A Blueprint for Green Energy in the Americas

Strategic Analysis of Opportunities for Brazil and the Hemisphere

Featuring: The Global Biofuels Outlook 2007

Prepared for the
Inter-American Development Bank
by Garten Rothkopf

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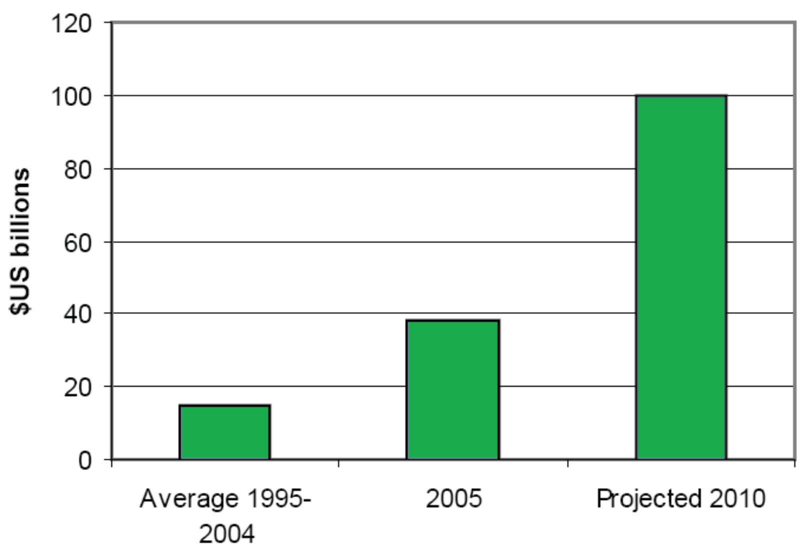
I. EXECUTIVE SUMMARY

A) Introduction

This report was commissioned by the Inter-American Development Bank to identify opportunities in Brazil, and in the Americas more broadly, in the emerging global biofuels industry. The goal is to offer a strategic blueprint for IDB activities in the region and serve as the basis for even more focused and policy-oriented studies in the future.

Much of the world is in the midst of a major reexamination of—and investment in—clean energy. Soaring oil prices and increasingly acute concerns about climate change have turned what used to be a cottage industry into a booming business. By 2010, it is estimated that US$100 billion will be invested in clean energy, compared to US$38 billion in 2005, and just over US$5 billion a decade before. Investment is coming from a variety of different, and sometimes unexpected, sources. China's government recently announced that it will invest US$187 billion in clean energy through 2020.

Chart 1a: Global Renewable Energy Investment

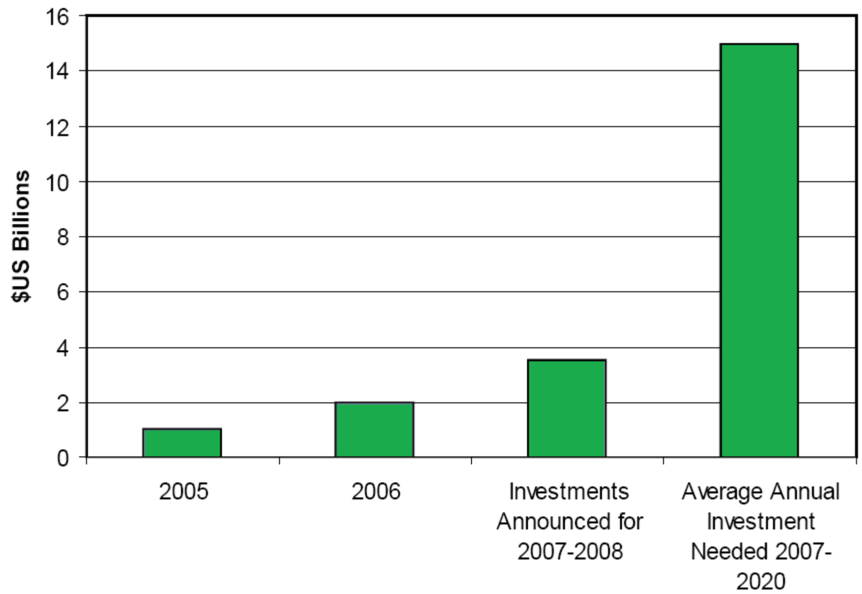


Source: Compiled from Ren21 and New Energy Finance

Biofuels are an important element in this rapidly shifting environment. Around the world, large subsidies are being offered to spur production of ethanol and biodiesel. And a growing number of governments are requiring that biofuels be blended with fossil fuels. Blend mandates have been enacted or are under consideration in 27 of the 50 countries surveyed by this report, and 40 have some form of biofuels promotion legislation. Perhaps most significantly, the promise of second-generation technology, particularly commercially viable cellulosic ethanol, will dramatically change the global competitive landscape. Nations capable of innovating will have tremendous advantages, both because the emerging technologies will support their industries and because they will possess a high value-added export.

Given the aggressive blend mandates established or under consideration in the world's leading transport fuel markets, a conservative projection of the potential share of biofuels in global transport energy consumption in 2020 is 5%, up from just over 1% today. Meeting this demand would require a nearly five-fold increase in biofuels production worldwide, and an investment of over $200 billion in the next 14 years in capacity expansion alone. This dwarfs the investment in biofuels in recent years, $1 billion in 2005 and a projected $2 billion in 2006, although the pace is picking up with $7 billion already announced in new projects through 2008.[1]

Chart 1b: Annual Global Biofuels Investment



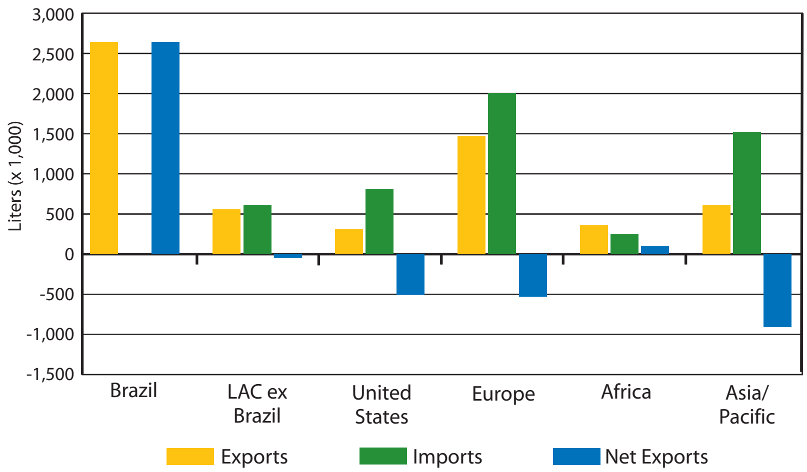
Source: Compiled from Ren21 and Garten Rothkopf calculations

The enthusiasm surrounding the biofuels sector is infectious. However, it is a basic assumption of this report that biofuels are not a panacea, but one important choice in an increasing array of energy options. They have a significant role to play in the reduction of greenhouse gas emissions from transport and represent an opportunity for the region to build on its natural endowments by establishing world-class centers of innovation and production, developing rural economies, and attracting private sector investment. The report seeks to cut through the hype surrounding biofuels, and alternative energy writ large, and present an objective, fact-based analysis of the region's global competitive position looking forward to 2020.

The development of biofuels in the Americas must be understood within the global context of larger trends in energy production and consumption. This report therefore begins with the major trends in global energy: the drivers of demand, the constraints on supply, and the twin imperatives of energy security and emissions reductions. The promise of biofuels is then assessed relative to the leading alternative technologies in the transport sector: hydrogen fuel cells and coal liquefaction. This is followed by the "Global Biofuels Outlook 2007", an assessment of the state of biofuels in 50 countries on 6 continents, highlighting the critical areas of government policy, productive capacity, private sector investment, and research and development. It is, to the best of the authors' knowledge, the most extensive survey of global biofuels (both ethanol and biodiesel) available today.

Brazil has a unique and leading position in the emerging global biofuels industry. Its role in developing technologies that allow consumers to switch easily between fossil fuels and biofuels has been little short of revolutionary. ***Energy choice, a concept this report will focus on, has a powerful champion in Brazil.*** On the production side as well, Brazil is second only to the US. In 2005, Brazil exported 2.6 billion liters of ethanol, about half of all ethanol traded internationally that year. Its sugarcane-based ethanol is the most cost-competitive biofuel in existence. Brazil is also one of the few countries with the available arable land to expand production enough to become a major exporter. All these factors have made Brazilian advice and expertise on biofuels highly sought after commodities. As will be discussed, the Brazilian government has developed a number of initiatives to work more closely with neighbors and regional partners. In light of Brazil's prominence, this report devotes considerable attention to the path it has taken and the choices it is making to adjust to this changing environment.

Chart 1c: Top Global Exporters of Ethanol (2005)



Source: F.O. Licht

However enviable Brazil's current position in biofuels, the challenges it faces are not minor ones. Brazil's competitive position is the product of decades of private and public sector investment, but continued leadership is far from assured. Indeed, in 2005, the United States surpassed Brazil in total ethanol production. The Brazilian government is acutely aware of the need for both increased production and infrastructure and additional resources for innovation. It has set ambitious goals, and this report seeks to provide the IDB with strategies to help achieve them.

The report also looks to the rest of the Americas with the goal of developing a strategy for IDB regional support that will enable countries in the region to take full advantage of the opportunities for growth. Because energy choice is an important paradigm in this report, it does not offer a one-size-fits-all strategy. The decision to focus on biofuels is a complex choice that will depend on the priorities of each government and public. Rather than proffering policy, the report seeks to identify the tools necessary for countries to make informed choices if they do move forward with a biofuels strategy, including in-depth feasibility studies, R&D centers, financing lines for capacity expansion, and investment in infrastructure projects. To do so, this report uses a basic framework through which countries can be evaluated in terms of the current state of their biofuels industries and the appropriate next steps.

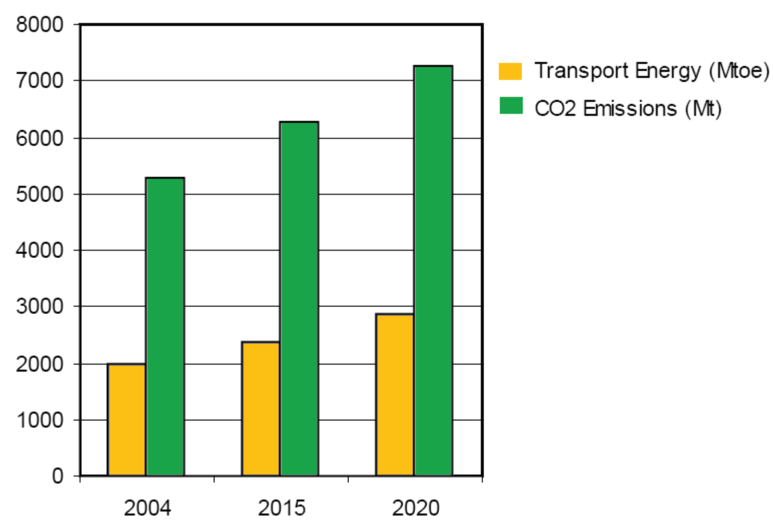
A central challenge addressed by this report is that ***the region, despite having achieved sustained economic growth, has not yet succeeded in cultivating centers of excellence*** - key sectors and regions that achieve a level of enduring international competitive leadership and become a natural destination for investment, like India's Bangalore, Boston's Route 128, or China's Shenzhen. The biofuels industry in Brazil, already a global leader, has the potential to achieve this distinction. Opportunities in biofuels are not limited to Brazil, however, and include Colombia's promising biodiesel program, Chile's potential for cellulosic ethanol production, and the sugar export centers of Central America and the Caribbean. A primary focus of the IDB biofuels strategy will be developing centers of excellence that bring together the best minds, best companies, and best thinking of not only the hemisphere, but the world, organized around showcase projects designed to be magnets for future investment and engines of future growth.

B) Global Trends

There is a general consensus among leading energy information sources that ***energy consumption will surge as much as 30% by 2020.*** A growing world population and strong economic growth in developing countries will propel energy consumption, and the twin forces of urbanization and industrialization will accelerate this trend. On the supply side, the depletion of the world's fossil fuels will continue, though the precise pace and course is uncertain. Concerns about geopolitical instability and fuel-supply security, as well as pollution and climate change, are pushing the world to find alternative sources of clean energy and reduce harmful emissions.

The transport sector is a vital component of an effective response to growing energy demand. It contributed 20% of global gas emissions in 2001; it registered the fastest greenhouse gas emission growth in developed countries like the US, Japan, and the EU; and the sector is on course to consume 55% more energy by 2030. In this environment, the introduction of cleaner, non-fossil fuels to the transport sector is a priority. Developing countries, such as China and India, which face an explosion in vehicle growth, also cannot afford to ignore the issue. Governments around the world, aware of the wealth of new technologies and energy alternatives available in this new age of energy choice, are already tailoring energy policies to their unique circumstances.

Chart 1d: Transport Energy Demand and CO2 Emissions[2]



Source: Based on IEA Alternative Policy Scenario

This report lays out the competitive position of biofuels relative to its two principal alternatives: coal-to-liquid technology and hydrogen fuel cell technology. Coal liquefaction is popular with governments because it is, like biofuels, a proven technology. It also represents a cheap source of energy, burns more cleanly than gasoline, and is readily available for countries with huge coal reserves. The second alternative, hydrogen fuel cell technology, is favored because it is potentially the cleanest energy possible. Hydrogen is also abundant, because it can be produced from renewable energy sources such as solar, wind, water, and biomass energy, as well as from traditional energy sources such as oil and natural gas.

Despite its environmental drawbacks, coal liquefaction is likely to remain an important energy choice in coal-rich countries like China, Russia, India, and even the US. For its part, hydrogen fuel cell technology remains prohibitively expensive, and it is unlikely to emerge as a feasible alternative energy source in the transport sector for at least the next decade. Even then, the high cost of new infrastructure will likely render it infeasible for all but the wealthiest countries.

There are a number of risks associated with the production of biofuels. Environmental risks, which are probably the most often cited with regard to the capacity expansion, range from the conversion of different ecosystems into farmland to the potential negative impacts of production processes, which include soil depletion, emissions, and water use and contamination. There are also social risks that are particularly important when one views the biofuels industry through the lens of rural development. Use of limited arable land for biofuels production could drive up the costs of other goods that are staples of local populations. Finally, because biofuels are tied to both agriculture and energy, there are market risks associated with the price of fossil fuels and the price of agricultural commodities. As suggested in the sections that follow, a thorough evaluation of these risks on a country and feedstock specific basis is an important area for further study.

In this context, biofuels have emerged as a strong transport fuel alternative. The Kyoto Protocol has provided an additional impetus to biofuels development as industrialized countries seek to meet their emissions reduction targets. Biofuels have the added advantage of being commercially tested. National biofuels programs can aid a country's agroeconomic goals by creating rural jobs and developing the rural economy. Most importantly, the development of biofuels can limit a country's reliance on imported crude oil, diversify the national energy mix, and improve energy security.

It should be clear that biofuels are not a replacement for fossil fuels. Instead, they offer an alternative with a number of attractive benefits. The advantages offered by biofuels, such as lower carbon emissions and competitive production techniques, rely on existing technology. As the billions of dollars poured into biofuels R&D worldwide take hold, these advantages will only increase. Second-generation biofuels, such as cellulosic ethanol, which is proven to be even more effective in reducing carbon emissions, will be increasingly cost competitive. New technologies will also help address potential drawbacks to biofuels technology, such as the tension between food and energy security. Further, ethanol could one day be used in fuel cell engines, should that technology become commercially viable.

C) Brazil

Brazil's long history—and great success—with biofuels place it in a unique category. ***The development of flexfuel engines and the complex production and distribution infrastructure needed to service the skyrocketing demand for them is just the most dramatic example of Brazilian innovation that is leading the world.*** Yet, as discussed, Brazil's future success as an innovator and production leader in biofuels is not assured. This report addresses the growing and complicated industry by identifying four pillars that have helped generate its success, and which will be critical to its future prospects. Required investment in these pillars in ethanol alone, based on the stated goal of tripling production by 2020, is between $40 and $60 billion, based on an estimated need for average annual investments of between $3 and $4 billion in capacity expansion, $1 billion in infrastructure, and significantly increased activity and investment in biofuels R&D and education.

Innovation: Technological and agricultural innovation will be a cornerstone of Brazil's biofuels strategy, requiring investment in both R&D and education. The ethanol industry has since 1976 averaged an annual efficiency gain of 3.7%. To continue this trend, advancements in biotechnology and industrial and agricultural processes will be essential. Achieving those advances will require the expansion of research and test facilities as well as training and professional development for the sector's labor pool. Today, Brazil produces just .08 engineers for every 1000 people, compared to .20 in the US, .33 in the EU, and .80 in Korea. ***Coordination between the government, private sector, universities, and research institutions to strengthen the connection between the scientific research activities and practical technological needs of the sector is critical.***

Capacity Expansion: Brazil is already the world's leading exporter of ethanol, accounting for just over 50% of total trade in 2005, but its capacity is growing at a slower pace than the US and new producing countries, which both expanded production 21%

in 2005, compared to Brazil's 6%. $10 billion in new investments should add 7 billion liters of production by 2010. *The country plans to meet global demand by tripling production by 2020.* In contrast, the relatively young biodiesel industry is focused on expanding to meet ambitious domestic blend targets that will require 2.4 billion liters. The Brazilian government has set ambitious targets for future production that will require improving efficiency, identifying additional land, recruiting a workforce with the skills to cultivate it, and providing the necessary infrastructure to facilitate export.

Infrastructure: As Brazil develops a strategy to maintain its position as the global leader in biofuels and meet a projected surge in export demand, it must address both the inadequacies in current infrastructure and the need for infrastructure expansion. Infrastructure, particularly transport infrastructure for export, is the leading concern of virtually every expert and industry representative consulted for this report. ***The real challenge is reorienting Brazil's biofuels transport infrastructure to face out to export markets, expanding its overall capacity, and pushing into new regions of production.*** It is estimated that Brazil will need to invest $1 billion each year for the next 15 years in infrastructure to keep pace with capacity expansion and export demand.

