ISSUE PAPER
ON
BIOFUELS IN LATIN AMERICA
AND THE CARIBBEAN

Prepared For:

INTER-AMERICAN DEVELOPMENT BANK
Environment Division
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EXECUTIVE SUMMARY

The Inter-American Development Bank (IDB or Bank) is a long-standing initiative of the Latin American countries; it was established in 1959 as a development institution with novel mandates and tools. Its lending and technical cooperation programs for economic and social development projects went far beyond the mere financing of economic projects that was customary at the time. The IDB is owned by its 47 member countries.

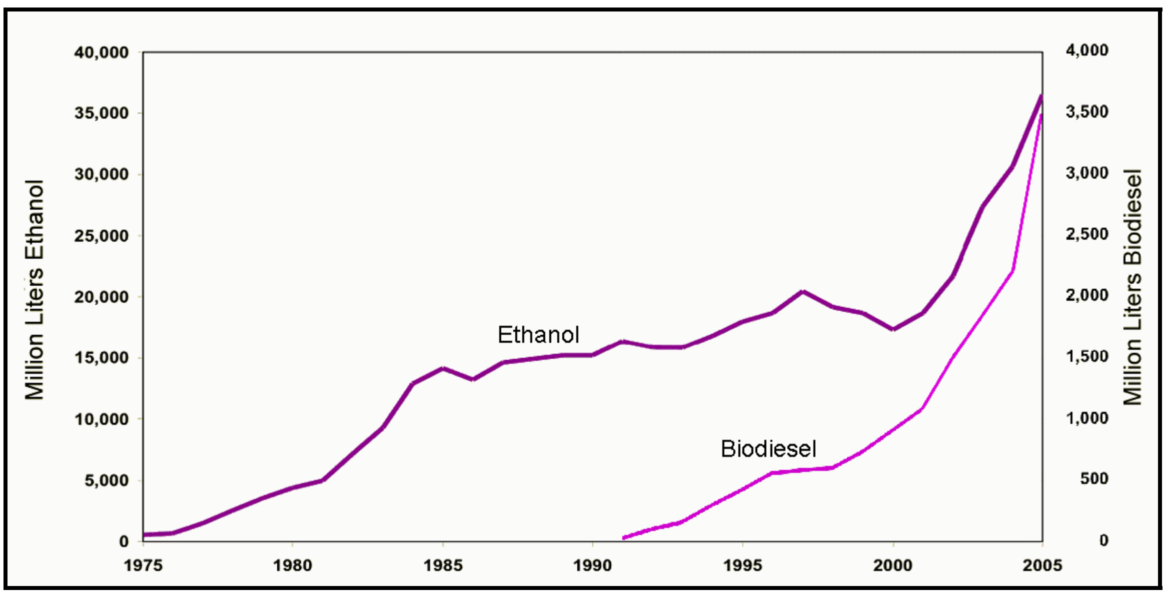
The Bank's two main goals are to promote poverty reduction and social equity as well as environmentally sustainable growth. One of the key tactics that the Bank uses to reach its objectives is through the development, assessment, and dissemination of knowledge and good practices information on important subjects. The objective of this Biofuels Issue Paper is to support this tactic and:

- To present the basic concepts and principles underlying biofuel production, distribution and use;
- To present the key technical, economic, infrastructure, social and environmental dimensions of biofuels, which determine the degree of success of any biofuel program;
- To identify and address the key policy and regulatory aspects that affect biofuel development and use; and
- To present key areas of development in support of biofuels in the region.

Biofuels can be broadly defined as any combustible material produced from biomass. This could include solid fuels such as wood and charcoal, liquid fuels such as ethanol and biodiesel, and gaseous fuels such as methane. The focus of this paper is on biofuels for transportation applications. There are two primary biofuels used for transportation applications in the world today. The largest biofuel is ethanol, manufactured from sugar or starch feedstocks. The other primary biofuel is biodiesel, usually a methyl ester made by transesterification of vegetable oils or animal fats.

The growth in world ethanol and biodiesel production is shown in the following figure (Worldwatch, 2006). Note that the scale for the biodiesel line is one-tenth that of the ethanol line.

Figure ES- 1 Biofuel Production Growth



Ethanol has been used as a motor fuel in North America since the early 1900's. In 1908, Henry Ford designed his Model T to run on ethanol. Ethanol gasoline blends were used in Brazil as early as 1925. Ethanol gasoline blends were also used in parts of the United States prior to the Second World War but through the 1950's and 1960's there was no ethanol used in gasoline in North America. In 1974, in response to the 1973 oil crises, the Brazilian Government launched its PROALCOOL program that began the widespread production and use of fuel alcohol in modern times and in 1979, the US Congress established the federal ethanol program to stimulate the rural economy and reduce the dependence on imported oil. The production and use of ethanol as a motor fuel in Brazil, the United States and in other parts of the world has increased continuously since that time.

Fuel ethanol has a high octane value, contains oxygen (which reduces exhaust emissions but also increases volumetric fuel consumption), and when made from biomass using modern production practices results in lower lifecycle greenhouse gas emissions than gasoline produced from crude oil. Ethanol also tends to increase the vapour pressure of gasoline which if not addressed could lead to driveability problems and with vehicles built before 1980 there are some materials compatibility issues with fuel system components that must be considered.

There are four ways that ethanol can be used in the transportation system, although two applications, low and high level blends in gasoline engines dominate the use. The other two applications, ethanol with an ignition improver for use in diesel engines, and ethanol blended with diesel fuel and a blending agent are being used in niche applications in some regions.

World ethanol production is about equally divided between sugar based feedstocks and starch based raw materials. The choice of raw material is dependent to a large degree on the local climate and agronomic conditions. In Latin American and the Caribbean sugar cane is the dominant feedstock that would be used for ethanol production.

Ethanol production from starch rather than from sugar requires an additional process step to convert the starch to fermentable sugar. Today this is generally accomplished by cooking the grain in the presence of an enzyme. In Latin America the dominant starch crops are corn, cassava, wheat, rice, potatoes, and sorghum. There are smaller amounts of barley, rye and other cereals also produced. The starch crops that are exported are primarily corn and wheat and these could be considered as potential ethanol feedstocks in some countries.

Biodiesel is an ester produced by chemically reacting vegetable or animal fat with an alcohol, usually methanol. As the name implies it has properties similar to diesel fuel except it is made from renewable resources. Biodiesel is fully soluble in petroleum diesel fuel at most operating temperatures. It can be used in low level blends such as B2 and B5 and even as a pure fuel as B100. Biodiesel contains some oxygen in the fuel and thus has about a 4.5% lower energy content than petroleum diesel on a volumetric basis. The volumetric fuel usage is correspondingly higher for biodiesel than for petroleum diesel fuel. Biodiesel contains no sulphur and has excellent lubricity properties.

Biodiesel is readily biogradable and non-toxic in the environment. The engine exhaust emissions of particulate matter, carbon monoxide and hydrocarbons are reduced when biodiesel is used. In some situations NOx emissions can increase when biodiesel is combusted. The emissions benefits are generally directly proportional to the amount of biodiesel in the fuel, that is a B10 blend provides twice the emissions benefit as a B5 blend. The lifecycle greenhouse gas emissions are much lower for biodiesel compared to fossil diesel fuel. The low temperature characteristics of biodiesel are generally not as good as most fossil fuels and care must be exercised when using biodiesel in colder climates.

Animal tallow and vegetable oils are suitable feedstocks for biodiesel production. In Latin America and the Caribbean there are three primary vegetable oils of interest, soyoil, palm oil and sunflower oil. There are small amounts of other oils produced such as rapeseed, olive oil, and castor oil but the volumes are currently too small to be of commercial interest. Most vegetable oils are traded on world markets and there is a strong price correlation between most individual products. The choice of which oil to use for biodiesel production is therefore more a function of the suitability to the local agricultural environment than using the lowest cost feedstock.

The policy drivers for biofuels fall into three categories, climate change and clean air, energy security, and the need for diversification in agricultural and expanded rural economic opportunities. These three themes are common throughout both the developed and developing world.

Rising concentrations of greenhouse gases (GHG) in the earth's atmosphere are leading to potentially irreversible climate change. A shift in temperature zones caused by climate change could seriously affect biodiversity. At the global level, climate change is expected to have a negative impact on agricultural production and worsen food security.

Air quality is also poor in many urban areas of the world. In developed countries, governments have been moving for many years to tighten fuel quality and vehicle emission control standards to address this issue. In the developing world fuel quality and vehicle emission standards are only beginning to be changed and air quality can be improved significantly through the use of biofuels to reduce particulate emissions and contaminates such as carbon monoxide and volatile organic compounds.

In the transport sector, 98% of the energy used comes from fossil oil. Known oil reserves are limited in quantity and restricted to a few world regions. New reserves exist, but will mostly be more difficult to exploit. Securing energy supplies for the future is therefore not only a question of reducing import dependency, but calls for a wide range of policy initiatives, including diversification of sources and technologies. Over the last several years, consumers have had to face price increases for transport fuels and other energy sources. The price of a barrel of oil exceeded the $75 US mark in 2006. This increasing cost of energy had a strong negative impact on purchasing power.

New market opportunities are always of particular interest to the agricultural sector as prices for agricultural commodities are often below breakeven levels due to a combination of oversupply and market distortion created by government support programs. Rural regions generally suffer from having lower incomes, higher unemployment rates and a relatively higher dependency on the primary sector than urban regions.

The challenges to be addressed in rural areas can be summarized as follows:

- *Economic:* rural areas have incomes significantly below the average, an ageing working population, and a relatively greater dependency on the primary sector.
- *Social:* there is clear evidence of a higher than average rate of unemployment in rural areas. Low population density and depopulation in some areas may also increase the risk of problems like poor access to services, social exclusion and a narrower range of employment options.
- *Environmental:* the need to ensure that agriculture and forestry continue to make a positive contribution to the countryside and the wider environment.

The market potential for biofuels in each country will be a function of the energy supply situation and the feedstock availability. Those countries which are currently exporting potential biofuel feedstocks will be the best placed to move into biofuels production. Other countries may consider expanding the feedstock supply if a biofuels market were to develop but that will take some time to accomplish.

The following table summarizes the oil and petroleum products production situation for each of the countries as well as the biofuel feedstock supply situation. Those countries, which either import gasoline and have an ethanol feedstock surplus or import biodiesel and have biodiesel feedstock exports, are identified in bold. They are prime candidates for the development of a domestic biofuels industry. Note that there are other countries that have the potential to produce biofuels but the market for the fuels would either be the export market for the biofuel or for the petroleum fuel displaced by the biofuel.

Table ES- 1 Biofuel Market Potential Summary

	Crude Oil Producer	Net Crude Oil Importers	Refiner	Net Gasoline Importer	Ethanol Feedstock Exporter	Net Diesel Importer	Biodiesel Feedstock Exporter
Argentina	Yes	No	Yes	No	Yes	No	Yes
Bahamas	No	No	No	Yes	No	Yes	No
Barbados	Yes	No	No	**Yes**	**Yes**	Yes	No
Belize	No	No	No	**Yes**	**Yes**	Yes	No
Bolivia	Yes	No	Yes	No	Yes	**Yes**	**Yes**
Brazil	Yes	Yes	Yes	No	Yes	**Yes**	**Yes**
Chile	Yes	Yes	Yes	No	No	Yes	No
Colombia	Yes	No	Yes	No	Yes	No	Yes
Costa Rica	No	Yes	Yes	**Yes**	**Yes**	**Yes**	**Yes**
Dominican Republic	Yes	Yes	Yes	**Yes**	**Yes**	Yes	No
Ecuador	Yes	No	Yes	**Yes**	**Yes**	Yes	Yes
El Salvador	No	Yes	Yes	**Yes**	**Yes**	Yes	No
Guatemala	Yes	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Guyana	No	No	No	**Yes**	**Yes**	Yes	No
Haiti	No	No	No	Yes	No	Yes	No
Honduras	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Jamaica	No	Yes	Yes	**Yes**	**Yes**	Yes	No
Mexico	Yes	No	Yes	**Yes**	**Yes**	Yes	No
Nicaragua	No	Yes	Yes	**Yes**	**Yes**	Yes	No
Panama	No	No	No	**Yes**	**Yes**	Yes	No
Paraguay	No	Yes	Yes	**Yes**	**Yes**	Yes	No
Peru	Yes	Yes	Yes	No	No	**Yes**	**Yes**
Suriname	Yes	No	Yes	Yes	No	Yes	No
Trinidad and Tobago	Yes	Yes	Yes	No	No	No	No
Uruguay	Yes	Yes	Yes	No	Yes	**Yes**	**Yes**
Venezuela	Yes	No	Yes	No	No	No	No

Any discussion of biofuel economics needs to consider not only the costs but also the market values for the various inputs. For those commodities that are traded internationally the market values are more important in determining the costs of biofuels and for those that are more local in nature then the costs are of more interest. Most feedstocks are traded internationally but there are a few that are not such as cassava. Note that from an agricultural perspective the costs of producing feedstock in comparison to the market values are important but that is the case whether biofuels are produced or not.

In the past several months in Brazil the wholesale price of ethanol has gone from being substantially less than the price of gasoline to being equal to the price of gasoline. Not all Latin American sugar producers have the same low cost structures as Brazil. Some have traditionally received some government support and in some countries they have access to the regulated sugar markets in the United States and Europe. The opportunity cost of ethanol production in these countries will be quite a bit higher than in Brazil.

With the volatility in world oil prices and sugar prices along with the country to country variance in sugar production costs, there is still some need for government support for ethanol producers in order to make a viable business case for biofuel production in most countries.

The production costs for biodiesel are higher than they are for ethanol. Diesel fuel from crude oil has a similar value to gasoline so the relative economics of biodiesel are not as attractive as they are for ethanol. On the other hand, Latin America is a larger net importer of diesel fuel than it is of gasoline so there may be less resistance to biodiesel implementation that ethanol use.

In most countries biofuel producers have been price takers. Biofuel production is such a small part of the overall energy supply situation that it does not really impact the price of fossil energy and biofuel producers must accept what the market will give them for their production, hence the term price takers. Brazil is a different situation; here the price of ethanol has more closely tracks the movements in the price of sugar. Sugar and ethanol mills look for the best netback when they decide how much sugar and ethanol to produce and many of them are very flexible in determining their production schedules. The demand for the product is relatively inelastic because of the mandated use of ethanol. When oil prices are high much of the benefit of the high price accrues to the ethanol blender and marketer and not to the ethanol producer. This is a very different situation than in most other countries with biofuel programs.

Given that one of the driving forces for biofuel production has been the desire to provide local rural economic development opportunities and that traditionally biofuels have required some level of government support to be economically attractive the focus of biofuels development in most countries has been on domestic production and consumption, it is only in the very recent past that more thought has been given to the international trade opportunities with bioenergy. Most countries, including Brazil apply import tariffs to ethanol and biodiesel.

The infrastructure requirements to establish a biofuels industry will vary from country to country depending on the biofuel produced, feedstocks consumed, the markets to be accessed, the existing transportation fuels infrastructure and local conditions.

Rural regions suffer from lower incomes, higher unemployment and a relatively high dependency on the primary sector for job creation. Biofuel production is seen as an opportunity to address some of these issues. The primary cost of biofuel production is the feedstock cost for both ethanol and biodiesel. This means that while some jobs are created in the biofuel manufacturing facilities most of the jobs are indirect ones and most are related to feedstock manufacturing.

There has been some concern expressed by some that increased biofuels production will increase the competition for land that is used for food purposes. This argument has some basis of concern when land availability has reached the limit. The limit is not easy to define. It appears that in some countries most of the arable is in production and thus near the limit but in other countries only a small portion of the arable land is in production.

The increased production of agricultural products so that some can be used for biofuel production can basically be accomplished three ways, the yields of current crops can be increased through better cultivation practices, there can be some crop substitution to higher yielding species, or new land can be brought into cultivation. In many areas of the world all three approaches are being used and there are advantages and disadvantages of each approach. It is not possible to generalize about the environmental benefits and land use issues surrounding biofuels since the impacts depend more on how the biofuels are produced rather than if biofuels are produced.

Biofuel industries have been developed in many countries around the world including the United States, Brazil, Germany and many more countries and regions are considering measures that need to be adopted to facilitate the growth of the biofuels industry. Policy and regulatory tools used to promote biofuels must be designed to address the barriers that the biofuels face in the marketplace. Too often governments implement programs that, while well intentioned, nevertheless, fail because they do not address the specific barriers that biofuels face. While these barriers can theoretically differ from country to country, in the case of biofuels the barriers are remarkably similar for both ethanol and biodiesel and in developed and developing countries.

The two most significant barriers facing biofuels have been the price of biofuels compared to petroleum fuels and the difficulty marketing the product through the established fuel distribution companies. In addition, new enterprises almost always face finance and business risk barriers during the start-up phase of the industry. In many countries ethanol and biodiesel projects have struggled with issues such as project financing, uncertainty with being able to design and construction facilities with new technology and dealing with the risk of commodity prices. In some countries these issues are mostly behind the industry as plants have been built and experience has been gained with dealing these issues. In other countries that are just beginning to develop their biofuels industries these are still issues that companies must face.

Ethanol and biodiesel have also faced less significant barriers in terms of price distortion and inefficient regulation. The industry has learned either how to deal with the issues or the removal of some of the other barriers, such as the competitive price issue, has also addressed or reduced the price distortion barrier.

Thus there are six barriers, uncompetitive price, inefficient market organization, finance risk, business risk, price distortion and inefficient regulation that biofuels face in most regions of the world when they are first introduced. The first four are the primary barriers and the second two, price distortion and inefficient regulation can slow down market penetration but are not usually show stoppers.

There are a large number of measures that can be implemented to address the market barriers that biofuels face. Each of the measures can have advantages and disadvantages but governments must be aware that unless all of the barriers are addressed biofuels adoption will be hindered.

Interest in biofuel development is likely to increase as long as energy prices remain high, environmental issues persist and unemployment remains a problem in rural areas around the world. The biofuel success stories of ethanol in Brazil and the United States and biodiesel in Germany will serve as examples to be replicated in developed and developing countries around the world. In all countries there is a tendency to overlook the time and effort that was required for these success stories to develop. It is also possible to find examples where biofuels have had a difficult time developing and reaching their potential. Often the measures introduced by governments address only some of the barriers and stakeholders become frustrated at the lack of or slow pace of development.

There is no shortage of opportunities for the Bank to pursue in the field of biofuels. The bank needs to develop its strategy in this area so that it can successfully participate in the field. The biofuels strategy needs to be compatible with the Bank’s goals to promote poverty reduction and social equity and foster environmentally sustainable growth in the region. The strategy should address the main issues that the biofuels sector faces:

- Stimulating demand for biofuels. Can the Bank play a role in fostering good policy development in the region?
- Capturing the environmental benefits. Should the Bank become an advocate for ensuring that the environmental benefits of biofuels are optimized as the industry expand in Latin America?
- Develop production and distribution of biofuels. Can the Bank develop programs that will be beneficial to biofuel proponents building an industry in Latin America? Should the Bank be a lender to all potential participants or should it focus its efforts on projects that will deliver the maximum benefits to the rural economy and the environment?
- Expand the feedstock supply. While diverting exports to new domestic markets is the easiest means of establishing a new biofuels industry the real benefits in terms of rural economic development will result from increased rural economic activity resulting from the expansion of the feedstock supply. Can the Bank play a unique role in facilitating this expansion?
- Enhance trade opportunities. Most of the biofuels produced around the world are used in local domestic markets. Some of the poorest countries are likely to have a large imbalance between their production capacity and their domestic demand. These countries would benefit from a more open international market for biofuels. Is there are strategy that the Bank can follow that would enhance these opportunities?

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1. INTRODUCTION

The Inter-American Development Bank (IDB or Bank) is a long-standing initiative of the Latin American countries; it was established in 1959 as a development institution with novel mandates and tools. Its lending and technical cooperation programs for economic and social development projects went far beyond the mere financing of economic projects that was customary at the time. The IDB is owned by its 47 member countries.

Figure 1-1 Borrowing Member Countries

There are 26 countries that are borrowing members of the bank, all of them in Latin America and the Caribbean. The countries are; Argentina, Brazil, Bahamas, Barbados, Belize, Bolivia, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay and Venezuela.

