AIES) at Kibbutz Ketura and Dr. Eli Harlev at Ben-Gurion University of the Negev, is aimed at the developing of an infrastructure for economic ethanol production based on energy-rich crops that can grow in the Israeli Arava. It is believed that this area in the southern part of Israel is extremely attractive for such an enterprise, as it can sustain "energy crops" on a commercial scale owing to the availability of large cultivatable lands, 350 days of full sunlight, a very mild winter and an ample supply of usable brackish water. A large part of the Arava's available land can be accommodated to bio-energy production. Crops have been selected that are sustainable in respect to climate and soil, which growing is economical and furnishes a basis for an economical production of ethanol. Ethanol sources to be considered are plants producing starch and sugar, which can be transformed into ethanol via fermentation. However, producing ethanol from cellulosic biomass much outweighs the former. This is because "cellulosic ethanol", can be produced from farm wastes – a feedstock not being part of the food-chain and also of almost limitless availability. However, more research is needed to improve the economy of this source. We aim at being part of the current efforts to transform agricultural feedstock into bio-fuels, particularly ethanol. Our advantages reside on both highly skilled human resources and the special advantages of the Israeli Arava.

ACADEMIC INSTITUTE	FIELD OF RESEARCH
Prof. Sharon Amir Department of Plant Sciences, Faculty of Life Sciences, Tel Aviv University. Contact details: amirsh@ex.tau.ac.il.	Fungi are primary producers of biodegrading enzymes. We developed transgenic fungi that are long-lived, capable of withstanding various stresses, and produce more biomass. We propose to utilize this technology to enhance biodegradation of wastes, production of fiber-degrading enzymes etc.
Prof. Shoham Yuval Department of Biotechnology and Food Engineering Technion-IIT, Haifa 32000 Israel Contact details: yshoham@tx.technion.ac.il	Nearly half of the biomass synthesized by photosynthetic fixation of carbon dioxide is composed of cellulose and hemicellulose which make the majority of the plant cell wall matter. These polymers are the most abundant renewable natural resource available for conversion to liquid fuels. They are inexpensive, plentiful, renewable and most importantly their utilization do not contribute net CO_2 to the atmosphere. In Nature, the main decomposition of lignocellulose is mediated by microorganisms, providing a key step in the carbon cycle on Earth. Currently, the main bottleneck in the economic utilization of the plant cell wall matter as renewable energy source is the efficient degradation of crystalline cellulose. Our laboratory is engaged in studying thermophilic microorganisms capable of utilizing cellulose and hemicellulose, in particular the anaerobic bacterium *Clostridium thermocellum* and the aerobic strain *Geobacillus stearothermophilus*. We are interested in revealing the catalytic mechanisms and structure-function relationships of selected glycoside hydrolases, and understanding the physiology and gene regulation of these microorganisms in the context of cellulose and hemicellulose utilization. Our studies combine fermentation technology, molecular biology, biochemistry and X-ray crystallography in an attempt to design and produce efficient microbial and/or enzymatic systems for the breakdown of hemicellulose and cellulose.

An emerging area of research that show promise is in the areas of algae, especially salt water algae that can be trained to produce ethanol directly. Some forms of algae that are known as cyanobacteria, or blue-green algae, can make ethanol, directly from the sun, seawater and carbon dioxide as the principal ingredients according to findings by Algenol, a privately held biofuels company[86]. Algenol has recently announced its most advanced 3rd generation biofuels technology that can potentially produces industrial-scale, low-cost ethanol, at a rate of over 6,000 gallons per acre per year.

Since the bacteria love carbon dioxide, feeding them from combustion devices vents would boost growth and could be a market for captured CO2. The company estimates that for a billion-gallon plant, the target size being planned now, 15 million metric tons of CO2 would be required per year. For comparison, the US DOE plan for geologic sequestration of CO2 is based on several plants each storing 1 million metric tons annually.

Several Israeli start-up companies are involved in advanced algae research. The abundance of sun, arid land and salty seawater in Israel in addition to extensive knowledge in the algae biotechnology field, can position Israel to be a center for such R&D and demonstration projects. Table 8.2 lists of a few start-up companies in Israel that are engaged in this research, with new ventures on the horizon.

