Handbook of Bioenergy Crop Plants

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Public Policies, Economics, Public Perceptions, and the Future of Bioenergy Crops

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12 Public Policies, Economics, Public Perceptions, and the Future of Bioenergy Crops

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12.1 INTRODUCTION

Over the past decade, a renewed interest in biofuels has arisen as concerns about energy security, fuel prices, and the adverse impacts of global climate change have grown. Government support has been especially strong for biofuel programs in the US, European Union (EU), and Brazil, although not without controversy. Environmental groups are concerned about possible deforestation from an increase in cropland, and concerns have arisen over the use of food-crops for fuel instead of food.

Crops have been used to make synthetic fuels for many years. For instance, engines were developed in the 1800s by designers such as Henry Ford and Nicholas Otto that used grain ethanol as fuel, and the 1908 Model T had an adjustable carburetor that could use alcohol, gasoline, or a blend of the two (Solomon et al. 2009). Rudolph Diesel, the inventor of the diesel engine, used peanut oil in an engine (Shay 1993). In 1919, the British government experimented with using Jerusalem artichokes to produce fuel alcohol because of an oil shortage, and near the end of World War II Japan
was using potatoes, sugar, and rice wine to produce alcohol for fuel (Yergin 1992). After the oil crises of the 1970s, Brazil and the United States enacted policies that successfully encouraged ethanol production as a gasoline substitute. More recently, legislation in the United States set an ambitious goal of $1.36 \times 10^{11}$ L/year of ethanol production by 2022, with most of that to be made from cellulose. In the past decade, the EU, especially Germany, has also greatly increased its production of biofuels, particularly biodiesel. In 2008, $67 \times 10^9$ L of ethanol and $12 \times 10^9$ L of biodiesel were produced worldwide, compared with $39 \times 10^9$ and $6 \times 10^9$ L, respectively, produced in 2006 (REN21 2009). Table 12.1 shows the top 15 producing countries of biofuels as of 2008.

There are many types of biofuels, the two most common of which are the liquid fuels ethanol and biodiesel (Solomon and Johnson 2009a). Ethanol is produced from grains (especially corn) and crops with high sugar content, such as sugarcane and sugarbeets. To process the starch in grains to alcohol, seven steps are required: milling, liquefaction, saccharification, fermentation, distillation, dehydration, and denaturing. Processing crops with high sugar content is cheaper than processing grains and it requires five steps: milling, pressing, fermentation, distillation, and dehydration (Solomon et al. 2009). Other alcohols, especially methanol, propanol, and butanol, can also be manufactured. Alcohol can also be processed from cellulosic-based feedstocks, including wood, agricultural residues, straws, and grasses. Although little cellulosic ethanol is currently produced commercially because of the immature technology and high costs involved, capacity to produce cellulosic ethanol will grow rapidly in the next decade.

Biodiesel is produced primarily from vegetable oils, but it can also be created from animal fats. Common crops include rapeseed, palm, soy, sunflower, and peanut. After oil is extracted from

TABLE 12.1
Global Biofuels Production in 2008 for the Top 15 Producing Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Fuel Ethanol</th>
<th>Biodiesel</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>34</td>
<td>2.0</td>
<td>36</td>
</tr>
<tr>
<td>Brazil</td>
<td>27</td>
<td>1.2</td>
<td>28</td>
</tr>
<tr>
<td>France</td>
<td>1.2</td>
<td>1.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Germany</td>
<td>0.5</td>
<td>2.2</td>
<td>2.7</td>
</tr>
<tr>
<td>China</td>
<td>1.9</td>
<td>0.1</td>
<td>2.0</td>
</tr>
<tr>
<td>Argentina</td>
<td>–</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Canada</td>
<td>0.9</td>
<td>0.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Spain</td>
<td>0.4</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Colombia</td>
<td>0.3</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Italy</td>
<td>0.13</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>India</td>
<td>0.3</td>
<td>0.02</td>
<td>0.3</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.14</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Poland</td>
<td>0.12</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>–</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>EU total</strong></td>
<td><strong>2.8</strong></td>
<td><strong>8</strong></td>
<td><strong>10.8</strong></td>
</tr>
<tr>
<td><strong>World total</strong></td>
<td><strong>67</strong></td>
<td><strong>12</strong></td>
<td><strong>79</strong></td>
</tr>
</tbody>
</table>

crops, three reversible steps are used to chemically modify the oil so that its properties are similar to diesel fuel: transesterification, pyrolysis, and emulsification (Meher et al. 2006). In addition to ethanol and biodiesel, bioenergy crops, especially from forestlands, are used to produce many other types of energy, including heat, electricity, and syngas (Solomon and Johnson 2009a).