In its Charter, the founders of the Inter-American Development Bank defined its mission to be to "contribute to the acceleration of the process of economic and social development of the regional developing member countries, individually and collectively."

The Bank's two main goals are to promote poverty reduction and social equity as well as environmentally sustainable growth. To attain these goals, the Bank focuses its work on four priority areas:

- Modernizing the state by strengthening the efficiency and transparency of public institutions.
- Investing in social programs that expand opportunities for the poor.
- Promoting regional economic integration by forging links among countries to develop larger markets for their goods and services.
- The Inter-American Development Bank helps foster sustainable economic and social development in Latin America and the Caribbean through its lending operations, leadership in regional initiatives, research and knowledge dissemination activities, institutes and programs.

The Bank's Environment Strategy is a guiding instrument whose fundamental objective is to attain greater effectiveness in the support that the Bank offers each of the borrower countries of Latin

America and the Caribbean to achieve their sustainable development goals. The Strategy is horizontal and sets forth a new paradigm for Bank action in environmental matters by establishing cross cutting links to all sectors through its focus on governance and the policy and incentive frameworks that affect natural resources and environmental management.

The Sustainable Development Department of the Bank provides technical advisory support to Bank project teams and conducts quality reviews of projects. It develops sector strategies, policies and guidelines to enhance the design of loans and the management of the Bank's portfolio. In addition, it generates and disseminates knowledge that can be incorporated into future Bank lending.

One growing area of interest for Bank support in renewable energy in the region is biofuels. The recent increase in international oil prices has driven many countries in the region to participate in international markets of biofuels, as well as intensify their efforts to adopt alternative sources of energy for fuel substitution in high-energy consuming sectors, including transport and industry. The large potential for biofuel production in the region stems from the abundant stock of biomass, sugar cane and other feedstocks, and from the adequate socio-economic conditions that make production and distribution more cost-effective. The successful bio-ethanol program implemented by Brazil during the past decades is now providing comparative advantages vis-à-vis other regions in the development of ethanol programs and their successful implementation. Global and more localized concerns about the impact of fossil fuels on the environment are also paving the ground for the development of renewable sources of energy, and their wider insertion in the energy markets.

Biofuels programs involve a wide range of complex technological, socio-economic and environmental issues that need to be considered in order to produce successful interventions. The Bank, with the implementation its IDB/German SPA program and other clean energy initiatives sponsored by other donor countries (Canada, Spain, UK, Netherlands and Austria), is providing specific analytical guidance and strategic support to facilitate its involvement in biofuel development in the region.

1.1 Objectives of the Issue Paper

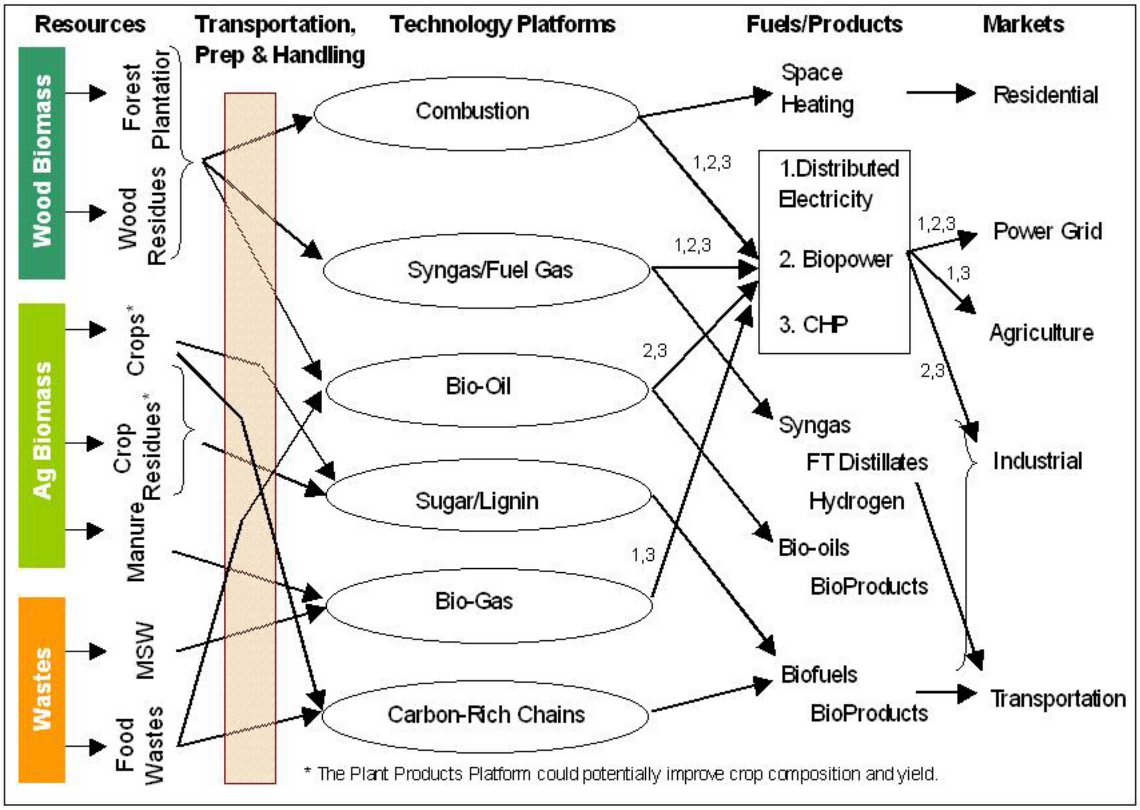
One of the key tactics that the Bank uses to reach its objectives is through the development, assessment, and dissemination of knowledge and good practices information on important subjects. The objective of this Issue Paper is therefore to support this tactic and:

- To present the basic concepts and principles underlying biofuel production, distribution and use;
- To present the key technical, economic, infrastructure, social and environmental dimensions of biofuels, which determine the degree of success of any biofuel program;
- To identify and address the key policy and regulatory aspects that affect biofuel development and use; and
- To present key areas of development in support of biofuels in the region.

2. BIOFUEL BASICS

Biofuels can be broadly defined as any combustible material produced from biomass. This could include solid fuels such as wood and charcoal, liquid fuels such as ethanol and biodiesel, and gaseous fuels such as methane. All of the pathways that could produce bioenergy or biofuels are shown in the following figure.

Figure 2-1 Biofuel Pathways

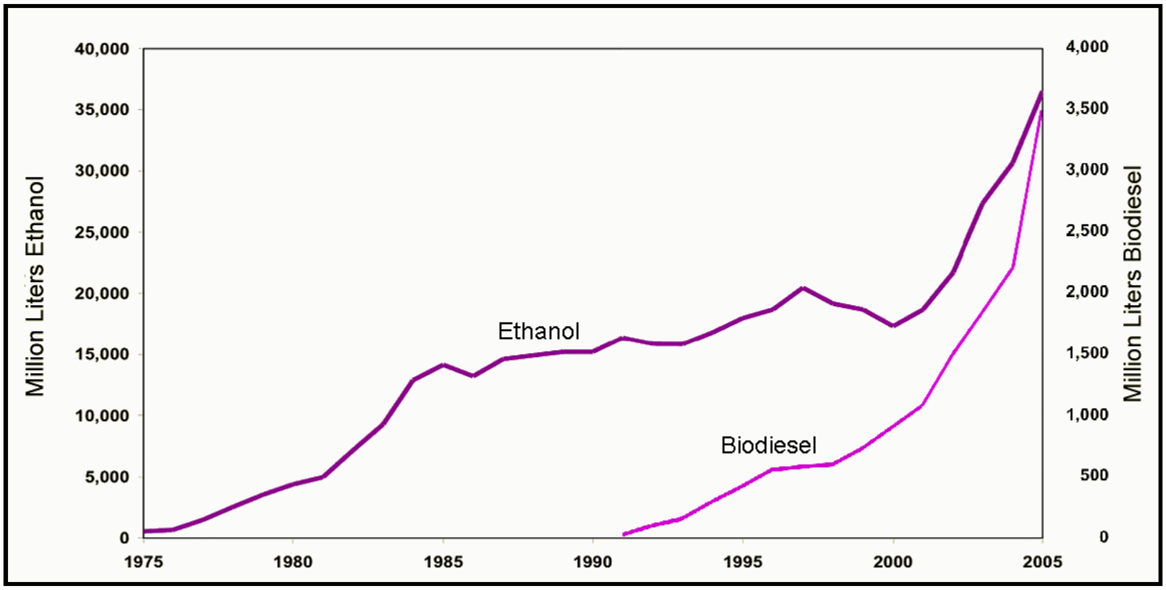


Some of the fuels shown in the figure are suitable for transportation applications and other fuels, including some liquids such as pyrolysis oils, are not. Several hundred years ago biofuels dominated the world's energy supply but they were gradually replaced first by coal, then by oil and natural gas as these other fuels became available and offered more convenience and lower costs to the users. Nevertheless, some biofuels are still used for heating and cooking in various parts of the world including small shares in some industrialized countries.

The focus of this paper is on biofuels for transportation applications. There are two primary biofuels used for transportation applications in the world today. The largest biofuel is ethanol, manufactured from sugar or starch feedstocks. The other primary biofuel is biodiesel, usually a methyl ester made by transesterification of vegetable oils and animal fats.

Ethanol can also be manufactured from hydrocarbons and while this product has the same combustion characteristics as bio ethanol it is used primarily as a chemical solvent. Most governments differentiate between bio ethanol and petroleum-derived ethanol in their support programs. There is also a large chemical market for methyl esters but this is also served by the same biomass based product as is being used for fuel. The growth in world ethanol and biodiesel production is shown in the following figure (Worldwatch, 2006). Note that the scale for the biodiesel line is one-tenth that of the ethanol line.

Figure 2-2 Biofuel Production Growth



There are other potential biofuels that could be used for transportation applications. These are sometimes labelled as 2nd generation biofuels. There is no clear definition for these new products. They are usually manufactured from cellulosic feedstocks and they could be ethanol or a diesel like hydrocarbon product. There is no commercial production of these 2nd generation biofuels today. The production processes are generally more complicated than the existing commercial fuels and the production processes are more capital intensive than the existing production processes.

2.1 Ethanol

Ethanol or ethyl alcohol, is a primary alcohol containing two carbon atoms, which may be produced in a petrochemical process from ethylene or biochemically by fermentation of various sugars and starches found in agricultural crops.

Ethanol has been used as a motor fuel in North America since the early 1900's. In 1908, Henry Ford designed his Model T to run on ethanol. Ethanol gasoline blends were used in Brazil as early as 1925. Ethanol gasoline blends were also used in parts of the United States prior to the Second World War but through the 1950's and 1960's there was no ethanol used in gasoline in North America. In 1974, in response to the 1973 oil crises, the Brazilian Government launched its PROALCOOL program that began the widespread production and use of fuel alcohol in modern times and in 1979, the US Congress established the federal ethanol program to stimulate the rural economy and reduce the dependence on imported oil. The production and use of ethanol as a motor fuel in Brazil, the United States and in other parts of the world has increased continuously since that time.

The 2005 world production of fuel ethanol in was 32.4 billion litres (BP Statistical Review) and the regional production is shown in the following table. Data in the BP Statistical Review is based on government or trade association sources. Public data is very limited in most countries, and small amounts of production in some countries are missed. Note that the table and the figure above are from different sources and do have some differences in the total volume.

Table 2-1 2005 World Fuel Ethanol Production

Country	Production, million litres
Brazil	15,126
USA	14,760
China	1,286
Spain	302
Canada	260
Sweden	164
Germany	152
France	126
Poland	86
Finland	46
Australia	22
Hungary	14
Lithuania	8
Netherlands	8
Czech Republic	2
Latvia	2
Total	32,364

Some of the notable characteristics of fuel ethanol are:

- *Octane:* Although the octane (RON) of pure ethanol is only 112, ethanol exhibits a much higher blending octane value – in the range of 130-132 RON (~115 (R+M)/2).
- *Vapour Pressure:* The Reid Vapour Pressure (RVP) of pure ethanol is not particularly high – about 2.4 psi, the blending RVP is much higher – about 18 to 22 RVP, depending on the ethanol concentration. The addition of 10% ethanol to gasoline usually increases the RVP by roughly 1.0 to 1.3 psi.
- *High Oxygen Content:* Ethanol contains some 35 weight % of oxygen, which enables the complete combustion of compounds such as carbon monoxide and volatile organics (VOCs), resulting in lower emissions of these compounds.
- *Fuel Economy:* Although ethanol has 35% lower energy content per litre than gasoline, the more complete combustion of abovementioned compounds combined with other combustion effects results in a much lower reduction in fuel efficiency than anticipated by the differential in energy content; this lower reduction in fuel efficiency has been observed to be more pronounced in older vehicles.
- *Material Compatibility*: Some materials used in fuel systems, such as elastomers used to make hoses and valves, tend to degrade over time. Some older elastomers were found to deteriorate more rapidly in the presence of aromatics (found in higher concentrations in unleaded gasolines) and alcohols. However, since the early-1980s, all vehicles have used materials that are specifically designed to handle all modern gasolines, including ethanol/gasoline blends.
- *Exhaust Emissions:* Ethanol/gasoline blends reduce CO, VOC, and particulate emissions; although Nitrogen Oxide (NOx) emissions may increase depending on the vehicle and the driving conditions. Ethanol reduces particulate emissions, especially fine particulates that pose a health threat to individuals suffering from respiratory ailments
- *Greenhouse Gas Emissions (GHG):* Considering the full crop production and fuel consumption cycle there is a net reduction in carbon dioxide in the ecosystem.

2.1.1 Production Processes

The fundamental biochemical production process is the fermentation of biomass-sourced sugars via yeast. In the case of sugar cane juice and byproduct molasses the sugar is naturally occurring and fermented directly. In the case of starchy crops, such as grains and corn, the starch must be enzymatically converted to sugar followed by the yeast-induced fermentation process. The fermentation process produces a liquid of low ethanol concentration ("beer"), which must then be concentrated through distillation. Conventional distillation will produce a maximum 95% ethanol. Since water prevents the ethanol from being miscible with the gasoline, the hydrous 95% alcohol cannot be used in low level ethanol blends for conventional unmodified spark ignition engine systems. The azeotropic limit is overcome and anhydrous 99% ethanol is produced, either through extractive distillation (using benzene or cyclo-hexane) or the use of molecular sieves.

2.1.2 Applications

There are four ways that ethanol can be used in the transportation system, although two applications, low and high level blends in gasoline engines dominate the use. The other two applications, ethanol with an ignition improver for use in diesel engines, and ethanol blended with diesel fuel and a blending agent are being used in niche applications in some regions.

2.1.2.1 Low Level Blends

The most common use of fuel ethanol has been in blends containing up to 10% ethanol and 90% gasoline. This fuel can be used in standard automobile engines interchangeably with ordinary gasoline. Low level blends are being used in Europe (currently with 5% ethanol but looking at using 10% in the future), the United States, Canada, Australia, Columbia and other countries.

In some counties the ethanol is mixed with commercial gasoline, but in other countries the gasoline is a special blendstock that is designed to accommodate the changes that mixing with ethanol imposes. This special blend stock might have a lower octane to take advantage of ethanol octane boosting properties and a lower vapour pressure the offset the increase in vapour pressure that ethanol causes.

A 10% ethanol blend will contain 3.5% less energy than gasoline. Modern vehicles exhibit about 2 to 2.5% fuel economy penalty when using 10% ethanol, stated another way they exhibit 1 to 1.5% better thermal efficiency on E10 than on gasoline. Older vehicles showed even better response to the use of ethanol. These older vehicles are often carburetted rather than fuel injected and poorly tuned. It was not uncommon to find that these vehicles obtain the same fuel economy with gasoline and E10.

Low level ethanol blends in Brazil can vary from 20 to 26% ethanol with the reminder gasoline. The government uses the required percentage to manage supply and demand. During the past ten years the ethanol content has stayed in this 20 to 26% range but prior to that there were times when the ethanol content dropped to as low as 13% when ethanol was in short supply. The automobiles in Brazil have been designed to operate on this high level and since gasoline with no ethanol is not available, the vehicle does not have to tolerate a wide range in ethanol content. This situation is acceptable in Brazil because large portions of the vehicles that are sold in the country are produced there. In may not be possible to duplicate this situation in other countries of interest that rely on automobile imports.

2.1.2.2 High Level Blends

Vehicles can also operate on high level blends containing 85% ethanol and the remainder gasoline. In this case the engine must be specifically tuned to accept the fuel as the air to fuel ratio is considerably different from that required for gasoline. Introducing a new fuel that requires a new engine is a difficult task since the question always becomes which one do you introduce first, the fuel or the vehicle? To overcome this issue automakers have introduced flexible fuel vehicles. These vehicles sense the fuel in the tank and automatically adapt the engine settings to accommodate the new fuel. In North America and Europe, these vehicles can operate on gasoline or E85 or any combination in between. In Brazil, the latest technology flexible fuel cars, initiated in 2003, are capable of using a complete range of ethanol/gasoline fuels containing from E20 to 100% hydrous ethanol.

The flexible fuel vehicles do offer some improvement in combustion efficiency but since E85 only contains about 73% of the energy of gasoline these vehicles do require about 20% more fuel to travel the same distance as a gasoline vehicle.

2.1.2.3 Diesel Engines

Ethanol has combustion characteristics (high octane) that make it ideally suited to spark ignited engines, however it has been used successfully in some compression ignition engines. The Swedish vehicle and engine manufacturer Scania, has been supplying ethanol buses to public transport companies in Sweden for 15 years. Around 600 ethanol buses have been delivered so far. Scania is now developing its third generation ethanol compression ignition engine, planned to be ready for introduction in late 2007. Scania has designed the engines to use pure ethanol with 5% ignition improver.

Scania is the world’s only manufacturer of ethanol-powered commercial vehicles and is supplying the city buses for use in the BEST (BioEthanol for Sustainable Transport) consortium’s field trials of ethanol as a vehicle fuel. The initial trials will take place in La Spezia, a coastal city in north-western Italy. The aim of the BEST consortium is to support large-scale use of ethanol as a vehicle fuel. Among other things, it encompasses the building of ethanol refuelling stations and the launch of trials involving both cars and city buses in ten locations throughout the world. In addition to La Spezia, Stockholm, Rotterdam, Dublin, Madrid, Basque Provinces (Spain), Nanyang (China) and São Paulo (Brazil) are taking part.

2.1.2.4 Ethanol Diesel Blends

Ethanol has been used in low level blends (5 to 15% vol ethanol) with diesel fuel. This fuel is often described as e-diesel. There are several issues with the fuel that must be overcome, the first if the low solubility of ethanol in diesel fuel, the second is the low cetane value of ethanol, and finally adding even small amounts of ethanol lowers the flash point of diesel fuel and requires the blend to treated more like a gasoline fuel from a fire safety perspective.

There are a number of companies that have developed additives (used at the 1% level) that improve the solubility of ethanol in diesel fuel. In addition to emulsifier effects, a number of other benefits are claimed for the emulsifiers. These include improved lubricity, detergency, and low temperature properties.

Because of the low cetane number of ethanol (on the order of 8 vs. 40 to 55 for diesel) the additive package (i.e. the emulsifier plus other additives) must also include a cetane-enhancing additive. Depending upon the cetane additive blending level, the e-diesel cetane number can be increased relative to that of the blending diesel. These cetane improvers help to address the second issue with e-diesel fuels.

The third issue of very low flash point cannot be addressed through additives and must be addressed through engine and vehicle modifications such as installing fame arrestors in the fuel system and through changes in the way that vehicles are refuelled and stored.

In spite of these challenges there have been a number of large-scale demonstration programs underway in the United States for a number of years. There has also been some work undertaken in Brazil and Mexico by one of the additive suppliers, O_2 Diesel. The Brazilian demonstration programs have involved sugar and ethanol mills and some municipal fleets. E-diesel fuels do reduce the emissions of particulate matter, VOC’s and NOx from diesel engines and due to the renewable nature of the ethanol the lifecycle GHG emissions are also reduced.