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[86] Algenol, at: http://www.algenolbiofuels.com

Table 8.2- Short List of Biofuel Related Israeli Start-up Companies

COMPANY	FIELD OF ACTIVITY
Algatechnologies (1998) Ltd. Contact details: amir@algatech.com, elizabeth@algatech.com	Algatechnologies and the American company GreenFuel Technologies Corporation develop a system to reduce greenhouse gas emissions profitably while producing renewable energy in the form of liquid fuels, such as biodiesel and ethanol. The process harnesses photosynthesis to grow algae, capture CO2 that is emitted by power stations and produce high-energy biomass. Using commercially available technology, the algae can be economically converted to solid fuel, methane, or liquid transportation fuels such as biodiesel and ethanol.
Evogene Ltd. Contact details: hagai@evogene.com, eyal.emmanuel@evogene.com	Evogene is an Ag-Biotech Trait Development Company, geared toward developing improved plant traits for the agriculture and biofuel industries through the use of plant genomics. Evogene's core competence is derived from its state-of-the-art, unique computational gene discovery platform (The "ATHLETE"), which enables highly accurate and creative comparative genomics through assembly and mining of vast genomic data. Leading candidate genes are used for the development of GM[87] (trait enhancers) and non GM (Marker Assisting Selection System for Breeding) solutions. These genes are further licensed for commercial application through collaboration with leading seed companies, among them: Monsanto, Bayer CropScience, Syngenta and Limagrain.
PPSV Ltd. Contact details: ppsv@pps.co.il.	PPSV Ltd. is an Israeli company, focusing on the development and commercialization of processing agricultural waste to produce bio-fuel ethanol, as fuel alternative. The company has raised private capital for the early stage development. Following a successful proof of concept and a provisional US patent application, the company continues to further develop its process to pilot scale.

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[87] GM- Genetically Modified

9 Major Findings and Conclusions

Over the months that this study has been conducted biofuels have gone from making headline news as the world's safety valve against crude oil shortages and ensuring countries' energy security to becoming a "pariah." The media seems to attribute most of the world's current disasters to biofuels. For example, even the recent spikes in the price of rice were blamed on biofuel production despite the fact that rice is not used as a feedstock at all. The fact is that increased global production of biofuels has probably distorted some commodity prices and therefore contributed to recent price increases in grains and vegetable oils. However other factors, such as recent droughts, surging demand for meat and milk products in Asia and other factors, have probably played a far greater role.

Despite the legitimate concerns about the sustainability of some biofuel sources it is important to put the issue into perspective. Not all biofuels are created equally and there are some “bad” and some “good” biofuels. Biofuels ought to be produced in a sustainable manner, support local development without exploitation, and result in a reduction of overall environmental impacts including greenhouse gas emission reductions. These conflicting claims and viewpoints have prompted some to take action and work towards the development of consensus criteria to assess biofuels sustainability in order to ensure that policy considerations regarding the production and use of biofuels would be based on sound sustainability considerations[88,89].

9.1 Biofuels Sustainability Considerations

Biofuels presently account for < 2% of liquid transport fuels globally and take up well below 1% of world agricultural land (Figure 9.1). At over 1 million barrels of oil equivalent per day, they have contributed to meet around 30% of the growth in global demand in liquid transport fuels over the past three years and thus made a significant contribution to the balance of the oil market.

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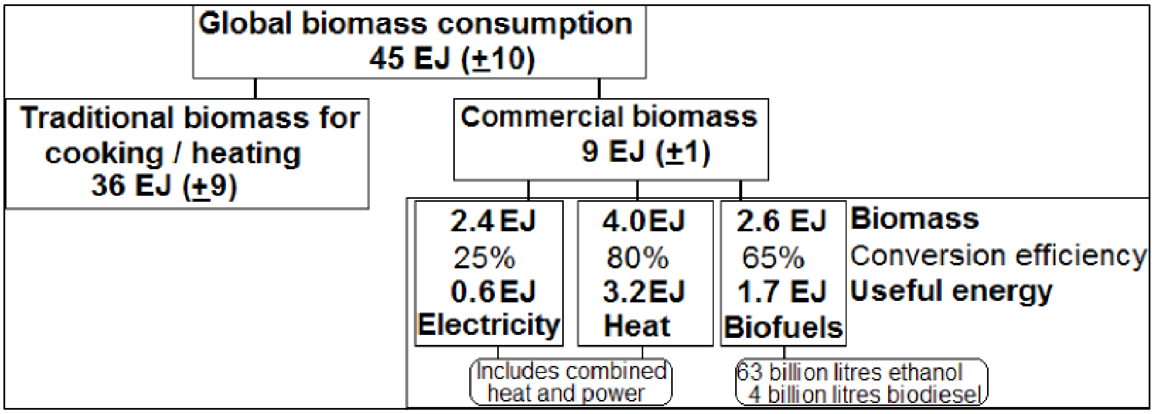
[88] Bellagio Consensus, 2008, A Sustainable Biofuels Consensus, from Dialogue Forum sponsored by the Rockefeller Foundation, 24-28 March 2008, at: http://www.renewableenergyworld.com/assets/documents/2008/FINAL%20SBC_April_16_2008.pdf