This chapter begins by presenting the policies that are helping drive the rapid increase in the worldwide production of biofuels, especially in the United States, EU, and Brazil, with an examination of the current economic situations in each of these places. Results of a case study of public perceptions in the upper midwestern United States are presented, along with some ideas about what the near future might hold for biofuels.

12.2 GOVERNMENT POLICIES

12.2.1 United States

The United States is the world’s leading ethanol producer. Government support for ethanol development in the United States has existed at the federal and state levels. Three basic federal subsidies fueled the early years of the modern fuel ethanol industry, which was focused on corn until 2007. The first and most important of these was a partial exemption from the federal gasoline excise tax for “gasohol” (defined as a fuel containing at least a 10% component of biomass-derived ethanol). This exemption was approved by the Energy Tax Act of 1978 and implemented in 1979 (Solomon 1980). A fuel blender’s tax credit and a pure alcohol fuel credit were added in 1980. These new initiatives were basically the same subsidy as the fuel excise tax exemption but recouped through a different system and available to a small number of companies who were unable to claim the fuel tax exemption. Through later years, all of these tax provisions were periodically renewed and altered in terms of the benefit magnitude, with changes in one being mirrored by changes in the others. The excise tax exemption has been by far the most widely used incentive (double crediting with the fuel blender’s tax credit is not allowed) with total government revenue impacts estimated at between 16 and 56 times those of the other two tax credits combined (GAO 2000). Thus, this exemption was the most important of the early ethanol support mechanisms and it remains of critical importance to this industry in the United States today.

Further federal support came in 1990 with passage of the Small Ethanol Producer Tax Credit, which provided small refineries (less than $1.1 \times 10^8 \text{ L/year production capacity}$) with an additional $0.026/\text{L}$ income tax credit for volumes up to $5.7 \times 10^7 \text{ L/year}$ (California Energy Commission 2004). The Energy Policy Act of 2005, which is discussed below, redefined small producers as those producing up to $2.3 \times 10^8 \text{ L/year}$. In recent years the total federal and state support for ethanol and biodiesel has equaled a taxpayer subsidy of $10 + \text{ billion/year}$ (Koplow 2007), including a tariff on ethanol imports, although these subsidies arguably offset an even larger subsidy to U.S. farmers and the cost of foreign oil imports (Goldemberg 2007).

From 1978 to 2004, there was little change to the main component of federal support, the excise tax exemption. Benefit levels changed several times, culminating in a progressive reduction from $0.14/\text{L} \ ($0.54/\text{gal})$ to $0.13/\text{L} \ ($0.51/\text{gal})$ of ethanol during 1998–2005 as a result of the Transportation Equity Act of 1998. However, in 2004 the basic mechanics of the subsidy were changed by the introduction of the Volumetric Ethanol Excise Tax Credit (VEETC). The VEETC (or “blender’s credit”) streamlined the system by (1) making it volume-based rather than limited to specific blends; (2) eliminating negative impacts on the Highway Trust Fund by taking the credit from general government revenues; and (3) renewing the subsidy at $0.13/\text{L} \ ($0.51/\text{gal})$ of ethanol, which was lowered to $0.12/\text{L} \ ($0.45/\text{gal})$ for 2009 by the 2008 Farm Bill (RFA 2011). Similarly, biodiesel was given a Volumetric Biodiesel Excise Tax Credit (VBETC) of $0.13/\text{L} \ ($0.50/\text{gal})$ for biodiesel from waste cooking oils and $0.26/\text{L} \ ($1.00/\text{gal})$ for biodiesel made from virgin agricultural feedstock (Koplow 2007). Most of the biodiesel produced in the United States is soybean based.
The Energy Policy Act (EPAct) of 2005 approved several major incentives to usher in a new era of renewable transportation fuels (Public Law 109-58 2005). The most widely publicized provision of EPAct, the Renewable Fuel Standard (RFS), applies to corn and cellulosic ethanol and will operate in the place of the now eliminated oxygenate requirement for reformulated gasoline. Implementation of the RFS by the U.S. Environmental Protection Agency (EPA) began in 2006 at $1.5 \times 10^{10}$ L/year (which was nearly met in 2005) and was scheduled to increase to $2.8 \times 10^{10}$ L/year in 2012. In light of the current market for ethanol, EPAct has provided only a modest production boost. Additional provisions of EPAct were designed to improve commercialization prospects for cellulosic ethanol through increased research and development funding in all aspects of the industry, including feedstock development, processing technology, co-product production, and systems optimization (Wyman 2003). Project financing and funding, a major bottleneck (Hamelinck et al. 2005), received attention as well through a series of large grants and loan guarantees for biorefinery development and commercialization (Public Law 109-58 2005). Overall, EPAct provides a short-term boost to accelerate commercialization and technological development while also attempting to cement a place for the new technology in the longer-term ethanol market. Implicit in this is the assumption that cellulosic ethanol is capable of providing larger societal benefits than corn ethanol, although in the near future, corn ethanol will still dominate the market.