Building Global Markets: With just 10% of ethanol traded internationally and demand rising rapidly, global markets have substantial room for growth, and Brazil could be a major beneficiary. Unfortunately, in many quarters energy security has come to be associated with domestic production, an association that has limited development of the export sector and led some countries to protect their domestic biofuels industry through trade barriers. As with other agricultural commodities, protectionist policies on biofuels distort the global market and drive up prices for consumers. ***True security is found in an international commodity market with diverse consumers and producers, which will require global standards, liquid futures markets, and trade liberalization.*** The IDB can play a role in helping Brazil and region develop the networks, regulations, and structures needed to support the growing export market.

D) Latin America

The Brazilian success story has generated considerable interest in biofuels across Latin America and the Caribbean (LAC), but ***no other industry in the region has yet approached the size or sophistication of Brazil's.*** A number of countries have taken important regulatory and legal initiatives to lay the groundwork for future expansion and investment. A few countries have begun to attract international investors, and others have announced plans for major expansions of their biofuels sector. In some places, the Brazilian government has actively forged relationships that are yielding joint projects and research.

Many of the necessary ingredients for a vibrant biofuels sector are present. The abundance of arable land, the existence of optimal climatic conditions in the region, and excess production of feedstocks used for biofuels in many LAC countries make the region well suited to become a productive center in a global biofuels trade. Added to their natural endowments is the concentration of activity and labor in their agricultural sectors, a reality that makes biofuels an attractive rural development strategy.

The overwhelming proportion of biofuels production in the region (outside of Brazil) still goes to domestic consumption, in many cases by the same entities that produce the fuel. Few countries in the region other than Brazil export significant quantities of biofuels. Costa Rica exports domestic ethanol production to the US with tariff-free access through CAFTA, and other CAFTA countries are dehydrating and re-exporting Brazilian ethanol and developing their own production to exploit this opportunity. Looking forward, Colombia and Peru, which have negotiated free trade agreements with the United States, have a potential advantage because of that access to the US market. Indeed, Colombia is planning a major expansion of its palm oil production as a biodiesel feedstock, with an eye to the export market. Similarly, Mexico, with its proximity to the United States and open access to the US market under the North America Free Trade Agreement (NAFTA), has strong external incentives to produce biofuels, including to reduce air pollution, promote rural development, and potentially supplement its declining oil reserves through biofuels production and use.

In Central America, Guatemala holds great potential for ethanol production as the largest sugar producer in Central America: the country harvests 197,000 hectares of sugarcane, using 15 sugar mills for processing. Its sugar industry earned the country nearly $500 million in 2005, and Guatemala ranks fifth in terms of global sugar exporters, exporting 72% of its production. In the Caribbean, Jamaica also has great potential for expanded ethanol production and exportation with roughly 347 million liters of ethanol production capacity and expansion plans for up to an additional 220 million liters in the short- to medium-term.

R&D activity in the region is unevenly distributed. A broad range of research activity exists in Colombia, including public-private partnerships and research sponsored by the state oil company, Ecopetrol. There is also ongoing university research into palm oil-based biodiesel, and work by the sugar and palm oil producers associations to improve yields and identify optimum varietals for feedstock. In Costa Rica, a promising ethanol initiative between Petrobras and RECOPE is underway. In Argentina, where there is a long history of interest in biofuels, private sector investors have established a Biofuels Research Center. Several universities are promoting biofuels, and particularly biodiesel, through research and involvement in initiatives like the New Technologies for Biofuels Network. Elsewhere in the region, R&D efforts are much more limited.

As in most countries, the trend in the Americas has been for the private sector interest and activity that exists to follow government engagement, although countries like Costa Rica, which produces almost exclusively for export to the US market, are exceptions. In Colombia, where there are already five operational ethanol distilleries, a variety of investment projects have been announced, largely by Colombian groups but with some foreign involvement. In Argentina, about 20 companies currently produce biofuels, but principally for their own consumption. There is some minor local investment in Peru, and China has expressed interest in an ethanol investment in Ecuador.

As a whole, the region has made important strides toward establishing a regulatory framework for biofuels. And a number of countries, including Colombia, Guatemala, and Argentina have advanced well beyond the initial steps. However, governments and regional institutions, with the IDB in the lead, will need to coordinate and facilitate investment and research.

E) Blueprint for Green Energy in the Americas

The report concludes with a blueprint for green energy in the Americas. This strategic blueprint is organized around the four pillars that will drive and shape competition and demand: innovation, capacity expansion, infrastructure, and building global markets. Rather than simply a response to exogenous market trends, it is a vision for how the Western Hemisphere, which today produces more than 80% of biofuels, can build on those trends and lead the global development of this industry – through technology, production, and trade. The region's competitive position in these four pillars is assessed in a dynamic global context. The future of biofuels is uncertain and the choices made by countries, companies, and consumers moving forward will define not just the extent to which biofuels are integrated into global transport energy consumption, but also the patterns and volume of global biofuels trade, and the countries and regions that become centers of production and innovation, and destinations of investment. With an estimated $200+ billion in new investment necessary for biofuels to provide 5% of transport energy in 2020, the stakes are high. For the region, there is also an opportunity to buck historical precedent and position itself as a hub of technological innovation and value-added exports.

The fundamental assumption of this approach is that while each pillar can be pursued on its own, and to date, largely has been, it is in integrating them into a cohesive strategy that sustainable global competitiveness will be achieved. Innovation creates value-added technology exports, but it also drives production efficiencies and decreases the land requirements of agroenergy, major factors in national competitiveness. Likewise infrastructure allows for both the expansion of production and its connection, both physically and virtually, to local and global markets. It is in these markets that the true promise of biofuels lies – in creating a globally traded commodity with diverse producers and consumers that offers a clean and secure alternative to fossil fuels. Innovation, the expansion of production, and the construction of infrastructure cannot wait for markets, but nor should markets be expected to form naturally. What is necessary is an aggressive marketing campaign to change the perception of biofuels as solely "home-grown" energy, promote the liberalization of trade, the proliferation of producers and consumers, and the development of the mechanisms of that trade: international standards and liquid futures markets.

This report concludes with a series of ideas for major programs that could be promoted in collaboration with regional governments and the private sector. It is expected that all of these will be developed through private discussions with the bank and leading players in the hemisphere and, perhaps, through a program of events and seminars designed to refine and advance the hemispheric biofuels agenda to ensure leadership in this rapidly growing area for decades to come.

E-1) Brazil

Brazil – its government, its industry, and its citizens, have made an unprecedented commitment to the production and use of biofuels. This commitment has produced not only the highest share of biofuels in transport fuels consumption, but in ethanol, the most efficient production, the most cutting-edge innovation, and made it the world's only net exporter. President Luiz Inácio Lula da Silva has made the promotion of biofuels a central element of his foreign policy, promoting the creation of biofuels industries in developing countries, signing technical cooperation agreements, and calling for the creation of global markets. At home, Brazil is engaged in a large scale capacity expansion of ethanol for export and has launched a domestic biofuels program. For Brazil to expand capacity and position itself as the unchallenged center of biofuels excellence moving forward, it must think and act strategically. There are already a number of initiatives underway in each of the areas highlighted by this report, but ***the very number and diversity of actors and initiatives in the Brazilian biofuels sector make policy coordination a central challenge.*** Establishing a formal body within the government to coordinate government agencies and reach out to the private sector and academic and research institutions would greatly enhance the effectiveness and agility of policy making.

<u>Pillar 1: Innovation</u>

Brazil's leadership in biofuels innovation has made it the center of this developing global industry, with countries around the world seeking to learn from the "Brazilian experience"and acquire Brazilian technology and Brazilian-born flex fuel cars. As interest in the sector expands both within Brazil and globally, the country is facing a new competitive environment for biofuels innovation. Likewise, innovation also plays a critical role in Brazil's competitiveness. It is fundamental to the continued optimization of agricultural and industrial processes for efficiency gains, and as the ethanol and biodiesel industries expand, the adaptation to new conditions and new feedstock. Of even greater import is the disruptive potential in the development of cellulosic technology, which is expected to dramatically decrease the costs of production.

Governments, universities and companies around the world are making major investments in biofuels innovation, often together. In the past year, the US has announced plans to provide $125 million each to two bioenergy research programs, BP has pledged $500 million to fund a US or UK university biofuels research program, the British government has launched what it hopes to be a close to $2 billion public and privately funded renewable energy research institute, and Australia hopes to leverage a $382 million clean energy fund into more than $1 billion with funds from the private sector. These examples are representative of the major commitments being made around the world to biofuels innovation. While exact data is not available, total R&D funding for biofuels in Brazil appears to be below $500 million.

The private sector has traditionally contributed 70-80% of the funding that has gone into biofuels R&D, but this is changing through active government engagement in biodiesel research. The disconnect between Brazil's business and research sectors and the lack of a coordinated and cohesive national strategy are significant obstacles in the country's quest to remain the foremost authority in biofuels technology and expertise.

The current orientation of the biofuels sector is towards the food and agricultural industries; however, there is a school of thought that believes that the sector will need to be refocused on the energy sector to truly develop into a high-volume, high-profit industry. This re-orientation has begun to take place in small steps, through the restructuring of the Ministry of Agriculture and the creation of an agroenergy unit for example; however, some advocate that this be taken a step further, involving the major oil companies in fundamental discussions about which direction the industry should head. In this scenario, the problems of the biofuels sector would be re-defined in terms of how biofuels could provide a base for transport fuel consumption on a global scale. In thinking about the breakthroughs needed to push the bioenergy sector forward, this school of thought believes that if the sector remains rooted in the food industry, the breakthroughs would likely be feedstock specific; however, if they are realigned with the energy industry, breakthroughs could be more universal.

A great number of biofuels projects and programs are underway in Brazil. Various funds and agencies are in place to support the development of the sector and of new industrial technology; all of these moving parts need greater coordination and synthesis to increase their impact. There is always a need for additional financing for projects, but the funds available should also reach the agribusiness and research communities in the quickest, most efficient and effective way possible. Coordination of funding activities, away from the heavy bureaucracy of government, could help to ease any bottlenecks in funding supply. For better coordination within the government, it might be helpful to create an inter-ministerial committee to organize all of the federal activities of the various ministries, along with their funds and promotion agencies, acting in the biofuels space.

The IDB could support Brazil's biofuels strategy through:

A ***Brazilian Biofuels Research Center*** would create a major focus point and symbol for the development and growth of a more unified, coordinated and innovation-driven biofuels sector. Funding for this emblematic center could include the development of projects, such as:

1. A Global Renewable Resources Institute as a platform from which Brazilian know-how would be exported to other developing countries through various means, including academia, policy expertise and private sector investment;
2. A Biofuels Human Capital Fund to support scholarships at international universities and attract global academic luminaries to work in Brazil;
3. A competitive fund to distribute grants for research and development in the private and public sectors, promoting firm-university collaboration in biofuels;
4. A facility to finance new ventures by technology-based firms in biofuels, possibly including an incubator;
5. A fund to support the development of new feedstock varietals and production processes, including second-generation technology, to facilitate capacity expansion;
6. An initiative to improve regulations already in place to promote greater private participation in R&D, including tax incentives for equipment purchased for use in biofuel R&D by firms and universities, economic subsidies, and government procurement of technology generated through R&D activities.

Investment also needs to be made in the other side of innovation: education. The most pressing issues facing the Brazilian biofuels sector with respect to education are:

1. Deficiencies in basic education in Brazil's north and northeast, due in large part to regional disparities in income and educational spending, the repercussions of

which impact biodiesel producers in these areas;
2. The availability of a labor force with technical training to operate in various capacities within the expanding biofuels value-chain; and
3. The output of scientists and engineers in the disciplines relevant to biofuels feedstock development and production processes.

These issues all levels of the Brazilian education system, and policies aimed at bridging these gaps will be a key element of an overall development strategy for the sector. In particular, the education and biofuels sectors need to work together to address the following challenges:

Cultivation and production - The provision of basic education and literacy as well as agricultural training to farmers and machine operators, particularly in the northeast, where literacy rates are the lowest in the country.

Industrial processing - The provision of basic education and advanced technical training for plant operators in ethanol and biodiesel processing plants, including pre-service and in-service training to ensure that workers are current with the latest technologies and innovations in the field. Plant supervisors and lab scientists require at minimum a degree in chemical engineering and/or agribusiness management.

Research and development - Training to produce highly qualified support staff and management-level workers with minimum degrees in engineering, computer technology or agribusiness management; and researchers with advanced doctoral degrees in fields including microbiology, biochemistry, biochemical engineering, bioinformatics, and organic chemistry.

Flex-fuel Technology - Training to produce technologically adept support staff as well as scientists for the laboratories of the automotive industry.

In presenting these ideas, it must be emphasized that educational development is not linear in nature. Some kinds of education, and particularly scientific training, require a long lead time. One cannot hope to change one set of educational institutions and practices without making inputs into related institutions and practices. With these caveats in mind, the following recommendations are presented to assist with systematic planning and cost discussions, keeping in mind both short-term and long-term goals listed below.

One of the most effective educational models identified by a roundtable discussion at the World Economic Forum[3] was the engagement of domestic corporations, industry associations, and foreign investors in basic education through coalitions working in partnership with government to enhance regulatory reform, policies, and incentives. Collaborations of this type can be effective in basic education as well as technical training and higher educational programs.

In coordination with the Brazilian Biofuels Research Center, a number of funds could be created to support education and training:

1. A new strategy to support reforms such as the education and training framework to create a sufficient supply of skilled labor for the sector;
2. Competitive grants for teaching institutions in biofuels-producing regions to set up new programs in biofuels, responding to clearly identified local human resource demands in the sector;

The current administration has prioritized reforms in both higher education and vocational and technical education; the success of these reforms will help determine whether Brazilian workers are able to rapidly learn new technologies and become innovators in their own right. Achieving this will require flexible systems that enable trainees to move beyond the conventional curriculum, the lecture room and the workshop, and into the laboratories and workplaces of the businesses that are practicing those technologies. Education, human resource development programs, and adequate provision of infrastructural support are all vital components of a healthy scientific and technological culture.

Pillar 2: Capacity Expansion

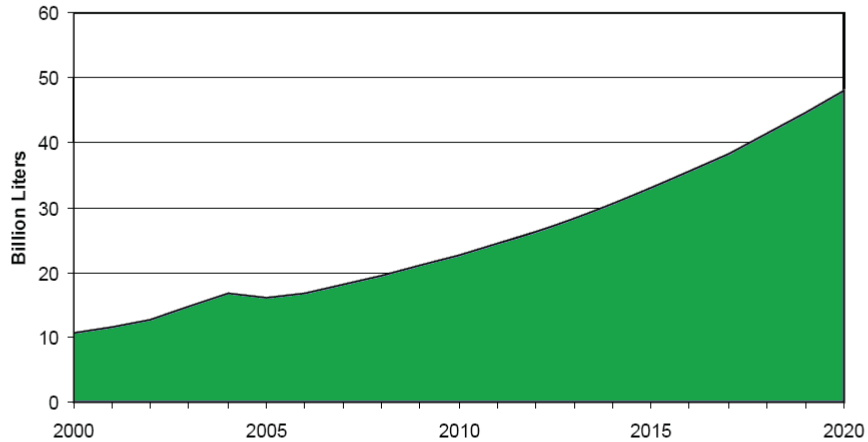
Brazil's potential for capacity expansion makes it unique among biofuels producers. Technology and land availability are the primary constraints to significant integration of biofuels into global transport fuels consumption. Both factors restrict the supply of biofuels and negatively impact their price competitiveness with fossil fuels. Technological innovation, particularly the advent of next generation biofuels like cellulosic ethanol could dramatically reduce the cost of production, increase yield per hectare, and allow for the use of marginal land. However, the scientific breakthroughs necessary to make cellulosic technology commercially viable may be 10 to 20 years away. Land availability, the demand for which could be reduced through technological innovation, is and will remain the critical factor for agriculturally derived fuels.

There is a mismatch between those nations suited to produce biofuels and those expected to drive consumption. Countries around the world are implementing domestic agroenergy programs, but many, particularly those that are highly industrialized or have limited arable land, will not be able to meet local demand with local production. For example, both the US and the EU would have to dedicate approximately 20% of their arable land to biofuels to meet a 5% blend target in biodiesel and ethanol. In Asia, Japan is considering increasing its ethanol blend to 10%, which would create a 6-billion-liter-a-year market. In China, an effort to reduce car pollution is expected to produce an 11 billion liter shortfall in biofuels by 2020, despite significant increases in domestic production. Brazil stands at the forefront of potential biofuels exporters, with vast expanses of available, arable low-cost land and cutting edge technology and production practices. The challenge is to build on these competitive advantages and maximize the contribution biofuels production can make to the national economy.

Brazil, already the world's leading exporter of ethanol, is expanding capacity to meet global demand. In contrast, the relatively young biodiesel industry is focused on expanding to meet ambitious domestic blend targets of B3 in 2008 and B5 in 2013. The two industries share three key variables affecting their growth: the impact of efficiency gains, the availability of suitable land (including environmental constraints), and access to financing, particularly private capital. In addition, the biodiesel industry has social development aspects that will shape its growth. While the challenges are conceptually similar, the current position of the two industries argues for addressing them separately.

Ethanol
There is consensus in Brazil that the country will need to triple current capacity of 16 billion liters a year by 2020 to accommodate internal demand and position itself as the global market leader. This would mean a total capacity of 48 billion liters, to be achieved through a combination of efficiency gains and greenfield projects. Estimates for the investment required range from $2 billion to $4 billion a year. With the caveat that global demand could possibly absorb a larger capacity expansion than Brazil is planning, ***based on current projects, this report estimates that the required investment in capacity expansion to meet the targeted 48 billion liters is approximately $3-4 billion annually.*** To date, expansion in sugarcane production has been almost entirely driven by efficiency gains through intensive research into the sugarcane genome, the development of varietals resistant to disease and pests and with a high sugar content, and the optimization of agricultural and processing techniques. If this trend continues as expected, yield per hectare could increase approximately 50% by 2020, even without cellulosic technology, which could become commercially viable in this timeframe. It is important to note that the introduction of cellulosic technology would represent a major investment hurdle for Brazil to stay globally competitive.

