THE BILLION GALLON CHALLENGE

GETTING BIOFUELS BACK ON TRACK




Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

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UNION OF CONCERNED SCIENTISTS

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The Union of Concerned Scientists (UCS) is the leading science-based nonprofit working for a healthy environment and a safer world.

The UCS Clean Vehicles Program develops and promotes strategies to reduce the adverse environmental impact of the U.S. transportation system.

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Contents

Text Boxes

Figures

Tables

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Executive Summary

Biofuels hold out the promise of reducing two major problems: oil dependence and global warming emissions from transportation. Yet despite numerous government programs and subsidies, biofuels are not yet measuring up to their potential.

Corn ethanol production has more than tripled in the last five years, driven by mandates for biofuel consumption, tax credits, and other programs. While this support has launched a major industry, it has also had unintended consequences. Most important is that the increased demand for corn is straining the agricultural system and environment. Food prices have gone up, water supplies have been put at risk, and habitat and biodiversity have been sacrificed, all without making any progress toward reducing the emissions responsible for global warming. Moreover, with almost a third of the U.S. corn crop now going to ethanol, the continued growth of biofuels can no longer rely on making food crops into fuel. Instead, growth depends on the successful and timely commercialization of the next generation of biofuels: *cellulosic* biofuels made from grass, wood waste, or even garbage. Unfortunately, this nascent alternative is stalled, a victim of inadequate policies and the global economic downturn, which have dried up investments.

This report lays out a plan for accelerating cellulosic biofuels to commercial scale and for cleaning up *all* biofuels. The first part of the plan is to establish "The Billion Gallon Challenge," which would provide investment tax credits and loan guarantees to support the first 1 billion gallons of annual cellulosic biofuels production capacity. The second part is to replace existing biofuels tax credits, as they expire, with a Biofuels Performance Tax Credit that supports all biofuels based on their performance in replacing oil and reducing global warming emissions. With smart policy choices like these, the United States could get biofuels back on track toward reducing oil dependence and cutting global warming pollution without breaking the bank or damaging the environment.

Key findings from our report include:

- Extending current tax credits would cost almost $100 billion (2009 dollars) over the next 10 years, with more than 60 percent of this sum supporting mature ("conventional") industries such as corn ethanol and soybean biodiesel.
- Investing $4 billion in loan guarantees and investment tax credits would support investment in the 10 to 20 new commercial-scale facilities needed to reach the first billion gallons per year of cellulosic biofuels production capacity.
- Successfully commercializing cellulosic biofuels and meeting the Renewable Fuel Standard (RFS) mandates would reduce global warming emissions by 45 million metric tons a year (compared with status quo projections) by 2022.
- Replacing current biofuels tax credits with the Biofuels Performance Tax Credit would save $20 billion between 2011 and 2014 (compared with extending today's tax credits), while providing an incentive for cleaning up all biofuels.
- By rewarding improvement over today's corn ethanol, the Biofuels Performance Tax Credit would motivate corn ethanol producers to adopt the latest clean technology and qualify for a tax credit of up to $20 million a year.[1]
- Upgrading the technology at all existing corn ethanol facilities could reduce global warming emissions by more than 20 million metric tons a year.

1 A 100-million-gallon-per-year natural-gas-fired corn ethanol facility that upgrades to a biomass-fired combined-heat-and-power system could qualify for a tax credit of $20 million a year.

- The Biofuels Performance Tax Credit would also provide an incentive for advanced and cellulosic biofuels producers to exceed the minimum thresholds of the national RFS—specifically, to reduce global warming emissions an additional 30 million metric tons beyond the standard's basic requirements.

- Together, the Billion Gallon Challenge and the Biofuels Performance Tax Credit could reduce global warming emissions almost 100 million metric tons a year by 2022—equivalent to taking some 15 million of today's cars and light trucks off the road that year.

Cellulosic Biofuels Could Be an Abundant Source of Clean and Sustainable Fuel

Scientists, engineers, farmers, foresters, and entrepreneurs around the country are ready to tap the potential of cellulosic biofuels, which present us with several important opportunities:

Cellulosic biofuels could avoid the competition between food and fuel. Cellulosic biofuels can be made from grasses or trees grown on land poorly suited to agriculture; they can also be made from waste products such as wood chips or post-recycled municipal waste. Perennial grasses could add diversity to our agricultural landscape and offer economic opportunity to regions outside the Corn Belt. A shift to cellulosic biofuels could minimize the damaging consequences—including rising food prices; pollution of our air, water, and soil; and global warming emissions from land-use changes—of relying solely on conventional biofuels such as corn ethanol.

Cellulosic biofuels could cut global warming emissions by 80 percent or more when compared with the equivalent energy delivered by gasoline. According to data from the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board, cellulosic biofuels could deliver significant reductions in global warming emissions. Conventional biofuels, on the other hand, offer limited opportunities to reduce global warming emissions, and much of the biofuel produced today is actually more polluting than gasoline.

Current biofuels policy is costly and ineffective, leaving cellulosic biofuels stalled at the starting line. But with smart policy choices we can launch the cellulosic biofuels industry, clean up existing biofuels, and save billions of dollars.

For cellulosic biofuels to realize their potential, farmers must make wise use of land and water resources when growing new crops. While cellulosic biofuels can be produced in a sustainable manner, they could also compete with existing food crops, leading to many of the same problems as conventional biofuels or to new and currently unforeseen problems. Policies beyond the scope of this report will need to differentiate among the sustainable sources to avoid such problems.

Unfortunately, current production of cellulosic biofuels is falling far short of government targets because entrepreneurs have not been able to raise the capital to build commercial facilities. The RFS consumption mandate of 100 million gallons in 2010 was recently reduced to just 6.5 million gallons, based on an EPA assessment of current production capacity. Other analysis by the U.S. government indicates that cellulosic biofuels production capacity may be as much as four years behind the 2013 target of 1 billion gallons. These delays demonstrate that the current set of policies is not working and that a new approach is needed.

Policy Recommendations

The Billion Gallon Challenge: Launching the Cellulosic Biofuels Industry. The Billion Gallon Challenge, an overhaul of government support for biofuels, is designed to give the industry a chance to deliver on the potential of cellulosic biofuels. A billion gallons of annual capacity would require the construction of 10 to 20 new facilities around the country. Along the way, workers would learn new skills while engineers enhance the technology to improve efficiency and reduce cost. Operators of the biofuel facilities would develop relationships with farmers and foresters, among others, to supply millions of tons of biomass and develop the infrastructure and logistics for collecting, delivering, and storing these feedstocks. Such learning could only begin in earnest when production reaches a meaningful commercial scale at a significant number of facilities around the country. Until these initial challenges are met, more ambitious targets beyond a billion gallons are out of reach.

Bringing cellulosic biofuels out of the laboratory and pilot plant and up to commercial scale at numerous facilities would provide concrete data for evaluating different feedstocks and fuel-production technologies. Armed with such valuable information, we could pursue the best alternatives and avoid dead ends. In particular, a billion gallons per year would be sufficient to assess commercial production but not so large as to drastically alter agricultural landscapes and fuel markets. Meeting the Billion Gallon Challenge would be a necessary step on the way to truly sustainable low-carbon biofuels and well worth the investment required.