[89] CEN Energy Center, Principles on Sustainable Biofuels Production, on-going dialogue till June 2008, at: http://cgse.epfl.ch/page70341.html; http://www.bioenergywiki.net/index.php/Main_Page

Figure 9.1- Contribution of Biomass to Global Primary and Consumer Energy Supplies in 2007



Source: IEA

An important consideration as to the sustainability of biofuels is the high national costs of either agricultural subsidies or preferred taxation schemes that are necessary to support biofuels. Also for some biofuels, greenhouse gas emission reductions are not always as good as was commonly thought, when demonstrated by using well-to-wheel life cycle analyses. Land use change and deforestation, additional water use, and increased fertilizers and chemical inputs, all raise questions as to the longer-term sustainability of energy crop production.

In some tropical/sub-tropical regions where arable land for sugarcane production is available (from improved land management rather than from deforestation), local development opportunities should not be discounted. If biofuels can be produced in a sustainable way, and be certified as such according to an agreed international standard currently being debated, then they can offer valuable economic opportunities, particularly to developing countries.

In the longer-term second-generation biofuels from ligno-cellulosic, non-food feedstocks (straw, woody biomass residues, vegetative grasses) hold promise and should address most of the current concerns. Several demonstration projects are under way and major deployment of commercially viable second-generation biofuels may be just a few years off. Development of flex-fuel vehicle engines that run on low- or high-level blends of ethanol or gasoline has been a major step forward to support the increased uptake of biofuels. With over 6 million such vehicles already running on the roads of Brazil, the

U.S., Sweden and elsewhere, and more auto manufacturers showing interest, demand is likely to continue. Also, “plug-in hybrid” flex-fuel engine vehicles show promise for the future.

The aim should be to progressively phase out subsidy systems or tax incentives for the less sustainable biofuels and focus on incentives to bring forward second-generation production of both ethanol and synthetic diesel as well perhaps of "third generation" biofuels from algae using advanced biotechnologies. Recent increases in public and private investments in research, including by the biotechnology industry, may help reduce the production costs.

9.1.1 Sustainable Biofuels Recommendations

The Sustainable Biofuels Consensus (footnote 87 above) calls on governments, the private sector, and other relevant stakeholders to take concerted, collaborative and coordinated action to ensure sustainable trade, use and production of biofuels. This may ensure that biofuels play their key role in the transformation of the energy sector, contribute to climate stabilization and result in the worldwide renaissance of rural areas, all of which are urgently needed.

Key recommendations include:

- Integrate and better coordinate policy frameworks.
- Assess benefits and impacts of biofuels trade, use and production, and monitor them.
- Address negative indirect effects of biofuels trade, use and production.
- Reward positive impacts and investments, including thorough carbon management.
- Use informed dialogues to build consensus for new projects.
- Increase investment in research, development and demonstration.
- Build capacity to enable producers to manage carbon and water.
- Make sure that trade policies and climate change policies work in unison.

9.2 Feedstocks for First Generation Biofuels in Israel

The vast majority of grain as well as finished sugar- products that could comprise feedstock for bioethanol production are imported into Israel. Additional production of grain in Israel at present conditions would be designed to substitute imports rather than be used for bioethanol production.

Conditions in Israel are fundamentally unsuitable for large scale commodity crop production and from an economic stand point (see below) Israel does not have a competitive advantage in this field as well.

Admittedly, for political reasons, limited crop production such as a locally produced emergency inventory of grains could be envisioned as a strategy for partial self sufficiency. Additionally, the interest of utilizing land for reclamation may also play a role in a potential Israeli strategy to encourage a limited local agricultural production of grains. However, these considerations and potential production volumes cannot fulfill the feedstock requirement for bioethanol. First and foremost any additional local production would be used for food and feed to substitute for imports. Only if there was any surplus feedstock, it could be allocated to bioethanol production, which is not a realistic scenario.

The three most influential parameters for comparing different feedstock routes of bioethanol production include:

- Conversion yield, i.e. liters of ethanol per kg grain.
- Crop yield, i.e. tons (Mg) per hectare.
- Conversion thermal energy inputs, i.e. MJ of energy in the produced ethanol vs. the required energy input.

