

CONTRIBUTION OF BIOFUELS TO THE GLOBAL ECONOMY

Prepared for the Global Renewable Fuels Association John M. Urbanchuk Technical Director – Environmental Economics May 3, 2012

The global biofuels industry has grown significantly in recent years and is making a significant contribution to the individual economies of producing countries and to the global economy as a whole. Key drivers for the global biofuels industry are the desires to develop alternative sources of energy in response to soaring crude oil prices, generate increased revenue for farmers through the production of value added biofuel products, mitigate climate change, and to stimulate agricultural production. Reflecting this, growth in the ethanol and biodiesel industries has been stimulated by national policies in the form of mandates and renewable energy goals and high crude oil and refined petroleum prices. The purpose of this study is to examine global production trends in ethanol and biodiesel, estimate the global economic footprint of the biofuels industry, and to identify new and emerging production markets such as Africa.

Ethanol

As shown in Table 1 global ethanol production was estimated at 93.2 billion liters in 2010, more than double 2005 output and a threefold increase over the past decade.¹ Global ethanol production is dominated by three major producers, the U.S., Brazil, and the EU, who together account for 87 percent of global production.

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¹ OECD-FAO Agricultural Outlook 2011-2020, Chapter 3.

	2000	2010	2020	2010-20
	(Mil	(Mil	(Mil	%
	Liters)	Liters)	Liters)	Change
U.S.	7,603	50,333	63 961	27.1%
Brazil	10,615	26,200	50 393	92.3%
EU-27		4,455	16 316	266.2%
China	2,970	2,048	7 930	287.3%
India	1,720	1,892	2 204	16.5%
Canada	215	1,363	2 359	73.1%
Thailand	60	672	2 111	214.1%
South Africa	339	384	421	9.7%
Columbia		310	587	89.5%
Japan	11	307	946	208.6%
Argentina	171	303	470	55.1%
Australia	150	299	492	64.6%
Indonesia	160	210	248	17.8%
Viet Nam		150	423	182.5%
Philippines	80	118	603	410.1%
Peru		71	217	205.1%
Malaysia		66	74	12.8%
Turkey	22	64	88	36.6%
Mexico	67	64	90	40.3%
Tanzania		29	55	90.6%
Mozambique		25	59	133.9%
Other	5,135	3,880	4 916	26.7%
TOTAL	29,319	93,242	154 962	66.2%

Table 1 World Fuel Ethanol Production (Million liters)

Source: F.O. Licht; OECD-FAO 2011-20

United States of America

The U.S. has overtaken Brazil as the world's largest ethanol producer largely due to implementation of the Renewable Fuels Standard (RFS2), which mandates the use of 36 billion gallons (136 billion liters) of renewable biofuels in the U.S. motor fuel supply by 2022. Federal tax incentives in the form of an excise tax credit for ethanol also played a key role in keeping ethanol competitive with gasoline and supporting demand. However at the end of 2011 the principal Federal incentive, the 45 cents per gallon Volumetric Ethanol Excise Tax Credit (VEETC) expired and a secondary tariff on imported ethanol that largely affected Brazilian exports were also eliminated. Currently, virtually all ethanol produced in the U.S. uses grain (corn) as the principal feedstock. Future growth is expected to come largely from new cellulosic biomass feedstocks such as agricultural residues, municipal solid waste and forest biomass.

Brazil

Brazil is the world's second largest ethanol producer. Its growing domestic demand is fueled by rapidly increasing incomes and a growing fleet of flex-fuel vehicles. The primary feedstock for ethanol in Brazil is sugar cane, with an estimated half of the crop dedicated to ethanol production. Drought over the past two years has resulted in smaller sugar crops, record sugar prices, and in turn, restrained ethanol output. Anticipated recovery in sugar production is expected to enable Brazil to increase ethanol output and retain its place as the world's second largest producer. Substantial re-investment in Brazilian ethanol in recent years is expected to allow growth in output to recover and Brazil is expected to increase exports primarily to the U.S. market.

European Union

The EU is the third largest ethanol producer using a combination of grain and sugar beet feedstocks. Stimulated by the EU Renewable Energy Directive (RED), which requires renewable energy sources to make up 10 percent of transport fuels by 2020, ethanol production in the EU is projected to increase strongly over the next decade. According to the European Renewable Ethanol Association (ePure), France is the largest European ethanol producer followed by Germany and the United Kingdom. Together these three countries account for

nearly half of EU installed ethanol capacity.² The primary feedstocks for ethanol in Europe are grain (wheat and barley), which accounts for about two-thirds of production, and sugar beets, which make up the balance.