Financing the Billion Gallon Challenge. We propose a package of capital-support programs for the first billion gallons of capacity, including a 30-percent investment tax credit and loan guarantees to help pioneering investors bear the costs that come with going first. The investment tax credits would help investors with their initial capital costs—as opposed to current biofuels tax credits that are paid years later, provided they have not expired. Loan guarantees would offer crucial help to investors in getting the loans to build their facilities.

The Billion Gallon Challenge would rapidly phase out all capital support once the industry reaches a capacity of 1 billion gallons a year, thus creating an incentive for early investment. The tax credit, of 30 percent for the first billion gallons, would be reduced 6 percent for each additional billion gallons, ending entirely after the industry reaches an annual capacity of 5 billion gallons. At that level we would have some 50 to 100 facilities nationwide making cellulosic biofuels, which is about where the corn ethanol industry was in 2006. Government should then vacate the driver's seat, allowing different companies and technologies to compete on the basis of their ability to deliver clean, cost-effective cellulosic biofuels.

The Biofuels Performance Tax Credit: Cleaning Up Current and Future Biofuels. At the same time that we invest in next-generation biofuels we also need to make the most of conventional biofuels. In setting the RFS, the EPA established assessments of life-cycle global warming emissions that provide an essential yardstick for separating the best biofuels from the rest. These assessments show that there is a major opportunity to clean up corn ethanol, but current policy provides no incentive to make investments in this area. Instead, billions of dollars in tax credits are paid to oil companies and other fuel blenders merely for complying with existing law.

A performance-based tax credit, in contrast, would provide incentives for making all biofuels as clean as possible by rewarding fuel producers that surpass the standards set in the RFS. The performance-based tax credit would also save money, thus freeing up scarce resources to invest in next-generation cellulosic biofuels. In other words, focusing resources on the best biofuels while providing performance incentives for *all* biofuels would make the most of our investments and get biofuels on the right track.

We propose a Biofuels Performance Tax Credit of $10 per million Btu, based on the extent to which the biofuel replaces oil and reduces global warming emissions. The maximum tax credit works out to $1.15 per gallon of gasoline replaced. But to qualify for the whole credit a biofuel must have zero global warming emissions on a full life-cycle basis. All biofuels would be eligible, but they would get partial payment in proportion to how much their global warming emissions performance improves over today's typical corn ethanol.[2]

Typical corn ethanol (rather than gasoline) is the baseline for emissions because the Biofuels Performance Tax Credit pays for improvements beyond what is already mandated. Structured this way, the tax credit is complementary to the RFS and delivers additional benefits at a much lower cost to taxpayers than today's tax credits.

The actual tax credit a particular biofuel receives would depend on its energy content and life-cycle global warming emissions. Representative numbers are included in Table 1.

2 The baseline corn ethanol would be natural-gas-fired dry-mill corn ethanol with dry distillers grains, as described in the RFS final rule (Federal Register: 14669–15320. March 26, 2010)

Table 1. BIOFUELS PERFORMANCE TAX CREDIT

FUEL	GLOBAL WARMING EMISSIONS REDUCTION VS. TYPICAL CORN ETHANOL	ENERGY CONTENT PER GALLON VS. GASOLINE	BIOFUELS PERFORMANCE TAX CREDIT
Typical Corn Ethanol	0%	66%	N/A
Improved Corn Ethanol	27%	66%	20¢/gallon
Cellulosic Ethanol	85%	66%	65¢/gallon
Soy Biodiesel	44%	100%	50¢/gallon
Waste Grease Biodiesel	89%	100%	$1.03/gallon

The Biofuels Performance Tax Credit would provide a powerful incentive for corn ethanol producers to adopt clean technology. For example, a typical 100-million-gallon-a-year corn ethanol facility retrofitted with biomass-fired combined-heat-and-power systems would qualify for a $20 million a year tax credit—enough to pay for the retrofit within two years.

For the fledgling advanced and cellulosic biofuel industries, the Biofuels Performance Tax Credit would provide incentives to design facilities from the start with the cleanest technologies, which in surpassing the minimum thresholds of the RFS would allow companies to claim the largest possible tax credits. Overall, the Biofuels Performance Tax Credit would build on the RFS rather than duplicate it, delivering additional benefits in exchange for the tax credit's additional support.

Conclusions

Biofuels have an important role to play in launching a clean energy economy and addressing global warming, but their progress is currently stalled. We cannot afford to stay on this path, though with some sensible reforms we could redirect resources to get the cellulosic biofuels we need at affordable prices. The Billion Gallon Challenge laid out in this report would help to put the cleanest cellulosic biofuels on track, reduce oil dependence and global warming emissions, and contribute to making the United States a technology leader in cellulosic biofuels. At the same time, by adopting the Biofuels Performance Tax Credit in place of today's existing biofuels tax credits, we could save money, fund the Billion Gallon Challenge, and clean up all biofuels.

CHAPTER ONE

Introduction

Every day, the world consumes more than 83 million barrels of oil (EIA 2009b). The United States accounts for 22 percent of this oil, which is used mostly in the production of transportation fuel for our cars and trucks. This voracious consumption of oil is not only a significant source of the heat-trapping gases that lead to global climate change but has also helped to destabilize geopolitics—to which the United States, as the world's largest oil consumer, is especially vulnerable.

Biofuels hold the promise of a viable alternative to oil. They are a solution that could simultaneously provide energy security while dramatically reducing the heat-trapping emissions responsible for climate change. At the same time, these fuels could offer new economic opportunities for rural communities. Given such potential benefits, the United States is investing heavily in biofuels and has established legal requirements to steadily increase the volume consumed each year. However, as production has increased there has been a growing awareness that not all biofuels are created equal.

Currently, the vast majority of the biofuels produced in the United States are made from corn. As a result, a growing percentage of American agricultural production has shifted from food toward fuel. According to the U.S. Department of Agriculture, 30 percent of the country's corn crop is currently used to make ethanol (USDA 2009b). This change has exacerbated the existing environmental problems—such as the transformation of forests and grasslands into farmland, diminishing water resources, the pollution of rivers, the "dead zone" in the Gulf of Mexico, and threatened biodiversity and habitat—that are associated with agriculture (GAO 2009).

Further, it is becoming increasingly unclear whether corn ethanol actually reduces global warming emissions. Recent analysis suggests that as a result of changes in land use, today's corn ethanol has *higher* global warming emissions than gasoline, although there is the potential to reverse this situation in the future (CARB 2009a; EPA 2010c).

Instead of using corn or other food crops to produce biofuels, *cellulosic* biofuels can be produced with less impact on food production and the environment. Cellulosic biofuels may be made from a wide variety of nonfood sources including crop residues, forest residues, perennial grasses, woody biomass, and post-recycled waste (see the Glossary on p. 3 for definitions of these terms and details on how we use them in this report). These sources minimize or eliminate competition with food and they ease other agricultural demands. Moreover, increased production of cellulosic biofuels could reduce the harmful side effects of food-based biofuels, lower global warming emissions, and reduce oil dependence. As a result, many and diverse voices are speaking up, stressing the need to transition toward these types of biofuel (GAO 2009; Obama 2009; Rosengrant et al. 2006).

But despite the promise of cellulosic biofuels, they have yet to be produced in substantial volumes. In fact, cellulosic biofuels are falling short of government-mandated levels by three or four years, according to the U.S. Department of Energy (EIA 2009a). If the industry falls farther behind, the ability of cellulosic biofuels to make a substantial contribution to reducing climate change and enhancing energy security—especially in the critical next decade or two—will be called into question.