Under the scenarios analyzed for the Israeli situation the following should be considered when evaluating the energy balance:

- If grain is produced locally- one would have to sum up the energy input for machinery, fertilizer, water application, chemicals and other production requirements per ton (Mg) of produced grain under different production regimes (as shown in Tables 6.4 and 6.5)

- If grain is imported- one would have to also take into account the energy required for transporting the grain (or the finished bioethanol) to Israel. Since all transport to Israel will be via marine vessels, the fuels used by those vessels have substantial greenhouse gas emissions[90] that would need to be factored into the assessment.

For locally produced grain, a previous work has demonstrated different energetic output figures for corn.[91] Efficiency levels have been reported to vary between highly inefficient (-33 K Btu/gallon bioethanol) to efficient output (+30 K Btu/gallon bioethanol). The factors causing this wide variation are linked to the efficiency of corn ethanol production that has been rising over time. This is primarily due to technological advances in ethanol conversion and increased efficiency in farm production. Most studies indicate that corn ethanol production has an energy output-to-input ratio of 1.34.

For imported grains (or direct importation of bioethanol) the shipping energy input will also have to be factored into the balance. In a study performed by Iowa State University, they have evaluated fuel consumption and fuel costs for individual grain shipments[92]. Their analysis compared ocean vessel net ton-miles per gallon and found wide variations, as shown in Table 9.1 below.

Table 9.1- Average Net Ton-Miles per Gallon

SIZE OF SHIP	NET TON-MILES PER GALLON
30,000 dwt	574.8
50,000 dwt	701.9
70,000 dwt	835.1
100,000 dwt	1, 043.4

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[90] International Maritime Organization (IMO), 2000, “Study of Greenhouse Gas Emissions from Ships”, at: http://unfccc.int/files/methods_and_science/emissions_from_intl_transport/application/pdf/imoghgmain.pdf

[91] Shapouri H., Duffield, J.A., Wang, M., 2002, “The Energy Balance of Corn Ethanol: An Update”, Agricultural Economic Report No. 814, USDA, http://www.usda.gov/oce/reports/energy/aer-814.pdf

[92] Baumel, C.P., Hurburgh, C,R., Lee, T., 2007 , “Estimates of Total Fuel Consumption in Transporting Grain from Iowa to Major Grain Countries by Alternatives Modes and Routes”, Iowa Grain Qulaity Initiative, http://www.extension.iastate.edu/grain/info/estimatesoffuelconsumption.htmtl

In order to assess the additional GHG emissions impact that could be associated with shipping grains, we need to multiply the average fuel consumption by the fuel specific emission factors:

- For marine diesel = 0.01005 metric tons of CO_2 / gallon fuel; and/or
- For bunker fuel (heavy fuel oil) = 0.011672 metric tones of CO_2 / gallon fuel.

Hence, or the largest, and most efficient, vessels this could amount to over 100 Metric tons of CO_2 when transporting 100,000 tons of cargo for 100 miles.

9.3 Cellulosic By-Products and Waste in Israel

Chapter 7 provides a summary of potential amounts of cellulose available in Israel based on production of materials of origin, estimated cellulose content, and retrievable amounts based on the above estimates. The origins included are available agricultural by-products (section 7.1), forest products (section 7.2) and other by-products and waste (section 7.3).

According to this estimate approximately 885,000 MT of cellulose from origins of agricultural by-products, forest and garden waste, MSW and sludge comprising the total available waste produced from these origins, which could be made available for bioethanol production. The breakdown of origins is 3%, 25%, 71% and ~0% for agricultural by-products, forest and municipal prunings, MSW and sludge respectively.

As technologies to efficiently convert cellulose develop these figures are expected to grow.

For example, should 1 million MT of cellulose and hemi-cellulose be made available for conversion within the forthcoming decade in Israel, this amount should suffice for the production of 350,000 M^3 of ethanol based on a typical conversion factor of 0.35 Lt ethanol per 1 Kg cellulosic matter, thus generating a total of about 250,000 MT of ethanol for blending.

9.3.1 Availability of cellulosic feedstock for conversion to bioethanol in Israel

In summary, approximately 885 million MT of cellulosic material are potentially available in Israel presently from agricultural by-products (Table 7.1) and forest, MSW and sludge origins (Table 7.2). These sources currently suffice to provide about 265 million liters (200,000 MT) of bioethanol if utilized efficiently.