Emerging Ethanol Producers

Figure 1 illustrates the distribution of projected growth in ethanol output by major producers through 2020. With relatively few exceptions (notably the EU and Japan) the most significant growth in ethanol production over the next decade is expected to take place in emerging and developing nations largely in Asia (China, Thailand, the Philippines and Vietnam) and Africa (Tanzania and Mozambique). These developing nations will see exceptional growth in their own countries, but from a volumetric perspective the amount of biofuels they will produce will remain a small share of global production.





Source: F.O. Licht; OECD-FAO Projection

Increased demand for biofuels, their production and the resulting rise in agricultural commodity prices can present an opportunity for promoting agricultural growth and rural development in

² http://www.epure.org/statistic/info/Productiondata

developing countries. Production of biofuel feedstocks may offer income-generating opportunities for farmers in developing countries. Analyses conducted by the UN Food and Agriculture Organization (FAO) suggest that cash-crop production for markets does not necessarily come at the expense of food crops and that it may contribute to improving food security.³

Developing countries will benefit significantly from biofuels. Many of the world's poorest countries have the basic agricultural resources to become major producers of biomass for biofuel production and to respond to higher agricultural prices. Biofuels production increases prices for agricultural commodities used as feedstocks in all countries. A 2008 FAO study indicated that these higher prices could result in a positive supply response from small farmers who are able to react to the price incentives and that the emergence of biofuels as a major new source of demand for agricultural commodities could help revitalize agriculture in developing countries, with potentially positive implications for economic growth, poverty reduction and food security.⁴ A more recent FAO study concludes that "... integration of food and energy production may be one of the best ways to improve national food and energy security and simultaneously reduce poverty in a climate smart way".⁵ Drawing from experience in Africa, Asia and Latin America, the FAO points out that combining food and energy crops present numerous benefits to poor rural communities by enabling farmers to save money by using byproducts to cogenerate power or use biowaste from energy crops for compost and nutrient production. Moreover, the development of new biomass feedstocks such as cellulose, waste streams like MSW, Jatropha and algae that do not compete for resources used for food production will help avoid pressure on low income consumers, particularly in developing countries.

From a macroeconomic perspective the job creation impacts of biofuels are likely to be more pronounced if biofuel feedstock production does not displace other agricultural activities or if the displaced activities are less labor-intensive.

³ FAO. "New tool for weighing pros and cons of bioenergy" May 17, 2011. http://www.fao.org/news/story/en/item/74708/icode/

⁴ FAO. The State of Food and Agriculture 2008. Biofuels: Prospects, Risks and Opportunities.

⁵ Bogdanski, Anne, Olivier Dubois, Craig Jamieson, and Ranier Krell. *Making Integrated Food-Energy Systems Work for People and Climate*. FAO. 2010.

However, as the FAO study points out, these developing countries will "...continue to face many of the same constraints that have prevented them in the past from taking advantage of opportunities for agriculture-led growth. Their ability to take advantage of the new opportunities offered by biofuels – either directly as biofuel feedstock producers or indirectly as producers of agricultural commodities for which prices have gone up – will depend on how these old constraints (and a few new ones) are addressed." ⁶

A recent World Bank study suggested that "the rapid increase in the global demand for biofuels, especially ethanol, over the next decade or more will provide opportunities for African exporters because neither the EU nor the United States is expected to be able to meet its consumption mandates completely from domestic production. The EU ethanol market is especially attractive for African biofuel producers because of duty-free access afforded to most African countries under various preferential trade agreements and the high EU tariff on ethanol imports."⁷

While there are substantial opportunities for export development, which is an important contributor to economic growth, the domestic market for biofuels throughout Africa also is expected to be robust because of high fuel prices and rapid demand growth. Most of the increase in biofuels production in Africa is likely to be met from existing first-generation feedstocks and technology. This primarily consists of ethanol production by fermentation of sugar crops, such as sugarcane or sweet sorghum, and from starchy crops, such as cassava. New technologies for ethanol production such as conversion of cellulose or the use of other advanced biofuel feedstocks are expected to be developed and exploited in developed countries first with a likely slow transfer of technology to Africa.

A World Bank study reported, "African countries are well placed to benefit from the increased demand for biofuels because many have large areas of land suitable for producing biofuels as well as abundant labor."⁸ According to the FAO, Sub-Saharan Africa has more than one billion

⁶ FAO 2008 p.86

 ⁷ Donald Mitchell. Biofuels in Africa: Opportunities, Prospects and Challenges. The International Bank for Reconstruction and Development / The World Bank 2011.
 ⁸Mitchell World Bank. p xx11

hectares of land with potential for crop production of which less than one-quarter is being cultivated.⁹

As is the case with virtually all other emerging and developing countries, biofuels offer the prospects of a new cash crop for farmers, increased employment in rural areas, expanded manufacturing output, reduced fuel import costs, and foreign exchange earnings. Africa stands to benefit significantly from the development of biofuels as a displacement for imported oil and petroleum products. Table 2 illustrates the net trade position for crude oil and oil products in Sub-Sahara Africa by country. While there are several major oil producers and exporters in Sub-Sahara Africa, led by Nigeria and Angola, only five countries in the region have net positive trade balances for oil. Despite this, most countries in Sub-Sahara Africa lack adequate refining infrastructure and all but two, Gabon and Cameroon, are net importers of refined petroleum products. These countries will benefit from domestically produced biofuels that can displace – and extend – imported petroleum products.