As a result, the United States is at an important crossroads on biofuels. If current policies continue, it is likely that more food crops will be diverted to produce fuel, the cellulosic biofuels industry will not likely satisfy the government mandates (much less reach commercial scale), and unintended environmental consequences will be increasingly severe. Unless policy changes are made soon, the country will invest billions of taxpayer dollars in the food-based biofuels industry without achieving the potential environmental and energy-security benefits that could be realized if cellulosic biofuels were commercialized.

This report proposes a new path forward to achieving the promise of biofuels, and at a lower cost to taxpayers. Instead of continuing the current and misguided biofuels policy, the country should shift its focus to a more propitious agenda—making the investments required to produce the first 1 billion gallons of cellulosic biofuels. Helping the industry reach this threshold will get the necessary technology deployed, provide markets for the relevant feedstocks, and build critical experience in commercializing these fuels. This goal can be accomplished through two policy initiatives: 1) supporting capital investment in the first billion gallons of cellulosic biofuels capacity; and 2) adopting a comprehensive Biofuels Performance Tax Credit that pays for improvements beyond the status quo and replaces existing biofuels tax credits as they expire. If these changes are made, the United States can get back on track to developing a robust biofuels industry that achieves both environmental and energy-security benefits.

In the following chapters, we lay out the challenges facing biofuels in the United States, how to overcome these challenges (and thus realize the potential of low-carbon biofuels), and reduce the costs to taxpayers. In Chapter 2 we discuss problems that are besetting the industry, the pitfalls of food-based biofuels, and the opportunities presented by a transition to cellulosic biofuels. Chapter 3 describes the current policy landscape, including its high costs and looming failure to launch cellulosic biofuels. Chapter 4 presents a better path forward; by focusing resources on a Billion Gallon Challenge, we can allow cellulosic biofuels to move from the lab to the market, thus supporting the shift to low-carbon biofuels. Chapter 5 describes a path for making the most of all biofuels, cellulosic and corn-based alike. It would replace the current wasteful tax credits with a Biofuels Performance Tax Credit, which would provide an incentive for all biofuels to be made as clean as possible. Chapter 6 compares our proposal to the status quo, highlighting the opportunity to advance low-carbon biofuels and save taxpayer money at the same time. In Chapter 7, we offer concluding thoughts on the benefits of implementing the Biofuels Performance Tax Credit and meeting the Billion Gallon Challenge. Finally, we provide appendices that cover the key technical assumptions underlying our analysis.

This report proposes a new path forward to achieving the promise of biofuels. The country should shift its focus to making the investments required to produce the first 1 billion gallons of cellulosic biofuels.

Glossary: Key Terms and How We Use Them in This Report

Biofuels: Transportation fuels, made from plants or animal-based materials, most commonly in reference to ethanol or biodiesel but that can also include synthetic diesel, biobutanol, or any other mixture of hydrocarbons that can be easily burned in an engine.

Biomass: Biomass, referring to various plant and animal-based materials that can be processed into fuel, includes food crops, wood, grass, agricultural and forest residues, and animal waste products. "Cellulosic biomass," defined below, is an important component of the overall biomass pool. Biomass can also be used directly for heat or power, in which case it replaces coal, oil, or natural gas with a low-carbon renewable alternative.

Biorefinery: A factory that makes biofuel or other products from biomass feedstocks.

Cellulosic biofuels: We use this term (more broadly than some other publications) to mean ethanol, synthetic diesel, or any other fuel made from cellulosic biomass by any of a variety of techniques, including but not limited to:

- **Biochemical processing:** Enzymes or microbes are used to convert the cellulose and hemicellulose in biomass into sugars, which are then fermented into ethanol or some other molecule.
- **Gasification:** Biomass is heated in the presence of a controlled amount of oxygen to make carbon monoxide and hydrogen, called syngas. After purification, it reacts with catalysts to make ethanol, synthetic diesel, or other fuels.
- **Pyrolysis:** Biomass is heated in the absence of oxygen to make a bio-oil that can be further refined to make a transportation fuel that substitutes for diesel.

Cellulosic biomass: Materials composed primarily of cellulose, hemicellulose, and lignin—the structural components of plants. These materials come from nonfood plant matter, especially nondigestible fibrous plants (such as wood or grass) or parts of plants (e.g., corn stalks). Key examples include:

- **Agricultural residues:** Leftover parts of plants grown for another purpose. They include corn cobs and corn stover (stalks and leaves that remain after the corn has been harvested), straw leftover, and residues from other crops such as wheat or rice.
- **Forest residues:** These materials include tree tops and branches that are not large enough to be sold for lumber, wood chips or sawdust left after wood has been cut, and other wood products.
- **Perenial grasses:** These materials, which include switchgrass and miscanthus, can be harvested for several years without being replanted.
- **Waste biomass:** Biomass left behind after other uses. It includes, for example, the food waste, yard clippings, and soiled paper in household garbage after recyclables have been separated out. The term waste biomass can also apply to agricultural or forest residues.
- **Woody biomass:** Trees, wood chips, forest residues, waste wood from construction, and demolition debris.
- **Energy crops:** Grasses and trees specifically bred for efficient production of cellulosic biomass.

Feedstock: The starting material from which biofuels are made. Thus corn ethanol is made from a corn feedstock, soybean biodiesel is made from soybean oil, and switchgrass ethanol is made from switchgrass.

Global warming emissions: Carbon dioxide (CO_2) and other gases responsible for climate change. These other heat-trapping gases are characterized in terms of their CO_2-equivalent (CO_2e) impact on the climate.

CHAPTER TWO

The Growing Challenge Facing U.S. Biofuels

Since the 1970s, the United States has supported the growth of a domestic biofuels industry through a variety of subsidies and other supportive policies. As a result, in 2008 the country produced more than 9 billion gallons of ethanol and almost 700 million gallons of biodiesel, making it the world's largest producer of biofuels (EIA 2009c; EIA 2009d). The vast majority of this fuel was corn-based ethanol. Today there are 189 ethanol refineries across the country with a total capacity of 13 billion gallons per year (RFA 2009).

In the production of corn ethanol, the starch from the corn kernel is fermented and then distilled into ethanol. The remainder of the corn left behind, called distillers grains, is typically used as animal feed. Beyond corn, most other U.S. biofuels are made from other food crops, such as soybean oil; very little production comes from nonfood-based crops. The same is true for the world's second largest ethanol producer, Brazil, where ethanol is made from sugar. In 2008, Brazil produced almost 7 billion gallons of ethanol, largely from sugarcane (EIA 2009c).

Corn ethanol production in the United States has grown at an astonishing rate over the past decade. Current production is more than triple that of 2003, and corn ethanol blended into gasoline (EIA 2009a; RFA 2009) accounted for about 5 percent of that composite fuel's energy in 2008. While corn yields have improved, the use of corn for fuel has increased much faster (USDA 2009b). In order to produce the current volume of corn ethanol, a dramatic share of the U.S. corn crop has shifted toward fuel production and away from its previous use as food and animal feed. Currently, almost a third of the country's corn crop is used for ethanol production (USDA 2009a). And because corn ethanol production is expected to grow in the next decade, there will be increasing pressure on agriculture to meet the demand both for food and fuel.