Chart 1e: Historic and Planned Brazilian Ethanol Production



Source: Data for 2000-2006 from F.O. Licht

By the end of 2005, 6 million hectares were under cane cultivation. This is just 0.6% of arable land in Brazil and only about half of this is dedicated to ethanol production, with the remainder going to sugar. According to a study commissioned by the Brazilian government, there are an estimated 7.9 million hectares of land available that would produce well above the national average. An additional 113 million hectares would produce at the national average. The primary constraints on expanding production are environmental issues, infrastructure, and supporting industries. Today, sugarcane production is concentrated in Sao Paulo state and a cluster in the north of the country. High land prices in Sao Paulo have pushed greenfield projects further afield. Much of the land identified as ideal for sugarcane plantation is located in Brazil's vast grassland, the Cerrado. A bill under consideration in the legislature would restrict agriculture in this region and will be an important variable. Further, as expansion occurs in new regions, the supporting infrastructure and related industries will need to accompany it, suggesting that expansion should be strategic, supported by the government through financing and infrastructure projects to facilitate export.

Investment in capacity expansion is also an issue. $10.5 billion has reportedly been committed to greenfield projects through 2010 and industry leaders report that there is no lack of investment funds for the industry. Yet the pace of investment in Brazil is slower than in the US and under the $3-4 billion a year needed to achieve targeted three-fold growth by 2020. International investors consulted for this report cited a lack of good investment opportunities and partners in an industry that has historically been dominated by traditional family businesses. Market leader Cosan's IPO this year is an excellent example of how the industry could modernize and tap into international capital markets, rather than depend on loans in Brazil's high interest rate environment. Of the four pillars, capacity expansion is the one most able to rely on private-sector leadership, but competitively-priced financing lines and technical support in entering equity markets are areas that could improve the sector and allow SMEs to share in the industry's growth. There is also a strong argument in favor of a new approach to ethanol production that is divorced from the sugar industry – a true agroenergy business that would integrate biodiesel and ethanol to create entirely self-sufficient productive environments geared exclusively to biofuels export. There is already a trend in Brazil among new mills to focus solely on ethanol, rather than employ turnkey technology that allows the refinery to switch between sugar and ethanol production depending on the market price, a practice that put supplies in jeopardy in the past.

The optimal strategy for capacity expansion in ethanol is one that is seamlessly integrated with investment in infrastructure and innovation and the development of global markets. For ethanol, it is the global market that is driving the expansion, and as such, global demand and global capital should be engaged whenever possible. The biggest incentive to increased capacity utilization would be solid assurances of markets abroad. Ideally, existing research could be employed by the government, in coordination with the private sector, to zone the country, identify the ideal areas for capacity expansion, and encourage the development of production clusters, with supporting infrastructure, education and research centers. The whole industry is a potentially high-payoff development initiative, with important second-generation effects on human capital development, new business, and broader use of new infrastructure. A modern agroenergy cluster, with integrated biodiesel/ethanol facilities and supporting small businesses, infrastructure, and training would be an anchor and driver of development, with tremendous knock on effects down the road. Program ideas include:

1. Providing ***technical support and financing for a zoning effort***, including involvement of the MMA so that environmental constraints can be considered from the start.
2. Creating ***dedicated low interest financing lines and guarantees*** for the acquisition of land and equipment.
3. Developing ***specialized financing lines and investment strategies for SMEs*** to establish support enterprises.
4. A program to ***develop private sector transparency to encourage foreign participation***, taking the Cosan IPO as a model.

Biodiesel

Biodiesel is still finding its feet in Brazil. In addition to being a relatively new priority (the National Program for the Production and Use of Biodiesel was only created in 2003), the industry has characteristics and objectives quite distinct from ethanol.

First, it is oriented to the domestic market and is not conceived of as a significant export industry in the medium term. Domestic fuel blending targets, mandated by the National Program, constitute the essential demand base for the product. Major expansion of feedstock crop production and refining capacity will be necessary simply to meet the National Program's 2013 target of a B5 blend, which translates to an annual production of 2.4 billion liters of biodiesel.

Second, biodiesel does not have an obvious feedstock source in Brazil, such as sugarcane provides for ethanol. Several crops are suitable for biodiesel production and are being evaluated by the government based on their yields, cost of production, availability of suitable land, and contribution to the government's rural development goals. Each has its pluses and minuses. Soy is a highly developed industry in Brazil and is suitable for large scale production. It is the cheapest source of oil for biodiesel, but only because soy meal, which represents nearly 80% of production, is also a marketable commodity. The expansion of soy is thus tied to the international protein market. This parallel demand structure imposes a constraint that must be considered in expanding soy production.

Palm is considered an ideal feedstock for biodiesel, given its strongly positive energy balance, high oil content, hardiness, and suitability for large-scale production. Its major drawback is the length of the production cycle (three years to the first harvest), which means high start-up costs and the need for specially targeted financing, especially for family farmers. Finally, castor is being seriously considered for production in the northeast, where it is an indigenous crop. The Ministry of Mines and Energy estimates that half of future biodiesel production will come from castor. Like palm, it is a hardy plant with potential to employ family farmers. Unlike with palm, however, there is no parallel demand for human consumption, so price instability due to competitive uses is not a factor. However, castor also has numerous drawbacks. Current yields are low and highly variable, production and cultivation technology is poor, and castor does not mix well with other vegetable oils in the production of biofuels.

Given these variables, Brazil has wisely chosen to avoid dependence on any one feedstock. However, it has yet to fully zone the country for biodiesel production or implement a coherent strategy for the industry's expansion. A decisive determination of the feedstock it intends to foster, and where, is essential to meet blending targets.

Third, biodiesel is a critical element in achieving the country's rural development goals. The government in 2004 instituted the Social Fuel Seal to encourage biodiesel producers to support agrarian development by buying a minimum amount of their raw materials from family-based farmers and promoting their social and local inclusion. The Social Fuel Seal has been a requirement for participating in biodiesel auctions (the main marketing vehicle) overseen by the National Petroleum Association. The high subsidized prices offered at the auctions have enabled the government to reach its B2 blending target for 2008. However, there is no long-term guarantee that these above-market prices will be maintained, a clear disincentive to any major expansion of private sector investment.

Finally, there are environmental considerations. These include the possibility of overfarming in the south, invasion of Amazon lands for production of palm oil, and the possibility that the Cerrado Amendment could drastically restrict feedstock production in a large area of the country.

Despite these uncertainties, the number of firms participating in the biodiesel sector is growing. Private fuel distributors Ipiranga and AleSat have joined the biodiesel distribution chain and large-scale operators such as Bunge, Cargill and ADM are entering the market. Smaller scale firms have also begun participating in the auctions. More robust growth will stimulate efficiency gains as practical experience develops, best practices form, and innovations emerge.

A number of steps could be taken that would speed the process of innovation and capital investment needed to put the industry on a sound footing. As with ethanol, a strategy for capacity expansion will be most successful if integrated into an overarching strategy that includes infrastructure and innovation projects to facilitate production and distribution and develop improved varietals and production methods. What is needed is a macro-level blueprint which would:

1. ***Identify appropriate zones for the production of each feedstock***, with an eye to closely coordinating environmental and development objectives, particularly in regions like the Cerrado where expansion may be constrained by restrictions on GMO use, and identify resource requirements.
2. In coordination with a well financed research program to improve yields and farming practices, develop a program for the ***identification and creation of vertically integrated production centers***, particularly in the northeast, that would address the interrelated needs for small farmer financing, extension services in best agricultural practices, small-scale infrastructure development and investment financing for refineries.
3. ***Develop a marketing system*** that will give biodiesel producers more stable long-term price assurances to limit downside risks.
4. Provide ***incentives to joint ventures***, such as concessionary loan financing, that will leverage equity investment and stimulate technology transfer from countries with more experience in biodiesel production.
5. ***Facilitate greater coordination among lending agencies*** at the various levels of government to maximize the impact of available resources and establishment of credit lines to finance biodiesel production, including resources targeted to SMEs.

Pillar 3: Infrastructure

Infrastructure, particularly transport infrastructure for export, is the leading concern of virtually every expert and industry representative consulted for this report. Cogeneration represents an opportunity for diversifying Brazil's electricity generation capacity both geographically and by source. Communications networks, while not universal, are expanding rapidly and offer a platform, rather than a constraint for capacity expansion. The real challenge lies in reorienting Brazil's biofuels transport infrastructure to face out to export markets, expanding its overall capacity, and pushing into new regions of production.

There are fundamental problems in the existing transport infrastructure, which depends largely on Brazil's roadways, that are universally acknowledged and not sector specific. The poor conditions of the highway system and the congestion in port access affects export industries across the board. There is no short-term, easy solution. However, looking forward, the growth of the biofuels export industry should bring a graduation of sorts. If the conservative estimate referenced in this report of 6 billion liters of ethanol exported in 2012 is accurate, a shift into rail, waterway, and most importantly, pipeline transport will be critical. While roads will likely remain the primary means of domestic distribution, their relevance to export will lie in providing access to collection points for conveyance via these other forms of transport. Various studies of ethanol expansion have concluded that a major investment in infrastructure is needed, ranging from $1 billion a year for the next 20 years for production of just over 100 billion liters to $1 billion a year for production of 31 billion liters by 2020.

The other significant bottleneck to export growth is port capacity. The primary constraints are crowding due to a lack of shipping berths and terminals, storage capacity in ports, and depth of shipping channels. Determining where and how an estimated $320 million in short-term (to increase export capacity by 7 billion liters) investment is distributed is under active discussion today in Brazil, requiring an assessment of ports as an intermediate step in a supply chain from farm to foreign market. Given Brazil's ambitious capacity expansion goals and the costs of port projects underway – terminals ($70 million each), shipping berths ($30 million each), etc. – investment needs in the medium term are likely to be closer to $1 billion.

The interdependence of capacity expansion and infrastructure demands that both be integrated into a common strategy. What is now required is a dual focus – looking into Brazil to facilitate the growth of the biofuels industry in underdeveloped regions and looking outward to how production reaches ports for exports. Industry leaders complain that to date, infrastructure has followed, rather than led production. With the current pace of investment, and with some $10 billion in new projects underway, the time to move forward is now.

Actions that could be taken to improve the infrastructure to support biofuels capacity expansion are:

1. Develop an ***Agroenergy Infrastructure Fund*** that, with the Brazilian government and private sector, would structure and finance integrated infrastructure projects already identified or underway to service existing production as well as develop new integrated infrastructure projects for areas of potential production. The Fund would anticipate and create the market, rather than follow it:
   a. Existing production projects: A number of projects are planned or underway to facilitate export from areas of concentrated existing production. Notable examples are the construction of a pipeline to connect the Sao Paulo State REPLAN refinery with the Ilha D'Agua port in Rio de Janeiro and the planned $600 million Petrobras pipeline expansion project. In these cases, the Fund would provide financing for complementary infrastructure projects, as needed, such as the construction of storage facilities, the expansion of terminals and berths, and access roads to the pipelines.
   b. Identified/Proposed Projects: There are also a number of projects that have been proposed and which reflect a clear need, but for reasons of financing, regulatory restrictions, or insufficient buy-in from key actors, have not moved forward. Notable examples are a possible rail connection between Minas Gerais and the Vitoria port in Espirito Santo and the development of an ethanol-dedicated terminal in Sao Paulo state. In these cases, the Agroenergy Infrastructure Fund would collaborate with relevant public-and private-sector actors to develop an integrated infrastructure project, analyzing the entire supply chain to identify the most cost-effective means of transport at each stage. A set of financing packages would be made available to the appropriate actor or actors for each component of the project.
   c. New Projects/New Regions: In regions like Tocantins and Maranhao, integrated infrastructure projects could serve as the impetus for the expansion of production itself. In these places, pipelines or rail would help create a transport infrastructure

system designed specifically for export. Today, the lack of infrastructure in these regions is the primary disincentive to productive expansion. Studies done for the Brazilian government predict that productive capacity could increase more than six-fold if investment is made in new projects and the research necessary to adapt cane production to these areas is successful. Infrastructure can lead this investment, if projects are undertaken as part of a cohesive strategy, as advocated by this report.

2. Conduct an in-depth study of the economic impact of current regulations which have created a near monopoly in pipeline transport and suggest policy alternatives.

Cogeneration:
Cogeneration offers Brazil a substantial opportunity to increase generation capacity, diversify its electricity system, improve the geographic distribution of generation, address the specific vulnerabilities of hydroelectric power, and meet the government's rural electrification goals. 85.4% of electricity comes from just one source, hydro, with current supplies concentrated in the country's south and with an average loss of 16% in distribution. Further, while industrial growth and urban populations are concentrated in this same region, there is limited potential for new projects there. Additionally, hydroelectric power is seasonally variable, and a drought in 2001 contributed to a shortage that year. There is also a great disparity in Brazil between rural and urban electrification, with nearly 60% of rural households in the country's north still without electricity according to the most recent data. The government has recognized these issues and is actively engaged in their resolution through new hydro, nuclear, and renewable power projects, the ProInfa program, and an ambitious rural electrification program, Luz para Todos. Cogeneration is not an alternative to these efforts; it is an additional source of power that could make a much greater contribution than it does today to addressing the specific vulnerabilities of the system. According to Brazilian government estimates, if existing mills upgraded to high-pressure boilers, they could provide more than 6% of the country's power consumption in 2004, and that does not consider further technological advances or the construction of new mills. To best exploit this opportunity, the following actions could be taken:

1. Identify appropriate policy reforms to encourage cogeneration by streamlining the bureaucratic process or, possibly, providing a blanket authorization allowing producers to connect to the grid.
2. Conduct an in-depth study of the potential of biofuels as a source of "off-grid" electrification, either through biodiesel-fueled systems or through mill-generated electricity used locally.
3. Provide financing lines for investment in high-pressure boilers and infrastructure to connect to the grid.

Communications:
Access to the internet in Brazil is still far from universal, but is growing rapidly and offers a platform for increased efficiency in the biofuels industry and an increased connectedness with global markets. Unlike fossil fuels, biofuels can be produced on a relatively small scale, which fits into the Brazilian government's additional goal of using the industry as a tool for rural development. These smaller producers could gain efficiency by using the internet to establish virtual economies of scale. This could be through simple knowledge and information sharing, or though a more sophisticated system of collective purchasing and marketing.

Further, as global markets develop, electronic trades in liquid global markets should allow producers and consumers with access to the system to have direct links to one another, or to a common global futures exchange on which to trade their products, rather than rely on a trading company. In effect, the middle men will disappear. Possible actions to support these developments include:

1. Developing an "Agroenergy Internet Project" which would:
   a. Serve as an initial platform for knowledge and information sharing between producers;

   b. Develop into a means of establishing "virtual economies of scale" through collective purchasing and marketing; and
   c. Connect producers to Brazil's Innovation Center of Excellence network to facilitate the dissemination of new technologies and improved agricultural or processing methods.
2. Provide training to farmers and small-scale producers to ensure that they can reap the benefits of such a system.
3. Create a "micro-financing" line that would enable small-scale producers to acquire the necessary technology to access these systems.

Pillar 4: Building Global Markets

Brazil's ethanol expansion strategy rests on the promise of global markets, but the continued growth of international trade cannot be taken as a given. Due to the price and supply volatility of oil, many nations are embracing biofuels as a means of reducing their oil dependence. However, in the drive to augment domestic production capacity, few countries have recognized biofuels trade as an integral component of their energy security strategy. Protectionist measures, heterogeneous classifications and undeveloped trading mechanisms impede the cross-border flow of biofuels. While domestic investment will assist countries' to diversify their energy supply portfolios, adverse weather conditions or damage to domestic feedstocks could actually undermine energy security if there is not a functioning, liquid market to rapidly supply shifted demand.

While biofuels are currently traded on a limited scale, a defined set of production and exchange standards will need to be established in order to facilitate the free flow of supply stocks. Establishing an international, cooperative trading framework is undoubtedly complex and will require the participation and agreement of nations currently employing (and promoting) unique standards. With the exception of recent, preliminary discussions within the World Trade Organization, there has not been a collective international effort to harmonize biofuels standards and to develop a trading mechanism to facilitate the exchange. The WTO does not currently define fuel and non-fuel ethanol and, further, has not determined the appropriate treatment for biofuels given the substantial subsidies and state support currently characterizes the industry. As a pioneer and leading global producer of ethanol, Brazil has, however, engaged in an international diplomatic and commercial campaign to promote global biofuels exchange.

Timely efforts to harmonize standards, reduce trade barriers, and standardize contract requirements will help provide a basic framework for a functioning futures market allowing buyers and sellers to reduce their exposure to the various risks associated with commodity trade. At present, the Brazilian Mercantile Futures Exchange (BM&F), the Chicago Board of Trade (CBOT), and the New York Board of Trade (NYBOT) offer ethanol futures contracts, although a limited scale. In order for one of the referenced Boards to gain the confidence of traders and become the primary mechanism for international ethanol exchange, it must incorporate a harmonized set of international standards, provide sound financial infrastructure and have sufficient liquidity. While barriers remain, the global demand for biofuels continues to grow and the need for a functioning global market becomes increasingly acute.

- As part of the Global Centers of Excellence Initiative, the IDB could support the creation of a ***Global Standards Initiative*** to develop, promote, and foster the adoption of global standards in biofuels production, processing, transportation, etc. At the outset, the IDB and other International Financial Institutions could jointly sponsor an international conference bringing together governmental, industrial, agricultural, and commercial stakeholders to draft preliminary biofuels standards;
- Provide financial, political and organizational support for the development of an international biofuels certification board that guarantees the quality and composition of exported biofuels;
- Support the creation of a ***strategic ethanol reserve*** *in Brazil* to prevent disruptions in the domestic supply of ethanol and preserve Brazil's global reputation as a reliable

producer;
- Support the ***BM&F as a preferred biofuels exchange board*** and assist in the modernization of exchange such that the BM&F will operate at a level on par with the NYBOT and CBOT;
- Coordinate with other International Financial Institutions such as the African Development Bank, Asian Development Bank and others to ***support technology transfer*** to diversify and increase global capacity and assist producers in adapting current facilities for bio-fuel conversion;
- Cultivate dialogue with the automobile industry to develop more efficient engine technology and promote flex-fuel vehicles around the world;
- Incorporate all stakeholders including the petroleum industry into periodic global biofuels strategy sessions to enhance cooperative 'buy-in' and to broaden the scope of biofuels promotion.