⁹ OECD/FAO Agricultural Outlook 2011-2020

	Crude	Crude	Crude	Crude Oil	Oil	Oil	Oil Prod
	Oil	Oil	Oil	Balance	Products	Products	Balance
	Production	Imports	Exports	(X-M)	Imports	Exports	(X-M)
Country	(ktoe)	(ktoe)	(ktoe)	(ktoe)	(ktoe)	(ktoe)	(ktoe)
Nigeria	117,470	0	111,595	111,595	7,677	678	-6,999
Angola	92,971	0	90,483	90,483	2,883	1,240	-1,643
Gabon	12,252	0	11,546	11,546	146	237	91
Camaroon	3,810	1,440	3,282	1,842	330	680	350
Dem Rep Congo	1,116	0	1,117	1,117	554	0	-554
Benin	0	0	0	0	1,493	0	-1,493
Botswana	0	0	0	0	875	0	-875
Eritrea	0	0	0	0	159	0	-159
Ethiopia	0	0	0	0	2,304	0	-2,304
Mozambique	0	0	0	0	739	0	-739
Namibia	0	0	0	0	1,110	0	-1,110
Tanzania	0	0	0	0	1,705	0	-1,705
Togo	0	0	0	0	335	0	-335
Zimbabwe	0	0	0	0	611	0	-611
Zambia	0	518	0	-518	128	0	-128
Senegal	0	667	0	-667	1,074	23	-1,051
Cote d' Ivorie	2,607	3,153	2,359	-794	87	2,316	2,229
Ghana	0	999	0	-999	1,924	465	-1,459
Kenya	0	1,636	0	-1,636	1,906	54	-1,852
South Africa	150	24,234	0	-24,234	6,298	2,701	-3,597
	230,376	32,647	220,382	187,735	32,338	8,394	-23,944

Table 2Oil Production and Trade Balances for Oil and Oil ProductsSub-Sahara Africa: 2009

Source: International Energy Agency. Data in thousand tonnes of oil equivalent (ktoe) on a net calorific basis.

Biodiesel

The global biodiesel industry is not as established or as developed as the global ethanol industry. Industry analysts indicated that in 2010 global biodiesel production totaled 17.6 billion liters, a nearly six-fold increase from 2005 production levels. As shown in Table 3, the EU is the world's largest biodiesel producer accounting for more than half of global output. Within the EU

Germany is the largest producer accounting for more than half of EU production, followed by France, Italy and the UK. As reported in a study published by the Center for Global Trade Analysis at Purdue University "The spectacular growth in the German market was the result of very favorable legislation granting a total tax exemption for biofuels. This exemption has been particularly important in the EU, where fuel taxes are extremely high; however, the exemption was rescinded in 2008 due to its high budgetary cost, as well as the suspicion that it might be having adverse impacts on land use in the rest of the world."¹⁰

Argentina, Brazil and the U.S. are the next largest producers' together accounting for a quarter of the world's output. The most significant recent development in the global biodiesel industry is the increase in production from new Asian biodiesel producers. In addition to Malaysia, Thailand and Indonesia, the Philippines and Vietnam are developing emerging biodiesel industries.

	2000	2005	2010
EU-27	755	2,808	9,184
Argentina	0	0	1,576
Brazil	0	0	1,550
U.S.	6	271	1,192
Malaysia	0	0	765
Australia	0	54	627
Thailand	0	0	584
All Others	0	31	2,130
TOTAL	761	3,164	17,608

Table3 World Biodiesel Production (Million liters)

Source: F.O. Licht; OECD-FAO

As shown in Figure 2, the EU is expected to remain the world's largest biodiesel producer due to several factors including the commonness of diesel powered passenger vehicles, the stimulus provided by the RED mandate, and the relative cost advantage of diesel over motor gasoline

¹⁰ Thomas W. Hertel, Wallace E. Tyner and Dileep K. Birur. "Biofuels for all? Understanding the Global Impacts of Multinational Mandates". GTAP Working Paper No. 51. 2008. Center for Global Trade Analysis. Purdue University.

due to considerably lower taxes.¹¹ Biodiesel production also is expected to expand in the U.S., Argentina and Brazil. However the most significant growth is expected to take place in smaller developing countries in Asia and Africa.