While U.S. policy has successfully established a mature corn ethanol industry, it has not been as successful in bringing cellulosic biofuels to market. According to estimates by the U.S. Department of Energy's Energy Information Administration (EIA), not even 10 million gallons of cellulosic ethanol will be produced in 2010, compared to more than 10 billion gallons of corn ethanol (EIA 2009e). The country needs cellulosic biofuels to succeed, however, in order to achieve its energy-security and environmental goals.

The Pitfalls of Food-Based Biofuels

The global agricultural system is already straining to meet the food demands of a growing and increasingly affluent population. Producing even more corn and soybeans for use as fuel could aggravate problems already associated with our current agricultural system: rising food prices; pollution of the air, water, and soil; depletion of water resources, soil carbon and nutrients; and increasing global warming emissions due to land-use changes.

Expanding the production of corn to accommodate demand for biofuels would enlarge agriculture's environmental impact; corn is a resource-intensive crop that requires relatively high levels of fertilizer and pesticide application. Such expansion would aggravate existing problems with nutrient and contaminant runoff into surface and ground waters. Also, the high corn prices caused by increased corn ethanol production could contribute to reduced enrollments of land in conservation programs, thereby increasing erosion and reducing habitat for wildlife. Finally, expansion of corn may increase use of irrigation in regions of the country that lack sufficient rainfall, which could deplete important aquifers (GAO 2009).

Further, it is becoming unclear whether food-based fuels significantly reduce global warming emissions. Recent analysis suggests that when emissions from land-use changes are taken into account, corn ethanol may have a global warming emissions profile similar to that of gasoline (EPA 2010c; CARB 2009).

In recent years, the dramatic growth in demand for food-based biofuels has put new pressure on global commodities markets. Because global demand both for food and animal feed has increased as well, food and fuel are competing for a limited supply of food crops. In other words, producing biofuels from food crops—corn, soybeans, and sugarcane, for example—puts food and fuel demands in competition with each other for the same resource (FAO 2008).

Using food to make fuel means that global food production has a bigger footprint than it would otherwise have, with increased acreage of agricultural land worldwide. Expansion is not restricted to the place where the biofuels are produced, moreover, because food crops such as corn and soybeans are traded on global markets. And because agricultural demand is already increasing rapidly to accommodate a growing population that demands more meat as it becomes more affluent, diverting food crops for use as fuel only makes the satisfaction of this demand problematic. Thus, adding fuel production to food production increases the scale of global agriculture, both by expansion and by intensification (FAO 2008).

Clearing New Land Undermines the Climate Benefits of Food-Based Fuels

The expansion of global agriculture to accommodate the growing demand for food-based biofuels dramatically undermines their environmental and climate benefits. While corn ethanol and cellulosic ethanol displace the same amount of petroleum, they do not achieve the same level of heat-trapping emissions reductions when the full life cycle of the fuel, and especially the emissions from changes in land use, are considered (for more information on life-cycle accounting for biofuels, see Appendix A).

Current research indicates that one of the primary impacts of the increased demand for food-based fuels is the expansion of agricultural land—at the expense of sensitive ecosystems that store a great deal of carbon in plants and soils. Since 1980, the majority of new cropland expansion has occurred in the tropics, and looking to the future, tropical areas hold two-thirds of the suitable land on the planet not currently in use for agriculture—the vast majority of which is currently forested (Gibbs et al. 2009; FAO 2008). Once the low cost of land and labor is taken into account, growing food and fuel demands make expansion into these high-carbon and biodiverse forests very likely (Gibbs et al. 2009). Such deforestation will dramatically accelerate global climate change.

In addition to the global warming emissions from land-use change, the production of corn and other food crops results in additional heat-trapping emissions and other environmental impacts. Food-based biofuels generate significant heat-trapping emissions when the biomass feedstocks are grown (through the production and use of chemical fertilizers and pesticides) and when energy is used to convert the feedstocks into fuel. For instance, agriculture was responsible for two-thirds of the nitrous oxide (N_2O) emissions in the United States in 2007 and 6 percent of total U.S. global warming emissions (EPA 2009a).

Harvesting the Potential of Cellulosic Biofuels

Cellulose is the most abundant chemical component of biomass and the basic structural component of plant-cell walls, which give plants the strength to stand erect. Cellulose is found in all plants, including trees, grasses, and the leftover parts of food crops such as corncobs and orange peels. Using cellulose to make fuel provides a valuable new use for crops, wastes, and residues that previously were underutilized or discarded altogether. The diversity of sources and the ability to use the leftovers from other activities means that cellulosic biomass is relatively inexpensive and plentiful, which makes it an ideal biofuel feedstock.

Thus there is a growing consensus that in order to achieve energy security and the necessary reductions in global warming

Cellulosic Biomass Production Requires Sound Policy to Avoid New Problems

While cellulosic biomass is potentially cheap and plentiful, the sustainability of cellulosic feedstocks depends on where and how they are produced. Appropriate changes to policy in other areas are required to avoid causing new problems. For example, corn stover (the leaves and stalks left behind after corn has been harvested) is an agricultural residue that has been identified as one of the largest potential sources of biomass available for cellulosic biofuel production (NAS 2009; Perlack 2005). However, just because corn stover is left on the fields does not mean it has no value—in typical current practice the stover protects soil from erosion and adds organic matter to the soil. Using agricultural residues for biofuel in a sustainable manner will require limiting the extent of removal along with additional changes in agricultural practice, including the use of cover crops (Marshall 2009; NAS 2009).

Another large potential source of cellulosic feedstocks are the so-called dedicated energy crops, including perennial grasses (such as switchgrass and miscanthus) and fast-growing trees. Energy crops can be grown on land that is not well suited to corn and soybean production, which could minimize the competition between fuel production and food. But just because energy crops *can* be grown on marginal land does not mean they *will* be; these crops would likely have the highest yields on land that are also most productive for existing food crops (Marshall 2010). As cellulosic biofuels production grows to a scale of billions of gallons a year, demand for feedstocks like energy crops will start to compete with food and feed production for scarce agricultural resources (i.e., fertile land, water, and nutrients). Policies that appropriately balance the competition between bioenergy crops and existing agricultural products for such resources must be developed in parallel with increasing cellulosic biofuel production.

Some researchers, including a recent National Academy of Sciences panel, have identified Conservation Reserve Program (CRP) land as potentially convertible to biomass production without significant impact on wildlife or on other environmental benefits provided by the current CRP program (NAS 2009). While it is possible to use biomass from CRP lands under some limited circumstances, the management of land for conservation objectives is quite different from management to maximize biomass production. Thus the use of this land would need to be sensitive to competing nonmarket uses for environmental purposes, such as wildlife habitat.

These examples show that as the cellulosic biofuel industry grows, the impact of producing biomass on a vastly enlarged scale must be carefully understood and any adverse effects minimized. While the impacts of the first billion gallons would likely be limited, they would provide important data for studying which problems are most important and how they could be mitigated. In that way, the industry could subsequently grow by balancing competing demands and keeping cellulosic biofuels on a sustainable path.

emissions from transportation fuels, growth in biofuels should come from cellulosic biofuels. A recent National Academy of Sciences report found that the potential for expansion of corn ethanol is limited and environmentally problematic; it regarded "corn-grain ethanol as a transition to cellulosic biofuels," which have the potential to expand as a fuel source for years to come. It further noted that, "Cellulosic biomass—obtained from dedicated fuel crops, agricultural and forestry residues, and municipal solid wastes—could potentially be sustainably produced at about 400 million dry tons per year with today's technology and agricultural practices and with minimal adverse impacts on U.S. food and fiber production or on the environment." This much cellulosic biomass, according to the Academy, would be enough to produce 32 billion gallons of cellulosic ethanol, or double the government mandate for cellulosic ethanol in 2022 (NAS 2009). We provide more information on these mandates in Chapter 3.