2.1.3 Feedstocks

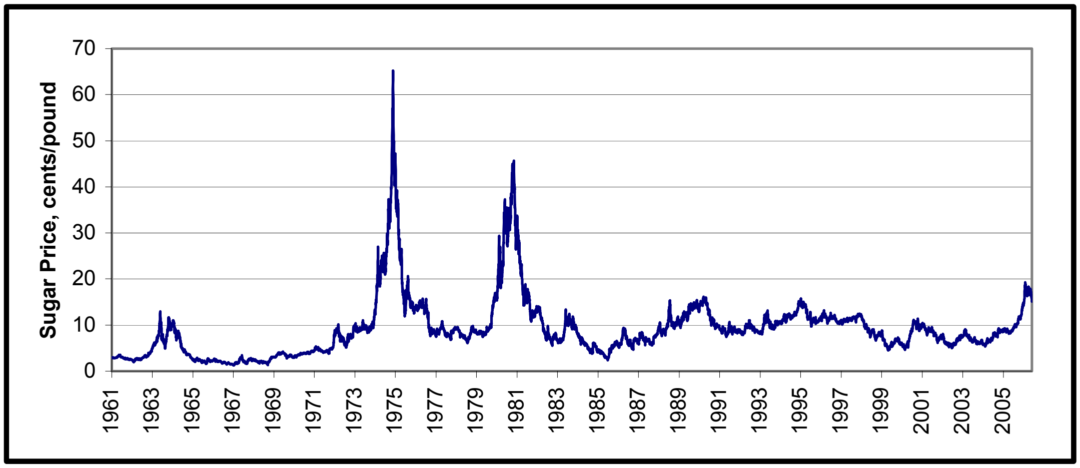
World ethanol production is about equally divided between sugar based feedstocks and starch based raw materials. The choice of raw material is dependent to a large degree on the local climate and agronomic conditions.

2.1.3.1 Sugar Crops

The two sugar based feedstocks for ethanol production are sugar cane and sugar beets. Ethanol can be produced from sugar juice or from molasses. When the sugar juice is crystallized to produce granular sugar in becomes progressively more difficult to crystallize the sugar as crystal sugar is produced and removed from the system. Ultimately only about two thirds of the sugar in the juice can be converted to crystal sugar and the remainder is molasses. Molasses still contains sugar and it is a suitable material for producing ethanol. Many sugar mills produce ethanol from the molasses and in countries without a fuel ethanol market the ethanol can be used for potable or industrial purposes. In countries with a fuel ethanol industry the mills have some flexibility to vary the amount of sugar and ethanol produced and will do so depending on the market conditions.

Sugar is an internationally traded commodity and prices are set on the world markets. The prices can be influenced not only by the supply and demand situation but also by various international agricultural policies. In the last few years demand has slightly exceeded the supply and this has put upward pressure on sugar prices. This change in the supply balance has been partially caused by increased demand for fuel ethanol and partially by changing government policies towards sugar production, particularly in the European Union. The world price of sugar is shown in the following figure (NYBOT). One litre of ethanol requires about 1.7 kg (3.7 pounds) of sugar as feedstock.

Figure 2-3 World Sugar Price



Sugar Cane

In Latin America sugar cane is the most important crop for ethanol production. Sugar cane is grown in 25 of the 26 countries that the Bank has an interest in (only Chile does not produce sugar cane). Eighteen of the countries are sugar exporters and information on the quantities of sugar exported is presented later in the report.

Sugarcane cultivation requires a tropical or subtropical climate, with a minimum of 600 mm (24 in) of annual moisture. In prime growing regions, sugarcane can produce up to 120 tonnes of cane per hectare per year. The ethanol yield from sugar cane is 86 litres of ethanol per tonne of cane.

Sugarcane is harvested by hand or mechanically. Hand harvesting accounts for more than half of the world's production, and is especially dominant in the developing world. A skilled harvester can cut 500 kg of sugarcane in an hour. In most countries the sugar cane harvest extends for 8 to 10 months of the year but there are a few countries (such as Peru and Guyana) where the harvest proceeds continuously. These countries often rely on irrigation to supply the water requirements. In the countries where weather prevents continuous harvesting the products, either sugar or ethanol must be inventoried to meet the demand when the factories are not operating.

The other significant difference between sugar cane ethanol plants and starch based ethanol plants in North America is that the sugar cane mills will burn the bagasse (the fibre portion of the cane after sugar extraction) to supply the thermal and electrical requirements of the plants. The lack of purchased fossil energy results in a significant reduction in GHG emissions.

Sugar Beets

Sugar beet is a hardy biennial vegetable that can be grown commercially in a wide variety of temperate climates. Up until the latter half of the 20th century, sugarbeet production was highly labour-intensive, as weed control was managed by densely planting the crop, which then had to be manually thinned with a hoe two or even three times during the growing season. Harvesting also required many workers. Today, harvesting is now entirely mechanical.

The only significant sugar beet producer in Latin America is Chile with about 2.4 million tonnes produced per year but all of that is consumed domestically. None of the Latin American countries are significant exporters of sugar beet.

2.1.3.2 Starch Crops

Ethanol production from starch rather than from sugar requires an additional process step to convert the starch to fermentable sugar. Today this is generally accomplished by cooking the grain in the presence of an enzyme. Technology is also being developed to accomplish this conversion without the cooking step and this new technology is being adopted by some of the US corn ethanol plants. The technology is also suitable for other starch feedstocks as well.

In Latin America the dominant starch crops are corn, cassava, wheat, rice, potatoes, and sorghum. There are smaller amounts of barley, rye and other cereals also produced. The starch crops that are exported are primarily corn and wheat. The crops are briefly discussed below.

Corn

Corn (maize) is the dominant feedstock used for ethanol production in the United States. It is a relatively efficient photosynthesis plant with crop yields from 7 to 11 tonnes/hectare with an average of about 9 tonnes/ha. This high yield is achieved with relatively high applications of fertilizer, sufficient water and heat units and the use of hybrid varieties. Crop yields in other regions of the world may not be as high as they are in the United States due to shortcomings in fertilizer application, moisture, and the use of different varieties of corn.

The United States produces about 40% of the world's production but other significant producers include France, China, Brazil, Mexico and Argentina. More corn is grown each year than all of the rest of the cereal grains combined.

Corn production is highly mechanized in the industrial countries with the combining in the field resulting in the stalk, leaves and cobs being returned to the soil at the time of harvest. There is significant world trade in corn and prices are determined by the global supply and demand situation and the impact of government support programs.

Cassava

Cassava is grown for its enlarged starch-filled roots, which contains nearly the maximum theoretical concentration of starch on a dry weight basis among food crops. Fresh roots contain about 30% starch and very little protein. It is a staple food in many parts for western and central Africa and is found throughout the humid tropics. The largest producer of cassava in the world is Brazil, followed by Thailand, Nigeria, Zaire and Indonesia. Production in Africa and Asia continues to increase, while that in Latin America has remained relatively level over the past 30 years.

The world market for cassava starch and meal is limited, due to the abundance of substitutes. Latin America is a minor player in the world trade. Most cassava is harvested by hand, lifting the lower part of stem and pulling the roots out of the ground, then removing them from the base of the plant by hand.

There is some industrial processing of cassava to produce starches and potable or industrial alcohol. Production of fuel ethanol is technically feasible but the limited shelf life of the roots will create the same issues as sugar beets and to a lesser degree sugar cane with respect to the need for product storage. China has announced a plan to produce fuel ethanol from cassava in up to five plants (Worldwatch, 2006b).

Wheat

Wheat is the most important food grain of the temperate zones - both north and south. World acreage in wheat is estimated at near 200 million hectares. Globally, wheat is the second largest cereal crop after corn.

Twelve Latin American countries produce wheat with Argentina, Brazil and Mexico being the largest producers. Argentina is the most important exporter of wheat in the region. Wheat is an important international commodity with significant trade flows. Prices are determined by supply and demand considerations and the impact of government programs and policies.

Rice

Rice is the world's third largest crop, behind corn (maize) and wheat. Rice cultivation is well suited to countries and regions with low labour costs and high rainfall, as it is very labour-intensive to cultivate and requires plenty of water for irrigation. World production of rice has risen steadily from about 200 million tons of paddy rice in 1960 to 600 million tons in 2004.

There is some rice production in 23 of the 26 countries of interest but only seven of those countries are involved in export trade. Uruguay is the largest rice exporter in the region. There is no significant amount of rice used for fuel ethanol in the world.

Potatoes

Potatoes are the world's most widely grown tuber crop, and the fourth largest crop in terms of fresh produce (after corn, wheat, and rice), but this ranking is inflated due to the high water content (75 to 80%) of fresh potatoes relative to that of other crops. The potato originated in South America, likely somewhere in present-day Peru, Bolivia and Chile.

Potatoes are now grown commercially in every continent, with 70% of the world's production grown in Eastern Europe and Russia. Potatoes grow best in cool climates with good rainfall or irrigation. Potatoes are grown in 22 of the 26 counties in the region but only four countries are net exporters of the crop. Potatoes are used mostly for human consumption directly. There are some potatoes used industrially for starch and potable alcohol production.

Sorghum

Sorghum is a species of grasses raised for grain, native to tropical and subtropical regions of Eastern Africa, with one species native to Mexico. It is drought tolerant and heat tolerant and is especially important in arid regions. It is an important food crop in Africa, Central America, and South Asia, and is the fifth most important cereal crop grown in the world.

The United States accounts for about 20% of the world’s production of 58 million tonnes, but Argentina, Brazil and Mexico are also significant sorghum producers. In the US, sorghum grain is used primarily as a corn substitute for livestock feed because their nutritional values are very similar. Sorghum is produced by 18 of the countries in the regions but only Brazil and Argentina are net exporters.

Barley

Barley is a major food and animal feed crop, in 2005, barley ranked fourth in quantity produced and in area of cultivation of cereal crops in the world. Barley was grown in about 100 countries worldwide in 2005. The world production was 138 million tonnes. Eight countries in the region produce barley but only Argentina and Uruguay are net exporters.

Other Cereals

Other cereal grains such as rye and triticale are also potential ethanol feedstocks. Small amounts of these cereals are grown in the region but the volumes are very small.

The yield information for all of the ethanol crops is summarized in the following table.

Table 2-2 Crop Summary – Ethanol

Crop	Yield	Ethanol Yield	
	Tonnes/ha	Litres/tonne	Litres/ha
Sugar Cane	60-120	86	5,000 – 10,000
Sugar Beet	40	90-120	3,600 – 4,800
Corn	7-11	400	2,800 – 4,400
Cassava	10-90	165	1,650 – 14,850
Wheat	2-3.5	370	740 –1,300
Rice	4 - 6	375	1,500 – 2,200
Potatoes	2 - 38	100	200-3,800
Sorghum	5 - 8	400	2,000-3,200
Barley	3- 4	330	1,300 –1,750

2.1.3.3 Lignocellulosic Feedstocks

Technology to produce ethanol from lignocellulosic feedstocks is not yet commercially available. The feedstocks for cellulose ethanol processes include agricultural crops and residues, hardwoods, softwoods, and other mixtures such as municipal solid wastes. There are advantages and disadvantages for each of these feedstocks from both a technical perspective and an economic perspective.

Agricultural residues, such as bagasse, corn stover and cereal straw, and energy crops such as switchgrass are considered attractive potential feedstocks for future cellulosic ethanol plants. The residues are available in large quantities from existing agricultural production and the energy crops have the potential for high yields (and therefore low costs) from production on set aside lands and marginal farmlands. The agricultural crops have the lowest lignin levels of the cellulosic feedstocks, which make them the easiest to process but they are relatively high in C5 sugars, which means that they require a different yeast than currently used in the fuel ethanol industry to convert these sugars to ethanol. The theoretical ethanol yield from these feedstocks is 400 to 450 litre/tonne depending on the feedstock.

Hardwood feedstocks are of some interest since these species are well suited to fast growing agro-forestry situations. The theoretical ethanol yield is about 450 litres/dry tonne of feedstock.

The most likely source of softwood feedstock is mill and forest residue although some softwood species, are grown in plantation conditions in some regions. The theoretical ethanol yield is 450 l/tonne but the low pentose sugar concentration should result in relatively high actual ethanol yields. The softwoods are the most difficult of the cellulosic feedstocks to separate into the lignin, cellulose and hemicellulose fractions. Processes that can convert softwoods into ethanol effectively are further behind in development than those that can convert agricultural residues and herbaceous crops.

When the availability, cost, and composition of the feedstocks are considered the agricultural residues and herbaceous energy crops are currently considered the most attractive lignocellulosic feedstocks for ethanol production. They are the easiest materials to fractionate into cellulose, hemicellulose and lignin but they have considerable pentose sugars that require fermentation.

2.2 BIODIESEL

Biodiesel is an ester produced by chemically reacting vegetable or animal fat with an alcohol, usually methanol. Chemically, it is a fuel comprised of a mix of mono-alkyl esters of long chain fatty acids. A transesterification production process is used to convert the feedstock oil to the desired esters and remove free fatty acids. As the name implies it has properties similar to diesel fuel except it is made from renewable resources.

Biodiesel can be used in conventional diesel engines in its neat form or blended with conventional diesel fuel. One common blend in the United States is 20% biodiesel and 80% petroleum diesel (B20). It can also be used as an additive to enhance the lubrication properties of petroleum diesel fuel.

Estimated total world production of biodiesel in 2005 was 2 billion litres. Important biodiesel producers worldwide are summarized in the following table. As with ethanol it is difficult to quantify world biodiesel production, as good quality statistics are not currently compiled. There was some biodiesel production in countries such as Brazil, Malaysia, Canada and others in 2005 that are not shown in this table. It is interesting to note that world biodiesel production is about an order of magnitude lower than world ethanol production in the year 2005.

Table 2-3 2005 World Biodiesel Production

Country	Production, million litres
Germany	1,886
France	556
Italy	447
United States	280
Czech Republic	150
Poland	113
Austria	96
Slovakia	88
Spain	82
Denmark	80
UK	58
Slovenia	9
Lithuania	8
Estonia	8
Latvia	6
Total	3,867

Some of the notable characteristics of biodiesel are:

- *Safe, Environmentally Benign*: Biodiesel is readily biodegradable and non-toxic.
- *Exhaust Emissions*: Biodiesel and biodiesel blends significantly reduce harmful tail pipe emissions. Exhaust emission improvements include substantial reductions in carbon monoxide, hydrocarbons, carcinogenic compounds and particulates. Pure biodiesel has zero sulphur – hence SOx emissions are eliminated.
- *GHG Emissions*: Biodiesel produces less GHG on a lifecycle basis than petroleum diesel. The exact amount of the reduction does depend on the specific feedstock being utilized.
- *High Lubricity:* Diesel fuel blends with biodiesel have superior lubricity, which reduces wear and tear on engines and makes the engine components last longer.
- *Cetane:* The cetane of a fuel is an important measure of its combustion properties in a diesel engine. Higher cetane values can improve starting, lower emissions and improve fuel economy. The cetane rating of biodiesel is in the range of 50 to 65 and depends on the feedstock. Petroleum diesel fuel has typical cetane of 40 to 55 depending on the type of crude oil processed and the refinery configuration.
- *Low Temperature Flow characteristics*: Biodiesel has a relatively high pour point compared with most petro diesels; special precautions have to be taken in cold weather to avoid gelling in the fuel system. The extent to which pour point is higher than typical petro diesels depends on the precursor raw oil source. Virgin vegetable oil precursors tend to produce biodiesel esters with lower pour points than those from waste oils or animal fats.
- *Materials Compatibility*: Biodiesel is a fairly strong solvent affecting natural rubber hoses and gaskets in the fuel system and some paints at blends greater than 20%. The solvent effect results in a cleansing effect on a diesel fuel system, removing accumulated deposits; this can result in fuel filter clogging during the first two or three uses of biodiesel.

2.2.1 Production Process

Biodiesel is made through the transesterification of vegetable and animal oils. The raw oil is reacted with methanol or ethanol[1] in the presence of sodium hydroxide or potassium hydroxide as a catalyst. The Biodiesel is separated from the byproduct glycerine and water washed to produce specification biodiesel product. The production process is simple and does not require a highly trained workforce. Care must be taken to ensure that the biodiesel produced meets the required quality specifications.

2.2.2 Applications

Biodiesel is fully soluble in petroleum diesel fuel at most operating temperatures. It can be used in low level blends such as B2 and B5 and even as a pure fuel as B100. Biodiesel contains some oxygen in the fuel and thus has about a 4.5% lower energy content than petroleum diesel on a volumetric basis. The volumetric fuel usage is correspondingly higher for biodiesel than for petroleum diesel fuel. Biodiesel contains no sulphur and has excellent lubricity properties.

2.2.2.1 Low Level Blends

The blend B2 is of interest primarily because of its lubricity properties. Diesel fuel lubricity has become a problem in some areas, particularly during the winter, as the sulphur content of the diesel fuel has been reduced. Some refiners are adding additives to overcome the problem. The lubricity of diesel fuel is expected to decline further in coming years as the fuel sulphur is reduced to 15 ppm. B2 also creates minimal cold weather issues.

The blend B5 is commonly used in Europe. It is driven in part because the existing diesel fuel specification allowed the use of up to 5% biodiesel. The cold weather issues are more significant with B5 than with B2 are but are generally manageable.

The B20 blend is the blend that has had the most demonstration in the United States. It does offer some significant benefits in terms of exhaust emissions and greenhouse gas benefits but also requires more care in ensuring that the cold weather performance is acceptable. Cold weather performance is of course not an issue in all countries.

In all cases the blending of biodiesel is done with normal specification diesel fuel. The environmental benefits of biodiesel are generally linearly proportional to the biodiesel component of the blend.

2.2.2.2 High Level Blends

The 100% biodiesel fuels can also be used in engines directly. This approach maximizes the environmental benefits but also creates the largest issues for engine manufacturer acceptance of the fuel and the cold weather properties. There has been a great deal of experience with B100 in Germany as that was the primary fuel marketed up until 2004 when B5 blends became financially feasible due to changes in their tax regulations.

2.2.3 Feedstocks

Fats and oils are composed of molecules called triglycerides. Each triglyceride is composed of three long-chain fatty acids of eight to 22 carbons attached to a glycerol backbone. Biodiesel is composed of fatty acid chains that are chemically bonded to an alcohol molecule. The glycerol molecules are almost completely removed in the process and are generally not found in the final product. The glycerine is produced as a co-product of the process. The characteristics of biodiesel are dependent on the feedstock that is used.

1 The use of ethanol as a reagent in Biodiesel production is technically feasible but it is not as economic as using methanol.

2.2.3.1 Animal Tallow

Tallows are used in the manufacture of products such as cosmetics, soaps, shampoos, candles, lubricants, paints, tires, perfumes, textiles, plastics, inks, polishes, cleaners, and solvents. Different grades of tallow are produced to meet the varying needs of customers worldwide. They are also an important source of fatty acids and glycerin for the chemical industry.

Tallow volumes that are available for biodiesel production are by-products based on the animal processing industry and are limited in volume. They are also mostly used in various applications and their use in biodiesel manufacturing would require the diversion of the material from the existing market. Nevertheless some tallow is available in most of the countries of interest and six of the countries are net exporters.

When the fatty acid chain breaks off the triglyceride, it is known as a free fatty acid. Free fatty acids break off the triglyceride through hydrolysis. This can be caused by steam from cooking foods, salts, some chemicals, or heat. Tallows and yellow grease can have higher free fatty acid contents than virgin vegetable oils. These materials require a slightly different processing system to effectively convert them to biodiesel. This can result in slightly higher capital and operating costs than for plants designed exclusively to process vegetable oils.