The prospects for cellulosic ethanol received a much larger boost through passage of the Energy Independence and Security Act in December 2007. This law revises and extends the RFS beginning in 2008 at $3.4 \times 10^{10}$ L/year, up to a rather ambitious $1.36 \times 10^{11}$ L/year by 2022. Of this total, no more than $5.7 \times 10^{10}$ L/year will come from cornstarch, with the remaining $7.9 \times 10^{10}$ L/year to come from advanced biofuels with greatly reduced greenhouse gas emissions (including biodiesel). Over 75% of all advanced biofuels will eventually come from cellulose, and this part of the mandate could be met by any combination of ethanol and other alcohols (Sissine 2007).

During the revival of the domestic ethanol industry in the late 1970s, more than a dozen state governments quickly approved partial or total gasohol exemptions from state road use taxes (Solomon 1980; Solomon et al. 2009). These state programs are generally similar to the federal programs, and as of 2010, 32 states were supporting ethanol development (Voegele 2010). The most important state policies included mandates and various levels of excise tax exemptions.

The policy environments in Minnesota and Iowa have been especially strong, combining measures that support production and consumption of ethanol (Solomon et al. 2009). Instrumental to this effort in Minnesota has been a 1997 state requirement that all gasoline sold in the state must have a 10% ethanol content. An increase to a 20% mandate was approved in Minnesota in 2005 (which would take effect in 2013) pending the granting of a waiver by EPA under the Clean Air Act. Similar laws that mandate a 10% ethanol-blended fuel were passed in Hawaii and Montana in 2005, and Missouri, Washington and Oregon in 2006–2007, and Florida in 2008 (RFA 2011). The requirements have varying phase-in dates. Kansas has a 10% ethanol blend mandate that only applies to state fleet vehicles. Iowa joined Minnesota in 2006 by approving a comprehensive state RFS—a 10% mandate for 2009 that increases to 25% in 2020. In addition, a retail tax credit on E85 (a blend of 85% ethanol and 15% gasoline) of $0.07/L ($0.25/gal) was approved, although it is being lowered over time. This compares with Minnesota, which has a state fuel tax exemption on E85 of $0.015/L ($0.058/gal) and an ethanol production payment of $0.05/L ($0.20/gal). Minnesota also has the most extensive E85 infrastructure in the country, with 360 retail fueling outlets (DOE 2011).

12.2.2 European Union

The European Union (EU) also provides support for a domestic biofuels industry, most notably through its Biofuels Directive of 2003 and the Renewable Energy Directive of 2008 (Rosch and Skarka 2008). Only a small amount of ethanol is produced, mostly from sugarbeets, wine, wheat, and corn in France, Germany, and Spain. More significant biofuel production is in the form of biodiesel from rapeseed, especially from Germany (the world leader) and to a lesser extent from
France, Spain, Italy, and Austria. This pattern is not surprising given the greater use of diesel vehicles in Europe than in the United States.

The EU Biofuels Directive, officially 2003/30/EC—the directive on the promotion of the use of biofuels and other renewable fuels for transport—entered into force in May 2003. The Biofuels Directive initially set a target of 2% biofuels for 2005, which was not met. This measure mandated that national measures among member countries must be taken that will result in the replacing of 5.75% of all transport fuels (i.e., gasoline and diesel) with biofuels by December 31, 2010 and 10% by 2020. Differentiation of national target levels was allowed for various reasons, such as limited national production potential and allocation of resources to biomass production in sectors in addition to transport. For example, France had a 7% target for 2010 whereas Italy’s was 2.5%. This became moot, however, when controversy over its effects led to repeal of this Directive in 2009. The replacement EU Directive 2009/28/EC promotes biofuels that can significantly reduce greenhouse gas emissions through a shift to second-generation biofuels, similar to that required in the United States, and that sustainability criteria be met. The latter criteria are being developed internationally, although the Swedish firm SEKAB already has a sustainable ethanol standard (Solomon 2010).

The greenhouse gas reduction and sustainability criteria for biofuels in the EU will be instituted in response to the Fuel Quality Directive 98/70/EC approved in Brussels in December 2008. This directive focuses on the incorporation of sustainability criteria for biofuels to reduce life-cycle greenhouse gas emissions, among other considerations, and will be coordinated with the broader EU Renewable Energy Directive (Rosch and Skarna 2008).