In the Region:
The story does not end with Brazil. Countries throughout Latin America have biofuels industries in varying stages of development. This study examined the potential in countries and the needs that might be addressed by the IDB with the same four pillar framework. Rather than prescribe a formula for the development of a biofuels industry, which would be unable to reflect the diversity of conditions, advantages, and challenges throughout the region, this report has instead identified a number of areas of common need:

1. Feasibility Studies: There are a variety of countries interested in entering the biofuels market or significantly expanding production, and they require, or will require, technical assistance and financial support in analyzing the feasibility of such a move, as well as for pilot programs. There are several reports available on biofuels development at the regional level; however, a number of countries have expressed an interest in studies which focus on the specific issues facing their particular country, including the impact of biofuels production on their economy or the competitiveness and viability of biodiesel production within their borders. Guatemala and Honduras, for example, are two countries with the potential for commercial-scale biodiesel and ethanol production, and they have each voiced an interest in individual, detailed feasibility studies to outline the potential impact of biofuels development. A number of other studies could be executed in a variety of countries, such as:

- Examination of soil quality to identify optimal areas for feedstock cultivation and test farms for the growth and harvest different feedstock;
- Environmental impact assessment of biofuels production, including water demand, deforestation, soil erosion and degradation, and carbon and other pollutant emissions from production;
- Examination of the rural development impact of biofuels production and the potential for social inclusion programs tied to the industry; or
- Assessment of government biofuels incentives and subsidies to promote and support production and use, or simple demand guarantees, and evaluation of the sustainability of biofuels markets.

Countries already producing biofuels are also looking to generate economies of scale and, in some cases, identify export markets, which also require study of the feasibility of co-generation and co-product development as well as that of improving harvesting and production processes, and an examination of global markets to identify demand gaps which need to be filled.

2. Regulations: Of the 22 countries examined in this report, a number which excludes Brazil, only five (all in South America) have a cohesive national biofuels plan. Of these same 22 countries, 50% have regulations to either mandate blend targets, to define the parameters of the sector, or outline fiscal incentives for production; four countries have pending legislation. These countries are at varying stages of development, from Colombia, which has comprehensive regulation as well as production, to Trinidad & Tobago, which dehydrates and exports ethanol but has

no national framework in place. In countries where there is not a comprehensive framework in place, regulatory assistance and collaboration would be beneficial. The following have been identified as areas of need for LAC in terms of regulatory structure:

- Privatization - including the overhaul of aging and inefficient government sugar industries, including plant infrastructure;
- Market Parameters - including the development of fuel definitions and specifications; the mandate of environmentally and socially sustainable methods of feedstock cultivation and biofuels production; and the creation of incentives for production, such as tax holidays;
- Domestic Consumption - including mandatory blending; mandatory use of biofuels by public vehicles and taxi fleets (to ensure a minimal level of demand); public education campaigns; and tax structures which support the competitiveness of biofuels; and
- Clean Development Mechanism (CDM) Project Development - including the provision of assistance to project sponsors hoping to develop CDM projects in the host country, and the establishment of regulations to account for uncertainties regarding the Kyoto framework extending beyond the Protocol's 2008-2012 commitment period or between periods.

3. Capacity Expansion: As countries increase their biofuels production and consumption, they will need to augment their processing capacity. This could require financing lines for land and equipment acquisition. Seven of the 22 countries examined in this report have mandatory blending regulations in place. To move beyond a certain blend level (roughly 10%), consumers will need access to flex-fuel technology.

4. Infrastructure Financing: Infrastructure development is a formidable obstacle to biofuels development in parts of the region. As industries grow, infrastructure needs will include investment in storage tanks and transport needed for distribution. As production increases and blend levels rise, particularly with the use of second-generation technology, major investment will be needed for dedicated pumps at fuel stations and increased capacity in domestic and export infrastructure. Recent reports by the World Bank and IDB have highlighted Latin America's infrastructure lag vis-à-vis Asia and OECD countries. A concentrated effort in strategic transport infrastructure must include pipelines, which are the most cost-efficient means of transporting fuel in large quantities. Port infrastructure, including dedicated terminals and storages facilities, will be critical as well to the region's biofuels export competitiveness.

5. Innovation Support: For countries across the board, there is a need to promote technological advancement and to match labor training to support the development of competitive, efficient biofuels production region-wide. In addition to cultivating and supporting indigenous innovative capacity, countries in the region would benefit from collaborative efforts on R&D and technology transfer within the biofuels community locally as well as globally.

The IDB has the resources and qualities to play a useful role in addressing these needs. As a regional institution, it can work with individual countries and facilitate regional initiatives, be they infrastructure projects or technology transfers. A number of ideas for possible IDB programs are listed below.

- Launch a ***Global Biofuels Market Development Fund*** that could help address financial barriers to biofuels production and consumption. The bank could assist in financing a variety of the phases of industry development and growth, including feasibility studies, technological advancement, financing capacity expansion, infrastructure development, and regulatory improvement, through lending to public and private entities using equity, debt and risk insurance instruments.

- Creating a legal and regulatory framework for biofuels production is an essential first step. The Bank could play an important role as a center of expertise through a ***Hemispheric Renewable Resource Regulatory Initiative***. Such an initiative would provide technical assistance in framework-building and benchmarking to measure regulatory progress. It might also coordinate forums in which countries could exchange regulatory experiences, highlight successes and failures, and discuss long-term regional integration prospects for the biofuels industry.

- For the countries of the Caribbean Basin, regional collaboration will be particularly important in developing feasible innovation programs. Because these countries have smaller budgets but share common characteristics with neighboring countries, collaboration on research and development offers a viable option for developing innovating technology while sharing the cost burden of investing in R&D activities. To support this effort, the IDB could support an ***Ethanol Research & Development Project of the Caribbean Basin***. The project could, among other activities, provide financial and technical assistance to build R&D regional programs, incorporate the private sector into funding and research activities, and support the strengthening of regional trade agreements and patent-enforcement laws to facilitate the transfer of ideas and technology across borders.

- The IDB could sponsor the creation of a hub for the development of next-generation biodiesel technologies and markets, linked to Colombia's strong potential in palm oil-based biodiesel. This ***Next-Generation Biodiesel Research and Development Project*** would be a cooperative endeavor among a range of countries with interests in biodiesel (most countries in the region) and would enable the creation of the kind of collaborative environment required to maximize the output of research efforts.

- Similar to the initiative described above, the IDB could sponsor a Next-Generation Ethanol Research and Development Project as a hub for the development of next-generation ethanol technologies and markets based on Chile's competitive position in the export of woodchips. Already, countries such as Sweden are investing heavily in technology to lower the cost of cellulosic ethanol production from wood products. Based in Chile, this center would bring together research talent from countries throughout the region with forestry/cellulose industries interested in ethanol production from this feedstock to maximize the effectiveness and spread the benefits of this effort.

- In 2006, with support from the IDB, the Mesoamerican Biofuels Working Group was formed. The countries represented by the group are currently investigating ways to expand their biofuels consumption and production capacity. The IDB can further promote biofuels production expansion in the region by launching a ***Mesoamerican Capacity Expansion Initiative*** to help coordinate activities in connection with the various organizations, plans and agreements in place that touch on biofuels development.

- Pacific trade is booming, and Asian markets such as China and Japan are projected to have massive shortfalls in biofuels production in the coming years, but Latin America's export infrastructure faces east. The existence of such hub ports not only increases the level of trade through those facilities, but also lowers the costs of transportation for the region as a whole. Through a ***Trans-Pacific Infrastructure and Market Development Project***, the IDB could support regional biofuels "hubs" or transport centers, helping to facilitate trade between supply and demand centers.

Endnotes

[1]Renewable Energy Policy Network for the 21st Century. Renewables: Global Status Report Update 2006. Paris: REN21. 2006.
[2]International Energy Agency (IEA), World Energy Outlook 2006, Paris: IEA, 2006, 223.
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II. 2020 GLOBAL COMPETITIVE OUTLOOK

1) Global Energy Markets

The purpose of this report is to assess the competitive position of Brazil and other countries of Latin America and the Caribbean in the global biofuels industry looking forward to 2020. It is a market that is more potential than actual. It is heralded as a panacea by some and condemned as a false promise by others. Neither assessment is accurate. Biofuels will not, in the medium term, cure the world of its dependence on fossil fuels, but they do represent a clean alternative with many possible benefits. The development of this industry will depend on choices–the choices of governments, consumers, and investors–and those choices will be made within the context of global energy markets. As such, this analysis must begin with the outlook for global energy demand, supply, and the geopolitical, environmental and social factors that will shape decision making.

1.1) Drivers of Global Energy Markets

A) Introduction

A survey of the leading energy information sources, from international institutions to governments to major energy companies, yields a range of projections and analytical approaches, but there is consensus that certain key issues will drive the evolution of energy markets. On the demand side, population and economic growth, and more specifically urbanization, industrialization, and trends in energy efficiency, are critical. On the supply side, the key questions are when, how, and at what pace we will deplete the world's fossil fuel reserves. The concentration of reserves in volatile regions also creates deep concern about the security of supply and price volatility. Over and above calculations of supply and demand loom major environmental concerns. As the negative impact of climate change becomes apparent, the hunt for alternative sources of clean, green energy is accelerating. Green energy is no longer a choice, it is a requirement.

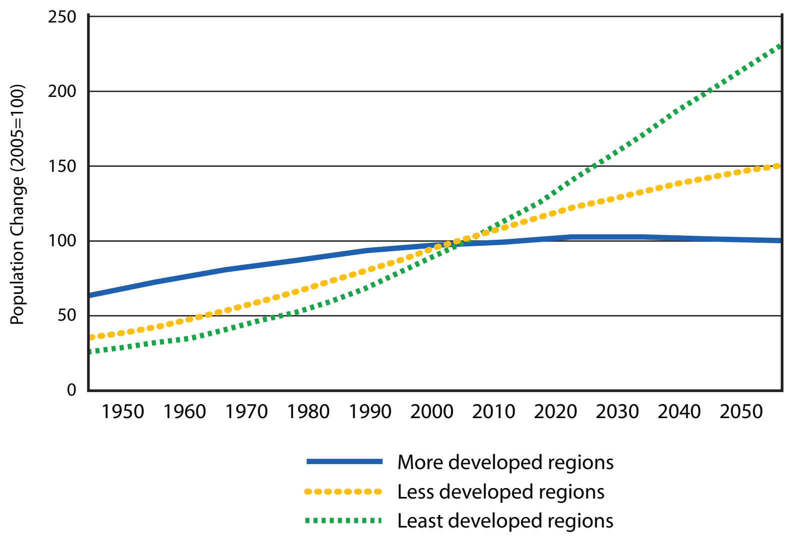
B) Energy Demand

Projections for the growth in global energy demand from 2005-2020 range from 25% to 30%. All sources agree that this growth will be driven by the developing world, which will account for the vast majority of world population growth. Economic growth in developing countries will be energy intensive as industrialization proceeds and urbanization introduces new populations to conventional energy use. In contrast, already industrialized countries are expected to move increasingly into less energy intensive service and knowledge economies. The International Energy Agency estimates that non-OECD countries will account for 71% of the growth in oil consumption, compared to 29% in the OECD. The US Energy Information Agency predicts that by 2025, developing countries will increase energy consumption by 91%, while energy consumption in industrialized countries will grow just 33%. The International Energy Outlook 2006 foresees the growth in energy use between 2003 and 2030 in non-OECD countries outpacing OECD countries, with average annual growth rates of 3% and 1%, respectively. The implication of this is clear: developing countries will be increasingly vulnerable to supply scarcity and volatile energy prices.

C) Population Growth

In the past half century, global consumption of commercial energy has risen fourfold[1], outpacing even the unprecedented growth in world population. Though the U.S is still the largest oil consumer, emerging economies already account for more than half of the world's total energy consumption[2], and demographic and economic trends indicate they will become increasingly responsible for world energy demand. The United Nations predicts that by 2050 world population will reach 9.1 billion, an addition of 34 million persons annually. Presently, 95% of all population growth is taking place in the developing world, and it is estimated that by 2050 the population of the more developed countries as a whole will decline by about 1 million persons a year.[3] The 50 least developed countries are expected to reach 1.7 billion persons by 2050 (more than doubling their population in 2005), while the rest of the developing world's population will reach 6.1 billion (up from 4.5 billion in 2005) [Chart 1.1a][4]. Clearly, developing countries will require a larger share of world energy resources in order to meet the demand of their growing populations.

Chart 1.1a: Population Dynamics by Development Group



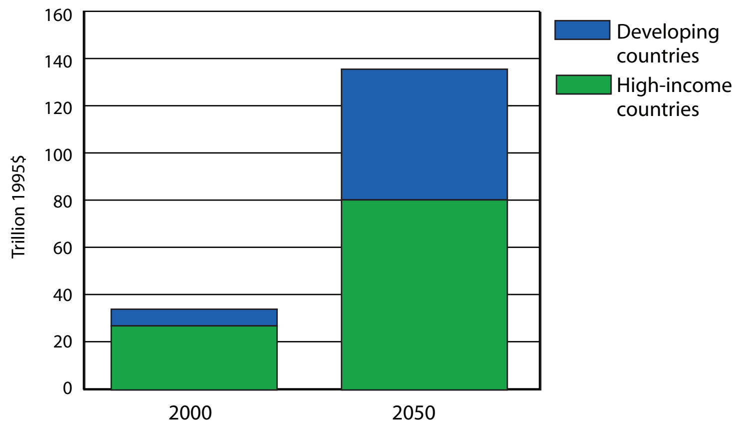
Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2005). *World Population Prospects: The 2004 Revision. Highlights.* New York. United Nations.

D) Economic Growth

There is consensus that economic growth, particularly in the developing world, will be another critical driver of energy demand. Many developing countries are experiencing dynamic growth and are expected to account for an ever-growing portion of global GDP [Chart 1.1b]. Perhaps most famously, Goldman Sachs has predicted that the giants of the emerging markets—Brazil, Russia, India and China (the BRIC countries)—could account for more than half the size of the G6 in US dollars terms in less than 40 years. Exxon Mobil projects that developing economies will grow from 20% to 30% of global GDP.[5]

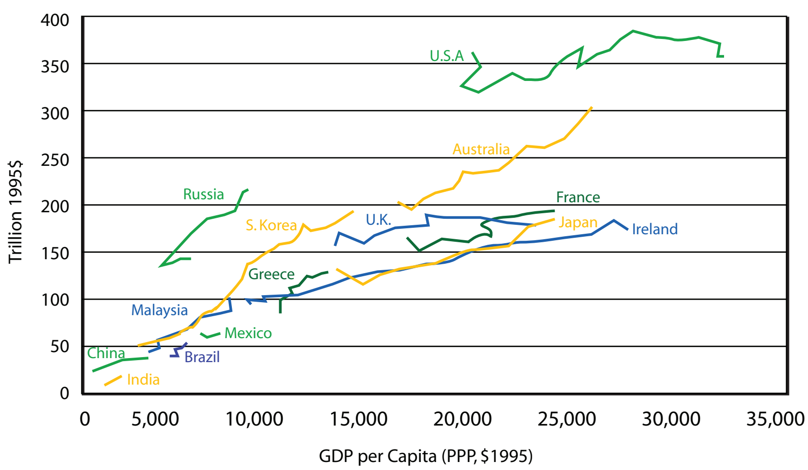
As per capita incomes in developing countries rise, energy consumption will increase to meet people's expectations. Higher incomes will result in a shift away from local biomass energy sources and towards an increased reliance on carbon-intensive energy. The World Bank reports that, historically, each 1% increase in GDP has led to a 1% increase in carbon dioxide emissions.[6] ExxonMobil predicts that the economies of China, India, Indonesia and Malaysia will produce an average annual economic growth of 5% for non-OECD Asia Pacific, creating combined economic output that approaches that of Europe.[7] The IEO2006 points out that, with the exception of non-OECD Europe and Eurasia, energy demand and economic growth have been closely correlated for the past two decades.[8] It is clear that industrialization and urbanization are the key elements responsible for this close relationship.

Chart 1.1b: Historical and Projected GDP



Source: World Bank[9]

Chart 1.1c: Energy Demand and GDP



Source: UN and DOE E/A

E) Industrialization

Industry is relatively energy-intensive compared to an agrarian economy, at one end of the development spectrum, or a service economy, at the other end. Countries that are more mature energy consumers with well-established infrastructure will use energy more efficiently, particularly as they move toward less energy-intensive service industries. On the other hand, as developing countries continue to industrialize their energy needs will expand. According to the 2004 Global Energy Challenges Conference, led by the Executive Director of the IEA, developing economies will greatly expand their energy intensive industries over the next 30 years, making them relatively more vulnerable to increasing oil prices than industrialized economies. The World Bank estimated that service sectors could constitute 60% of GDP in developing countries in 2050, but that figure would still be 10 percentage points lower than in developed countries today.[10] China's heavy industrial outputs, for example, accounted for 69% of its total industrial output, and the country's oil demand is not expected to peak until 2040.[11] Primary and industrial sectors–those requiring large energy inputs–will play a significant role in emerging market economies well into the 21st century.

F) Urbanization

As the world's population increases, it will also become increasingly urban. In 2005, 49% of the world's population lived in urban areas. By 2030 that figure is expected to reach 60% or 4.9 billion [Table 1.1a].[12] Today, the majority of those living in developing countries still reside in rural areas. ExxonMobil points out that 1.6 million individuals still lack access to electricity, and 2.4 billion people use only basic fuels, such as firewood, instead of fossil fuels. The UN predicts that by 2030, 56% of the developing world, or 3.9 billion people, will be urban dwellers, a population that will be nearly four times as large as that in developed countries. As an increasing percentage of the world's people move to urban areas, there will be marked shift from the consumption of biomass to the consumption of fossil fuels. With the average per capita energy consumption of urban citizens 3.5 times that of rural residents, the demand for energy will increase dramatically.[13] Accordingly, BP sees urbanization as a key driver of future energy demand. The Global Energy Center, supported by the U.S. Department of Energy and the utility industry, suggests that rapid urbanization and economic growth, particularly in developing economies, will lead many countries to look for new energy resources and environmental policies.