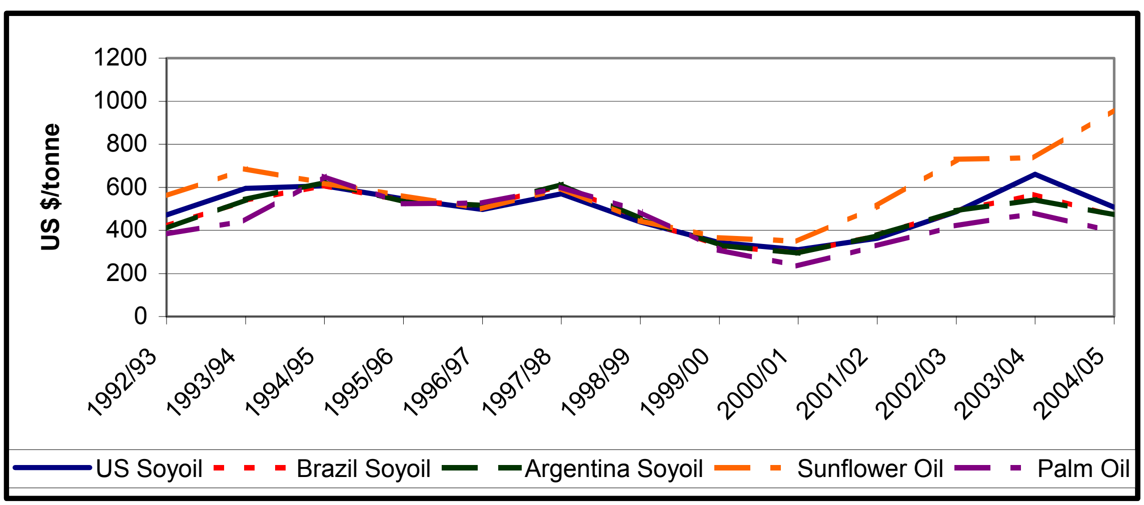
Tallow prices do tend to follow vegetable oil prices but they sell at a discount to most vegetable oils. There are therefore a low cost feedstock for biodiesel production although because of their free fatty acid contents the capital and operating costs of the plants can be higher than plants that just process vegetable oils. Tallow biodiesel has a high cetane value but has relatively poor cold weather properties.

2.2.3.2 Vegetable Oils

Vegetable oils may excellent biodiesel feedstocks. There are some small differences in the biodiesel properties that result from the properties of the individual vegetable oils. There are three primary vegetable oils of interest in Latin America, soyoil, palm oil and sunflower oil. There are small amounts of other oils produced such as rapeseed, olive oil, and castor oil but the volumes are currently too small to be of commercial interest.

Most vegetable oils are traded on world markets and there is a strong price correlation between most individual products. The choice of which oil to use for biodiesel production is therefore more a function of the suitability to the local agricultural environment than it is to the lowest cost feedstock. Historical prices for soyoil, palm oil, and sunflower seed oil are shown in the following figure (USDA).

Figure 2-4 Vegetable Oil Prices



Soybeans

Soybeans are an important global crop. The crop is grown for its oil and protein. The bulk of the crop is solvent extracted for vegetable oil and the defatted soy meal is used for animal feed. A very small proportion of the crop is consumed directly for food by humans.

Soybeans are native to southeast Asia, but 45 percent of the world's soybean area, and 55 percent of production, is in the United States. The U.S. produced 75 million metric tons of soybeans in 2000, of which more than one-third was exported. Other leading producers are Brazil with 25% of the 215 million tonnes of production, Argentina with 20% of production, China, and India. Soybeans are produced in one half of the countries in the region but only five of the countries are net exporters of soybeans.

To produce soybean oil, the soybeans are cracked, adjusted for moisture content, rolled into flakes and solvent-extracted with commercial hexane. The oil is then refined, blended for different applications, and sometimes hydrogenated. Soybean oils, both liquid and partially hydrogenated, are exported abroad, sold as "vegetable oil," or end up in a wide variety of processed foods. The remaining soybean husks are used mainly as animal feed.

The biodiesel produced by soyoil is a good quality product with most of its properties in the middle of the range produced by the various feedstocks.

Palm Oil

Palm oil is the world's largest source of vegetable oil. The oil palm is also the most productive vegetable oil with yields three to eight times higher than other vegetable oils. In addition the nutrient requirements of the palm tree are relatively low, the harvesting requirements are low, and much of the energy required for extraction is provided by bioenergy. The protein meal co-product production is of lower quality and quantity than most oil seeds.

The oil yields of the leading crops are summarized in the following table (Hai). The palm oil yield shown here includes just the crude palm oil from the fruit and not the palm kernel oil, which can increase the oil yield by a further 10%.

Table 2-4 Oil Crop Yields

	Tonnes oil/hectare
Oil Palm	3.30
Canola or rapeseed	1.33
Sunflower	0.66
Soybean	0.46

A normal oil palm tree will start bearing fruits 30 months after planting and will continue to be productive for the next 20 to 30 years thus ensuring a consistent supply of oil. Oil production does peak in the first decade after planting and will slowly decline through the second decade.

Biodiesel produced from palm oil has a high cetane value but has relatively poor cold weather properties. It is best suited for use in warm climates.

Palm oil is produced in 14 of the countries of interest although only six of the countries are net exporters.

Sunflower Oil

Sunflower oil is one of the most popular oils in the world for human food applications as it is high in polyunsaturated fatty acids and low in saturated fats. The oil is typically extracted by applying pressure to the sunflower seeds and collecting the oil. After extraction, the pressed sunflower seed cake can be used as a valuable livestock feed, which is rich in proteins.

Argentina is the world's third largest sunflower seed producer with about 3.7 million tonnes per year of seed. The oil content of the seed is about 30 to 40%. Eight countries in the region have some level of production but only four are net exporters.

In recent years the price of sunflower seed oil has diverged from the pricing trend for other vegetable oils and it is probably too expensive to use for biodiesel production in the current supply and demand scenario. Sunflower seed oil has been used in Europe in the past to produce biodiesel.

Emerging Biodiesel Feedstocks

There is some interest in developing feedstocks that can be produced on marginal land and may not be suitable for human consumption. These feedstocks include jatropha and castor. The oil from these plants is expected to be lower cost than existing vegetable oils and since the oil is generally not suitable for human consumption it should not follow the same price pattern as the edible oils. There is not yet a significant amount of experience growing jatropha commercially but there are some development programs underway in Africa, Asia and South America that will provide information about the long suitability and performance of these plants as a source of oil for biodiesel production.

2.3 Other Biofuels

There are many other products besides ethanol and biodiesel that can be produced from biomass and could be classified as biofuels. These products are either 2nd generation biofuels or have characteristics that make them unsuitable for use in an internal combustion engine.

2.3.1 Bio-Oils

If biomass is heated to high temperatures in the total absence of oxygen, it pyrolyzes to a liquid that is oxygenated, but otherwise has some similar characteristics to petroleum. This pyrolysis- or "bio-oil" can be burned to generate heat or electricity or it can be used to provide base chemicals for biobased products.

The technology platform can process a variety of feedstocks although most of the effort is on utilizing lignocellulosic feedstocks. Pyrolysis liquid typically is a dark brown free flowing liquid. The liquid has a distinctive odour – an acrid smoky smell that can irritate the eyes if exposed for a prolonged period. The liquid contains several hundred different chemicals in widely varying proportions, ranging from low molecular weight and volatile formaldehyde and acetic acid to complex high molecular weight phenols and anhydrosugars. The liquid can have a high ash content making it unsuitable for use in internal combustion engines.

2.3.2 BTL Biomass to Liquids

Gasifying any biomass material and then synthesizing a diesel type fuel using a Fischer-Tropsch (FT) synthesis step or the similar Shell Middle Distillate Synthesis technology can produce a compression ignition fuel. The fuel produced by these processes is a high cetane hydrocarbon that can be used as a diesel fuel component. The fuel has clean burning properties but does not contain any oxygen. Compared to conventional biodiesels, one advantage of this process is that the feedstock is not limited to oils and fats but can used agricultural residues such as straw or wood chips. While the synthesis step is employed commercially in South Africa and Malaysia, the feedstocks used have been coal and natural gas.

The technology has not yet been combined commercially with biomass gasification although some product has been produced in a pilot plant unit operated by the German company Choren (www.choren.de/).

These FT diesel fuels are able to be produced from a range of feedstocks and are not limited to vegetable oils and animal fats like conventional biodiesel. The production potential is therefore much larger. Like many of the 2nd generation biofuels there is not a lot of independently verified information available on these processes. The processes are believed to require between 4 and 6 kg of feedstock to produce 1 kg of FT distillate. This compares to methyl esters that produce about 1 kg of fuel from 1 kg of oil and depending on the feedstock can produce 1 kg of oil from 2.5 kg of rapeseed or 5 kg of soybeans.

The FT distillates do have the advantage that the products are fungible with the existing diesel fuels and thus distribution system issues are largely avoided by these products. The chemical composition of the products is also controllable, largely free of aromatic compounds, and essentially zero sulphur making them excellent fuels from a combustion emissions perspective. It is the combustion properties that make them attractive to the automotive sector.

2.3.3 Bio DME

Dimethyl ether is a product that is currently manufactured from natural gas that has been promoted as a potentially attractive alternative fuel. The product has some attractive chemical and combustion properties that allow it to be used in compression ignition engines as well as being a possible hydrogen carrier for use in fuel cell applications. Its physical properties resemble those of LPG. Like natural gas or LPG, the use of DME requires a sequential decision process as part of the market implementation. The vehicles must be built to use the fuel and the fuel infrastructure must be built to supply these vehicles.

DME can also be produced from the gasification of biomass to produce syngas and then the syngas is converted to DME. It is this biomass gasification process that results in DME being identified as a 2nd generation biofuel. Like all of the gasification processes Bio-DME can utilize a wide range of feedstocks. The energy requirements for the process are supplied by the biomass with very little fossil fuel used in the lifecycle. The GHG emission performance is expected to be quite good. The natural gas to DME process is reported to have a relatively high conversion efficiency and it is expected that the Bio-DME would also have a good conversion efficiency compared to other biomass gasification pathways.

2.3.4 Biogas

Methane can be produced through the anaerobic digestion of waste materials including lignocellulose. These biogas systems are usually used to produce heat and power but there is also the potential to concentrate the methane that is produced and produce pipeline quality natural gas. Natural gas is used as a transportation fuel in many regions of the world but it requires engines designed for the fuel or converted gasoline engines.

Biogas systems usually have a low requirement for external fossil energy so the overall GHG emissions performance and fossil energy balance are relatively good. Like all biological systems they can be difficult to operate at their most efficient state and some developers have experienced operational issues when very large systems have been built. Small systems will also negate the potential for economies of scale to be generated and the resulting benefits in terms of capital and operating costs.

The use of natural gas as a vehicle fuel requires a sequential decision process. First the user must decide to purchase a vehicle that is capable of using the fuel and then a fuel supplier must supply the infrastructure that is necessary to supply the fuel. These “chicken and egg” scenarios result in slow penetration rates since each decision maker waits for the other to commit first before they commit.

3. BIOFUEL DIMENSIONS

The policy drivers for biofuels fall into three categories, climate change and clean air, energy security, and the need for diversification in agricultural and expanded rural economic opportunities. These three themes are common throughout both the developed and developing world.

Rising concentrations of greenhouse gases (GHG) in the earth's atmosphere are leading to potentially irreversible climate change. A shift in temperature zones caused by climate change could seriously affect biodiversity. At the global level, climate change is expected to have a negative impact on agricultural production and worsen food security. Climate change, apart from having direct economic effects on already vulnerable livelihoods in terms of lost endowments and entitlements, is also likely to have major macroeconomic implications.

Air quality is also poor in many urban areas of the world. In developed countries, governments have been moving for many years to tighten fuel quality and vehicle emission control standards to address this issue. In the developing world fuel quality and vehicle emission standards are only beginning to be changed and air quality can be improved significantly through the use of biofuels to reduce particulate emissions and contaminates such as carbon monoxide and volatile organic compounds.

In the transport sector, 98% of the energy used comes from fossil oil. Known oil reserves are limited in quantity and restricted to a few world regions. New reserves exist, but will mostly be more difficult to exploit. Securing energy supplies for the future is therefore not only a question of reducing import dependency, but calls for a wide range of policy initiatives, including diversification of sources and technologies. Over the last several years, consumers have had to face price increases for transport fuels and other energy sources. The price of a barrel of oil exceeded the $75 US mark in 2006. This increasing cost of energy had a strong impact on purchasing power.

New market opportunities are always of particular interest to the agricultural sector as prices for agricultural commodities are often below breakeven levels due to a combination of oversupply and market distortion created by government support programs. Rural regions generally suffer from having lower incomes, higher unemployment rates and a relatively higher dependency on the primary sector than urban regions.

The challenges to be addressed in rural areas can be summarized as follows:

- *Economic:* rural areas have incomes significantly below the average, an ageing working population, and a relatively greater dependency on the primary sector.
- *Social:* there is clear evidence of a higher than average rate of unemployment in rural areas. Low population density and depopulation in some areas may also increase the risk of problems like poor access to services, social exclusion and a narrower range of employment options.
- *Environmental:* the need to ensure that agriculture and forestry continue to make a positive contribution to the countryside and the wider environment.

Developing the provision and innovative use of renewable energy sources can contribute to creating new outlets for agricultural products, the provision of local services and the diversification of the rural economy.

3.1 MARKET POTENTIAL

The market potential for biofuels in each country will be a function of the energy supply situation and the feedstock availability. Those countries which are currently exporting potential biofuel feedstocks will be the best placed to move into biofuels production. Other countries may consider expanding the feedstock supply if a biofuels market were to develop but that will take some time to accomplish.

The following table summarizes the oil and petroleum products production situation for each of the countries as well as the biofuel feedstock supply situation. The information has been drawn from the US Energy Information Administration and the UN Food and Agricultural databases. Those countries, which either import gasoline and have an ethanol feedstock surplus or import biodiesel and have biodiesel feedstock exports, are identified in bold. They are prime candidates for the development of a domestic biofuels industry. Note that there are other countries that have the potential to produce biofuels but the market for the fuels would either be the export market for the biofuel or for the petroleum fuel displaced by the biofuel. More detail on the petroleum and feedstock supply situation can be found in the Appendices.

Table 3-1 Biofuel Market Potential Summary

	Crude Oil Producer	Net Crude Oil Importers	Refiner	Net Gasoline Importer	Ethanol Feedstock Exporter	Net Diesel Importer	Biodiesel Feedstock Exporter
Argentina	Yes	No	Yes	No	Yes	No	Yes
Bahamas	No	No	No	Yes	No	Yes	No
Barbados	Yes	No	No	**Yes**	**Yes**	Yes	No
Belize	No	No	No	**Yes**	**Yes**	Yes	No
Bolivia	Yes	No	Yes	No	Yes	**Yes**	**Yes**
Brazil	Yes	Yes	Yes	No	Yes	**Yes**	**Yes**
Chile	Yes	Yes	Yes	No	No	Yes	No
Colombia	Yes	No	Yes	No	Yes	No	Yes
Costa Rica	No	Yes	Yes	**Yes**	**Yes**	**Yes**	**Yes**
Dominican Republic	Yes	Yes	Yes	**Yes**	**Yes**	Yes	No
Ecuador	Yes	No	Yes	**Yes**	**Yes**	**Yes**	**Yes**
El Salvador	No	Yes	Yes	**Yes**	**Yes**	Yes	No
Guatemala	Yes	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Guyana	No	No	No	**Yes**	**Yes**	Yes	No
Haiti	No	No	No	Yes	No	Yes	No
Honduras	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Jamaica	No	Yes	Yes	**Yes**	**Yes**	Yes	No
Mexico	Yes	No	Yes	**Yes**	**Yes**	Yes	No
Nicaragua	No	Yes	Yes	**Yes**	**Yes**	Yes	No
Panama	No	No	No	**Yes**	**Yes**	Yes	No
Paraguay	No	Yes	Yes	**Yes**	**Yes**	Yes	No
Peru	Yes	Yes	Yes	No	No	**Yes**	**Yes**
Suriname	Yes	No	Yes	Yes	No	Yes	No
Trinidad and Tobago	Yes	Yes	Yes	No	No	No	No
Uruguay	Yes	Yes	Yes	No	Yes	**Yes**	**Yes**
Venezuela	Yes	No	Yes	No	No	No	No

It is important to note that international trade in biofuels is relatively small compared to domestic consumption. There are several reasons for this, the first is that biomass feedstocks are found all around the world so most countries can be biofuel producers. The second is that most national biofuels programs have developed as the result of concerted efforts of local agricultural producers who wish to see improved market opportunities for their production. The third reason would be that historically biofuels have been more expensive than petroleum fuels and have only flourished because of government support. While governments have been willing to provide support to local producers they have been far less willing to support foreign producers.

Given that international trade is only a small part of the biofuels market, local markets are much more important than they might be for other commodities. Since biofuels will displace some petroleum products or local crude oil production and this displacement may require the incumbent petroleum producers to find other markets there can be substantial resistance to biofuels development in some countries. Therefore the market potential of biofuels in each country will depend not only on the feedstock capability, but also the refined product supply and demand situation, and the size of the potential market. In an ideal situation for biofuels development the country will be an exporter of biomass feedstock and an importer of refined petroleum fuels with a market that is large enough to allow a plant to be built that can take advantage of the economies of scale.

Many countries will have the potential to expand the production of some agricultural products but it is beyond the scope of this work to identify the potential for feedstock expansion. This is an area where the Bank may have an interest in funding further work. Some international agencies have promoted the expansion of some of these feedstocks such as oil palm as potential replacement crops for current crops such as cocoa in some South American countries (UNODC).

3.2 Technical Aspects

Latin America produces many feedstocks that can be used in commercial processes to produce ethanol and biodiesel. In many cases Latin American countries are among the world's lowest cost producers of these feedstocks. Brazilian sugar is a very good example, where a combination of excellent climatic conditions, low labour costs, and advances resulting from agro-industrial development, Brazil has become the world's lowest cost sugar producer and the world's largest sugar exporter.

From the previous analysis of feedstock supply it is apparent that in most countries sugar cane or molasses from sugar processing is the obvious choice for ethanol production. Argentina, Brazil and Paraguay also have opportunities to produce ethanol from cereal grains and rice could be attractive in a few countries. The technology for all of the feedstocks is commercially available. In the case of sugar cane, many of the countries will already produce ethanol from the molasses that is a co-product of crystal sugar production. This alcohol may not currently be dehydrated so that it is suitable for blending with gasoline but that is a relatively easy step to add to an existing facility. This alcohol is probably used for potable and industrial applications. There are also other markets for molasses ranging from flavourings to a substrate for yeast production.

In general all ethanol plants will benefit from economies of scale. The lower cost of sugar cane plants does lend itself to smaller plants and if the plant is mostly producing ethanol from the molasses then some smaller plants may be attractive.

Fuel ethanol used for blending with gasoline must be anhydrous (contains less than 1% water) in order to be soluble in the gasoline. Ethanol is also hydroscopic in that it attracts water. An excellent analysis of the issues in the distribution and transportation of the fuel ethanol from the point of production to the point of blending with gasoline was undertaken for the US DOE. Pipeline distribution and barge transportation are two modes where special precautions must be taken. The pipeline distribution in particular is a mode that is not often used because of the difficulty of keeping it water free. Several documents are available from the Renewable Fuel Association in the US that describe the issues with respect to procedures and quality control measures.

In the case of biodiesel, some countries are well situated to use soyoil as a feedstock while in other cases palm oil would be a more logical choice for feedstock. The technology for using both is well established. Biodiesel production is a relatively straightforward process, which is both an advantage and a disadvantage. The advantages are that capital costs are relatively low, and the process is simple and easy to control. The disadvantage is that because the process is so simple many people get involved and they don't spend the appropriate amount of effort on ensuring the quality of the final product. Poor quality product can create engine problems and it can take some time to find these problems in the field, which makes it difficult to trace the problem back to an individual supplier, and the result is that the fuel gets a bad reputation when the problem was really just with an individual supplier.

The US National Renewable Fuels Laboratory has developed biodiesel handling guidelines. This document addresses many of the issues related to biodiesel production and use including the precautions that are necessary in the implementation of a biodiesel product into the marketplace. Provided that the biodiesel product meets the quality standards when it leaves the production facility the primary concern in the distribution system is ensuring that the cold weather issues are addressed. When pure biodiesel is transported the product can start to cloud at temperatures from 0 to 10 °C, temperatures that can be reached at higher elevations even in countries that are generally temperate.