Expenditures by the Biofuels Industry

Ethanol and biodiesel producers are an integral part of the manufacturing sector that adds substantial value to agricultural commodities used as feedstocks. The production of biofuels is a refining process that is an integral component of the organic chemical manufacturing industry. As a result, development of biofuels production benefits not only farmers and the agricultural sector, but stimulates the manufacturing sector, which typically provides higher wage jobs than in agriculture.

Technology and Feedstocks

Typically feed stocks are the largest expenditure for ethanol producers accounting for about 75 percent of operating costs, and 90 percent of biodiesel production costs.¹² As indicated earlier

¹¹ Romain Davoust. "Gasoline and Diesel Prices and Taxes in Industralized Countries" IRFI. December 2008.

corn is the primary ethanol feedstock in the U.S.; Brazil uses sugar from cane; and the EU uses a combination of coarse grains, wheat and sugar from beets. Among other producers, the feedstock choice depends on the crop grown. For example wheat and corn are used as a feedstock in Canada; sugar in India and corn, wheat and cassava in China. Many ethanol producers in developing countries rely on sugar with South Africa relying on grain.

As shown in Figure 3, the OECD reports that half of all ethanol is produced from coarse grains (predominately corn) while sugar from cane, beets and molasses account for an additional 35 percent. The other feedstock categories includes a wide range of products ranging from starchy crops such as cassava and potatoes to brewery waste and wine.





Source: OECD/FAO

Ethanol production utilizing conventional fermentation technology based on sugar and starch crops and biodiesel produced from oilseed crops, waste grease and animal fats using a process known as transesterfication is generally referred to as first-generation biofuel production. A

¹² Comparable examples of production costs for ethanol and biodiesel are provided for Iowa, a low cost producer of corn and soybeans and major biofuel producer, by the lowa State University's Agricultural Marketing Resource Center available at <u>http://www.agmrc.org/renewable_energy</u>/. The estimates of feed stock share of production costs is on a gross basis and does not factor in the net impact of coproducts such as Distiller's grains.

second generation of technologies currently under development will make it possible to use a wider range of new feedstocks for biofuels production. The drive for new technologies and feedstocks is being stimulated by government policy, high prices for conventional feedstocks (grain and sugar), the desire to shift biofuels production to crops that do not compete for resources needed for human food and increasing competition for land resources, particularly in developed economies. The best illustration of the impact of government policy is the requirement for 21 billion of the 36 billion gallon RFS2 mandate in the United States to be produced from cellulosic sources, other "Advanced Biofuel Feedstocks", and biomass derived biodiesel.¹³

Ethanol can be produced converting cellulose in biomass into its constituent sugars, which then are fermented and distilled into alcohol. Examples of cellulosic materials include wood, other fibrous plant materials such as crop residues, energy grasses, waste materials such as paper and cardboard and Municipal Solid Waste (MSW), which has shown tremendous potential. Dedicated cellulosic energy crops also hold promise as a source of feedstock for second-generation technologies. Potential crops include short-rotation woody crops such as willow, hybrid poplars and eucalyptus or grassy species such as miscanthus, switchgrass, elephant grass and reed canary grass. These crops provide major advantages over first generation crops from their ability to produce more biomass per hectare of land because the entire crop is available as feedstock for conversion to fuel. Furthermore, some fast growing perennials such as short-rotation woody crops and energy grasses can be grown on poor, degraded soils where food crop production is either not possible or profitable. Both these factors may reduce competition for land with food and feed production. On the downside, some of these species are considered invasive or potentially invasive and may have negative impacts on water resources, biodiversity and agriculture.¹⁴

Cellulosic resources are widespread, abundant, potentially inexpensive, and are out of the food chain. For example forests comprise about 80 percent of the world's biomass. The limiting factors for cellulosic ethanol production principally involve technology and economics.

¹³ Under the RFS2 provisions of the Energy Policy Act of 2008 ethanol produced from corn starch is capped at 15 billion gallons in 2015. Consequently, the remaining 21 billion are to come from cellulose and other non-corn starch feedstocks.

¹⁴ Urbanchuk, John M. "Current State of the Ethanol Industry". White Paper prepared for the U.S. Department of Energy, Office of Biomass Programs. November 2010.

Accessing the glucose in cellulose under existing technology has high capital and operating costs. Cellulosic materials are comprised of lignin, hemicellulose, and cellulose. One of the primary functions of lignin is to provide structural support for the plant. Thus, in general, trees have higher lignin contents then grasses. Unfortunately, lignin, which contains no sugars, encloses the cellulose and hemicellulose molecules, making them difficult to reach.¹⁵ Despite these challenges, there has been tremendous progress made on the commercialization of this technology. Several demonstration/pilot plants are in operation in North America and Europe and commercial scale second-generation feedstock plants are under construction by Abengoa in Kansas and Mossi & Ghisolfi in Italy.