Table 1.1a: Total, Urban and Rural Population by Development Group, Selected Periods, 1950-2030

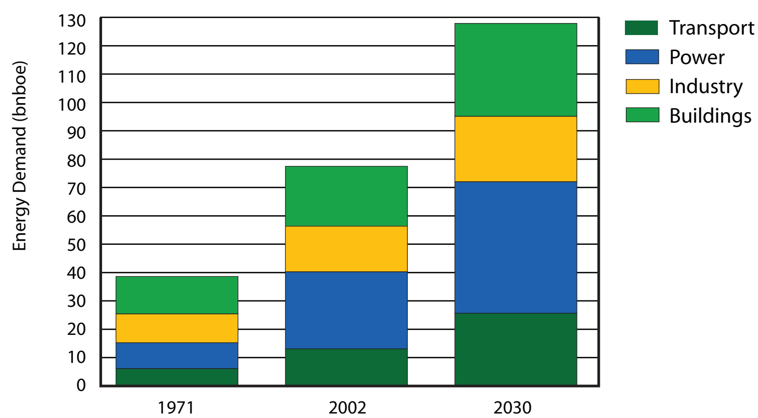
	Population *(Billions)*					**Average Annual Rate Of Change**	
Development Group	**1950**	**1975**	**2000**	**2005**	**2030**	**1950-2005**	**2005-2030**
Total Population							
More developed regions	0.81	1.05	1.19	1.21	1.25	0.73	0.13
Less developed regions	1.71	3.03	4.89	5.25	6.95	2.04	1.12
Urban Population							
More developed regions	0.42	0.70	0.87	0.90	1.01	1.37	0.47
Less developed regions	0.31	0.82	1.97	2.25	3.90	3.61	2.20
Rural Population							
More developed regions	0.39	0.35	0.32	0.31	0.24	-0.40	-1.07
Less developed regions	1.40	2.21	2.92	3.00	3.05	1.39	0.06
	Urban Percentage					**Rate of Urbanization** *(%)*	
More developed regions	52.1	66.9	73.2	74.1	80.8	0.64	0.35
Less developed regions	18.1	26.9	40.3	42.9	56.1	1.57	1.08

Source: United Nations, Department of Economic and Social Affairs, Population Division (2006). World Urbanization Prospects: The 2005 Revision. Working Paper No. ESA/P/WP/200.

G) Transport Sector

Estimates vary considerably as to how patterns of energy consumption will change in various sectors of the economy. The International Energy Outlook 2006 predicts that worldwide energy demand in the industrial sector will grow most rapidly, at an average rate of 2.4% per year, and that transportation will see the slowest rate of growth at 1.4 % per year. For its part, BP estimates that the power sector will be critical to growth in energy demand. Its analysis predicts that developing countries will rely more on the power sector than the transportation sector due to the rapid expansion of energy-intensive industries over the next two decades. BP expects that the power sector will account for 40% of total energy needs by 2030, twice as much as transportation [Chart 1.1d].

Chart 1.1d: Demand Growth by Sector

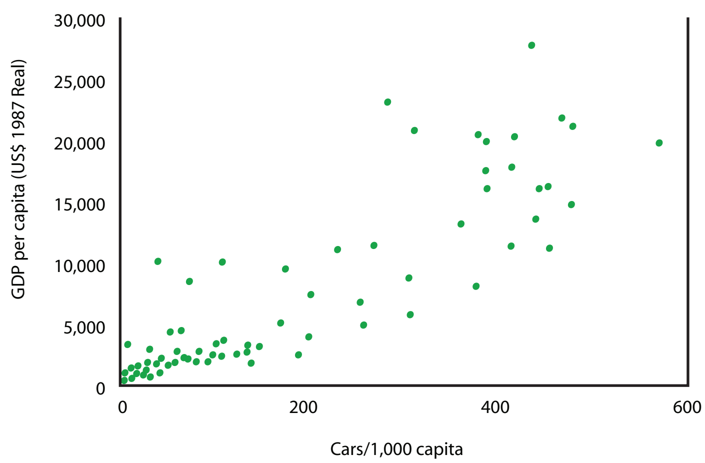


Notes: *1. Power includes heat generated at power plants.*
2. Other sectors include residential, agricultural, and service.

Source: IEA WEO 2004

Yet the transport sector remains a critical variable in the energy equation, particularly in the developing world. Most of the projected growth in demand for petroleum products in the transportation sector comes from the non-OECD economies (2.3% per year) as compared with the OECD countries (0.8 % per year).[14] A recent publication by the IAE looks at the relationship between growth in per capita income and automobile ownership in Asian countries. The report contends that the key uncertainty for projecting Asian oil demand is the extent of future automobile ownership and use.[15] A recent sharp rise in automobile ownership in China has increased the country's demand for oil to such an extent that Chinese experts now expect oil shortages to become a chronic problem, fundamentally threatening the country's energy security.[16]

Chart 1.1e: Car ownership and per capita income in a selection of developed and developing countries



Source: IEA

H) Efficiency

Thanks to technological innovation and the shifting patterns of global industrialization, the U.S. and other developed countries are able to harness more economic growth from each barrel of oil consumed than ever before.[17] Moreover, rapid urbanization in developing regions has resulted in the more efficient use of energy resources even as it has increased overall energy demand. For instance, as Chinese households have seen their incomes rise, they have shifted from the use of firewood to fossil fuels. Typically, energy intensity (the amount of energy required to produce a unit of GDP) increases during the first stage of industrialization in developing countries before decreasing as an economy matures. The UN cites a decline in global energy intensity of more than 28% during the past decade, with efficiency improving in major industrialized and developing countries.[18] Yet, industrialization and urbanization, and the accompanying shift from biomass to fossil fuels have still resulted in a dramatic increase in greenhouse gas emissions and air pollution; China has 16 of the world's 20 most polluted cities. Economic growth stimulates the demand for better quality energy, but many developing counties are still struggling to meet their energy needs in an efficient and sustainable manner.[19] The opportunity for improved energy efficiency exists, yet access to affordable technologies, and the transfer and adoption of knowledge remain major hurdles to the implementation of efficient energy solutions in the developing world.

I) Supply Side Overview

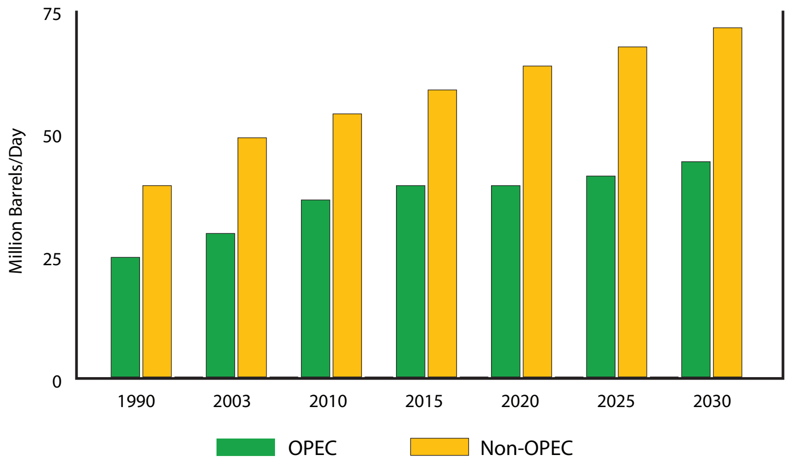
"Energy security" has become a broad term that encompasses the availability and cost of energy resources, political stability, terrorism and militant fundamentalism, environmental concerns about climate change and pollution, and the rising role of India and China in the global energy market. Paramount to energy security is the political stability of oil exporting nations, the security of oil fields within these nations, and the security of transport routes used to deliver product to market.

World attention remains firmly focused on the Middle East oil supply. The Gulf Region holds 65% of the world's proven oil reserves and is beset by persistent political turbulence–from Iran's nuclear ambitions to terrorism in Saudi Arabia and the war in Iraq–resulting in a volatile oil market and rising prices.[20] But political instability is not limited to the Middle East. Oil production in Nigeria has been hampered by attacks on pipelines, and nationalism and political turmoil have created doubts about the stability of Latin American supplies. Exacerbating the volatility of the world oil market is uncertainty about how much oil exists and how quickly those reserves will be depleted. As demand for oil increases at a record pace, there is growing concern about the ability of oil production to meet demand and the price increases associated with dwindling supplies. The major forces shaping global energy supply are pushing consumers, governments and corporations to mitigate the risk associated with oil dependency.

I-1) Fossil Fuel Reserves

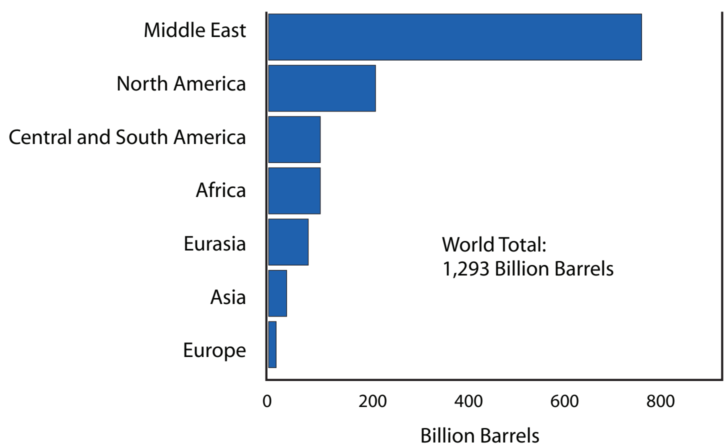
Together, oil, natural gas, and coal constitute 80% of global energy consumption, and at the current annual rate of production BP estimates that about 155 years of coal, 40 years of oil, and 65 years of natural gas remain.[21] Major debate exists over remaining oil reserves, and most analyses distinguish between "proven" reserves—those that can be economically developed with known technologies—and reserves that are less certain or difficult to access with existing technology [Chart 1.1f]. The future composition of world oil supply and production expansion are similarly difficult to predict, but the International Energy Outlook 2006 indicates that non-OPEC countries will meet the majority of increased oil demand during the next 25 years [Chart 1.1g]. This figure, like any existing fossil fuel reserve estimate, is highly dependent on factors such as resource extraction, investment in production, and the accessibility of new reserves.

Chart 1.1f: OPEC and non-OPEC Total Petroleum Liquids Production



Source: **1990 & 2003:** Energy Information Administration (EIA), Energy Markets and Contingency Information Division. **2010-2030:** EIA, System for the Analysis of Global Energy Markets (2006).

Chart 1.1g: World Proved Oil Reserves



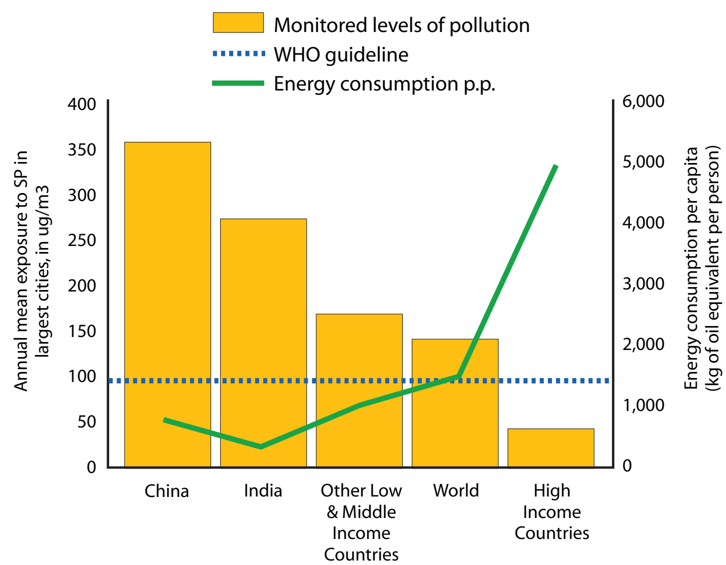
Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 103, No. 47 (December 19, 2005), pp. 24-25.

Many experts agree that world oil production is close to peaking. Absent significant new developments, existing excess production capacity will likely soon disappear and an already volatile market will be even more vulnerable to shocks. In its annual World Energy Outlook, released in November 2006, the IEA indicated that "despite the recent rise in the oil price and the jump in investment, the world's energy industry was not building enough new oil and gas capacity to ensure secure supplies."[22] Indeed, the IEA now predicts that nominal oil prices will hit $97.30 a barrel in 2030.[23]

J) The Environment

Concerns about global warming and carbon dioxide emissions are gaining traction in the geopolitical arena and are igniting serious interest in the development and adoption of alternative and renewable sources of energy. There is a general scientific consensus that increases in the Earth's temperature at the surface are largely the result of emissions of carbon dioxide and other greenhouse gases from human activities, including industrial processes and fossil fuel combustion. The effects of global warming are numerous and have been linked to a greater frequency of extreme weather conditions, including droughts, heat waves and floods caused by rising sea levels. Increasingly, developing countries, and small island nations in particular, are bearing a disproportionate share of the effects of global warming and have limited resources to invest in cleaner and more efficient energy. According to the Deloitte report, Energy in Flux, fossil fuel use accounts for 45% of all carbon dioxide emissions. Of this 45%, one third comes from vehicles.[24] Since 1990, transport has recorded the fastest greenhouse gas emission growth in the EU, Japan and the US.[25] Urban air pollution itself is also an acute problem in many cities in the developing world, especially in Asia [Chart 1.1h], and the health impact of air pollution is currently second only to the impact of water and sanitation in urban areas.[26]

Chart 1.1h: Global Perspective of Urban Air Pollution



Source: Leautier[27]

Faced with this challenge, countries across the globe have responded with the Kyoto Protocol.

1.2 The Kyoto Protocol [28]

A) Introduction

The Kyoto Protocol was created under the United Nations Framework Convention on Climate Change (UNFCCC) to address growing concerns over greenhouse gas emissions and climate change. Kyoto mandates the reduction of carbon emissions and provides incentives for member countries to sponsor clean energy projects in other countries, particularly developing countries.

B) The Agreement

The UNFCCC went into effect in 1994 with the intent of creating a multinational framework to coordinate government efforts to address climate change. Quite soon, however, member states sought ways to augment the Convention by mandating reductions in greenhouse-gas emissions. They began working on a protocol which would be tied to the Convention, but also have autonomy as a stand-alone agreement. Members unanimously approved the text of the Kyoto Protocol in 1997. In 2001, the Marrakesh Accords provided detail on how the agreement would operate, and Kyoto went into effect February 16, 2005.

Kyoto requires most industrialized member states to reduce emissions by 8% to 10% of their 1990 emissions levels (though a few countries may increase emissions) and seeks an overall reduction in global emissions of at least 5% during 2008-2012. Kyoto anticipates that member states will then set targets for future reductions.

Table 1.2a: Emission Reduction and Increase Targets for 2012

Target	Percentage	Countries	Details
Emissions Reductions	8%	EU15, Switzerland, Central/ Eastern Europe	The EU has devise an internal agreement to meet this target by distributing different rates among member states
	7%	United States	US has since withdrawn its support for the Protocol
	6%	Canada, Hungary, Japan Poland	-
Stabilization of Emissions	-	New Zealand, Russia Ukraine	-
	1%	Norway	-
Increase of Emissions Cap	8%	Australia	Australia has since withdrawn its support for the Protocol
	10%	Iceland	-

The European Union target-range includes variations in emissions allowances per country, such as 28% and 21% reduction targets for Luxembourg and Denmark respectively, and 25% and 27% increase caps for Greece and Portugal respectively. Kyoto offers flexibility in how member countries may meet their targets. Countries may, for example, partially compensate for their emissions by increasing sinks, or forests that remove carbon dioxide from the atmosphere either domestically or in other countries. Countries may also fund other foreign projects that result in greenhouse-gas cuts.

Several mechanisms have been set up to achieve these ends, including emissions trading, joint implementation, and the clean development mechanism.

C) Protocol Mechanisms

C-1) Emissions Trading

Emissions trading, as outlined in Article 17 of the Kyoto Protocol, allows Annex I Parties[29] (developed countries) to acquire units from one another to help meet Protocol emissions targets. This provision enables Parties to take advantage of lower-cost opportunities to reduce emissions, regardless of where those opportunities exist. Only countries with emissions limitation and reduction commitments [Table 1.2a] may participate in emissions trading; those countries may transfer units when they no longer need them to meet their own emission targets. The units which may be transferred are each equal to one metric ton of emissions (in CO2-equivalent terms).

C-2) Clean Development Mechanism

The clean development mechanism (CDM), defined in Article 12, provides a mechanism for developed countries to implement projects which reduce emissions in non-Annex I Parties, in return for certified emission reductions (CERs). CERs generated by CDM projects can, in turn, be used by developed countries to help meet their emissions targets, as well as to assist developing-country project hosts in achieving sustainable development. The goal of the CDM is to promote investment in developing countries, especially from the private sector, and the transfer of green technologies. Developed countries may use CERs from CDM projects to help meet their emissions targets, though they may do so only up to 1% of the country's emissions in its base year annually during the five-year commitment period.

C-3) Joint Implementation

The Joint Implementation (JI) principles, defined in Article 6, allow developed countries to implement emission-reducing projects, or projects that enhance emission removals by sinks, in another developed country. The project sponsor may then count the resulting emission reduction units (ERUs) towards its own Protocol target. Developed countries may also authorize legal entities (businesses, NGOs or other bodies) through national registry offices to participate in JI projects on the country's behalf and under its responsibility. As with CDM project activities, JI projects must have the approval of all Parties involved and reduce or enhance the removal of emissions in ways that would not have occurred without the project.