Because cellulosic biofuels reduce competition with food crops, they could take pressure off food markets while delivering greater reductions in global warming emissions and providing equivalent oil savings. For instance, the International Food Policy Research Institute explored the effect on food prices of two biofuels production scenarios: one in which biofuels continued to be produced primarily from food crops, and one that had cellulosic biofuels beginning large-scale production in 2015. The institute reported that the successful and timely commercialization of cellulosic biofuels would minimize increases in global food prices. In the scenario with food-based biofuels, the corn price was projected to rise 41 percent by 2020, while with commercialization of cellulosic biofuels the price would rise an estimated 29 percent (Rosengrant et al. 2006).

In addition to taking pressure off food prices, cellulosic biofuels could deliver important environmental benefits, such as reducing heat-trapping emissions from transportation (compared with either gasoline or food-based biofuels). Broadly speaking, there are two reasons why cellulosic biofuels can achieve greater global warming emissions reductions than food-based fuels: (1) they have lower emissions from land-use changes, and (2) the direct emissions from growing and producing the fuel are lower as well.

Reducing Global Warming Emissions from Land Use. In the United States, cellulosic biofuels could be made from a diverse combination of energy crops, organic wastes, and residues.

Because cellulosic biofuels reduce competition with food crops, they could take pressure off food markets while delivering greater reductions in global warming emissions and providing equivalent oil savings.

Using marginal land, farmers could grow perennial grasses, such as switchgrass, as well as fast-growing trees. By using land that was not currently farmed or forested, these feedstocks could minimize competition with food while simultaneously building up the carbon stored in the soil. In addition, cellulosic fuels could be made from agricultural residues, such as corncobs or corn stover, adding a fuel source without displacing the existing land use. Sustainably managed forests could also contribute to cellulosic fuels through wood and wood waste. Finally, cellulosic feedstocks would be available in waste products ranging from construction and demolition debris to the nonrecyclable part of ordinary household garbage (Tilman et al. 2009).

While these examples highlight the potential for producing cellulosic feedstocks so as to minimize competition with existing land uses, some competition would be inevitable, especially as demand for biomass reaches hundreds of millions of tons (or enough to produce more than 10 billion gallons of biofuel). The most productive land for corn and soybeans has soil, climate conditions, and rainfall that also make it highly productive for cellulosic feedstocks. So if demand and prices for biomass were sufficient, cellulosic crops could compete for this land, leading to the same indirect changes in land use currently associated with corn and soybeans.[3] Whether these changes were on balance beneficial or damaging would depend on how the technology, the markets, and the policy landscape develop.

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3 The EPA estimated that in 2022 the emissions from agriculture and land use for cellulosic ethanol made from switchgrass would be 1.5 Kg CO_2e/gallon versus 3.4 Kg CO_2e/gallon for corn ethanol. Because of the very low emissions from the rest of the cellulosic ethanol production process and credits for electricity production, the total life-cycle emissions of cellulosic ethanol (including land-use-change emissions) were determined to be 110 percent lower than gasoline, which is to say *better* than carbon-neutral. The EPA also analyzed feedstocks from agricultural residues, where no land-use-change emissions would be expected.

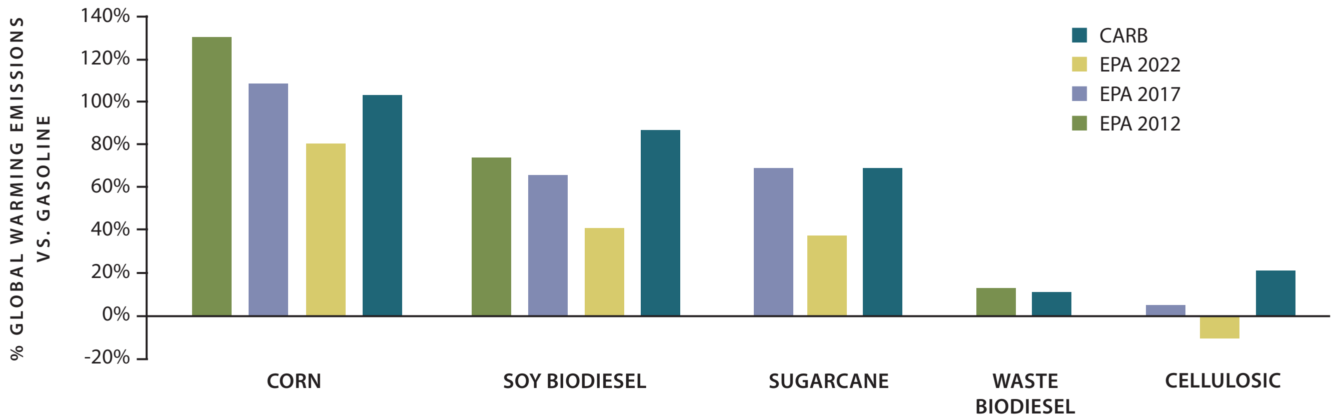
Reducing Global Warming Emissions from Fuel Production. Cellulosic biofuels technologies are being developed so as to minimize the use of fossil-fuel-based fertilizers in the growth of the crops and also to reduce or eliminate the need for fossil fuel energy in the conversion of the cellulosic biomass to fuel. Making good choices in terms of which crop to grow and where to grow it can also reduce fertilizer use. For example, scientists have recently found that diverse native grasses could yield low-carbon biofuels while simultaneously restoring degraded agricultural land and providing other essential ecosystem services such as soil fertility, clean water, and wildlife habitat (Tilman, Hill, and Lehman 2006). These grasses can grow with much lower inputs of pesticides and fertilizer than most food crops, thus reducing water pollution and global warming emissions; and they can grow under conditions not suitable for food crops, thereby avoiding the displacement of food production.

In addition to utilizing low-carbon feedstocks, cellulosic biofuels can be produced with conversion technologies that have relatively low energy requirements—and, consequently, lower global warming emissions. For example, when the cellulose and other useful components are removed from the cellulosic biomass to make biofuel, there is a leftover chemical component called lignin. This material can be burned to produce heat and power to run the biofuel facility, thus eliminating the need for natural gas or coal to produce heat and even generating enough surplus power to export electricity to the grid. This efficient use of all of the biomass reduces the life-cycle emissions of the resulting fuel.

To realize the opportunities presented by these better crops and production technologies, cellulosic biofuels must be moved out of the laboratory and into the commercial arena. Technological advances highlighted in the case studies in this report show examples of how such transitions are occurring with woody biomass, prairie grasses, and even ordinary garbage. New "superbugs" are being developed that could efficiently convert grasses, wood, or other types of cellulosic biomass into ethanol. Gasification technology is also being developed to convert cellulosic biomass into fuels ranging from ethanol to synthetic diesel. Finally, pyrolysis—yet another production technique for converting cellulosic biomass into a

Figure 1. LIFE-CYCLE ANALYSIS RESULTS

(Biofuels Life-Cycle Global Warming Emissions per Unit of Energy Compared with Gasoline)



Sources: CARB 2010, EPA 2010c, CARB 2009.

type of oil, which could then be refined into a transportation fuel—is being developed as well. Regardless of the technology used to convert cellulosic biomass into fuel, the ultimate goal is the production of cost-effective low-carbon fuels from plentiful, diverse, inexpensive, and sustainable cellulosic biomass.