12.2.3 Elsewhere

Brazil’s modern sugarcane ethanol industry is older than that of the United States because it began as the Pro-Alcool (National Alcohol) Program in 1975 to wean the nation off of oil imports. Today Brazil is the world’s second-largest ethanol producer, after the United States, and has a modest but growing biodiesel program based on soybeans and castor oils. Brazil is also the world’s leading exporter of ethanol, mostly to the United States and the Netherlands.

Brazil has supported its ethanol industry with various policies (Reel 2006). First, since 1976 the federal government has mandated the blending of anhydrous ethanol with gasoline at levels that have varied from 10 to 25%. In addition, the Brazilian government has guaranteed ethanol purchases by Petrobras (the state-owned oil company), subsidized sugarcane growers, provided low-interest loans and credit guarantees to ethanol refiners, mandated that gasoline service station owners in towns of more than 1500 people install ethanol pumps, and instituted price controls that made ethanol available for 59% of gasoline prices. Ethanol-only automobiles (technically ethanol with a E95 blend with gasoline) were even promoted in the 1980s by tax breaks, and over half of the nation’s cars ran on the fuel in the late 1980s. Most of the ethanol price supports and subsidies were eliminated by the mid 1990s because greater efficiency and lower production costs have allowed Brazilian ethanol to compete without government support (Gallagher 2007).

There are small but growing biofuels programs elsewhere in South America, most notably in Colombia and most recently in Venezuela, Argentina, and Uruguay. Another new player to the biofuels scene is Africa. For example, in South Africa, seven corn ethanol refineries are planned as well as one each based on sorghum and sugarbeets, plus a biodiesel plant based on waste vegetable oil. Other ethanol plants are at various stages of development in Nigeria, Tanzania, Kenya, and Mozambique that are based on cassava, sugarcane, and sorghum along with a biodiesel plant in Zimbabwe that is based on cotton and sunflower seeds, soybeans, and possibly jatropha oil (Solomon 2009).

There are also several important biofuels markets in Asia. The leading ethanol producer in the region is China, although its output in 2008 was only 5.6% that of the United States and 7.8% that of Brazil (RFA 2011). Like the United States, China subsidizes its ethanol industry. China has had plans to expand its ethanol production by 650% from 2007 to 2020, although in the summer of 2007
(and again in summer 2008) the government announced restrictions on ethanol made from food grains, corn in particular (Koizumi and Ohga 2007). Even so, approximately 80% of ethanol production in China is made from cornstarch, with most of the rest derived from wheat and rice. Other feedstocks are now getting greater attention, such as cassava, sweet potato, sweet sorghum, and sugarcane, and a demonstration plant that converts corn stover to ethanol (Leng et al. 2008; Solomon 2009). However, short-term ethanol production goals are not being met because of a shortage of raw materials during this transition period. India has also been a major producer of sugarcane-based ethanol, but its industry has fallen on hard times and output has dropped dramatically since 2006.

Several countries in Southeast Asia have growing biofuels industries. For example, Indonesia, Malaysia, and even Singapore are all planning major expansion of palm oil production to make biodiesel. Serious concerns have been raised in Europe and elsewhere about these plans because of their contribution to tropical deforestation (Koh and Wilcove 2008; Danielsen et al. 2009). A fourth country in the region, Thailand, is also expanding its biodiesel capacity, as well as ethanol production, from sugarcane and cassava feedstocks (Solomon 2009).

12.3 ECONOMICS

Recent years have seen a spike of oil, crop, and seed prices. From the beginning of 2007 to the middle of 2008 global seed prices and oil prices doubled, and meal prices also experienced a sharp increase (FAO 2009). At the same time, the global recession caused numerous biofuel producers to file for bankruptcy and others to not produce at full capacity (HGCA 2009). For biofuels to be competitive on the market, crude oil prices need to be between $50 and $100 per barrel (Lange 2007), a level they have been at since March 2009, following 3 months below that range.

12.3.1 United States

The primary bioenergy crop in the United States is corn, accounting for over 95% of total ethanol production (RFA 2011). As discussed in the aforementioned policies, the United States has seen widespread implementation of a corn-based ethanol market, an increasingly common additive to gasoline. In 2010, ethanol production totaled approximately $5 \times 10^9$/L, or 9% of all gasoline-type fuel sold in the United States (EIA 2011). This accounted for just over half of the global output, and there is capacity to produce over $54 \times 10^9$/year (RFA 2011). In September 2011 there were 2442 E85 fuel stations, mostly in the Midwest, an increase of over 1000 in the past three years (DOE 2011; Solomon et al. 2009).

