1

Current Status of the Biofuel Industry and Markets

A GLOBAL OVERVIEW

The liquid biofuels most widely used for transport today are ethanol and biodiesel. Ethanol is currently produced from sugar or starch crops, while biodiesel is produced from vegetable oils or animal fats. The growth in the use of biofuels has been facilitated by their ability to be used as blends with conventional fuels in existing vehicles, where ethanol is blended with gasoline and biodiesel is blended with conventional diesel fuel.

Ethanol currently accounts for 86 per cent of total biofuel production.[1] About one quarter of world ethanol production goes into alcoholic beverages or is used for industrial purposes (as a solvent, disinfectant or chemical feedstock); the rest becomes fuel for motor vehicles.[2] Most of the world's biodiesel, meanwhile, is used for transportation fuel, though some is used for home heating.

Global fuel ethanol production more than doubled between 2001 and 2006, while production of biodiesel, starting from a much smaller base, expanded nearly sixfold (see Figures 1.1 and 1.2).[3] In contrast, the oil market increased by only 10 per cent over this period (in absolute terms, however, world petroleum production increased by some 80 million litres a year from 2001 to 2006, compared to some 5 million litres annually for biofuels).[4] In 2006, biofuels comprised about 0.9 per cent of the world's liquid fuel supply by volume, and about 0.6 per cent by transport distance travelled. Yet, as a percentage of the increase in supply of liquid fuels worldwide from 2005 to 2006, the surge in production of the two biofuels accounted for 17 per cent by volume and 13 per cent by transport distance travelled.[5]

HISTORY OF BIOFUEL PRODUCTION PROGRAMMES

Biofuels have been used in automobiles since the early days of motorized transport. American inventor Samuel Morey used ethanol and turpentine in the first internal combustion engines as early as the 1820s. Later that century, Nicholas Otto ran