Comparing the Life-Cycle Global Warming Emissions of Food-Based and Cellulosic Biofuels

Recent analyses by the U.S. EPA and the California Air Resources Board (CARB) demonstrates how the benefits of cellulosic biofuels translate into actual emissions reductions. As shown in Figure 1, cellulosic biofuels have substantially lower life-cycle global warming emissions than either petroleum or food-based biofuels. Life-cycle analysis provides a comprehensive comparison between different types of fuels because it accounts for all the sources of heat-trapping emissions associated with production, distribution, and fuel consumption (for more information on life-cycle analysis, see Appendix A).

This figure demonstrates the clear differences between food-based biofuels and cellulosic biofuels. It shows in particular that conventional biofuels currently offer limited opportunities to reduce heat-trapping emissions. For instance, both the EPA and CARB found that today's corn ethanol typically has life-cycle global warming emissions that are higher than those of gasoline. The EPA did find, however, that by 2022 corn ethanol should be able to reduce emissions by 17 percent and, with advanced technologies likely to be in use then, could reduce emissions by more than 20 percent.

Soybeans use lower levels of inputs than corn, and soybean oil can be converted to biodiesel without as much additional energy, but soybeans also produce a much smaller quantity of biofuel per acre than does corn. For this reason, soybean biodiesel has a large impact on agricultural land use, and when a life-cycle analysis is done, the fuel's overall emissions today are 12 to 25 percent lower than either a gasoline or diesel baseline. Of all the food-based fuels, sugarcane ethanol is the most efficient. This is because it has a high yield of fuel per acre and is relatively easy to convert to fuel. Nevertheless, because of its impact on land use, both the EPA and CARB found that sugarcane ethanol only delivers about 25 percent lower global warming emissions than gasoline.[4] Expanding production of food-based fuels dramatically will thus take a heavy toll on the environment, and particularly on tropical forests, as agriculture expands to make up the lost food crops.

In contrast, the EPA and CARB analyses show that cellulosic ethanol could achieve substantial global warming reductions compared with gasoline. The EPA's analyses suggest that some cellulosic biofuels actually have the potential to be better than carbon-neutral, including the benefit of electricity that is produced. CARB's analysis finds that cellulosic biofuels have emissions 80 to 97 percent lower than gasoline.[5]

4 The EPA analyzed the emissions of biofuels at different time frames, including 2012, 2017, and 2022. In this report, we focus on the 2012 analysis, or on 2017 if no 2012 analysis is available, given that the more near-term the study the more indicative it is of the performance of biofuels today. The EPA used the 2022 analysis as the basis for its determinations of compliance with RFS requirements. The 2022 estimates are lower because of projected improvements in crop yields and other uncertain factors.

5 Biodiesel made from waste oils can also produce very low global warming emissions. For example, the EPA and CARB both found that, on a life-cycle basis, waste grease has 80 percent lower global warming emissions than petroleum diesel. However, because the United States does not produce sufficient volumes of waste grease to displace large amounts of petroleum diesel, the greatest potential for growth in biomass-based fuels is in cellulosic biofuels.

CHAPTER THREE

Current Policy: A Roadblock to Low-Carbon Biofuels

The United States has promoted the use of biofuels since the 1970s. Historically, the associated policies have covered a range of activities, such as production tax credits, mandates that a specific volume of ethanol be sold nationally, subsidies for gas stations to install ethanol-fueling infrastructure, and even incentives for automakers to produce vehicles capable of operating on high-level ethanol blends. While some of the most recent policies differentiated between types of biofuels, the vast majority of the support was focused on expanding the production and use of corn ethanol.

To a certain extent, this effort has been successful in launching the corn ethanol industry in the United States. While corn ethanol still relies on government policies to be competitive in the marketplace, the industry itself has reached commercial scale, with the EPA's analysis suggesting that the industry will soon have the capacity to produce almost 15 billion gallons of corn ethanol a year (EPA 2010b). The next challenge facing U.S. biofuels policy is whether it can now successfully launch cellulosic biofuels and bring them to commercial scale.

This chapter begins by providing an overview of the current policy landscape, focusing particular attention on the national Renewable Fuel Standard (RFS) and the Volumetric Ethanol Excise Tax Credit (VEETC). Once this context is established, it then addresses whether current U.S. policy is sufficient to jump-start the next generation of low-carbon cellulosic biofuels and produce them in sufficient volume.

The National Renewable Fuel Standard

The RFS was enacted as part of the Energy Policy Act of 2005 (EPAct 2005) and is currently the single most important source of government support for biofuels. The RFS requires that a specific annual volume of biofuel be blended into motor vehicle fuels sold in the United States. This mandate increases each year, helping to expand production and market share for biofuels. Initially, the RFS set a mandate of 7.5 billion gallons of ethanol by 2012, which was expected to come primarily from corn ethanol, as the other low-cost biofuel, sugarcane ethanol, was largely excluded by a substantial tariff. In addition, the program included specific requirements for cellulosic ethanol, starting at 250 million gallons per year in 2012 and rising to 1 billion gallons in 2015.

Two years later, Congress revised and expanded the RFS program as part of the Energy Independence and Security Act of 2007 (EISA)—an effort to increase the program's energy security and climate benefits. The revised program upped the ante by increasing the short-term and long-term volume requirements both for food-based and cellulosic fuels, by limiting eligible feedstocks, and by adding requirements for reductions in life-cycle global warming emissions (see the box on p. 14).

Renewable Fuel Standard (RFS)

The RFS establishes a mandate that fuel providers use increasing volumes of four categories of biofuels. These categories each have different eligibility requirements and volume mandates, all of which change over time. The most important rule is that each biofuel meet a minimum threshold for global warming emissions reductions (on a life-cycle basis) compared with a petroleum baseline (Table 2). Also, all fuels must be made from renewable biomass, which is defined so as to exclude unsustainable feedstocks.

The volume mandates for the different categories are shown in Figure 2. In 2022 the program requires a total of 36 billion gallons of renewable fuel, including 16 billion of cellulosic fuel. Achieving this level of production would supply 18 percent of the fuel projected to be used for light duty vehicles in 2022 (EIA 2009a).

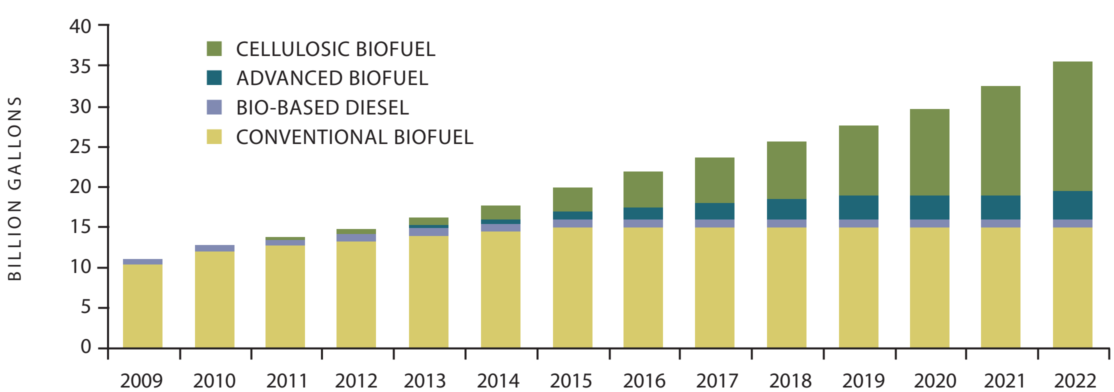
The RFS also includes a big loophole, under which existing biofuel facilities and facilities under construction are exempt or "grandfathered" from the global warming emissions requirements. The EPA estimates that essentially the entire 15-billion-gallon mandate for conventional biofuels (more than 40 percent of the total) can be met by fuel from grandfathered facilities (EPA 2010a), thus rendering the emissions requirements for corn ethanol largely symbolic.