Since the late 1970s, gasoline has consistently been less expensive than corn ethanol. This has been the case although the price of grain ethanol has been partially offset by the production and sale of co-products, such as distillers dried grains with solubles. Over 80% of U.S. production, including the most recently built plants, has come from anhydrous mills with the rest made in the more costly hydrous mills (Urbanchuk 2006). However, the actual price differential between ethanol and gasoline has been relatively small, mainly because of the large government subsidies noted earlier, especially the federal excise tax exemption and the fact that most ethanol sold in the United States is through a 10% ethanol blend with 90% gasoline (E10). Even if the retail price of the ethanol blend is less expensive than gasoline, as is typically the case for E85, the real economic efficiency of corn ethanol is much lower because the energy density of ethanol is only two-thirds that of gasoline (Lide 1992).

Perhaps the largest controversy involved in the large quantity of corn-to-ethanol production is the impact this has had on food prices. The increase of ethanol production has come with an increase of corn production—from $9.5 \times 10^9$ bushels produced in 2001 to $12.1 \times 10^9$ bushels produced in 2009 (DOA 2009). Approximately 11 L (2.8 gal) of ethanol is produced from a bushel of corn (de Gorter and Just 2009). Corn converted into fuel alcohol from 2001 to 2009 expanded from $0.7 \times 10^9$ bushels to $4.1 \times 10^9$ bushels. Thus, the additional ethanol production came largely from an increase in crop
yield, as shown in Figure 12.1. A study by the U.S. Department of Agriculture (USDA) concludes that food prices have risen very modestly because of the growth of corn-based ethanol, and the price rises have been largely in the beef sector (because most corn grown in the United States is used as feed), not in corn-based products such as cereals. It was calculated that even if corn prices were to increase 50%, overall food prices would raise less than 1% (Leibtag 2008). However, the debate is far from over because a diversity of opinions remains on this subject (cf. Pimentel et al. 2009). Ultimately, the constraining factor on increasing ethanol production will be the land available for feedstock supply growth as the ethanol market expands.

Although almost all ethanol in the United States is currently made from corn, there is substantial interest in producing cellulosic ethanol, i.e., ethanol that is produced from wood, farming, and forestry residues or grasses rather than the starch in grains. According to the optimistic 2005 “Billion Ton Study,” cellulosic ethanol has the potential to offset at least 30% of the current petroleum consumption in the United States (Perlack et al. 2005). Thus, the potential for cellulosic ethanol is much higher than that of corn ethanol.

However, cellulosic ethanol is not yet market-efficient, and a widespread cellulosic ethanol market has yet to be created. This could change in the near future; worldwide, approximately 15 or so commercial cellulosic ethanol plants are expected to be commissioned in the next few years, with capacities ranging from $3.8 \times 10^6$ to $3.8 \times 10^8$ L/year. Most of these plants will be located in the United States. The cellulosic ethanol plants will use various feedstocks, including corn stover, bagasse, wheat straw, wood waste and residues, wood chips, municipal solid wastes, and switchgrass. About a dozen demonstration plants and 20 pilot plants have also been built (Solomon et al. 2009). The wood chips would probably be produced from fast-growing trees such as willow shrubs or poplar (Volk et al. 2006).

Cellulosic ethanol is expensive to produce for three main reasons. First, achieving economies of scale is difficult because processing plants must be located near ethanol feedstocks since transportation of the feedstocks is expensive. Thus, processing plant necessarily have to be limited in size because the maximum shipping range for the feedstock is approximately 120 km (Froese et al. 2008). Interestingly, this could provide an opportunity for numerous small-scale markets to be created, rather than one or several large markets, as is the case with grain. Second, the initial capital costs for constructing processing plants are much larger than for grain ethanol plants. This is because of the need for pretreatment of the biomass and the high cost of utilities. For example,
Wyman (1999) calculated that a 2.2 \( \times \) 10^8 L/year processing plant would cost $250 \( \times \) 10^6 (1997 dollars). Third, the technology and processes (both biochemical and thermochemical) involved in creating ethanol from various feedstocks are still immature and are being actively researched (Ruth 2008; Solomon et al. 2009). This can be seen in Figure 12.2, which shows the relative costs of feedstocks and processing for various transportation fuels. Access to capital investment and the need to create transportation and market infrastructures are other challenges that will need to be overcome for cellulosic ethanol to be commercially viable in large quantities.