Biodiesel plants will also benefit from economies of scale but the capital cost requirements are lower than ethanol plants so the capital cost component of the economics are less important. This has lead to the construction of smaller biodiesel plants. These smaller plants have a tendency to not invest in quality control measures to the same degree as larger plants and that may allow inferior product into the marketplace.

3.3 THE ECONOMICS OF BIOFUELS

Any discussion of biofuel economics needs to consider not only the costs but also the market values for the various inputs. For those commodities that are traded internationally the market values are more important in determining the costs of biofuels and for those that are more local in nature then the costs are of more interest. Most feedstocks are traded internationally but there are a few that are not such as cassava. Note that from an agricultural perspective the costs of producing feedstock in comparison to the market values are important but that is the case whether biofuels are produced or not.

The economics of ethanol production from sugar cane in Brazil and in Peru were reported on by TechnoServe in 2005. These costs are shown in the following table. In the case of Peru the ethanol is produced from the molasses co-product, which has been priced at its market value of $34/tonne (264 l/tonne yield).

Table 3-2 Sugar Cane Ethanol Production Costs

	Brazil	Peru
	US cents/litre	US cents/litre
Feedstock	9.24	13.0
Ingredients	0.39	
Materials	0.77	
Labour	0.79	1.0
Administration and benefits	0.61	
Technical Assistance	1.01	
Other Costs	0.09	6.0
Depreciation	0.73	2.0
Total	13.63	21.0

The cost of producing sugar in Brazil with a cane cost of $8.44/tonne as used above was estimated by TechnoServe to be 17.3 US cents/kg (7.85 cents/lb). This is significantly lower than the current world sugar price of 12 to 13 cents/pound (NYBOT futures market) and should result in a good profit margin for Brazilian producers. Domestic sugar prices can be higher than the export prices in some cases. Since many Brazilian sugar and ethanol producers are able to swing production between the two commodities the netback from producing ethanol must be comparable to producing and exporting sugar. Therefore cost of producing ethanol when the current world sugar price is used is about 43 cents/litre (which is comparable to the August 2006 Brazilian ethanol price of 42 to 45 cents/litre).

The August world price for gasoline was about 50-55 cents/litre and thus Brazilian ethanol producers can be quite profitable selling ethanol domestically as a gasoline substitute even if there is little government support. However, the costs of shipping ethanol to foreign markets would make even Brazilian ethanol uncompetitive with gasoline at the current time. Gasoline prices in September have dropped to 40-43 cpl and Brazilian ethanol prices have dropped to the same level, demonstrating the price volatility that energy and agricultural commodities face.

When ethanol is used in low level blends it can usually be sold at a price equal to gasoline on a volumetric basis since the impact of ethanol's lower energy content is small. When it used in high level blends the lower energy content becomes more important and the ethanol must be sold on an energy basis so it must be priced at about 70 to 75% of the price of gasoline. In countries like Brazil, were both markets are important the ethanol must be priced (once all taxes are included) to be competitive with gasoline on an energy equivalent basis.

Not all Latin American sugar producers have the same cost structures as Brazil. Some have traditionally received some government support and in some countries they have access to the regulated sugar markets in the United States and Europe. The opportunity cost of ethanol production in these countries will be quite a bit higher than in Brazil. With the volatility in world oil prices and sugar prices along with the country to country variance in sugar production costs, there is still some need for government support for ethanol producers in order to make a viable business case for biofuel production in most countries.

Table 3-3 US Corn Ethanol Production Costs

Component	US cents/litre
Corn	22.2
Less DDG sales	6.2
	16.0
Natural Gas	5.8
Electricity	1.0
Transportation	4.2
Other	5.0
Total Production Costs	32.0
EBITDA	10.3

Ethanol production costs from other feedstocks will be higher than shown here for sugar. The capital costs of grain plants are higher than sugar plants, the operating costs are also higher and the grain plants do not have the biomass fuel delivered to the plant as part of the feedstock as sugar cane producers do. The grain plants may even use fossil fuels and purchased electricity to meet their energy requirements. A recent analysis of the US ethanol industry by Credit Suisse found that the price point to provide a 10% return on capital for US ethanol plants is 38 to 44 cents/litre with corn prices of $2.35/bushel. The production cost as estimated by Credit Suisse for US Corn ethanol production is shown in Table 3-3.

The following economic analysis of biodiesel production costs in the United States was prepared for the IEA Bioenergy Task 39 group in 2004 ((S&T)[2]). The average price of soyoil from 1991 to 2001 was 47 cents per kilogram. A price of 50 cents per kilogram will be used for the analysis here. The energy and other input price assumptions for the two plants are summarized in the following table. It is assumed that the crude glycerin from the small plant can be sold for $0.65/kg and from the larger plant is will bring $1.00/kg. These may be optimistic given the worldwide oversupply of glycerine at the present time. The biodiesel production costs are shown in the following table.

Table 3-4 Biodiesel Production Costs United States

	Total $	**$ Per Litre**	**Total $**	**$ Per Litre**
Annual Production - millions of litres	**10**		**125**	
Feedstock	4,440,000	0.440	55,061,012	0.440
Processing supplies	560,000	0.056	5,750,000	0.046
Direct labour & benefits	399,360	0.040	998,400	0.008
Maintenance and operating supplies	86,000	0.009	483,000	0.004
Energy	101,500	0.010	1,181,250	0.010
Overhead	139,830	0.014	474,195	0.004
Depreciation	215,000	0.022	1,207,500	0.010
Interest on long-term debt	215,108	0.022	1,208,104	0.010
Glycerine Revenue	-577,513	-0.058	-11,011,905	- 0.088
Total Costs	**5,579,285**	**0.554**	**55,351,556**	**0.443**

It is obvious that scale is important and that production costs for biodiesel are higher than they are for ethanol. Diesel fuel from crude oil has a similar value to gasoline so the relative economics of biodiesel are not as attractive as they are for ethanol. On the other hand, Latin America is a larger net importer of diesel fuel than it is of gasoline so there may be less resistance to biodiesel implementation that ethanol use.

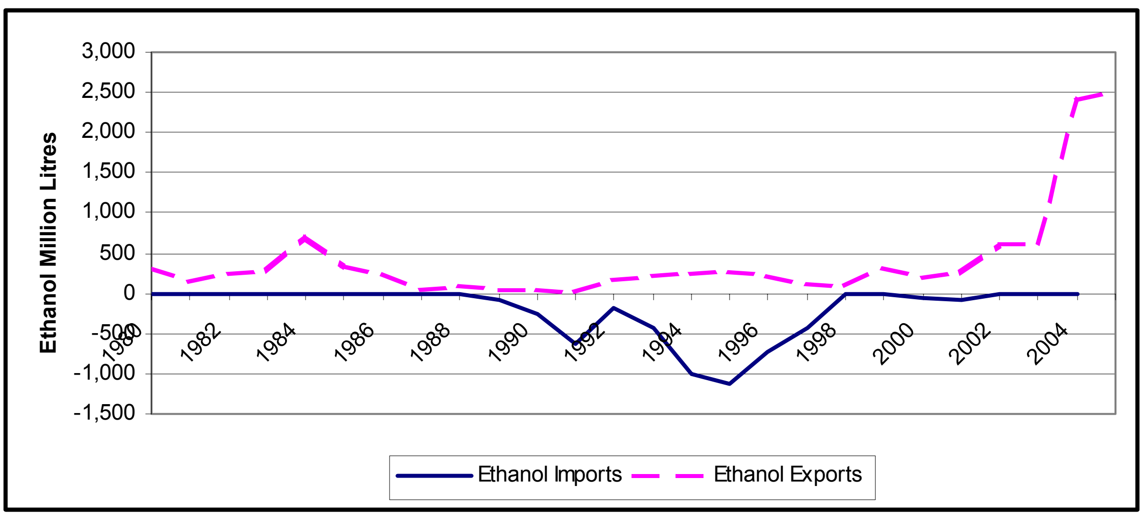
The use of palm oil as a feedstock could be expected to lower production costs by about 5 cpl due to its lower market price.

In most countries biofuel producers have been price takers. Biofuel production is such a small part of the overall energy supply situation that it does not really impact the price of fossil energy and biofuel producers must accept what the market will give them for their production, hence the term price takers. Brazil is a different situation; here the price of ethanol has more closely tracks the movements in the price of sugar. Sugar and ethanol mills look for the best netback when they decide how much sugar and ethanol to produce and many of them are very flexible in determining their production schedules. The demand for the product is relatively inelastic because of the mandated use of ethanol. When oil prices are high much of the benefit of the high price accrues to the ethanol blender and marketer and not to the producer. This is a very different situation than in most other countries with biofuel programs.

3.3.1 International Trade

Given that one of the driving forces for biofuel production has been the desire to provide local rural economic development opportunities and that traditionally biofuels have required some level of government support to be economically attractive the focus of biofuels development in most countries has been on domestic production and consumption, it is only in the very recent past that more thought has been given to the international trade opportunities with bioenergy. One of the leading proponents of international trade has been Brazil and their ethanol import export picture is shown in the following figure.

Figure 3-1 Brazilian Ethanol Trade



Fuel ethanol imported into the United States has a tariff of 14.27 (US$) cpl unless it comes from a country with a trade agreement with the United States. Ethanol from a Caribbean Basin nation is exempt. Ethanol from Brazil and the EU must pay this duty. The Brazilians have been lobbying to have this tariff removed but this has met strong resistance from domestic producers who view Brazilian ethanol as heavily subsidized. Brazil also has a high import tariff on ethanol from other countries.

In the EU, the import duty on denatured ethanol is 0.102 €/litre (13 cpl US). This rate applies to Canada, the United States and Brazil. This is a relatively low duty rate compared to the tax exemptions available for fuel ethanol. In an attempt to increase the barrier to Brazilian imports some European countries have stipulated that undenatured ethanol must be used for blending with gasoline. The duty rate for this material is 0.192 €/litre (24 cpl US). This is still a low import duty compared to the tax incentive available.

The European market is the world's largest market for biodiesel. Biodiesel faces import tariffs of 5 to 11% depending on the feedstock used and the country of origin. Similarly in the United States biodiesel imports face tariffs from 6 to 8 cpl depending on the feedstock and origin.

It is clear that a biofuels industry that is based on export markets faces public acceptance issues in many countries. Part of this resistance is due to the fact that Brazilian ethanol prices are more closely aligned with sugar prices rather than gasoline prices and there are therefore times when imports represent a price threat to local producers. While this resistance may change over time it is unlikely to disappear completely given the agricultural base to existing biofuels and the large trade barriers that many agricultural goods face in the world today. The establishment of a viable biofuels industry should be based on domestic demand as biofuel exporters should assumed that biofuel incentives currently available in some countries will continue to exist if biofuel imports become a significant market force.

3.4 Infrastructure Needs and Challenges

The infrastructure requirements to establish a biofuels industry will vary from country to country depending on the biofuel produced, feedstocks consumed, the markets to be accessed, the existing transportation fuels infrastructure and local conditions.

Developing new products for markets is always a more difficult task than expanding existing industries. The uncertainty of how well the new product may work, or how the factory built to make the new product might work, along with how quickly the market might adopt the new product weighs heavily on investors and lenders who would finance the new venture. If there are sequential steps involved in the process then this greatly increases the uncertainty because it offers more places where problems might occur. In order to reduce the uncertainty it is more likely that a biofuels industry will be established based on the production of existing feedstocks rather than on developing a new crop and an industry to process that crop. Once a new market is established the production of the feedstock may expand but that is a much easier situation to develop.

The capital costs for new large (175 million litres/year) grass roots sugar cane to ethanol facilities in Brazil has been reported to be $0.35/annual litre of capacity (Caelho, 2005). The capital costs for a similar sized corn ethanol plant in the United States is about $0.45/annual litre. Both of those countries have many years of experience with building ethanol plants and it may be that plants built in countries that don't have the same experience may initially be higher until the experience is gained.

The capital costs for biodiesel plants are lower if the feedstock is readily available. A large (110 million litres) tallow biodiesel in Brazil was announced in 2005 (Brazzilmag) and the capital cost was reported to be $0.16/litre. In the United States a 170 million-litre biodiesel plant processing soybean oil is expected to have a capital cost ranging from $0.18 to $0.21/litre of installed annual capacity (Michigan Department of Agriculture). When the oil for the biodiesel plant must be extracted from the oilseed as well as producing biodiesel the capital costs increase. These integrated crushing/biodiesel plants have capital costs in the range of $0.50 to 0.60/litre of annual capacity (Michigan Department of Agriculture, Wisconsin Soybean Board). These integrated plants produce a protein meal as well as the oil for biodiesel production.

Once the biofuel is produced it must be transported to a refinery or petroleum products terminal where it is blended the gasoline or diesel fuel. In some countries this transportation infrastructure will exist and in other countries it may not be adequate for the production volumes. The cost of this infrastructure can be significant depending on the mode of transportation. In general it is expected that in most locations the volumes will not be large enough to support a dedicated pipeline system and that rail, truck and perhaps barge movements will be the most likely to be utilized. These alternative transportation modes have lower capital costs but higher operating costs than pipelines.

The infrastructure requirements at the refineries and terminals will also vary by location. There is a tendency for these costs to be overestimated by the incumbent petroleum distributors at the early stage of project implementation. The most complete analysis of the distribution costs for biofuels was undertaken in the United States for the DOE. This analysis looked at the costs on a very specific location by location basis.

Downstream Alternatives (2000) describes the terminal requirements and modifications used in the United States as described below.

> *Costs of modifications will vary widely from one terminal to another depending on the extent of modification needed, the volume of ethanol handled and the mode of receipt.*
>
> *Tanks: New tankage, if required, would cost about $450,000 for a 25m barrel tank. This tank size should be adequate for most terminals to store sufficient ethanol supplies.*
>
> *Blending Systems: Estimates for blending systems and necessary piping modifications, meters, rack modification, etc. cover a fairly broad range from about $150,000 to $400,000.*
>
> *Product Receipt: For terminals receiving product by transport truck, modifications to accommodate such receipt would be minimal, often under $10,000. However terminals receiving product by rail or barge may have more complicated modifications such as adding delivery lines, or installing a rail spur. Such modifications have been estimated to be as high as $300,000 per terminal in the case where a rail spur addition is necessary.*
>
> *While these costs sound expensive, if one looks at it on a cost per gallon basis, these are relatively insignificant sums. For instance, combining the above investment sums for a 25m barrel tank, blending system/piping modifications, and a rail receipt facility results in high side cost estimates of approximately one million dollars. However if one assumes 24 inventory turns per year for ten years, this equates to 6 million barrels of throughput or a cost of $0.166 per barrel of ethanol ($0.004 per gallon). After amortizing the initial investment, this would equate to $0.294 per barrel ($0.007 per gallon) for ethanol or $0.0007 per gallon of gasoline ethanol blend (at 10 vol % ethanol).*

It should be noted that much of Latin America has been late in phasing out leaded gasoline. As countries do eliminate leaded gasoline some infrastructure at refineries and terminals becomes available and some of it may be suitable for biofuels storage and distribution.

All of this infrastructure must be financed by the various stakeholders. The issues with financing will depend on the perceptions of the lending community and the type of investment. New enterprises that are financed on a project basis are the most difficult to finance. Investments made by established companies that are expanding their operations are traditionally easier to finance. Unfortunately these established companies are not usually the ones that are first interested in new ventures.

3.5 Social Aspects

One of the key drivers for biofuels development throughout the world has been for increased rural economic development opportunities. Rural regions suffer from lower incomes, higher unemployment and a relatively high dependency on the primary sector for job creation. Biofuel production is seen as an opportunity to address some of these issues. The primary cost of biofuel production is the feedstock cost for both ethanol and biodiesel. This means that while some jobs are created in the biofuel manufacturing facilities most of the jobs are indirect ones and most are related to feedstock manufacturing.

Coelho noted that in Brazil 2,333 jobs are created for every one million tonnes of sugar cane harvested. This cane produces 80 million litres of ethanol. Compared to other sources of energy ethanol is much more labour intensive. Coelho reported that 152 jobs are created in the Brazilian ethanol industry for the same energy output that one job in the oil sector produces. Other estimates of the labour impacts of the sugar and ethanol industries in Brazil put the employment numbers even higher. UNICA, the Sao Paulo sugar cane association, reports that increasing fuel ethanol production by 500 million litres/year creates 20,000 direct jibs and 60,000 indirect jobs. Extrapolating that to the whole 15 billion litre per year industry would result in 600,000 direct jobs and 1,800,000 indirect jobs.

In Latin America much of the sugar cane is still harvested by hand but mechanized harvesting is growing in popularity. Mechanized harvesting eliminates the need to burn the cane fields prior to harvest and returns more carbon to the soil, improving the soil characteristics. It will have a negative impact on employment levels.

The number of jobs in the processing plants are to a degree a function of the amount of automation that is installed in the plant. In North America, modern 150 million biofuel plants require 25 to 35 employees. Some estimates ((S&T)^2, 2005) have put the number of indirect jobs at up to 10 times the number of direct jobs in the biofuels plants.

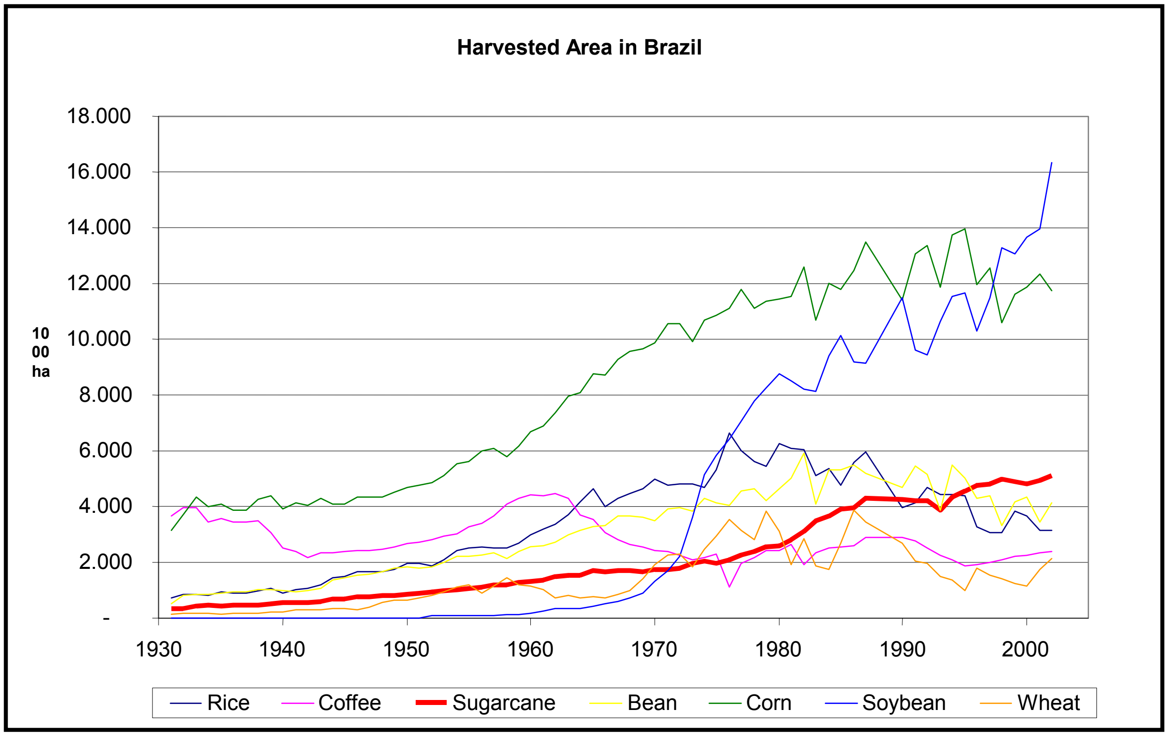
There has been some concern expressed by some that increased biofuels production will increase the competition for land that is used for food purposes. This argument has some basis of concern when land availability has reached the limit. The limit is not easy to define. The FAO land database has estimates of total arable land, the potential arable land accounting for factors like steep terrain, and estimates of the percentage of potential arable land in use. The information is shown in the following table. Note that not all of the IADB countries are included in the database. Those countries with greater than 100% land in use reflects the use of irrigation to increase the amount of arable land. There is a wide range in results, which make it impossible to generalize about the land availability.