The predominant first generation feedstock for biodiesel production is vegetable oils based on palm and soybean oil and non-agricultural feedstocks such as waste grease and recycled vegetable oils. The use of recycled vegetable (e.g. cooking) oils for biodiesel production has grown in popularity in the UK and U.S. Other technologies can also be used to produce biodiesel from non-vegetable oil or agricultural feedstocks. An example of this is the biorefinery announced in 2011 by the Finnish forestry and wood products firm UPM that will use gasification and the Fischer-Tropsch processes to produce biodiesel from energy wood.¹⁶ The Fischer-Tropsch process is a method of gassification where synthesis gas, a mixture of hydrogen and carbon monoxide, is reacted to produce synthetic fuels. UPM also announced plans to invest in another biorefinery to produce biofuels from crude tall oil. Tall oil is a by-product of the Kraft process of pulp manufacturing from pine woods. Another technology for biofuel production is the hydrotreating of vegetable oils (HVO). In the HVO production process, hydrogen is used to remove the oxygen from the triglyceride (vegetable oil). This process does not require chemicals such as methanol and does not produce glycerol as a side product.¹⁷

¹⁵ An excellent overview of cellulose conversion technology is presented in the EPA Proposed Rule for the 2011 Renewable Fuel Standard. *Federal Register*. Vol. 75, No. 138. Tuesday, July 30, 2010.
¹⁶ <u>http://www.upm.com/en/media/all-news/pages/upm-selects-rauma-or-strasbourg-as-the-possible-location-for-a-biorefinery-002-thu-31-mar-2011-15-44.aspx</u>. http://www.upm.com/en/media/all-news/pages/upm-to-build-the-world's-first-biorefinery-producing-wood-based-biodiesel-001-wed-01-feb-2012-10-05.aspx

¹⁷ Hannu Aatola, Martti Larmi, Teemu Sarjovaara, Seppo Mikkonen. "Hydrotreated Vegetable Oil (HVO) as a Renewable Diesel Fuel:Trade-off between NOx, Particulate Emission, and Fuel Consumption of a Heavy Duty Engine". 2008-01-2500. SAE International.

Second generation biodiesel technology involves the use of new feedstocks such as Jatropha and algae. Jatropha is considered to have significant potential in Africa because of its ability to grow on degraded land and the fact that it is not a food crop. Consequently, it does not compete directly for land and other resources used for food production.¹⁸ Algae are the fastest growers of the plant kingdom, and certain species can generate large amounts of carbohydrates or oil. Algae oil yields per hectare are claimed to be 16 times higher than palm oil, and algae consume 99 percent less water. But to produce large volumes of oil from algae requires large ponds and large capital investments. Algae's potential has been understood for many years but cost has been a limiting factor for adoption.¹⁹ Having said this, vegetable oils are expected to remain the predominant feedstocks for biodiesel production.

The biofuels industry is a major source of support for agricultural output and farm income. The purchase of feedstocks represents income for farmers and is a significant incentive for production. Taken together, the market value of feedstocks used to produce the world's ethanol production amounts to \$65.5 billion at 2010 prices.²⁰ A large percentage of these expenditures are income for the world's grain farmers and sugar producers.

- 47.9 billion liters of ethanol produced from coarse grains is the equivalent of 116.9 million metric tonnes, or 10.6 percent of world coarse grain production with a value of \$27 billion at 2010 prices.
- 31 billion liters of ethanol from sugar cane and molasses represents 6 million metric toones of sugar from cane, or about 5 percent of world production valued at \$3.6 billion;
- 1.7 billion liters of ethanol from beets is equivalent to nearly 2.8 million tonnes of sugar from beets, or 8.8 percent of world production valued at \$1.6 billion.

 ¹⁸ GEXSI (Global Exchange for Social Investment). 2008. *Global Market Study on Jatropha: Final Report*. Prepared for World Wide Fund for Nature. London: GEXSI LLP.
 <u>http://www.jatropha-alliance.org/fileadmin/documents/GEXSI_Global-Jatropha-Study_FULL-REPORT.pdf</u>
 ¹⁹ Mitchell World Bank. P11.

²⁰ All prices and values cited in this study are cited in U.S. dollars. Source for feedstock prices is OECD/FAO Agricultural Outlook 2011-2020. Available at

http://stats.oecd.org/viewhtml.aspx?QueryId=30107&vh=0000&vf=0&l&il=blank&lang=en. The prices for feedstocks The 10.5 billion liters of other ethanol feedstocks was valued at coarse grain prices and ethanol yields and is estimated at \$7.5 billion.

 17.6 billion liters of biodiesel is the equivalent of 15.9 million metric tonnes of vegetable oil (palm, palm kernel and soybean), or about 13 percent of global production of these oils, valued at \$19.4 billion.

Expenditures by ethanol and biodiesel producers for raw materials (feedstocks) and other goods and services represent the purchase output of other industries. As such, spending for these goods circulates through the local and national economy generating value-added output, income, and employment in all sectors of the economy.