The United States is the second-largest biodiesel producer in the world, behind Germany (Canakci and Sanli 2008). In the United States, biodiesel is made primarily from soybeans. The U.S. industry experienced rapid growth, expanding from 1.9 \( \times \) 10^6 L produced in 1999 to 2.65 \( \times \) 10^7 L in 2008 (NBB 2009). Production plummeted in 2009-2010 due to the recession, but has since rebounded because of the RFS. The major cost of biodiesel is the cost of the feedstock, which accounts for nearly 90% of the total fuel cost (Haas et al. 2005). Because the feedstock costs alone can be 1.5–3.0 higher than the price of diesel fuel, only lower feedstock costs or higher diesel prices will make biofuels a more attractive option. The prices of plant-based feedstocks such as soybeans, canola, sunflower, and rapeseed are typically more expensive than various animal fats (Canakci and Sanli 2008).

### 12.3.2 European Union

The EU is the world’s leading biodiesel producer, with approximately two-thirds of the world’s market (REN21 2009). Unlike the United States, biodiesel is the primary biofuel produced in the EU; biodiesel makes up approximately 80% of the total biofuels produced in the region (Bozbas 2008). Germany is by far the largest producer, producing half of all production. France, Italy, Spain, and Austria are the next three largest producers. In total, the EU has 241 plants with a total capacity of 16 \( \times \) 10^6 L/year, suggesting strong growth in the next few years (EBB 2008; REN21 2009). On the other hand, in 2009 Germany and the United Kingdom lowered their mandatory blend rate by 1 and 0.5%, respectively, for a year in response to market conditions (FAO 2009).

### 12.3.3 Brazil

Brazil is the world’s second-largest ethanol producer and has recently started producing biodiesel as well. Between 2006 and 2008 Brazil increased ethanol production from 18 \( \times \) 10^9 to 27 \( \times \) 10^9 L, and there are now 400 ethanol mills and 60 biodiesel mills in operation (REN21 2009). A total of 4.2 \( \times \) 10^6 ha of sugarcane is harvested yearly. One reason for this massive increase is that sugar prices have been dropping, whereas ethanol prices have been increasing (Moreira 2009).
The main advantage that Brazil has over the United States is that it is much cheaper to produce ethanol from sugarcane than corn because of the simplified processing, the availability of free bagasse, and the favorable agricultural environment in Brazil (Moreira 2000). Furthermore, sugarcane has an energy density approximately three times greater than corn (Ruth 2008).

## 12.4 Public Perceptions: Results of an Opinion Survey in the Upper Midwestern United States

Concerns about climate change, energy security, and environmental impacts have revived interest in using biofuels to produce energy. Although certain bioenergy crops, such as corn, and their associated biofuels have established markets, many do not. Forest residues and agricultural waste are plentiful in many areas of the world and could be used to provide liquid biofuels or electricity through combustion. However, markets that use these products are not widespread and are limited in scale.

A public opinion survey was sent to 1500 households in the states of Michigan, Minnesota, and Wisconsin to gauge attitudes about global climate change and to determine people's willingness to pay (WTP) for cellulosic ethanol as a substitute for gasoline. As part of the survey, responses were elicited as to whether or not biofuel production would be good for the respondents’ local economies. This section of the chapter will present descriptive results from some of the survey questions relevant to biofuels. It was found that residents generally believe that local biofuel production would be good for the local economies. Although owners of farm and forestland were more supportive than non-owners, they thought that they themselves would only be marginally affected. There was strong support for the idea that the United States should produce all of its own energy requirements. Overall, farmers and forestland owners did not have significantly different attitudes toward a potential biofuel market and climate change than did other survey respondents.

### 12.4.1 Previous Research

Little research has been conducted on the public perceptions of biofuel markets in the United States. However, there have been several recent studies completed that provide a good indication of current public attitudes. For example, a telephone survey of over 1000 people in the United States done by Wegener and Kelly (2008) found that although 78.6% of people agreed with the statement “using biofuels such as ethanol is a good idea,” only 70.6% of people agreed that “using corn to produce ethanol is a good idea” and 55.5% of people agreed that “using wood or wood chips to produce ethanol is a good idea.” In comparison, 58.6 and 56.6% of people agreed with the statements “using coal-based energy is a good idea” and “using energy from oil is a good idea,” respectively. Nearly 24% of the respondents felt “not at all informed” about biofuels, and about double this rate felt “not at all informed” about cellulosic ethanol (depending on the feedstock).

In a nationwide web and phone-based WTP study, which focused on support for energy research and development of nonfossil fuel technologies, Li et al. (2009) found very high support for spending on research and development of renewable energy technologies including biofuel crops. A dummy variable that accounted for corn-producing states was shown to be insignificant, thus suggesting attitudes about biofuel markets in the Midwest are not significantly different than those in the rest of the country. In another study, Borchers et al. (2007) found that solar power and wind power are favored more than bioenergy as renewable energy sources.