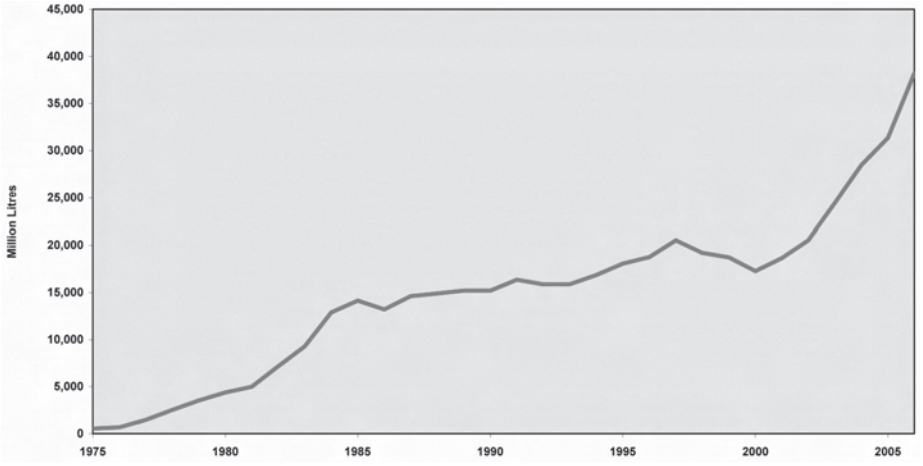

Figure 1.1 *World fuel ethanol production, 1975–2006*

Source: F. O. Licht

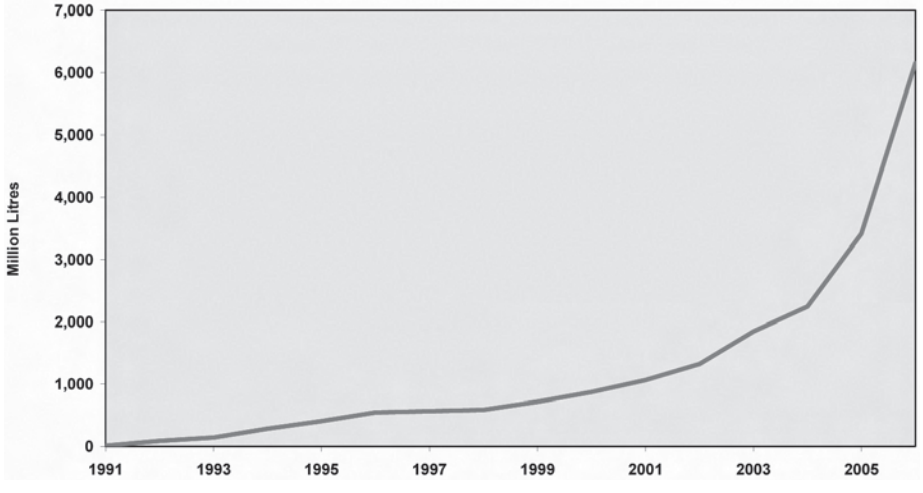

Figure 1.2 *World biodiesel production, 1991–2006*

Source: F. O. Licht

his first spark-ignition engines on ethanol, and Rudolph Diesel used peanut oil in his prototype compression-ignition engines. Henry Ford's Model T could even be calibrated to run on a range of ethanol–gasoline blends. However, just as automobiles were becoming popular at the beginning of the 1900s, the fuel market was flooded with cheap petroleum fuels.[6]

Biofuels represented only a small proportion of total fuel during the early 20th century. They were supported by policies in several European countries, especially France and Germany, where at times they neared 5 per cent of the fuel supply. In tropical areas with irregular supplies of petroleum and in enclosed settings such as mines, biofuels were often the favoured fuel; during World Wars I and II, ethanol was also used to supplement petroleum in Europe, the US and Brazil. However, military demobilization in the post-war period and the development of new oil fields in the 1940s brought a glut of cheap oil that virtually eliminated biofuels from the world fuel market.[7]

The oil crises of the 1970s prompted countries to again seek alternatives to imported oil. Brazil, which had maintained a small fuel ethanol industry since the 1930s, expedited a national ethanol programme called *Proálcool* with an eye to alleviating its great national debt and expanding its agricultural industry. Especially after the second oil crisis of 1979, when oil prices reach their historic zenith, the Brazilian government prioritized ethanol production, supporting expanded sugar cane acreage, new ethanol distilleries and ethanol-only cars. By the mid 1980s, ethanol was displacing almost 60 per cent of the country's gasoline.[8]

Also motivated by the high and volatile oil prices of the 1970s, the US launched its own fuel ethanol programme at the end of the decade, using corn to produce a proportionally small but increasing amount of ethanol. The Brazilian and US ethanol industries still produce the vast majority of the world's fuel ethanol – almost 90 per cent in 2005.[9]

The oil crises prompted other countries to promote biofuels as well, although these efforts were less successful. In China, the government encouraged peasants to cultivate oil plants that would provide insurance against disruptions in the supply of diesel fuels; but it abandoned these efforts after the price of oil fell in the mid 1980s.[10] In 1978, the Kenyan government initiated a programme to distil ethanol from sugar cane, mixing it in a 10 per cent blend with gasoline; but this programme faltered due to drought, poor infrastructure and inconsistent policies.[11] Zimbabwe and Malawi initiated larger programmes in 1980 and 1982, respectively; but only Malawi has consistently produced fuel ethanol since then.[12]

In Europe, a trade dispute triggered a rise in biodiesel production, starting in 1992. The European Union (EU) agreed to prevent gluts in the international oilseeds market by confining production to just under 5 million hectares. European governments helped to create a new market for farmers on the remaining 'set-aside' land, primarily by reducing the taxes on biodiesel – a policy that has led to a rapid increase in European biodiesel production, particularly in Germany.[13]

More recently, environmental standards have become important drivers for biofuel markets. In the US, the Environmental Protection Agency (EPA) began requiring cities with high ozone levels to blend gasoline with fuel oxygenates, including ethanol. When state governments learned in the late 1990s and early 2000s that the most common oxygenate, methyl tertiary-butyl ether (MTBE), was a possible carcinogen that was seeping into groundwater, 20 states passed laws to phase it out, creating a surge in demand for US ethanol in the early 2000s.[14]

In Brazil, the auto industry's 2003 introduction of so-called flexible-fuel vehicles (FFVs), which can run on any combination of gasoline or ethanol, has given drivers the freedom to choose whichever of the fuels is cheaper. Consumer demand for these vehicles has surged, and by early 2006, more than 75 per cent of new cars sold in the country were FFVs.[15] Combined with high petroleum prices, these cars have led to a dramatic increase in Brazilian ethanol production.[16]

CURRENT BIOFUEL PRODUCTION

The US and Brazil dominate world ethanol production, which reached a record 38.2 billion litres in 2006 (see Table 1.1).[17] Close to half the world's fuel ethanol was produced in the US in 2006, nearly all of it from corn crops grown in the northern Midwest, representing 2 to 3 per cent of the country's non-diesel fuel.[18] More than two fifths of the global fuel ethanol supply was produced in Brazil in 2006, where sugar cane grown mostly in its centre-south region provides roughly 40 per cent of the country's non-diesel fuel.[19]