It is difficult to average non-feedstock production costs across a wide range of countries where wage rates and energy costs vary significantly. However since biofuel production is so feed stock dependent we can estimate production expenditures on the basis of feed stock shares. Using an average of 75 percent of production costs for ethanol²¹ and 90 percent for biodiesel, we can estimate total variable production expenditures for ethanol on a global basis at \$87.3 billion and \$19.4 billion for biodiesel

Methodology

We estimate the impact of the ethanol industry on the global economy by applying economic impact multipliers for GDP (value added output), earnings, and employment to estimates of direct expenditures associated with biofuels production. Economic impact multipliers typically are derived from input-output (I/O) models of the economy and are a widely used tool to estimate the impact of industry activity and economic policy.²² To understand how the economy is affected by an industry such as biofuels production it is necessary to understand how different

²¹ The ethanol profitability spreadsheet maintained by Don Hofstrand "AgDecision Maker D1-10 Ethanol Profitability" available at <u>http://www.extension.iastate.edu/agdm/energy/xls/d1-10ethanolprofitability.xls</u> reports that corn costs represented 76 percent of variable production costs between 2007 and 2011. Mitchell reports that feedstocks account for 77 percent of variable production costs for sugarcane ethanol (Biofuels in Africa, Table 3.5).

²² There is an extensive literature on the use of economic impact multipliers. For a more detailed explanation see http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/Input-Output/Multipliers; Daniel H. Garnick, "Differential Regional Multiplier Models," Journal of Regional Science 10 (February 1970): 35-47; and Ronald L. Drake, "A Short-Cut to Estimates of Regional Input-Output Multipliers," International Regional Science Review 1 (Fall 1976): 1-17; U.S. Department of Commerce, Bureau of Economic Analysis, Regional Input-Output Modeling System (RIMS II): Estimation, Evaluation, and Application of a Disaggregated Regional Impact Model (Washington, DC: U.S. Government Printing Office, 1981).

sectors or industries in an economy are linked to each other. For example, in the renewable fuels production sector, an ethanol producer buys corn or sugar from the agriculture sector, who has bought crop production products like fertilizers from the agricultural chemicals industry, who has purchased their chemical supplies from a range of other industries. The household sector is linked to all other sectors as it provides the labor and management needed by each. In turn, changes that affect the incomes of the household sector typically have more significant impacts compared to a change in the sales of other sectors.

There are no readily accessible multipliers for the world economy or many developing countries. Typically analysts will utilize multipliers from developed economies as proxies, keeping in mind that structural differences in the allocation of various factors of production and key costs such as wage rates may overestimate the impact on developing economies.

In the case of biofuels, since the majority of production is concentrated in the U.S., EU, and more mature emerging markets such as Brazil (87 percent of ethanol and 80 percent of biodiesel production), the use of multipliers for the U.S. may be justified. It is useful to note that a review of multipliers for the Brazilian ethanol industry reveals that the output multipliers for ethanol are very close to those for the comparable U.S. industry.²³

Results

Utilizing the approach described above which incorporates RIMS II multipliers²⁴ for the other organic chemicals manufacturing industry (which encompasses both ethanol and biodiesel) the biofuels industry contributed \$277.3 billion to the global economy in 2010. This amounts to 0.4 percent of the globe's GDP. Table 4 summarizes the implications of ethanol and biodiesel for output and employment for 2010 and 2020. Tables 5 and 6 provide individual country results for ethanol and biodiesel.

²³ Roberto Guerrero Compeán, Karen R. Polenske, and Ciro Biderman. "Regional, Economic, and Environmental Implications of Dual Ethanol Technologies in Brazil ". Undated. The average output multiplier reported in Table 3 for the South and Southeast production regions of Brazil is 3.12 for ethanol production. The equivalent multiplier for the other organic chemical manufacturing industry in the U.S. further check for this Bureau of Economic Analysis RIMS II model is 3.378.

²⁴ RIMS II multipliers are from the Regional Input-Output Model prepared by the U.S. Department of Commerce Bureau of Economic Analysis.

Gross Output	2010	2020	
	(Mil \$)	(Mil \$)	% Change
Ethanol	\$301,480	\$525,088	74.2%
Biodiesel	\$72,952	\$154,663	112.0%
Total	\$374,432	\$679,751	81.5%
Employment	2010	2020	
	(Jobs)	(Jobs)	% Change
Ethanol	1,088,229	1,594,315	46.5%
Biodiesel	291,129	673,380	131.3%
Total	1,379,358	2,267,695	64.4%