In a mail survey sent to over 15,000 Tennessee farmers, Jensen et al. (2007) examined their willingness to grow switchgrass as a bioenergy feedstock. Approximately 3500 surveys were returned completed. Only approximately 21% of the respondents had heard of switchgrass being used as a biofuel. Although there was a large amount of uncertainty for many respondents as to whether or not they would be willing to grow it (~47%), approximately 30% said they would be willing to try it if it were profitable.
What is more typical than the measurement of the public perceptions of biofuel markets is the measurement of WTP for green electricity, of which biomass is one possible fuel. Several studies have shown a large gap between the number of people who say they are willing to pay more for green electricity and the number who actually do so when given the option by their electric power provider (e.g., Borchers et al. 2007; Wiser 2007; Hite et al. 2008).

Another typical way that public perceptions of biofuel markets in the United States are measured is through studies gauging public perceptions of climate change. For instance, Dietz et al. (2007) examined people’s attitudes toward eight possible climate change mitigation policies, including several that would make biomass combustion and liquid biofuel consumption in vehicles more economically viable. Policies that had the least direct economic impact on consumers, such as the reduction of government subsidies for fossil fuels, had the most support, whereas direct taxes, such as a 60-cent per gallon gasoline tax, had the least. Our three-state public opinion survey included sections on public perception and attitudes toward global climate change similar to Dietz et al. (2007), but also explicitly addressed cellulosic ethanol as a possible solution plus a section that addressed the WTP for this fuel (Solomon and Johnson 2009b).

### 12.4.2 Methodology

The survey was mailed to 1500 households throughout Michigan, Minnesota, and Wisconsin. Rural addresses received 60% of the surveys so as to increase the number of farm and forest owners in the sample. An expanded version of Dillman’s tailored design method was used to increase the response rate (Clendenning et al. 2004). This entailed sending out a presurvey notification letter, multiple survey mailings, and reminder postcards between mailings. A $2 bill was sent with the first survey as a thank you. The surveys were sent in three rounds between November 2007 and January 2008. After accounting for bad addresses, the final survey size was 1432. A total of 745 households returned a survey for an overall response rate of 52%. For this analysis, a further 75 surveys were discarded for not providing complete answers to all of the relevant questions. The survey responses were then weighted to correct for the aforementioned oversampling and for slightly varying response rates from different states, adjusting the results based on the actual populations on the basis of data from the U.S. Census Bureau for the rural and urban subpopulations in the three states.

As noted earlier, the survey had sections. The first section included 44 Likert scale questions that asked respondents about their opinions of climate change, energy cost and consumption, and the environment. The second section was a split sample contingent valuation method and “fair share” survey that measured WTP for cellulosic ethanol fuel in the states surveyed (Solomon and Johnson 2009b). Owners of farms or forests were asked several additional non-Likert scale questions to determine if the owners had forest residues or waste biomass they would want to sell. The average time to complete the survey was approximately 30 min.

### 12.4.3 Results

Table 12.2 shows the raw average responses and the weighted responses to the questions regarding public attitudes and beliefs toward cellulosic ethanol. Respondents who chose “don’t know” for answers were excluded from the average. There was some agreement that making biofuels would be helpful to local economies. Farmers and forestland owners exhibited greater support for a local biofuel economy than did the general population. It is interesting to note that not a single farm or forest owner (n = 93) was indecisive (“neither agree nor disagree”) to the statement “America should produce its own energy.” Similarly, only one farm owner and one forest owner responded with “neither agree nor disagree” to the statement “Making more biofuels, like corn ethanol, would be good for my area’s economy.” For non-farm and forest owners, this option was selected 16% and 14%, respectively.
### TABLE 12.2
Public Perceptions Survey Responses Comparing Farm and Forest Owners to the Total Population