C-4) Activities Implemented Jointly

Under the activities implemented jointly (AIJ) pilot phase, developed countries are allowed to implement policies and measures in conjunction with other members. Under this phase of the program, as apposed to the CDM and Joint Implementation mechanisms, no carbon credits accrue to any participating Party. The program is designed to help members build practical experience through hands-on, real-world implementation. Designated National Authorities (DNA)are official national contacts for AIJ projects, and there are a number in the developing regions of the world [Table 1.2b].

Table 1.2b: Kyoto Protocol Member Party Statistics

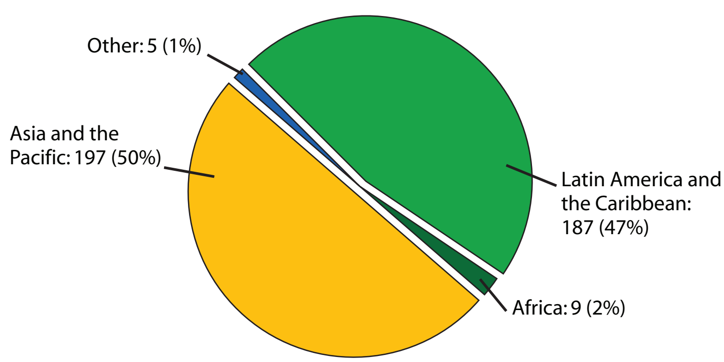
Region	Member Parties	Parties w/ DNA	Parties w/ Project Experience	Parties w/ Project Registered Projects
Annex 1 Parties	37	21	Not Available	15
Africa	42	29	9	4
Asia/ Pacific	48	30	23	17
Latin America/ Caribbean	32	25	19	16
Other	7	7	3	2

Source: CDM/ UNFCCC[30]

D) The Protocol and Biofuels in Latin America

The Kyoto Protocol offers a distinct opportunity for the development of ethanol and biodiesel initiatives in the region, particularly in Brazil. Latin America is second only to Asia as a location for CDM projects [Chart 1.2a]. There is interest in investing in these types of projects in the region, and there are parties already experienced in the CDM process.

Chart 1.2a: Number (Percentage) of Total Registered Project Activities by Region



Source: CDM/ UNFCCC[31]

2) Biofuels Competitiveness

The main drivers of global energy demand to 2020 and beyond will be:

- Population Growth
- Economic Growth
- Industrialization
- Urbanization

As has been demonstrated, these pressures will be strongest in the developing world. On the supply side, the depletion of the world's fossil fuels will continue, though the precise pace and course is uncertain. Concerns about geopolitical instability and fuel-supply security, as well as pollution and climate change, are pushing the world to find alternative sources of clean energy and reduce harmful emissions.

The Kyoto Protocol is an important element in this push, and it is particularly relevant for biofuels production and consumption. The emission targets set forth by the accord will likely not be met without change in the transport sector. If current policies prevail, global energy use for the sector is projected to increase 55% by 2030. Moreover, the transport sector is projected to have the fastest annual growth in emissions through 2030 (1.3 %).[32] There is also uncertainty as to how fast the Asian automobile market will grow as the region experiences a surge in its collective population, economy, and levels of industrialization and urbanization. The data strongly indicate that effecting a shift in the transport sector's fuel consumption will be essential in addressing climate change.

It is important to note, however, that the IEA's Alternative Policy Scenario envisions smaller emissions reductions in the transport sector than sectors such as electricity generation because of its conservative estimate of the potential for biofuels and other alternatives to replace fossil fuels in the medium term. Biofuels are projected to play an increasingly important role in the transport sector; however, the levels of consumption differ between the base-case and alternative scenarios. For the 2030 alternative scenario, biofuels use could reach 84.2 million and 62 million tons-of-oil-equivalent in OECD and developing countries respectively, but this is still believed to be insufficient. The alternative scenario posits that emissions reductions in the transport sector will occur due to decreased oil consumption, stemming from increased use-efficiency; the use of less carbon-intensive fuels; and changes in transportation modes, rather than the extensive adoption of biofuels.[33]

This dichotomy creates a space in which the Kyoto Protocol can act as a driver both for the increased inclusion of biofuels into the global energy matrix, and for increased investment in biofuels projects as a means of generating carbon credits through the mechanisms created under Kyoto. If biofuels are to make a bigger impact in the reduction of carbon emissions, a greater effort is needed to encourage wider consumption, which will in turn require increased production. Many developed countries have proposed a variety of biofuels measures, but they tend to focus on domestic production for consumption. Due to the land constraints in most countries, however, and the high relative cost of the biofuels production cycle in developed countries, domestic production alone will not suffice to significantly reduce carbon emissions. Importing biofuels might run contrary to the domestic agroindustry policy and energy security goals of some countries, but the failure to incorporate the transport sector into an overarching carbon emissions reduction scheme would be environmentally counterproductive.

In order to showcase the competitiveness of biofuels against other alternative transport fuel options, this section will examine biofuels, by outlining their feedstock, production processes, and advantages and disadvantages. A similar, but more concise delineation of the same for coal-to-liquid technology and hydrogen fuel cell technology follows.

2.1) Ethanol and Biodiesel

The focus of this report is on the biofuels ethanol and biodiesel. It should be noted that because the ethanol sector is much more developed than the biodiesel sector, there is a larger pool of data and research on ethanol.

A) Ethanol

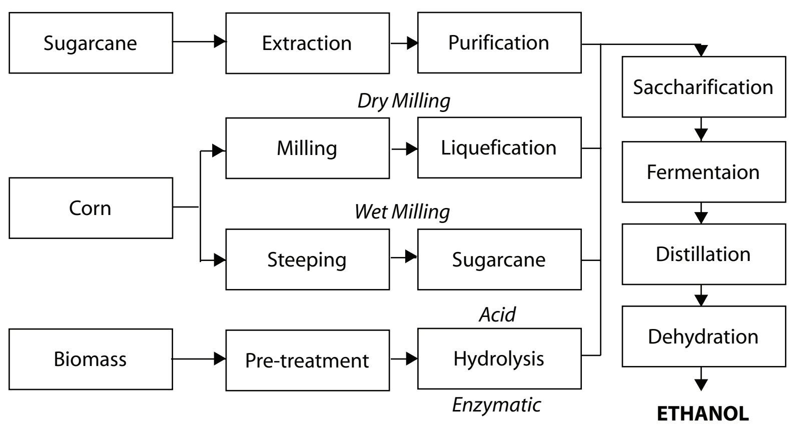
A-1) Ethanol Definition

Ethanol is an alcohol-based, clean-burning fuel produced from renewable feedstocks. It falls within the category of high-octane fuels, meaning it is highly efficient and preventative of engine knock. It can also be used as an oxygenate additive to gasoline to reduce carbon monoxide emissions by increasing the gasoline's octane quality, improving combustion, and diminishing exhaust emissions. It is produced from starch, which can be derived from a variety of feedstocks including sugarcane, corn, potatoes, sugar beets, switchgrass, barley, wheat and other grains, and through a variety of processes. Producers are also developing "second-generation" technologies which will allow them to produce ethanol from cellulosic biomass materials. In conjunction with ethanol production, biochemical products are also being developed, which can be used to produce bio-plastics and even pharmaceuticals.

A-2) Ethanol Production - First Generation

There are a variety of methods that can produce ethanol. The initial steps of each method tend to be feedstock-specific, but in all processes, the starch is extracted, fermented and distilled into ethanol [Diagram 2.3a].

Diagram 2.1a: Variation of Common Ethanol Production Methods



Source: Nexant[34]

From Sugarcane - The process of producing ethanol from sugarcane entails :[35]

1) Extraction – the sugarcane must be broken up to make the juice more easily accessible; this is typically accomplished using a three-roller press. The juice is then collected, and the leftover bagasse, comprised mostly of sugarcane stalks and water, can be burned in boilers to co-generate power for the processing plant. Additional steps such as imbibation or diffusion can maximize extraction. These steps involve extracting the remaining sucrose by adding water to the bagasse.
2) Purification – there are a number of impurities contained in the juice once it is extracted, including dirt and small pieces of bagasse. Once extracted, the juice is typically filtered through a variety of methods such as straining, sedimentation, and centrifuge force. It is then chemically treated, heated and put through a process of evaporation to extract excess water.
3) Saccharification – lime is added to the juice mixture and the liquid is then heated and cooled again. After this phase, the juice is pasteurized and sterilized.
4) Fermentation – the sugars are transformed into ethanol and carbon dioxide (a colorless, odorless gas produced by the respiration/ combustion of fuels containing carbon; also used by plants as food)[36] through a biochemical process where yeast is added to ferment the sugars. This process includes several stages of fermentation and can last from 4-12 hours. Afterwards, the yeast is removed from the ethanol

by centrifuge.

5) Distillation – the mixture now contains 7-10% alcohol and unfermented solids. It is processed in a series of distillation columns to remove the unfermented matter. The ethanol leaves through the top of the final column with a strength of 96%, and the leftover phlegm leaves through the bottom of the final column. At this stage, ethanol contains some small percentage of water, typically 4%, and is called *hydrous* ethanol.
6) Dehydration – to achieve maximum strength ethanol, the 96% mixture is dehydrated using benzol, which is later removed, leaving a mixture of 99.7% ethanol, called *anhydrous* ethanol.

The quality of the cane determines the amount of juice extracted. For good-quality sugarcane, 100 kilograms of crop can yield up to 50 kilograms of juice made up of 22% sugar, using the three-roller method. Sugarcane that has been harvested early would typically yield less—roughly 40 kilograms —with a sugar content of 17%.[37]

From Corn - Corn can be processed through either dry or wet milling. The *dry milling* process includes the following steps:[38]

1) Milling – the feedstock is ground into a fine powder called meal.
2) Liquefaction – the meal is mixed with water and an enzyme called *alpha-amylase*. It is then passed through a cooker to liquefy the starch.
3) Saccharification – the liquid starch, or mash, is cooled and a second enzyme called *gluco-amylase* is added to convert the liquid starch into *dextrose*, a fermentable sugar.
4) Fermentation – a biochemical process, yeast is added to the mash to ferment the dextrose into ethanol and carbon dioxide. This process entails several stages of fermentation and can last up to 48 hours.
5) Distillation – the fermented mash, now called beer and containing roughly 10% alcohol and unfermented solids left over from the feedstock and yeast, is processed in a series of distillation columns to remove the unfermented matter. The alcohol leaves through the top of the final column with a strength of 96% (*hydrous* ethanol), and the leftover residue, usually called stillage, leaves the bottom of the final column and is moved to a co-product processing area.
6) Dehydration – The remaining water is removed from the alcohol, often using a molecular sieve, and what is left is pure at nearly 200 proof (*anhydrous* ethanol).
7) Denaturing – a small amount of gasoline is added to the ethanol, usually 2-5%, making it ready for use as fuel as well as unfit for human consumption.

Distiller's grain and carbon dioxide are the two main co-products of ethanol production. Distiller's grain can be used as feed for livestock, and carbon dioxide can be compressed and sold for use in other industries.

In the *wet milling* process, the fiber, germ (oil) and protein are removed from the starch so that it can be fermented into ethanol. The first step is what differentiates wet from dry milling:[39]

1) Steeping/ Separation – the feedstock is steeped in water and sulfur dioxide for 24 to 36 hours to separate the starch and protein connections. The corn is then ground to break apart the germ and kernel.

For corn, dry milling is more cost effective than wet milling, and it requires less equipment. For wet milling, the equipment costs are high, and the process uses hazardous sulfur dioxide. The advantage of wet milling is that valuable co-products such as corn oil can be produced.[40]

A-3) Ethanol Production - Second Generation

The main process of second generation ethanol production involves the processing of the cellulosic biomass material found in plants. Cellulosic materials are comprised of cellulose, hemicellulose, and lignin (they are also called lignocellulosic materials).[41]

The key to this process of development is accessing the carbohydrates contained within the cellulose and hemicellulose found in feedstocks. Cellulose is a polysaccharide carbohydrate, the most common organic material on the planet and the main component of plant cell walls. Within these walls, cellulose is protected by a covering of hemicellulose and lignin (lignin also has commercial value). To process the cellulose and hemicellulose for ethanol production, the plant stalk must be pretreated to expose the carbon materials and allow them to be fermented and refined into ethanol or biodiesel.[42] The lignin, which provides structural support to the plant body, is a non-fermentable residue which can also be used as a fuel; it is frequently used for co-generation to power biofuel production plants.[43]

Thermo-chemical or gas-to-liquids processes can also be utilized to produce biofuels, including ethanol, from biomass. Biomass materials can be thermo-chemically liquefied and then converted, through exposure to either a microorganism or a catalyst, or fermented. This process, however, still requires further development to become cost efficient.[44] The Fischer-Tropsch gas-to-liquids process can also be used to produce ethanol from biomass such as plant material, residues and other recyclable matter, but is more often associated with second-generation biodiesel production and will be outlined in greater detail in that sub-section.

Second-generation processes will be pivotal to the advancement of the biofuels sector because they allow more of a given crop to be used in the production of biofuels, maximizing output per hectare. They also minimize the need to plant additional feedstock at the expense of trees or to divert crops away from use as food. If scientists can develop a firm understanding of the chemistry and biology of cellulose and of the microorganisms needed to break it down for processing, they will be able to unlock the great potential of biofuels as a viable, sustainable, alternative energy source.

From Biomass - the breakthrough in second generation production of biofuels occurs in the first two steps:[45]

1) Pretreatment – cellulose's protective sheath of hemicellulose and lignin must be treated to break it down, allowing for the release of the polysaccharides contained therein and for the enzymatic hydrolysis of the cellulose, which can be achieved either physically or chemically.
2) Hydrolysis – this step involves the conversion of cellulosic material into sugar and can be executed using either acid or enzymes. Acid can function to pre-treat as well as hydrolyze the cellulosic material; enzymatic hydrolysis, however, requires a separate pretreatment step to break down the structure of the material and allow the enzyme to gain access to the molecules to be processed.

Once fractioned, cellulose and hemicellulose yield glucose, a C6 monosaccharide (6-carbon sugar). The hemicellulose also yields pentoses, a C5 monosaccharide. A common example of a C5 monosaccharide is xylose. Glucose, the most abundant sugar in the material, is easily fermented into ethanol; however, an additional fermentation process involving special microorganisms is needed to convert xylose.[46] Learning how to efficiently break down and ferment C5 sugars will be a major discovery for the biofuels sector.

Acid hydrolysis can be performed with either dilute acid, which requires high temperatures and has a quick reaction time of minutes, but which has a sugar-recovery efficiency of only 50%; or concentrate acid, which needs only mild heat and can have a recovery rate of up to 90%, but involves a slow process often requiring several hours. C5 sugars break down more quickly than C6 sugars, which means that prolonged exposure through the use of concentrated acid would lead to sugar degradation for C5 sugars, whereas quick exposure through dilute acid hydrolysis would lead to underprocessing for C6 sugars. While some experts have explored the idea of a two-phase process in which C5 sugars are processed first under milder conditions, followed by C6 sugars using a harsher process, problems with sugar degradation and yield remain.[47]

The enzymatic process requires the discovery or development of enzymes, or naturally occurring plant proteins that bring about chemical reactions, which can convert carbohydrates to sugar without interacting with any pretreatment chemical residues or impeding fermentation. vThe enzyme process can be slow, requiring days, but there have been developments in the types of enzymes that can be used to make ethanol, as well as processes in which enzymes and yeast are added to materials to achieve simultaneous conversion and fermentation.[48]

The barriers to development of second-generation processing capabilities lie in the lack of complete understanding of the chemistry and biochemistry involved in the pretreatment and hydrolysis phases of cellulosic fuel production. For pretreatment, a need persists for the development of chemicals which can break down the protective hemicellulose and lignin layers without impeding the processes which follow it, including fermentation. For enzymatic hydrolysis processes, there is a high cost associated with enzyme use, a lack of commercialization of viable enzyme products, and a lack of understanding of their biochemistry as it pertains to biofuel development.[49]

B) Biodiesel

B-1) Biodiesel Definition

Biodiesel is a clean-burning, high-octane, renewable fuel derived from fatty acid methyl esters (FAME) and ethyl esters (FAEE), or long-chain fatty acids found in plant oils and animal fats. It is non-flammable and non-explosive, and it can be used in diesel engines at its purist concentration or when blended with regular diesel fuel. Potential feedstocks for biodiesel include rapeseed, canola, soy, palm oil, jatropha, used cooking oil and variety of other vegetable seeds and oils.

B-2) Biodiesel Production - First Generation

Biodiesel is a young industry, and its production is much lower worldwide than ethanol.[50] Biodiesel production usually occurs through the process of transesterification, in which one ester is converted into another using an alcohol and a catalyst.

From Oilseed Crops – this biodiesel production process involves:[51]

1) Extraction – the oil is extracted from the seed or nut either through the use of a solvent or through mechanical crushing.
2) Pre-Treatment - the oil is filtered and pre-processed to remove water and impurities. Free fatty acids present in the oil can be removed or converted into biodiesel using pre-treatment technologies.
3) Alcohol and Catalyst Mixing - an alcohol, either methanol or ethanol, and a catalyst, usually sodium or potassium hydroxide, are mixed together and the pre-treated fats and oils are then added to the mixture.
4) Reaction - the mixture is charged into a closed-reaction vessel; reaction time is from one to eight hours. The mixture is kept above the boiling point for alcohol, usually 160 ºF, to speed up the reaction. Some systems advise that the reaction actually take place at room temperature. During this phase, the triglycerides, or oil molecules, are broken down and reformed into esters, or biodiesel, and glycerin.
5) Separation – the biodiesel and glycerin can be separated by gravity, as glycerin is heavier, or by centrifuge, which is faster. At the beginning of the separation phase, each contains an excess amount of the alcohol used in the initial reaction; the mixture can be neutralized if need be.
6) Alcohol Removal – if not neutralized prior to separation, excess alcohol is removed through either flash evaporation or distillation. The alcohol can be collected and reused, but care must be taken not to allow water to accumulate in the recovered alcohol.
7) Glycerin Neutralization - unused catalyst and soaps still remain in the glycerin; they are neutralized with an acid and the glycerin is stored. On some occasions, salt forms during this phase. It can be collected and used as fertilizer.
8) Washing – after separation from the glycerin, the biodiesel can be gently washed, to remove impurities such as catalyst or soap, and then dried and stored. Biodiesel

can be distilled once more to produce a colorless fuel (the fuel is amber-colored after washing).