Table 4Global Economic Impacts of Biofuels

- \$87.3 billion of expenditures on feedstocks and other goods and services to produce
 93.2 billion liters of ethanol supported \$301.5 billion of gross output and \$125.2 billion of value-added output on a global basis. Based on OECD-FAO projections for ethanol production, the contribution to world gross output by ethanol is projected to increase 74 percent to \$525.1 billion by 2020
- \$21.6 billion of expenditures on feedstocks and other goods and services to produce 17.6 billion liters of biodiesel supported \$73 billion of gross output and \$30.3 billion of values-added output on a global basis. OECD-FAO projects global biodiesel production to more than double over the next decade. Reflecting this, the contribution of biodiesel to global output is estimated to increase 112 percent to \$154.7 billion.
- Global ethanol and biodiesel production supports nearly 1.4 million jobs in all sectors of the global economy in 2010. These jobs include not only direct biofuels production, but also the jobs in agriculture, other supplying industries, and other sectors such as retail and wholesale trade that benefit from the economic activity generated by biofuels. The largest share of employment for ethanol occurs in the U.S. and Brazil although the fastest growth is projected to be realized in the developing Asian and African producing

countries.²⁵ As the biofuels industry expands, the employment impact is projected grow to more than 2.2 million jobs by 2020.

	2010	2020	2010	2020	2010	2020
	Ethanol	Ethanol	Gross	Gross		
	Output	Output	Output	Output	Employment	Employment
	(Mil liters)	(Mil liters)	(Mil \$)	(Mil \$)	(Jobs)	(Jobs)
U.S.	50,333	63,961	\$129,191	\$170,983	400,677	434,997
Brazil	26,200	50,393	\$111,353	\$208,121	444,378	676,213
EU-27	4,455	16,316	\$17,376	\$63,180	69,343	205,280
China	2,048	7,930	\$5,191	\$25,437	20,714	82,648
India	1,892	2,204	\$8,041	\$9,102	32,088	36,358
Canada	1,363	2,359	\$3,454	\$8,199	13,784	26,639
Thailand	672	2,111	\$1,704	\$6,771	6,798	22,001
South Africa	384	421	\$1,373	\$1,350	5,481	5,394
Columbia	310	587	\$1,316	\$2,424	5,252	7,877
Japan	307	946	\$777	\$3,034	3,102	9,859
Argentina	303	470	\$1,019	\$1,634	4,065	5,308
Australia	299	492	\$1,956	\$1,710	7,807	5,556
Indonesia	210	248	\$894	\$1,024	3,568	4,091
Viet Nam	150	423	\$637	\$1,747	2,542	5,676
Philippines	118	603	\$503	\$2,490	2,006	8,091
Peru	71	217	\$302	\$896	1,205	2,912
Malaysia	66	74	\$279	\$306	1,112	1,221
Turkey	64	88	\$163	\$282	651	917
Mexico	64	90	\$163	\$289	650	938
Tanzania	29	55	\$123	\$176	490	572
Mozambique	25	59	\$106	\$189	424	614
Other	3,880	4,916	\$15,559	\$15,743	62,092	51,152
TOTAL	93,242	154,962	\$301,480	\$525,088	1,088,229	1,594,315

Table 5Economic Impact of Ethanol Production by Country, 2010 and 2020

²⁵ A check on our methodology is provided by a report that the Brazilian ethanol industry supports 465,000 jobs. See Thomas Alvares de Azevedo. "Fueling Brazil: The Effects of the Ethanol Cluster in the Local Community". P155. *The Journal of Energy and Development*. Vol 33, No 2. 2010. By comparison our estimate for Brazilian employment resulting from ethanol using more current data is 444,378.

	2010	2020	2010	2020	2010	2020
	Biodiesel	Biodiesel	Gross	Gross		
	Output	Output	Output	Output	Employment	Employment
	(Mil liters)	(Mil liters)	(Mil \$)	(Mil \$)	Jobs	Jobs
EU-27	9,184	17,610	\$38,049	\$64,977	151,840	282,901
Argentina	1,576	3,231	\$6,530	\$11,922	26,057	51,908
Brazil	1,550	3,139	\$6,423	\$11,583	25,633	50,430
U.S.	1,192	4,002	\$4,940	\$14,767	19,713	64,294
Malaysia	765	1,331	\$3,170	\$4,910	12,650	21,378
Australia	627	719	\$2,597	\$2,653	10,366	11,551
Thailand	584	1,697	\$2,420	\$6,262	9,658	27,263
Indonesia	369	811	\$1,530	\$2,992	6,105	13,028
Columbia	302	768	\$1,253	\$2,833	4,999	12,333
Canada	236	594	\$979	\$2,191	3,907	9,541
China	227	500	\$940	\$1,845	3,753	8,032
India	179	3,293	\$743	\$12,149	2,967	52,896
Peru	174	130	\$720	\$480	2,873	2,089
Philippines	158	271	\$653	\$999	2,606	4,349
Turkey	62	52	\$257	\$192	1,025	836
South Africa	57	100	\$235	\$369	939	1,605
Mozambique	51	80	\$212	\$297	848	1,291
Tanzania	50	61	\$205	\$224	820	977
Viet Nam	8	100	\$32	\$369	128	1,606
Other	257	3,428	\$1,063	\$12,649	4,241	55,072
Total	17,608	41,917	\$72,952	\$154,663	291,129	673,380