<table>
<thead>
<tr>
<th>Question</th>
<th>Total Population (n = 670)</th>
<th>Farm Owners (n = 42)</th>
<th>Forest Owners (n = 51)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making more biofuels, like corn ethanol, would be good for my area’s economy.</td>
<td>3.70, 3.72, 636</td>
<td>3.80, 3.83, 42</td>
<td>3.87, 3.78, 51</td>
</tr>
<tr>
<td>America should produce all of its own energy.</td>
<td>4.02, 4.02, 659</td>
<td>4.11, 4.02, 42</td>
<td>4.02, 4.10, 51</td>
</tr>
<tr>
<td>Climate change is not going to happen.</td>
<td>1.82, 1.87, 638</td>
<td>1.91, 1.92, 40</td>
<td>1.75, 1.86, 50</td>
</tr>
<tr>
<td>Climate change is not likely to be a serious problem.</td>
<td>2.12, 2.16, 636</td>
<td>2.30, 2.52, 42</td>
<td>2.14, 2.08, 51</td>
</tr>
<tr>
<td>Burning fossil fuels is one of the primary causes of climate change.</td>
<td>3.59, 3.60, 573</td>
<td>3.55, 3.47, 38</td>
<td>3.42, 3.48, 46</td>
</tr>
<tr>
<td>How well would removing leftover materials or residues, such as leaves and branches or corn and wheat stalks, fit with current management of your land?</td>
<td>–, –, –, 2.46, 42</td>
<td>2.28, 2.20, 42</td>
<td></td>
</tr>
<tr>
<td>How much do you think having a regional cellulosic or “cellulosic” ethanol-based market for these leftover materials or residues benefit you economically?</td>
<td>–, –, –, 2.59, 42</td>
<td>2.60, 2.69, 42</td>
<td></td>
</tr>
</tbody>
</table>

1, strongly disagree; 2, somewhat disagree; 3, neither agree nor disagree; 4, somewhat agree; 5, strongly agree; 0, don’t know.
Although there was a weak preference for the idea that making biofuels would be good for the local economy, neither farm nor forest owners thought that the removal of waste material on their property would fit with their current land management strategies. Similarly, there was only marginal support for the idea that a nearby cellulosic ethanol plant to which they could sell waste material would be economically beneficial.

To ensure that respondents were familiar with the subject of climate change, the first two questions of the survey were “I have heard the term climate change” and “I have heard the term global warming.” Of the 670 respondents, 635 (93%) answered either “strongly agree” or “somewhat agree” to one of these two questions. The subset of farm owners and forestland owners were similarly aware of the terms. It is interesting to note that although there was a high degree of disagreement with the statement “climate change is not going to happen,” 97 respondents expressed uncertainty (“don’t know”) about the statement “Burning fossils is one of the primary causes of climate change.” This indicates that although there is agreement that climate change is happening, the public is unsure of the causes.

12.5 THE FUTURE

The future proliferation of bioenergy crops will be highly dependent upon government policies supporting (or hindering) biofuels and the economics of both biofuels and the oil products they are market substitutes for, namely gasoline and diesel. In the near term, corn-based ethanol will reach a saturation point in the United States because of the limited quantity of additional available corn and the cap imposed by the RFS, although it is not known exactly what this saturation point is. As of September 2011, an additional $1 \times 10^9$ L/year of ethanol capacity was under construction in the United States (RFA 2011). However, the recent global economic downturn has had a toll. VeraSun Energy, formerly the largest commercial ethanol producer in the United States, entered bankruptcy in 2008 because of the credit crisis and falling oil prices (HGCA 2009). On the other hand, Brazil is in a flexible position because of its ability to produce relatively cheap ethanol and the availability of a significant amount of land that can be dedicated to additional sugarcane production.

As for cellulosic ethanol, the 2007 Energy Security and Independence Act, combined with decreasing industry costs as indicated by the number of commercial plants being built, indicate that it will become a major competitor to gasoline. World cellulosic ethanol production capacity is expected to be at least $1 \times 10^9$ L/year by 2012, primarily in the United States (Solomon et al. 2009). However, this is by no means assured because cellulosic ethanol is still an emerging market. Additionally, high fragmentation of land ownership, especially in the Midwest, will pose a barrier to the availability of feedstock (e.g., Potter-Witter 2005). Ethanol has to be shipped by road, rail, or barge because ethanol attracts water and transportation in oil pipelines can contaminate the pipeline. A major technological breakthrough in transportation infrastructure came in 2008 when ethanol was successfully shipped through a gasoline pipeline in Florida (UPI 2008). This should allow for a reduction in transportation costs and could allow for (cellulosic) ethanol production in regions with large amounts of feedstock but low population densities, such as federal lands in the North American West.

The EU is expected to maintain its strong growth in biodiesel production, with $3 \times 10^9$ L/year additional capacity under construction, although there has been some recent retrenchment, especially in Germany. Argentina is poised to be one of the world’s largest biodiesel producers. Currently, the country is the world’s third-largest producer of soy oil and the largest exporter; half of all cultivated land in Argentina is soy. There is currently approximately $3 \times 10^9$ L/year of biodiesel production capacity, with an additional $2 \times 10^9$ L/year of biodiesel production under construction there. Almost all of the biodiesel is expected to be exported (Mathews and Goldsztein 2009; REN21 2009). Biodiesel production is expanding in Brazil as well, and Asian markets continue to grow. Thus, although the near-term future of bioenergy crops is mixed, the long-term prospects remain bright.
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