Assuming present consumption of about 2.2 million MT of gasoline in Israel (Section 5.2) and a growth forecast estimated at 1.5% per annum to 2.8 million MT by 2025, the total potential volume of bioethanol from origins of unutilized by-products and waste alone already comprise over 9% of a possible fuel blend – beyond fractions presently planned for the future. These volumes of potential bioethanol could easily enable any of the 3 scenarios outlined in Section 5.3:

- ***Scenario 1 (5% blend in all gasoline)-*** requires 107 to 113 million liters (82,500 MT) of ethanol,
- ***Scenario 2 (10% blend in all gasoline)-*** requires 214 to 225 million liters (165,000 MT) of ethanol,
- ***Scenario 3 (penetration of 5% E85)-*** A stand alone E85 scenario would require 91 to 96 million liters (70,000 MT) of ethanol. If this scenario is to be introduced in conjunction with scenario 1, namely 5% ethanol to be blended in 95% of all gasoline with an incremental penetration of E85 to cover the additional 5% demand, would require about 197 to 203 million liters (150,000 MT) of bioethanol to be available for blending the different gasoline products.

  According to this estimate the amount of bioethanol that could be made available in Israel could suffice for an E85 penetration level of over 5% which would require 85,000 MT of bioethanol and an additional 105,000 MT to blend into the remaining less than 95% of consumed gasoline at a blending level of 5%.

Alternatively, should a policy of increasing blending levels be adopted, present day potential ethanol production from by-products and waste would suffice for a 9% blend of bioethanol into gasoline based on the assumptions of this analysis.

Since commercially efficient cellulose conversion is not yet an available technology, we assume that present forecasts of increase in demand to 2.8 million MT gasoline p.a. in 2025 will occur concurrently with an increase in the production and availability of waste and an increase in waste usage efficiency. This scenario will ensure that the ratio between demanded gasoline and bioethanol for blending will remain constant - in the worst case scenario. Significant improvements in waste usage efficiency or a drop in the demand for fossil fuels due to a shift to alternative transportation energy sources such as hybrid, electric or newer technologies by 2025 will increase the gasoline – bioethanol ratio level and enable higher concentrations of alternative fuel blends by then.

9.4 Is Bioethanol Production In Israel Sensible?

The government of Israel, in planning its biofuels policy measures and strategies should incorporate the biofuels sustainability recommendations outlined above.

The analysis presented hereby has established that Israel is at a fundamental disadvantage in production of agricultural commodities that presently constitute “first generation” feedstock for bioethanol production. Additionally, future production of cellulose via conventional agricultural methods is probably unsuitable as well.

Israel is far from self sufficient in staple starch and edible oil sources and is an importer of starch and oil rich commodity grain for food and animal feed. Agricultural policy in Israel is based on importing large amounts of animal feed for local meat, dairy and fish production. This policy enables a level of self sufficiency in animal protein production for food and also enables local animal husbandry as an agricultural industry and economic pursuit.

These imported animal feed consist – to a large extent - of the same feedstocks used for “first generation” biofuel production. Since production of bioethanol feedstock in Israelis probably implausible given Israel’s basic conditions, the same would apply also to importation of feedstock for local bioethanol production and could compete with the availability of animal feed. A better approach would be to promote importation of finished bioethanol, despite the inefficiencies involved, if it is deemed essential for national energy security. If bioethanol were to be imported to Israel as a finished product its transportation costs, the resulting energy imbalance and the potential impacts on greenhouse gas emissions would need to be assessed for individual policy scenarios.

A major finding of this research is that various forest and agricultural by-products as well as the cellulosic component of MSW could comprise raw materials for future bioethanol production, as soon as conversion technologies enable efficient production of bioethanol from sources of cellulose. This research has also found that approximately 885 million MT of cellulosic material are potentially available in Israel presently from agricultural by-products, forest, MSW and sludge origins. These sources would currently suffice to provide about 265 million liters (200,000 MT) of bioethanol if utilized efficiently.

The total potential volume of bioethanol from origins of unutilized by-products and waste alone could help produce a blending stock that comprises over 9% of the total present gasoline consumption of about 2.2 million MT per year. This represents a good start - and a potential initial target - for blending bioethanol into the motor gasoline distributed in the Israeli market.

The main problem with cellulosic ethanol is that technology to efficiently convert cellulose to ethanol on a commercial scale is still unavailable. Since “second generation” biofuels are perceived as sustainable fuels for transport and do not “carry” all the controversies of “first generation” bioethanol they are the subject of extensive global investments and intensive research.