Table 6Economic Impact of Biodiesel Production by Country, 2010 and 2020

- Biofuels displace petroleum and reduce the world's dependence on foreign oil, especially
 for major importers such as the U.S and EU and rapidly growing emerging markets such as
 China, India and Brazil. The production and use of ethanol and biodiesel displaces the
 crude oil needed to manufacture gasoline and distillate. The production of 110.8 billion liters
 of ethanol and biodiesel in 2010 is the equivalent of 1.2 billion barrels of crude oil valued
 \$135.4 billion at 2011 prices. The displacement of crude oil with biofuels is projected to
 increase to nearly 2.3 billion barrels by 2020 valued at \$253.6 billion.
- The impact of biofuels on displacing crude oil has a positive effect on the balance of payments and international financial health of net oil importers. As shown in Table 7, among the 21 major biofuels producers discussed in this study only seven (Argentina, Brazil, Canada, Colombia, Malaysia, Mexico, and Vietnam) were net crude oil exporters in 2010 and of these only two (Argentina and Malaysia) had positive current account balances. ²⁶ The aggregate current account deficit of the net oil importers was \$639 billion (including the U.S. which had the highest deficit of \$471 billion). These countries produced the equivalent of 821 million barrels of crude oil in the form of biofuels valued at \$91.3 billion. In other words, but for biofuels, the current account deficits of these countries would have been 14 percent higher.

²⁶ The current account records a country's net trade in goods and services, plus net earnings from rents, interest, profits, and dividends, and net transfer payments (such as pension funds and worker remittances) to and from the rest of the world.

Table 7
Current Account, Crude Oil Trade Balances and Biofuel Production: 2010
Major Biofuel Producers

	Current	Net Crude	Biofuel	Biofuel
	Account	nt Oil Trade Production		Share of
	Balance	Balance	(Crude Equiv)	Oil Trade
	(Mil \$)	(Mil bbl)	(Mil bbl)	Deficit
China	\$305,373	-1,454	23	1.6%
Japan	\$195,755	-1,247	3	0.2%
Malaysia	\$27,291	47	16	
Thailand	\$14,754	-245	18	7.4%
Philippines	\$8,924	-48	4	9.0%
Indonesia	\$5,643	-12	9	76.8%
Argentina	\$3,082	33	35	
Mozambique	-\$1,113	0	1	
Tanzania	-\$1,978	0	1	
Peru	-\$2,315	-30	4	13.9%
Viet Nam	-\$4,287	95	2	
Mexico	-\$5,665	460	1	
Columbia	-\$8,855	128	9	
South Africa	-\$10,117	-193	5	2.4%
EU-27	-\$23,270	-3,621	227	6.3%
Australia	-\$30,400	-52	15	30.0%
Brazil	-\$47,365	55	273	
Turkey	-\$47,695	-100	2	1.9%
Canada	-\$49,307	203	17	
India	-\$51,781	-1,185	21	1.8%
U.S.	-\$470,902	-3,481	488	14.0%

Sources: World Bank; IEA

Caveats to the Analysis

The data and projections used to prepare the economic impacts in this analysis were provided by the OECD-FAO Agricultural Outlook 2011-2020. The economic impacts were estimated by Cardno ENTRIX and do not reflect or represent projections of the OECD-FAO. Feedstock use by country on which expenditures were estimated was based on information obtained from published reports and from industry sources. Prices used are averages of world prices and may not necessarily reflect actual transactions costs in individual countries.

Projections of feedstock use associated with biofuels projections are based on current yields and technology.

The economic impacts estimated in this study reflect only production costs. The increase in biofuel production projected by OECD-FAO will require substantial capital investment that will result in additional output and job creation. However, the impacts from construction of production capacity are transitory and expire when construction is completed. Impacts from ongoing production are permanent.

Conclusion

The biofuels industry has grown significantly in recent years and promises to continue expanding as an increasing number of countries seek to expand sources of alternative energy, reduce dependence on volatile world oil and petroleum prices, create new revenue for farmers and stimulate agricultural production. This expansion will provide significant contributions to the global economy in terms of output growth, job creation and important contributions to environmental quality. The importance of biofuels to agriculture is particularly notable since feedstocks produced by the world's farmers provide significant revenue and stimulate future agricultural production that will enhance food security on a global basis. The fastest growth in biofuels production is expected to take place in emerging and developing countries particularly in Asia and Africa. For these countries biofuels will supply rapidly growing domestic markets and provide an important base for expanding export earnings needed to fuel economic growth.

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