Table 3-5 Land Use in Latin America

	Potential Arable Land	Arable Land In Use	% of Potential Land in Use
	1,000 ha	1,000 ha	1,000 ha
Argentina	90,571	27,200	30
Belize	984	57	5.8
Bolivia	61,917	2,380	3.8
Brazil	549,389	50,713	9.2
Chile	3,327	4,250	127.7
Colombia	65,536	5,460	8.3
Costa Rica	1,205	530	44
Dominican Republic	2,169	1,480	68.2
Ecuador	12,864	3,036	23.6
El Salvador	864	730	84.5
Guatemala	3,710	1,910	51.5
Guyana	13,305	496	3.7
Haiti	846	910	107.6
Honduras	3,424	2,030	59.3
Jamaica	156	219	140.4
Mexico	52,162	24,730	47.4
Nicaragua	5,546	1,270	22.9
Panama	2,363	665	28.1
Paraguay	21,589	2,270	10.5
Peru	43,363	4,140	9.5
Suriname	9,273	68	0.7
Trinidad and Tobago	321	122	38
Uruguay	14,245	1,304	9.2
Venezuela	55,092	3,915	7.1

This criticism has been made about sugar cane in Brazil but the data shows that there has been a much larger growth in arable land used for traditional crops, such as corn and soybeans, in Brazil than there has been in land devoted to sugar cane as shown in the following figure (Coelho).

Figure 3-2 Harvested Area in Brazil



If the world price for agricultural goods increase above the cost of producing the commodities due to demand for biofuel production then it becomes financially attractive to own land. Land use reform is a topic of great interest in many countries. On the one hand, increased prices for crops grown by small private land owners make their enterprises more viable, but on the other hand the economies of scale of biofuel production plants require large volumes of feedstocks which are easier to accumulate when a plant only has to deal with a small number of large land owners. Small land holdings and large biofuels plants are not necessarily incompatible, but the interaction between the land owners and the plant operators must be designed to meet the needs of both parties,

3.6 Environmental Aspects

The increased production of agricultural products so that some can be used for biofuel production can basically be accomplished three ways, the yields of current crops can be increased through better cultivation practices, there can be some crop substitution to higher yielding species, or new land can be brought into cultivation. In many areas of the world we see all three approaches being used and there are advantages and disadvantages of each approach.

Employing better cultivation practices can involved the application of more fertilizer, either natural or synthetic, better weed and pest control, better crop rotation, and a variety of other methods. While costs per hectare may increase, the cost per tonne should decrease. This approach could also result in higher soil carbon content over time. Reducing monocultures can have very positive benefits for soil health and controlling pests and diseases.

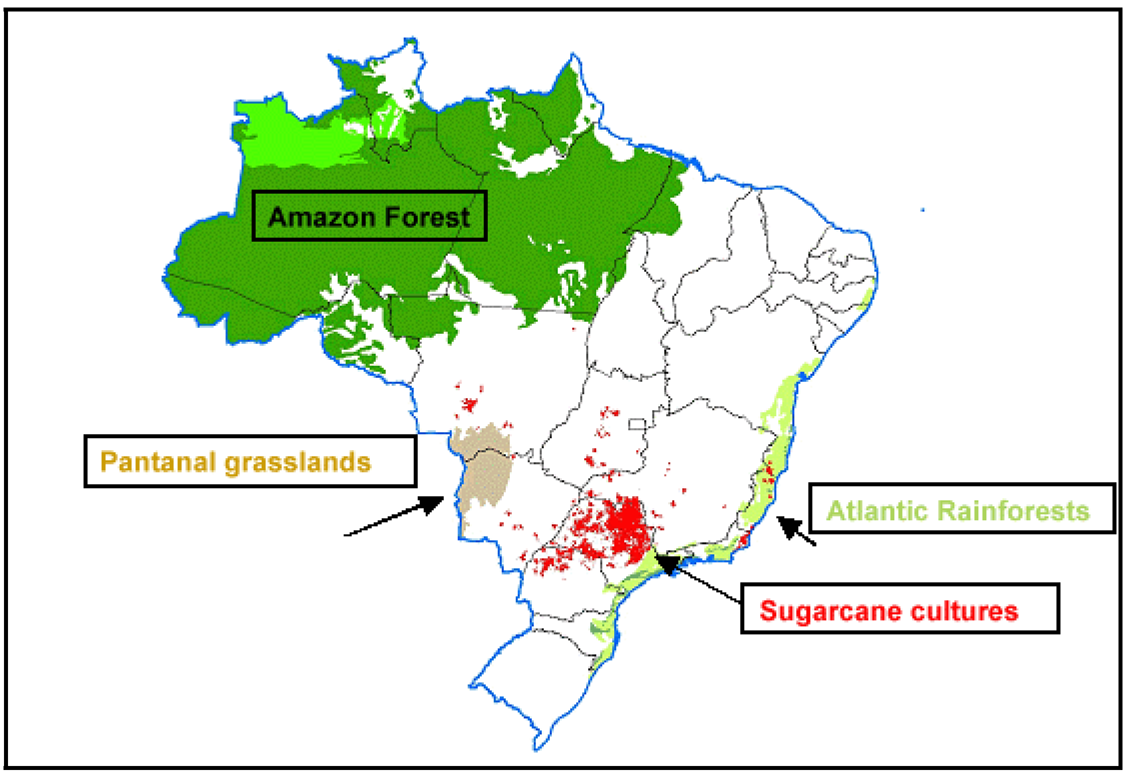
Crop substitution is employed in many regions where new demand for crops is introduced. One obvious example is the efforts by the United Nations to increase palm production at the expense of coca production in many parts of South America. There are limits to how much crop substitution can be employed due to the soil, moisture and climate conditions that the various crops need.

The final approach of increasing the utilization of arable land for the production of crops to produce biofuels can have an impact on a number of environmental parameters. These include reducing the biodiversity of the region due to a loss of habitat, increased soil erosion, a loss of soil carbon, and depletion of water resources. The type and magnitude of the impact depend to a large degree on how the change is made and how the crop is developed. There are means of mitigating many of these negative issues and some of them are employed in parts of Latin America.

The sugar cane industry in Brazil is often criticized for land expansion and the negative impact but much of the criticism is unjustified. It was shown earlier that corn and soybean acreage in Brazil has been increasing at a much faster rate than sugar acreage. The increased land devoted to sugar is not at the expense of the Amazon rain forest as shown in the following figure. The new land being cultivated is subject to strict land use requirements and harvest burning, which does destroy some habitat, is being phased out in favour of mechanical harvesting. This also has positive implications for soil carbon content and fertility but will require less labour.

While the argument about land use in Brazil has become very polarized with environmentalists concerned that rain forests are being destroyed to grow sugar cane and the industry supporters portraying new sugar cane land as just putting existing agricultural land to better use the issue will be more complex and the actual practices will encompass a range of prior uses for the new sugar cane land and in some cases there may be secondary implications. For example if it is unimproved rangeland that is converted to sugar cane production how are the displaced animals now being fed? This is just another example where details are extremely important and it is not necessarily what is being done that is important but rather how it is being done that is critical.

Figure 3-3 Sugar Cane Area in Brazil



The production and use of ethanol can provide greenhouse gas emissions reduction and air quality benefits. The exhaust emissions from vehicles are a function of the engine design and the fuel used in the engine. Great strides have been made by the automobile industry over the past 30 years in reducing the emissions from vehicles and new vehicles have reduced smog causing exhaust emissions by over 99%. The fuel used by vehicles can also have some impact on emissions and air quality. In recent years some regions in the United States have changed from using gasoline with MTBE to gasoline with ethanol and have found improvements in air quality as a result.

The real world evidence of the positive impact of the use of ethanol on the air quality in the major cities where it has been used in essentially all of the gasoline shows impressive improvements in air quality (Better Environmental Solutions and REAP). In regions where the automobiles do not have the same degree of emission controls as in the United States the magnitude of the reduction in emissions can be much larger.

The greenhouse gas emission reductions for fuel ethanol depend on the feedstock used and the details of the specific process but current practices for feedstocks such as sugar cane, corn and wheat all produce reductions in GHG emissions. The greatest reductions are derived from sugar cane ethanol. There are two reasons for this, the first is that sugar cane production has the lowest fertilizer requirements of the major sugar and starch crops, and secondly the current practice is that sugar cane mills use biomass (bagasse) to supply the thermal energy requirements for the process instead of fossil fuels. The newest plants are also producing more electricity that the mills use and in some regions this surplus power can displace electricity generated from fossil fuels providing an even larger GHG emissions benefit.

The combustion of bagasse can result in significant particulate emissions at the mills. With older, less efficient combustion systems that could create significant problems but newer, more efficient boilers are being used in new plants and retrofitted into older plants resulting in a large reduction in these emissions. In Brazil, the industrial sugarcane and ethanol plants have their atmospheric emissions controlled and monitored by government agencies.

Brazilian ethanol plants have also reduced their environmental impact on water and land surrounding the plants in recent years. Legislation addressing the discharge of mill effluents has been improved and enforced especially in the State of São Paulo (60% of all Brazilian sugarcane mills). The mills have reduced their discharge of effluents with high organic loads and replaced the discharge by controlled land application practices. This has the additional benefit of recovering some of the fertilizers in the effluent. There are probably still some examples of mills that do not follow the new practices but the trend is definitely towards better environmental performance of the mills.

Biodiesel has passed a multi-tiered process for assessing the safety and health impacts arising from handling and combusting the fuel in the United States. The US EPA determined that biodiesel does not pose an unreasonable risk to public health. The findings of the health effects testing of biodiesel include:

- The overall ozone (smog) forming potential of the speciated hydrocarbon exhaust emissions from biodiesel is 50% less.
- The exhaust emissions of particulate matter (recognized as a contributing factor in respiratory disease) from biodiesel are 30% lower.
- The exhaust emissions of sulphur oxides and sulphates, carbon monoxide, hydrocarbons are significantly reduced.

While biodiesel has been shown to increase NOx emissions in some steady state engine dynamometer testing, there is some uncertainty regarding the real world implications for two reasons. The first is that work with chassis dynamometer testing of biodiesel blends undertaken by the National Renewable Energy Laboratory (NREL) in the United States shows no clear trend in the direction of NOx emissions with varying biodiesel concentrations (Larson, 2006). Variables such as engine type, test cycle and vehicle size all appear to impact the emissions.

The other uncertainty is the impact of NOx on ozone emissions in many airsheds. NREL also found through extensive analysis of the time of day of emissions and the resulting impacts on air quality that reducing NOx emissions appears to increase the ozone levels in the atmosphere, the opposite reaction from what was expected. They concluded that reducing hydrocarbon emissions is a better strategy for improving air quality and they note that biodiesel blends clearly do decrease hydrocarbon emissions from diesel engines.

The production and use of biodiesel reduces the lifecycle emissions of GHG emissions when the all of the practical feedstocks are used in modern processes. The greatest GHG benefits result from the use of palm oil as the feedstock. Like sugar cane the benefits arise from two areas, the first is that the fertilizer and cultivation requirements are the lowest for palm oil of all of the oilseeds commercially produced and the second is that most oil crushers supply their modest energy requirements from burning some of the biomass collected in the process of harvesting the fresh fruit bunches of the palm tree.

4. BIOFUELS DEVELOPMENTS

Biofuel industries have been developed in many countries around the world including the United States, Brazil, Germany and many more countries and regions are considering measures that need to be adopted to facilitate the growth of the biofuels industry. Some of the issues and measures used to address the issues are presented here.

4.1 POLICY AND REGULATORY ASPECTS

Policy and regulatory tools used to promote biofuels must be designed to address the barriers that the biofuels face in the marketplace. Too often governments implement programs that, while well intentioned, nevertheless fail because they do not address the specific barriers that biofuels face. While these barriers can theoretically differ from country to country, in the case of biofuels the barriers are remarkably similar for both ethanol and biodiesel and in developed and developing countries. These barriers are briefly discussed here.

4.1.1 Market Barriers

The Market Barriers perspective for new product introductions views the adoption of new technologies as a market process and focuses on the frameworks within which decisions are made by investors and consumers. Anything that slows down the rate of adoption can be referred to as a market barrier. The emphasis on this perspective to market development should be on understanding the barriers and in what role governments and other key stakeholders may play to reduce those barriers.

Inertia is likely to be found in well-established markets based on conventional energy technologies that have been around for many decades. For a variety of reasons – such as ingrained consumer attitudes combined with the large expense involved in trying to change them or the advantages that existing sellers have if their technologies are based on costly capital infrastructure that has been paid for in the past – the market system may be sluggish when it comes to welcoming new products. In the past several decades, many proponents of energy conservation and diversification believed that normal market processes were far too slow at bringing about the widespread use of new energy technologies that were urgently needed to enhance energy security and the environment. They suggested that this was due to various barriers in the way of the rapid market penetration of technologies that were obviously superior in their view and they advocated government action to reduce or eliminate them. This view has created some debate about the proper role of government in addressing the barriers with the incumbent energy producers and many economists on one side and energy technology developers and environmentalists on the other side.

The various market barriers that are viewed as important are well known. The following table provides a summary list of some of the barriers that can be applicable to biofuels, along with some typical measures that are taken to alleviate the barriers. Note that a list of this sort is not comprehensive and is not meant to suggest that the individual barriers are tight categories. The barriers overlap and there is interaction between them and their effects on decisions to invest in new technologies.

Table 4-1 Types of Market Barriers

Barrier	Key Characteristics	Typical Measures
Uncompetitive market price	• Scale economies and learning benefits have not yet been realized.	• Learning investments • Additional technical development
Inefficient market organization in relation to new technologies	• Incentives inappropriately split owner/designer/user not the same. • Traditional business boundaries may be inappropriate • Established companies may have market power to guard their positions.	• Restructure markets • Market liberalization could force market participants to find new solutions
Buyer's or Business risk	• Perception of risk may differ from actual risk (e.g., 'pay-back gap') • Difficulty in forecasting over an appropriate time period.	• Demonstration • Routines to make life-cycle cost calculations easy
Finance	• Initial cost may be high threshold • Imperfections in market access to funds.	• Third party financing options • Special funding • Adjust financial structure
Price distortion	• Costs associated with incumbent technologies may not be included in their prices; incumbent technologies may be subsidized.	• Regulation to internalize 'externalities' or remove subsidies • Special offsetting taxes or levies • Removal of subsidies
Excessive/ inefficient regulation	• Regulation based on industry tradition laid down in standards and codes not in pace with development.	• Regulatory reform • Performance based regulation
Capital Stock Turnover Rates	• Sunk costs, tax rules that require long depreciation & inertia.	• Adjust tax rules • Capital subsidies
Technology-specific barriers	• Often related to existing infrastructures in regard to hardware and the institutional skill to handle it.	• Focus on system aspects in use of technology • Connect measures to other important business issues (productivity, environment)

According to the principles of market economics, governments should intervene in the economy only in a situation in which the market fails to allocate resources efficiently and where the intervention will improve net social welfare. In the 'strong' form of this view, barriers in the way of the adoption of new technologies should be dealt with by government action only if they involve *market failure*. In those cases, government should intervene to correct the market failure (again, subject to the intervention increasing net social welfare). Once this has been done, according to the market barriers perspective, government should leave decisions on the purchase of new technologies to the private sector. Therefore, one should consider to what extent the barriers identified involve market failure and whether there are any qualifications to the market failure argument. It is critical to note that not all market barriers involve market failure.

Some of the market barriers shown in Table 4-1, such as higher product costs, the risk of product failure, the high cost of finance for small borrowers, and others included in the table, are normal and inherent aspects of the operation of most markets and they should be allowed to influence decisions in energy markets just as they influence decisions in all other markets. These barriers do not usually satisfy the market failure criterion because they involve necessary costs that have to be covered for all goods and services; the existence of the barriers themselves does not provide a reason for favouring new energy technologies, which (in the classical economists view) should have to compete for investment dollars with everything else of value if resources are to be allocated efficiently.

Most instances of market failure involve *externalities,* which occur in a market transaction if any of the costs or benefits involved in it is not accounted for in the price paid for the product that is sold. If there are costs that are external to the market (i.e., the buyer does not pay some of the costs incurred in producing the product), a negative externality occurs. If there are external benefits, a positive externality occurs.

4.1.1.1 Biofuel Market Barriers

The market barriers facing biofuels are quite similar for both ethanol and biodiesel. The two most significant barriers have been the price of biofuels compared to petroleum fuels and the difficulty marketing the product through the established fuel distribution companies.

New enterprises almost always face finance and business risk barriers during the start-up phase of the industry. In many countries ethanol and biodiesel projects have struggled with issues such as project financing, uncertainty with being able to design and construction facilities with new technology and dealing with the risk of commodity prices. In some countries these issues are mostly behind the industry as plants have been built and experience has been gained with dealing these issues. In other countries that are just beginning to develop their biofuels industries these are still issues that companies must face.

Ethanol and biodiesel have also faced less significant barriers in terms of price distortion and inefficient regulation. The industry has learned either how to deal with the issues or the removal of some of the other barriers, such as the competitive price issue, has also addressed or reduced the price distortion barrier.

There are six barriers, uncompetitive price, inefficient market organization, finance risk, business risk, price distortion and inefficient regulation that biofuels face in most regions of the world when they are first introduced. The first four are the primary barriers and the second two, price distortion and inefficient regulation can slow down market penetration but are not usually show stoppers. Opponents of biofuels will often raise the issues of obsolescing the capital stock that they own in the existing fuel supply infrastructure and specific technologies issues such as the difficulty in pipelining gasoline ethanol blends or cold weather issues with biodiesel. In growing markets the issue of capital stock turnover is not usually a real issue and the technical problems can obviously be overcome when one observes the large ethanol markets in Brazil and the United States and the biodiesel markets in Europe.

Uncompetitive Price

The cost of producing biofuel is often higher than the cost of petroleum fuels, although the absolute value of the difference between the two is a function of commodity prices. In times of high crude oil prices and low agricultural prices, the gap can be small (or not exist at all) and when fossil energy prices are low, the gap can be large. In the regions of the world where biofuels have been used as a petroleum fuel blending component or fossil fuel substitute the gap has been eliminated through the use of tax incentives provided by governments. These tax incentives can be viewed as learning investments. The incentive mechanism itself can take many forms such as producer payments, payments to the biofuel blenders, or reduced consumer taxation. Governments have also invested in research and development in order to help to drive down the costs of production.

Even where there is an incentive there is concern on the part of some lenders, developers and marketers that the incentives could be removed in the future making their investments in biodiesel production and marketing unprofitable. Some governments have entered into contractual agreements with biofuel producers rather than relying just on government policy and regulation since these can usually be easily changed with little consequence to the government. Biofuels also face the problem of commodity price volatility. The changes of a few cents per litre in the selling margins could have a large impact on profitability.

Biofuels will likely require either large incentives to overcome the unattractive price (at the worst market condition) and the price volatility issue or a complicated support program that is flexible and responsive to changing market conditions that will ensure that the biofuel price is competitive with petroleum fuels but that the programs that yield the competitive price are not too costly. Policy options that just provide equity or low cost debt while effective at addressing the finance and business risk are usually not sufficient to remove the barrier of uncompetitive market price.

Inefficient Market Organization

Inefficient market organization applies when one firm or a small group of firms act in a similar manner and using the advantages of being the incumbent suppliers to resist the market penetration efforts of the new technology. In the case of transportation fuels, there are many end users of the fuel but they all purchase the product from a limited number of companies. These are also the companies that produce the competing product, gasoline or diesel fuel. In order for biofuels to penetrate the market and be available for the ultimate end user, they must be integrated into the existing distribution system.

The largest markets for biofuels in the world have used mandates and government intervention to directly or indirectly create markets for the fuels. However, mandates by themselves are not always sufficient to create markets. They must be well designed and accompanied by other measures to address the other barriers to market creation. They should not introduce additional barriers for the development of an industry.

The two largest ethanol markets in the world, Brazil and the United States both use a combination of market mandates and financial incentives to create their markets. In the past, these two markets have also used other measures to address finance and business risk barriers.

The only other policy measure that is available to address the issue of inefficient market organization is direct government involvement to restructure the industry. This is a drastic measure that has not yet been used to promote biofuels.