Israel is in a unique position to contribute significantly to research and development on future generation feedstock and production technology for bioethanol, provided proper incentives are made available to researchers and entrepreneurs.

In summary,

Feedstock for “first generation” bioethanol:

- Israel has a major disadvantage in conventional agricultural production for bioethanol feedstock– **this is not an option for Israel.**
- Importation of grain and seed feedstock for bioethanol production in Israel would require a deliberate self-sufficiency policy to justify the inefficiencies, much the same as with the meat and dairy industry.

- Importation of finished bioethanol would require thorough scrutiny regarding transportation cost and energetic and carbon balance justification.

Feedstock for “second generation” bioethanol:

- Present conventional cellulose production (timber, switchgrass, kenaf etc.) **is also irrelevant for Israel** due to much the same natural resource limitations.
- Waste and by-product cellulosic feedstock amounts are potentially available for conversion in Israel, however, waste recycling rates need to be improved.
- Conversion technologies from cellulose to bioethanol are not yet efficient enough and are not economically feasible.
- Awareness of research and development potential, legislative and regulatory frameworks and removal of bureaucratic bottlenecks are required.

10 Final Recommendations

- Venture capital investments in cleantech companies continued to show robust growth in the first quarter of 2008, according to an Ernst & Young report based on data from Dow Jones VentureOne. Capital invested grew by 18% to $571.6 million in Q1 2008 compared to $483.9 million for the same period in 2007, while the number of deals declined by 11% to 34. This growth in cleantech investment bucks the trend of overall US venture capital investment in Q1'08, which declined by 7% to $6.5 billion.

  Three cleantech industry groups accounted for the majority of the capital invested in the quarter. The **Alternative Fuels group (mainly cellulosic ethanol) was the largest recipient of capital with $178 million invested—31% of the quarterly industry total.** Energy/Electricity Generation group's investments represented 26% of the cleantech industry and totaled $148.3 million. Energy Efficiency group deals accounted for 20% of investment, netting $116.4 million for the quarter.

- The U.S. congressional research service (CRS) concluded in its report to Congress that

> ***"There are limits to the amount of biofuels that can be produced from current feedstocks and questions about the net energy and environmental benefits they would provide, Further, rapid expansion of biofuel production may have many unintended and undesirable consequences for agricultural commodity costs, fossil energy use and environmental degradation."*** *(CRS, 2007)*

There is no doubt now that present bioethanol feedstock (mainly sugar and corn) are causing negative global repercussions. Perceived food shortages and the surge in food commodity prices such as wheat, corn and soybeans is generating a growing backlash against feeding bioethanol plants with food and feed products.

As it seems, Israel will remain at a fundamental disadvantage regarding production of conventional feedstock whether "first generation" (food crops) or "second generation" (cellulose) by exploiting her limited land and water resources for purposes other than high value crops. Israel should adhere to superior agricultural production by utilizing advanced technologies such as intensive, covered cropping systems and precision irrigation. Israel should not attempt to compete with countries that are already producing “first generation” feedstock by utilizing large stretches of land in an extensive manner under rain fed conditions and will probably continue to produce “second generation” cellulose crops in much the same manner. Israel is a small and arid country and will probably remain an importer of the vast majority of her demand for food commodities.

10.1 Policy Measures, Regulations and Incentives

- Support R&D, pilot and demonstration projects in prioritized areas.
- Provide tax incentives for targeted activities associated with cellulosic feedstock production, such as: recycling, brackish water utilization, establishment of cellulosic pretreatment facilities, development of integrated biomass refineries, and bioethanol storage, blending and distribution.
- Develop national targets and a roadmap for blending of cellulosic ethanol into the gasoline pool in Israel
- Evaluate the feasibility of introducing flexible fuel vehicles and high concentration blends of bioethanol (up to E-85) into the Israeli market.

10.2 Research and Development

Research and development for cellulosic bioethanol development requires technological advances in four main areas, as delineated below:

1. **Feedstock development**

   - Cellulosic feedstock production, breeding and variety development, agronomic management and technology development with knowledge export in mind and collaborative agreements with target producing countries in place.
   - Alternative feedstock research and development such as algae and possibly other cellulose rich organisms with local production potential (e.g. brackish water, sea water) with proven local production potential.