The remainder of ethanol production comes primarily from the EU, where Spain, Sweden, France and Germany are the big producers, using mainly cereals and sugar beets. China uses corn, wheat and sugar cane as feedstock to produce

Table 1.1 *World fuel ethanol production, 2006*

Country or region	*Production (million litres)*	*Share of total (percentage)*
United States	18,300	47.9
Brazil	15,700	41.1
European Union	1550	4.1
China	1300	3.4
Canada	550	1.4
Colombia	250	0.7
India	200	0.5
Thailand	150	0.4
Australia	100	0.3
Central America	100	0.3
World Total	38,200	100.0

Source: see endnote 17 for this chapter

a large amount of ethanol destined mostly for industrial use. In India, sugar cane and cassava have been used intermittently to produce fuel ethanol.[20]

In 2005, many new ethanol production facilities began operating, were under construction or were in the planning stage. For example, US ethanol production capacity increased by nearly 3 billion litres during 2005, with an additional 5.7 billion litres of new capacity under construction going into 2006.[21]

Biodiesel has seen similar growth, almost entirely in Europe (see Table 1.2).[22] Biodiesel comprises nearly three-quarters of Europe's total biofuel production, and in 2006 the region accounted for 73 per cent of all biodiesel production worldwide, mainly from rapeseed and sunflower seeds.[23] Germany accounted for 40 per cent of this production, with the US, France and Italy generating most of the rest.

The rapidly changing character of worldwide biofuel production capabilities is illustrated by recent trends in the US. US biodiesel production, mainly from soybeans, was 1.9 million litres (500,000 gallons) in 1995; by 2005, it had jumped to 284 million litres (75 million gallons); and in 2006 it tripled, to 852 million litres (224 million gallons).[24] At mid-2006, US biodiesel production capacity stood close to 1.2 billion litres per year from 42 facilities, and more than 400 million litres per year of additional production capacity were under construction at 21 new plants.[25, 26] Meanwhile, the EU was home to approximately 40 biodiesel plants, and this capacity was also growing rapidly, both in Germany, which has been the

Table 1.2 *World biodiesel production, 2006*

Country or region	*Production (million litres)*	*Share of total (percentage)*
Germany	2499	40.6
United States	852	13.8
France	625	10.2
Italy	568	9.2
Czech Republic	153	2.5
Spain	142	2.3
Malaysia	136	2.2
Poland	114	1.9
United Kingdom	114	1.9
Australia	91	1.5
Austria	85	1.4
Denmark	80	1.3
Philippines	68	1.1
Brazil	68	1.1
China	68	1.1
Others	490	8.0
Europe Total	4504	73.2
Americas Total	1113	18.1
World Total	6153	100.0

Source: see endnote 22 for this chapter

clear leader in world biodiesel production, and also in Austria, the Czech Republic, France, Germany, Italy, Spain and Sweden.

World petroleum use and implications for biofuels

The doubling of petroleum prices, from about US$30 per barrel in early 2004 to about US$60 per barrel at the end of 2005, and subsequent price increases in 2006 have substantially heightened worldwide interest and investment in biofuels.[27] The expected growth in global demand for liquid fuels, together with increasing geological limitations in the supply of oil, have led many to assume that oil prices will remain high in years to come. In 2006, the US Energy Information Administration, for instance, upgraded its forecasted price for a barrel of oil in 2025 to US$54 from the previous year's projection of US$33.[28]

Substantial growth in energy use in many developing countries has also begun, most notably in China and India, whose populations are by far the world's largest. From 2002 to 2004, world oil demand increased by 5.3 per cent, while China's demand alone increased by a staggering 26.4 per cent; demand in other Asian countries increased by 5.8 per cent combined. This growth has come as oil consumption in many industrialized countries continues to rise. From 2002 to 2004, the demand for oil increased by 4.9 per cent in the US, 10.2 per cent in Canada and 6.3 per cent in the UK (demand in Germany and Japan, meanwhile, dropped by 1 per cent and 2.6 per cent, respectively).[29]