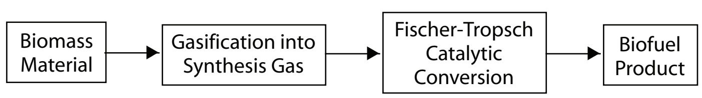
An excess of alcohol is often used to ensure the complete conversion of fats and oils to esters. The amount of water and free fatty acids in the incoming oil or fat must be monitored because if they are too high, problems with soap formation and separation will arise. Once the biodiesel is made, producers must take care to remove any water, alcohol, catalyst, or free fatty acids.

Presscake animal feed and glycerin are the main co-products of this process. Glycerin, in particular, is a valuable chemical, the capture and sale of which improves the economic viability of biodiesel production. Glycerin can be used to make cosmetics, pharmaceuticals, and food, among other things. It can also be used as a fuel to power the production process.[52]

B-3) Biodiesel Production - Second Generation

Second-generation biodiesel production is usually performed through gasification and Fischer-Tropsch, or gas-to-liquids, processing. Together, this process is often referred to as biomass-to-liquids production. The process was discovered in 1923 by German researchers Franz Fischer and Hans Tropsch at the Kaiser Wilhelm Institute and was used by Germany and Japan during World War II, but is not widely used today. The process involves the liquefaction of natural gas and other gasified energy sources, such as coal or biomass, into clean-burning, colorless fuel. This transformation is accomplished through the conversion of synthesis gas made up of hydrogen and carbon monoxide, using iron or cobalt as a catalyst, into liquid hydrocarbons through a heat-intensive process. For conversion into synthesis gas, biomass must be heated with little or no oxygen present. Residues, leftover kernels and shells, and waste oil constitute the biomass used in this production.

Diagram 2.1b: Biomass-to-Liquids Process



C) Benefits & Drawbacks of Biofuels Use

There are a variety of economic and social benefits to biofuels use, which can in turn have positive political benefits for a government managing successful biofuels policies and projects. These benefits include:

- Reductions in greenhouse gas emissions
- Improved energy security
- Economic gains
- Rural development and job creation
- Foreign exchange savings
- Reductions in waste

The potential benefits of biofuels, notably their higher yield-energy input ratio compared to gasoline, are currently under debate in the policy and scientific fields. It is clear, however, that improved air quality, lessened dependence on foreign sources of fuel, and agriculturally-based development are all potential benefits for both developed and developing countries.

The drawbacks to biofuels production and consumption center on the need for a large crop to produce commercial-level volumes of ethanol or biodiesel. The requirement of a large crop can have potentially negative environmental and human consequences of its own. There is also concern that the fuel produced provides less energy per unit of measure than gasoline.

C-1) Greenhouse Gas Emissions

The transport sector was responsible for one-fifth of global greenhouse gas emissions in 2001,[53] and emissions from this sector are expected to grow at an average annual rate of 1.3% between now and 2030 if energy policies remain static, a faster rate than all other sectors.[54] The use of biofuels could significantly reduce emissions, but only if their use becomes more widespread.

C-1.1) Ethanol

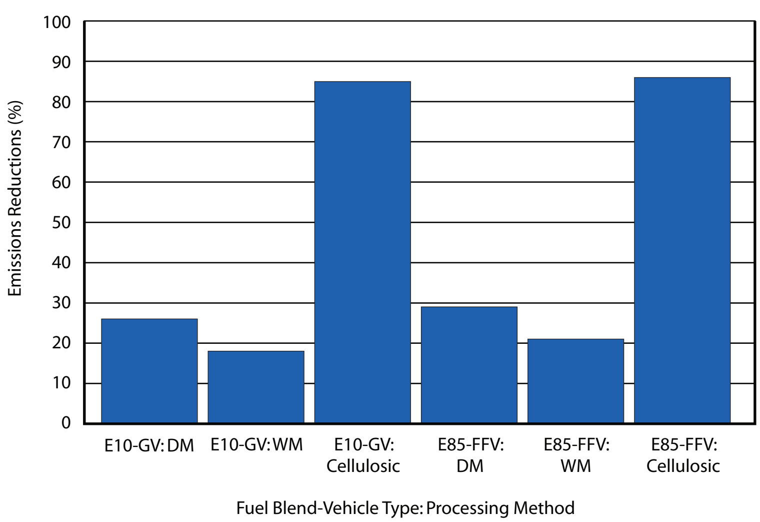
Ethanol produces a smaller quantity of greenhouse gas tailpipe emissions than gasoline. Oxygen comprises 35% of ethanol fuel, which means that ethanol burns more cleanly and completely than gasoline. The fuel is also biodegradable.[55]

The factors involved in the evaluation of ethanol's emissions reduction qualities include: the emission of nitrous oxide and methane from fertilizers and pesticides used in cultivation; the carbon dioxide released during the processing of ethanol; and the carbon monoxide exhaust emissions from the transportation of fuels within the value chain as well as their use in vehicles by consumers,[56] although the 2004 IEA report on transportation biofuels suggests that this effect is minor.[57] The co-products of fuel production, such as animal feed or co-generation of electricity, can also improve the overall emissions balance of ethanol based on the products they displace and their respective emission levels. Improvements in the value-chain processes would likely achieve greater emissions reductions.[58] Emissions calculations also depend on:[59]

- the feedstock used in production – corn versus sugarcane versus cellulosic material;
- the milling process used – dry milling (DM) versus wet milling (WM) for corn;
- the fuel blend level – 10% ethanol (E10) versus E85 or E100; and
- the type of car using the fuel – gas vehicles (GV) versus flex-fuel vehicles (FFV).

The emissions reduction figures also depend on the region in question. Some countries have mandatory blending proportions for regular gasoline—such as Brazil, where regular gas must have an ethanol content of 20-25%—or use ethanol as an oxygenate additive to increase the performance of regular gas.

Chart 2.1a: Greenhouse Gas Emissions Reductions for Corn Ethanol Use*

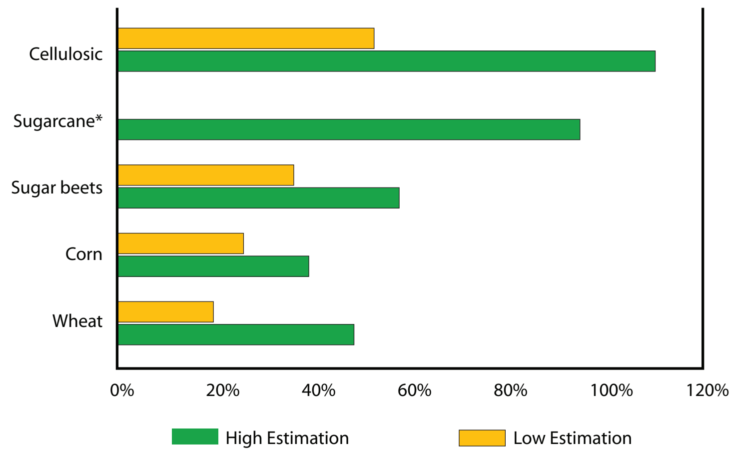


Source: National Laboratory[61], * Reductions are per 3.785 liters of ethanol used in place of energy-equivalent of gasoline in the United States.

In the United States, reductions in greenhouse gas (GHG) emissions from the use of a 3.785 liters (one gallon) of ethanol in place of an energy-equivalent amount of gasoline range from 18% for E10 made from wet-milled corn and used in gas vehicles, to 86% for E85 made from cellulosic material and utilized in a flex-fuel vehicle [Chart 2.1a].[60]

On a more general level, according to a report produced by the IEA on biofuels for transportation, the use of grain-based ethanol, in comparison to gasoline, yields a 20% to 40% reduction in carbon-dioxide-equivalent greenhouse gases from "well-to-wheel", or through the complete value chain to consumers.[62] The report also finds, through the compilation and analysis of several analyses, that potential emissions reductions vary markedly by feedstock [Chart 2.1b]. Of the feedstocks analyzed, ethanol produced from sugarcane and cellulosic materials demonstrated the greatest potential for GHG emissions reductions.

Chart 2.1b: Ethanol Well-to-Wheel GHG Emissions Reductions compared to Gasoline (Summary of Recent Reports)



Source: IEA[63], *Only one report available for comparison.

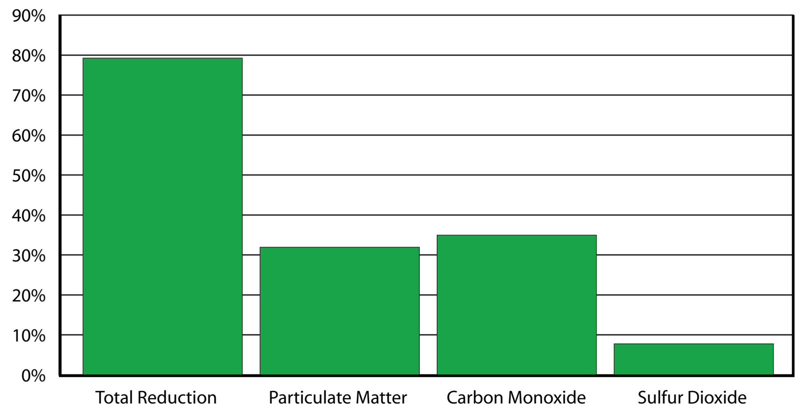
For cellulosic-based ethanol, GHG emission reductions range from 51% using wood from poplar trees, to 61% for corn stover, to 66-71% for grass, to 57-82% for different types of straw. The 107% value is for the use of wood as a feedstock, including biomass and non-biomass sources of energy, and takes into account the reductions achieved through the full cycle of wood use, from cutting down a tree to produce the fuel, to emissions through vehicle tailpipes, to the re-plantation of that tree and the emissions displaced by the use of the renewable fuel.[64]

C-1.2) Biodiesel

Through biodiesel use, exhaust emissions of sulfates and sulfur oxide, which are the major components of acid rain, are virtually eliminated in comparison to conventional diesel use. The ozone-forming potential of the emissions of unburned hydrocarbons and nitrogen oxides was about half that of conventional diesel fuel.[65]

A joint study between the US Departments of Energy and Agriculture showed that the production and consumption of biodiesel yields a 78.5% reduction in carbon dioxide emissions versus conventional diesel use.[66] Part of this calculation takes into consideration the fact that the carbon dioxide released into the atmosphere when biodiesel is burned is used by plants as food, and some of those plants are, in turn, processed into fuel. Biodiesel use can also reduce emissions of particulate matter by 32%, carbon monoxide by 35%, and sulfur oxide by 8%.[67]

Chart 2.1c: Potential Emissions Reductions through Biodiesel Use



Source: USDA

The IEA estimates that the use of biodiesel made from rapeseed in light-duty compression-engine ignitions could yield GHG emissions reductions of 40-60%, depending on assumptions of emissions savings derived from conversion processes and the use of co-products. The studies compiled by the IEA for its *Biofuels for Transport* report indicate that reductions in emissions came from the biodiesel itself, and that the blend ratio determined the reduction value. For example, if GHG emissions were reduced by 60% through the use of biodiesel, a 10% blend (B10) would reduce emissions by one-tenth of that percentage, or 6%. The IEA report also highlighted the findings of a 2002 study by General Motors and others, which stated that glycerin co-product utilization to replace production of the chemical for use in other goods added an additional 30% to net GHG emissions reductions.[68] As with ethanol, the distance involved in either transporting raw feedstock to producers or final fuels to consumers has a minor effect on overall carbon emissions.[69]

Biodiesel has been shown to actually increase emissions of nitrous oxide, thought to be particularly responsible for breaking down the ozone layer. Some experts speculate, however, that those emissions could be reduced by blending biodiesel with kerosene or Fischer-Tropsch diesel. The estimated nitrogen oxide emissions of blending Kerosene with B40 are no greater than those of conventional diesel, nor are those for a blend of Fischer-Tropsch diesel as high as B54.[70]

C-2) Energy Security

The use of ethanol or biodiesel as a transportation fuel can limit the consumption of crude oil, which reached a historic high of $79 a barrel in August 2006, and is found in regions with increasing political and economic volatility. The utilization of biofuels would allow countries to lessen their dependence on foreign sources of oil, improving their energy security position.

Renewable fuels also offer an advantage in that their production cycle is short, compared to that of petroleum, and the industry's value chain, particularly upstream, can be more easily controlled by producers. Biofuels producers face certain conditions beyond their control, including climate variations and natural disasters, but they can choose where crops are planted, how they are cultivated, and adopt measures against insects and pests. Petroleum producers, by contrast, cannot choose where oil is located and often must engage in expensive exploration based on seismic data that suggests the probability – but offers no certainty – of a petroleum deposit.

There is also more political volatility surrounding petroleum production, particularly in developing nations, which in turn affects the stability of supply. Biofuels are not without their supply constraints and concerns, but once adequate infrastructure is in place, including distribution and logistics networks, and second generation technologies are developed, biofuels could offer a more stable, secure supply of fuel for some segments of the global fuels market.

C-3) Economic Gains

C-3.1) Balance of Payment and Foreign Exchange

The production and consumption of biofuels could help the terms of trade of countries dependent on foreign sources of oil by reducing imports of crude oil at today's historically-high prices. This could be accomplished through the import substitution of domestically grown biofuels for foreign oil. The expense of acquiring crude products is, for countries with over-valued currencies, compounded by losses in the foreign exchange conversion to dollars for petroleum purchases. A switch to domestic biofuels consumption would lessen this burden, although it is important to note that such a switch could impose certain short-term costs on these same countries, including the import of biofuels production machinery from abroad.

In addition to reducing the petroleum bills of importing countries, biofuels production and use could provide a new source of income to those countries able to produce biofuels for export.

C-3.2) Agricultural Development

Biofuels use increases the demand for its crop-based feedstocks, adding value to the agricultural sector of a given country. As such, biofuels consumption can have a positive effect on rural development and the sustainability of the farming industry, including job creation and an increase in the income of rural workers and businesses. For developing countries with agriculturally-based economies and large income disparities between urban and rural areas, biofuels have the potential to function as an effective development tool.

This potential may require difficult choices for governments as they consider how to structure possible subsidies and incentives for biofuels production in rural areas. Governments must, of course, compare the costs and benefits of biofuels subsidies and programs to other government initiatives aimed at infrastructure development, microcredit, and support of small and medium enterprises (SMEs), or other business promotion efforts outside the biofuels industry.[71] These assessments will be country and region-specific, but the potential benefits of biofuels in the energy, environmental and rural development realms must make it a strong candidate for significant government support.

C-4) Socio-Environmental Sustainability

The food versus fuel debate is pervasive in the biofuels discourse. Critics believe that by increasing global consumption of renewable fuels, the availability of feedstock crops for food production will decline and in some cases exacerbate global hunger issues. For example, according to the United Nations Food and Agriculture Organization (FAO), Africa's dependence on food imports, including cereal grains, is expected to increase over the medium term.[72] If the countries which normally export grains to the continent begin to use their grain surpluses to produce biofuels instead, countries in need might experience more acute food shortages.

There is also some concern that increased demand for biofuels will actually promote environmental degradation through the destruction of virgin forests to clear land for feedstock cultivation, which will promote soil erosion, and the depletion of vital soil nutrients by crops such as corn, which can be costly to replace. Additionally, if crops are grown on less-optimal land, due to increased demand for biofuels in the face of growing land constraints, the additional water and fertilizer needed can promote soil contamination and erosion of the already sub-optimal cultivation area.[73] These types of obstacles can increase harvest and crop yield and price volatility.

Conversely, the cultivation of certain feedstocks can add nutrients back to the soil and help curtail soil erosion. For example, corn and soybeans are often grown in rotation on the same land because soybeans add back nitrogen depleted by corn crops. Plants like jatropha can be grown in drier, rougher climates, minimizing the need to irrigate land, which can promote soil erosion.[74]

C-4.1) Crop & Fuel Prices

The price competitiveness of biofuels is closely tied to feedstock prices. Price volatility tends to have a greater effect on biodiesel, but it affects the competitiveness of ethanol as well. This volatility tends to perpetuate the need for subsidies in the short- to medium-term.[75] The increased use of biofuels in the global market could have inflationary effects on the price of feedstock crops and thus biofuels, straining the ability of consumers to buy agricultural goods either in biofuels form or for food consumption. Government subsidies put in place to promote the nascent sector tend to artificially control the price of crops and fuel, and will likely be followed by potentially uncomfortable price adjustments as the sector liberalizes and experiences market pressures.

Ethanol produced from sugarcane, particularly in Brazil (and likely globally), and from cellulosic materials has the potential to be competitive with gasoline priced at $25 - $35 per barrel and higher. However, biofuels made through biomass gasification and Fischer-Tropsch synthesis are not likely to be competitive for the next 10-15 years, barring an unexpected technological breakthrough. Indeed, questions remain as to whether biodiesel, particularly made from soy, will ever be price competitive, suggesting that subsidies for the biodiesel sector will persist beyond those for ethanol.[76]

C-4.2) Technological Considerations

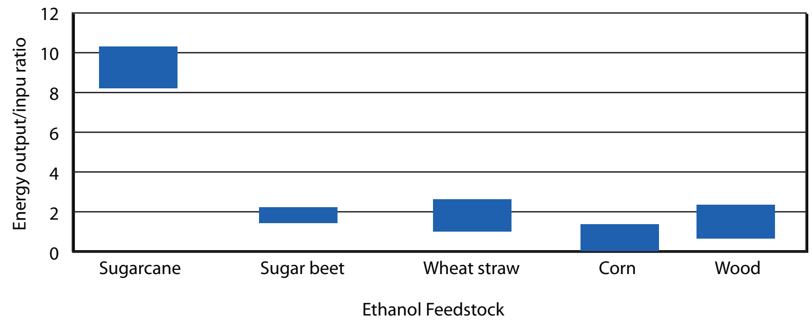
Second-generation technology is likely to alter the balance between social and environmental costs and benefits of biofuels that have already been discussed at some length. In particular, new technology should ease concerns surrounding hunger and deforestation with respect to ethanol and biodiesel production. Producers likely will be able to increase their output per hectare by utilizing more of a given crop to produce fuel, allowing for a ramp-up in production without necessarily planting more crops or diverting crops from the food industry.