Buyer's Risk

The Buyer's Risk could also be termed business risk and it is important to note that it is the perception of risk that may be more important that the actual risk. The gap between perception and actual risk is larger when an industry is new and one of the measures that reduced this gap and the buyer's risk for any venture is experience.

Perhaps the best descriptions of risk for fuel ethanol plants can be found in the prospectus' and managements discussion of results of ethanol plants that are public companies. The issues are quite similar in the reports of the different companies. Typical categories for the issues are:

- Risks related to equity financing
- Risks related to debt financing
- Construction and development risks
- Operation risks
- Ethanol production risks
- Organizational structure risks

There are methods of reducing some of these risks through insurance, bonding and structural approaches but these generally add cost to a project. There have been many projects in the United States that have successfully made it through all development and construction risks. There are also projects that have not been able to raise the debt and equity required. In general, the more successful projects that there are, the lower the perception of risk becomes.

The policy options that could be used to address these concerns include, process guarantees, ensuring the tax system treats biofuels at least as favourably as fossil fuel production, industry education and training programs and other similar measures.

Finance

A barrier that is somewhat related to Buyer's Risk is that of finance. Most projects are financed by a combination of equity and debt. Raising the debt portion can be challenging for a number of reasons including imperfections in market access to capital. Debt providers generally have no opportunity to participate in any project upside so they focus on ensuring that there are no downsides to their participation. They focus on the issues of what could go wrong.

Lenders have many opportunities presented to them and they chose those opportunities that provide them with their best returns or most limited risk. Many lenders also specialize in certain sectors of the economy. These are sectors which they understand the risks and rewards. New sectors require lenders to become comfortable with the risks or at least the perception of the risks. The first projects are therefore the most difficult to finance since there is no track record which lenders can rely on. It is extremely important that the first projects be successful. Problems or failures with early projects increase the difficulty in demonstrating that new projects won't have the same problems.

Note that in cases where there is imperfect access to capital, finance barriers could be considered a market failure barrier and increased government involvement may be warranted. The involvement could include special funding, third party financing options, loan guarantees or other approaches.

Senior debt lenders are more reluctant to lend to borrowers in the following circumstances, most of which currently exist within the current biofuels industry:

- The business is a start-up business with no proven track record or proven management expertise.
- The borrowers business is in an industry where the profits are viewed as being affected by cyclical fluctuations in either the price of its finished goods or in the cost of raw materials that are key to the production of the finished goods.
- The borrower is operating in an industry that is reliant on Government programs or incentives for market access and /or positive business economics.
- The borrower has no other assets or business interests that the senior lender can attach a security interest to.
- The lender has limited knowledge and in-house expertise of the industry that the borrower's is in.
- The borrowers industry is an industry that relatively few businesses operate in and/or has a limited market for the sale of its goods or services.
- The security provided for the loan is largely intangible.

The early stage leaders provide valuable experience for the industry and allow the potential lenders to gather information that ultimately makes them more comfortable with the risk profile of the industry. The establishment of any industry without the involvement of the large companies is much more difficult. In these cases there may be a number of actions that governments can take to lower or remove the finance barriers. These include the following:

- Capital incentives to increase the amount of equity in projects.
- Loan guarantees for projects that involve large amounts of technical risk.
- Commodity price support programs that will reduce the volatility and result in more stable margins.
- Contractual undertakings that provide commercial certainty to government policies.
- Industry awareness programs to assist with raising the level of understanding that lenders have with the industry.

Price Distortion

Price distortion arises when some of the costs or benefits that arise from using a product are not reflected in the selling price. The most common example of this is the environmental costs that arise from using products that pollute the environment. These costs are real and are paid for by society through reduced crop production, increased maintenance costs and higher health costs. They are not generally included in the product cost.

In the case of biofuels, the lifecycle analysis indicates that there are greenhouse gas reductions from using the fuel and there are also reductions in the emissions of some of the tailpipe contaminants from using the fuel. These should have some value and could be used to offset the higher cost of the fuel.

The magnitude of the price distortion caused by transportation fuels has been declining in recent years as regulations that require cleaner fuels and cleaner vehicles are adopted by many countries. New vehicles have emission rates that are more than 95% less than uncontrolled vehicles in most cases. The price distortion between the modern petroleum fuels and the new biofuels is therefore much less than it has been in the past and the importance of this barrier is therefore lower than it has been previously.

The fuel taxes currently applied by governments raise substantial revenue for governments. In almost all cases, the magnitude of the taxes have been determined by overall revenue requirements rather than by factors such as the costs of building and maintaining the highway infrastructure or the other societal costs imposed by the use of the fuels.

The imposition of emission taxes would ideally be based on the actual societal costs of using the fuels. This would be a major change in the process of determining the correct taxes and is unlikely to be implemented. Emission taxes are more likely to be considered as an incremental tax on the existing system.

Some alternative fuel proponents argue that the substantial direct financial incentives and the indirect incentives provided by the tax system for fossil fuel exploration and production leads to lower prices for gasoline and diesel fuels and that contributes to the price distortion faced by biofuels. While it is difficult to quantify the level of subsidies provided to the fossil industry it is even more difficult to gauge their impact on the price of refined products since these prices are determined by world market supply and demand factors.

Excessive/Inefficient Regulation

Regulations and standards are often prescriptive and not directly performance driven. This can be effective and efficient in cases where there is significant experience with a product and the performance can be controlled in a prescriptive manner. The system does not function particularly well when new products are introduced that may not have the wealth of experience associated with their use and may not behave in exactly the same manner as the incumbent technology.

In many countries, regulations are developed through a consensus process involving producers, consumers, and regulators. In most cases, the producers are the most knowledgeable members of the panels and exert a strong influence on the outcome. In the case of new products, the incumbent producers can use this dominance to resist change to the specifications that might favour a new product. Direct government involvement in the standards setting process can address this barrier but the government must have an excellent understanding of the technical issues to ensure that the appropriate results are obtained.

4.1.2 Policy Options

The previous section has identified the market barriers that biofuels face in many markets and the types of policy options and programs that can be used to address the barriers. It is also informative to consider some of the measures that have been employed by governments in some markets to create their biofuels industries. The world's largest ethanol markets are Brazil and the United States, and Germany is the world's largest biodiesel market.

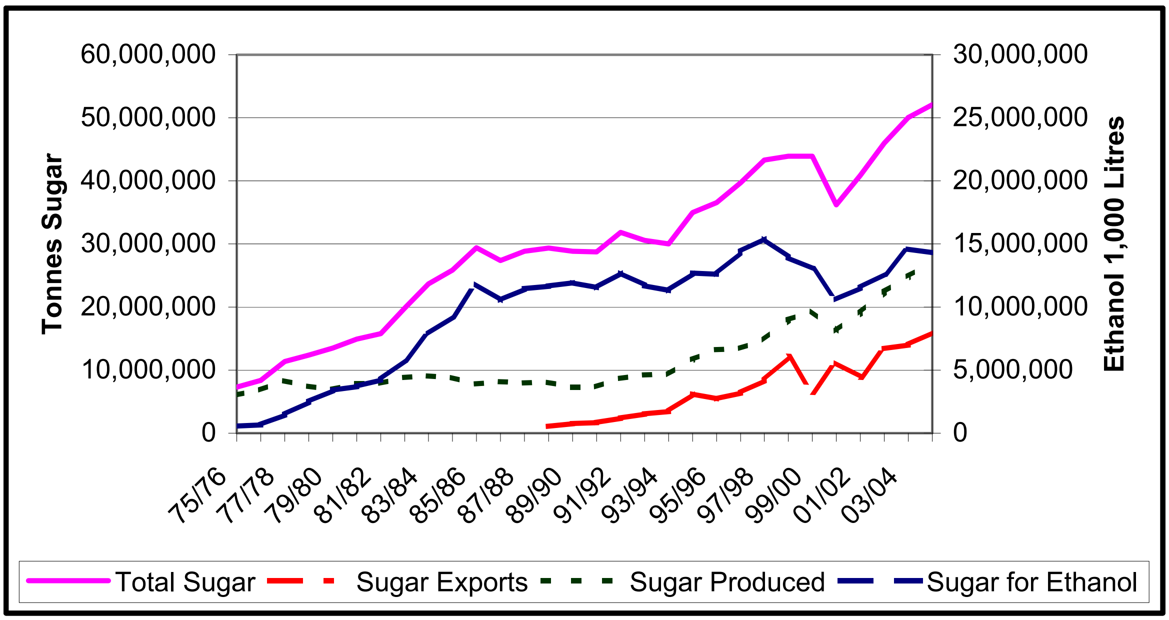
4.1.2.1 Brazil

Brazil has been the world's largest producer and consumer of fuel ethanol. All Brazilian ethanol is produced either directly from sugar cane or indirectly from sugar cane molasses and the country uses swing production of ethanol in part to manage its sugar production and sugar exports.

Ethanol is produced in more than 300 facilities in Brazil, 200 of them tied to sugar mills. This would suggest that the average output per facility is about 50 million litres per year. Sugar cane production in Brazil is increasing. The following figure shows the growth in sugar cane production over the past 27 years (Alcopar). Over this period the production has quadrupled due to increased acres planted and increased yield. The sugar yield per acre has increased by over 50% during the past 25 years as more modern agronomic practices are employed. The sugar content of the cane has also been increasing from about 10% in the 1970's to 14 to 16% in recent years.

The increased sugar production has been used for increased exports of sugar as well as increased ethanol production. The domestic sugar market in Brazil is relatively stable at about 7 million tonnes per year. The use of the sugar is shown in the following figure.

Figure 4-1 Brazilian Sugar Use



In the 1970's the government mandated the addition of ethanol to gasoline initially at the 10% level and then increased the requirements after several years to the 20 to 25% level. There were a large number of loans made to the private sector to facilitate the expansion of ethanol production. Many of these loans were at below market rates and some were eventually forgiven. The industry was also supply and demand managed by the government until the 1990's.

There were (and continues to be) fuel tax exemptions provided, which are independent of the relative price of ethanol and gasoline. These tax exemptions made ethanol very competitive with gasoline. In addition, one of the largest players in the petroleum products industry is government owned.

These combination of programs addressed the four primary barriers of price competitiveness, market access, business and finance risk that ethanol faced in Brazil.

The hydrous ethanol market is unique to Brazil and the price of hydrous ethanol at the pump has been determined by the government. This ability to control the relative financial attractiveness of this fuel through tax rates and set prices facilitated market growth and allowed a degree of demand management. This government control of the market eventually lead to the demise of the original hydrous ethanol market. The market has seen a recent resurgence with the introduction of flexible fuel vehicles and the market has been allowed to respond in a freer manner than it did in the 1990's.

While Brazilian ethanol production has been relatively stable for almost 10 years it is now in a growth phase again. Investments in new sugar mills and ethanol plants are being made by the existing producers and by some foreign companies attracted to the low production environment. This is also requiring and expansion of land devoted to sugar, which is causing increased environmental concern on the part of some stakeholders.

The biodiesel market in Brazil is being lead by government mandates.

4.1.2.2 United States

The ethanol market in the United States has been developed primarily with financial incentives and more recently by market mandates. Fuel tax incentives for ethanol were established in the late 1970's by the federal government and quickly followed by a number of states. Through the 1980's many of the states eliminated their tax incentives. Throughout this period the effective price of ethanol (after considering tax incentives) was about the same price as gasoline and yet market uptake was relatively slow.

There were also some loan guarantees provided for a few plants that were built or proposed to be built in the early 1980's. This program had some problems and only one of the plants that received a guarantee is still in operation. The US Government is a shareholder as a result of a default on the original loan provisions.

The first use of regulation to expand the US market was the Clean Air Act of 1990, which required areas that were in non-compliance with air quality regulations to add oxygen to the gasoline. Those areas that had a CO issue in the winter started adding either MTBE or ethanol in 1992 and those that had ozone problems had to add oxygen and make other compositional changes in 1995. Eventually ethanol dominated the winter market and had about one third of the summer market with MTBE having the remainder.

When it was determined that MTBE was causing ground water contamination some states moved to ban MTBE from gasoline and ethanol began to fill the void created since oxygen in gasoline was still required. With the passage of the Energy Policy Act of 2005 a requirement for renewable fuels was created that increases until it reaches 7.5 billion gallons in 2012. At the same time the oxygen requirement in gasoline was eliminated but the refiners were still required to meet the environmental performance that gasoline with oxygen had. In addition the US government decided not to offer liability protection for MTBE users. This combination of regulatory factors combined with high oil prices has lead to the surge in interest in ethanol and the rapid increase in production and plants under construction.

Through the years the US also provided programs that made direct payments to new plants and plants that expanded production. This facilitated the raising of capital for the plants.

The US programs initially focussed on equalizing the price of ethanol and gasoline and providing other forms of financial assistance to remove the barriers that ethanol faced. It is only recently that they have introduced to programs to remove the access to market barrier.

4.1.2.3 Germany

There are several lessons that can be learned from the development of the biodiesel market in Germany. The first is that for large scale market penetration it was necessary to equalize the price of petroleum diesel and biodiesel. Early efforts to introduce biodiesel at higher prices than petroleum diesel limited market uptake but did help to show for the general public that the fuel was technically feasible in the German environment.

Secondly, a large portion of the financing risk was offset by government programs that were available, not specifically for biodiesel but for any new business development in the less advantaged regions.

This combined with the relatively profitable existing agricultural co-operatives greatly reduced the barrier of access to capital. Agriculture in the European Union benefits from a number of policies and programs that are not available to the same degree in other parts of the world.

With respect to business risk, the very first German biodiesel producer was a large existing oil mill with considerable technical expertise. They also developed their own esterification process and thus were comfortable with the manageability of the technical risk. They received some funding from the EU for their first plant and their success was widely communicated as a requirement of the funding.

In the case of the market access barrier, there were fuel marketers that were willing to offer a new fuel to consumers and once the tax exemption was in place and the crude oil price high enough that all players in the supply chain, the biodiesel producers, the fuel marketers and the customers could improve their financial position the market developed rapidly. This was done in spite of a regulatory environment that effectively eliminated low level biodiesel blends, which probably have greater broad market appeal than B100.

All four of the primary barriers to creating a biodiesel market were addressed in Germany between about 1992 and 1998 when the market first started to take off. Some of the barriers were addressed by the government (tax incentives and direct financial injections), some by the industrial participants with government support (business risk and market access) and some factors, such as rising oil prices, were fortuitous.

The secondary barrier of inefficient regulation has taken longer to address. It should be noted that this barrier has been used both against and by the biodiesel producers. Low level biodiesel blends were first non-competitive due to the tax regulations and are now limited to 5% by the petroleum diesel fuel regulation. The biodiesel specification in Germany has an Iodine number requirement that is effective in reducing competition for the rapeseed biodiesel producers in Germany from soy biodiesel producers in North and South America.

4.2 A Regional View of Biofuel Development

There is worldwide interest in an expanded role for biofuels. This level of interest is evident from the actions of a number of governments and the investments that the private sector is making in the industry. The primary driving factors do vary from region to region and while there are sound policy reasons for expanding biofuels use, the motivating factor for action is often political rather than policy driven.

The world's economy is vulnerable to higher oil prices, in the past high oil prices have preceded global economic downturns. In general the developed nations have become more energy efficient since the oil shocks of 30 years ago and in theory are in a better position to absorb the impact of high oil prices but the situation may not be the same in all developing regions.

The high level scan of the countries in Latin America where the Bank has an interest has determined that many of them are dependent on imported crude oil or imported petroleum products. At the same time many of the countries are significant exporters of biomass that could be used to produce ethanol or biodiesel. These agricultural exports must also compete in world markets that are heavily subsidized. The OECD has estimated that its member countries provide $280 billion in support to their agricultural producers each year. Agricultural producers in the developing world are not always able to compete in the subsidy war with the developed nations and thus suffer either in terms of reduced production or reduced revenue. Either impact creates rural employment and economic development issues.

At the same time there are clearly success stories from those countries that have had a long history of supporting biofuels development and production. Biofuel proponents are very active in almost all countries of the region and in fact the world in promoting the benefits that biofuels offers. The biofuels proponents are sometimes local advocates but international companies that participate in the biofuels sector are also active in promoting the benefits of biofuels.

Traditionally biofuels have required some price support to achieve any significant degree of market penetration. With high oil prices, ethanol in particular and in some locations biodiesel, can be produced and marketed at prices competitive with petroleum products. There is no guarantee that oil prices will remain in the $70/bbl range and there is clear evidence that increased demand for feedstocks for biofuels has created upwards price pressure on the feedstocks. This is good for agricultural producers but it creates uncertainty for investors and lenders, which impedes market development.

There are international trade barriers that biofuels must face. This is not unexpected given the agricultural roots of the industry, the initial proponents in most countries being the agricultural producers, and the fact that the economic benefits from biofuels result from producing the product and the economic costs result from using the product. Thus when international trade is present it is difficult to offset the costs and benefits within a single jurisdiction.

Biofuel industries have thus developed in countries that have large markets (that allow economies of scale to be achieved), have their own substantial feedstock resources, and have implemented comprehensive incentive programs that have addressed the four primary barriers that biofuels face (price competitiveness, market access, buyers’ and finance risk).

There are a number of countries in Latin America that do have large transportation fuel markets and do have significant feedstock resources. If these countries make the commitment to implementing a policy framework to address the four primary market barriers then it is likely that a biofuels industry would takeoff in those regions.

There are other countries that do not have the same scale in terms of markets and feedstock production. However the other drivers of rural economic development and high costs associated with oil imports will still exist. These countries will have biofuel proponents and will face pressure to implement biofuels support programs but it will be more difficult (and probably more expensive) to develop a successful biofuels industries in these regions.

5. POTENTIAL ACTIVITY AREAS FOR BIOFUEL DEVELOPMENT

Interest in biofuel development is likely to increase as long as energy prices remain high, environmental issues persist and unemployment remains a problem in rural areas around the world. The biofuel success stories of ethanol in Brazil and the United States and biodiesel in Germany will serve as examples to be replicated in developed and developing countries around the world. In all countries there is a tendency to overlook the time and effort that was required for these success stories to develop. It is also possible to find examples where biofuels have had a difficult time developing and reaching their potential. Often the measures introduced by governments address only some of the barriers and stakeholders become frustrated at the lack of or slow pace of development. There are a number of potential areas where the Bank may wish to consider undertaking some activity in support of biofuel development.

5.1 POLICY DEVELOPMENT

Many governments get involved with biofuels without understanding all of the issues as it applies to their individual country. The governments typically respond to approaches by stakeholders promoting biofuels, other stakeholders provide their views, and soon governments are reacting to events rather than being proactive and rationally assessing the situation.

There is an obvious role for an independent body to provide assistance to governments both proactively and reactively. This assistance can take many forms but should include the following steps:

- Broad opportunity assessment. What is the potential for biofuels in an individual country? The bank may wish to proactively consider a relatively high level scan of the potential of biofuels in the member countries. This would consider the feedstock potential and domestic market opportunities in each country and could identify those countries most likely to achieve early success with biofuels.
- Strategic opportunity assessment. The development of a screening tool that individual countries could use to assess the market potential of biofuels, the production potential, and the barriers that could be faced. Other drivers, such as agricultural issues, could also be considered. While this would be in reaction to requests for assistance from individual countries it would be carried out in more detail than the broad opportunity assessment. There would be a higher level of engagement on the part of the interested country.
- Policy development guidelines. Experience has shown that biofuels face similar barriers in most of the world. While the magnitude of the barriers may be different in different regions and there are a variety of means of addressing the barriers, successful policy programs will address all of the barriers. The bank may wish to develop guidelines for developing successful programs. This could include not only the primary barriers and options but also good practice guidelines with respect to health, safety and environmental issues involving all aspects of feedstock and biofuel production and utilization of biofuels.

There are two broad policy issues that have applicability to biofuels development in all countries in the region that the bank may wish to gain a better understanding of and perhaps help to foster, these are international trade and the Clean Development Mechanism.