While there are dramatic differences in per capita gasoline and diesel fuel consumption between industrialized and developing countries, economic growth and lifestyle changes in populous countries such as China and India will probably put tremendous pressure on world petroleum supplies in the coming decades. Currently, US per capita gasoline consumption is a staggering 180-fold higher than in India and 45-fold higher than in China, and US per capita diesel consumption is 17-fold higher than in India and about 11-fold higher than in China (even German per capita consumption of these fuels is dramatically higher than in developing countries – for gasoline, about 45-fold higher than in India and 11-fold higher than in China, and for diesel, about 19-fold higher than in India and 12-fold higher than in China.) However, if all the residents of China were to consume oil at the same per capita rate as people in the US, they would require an amount greater than the current total production of oil worldwide (for national-level information on per capita gasoline and diesel fuel consumption, see Appendix 1).[30]

Although per capita energy consumption in the developing world is currently low, as these countries experience economic growth and increased demand for oil, they will require new energy supplies to meet their transportation needs. For countries that depend upon imported petroleum fuels, there is a clear need for alternative transport fuel supplies, either domestically produced or imported. There is an opportunity for biofuels to play an important role, particularly as petroleum

costs continue to rise and as the unpredictability of future oil availability triggers national security concerns (for national-level information on biofuel production in relation to petroleum consumption, production and imports, see Appendix 2; for a comparison of biofuel production as a percentage of petroleum use, see Appendix 3).

Recent developments in the biofuel industry

The recent proliferation of biofuel programmes around the world can be attributed to a combination of factors. Countries that seek to bolster their agricultural industries (long the main driver of biofuel programmes) have been joined by an increasing number of nations that are concerned about such factors as high oil prices, political instability in oil-exporting countries, climate-altering greenhouse gas emissions and urban air pollution. Continuing developments in biorefining technology have also brought greater attention to biofuels as a potentially large-scale and environmentally sustainable fuel.

A diverse range of countries around the world has recently sought new ways of promoting the use of biofuels. For example:

- In Japan, the government has permitted low-level ethanol blends in preparation for a possible blending mandate, with the long-term intention of replacing 20 per cent of the nation's oil demand with biofuels or gas-to-liquid (GTL) fuels by 2030.
- In Canada, the government wants 45 per cent of the country's gasoline consumption to contain 10 per cent ethanol by 2010. Ontario will be the centre of the ethanol programme, where the government expects all fuel to be a 5 per cent blend of ethanol by 2007.[31]
- An EU directive, prompted by the desire for greater energy security, as well as the requirements of the Kyoto Protocol, has set the goal of obtaining 5.75 per cent of transportation fuel needs from biofuels by 2010 in all member states. In February 2006, the EU adopted an ambitious Strategy for Biofuels with a range of potential market-based, legislative and research measures to increase the production and use of biofuels. Germany and France, in particular, have announced plans to rapidly expand both ethanol and biodiesel production, with the aim of reaching the EU targets before the deadline.[32]
- In the US, high oil prices and agricultural lobbying prompted the recently enacted Renewable Fuels Standard (RFS), which will require the use of 28.4 billion litres (7.5 billion gallons) of biofuels for transportation in the country by 2012. Many US government fleet vehicles that run on diesel fuel are now required to use B20 blends under new guidelines implementing the 1992 Energy Policy Act. Many in the industry believe that these targets represent a floor, rather than a limit, to biofuel production.[33]

- In Brazil, the government hopes to build on the success of the *Proálcool* ethanol programme by expanding the production of biodiesel. All diesel fuel must contain 2 per cent biodiesel by 2008, increasing to 5 per cent by 2013, and the government hopes to ensure that poor farmers in the north and northeast receive much of the economic benefits of biodiesel production.
- Elsewhere in Latin America, as of 2006, Colombia will be mandating the use of 10 per cent ethanol in all gasoline sold in cities with populations over 500,000. In Venezuela, the state oil company is supporting the construction of 15 sugar cane distilleries over the next five years as the government phases in a national E10 blending mandate. In Bolivia, 15 distilleries are being constructed, and the government is considering authorizing blends of E25. Costa Rica and Guatemala are also in the trial stages for expanding production of sugar cane fuel ethanol.[34] Argentina, Mexico, Paraguay and Peru are all considering new biofuel programmes as well.[35] As the world's leader in fuel ethanol, Brazil has helped many of these countries to learn from its example (see Box 1.1).[36]
- In Southeast Asia, Thailand, eager to reduce the cost of oil imports while supporting domestic sugar and cassava growers, has mandated an ambitious 10 per cent ethanol mix in gasoline starting in 2007.[37] For similar reasons, the Philippines will soon mandate 2 per cent biodiesel, to support coconut growers, and 5 per cent ethanol, probably beginning in 2007.[38] In Malaysia and Indonesia, the palm oil industries plan to supply an increasing proportion of the countries' diesel.
- Chinese and Indian planners have also sought to expand the national supply of ethanol and biodiesel. In India, a rejuvenated sugar ethanol programme calls for E5 blends throughout most of the country, a level that the government plans eventually to raise to E10 and then E20. In China, the government is making E10 blends mandatory in five provinces that account for 16 per cent of the nation's passenger cars.[39]
- In Africa, efforts to expand biofuels production and use are being initiated or are under way in numerous countries, including Kenya, Malawi, Zimbabwe, Ghana, Ethiopia, Benin, Mozambique, Senegal, Guinea Bissau, Ethiopia, Nigeria and South Africa.[40]