Table 2. RFS FUEL CATEGORIES

BIOFUEL CATEGORY	GLOBAL WARMING EMISSIONS REDUCTION VS. GASOLINE	ADDITIONAL REQUIREMENTS OR EXEMPTIONS
Conventional Biofuels	20%	Fuel from grandfathered facilities is exempt from global warming emissions requirement
Advanced Biofuels	50%	Excludes corn ethanol
Biomass-Based Diesel	50%	Includes biodiesel and synthetic diesel made from renewable biomass
Cellulosic Biofuel	60%	Limited to cellulosic biomass feedstocks

Figure 2. RENEWABLE FUEL STANDARD MANDATES

(Volumetric Mandates from 2009 to 2022)



The RFS volume mandates for corn ethanol scaled up rapidly before 2010, but after this year most of the growth in the mandates is to come from advanced biofuels, largely from cellulosic biofuels. These requirements reflect the intention of Congress to transition from today's biofuel pool, which is dominated by corn ethanol, to more sustainable and lower-carbon biofuels—and especially to cellulosic biofuels. Some of the key milestones marking this transition are summarized in Table 3.

Table 3. KEY MILESTONES ON THE ROAD TO CELLULOSIC BIOFUELS

2010	First mandate for cellulosic biofuels: 100 million gallons a year.
2013	1-billion-gallon mandate for cellulosic biofuels. From this point on, cellulosic biofuels are to provide the majority of the growth in biofuel volume mandates.
2015	3-billion-gallon mandate for cellulosic biofuels, with a cap on corn ethanol of 15 billion gallons a year.
2017	5.5-billion-gallon mandate for cellulosic biofuels.
2022	16-billion-gallon cellulosic biofuel mandate is the largest category of biofuel mandates.

Although the RFS requires fuel providers to buy biofuels, this only happens if the fuels are available; otherwise the EPA must adjust the mandates to more practical volumes. In finalizing the RFS rules in the beginning of 2010, the EPA did exactly that, reducing the 2010 mandate for cellulosic biofuels from 100 million gallons to 6.5 million gallons, based on projected production capacity. This initial waiver is clear evidence that the RFS alone is not enough to ensure the success of cellulosic biofuels.

Cost of the RFS. Estimating the cost or economic value of the RFS mandates is challenging, and estimates depend strongly on projected future prices for fuel, feedstocks, and conversion costs. Nevertheless, the Iowa State University's Center for Agriculture and Rural Development calculated the hypothetical tax credit that would be needed to reach the same production level as the RFS mandate. It found that tax credit to be $0.22 to $0.78 per gallon for corn ethanol, $1.97 to $2.90 for biodiesel, and $1.55 to $2.11 for cellulosic ethanol (Baker, Hayes, and Babcock 2008).

The cost of complying with the mandates is borne by the fuel suppliers that are responsible for compliance. These costs are generally passed along to their customers. However, the situation is a little more complicated because tax credits (discussed below), as well as subsidies for the production of corn and other biofuel feedstocks, reduce the cost of biofuels to the fuel suppliers. The bottom line is that the tax credits shift the cost of the RFS mandates away from fuel users and onto current or future taxpayers, who pay without regard to their own fuel usage.

Biofuels Tax Credits

Beyond the Renewable Fuel Standard, tax credits are another expensive component of the biofuels policy landscape. The primary tax credit at the federal level is the VEETC, which gives fuel providers a tax credit of $0.45/gallon to blend ethanol into their fuels. Biodiesel received a tax credit of $1/gallon[6] and cellulosic ethanol receives $1.01/gallon (JCT 2009). The tax credits are paid to the party that blends the ethanol into fossil fuel, usually the gasoline distributor.

Cost of Biofuels Tax Credits. The cost of the tax credits for corn ethanol has risen from less than $1 billion in 1999 to $3 billion in 2007. To put this growth in perspective, corn ethanol received three out of every four dollars of tax credits for renewable energy in 2007 (EIA 2009a). With RFS mandates rising, the price tag for the VEETC will exceed $5 billion a year (in real 2009 dollars) if the current policy is extended.

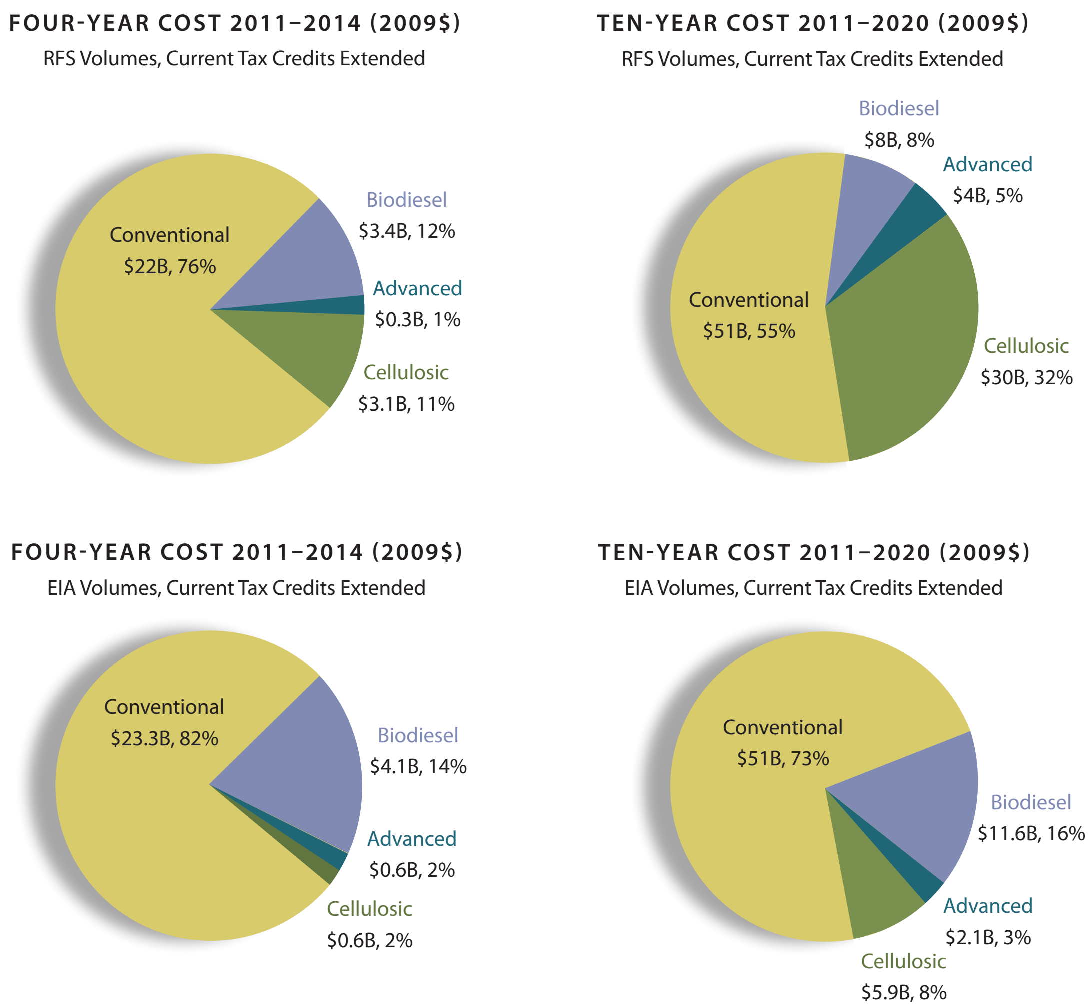
If the RFS reaches its full 36 billion gallon target in 2022, the price tag for extending all biofuel tax credits would reach $15 billion per year. This is the same amount that the federal gas tax of 18.4¢/gallon would bring in from all the projected gasoline use in 2022 (EIA 2009a). The cumulative total between 2010 and 2022 would be almost $130 billion, or more than twice the $55 billion in bailout funds that General Motors and Chrysler received from the Troubled Asset Relief Program (CBO 2009).