Most countries recognize the economic benefits of international trade for a broad range of goods and services. The challenge for biofuels has traditionally that the costs of biofuel programs are generally related to using the fuel (since it is often a higher price than fossil fuels) and the benefits arise from producing the fuel. When the fuel is used in the country that it is produced in the costs and benefits can offset each other but when international trade is involved the costs and benefits accrue to different governments. Government support for biofuels exports is not aligned with most countries international trade obligations and should not be encouraged but perhaps there are some alternatives that could be considered such as bi-lateral trade agreements or regional trade pacts. The Bank could consider investigating some of these issues and alternatives.

The Clean Development Mechanism (CDM), as outlined in Article 12 of the Kyoto Protocol and elaborated in the Marrakech Accords, is a project-based mechanism that allows public or private entities to invest in greenhouse gas mitigating activities in developing countries and earn abatement credits, which can then be applied against their own GHG emissions or sold on the open market. In addition to reducing emissions, CDM projects have the dual objective of contributing to the sustainable development of the host country.

An industrialised country that wishes to get credits from a CDM project must obtain the consent of the developing country hosting the project that it will contribute to sustainable development. Then, using methodologies approved by the CDM Executive Board (EB), the industrialised country must make the case that the project would not have happened anyway (establishing additionality), and must establish a baseline estimating the future emissions in absence of the registered project. The case is then verified by a third party agency, a so-called Designated Operational Entity to ensure the project results in real, measurable, and long-term emission reductions. Upon final approval by the Executive Board a number of Certified Emission Reductions, CERs, are awarded to the applicant based on the difference between the baseline and the actual emissions.

There have been about 300 CDM projects approved by the Executive Board. None of the approved projects involved biofuels for transportation applications. While there has been some interest in biodiesel and fuel ethanol projects from a CDM mechanism none of the proposals have been able to meet all of the requirements of the Executive Board so far. There is still one biodiesel project proposal that appears to be in process.

A successful biofuel CDM project may provide a template for other projects to follow and having access to the CDM process may make financing and operating CDM projects feasible. There are a number of roles that the Bank may wish to consider in the CDM process including assistance with methodology development, facilitating or participating the financial transactions involved, or other roles. The relationship between CDM and expanded International trade may be an issue that could be investigated.

5.2 Technical Support

If there is a suitable combination of policy environment and commodity prices then there will be groups wishing to build and operate biofuels facilities in various countries. These proponents will have to go through a similar learning curve in all of the countries. The cost and ease of acquiring this experience can be reduced if technical support is provided to the proponents. This support can take many forms including:

- A good central depository of information of biodiesel and fuel ethanol production including a roster of available experts to assist with project development. The development of similar information on feedstock production may be advantageous, particularly if it emphasizes sustainable development issues that other source may not focus on.
- Biofuel plant guides have been developed in a number of countries. These guides walk a proponent through the steps of pre-feasibility evaluations, feasibility studies, project development activities such as site selection, process supplier identification and assessment, the permitting process, identifying and applying for incentive programs, and the pre-start-up activities. The Bank could consider the development of guides targeted to biofuels production in Latin America and the Caribbean. These guides should have some emphasis on the environmental precautions that are necessary to ensure that the projects are developed in a sustainable way.
- There will be a need for educational tools for all stakeholders in the process from the feedstock producers through to the end user of the biofuel. The bank could consider developing or supporting the development of these tools. These tools could range

from educational curriculum at post secondary institutions for training skilled labour to mass media information to assist with product marketing.

5.3 Investment

As a biofuel industry develops in Latin America and the Caribbean there likely will be a number of investment opportunities presented to the Bank. It may be advantageous to prepare for this eventuality. The Bank could adopt a reactive positioning where they would need to develop or have access to the expertise required to assess the opportunities presented to it not only from a financial perspective but also from a technical and environmental perspective.

The Bank could also consider a more proactive posture where they develop and market a number of financial tools and programs that will be helpful in addressing the financial barriers that biofuel proponents are likely to face as they try and develop their projects.

The Bank should consider the potential of both the reactive and proactive positioning and how each might fit with the Banks policies, objectives, and strategies.

5.4 Summary

It was identified in Section 3 that 18 of the 26 countries of interest are importers of petroleum products and exporters of the feedstock that could be used to produce a biofuel to substitute for the fossil fuel import. These countries would appear to be natural candidates for biofuels. However, even some of the other eight countries have an interest in biofuels. Fossil fuel rich countries such as Columbia, Venezuela, and Argentina either have commercial biofuels programs underway or are in the process of establishing such programs. With such widespread interest in biofuels and the apparent market potential in almost all borrowing members it will be very difficult for the Bank to focus only on a few countries.

There is no shortage of opportunities for the Bank to pursue in the field of biofuels. The bank needs to develop its strategy in this area so that it can successfully participate in the field. The biofuels strategy needs to be compatible with the Bank's goals to promote poverty reduction and social equity and foster environmentally sustainable growth in the region. The strategy should address the main issues that the biofuels sector faces:

- Stimulating demand for biofuels. Can the Bank play a role in fostering good policy development in the region?
- Capturing the environmental benefits. Should the Bank become an advocate for ensuring that the environmental benefits of biofuels are optimized as the industry expand in Latin America?
- Develop production and distribution of biofuels. Can the Bank develop programs that will be beneficial to biofuel proponents building an industry in Latin America? Should the Bank be a lender to all potential participants or should it focus its efforts on projects that will deliver the maximum benefits to the rural economy and the environment?
- Expand the feedstock supply. While diverting exports to new domestic markets is the easiest means of establishing a new biofuels industry the real benefits in terms of rural economic development will result from increased rural economic activity resulting from the expansion of the feedstock supply. Can the Bank play a unique role in facilitating this expansion?
- Enhance trade opportunities. Most of the biofuels produced around the world are used in local domestic markets. Some of the poorest countries are likely to have a large imbalance between their production capacity and their domestic demand. These countries would benefit from a more open international market for biofuels. Is there are strategy that the Bank can follow that would enhance these opportunities?

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7. APPENDICES

Further detail on the supply and demand situation for transportation fuels and biofuel feedstocks in each country is presented here.

7.1 TRANSPORTATION FUEL SUPPLY AND DEMAND

The following three tables summarize the crude oil and refined products situation in the 26 countries that are borrowing member countries of the IADB. The data is from the US Energy Information Administration. Note that eight countries do not appear to have their own refining industries and thirteen countries do not have any crude oil production. Those countries that are net importers of crude oil or have no domestic refining industry and are thus dependent on the world market are identified in bold. These countries are most likely to have energy security concerns. One often finds that countries with large oil production sectors are not open to biofuels development, although there are exceptions such as Brazil and Columbia. The countries are ranked by the size of their oil exports.

Table 7-1 Crude Oil Supply and Demand

	Oil Production	Oil Imports	Oil Exports	Oil Demand
	1,000 bbls/day	1,000 bbls/day	1,000 bbls/day	1,000 bbls/day
Mexico	3,798.9	0	1,998.2	1,800.7
Venezuela	2,581.4	0	1,535.0	1,046.4
Ecuador	411.3	0	265.3	146.1
Brazil	1,847.5	351.2	241.7	1,957.0
Colombia	554.7	1.2	229.9	325.9
Argentina	865.8	32.7	229.8	668.7
Trinidad and Tobago	165.9	88.7	86.6	168.1
Peru	91.8	83.6	27.0	148.4
Guatemala	22.0	0	22.0	0.0
Bolivia	38.5	0	2.4	36.1
Suriname	9.5	0	2.1	7.3
Barbados	1.0	0	1.3	-0.3
Chile	16.9	200.2	0	217.1
Dominican Republic	0.01	41.8	0	41.8
Uruguay	0.5	32.8	0	33.4
El Salvador	-0.5	20.1	0	19.6
Nicaragua	-0.4	17.9	0	17.5
Jamaica	-0.5	17.7	0	17.1
Costa Rica	-0.3	10.6	0	10.3
Paraguay	-0.03	1.6	0	1.6
Bahamas, The	0	0	0	0.0
Belize	0	0	0	0.0
Guyana	0	0	0	0.0
Haiti	0	0	0	0.0
Honduras	0	0	0	0.0
Panama	0	0	0	0.0

Countries that are significant importers of gasoline are candidates for ethanol production. The average size of ethanol plant in Brazil is about 40 million litres/year; this is about one quarter the average size of ethanol plants in the United States. A 40 million litre/year plant produces about 700 bbls/day and thus could supply a 7,000 bbl/day gasoline market with a 10% ethanol blend. Nine countries import more than 7,000 bbls/day of gasoline. There are several other countries with large gasoline markets that could be good candidates for ethanol production. The gasoline supply situation is summarized in the following table. The countries are ranked by the size of their gasoline imports.

Table 7-2 Gasoline Supply and Demand

	Production	Imports	Exports	Consumption	Imports % Consumption
	1,000 bbls/day	1,000 bbls/day	1,000 bbls/day	1,000 bbls/day	
Mexico	470.2	119.9	2.2	587.9	20%
Guatemala	0.0	18.4	0	18.4	100%
Dominican Republic	6.6	16.7	0	23.3	72%
Costa Rica	0.7	12.8	0	13.6	94%
Ecuador	38.2	10.7	7.1	41.9	26%
Chile	53.9	10.6	15.9	48.7	22%
Panama	0.6	8.9	0.1	9.4	95%
Jamaica	2.6	8.8	0	11.4	77%
Honduras	0.1	7.4	0	7.5	99%
El Salvador	3.2	6.5	0.05	9.7	67%
Trinidad and Tobago	28.1	5.9	26.1	7.9	75%
Bahamas, The	0.0	5.1	0	5.1	100%
Colombia	107.5	5.0	19.8	92.7	5%
Paraguay	0.3	3.6	0	3.9	92%
Belize	0.0	3.3	0	3.3	100%
Brazil	320.8	3.1	46.4	277.5	1%
Haiti	0.0	2.5	0	2.5	100%
Guyana	0.0	2.0	0	2.0	100%
Barbados	0.0	1.9	0	2.0	98%
Suriname	0.0	1.8	0	1.8	100%
Nicaragua	2.4	1.5	0	3.9	39%
Uruguay	7.5	1.0	2.6	5.8	17%
Peru	24.1	0.9	5.9	19.1	5%
Argentina	144.3	0.3	59.6	84.9	0%
Venezuela	273.7	0	65.3	208.4	0%
Bolivia	11.9	0	0	11.9	0%

Similar information on the distillate fuel situation is summarized in the following table. Countries that import large quantities of diesel fuels are candidates for biodiesel production. More countries import diesel fuel than import gasoline. The countries are ranked by the quantity of diesel fuel imported.

Table 7-3 Distillate Supply and Demand

	Production	Imports	Exports	Consumption	Imports % Consumption
	1,000 bbls/day	1,000 bbls/day	1,000 bbls/day	1,000 bbls/day	
Brazil	605.2	65.8	14.1	656.9	10%
Dominican Republic	6.4	25.6	0	32.0	80%
Peru	33.1	22.6	0	55.7	41%
Mexico	286.0	22.6	2.9	305.7	7%
Guatemala	0.0	22.4	0	22.4	100%
Honduras	-4.0	20.0	0	15.9	125%
Panama	0.0	16.1	0	16.1	100%
Paraguay	2.6	15.6	0	18.2	86%
Ecuador	31.8	14.0	0.6	45.2	31%
Chile	79.5	13.7	6.7	86.4	16%
Costa Rica	2.8	12.2	0.0	15.0	82%
El Salvador	3.7	9.5	0.4	12.8	74%
Jamaica	3.3	8.0	0.5	10.8	74%
Bahamas, The	0.0	7.1	0.4	6.7	107%
Haiti	0.0	6.2	0	6.2	100%
Bolivia	9.6	5.5	0	15.1	37%
Guyana	0.0	5.4	0	5.4	100%
Argentina	207.7	4.0	27.3	184.4	2%
Uruguay	12.2	3.3	0	15.5	21%
Nicaragua	3.9	2.9	0.04	6.8	42%
Suriname	0.8	2.3	0	3.1	74%
Belize	0.0	1.9	0	1.9	100%
Barbados	0.0	1.5	0	1.5	100%
Colombia	63.7	0.7	2.3	62.0	1%
Trinidad and Tobago	23.8	0	18.1	5.7	0%
Venezuela	232.8	0	129.5	103.3	0%

7.2 BIOFUEL FEEDSTOCK SUPPLY AND DEMAND

The feedstock supply situation in the countries of interest has been identified by using the FAO statistical database (FAO Stats). This database provides access to over 3 million time-series and cross sectional data relating to food and agriculture. It contains data for 200 countries and more than 200 primary products and inputs and includes production data, trade data, consumption, price and resource data.

The primary ethanol feedstocks of interest include barley, maize (corn), wheat, sorghum, other cereals, rice, cassava, potatoes, sugar beats and sugar cane. These crops are grown in many of the countries of interest but in many cases the crops are currently used for domestic purposes for food or feed or are not produced in sufficient quantity to support a biofuels industry. The total production of the feedstocks that could be used for ethanol production is summarized in the following table. The countries are ranked by their sugar production.

Table 7-4 Ethanol Feedstock Production

	Barley	Other cereal	Maize	Cassava	Potatoes	Rice	Sorghum	Sugar cane	Wheat
	1,000 t/year								
Brazil	387	48	41,806	23,927	2,931	13,277	2,131	416,256	5,726
Mexico	932	2	21,670	24	1,735	279	7,004	48,373	2,321
Colombia	3	0	1,399	1,943	2,836	2,721	238	40,020	44
Argentina	1,004	234	15,000	170	2,021	1,060	2,160	19,300	14,560
Guatemala	1	0	1,072	16	283	35	52	18,000	11
Peru	177	34	1,181	961	2,996	1,817	0	9,680	169
Venezuela	0	0	2,176	511	350	974	563	8,814	0
Ecuador	24	1	733	115	431	1,346	10	6,590	14
Dominican Republic	0	0	38	91	37	577	5	5,547	0
El Salvador	0	0	648	18	13	27	148	5,280	0
Bolivia	62	24	686	434	828	305	151	4,800	108
Honduras	0	0	498	10	22	7	12	4,578	1
Nicaragua	0	0	444	87	30	233	97	4,027	0
Costa Rica	0	0	13	295	76	247	2	3,805	0
Paraguay	0	0	1,120	5,500	1	125	19	3,637	715
Guyana	0	0	4	29	0	502	0	3,000	0
Jamaica	0	0	1	15	4	0	0	2,100	0
Panama	0	0	80	30	25	318	5	1,650	0
Belize	0	0	31	1	1	11	8	1,149	0
Haiti	0	0	180	330	10	102	85	1,080	0
Trinidad and Tobago	0	0	3	1	0	3	0	580	0
Barbados	0	0	0	0	0	0	0	361	0
Uruguay	407	3	223	0	138	1,263	70	154	533
Suriname	0	0	0	4	0	195	0	120	0
Bahamas	0	0	0	0	0	0	0	56	0
Chile	56	70	1,321	0	1,144	119	0	0	1,922
Total	4,053	1,416	91,327	35,512	16,912	26,543	13,760	609,957	27,124

There are however, a number of countries that are net exporters of these crops and they could potentially divert these exports to fuel ethanol production. The net exports of the feedstocks of interest are shown in the following table. The countries have been ranked based on their sugar exports. Note that this produces a different ranking than that based on their sugar production.

Table 7-5 Ethanol Feedstock Potential

	Barley	Other cereal	Maize	Cassava	Potatoes	Rice	Sorghum	Sugar cane	Wheat
	1,000 t/year								
Brazil	0	0	4,924	0	0	0	133	129,311	0
Guatemala	0	0	0	0	16	0	0	12,055	0
Colombia	0	5	0	0	32	0	0	8,917	0
El Salvador	0	0	0	0	0	0	0	2,533	0
Guyana	0	0	0	0	0	357	0	2,481	0
Dominican Republic	0	0	0	1	0	0	0	2,222	0
Costa Rica	0	6	0	166	0	0	0	2,141	0
Argentina	440	602	10,823	0	138	347	191	1,877	10,257
Nicaragua	0	0	0	6	0	0	0	1,442	0
Bolivia	0	0	0	0	34	16	0	1,361	0
Honduras	0	0	0	0	0	0	0	1,140	0
Belize	0	0	0	0	0	0	0	699	0
Jamaica	0	0	0	0	0	0	0	520	0
Ecuador	0	0	0	8	0	23	0	413	0
Paraguay	0	0	355	28	0	15	0	394	311
Panama	0	0	0	0	0	0	0	281	0
Barbados	0	0	0	0	0	0	0	271	0
Mexico	0	0	0	0	0	0	0	250	0
Bahamas	0	0	0	0	0	0	0	0	0
Chile	0	10	0	0	0	0	0	0	0
Haiti	0	0	0	0	0	0	0	0	0
Peru	0	0	0	0	0	0	0	0	0
Suriname	0	0	0	0	0	34	0	0	0
Trinidad and Tobago	0	0	0	0	0	0	0	0	0
Uruguay	257	0	0	0	0	857	0	0	0
Venezuela	0	0	0	0	0	0	0	0	0
Total	1,697	1,623	17,102	1,209	1,220	2,649	1,324	169,308	11,568

The primary biodiesel feedstocks of interest are animal fats, palm oil, soybean oil, and sunflower oil. There are also minor quantities of other vegetable oils produced such as rapeseed and castor oil. The total production of the feedstocks that could be used for biodiesel production is summarized in the following table. This production is either used internally for food or feed or in some cases is exported. The countries are ranked by their total oil production.

Table 7-6 Biodiesel Feedstock Production

	Animal fats	Oil palm	Soyoil	Sunflower oil	Total
	1,000 t/year	1,000 t/year	1,000 t/year	1,000 t/year	1,000 t/year
Brazil	610	550	49,793	200	51,153
Argentina	251	0	31,500	3,100	34,851
Paraguay	17	126	3,584	45	3,771
Colombia	26	3,150	68	0	3,244
Ecuador	29	1,844	107	0	1,980
Bolivia	17	0	1,670	168	1,855
Honduras	3	1,135	1	0	1,139
Costa Rica	4	1,080	0	0	1,084
Guatemala	4	580	36	0	619
Uruguay	32	0	377	177	586
Mexico	133	221	132	1	487
Peru	205	209	3	0	416
Venezuela	20	315	3	1	339
Chile	163	0	0	3	166
Dominican Republic	8	154	0	0	162
Panama	29	64	0	0	93
Nicaragua	3	56	8	0	67
Haiti	5	0	0	0	5
El Salvador	1	0	3	0	4
Jamaica	1	0	0	0	1
Suriname	0	1	0	0	1
Trinidad and Tobago	1	0	0	0	1
Bahamas	0	0	0	0	0
Barbados	0	0	0	0	0
Belize	0	0	0	0	0
Guyana	0	0	0	0	0
Total	2,562	10,485	88,285	4,695	103,024

The potential net biodiesel feedstock production is summarized in the following table. These are based on the net exports of the feedstocks from each country. The countries are ranked by their total oil exports.

Table 7-7 Potential Biodiesel Feedstocks

	Animal fats	Oil palm	Soyoil	Sunflower oil	Total
	1,000 t/year	1,000 t/year	1,000 t/year	1,000 t/year	1,000 t/year
Brazil	16	0	6,979	0	6,996
Argentina	32	0	5,721	228	5,981
Colombia	0	1,075	0	0	1,075
Costa Rica	0	900	0	0	900
Paraguay	0	8	733	5	746
Honduras	0	348	0	0	348
Ecuador	3	326	0	0	329
Guatemala	0	291	0	0	291
Bolivia	0	0	256	6	263
Peru	154	0	0	0	154
Uruguay	7	0	53	13	73
Panama	9	0	0	0	9
Belize	0	0	0	0	0
Bahamas	0	0	0	0	0
Guyana	0	0	0	0	0
Barbados	0	0	0	0	0
Suriname	0	0	0	0	0
Haiti	0	0	0	0	0
Nicaragua	0	0	0	0	0
Trinidad and Tobago	0	0	0	0	0
Jamaica	0	0	0	0	0
El Salvador	0	0	0	0	0
Dominican Republic	0	0	0	0	0
Chile	0	0	0	0	0
Venezuela	0	0	0	0	0
Mexico	0	0	0	0	0
Total	1,221	3,948	14,742	1,252	18,165