2. **Conversion technology**

- Improvements in chemical, biotechnological and gasification processes to increase the efficiency of conversion and lower the cost of bioethanol production.
- Studies should look for advanced concepts for:
  - Pretreatment of cellulose,
  - Cellulolytic processes such as chemical and enzymatic hydrolysis,
  - Fermentation,
  - Gasification processing.

3. **Industrial technology**

- Catalyst systems for improved efficiency,
- Scaling up of technologies from laboratory to pilot plant to field demonstrations,
- Blending technology.

4. **Waste recycling**

- Improvement and support of by-product and waste recycling rates,
- Support and accelerate improved efficiency conversion technologies (chemical, biotechnological, gasification, etc.)
- Support and invest in organizational aspects of recycling such as collection, recovery, concentration of cellulose

TO RECAP

- **National biofuels policy should clearly state that the production of feedstock for “first generation” biofuels is irrelevant for Israel.**
- **Bioethanol production from imported feedstock should be used only within the framework of a deliberate *energy security* policy, and should require offsetting its energy inefficiency and environmental impact.**
- **Import of bioethanol for blending should be permitted for a limited time only and as part of a roadmap to a national policy that promotes the use of sustainable biofuels.**
- **Efforts to commercialize the production of cellulosic bioethanol from agricultural by-products and waste should be given a high national priority**
- **The emerging research into the use of salt-water algae as a biofuel feedstock is a very promising field of study in which Israeli expertise can be developed into global leadership.**

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ABBREVIATIONS

MEASURES UNITS	
Btu	British Thermal Units (international conversion = 1055.056 joules)
Ft^3	Cubic feet (1 cubic feet = 28.32 liters)
1 Gallon	3.79 liters
1 Lb	453.6 gr
Short Ton	2,000 Lbs (907.2 Kg)
1 HL	Hectoliter- metric unit of measure (capacity) equal to 100 liters.
1 Du	Dunam- equals to 1,000 Sq. meters or 0.1 hectare
KPa	kilopascal (1 kPa = 1000 Pa).
ABBREVIATIONS	
AIES	Arava Institute for Environmental studies
BAU	Business As Usual
BHB	brake horsepower
BTL	Biomass To Liquid
CAP	Common Agricultural Policy
CBS	Central Bureau of Statistics
CCC	Commodity Credit Corporation
CDS	Condensed Distillers Solubles
CEN	European Committee for Standardization
CHP	Combined Heat and Power
CIF	Cost, Insurance and Freight
CNG	Compressed Natural Gas
CRP	Conservation Reserve Program
DDGS	Dried Distillers Grains with Solubles
EAC	Environmental Audit Committee
EC	European Commission
EPA	Environmental Protection Agency
ETBE	Ethyl Tert-Butyl Ether
EU	European Union

FFVs	Flexi-Fuel Vehicles
HHV	Higher Heating Values
IEA	International Energy Agency
IISD	International Institute for Sustainable Development
GHG	Greenhouse Gas
GM	Genetically Modified
Kg	Kilogram
KKL	Keren Kayemet Le`Yisrael (Jewish National Fund)
LCA	Life Cycle Assessment
LHV	Lower Heating Value
LPG	Liquid Petroleum Gas
MSW	Municipal Solid Waste
MT	Metric Ton
MTBE	Methyl Tertiary-Butyl Ether
NIS	New Israeli Shekel
OPEC	Organization of Petroleum Exporting Countries
PEI	Princeton Environmental Institute
P&L	Profit and Loss
PPM	Parts Per Million
R&D	Research and Development
RFG	Reformulated Gasoline
RFS	Renewable Fuel Standard
RTFO	Renewable Transport Fuel Obligation
RVP	Reid Vapor Pressure
U.S	United states
VAT	Value Added Tax
VEETC	Volumetric Ethanol Excise Tax Credit
WDG	Wet Distillers Grains
WTW	Well-to- Wheel

BIOFUELS GLOSSARY

A - C : D - F : J - L : M - O : P - R : S - U : Y - Z

A-C

Algae- Algae are primitive plants, usually aquatic, capable of synthesizing their own food by photosynthesis. Algae is currently being investigated as a possible feedstock for producing biodiesel

Biobutanol- Biobutanol is an advantaged biofuel that offers a number of benefits over conventional biofuels. For example, biobutanol has an energy content closer to that of petroleum so consumers face less of a compromise on fuel economy. It can easily be added to conventional petrol due to low vapor pressure and can be blended at higher concentrations than bioethanol for use in standard vehicle engines. DuPont and BP are working together on a major project to produce biobutanol

Biodiesel- Biodiesel is a biofuel produced from various feedstocks including vegetable oils (such as oilseed, rapeseed and soya bean), animal fats or algae. Biodiesel can be blended with diesel for use in diesel engine vehicles.