C-5) Energy Balance

C-5.1) Ethanol

There is vigorous debate regarding the energy balance of gasoline, meaning the ratio of energy input to produce the fuel versus the energy contained within the fuel once produced. According to a study by the Argonne National Laboratory, which is managed by the University of Chicago for the US Department of Energy, 1.23 BTUs of fossil fuel are required to produce 1 BTU of gasoline, giving it a negative energy balance. Ethanol, by contrast, has a positive energy balance. Production of 1 BTU of ethanol from corn requires 0.74 BTUs, including cultivation, harvesting and processing, yielding an energy balance of +1.35.[77]

Chart 2.1d: Energy Balance of Ethanol Production from different feedstocks*



Source: Coehlo/ Cenbio[78]; * Given a range of production scenarios

The same study estimates that only 0.12 BTUs of fossil fuel are required to produce 1 BTU of ethanol from sugarcane, an energy balance of +8.3. The ability of producers to use the bagasse and stalks of the cane to help power a processing plant help make it significantly more efficient than other possible feedstocks, most of which have energy balances that fall between that of sugarcane and gasoline. Sugarcane has the added benefit of greater feedstock per hectare. At least for first-generation ethanol production, it must be considered the leading feedstock candidate.

Table 2.1a: Productivity Comparison

Raw Material	Production/ Hectare	Quantity of Feedstock/ Liter of Ethanol	Quantity of Ethanol/ Hectare
Sugarcane	85,000 kg	12 kg	7,080 liter
Corn	10,000 kg	2.8 kg	3,570 liter

Source: Brazilian Ministries of Agriculture, Development and Energy [79]

The American Petroleum Institute (API) disputes the findings of the Argonne study, citing an energy balance for gasoline of approximately +5 BTUs. It is worth noting, however, that 0.81 is the value used by the US Department of Energy.

C-5.2) Biodiesel

According to a study performed by the U.S. Department of Energy (DOE), biodiesel has a positive energy balance of 3.24 BTUs of energy yielded per BTU of energy required for production.[80] Standard diesel, by contrast, has an energy balance of 0.84.[81] A B20 blend has a slightly higher yield of .98 BTUs of energy.[82]

C-6) Fuel Economy

C-6.1) Ethanol

Ethanol does not offer advantages in fuel economy in comparison to gasoline. In most circumstances, a vehicle drives further on a liter of gasoline than a liter of ethanol. The use of regular fuel oxygenated with ethanol results in a loss of fuel economy of 1-3%.[83] E-85 contains nearly 28% less energy per liter than gasoline, while E-100 contains more than 33% less [Table 2.1c]. These values are general as actual performance varies by vehicle.

Table 2.1b: Gasoline Liter Equivalents of Biofuels

A gasoline liter equivalent is the volume of fuel needed to equal the energy content of one liquid liter of gasoline. This comparison of equivalent volumes of fuel is based on the energy content per unit and is measured in British thermal units (BTUs).

Fuel Type	BTUs Per Unit	Liter Equivalent
Gasoline, regular unleaded	30,145	1
Gasoline, reformulated (10% MBTE)	29,590	1.02
Diesel	34,293	0.88
Ethanol (E-100)	20,106	1.5
Ethanol (E-85)	21,612	1.4
Bio Diesel (B-20)	34,214	0.88

Source: National Association of Fleet Administers, Inc.[84]

How to properly weigh energy balance (which favors ethanol) and energy per liter (which favors gasoline) is still very much a matter for debate. It is important to recognize that any generalized calculation of efficiency will fluctuate depending on the feedstock used and the criteria selected to calculate the energy efficiency of either fuel. Additionally, the distance a vehicle can travel per liter of fuel depends not only on the fuel's energy content, but also on the fuel economy of the vehicle. Because ethanol has high octane rating, vehicles that are designed to run on ethanol usually have engines with higher compression ratios than regular gasoline engines, offsetting, in part, the lower energy content of the fuel.[85]

C-6.2) Biodiesel

Regular diesel and the 20% biodiesel blend have roughly the same energy content, which is greater than both ethanol and regular gasoline [Table 2.1c]. The energy content of pure biodiesel can average between 30,575 and nearly 31,500 BTUs per liter, depending on the feedstock [Table 2.1d], which means that B100 offers a little over 9% less fuel economy than regular diesel. The range of fuel economy deficits for biodiesel is 8.9% to 9.2%.

Table 2.1c: Energy Content of 100% Biodiesel (per Liter)

	Average BTUs
All biodiesels	31,254
Animal	30,573
Rapeseed/canola	31,495
Soybean	31,499
Rapeseed or soybean	31,497

Source: EPA[86]

C-7) Vehicle Requirements

C-7.1) Ethanol

In the United States, unmodified gas vehicles can run on E10 without difficulty. Most flex-fuel vehicles can run on blends up to E85. Flex-fuel technology is more advanced in Brazil, where flex-fuel vehicles can run on pure gasoline, pure ethanol, or any combination of the two.[87]

Some problems have been identified in relation to ethanol use in cars, including water absorption, the drying out of plastic parts, the corrosion of metal parts, and difficult starts in cold weather with E100, which can be used in vehicles specially designed for pure ethanol. The existence of gasoline in fuel blends such as E85, however, helps to address corrosion and cold-start problems.[88] Flex-fuel vehicles also offer added protection against corrosion.

C-7.2) Biodiesel

The addition of biodiesel to diesel fuel, even in small quantities, can significantly improve the performance of conventional diesel.[89] It has been proven to reduce friction, and thus wear-and-tear, between moving vehicle parts.[90] Biodiesel also offers similar power and torque, as well as kilometers per liter, as conventional diesel.[91] One of the unique benefits of biodiesel production is that it does not require the construction of additional infrastructure for transport or distribution, and only minor modification is required for the consumption of B100 in engines.

Pure biodiesel, or B100, can damage plastic and rubber equipment, such as hoses, gaskets or other sealants, but most diesel equipment is biodiesel-safe. Biodiesel also has a solvent effect that may cause deposits accumulated in pipes and on the tank walls to detach, clogging filters upon initial use. This can occur with B20+ blends, but can be monitored and addressed. There have also been concerns with cold starts with higher blends of biodiesel, such as B20, but some producers in colder areas have begun mixing in cold-flow additives to address this issue.[92]

2.2) Coal-to-Liquids Technology

Against the backdrop of rising oil prices and the global rush to uncover alternative forms of energy, coal-to-liquid (CTL) technology or coal liquefaction has also emerged as a strong candidate. CTL is used to describe the process of producing fuels from coal through two methods: direct and indirect liquefaction. Direct liquefaction breaks down the complex coal structure into smaller component molecules at elevated temperatures and pressure, which then can be further refined into liquid fuel products by reducing the contents of sulfur and nitrogen through interaction with hydrogen gas and a catalyst. Indirect liquefaction first gasifies coal and then converts the coal-derived synthetic gas (syngas) into fuels and petrochemicals. The most common indirect liquefaction process is the Fischer-Tropsch technology, which was developed by German scientists in the 1920s and has been perfected and commercialized over the last few decades by South African mining and energy company Sasol.

A) Advantages

CTL technology is attractive to many governments because unlike several other types of alternative energy, such as fuel cell technology and certain types of cellulosic biofuels, CTL is a proven technology. It was used to great effect by the Nazi and apartheid-era South African governments to meet their energy demands when those countries were isolated by the rest of the world. Second, unlike dwindling oil reserves, coal reserves are enormous (estimated at 1,001 billion tons) and projected to last approximately 180 years at current consumption levels.[93] They represent a cheap source of energy available to harness. Third, coal-based fuel, also called synfuel, requires no engine modifications, and burns more cleanly than gasoline, because it has almost zero-sulfur emissions.

Table 2.2a: World Recoverable Coal Reserves (Short Tons)

Region/Country	Bituminous and Anthracite	Subbituminous	Lignite	Total
World Total	530.4	297.0	173.4	1,000.9
United States	125.4	109.3	36.0	270.7
Russia	54.1	107.4	11.5	173.1
China	68.6	37.1	20.5	126.2
India	99.3	0.0	2.6	101.9
Other Non-OECD Europe/Eurasia	50.1	18.7	31.3	100.1
Australia & New Zealand	42.6	2.7	41.9	87.2
Africa	55.3	0.2	*	55.5
OECD Europe	19.5	5.0	18.8	43.3
Other Non-OECD Asia	1.4	2.0	8.1	11.5
Brazil	0.0	11.1	0.0	11.1
Other Central/South America	8.5	2.2	0.1	10.8
Canada	3.8	1.0	2.5	7.3
Other[3]	1.8	0.4	0.1	2.3

[3]Includes Mexico, Middle East, Japan, and South Korea.
*Less than 0.05 billion short tons.
Note: Data for the United States represent recoverable coal estimates as of January 1, 2004. Data for other countries are as of January 1, 2003.

Source: EIA, 2006

B) Disadvantages

Despite these advantages, CTL technology has not been embraced wholeheartedly by all stakeholders. The first objection is that coal is still a fossil fuel and will ultimately run out, unlike renewable energy sources such as biofuels, and will only provide short-term energy security. Second, coal-based fuel releases double the amount of carbon dioxide as petroleum. Carbon dioxide is first created during the process of turning coal into fuel and then released again when the fuel is used in vehicles. This feature makes it unattractive in an increasingly carbon-conscious world eager to reduce greenhouse emissions. Third, investing in CTL technology is risky because, given the capital-intensive process of building CTL plants, synfuels are only financially viable when oil prices are above $35 - $40 a barrel.

C) CTL in the World

Unsurprisingly, CTL technology is most attractive to the countries with large coal reserves, notably the US, Russia, China and India (see table below), which together account for 62% of the world's coal reserves. However, each country faces unique challenges in the implementation of a coal liquefaction strategy. In the US, for example, Peabody Energy, the country's largest mining company by market capitalization, is pushing for a plan to produce 2.6 million barrels of synfuel per day by 2025, which is equivalent to 10% of forecasted oil demand in that year. Achieving this goal would require the construction of 33 large-scale CTL plants, which would each cost $6.4 billion.[94] The idea resonates in coal states like Montana, which supports the Coal-to-Liquid Fuel Promotion Act of 2006. The proposed legislation would create tax incentives for CTL technology and the construction of CTL plants but faces resistance from communities reluctant to embrace large-scale plants. China, which already generates 70% of its energy by burning coal, has embraced CTL technology without these reservations, in large part because it offers strategic energy security. Investors have shown strong interest in the technology, and 30 CTL plants are currently under construction or undergoing the approval process.[95] The Chinese government has raised the capital threshold for CTL projects to $3.8 billion and boosted the required production capacity of proposed plants to more than 3 million tons.[96]

D) CTL Vs. Biofuels

As with the development of other forms of alternative energies, there are fears that investing such a huge stake in the coal industry will result in surging coal consumption and rising coal prices, which would in turn make it less competitive with traditional gasoline. Without this price advantage, the high carbon emissions produced during the production and utilization of synfuels make it a weak competitor against biofuels, which offers reduced carbon dioxide emissions compared to fossil fuels.

2.3) Hydrogen Fuel Cell Technology

Although fuel cells have been in existence since 1839, their potential to provide power was only harnessed in the 1960s.[97] Fuel cells are often associated with renewable energy, but the association is only correct if the feedstock in question is renewable energy. Hydrogen can be produced from renewable energy sources such as solar, wind, water and biomass energy, as well as from traditional energy sources such as oil and natural gas (the last being the most cost-effective and common way). In essence, the fuel cell works like a battery by converting chemical energy into electrical energy through the electrochemical reaction of hydrogen and oxygen.

A) Advantages

Fuel cells are often hailed as the cleanest energy possible because the only emission is water.[98] In addition, one kilogram of hydrogen contains approximately the same amount of energy as 3.785 liters (one gallon) of gasoline. This energy punch, combined with hydrogen's feedstock flexibility, has made hydrogen fuel cell technology a favorite of governments and industry stakeholders worldwide. Visions of a hydrogen economy have often captivated developed country governments and publics.

B) Disadvantages

Worldwide enthusiasm notwithstanding, fuel cell technology is still far from being commercially viable. Four major obstacles stand in the way:

1) Fuel cell technology lacks the necessary supporting infrastructure, such as hydrogen refueling stations, hydrogen gas pipes, uniform standards, as well as funding and education. This would require the involvement of all stakeholders (governments, consumers, energy companies, and auto companies).
2) A transition period is needed to introduce the concept of a hydrogen economy by educating consumers accustomed to a gasoline-based economy and to build up the hydrogen infrastructure.
3) Hydrogen storage is still very inefficient, especially when compared to gasoline. A tractor-trailer full of compressed hydrogen can fill only five or six automobiles.[99] Other technological limitations include fuel cell motors, which convert hydrogen to electricity and have been shown to decline in power with increased operation time and colder temperatures.[100]
4) Finally, the cost of fuel cells is still prohibitive, despite the fact that the cost of fuel cell stacks have decreased tenfold in the last three years.[101] The fuel cell production process is still very detailed and requires skilled labor.

C) Global Fuel Cell Technology

To succeed, fuel cell technology will require enormous government support, both in the form of financial support for R&D efforts and financial incentives. It is unsurprising that the most active countries in the development of hydrogen fuel cell technology are industrialized countries like the US, Western European countries, Japan and South Korea, which are home to the world's top auto companies. The US Department of Energy has made the development of fuel cells a top priority through its FreedomCar and Vehicle Technologies Program, a mission aided by $1.2 billion in federal grants.[102] Members of the FreedomCar and Fuel Partnership include industry stakeholders like

Daimler Chrysler, General Motors, Ford Motors, BP America, ChevronTexaco, ConocoPhilips, Exxon Mobil, and Shell Hydrogen. DaimlerChrysler in particular has invested over $1 billion to develop five generations of vehicles. The company currently has more than 100 fuel vehicles, both cars and buses, participating in demonstration projects all over the world.[103] In Asia, the R&D flag is carried by Japan's Honda, which released 20 of its most advanced fuel cell vehicles for unsupervised public evaluation in 2005, and South Korea's Hyundai, whose second-generation Tucson fuel cell vehicle exceeded expectations in its ability to operate in sub-zero temperatures, a key weak point in fuel cell motors.[104]

D) Fuel Cell Technology vs. Biofuels

Even with the enormous leaps in fuel cell competitiveness and technology, auto majors do not expect the technology to be commercially viable within the next decade. While fuel cell technology should not be discounted as an alternative energy in the long-term, in the short-term it lags behind biofuels, especially given that existing infrastructure requires minimal modifications to store and distribute biofuels. Hydrogen's advantage in offering clean emissions may also be reduced given the enormous strides made in commercializing cellulosic ethanol, which offers reductions in well-to-wheel carbon dioxide emissions of between 70% and 100% against gasoline, a significant improvement on grain ethanol's average of 20% to 40% reductions.[105]

3) Conclusion

There is a general consensus among leading energy information sources that energy consumption will surge as much as 30% by 2020. A growing world population and strong economic growth in developing countries will propel energy consumption, and the twin forces of urbanization and industrialization will accelerate this trend.

On the supply side, the growing realization that oil, natural gas and coal have limited lifespans as energy sources will continue to spur the development of alternative energy. Concerns about supply security given the concentration of fossil fuel reserves in volatile regions will add impetus to this movement. Meanwhile, growing concern about global warming and carbon dioxide emissions is prompting strong commitments worldwide to developing alternative sources of clean, green energy.

The transport sector is a vital component of an effective response. It contributed 20% of global gas emissions in 2001; it registered the fastest greenhouse gas emission growth in developed countries like the US, Japan and the EU; and the sector is on course to consume 55% more energy by 2030. In this environment, the introduction of cleaner, non-fossil fuels to the transport sector is a priority. Developing countries, such as China and India, which face an explosion in vehicle growth, also cannot afford to ignore the issue. Governments around the world, aware of the wealth of new technologies and energy alternatives available in this new age of energy choice, are already tailoring energy policies to their unique circumstances.

This report has laid out the competitive position of biofuels relative to its two principal alternatives: coal-to-liquid technology and hydrogen fuel cell technology. The first is popular with governments because it is, like biofuels, a proven technology. Coal liquefaction also represents a cheap source of energy, burns more cleanly than gasoline, and is readily available for countries with huge coal reserves. The second, hydrogen fuel cell technology, is favored because it is potentially the cleanest energy possible. Hydrogen is also abundant, because it can be produced from renewable energy sources such as solar, wind, water and biomass energy, as well as from traditional energy sources such as oil and natural gas.

Despite its environmental drawbacks, coal liquefaction is likely to remain an important energy choice in coal-rich countries like China, Russia, India and even the US. For its part, hydrogen fuel cell technology remains prohibitively expensive, and it is unlikely to emerge as a feasible alternative energy source in the transport sector for at least the next decade. Even then, the high cost of new infrastructure will likely render it infeasible for all but the wealthiest countries.

In this context, biofuels have emerged as a strong transport fuel alternative. The Kyoto Protocol has provided an additional impetus to biofuel development as industrialized countries seek to meet their emissions reduction targets. Biofuels have the added advantage of being commercially tested. National biofuels programs can aid a country's agroeconomic goals by creating rural jobs and developing the rural economy. Most importantly, the development of biofuels can limit a country's reliance on imported crude oil, diversify the national energy mix and improve energy security.

It should be clear that biofuels are not a replacement for fossil fuels. Instead, they offer an alternative with a number of attractive benefits. The advantages offered by biofuels, such as lower carbon emissions and competitive production techniques, rely on existing technology. As the billions of dollars poured into biofuels R&D worldwide take effect, these advantages will only increase. Second-generation biofuels, such as cellulosic ethanol, which is proven to be even more effective in reducing carbon emissions, will be increasingly cost-competitive. New technologies will also help address potential drawbacks to biofuel technology, such as the tension between food and energy security.

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