For more detailed information on international policies and initiatives under way to foster biofuel development, see Chapter 17.

Along with the rapid increase in government-supported biofuel programmes, recent advances in technology have brought new interest in biofuels. In addition to producing ethanol from so-called 'cellulosic' feedstock, technologies are currently being developed that will be able to convert abundant cellulosic biomass supplies to a variety of potential diesel fuel or gasoline substitutes (see Chapters 4 and 5).

For example, a conversion system that uses high temperatures and low-oxygen conditions to convert solid biomass into combustible gases can be coupled to a gas-to-liquid (GTL) conversion process to produce liquid fuel. The 'Fischer-Tropsch'

Box 1.1 Brazil's ethanol experience

In response to the oil crises of the 1970s, the Brazilian government turned to one of the country's oldest industries: sugar cane. By making it a national priority to build distilleries that ferment sugar into ethanol, and requiring that this fuel be mixed into all gasoline, Brazil became a global leader in the transition away from oil.

In the 1990s, rising sugar prices in Brazil coincided with lower petroleum prices, causing a drop in ethanol production and subsequent shortages. This forced the country to import ethanol and imperilled the national ethanol programme, *Proálcool*. Several key government initiatives and market changes worked in tandem to turn this situation around. Brazil phased out sugar and ethanol quotas, as well as a constrained government subsidy programme that had limited new capacity investments. It worked with farmers to help reduce sugar cane production costs and improve yields, mandated the use of ethanol in government vehicle fleets, and fostered sales and use of flexible-fuel vehicles – in addition to requiring 20 to 25 per cent ethanol blends in all regular gasoline sales.

Along with these changes, Brazil's industry has reduced ethanol production costs in a variety of ways, particularly through the increased use of sugar cane processing residues (bagasse) as fuel to produce the steam and electricity needed to process cane. The industry is also recycling organic-rich liquid effluent from cane processing (vinasse) and using it as a fertilizer and irrigation supply for cane production, thereby increasing cane yields and reducing feedstock costs. In addition, rising petroleum prices have increased the market value of ethanol. The end result is that Brazil has become the world's largest exporter of ethanol fuel while also meeting a growing share of its domestic fuel needs.

In June 2005, Brazilians could purchase ethanol for half the price of gasoline per litre (or about 75 per cent as much as gasoline costs per unit of energy, after adjusting for the lower energy content of ethanol per litre compared to gasoline). When they do, they are not sending money to oil producers overseas, but to Brazilians. Since the 1970s, Brazil has saved almost US$50 billion in imported oil – nearly ten times the national investment through subsidies – while creating as many as 1 million rural jobs.

Source: see endnote 37 for this chapter

(F-T) process, a technology originally developed by German researchers during the 1920s, uses chemical reactions with catalysts to convert the combustible gases from a biomass gasifier into a liquid fuel that can substitute for diesel fuel. Researchers from DaimlerChrysler, Volkswagen and Shell have recently collaborated to develop a marketable version of this technology.[41]

In Canada and the US, the governments have supported groundbreaking research into enzymes that could refine abundant low-value plant fibres into ethanol. The enzyme company Novozymes, with funding from the US National Renewable Energy Laboratory, announced in 2005 that it could reduce the cost of some of these enzymes by 10 to 30 times and promised further reductions in the near future. Abengoa, a multinational ethanol company, has already begun building a facility in Spain that will utilize these enzymes.[42] In Canada, Iogen Corporation

operates a pilot plant to convert straw into ethanol using enzymatic technology, and has now teamed up with Shell, Volkswagen and DaimlerChrysler to build a pre-commercial straw-to-ethanol plant in Europe.