Biofuel- The term biofuel applies to any solid, liquid, or gaseous fuel produced from organic (once-living) matter. The word biofuel covers a wide range of products, some of which are commercially available today, and some of which are still in research and development.

Biomass- Biomass is biological material, including corn, switchgrass, and oilseed crops that can be converted into fuel

Bioreactor- A bioreactor is a vessel in which a chemical process occurs. This usually involves organisms or biochemically active substances derived from such organisms

BTL- BTL, or biomass-to-liquid, is a multi-step process that converts biomass into liquid biofuels. BTL is also referred to as second generation biodiesel production. There are many different methods of BTL, but many processes include Fischer**-**Tropsch, hydrogenation or pyrolysis.

By-product- A by-product is a substance, other than the principal product, generated as a consequence of creating a biofuel. For example, a by-product of biodiesel production is glycerin and a by-product of bioethanol production is DDGS

Catalyst- A catalyst is a substance that increases the rate of a chemical reaction, without being consumed or produced by the reaction. Enzymes are catalysts for many biochemical reactions.

Conventional biofuels- Conventional biofuels such as bioethanol and biodiesel are typically made from corn, sugarcane and beet, wheat or oilseed crops such as soy and rape.

D-F

DDGS- Dried distillers grain with solubles is a by-product of dry mill ethanol production that is fed to livestock.

Emissions- Emissions are classed as any waste substances released into the air or water.

Enzyme- An enzyme is a protein or protein-based molecule that speeds up chemical reactions occurring in living things. Enzymes act as catalysts for a single reaction, converting a specific set of reactants into specific products.

Feedstock- A feedstock is any biomass resource destined for conversion to energy or biofuel. For example, corn is a feedstock for ethanol production, soybean oil may be a feedstock for biodiesel and cellulosic biomass has the potential to be a significant feedstock source for biofuels.

Fuel- A fuel is described as any material with one type of energy that can be converted to another usable energy.

J-L

Jatropha- Jatropha is a non-edible evergreen shrub found in Asia, Africa and the West Indies. Its seeds contain a high proportion of oil that can be used for making biodiesel.

M-O

Methanol- Methanol is an alcohol containing one carbon atom per molecule, generally made from natural gas, with about half the energy density of petroleum. Methanol is used as a component in the transesterification of triglycerides to give a form of biodiesel.

MTBE- MTBE, or methyl tertiary-butyl ether, is created from methanol and can increase octane and decrease the volatility of petroleum. It is often used as a petroleum additive because it raises the oxygen content of the fuel.

Octane number- The octane rating of a fuel is indicated on the pump. The higher the number, the slower the fuel burns. Bioethanol typically adds two to three octane numbers when blended with ordinary petroleum – making it a cost-effective octane-enhancer.

P-R

Palm oil- Palm oil is a form of vegetable oil obtained from the fruit of the oil palm tree. It is a widely used feedstock. The palm oil and palm kernel oil are composed of fatty acids, esterified with glycerol just like any ordinary fat. Palm oil is a widely used feedstock for traditional biodiesel production.

Petroleum- Petroleum refers to any petroleum-based substance comprising of a complex blend of hydrocarbons derived from crude oil through the process of separation, conversion, upgrading, and finishing, including motor fuel, jet oil, lubricants, petroleum solvents, and used oil.

Rapeseed- Rapeseed (Brassica napus), also known as rape, oilseed rape or (one particular artificial variety) canola, is a bright yellow flowering member of the family Brassicaceae (mustard or cabbage family). Rapeseed is a tradition feedstock used for biodiesel production.

RTFO- RTFO, or the Renewable Transport Fuels Obligation, is a UK policy that places an obligation on fuel suppliers to ensure that a certain percentage of their aggregate sales is made up of biofuels. The effect of this will be to require 5% of all UK fuel sold on UK forecourts to come from a renewable source by 2010.

S-U

Second generation biofuels- Although definitions vary, second generation biofuels are usually considered to be biofuels produced from biomass or non-edible feedstocks.

Switchgrass- Switchgrass is native to the US and known for its hardiness and rapid growth. It is often cited as a potentially abundant second generation feedstock for ethanol

Y-Z

Yeast- Yeast is any of various single-cell fungi capable of fermenting carbohydrates. Bioethanol is produced by fermenting sugars with yeast.

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