6 The biodiesel tax credit expired at the end of 2009. However, as it is expected to be renewed, we have included it along with the VEETC in our calculations of the cost of existing tax credits.

In principle, the existing biofuels tax credits will expire, first for biodiesel in 2009, then corn ethanol in 2010, and finally the cellulosic credit in 2012. However, the political support for the continuation of these credits has meant that they have been repeatedly renewed. With this much money potentially at stake, American taxpayers are entitled to know what they getting for their money.

While a large portion of the political rhetoric has focused on the need to develop cellulosic biofuels, the money continues to flow overwhelmingly to corn ethanol. As shown in Figure 3, if current tax credits are extended and biofuels production follows the RFS mandates, the vast majority of the money will flow to food-based fuels that are already fully commercialized.

Figure 3. COST AND DISTRIBUTION OF BIOFUELS TAX CREDITS



The cost (in billions of 2009 dollars) and the distribution of tax credits, assuming that current tax credits are extended and that production levels exactly match the RFS mandates (top) or follow the lower EIA 2010 projections (bottom). The left side shows the total cost for the four-year period 2011–2014, and the right side shows the 10-year period 2011–2020.

Over the four-year time span of 2011 through 2014—a critical period for the commercialization of cellulosic ethanol—more than three-quarters of the tax credits would flow to corn ethanol, and biodiesel would get 12 percent. Even over the 10-year period from 2010 to 2019, 60 percent of the tax breaks would go to well-established food-based fuels. Because cellulosic ethanol volumes are already trailing the RFS mandate, the real situation could be even more lopsided. If the production schedule followed the EIA 2010 forecast, the portion of the tax expenditures devoted to cellulosic biofuel would be just 2 percent over the next four years and 8 percent over the next 10 years. Allocation of scarce taxpayer dollars to the well-established technologies would be especially wasteful because the facilities needed to satisfy the RFS mandates for corn ethanol and biodiesel in 2022 were already built or under construction by April 2009 (EPA 2010b).

Perhaps the most glaring problem with the existing tax credits is that they are made redundant by the large biofuels mandates in the RFS. The current biofuels tax credits pay oil companies and other fuel suppliers to use biofuels they are already legally obligated to purchase by the RFS. In essence, we are handing out billions of dollars of tax credits to thank oil companies and other fuel suppliers for following the law. Several analyses have found that the VEETC provides little or no economic benefit to either corn farmers or biofuels producers (Babcock 2010; GAO 2009).

Another dramatic example of the poorly targeted nature of the current biofuels tax credits is the revelation that the paper industry may receive as much as $6.6 billion by adding diesel fuel to "black liquor," which it has been using to run its facilities for decades, and claiming it as biodiesel eligible for a generous tax credit (Ivry and Donville 2009). This inadvertent and unproductive loophole was closed when the biodiesel tax credit expired at the end of 2009, but not before a similar loophole was found in the cellulosic tax credit (IRS 2009). The latter loophole will also likely be closed, but the repeated problems with these tax credits points to the need for an overhaul that ensures taxpayers get their money's worth.

A final problem with the current tax credits is that they are extended for a few years at a time, which undermines their ability to stimulate investment. While the current $1.01/gallon tax credit for cellulosic biofuels seems generous, it is scheduled to expire before a facility starting construction today could

commence production; it would therefore see no benefit from the tax credit. While past practice suggests that the tax credit is likely to be extended, this expectation is unlikely to be persuasive to a bank considering a loan. Uncertainly about future policy support makes it hard for entrepreneurs to raise money to build new facilities.

Other Biofuels Support

While the RFS and tax credits are the largest sources of federal support, a 2008 report of the Congressional Research Service found 22 additional federal programs administered by five separate agencies and departments (see the box on p. 18).

For example, some of the larger DOE projects included grants totaling $272 million to four commercial-scale biorefineries and more than $200 million to eight smaller "demonstration-scale" projects (at about 10 percent of full production scale). The DOE also funds biofuels research and development through its Office of Science, which provided more than $100 million for basic biofuels research at three Bioenergy Research Centers at Oak Ridge National Laboratory, the

Federal Programs that Provide Biofuels Incentives

Environmental Protection Agency (EPA)

- Renewable Fuel Standard

Internal Revenue Service (IRS)

- Volumetric Ethanol Excise Tax Credit
- Small Ethanol Producer Credit
- Biodiesel Tax Credit
- Small Agri-Biodiesel Producer Credit
- Renewable Diesel Tax Credit
- Credit for Production of Cellulosic Biofuel
- Special Depreciation Allowance for Cellulosic Ethanol Plant Property

Department of Agriculture (USDA)

- Bioenergy Program
- Renewable Energy Systems and Energy Efficiency Improvements
- Value-Added Producer Grants Program
- Biorefinery Development Grants
- Business and Industry Guaranteed Loans
- Rural Business Enterprise Grants
- Biorefinery Assistance
- Repowering Assistance
- Bioenergy Program for Advanced Biofuels
- Feedstock Flexibility Program for Producers of Biofuels
- Biomass Crop Assistance Program

Department of Energy (DOE)

- Biomass Research and Development Initiative
- Biorefinery Project Grants
- Loan Guarantees for Ethanol and Commercial Byproducts from Cellulose, Municipal Solid Waste, and Sugar Cane
- DOE Loan Guarantee Program
- Cellulosic Biofuels Production Incentive

U.S. Customs and Border Protection

- Import Duty for Fuel Ethanol

Source: CRS 2008.

University of Wisconsin, and Lawrence Berkeley National Laboratory. The DOE, as well as the USDA, also has loan-guarantee programs. And the DOE is authorized to implement incentives to support the 1-billion-gallon milestone by 2015.

One big problem with these diverse programs is that they are not well coordinated, especially given that they often have different objectives and criteria. For example, the definition of cellulosic ethanol in the USDA loan-guarantee program (under the Farm Bill of 2008) is different from the DOE definition (under the 2005 Energy Act), and neither of these definitions match that of the RFS. Some of the programs overlap, creating a confusing and ill-directed effort toward implementing a particular set of policies. Clearly some consolidation, rationalization, and reform are in order to ensure success in energy security and climate change goals.

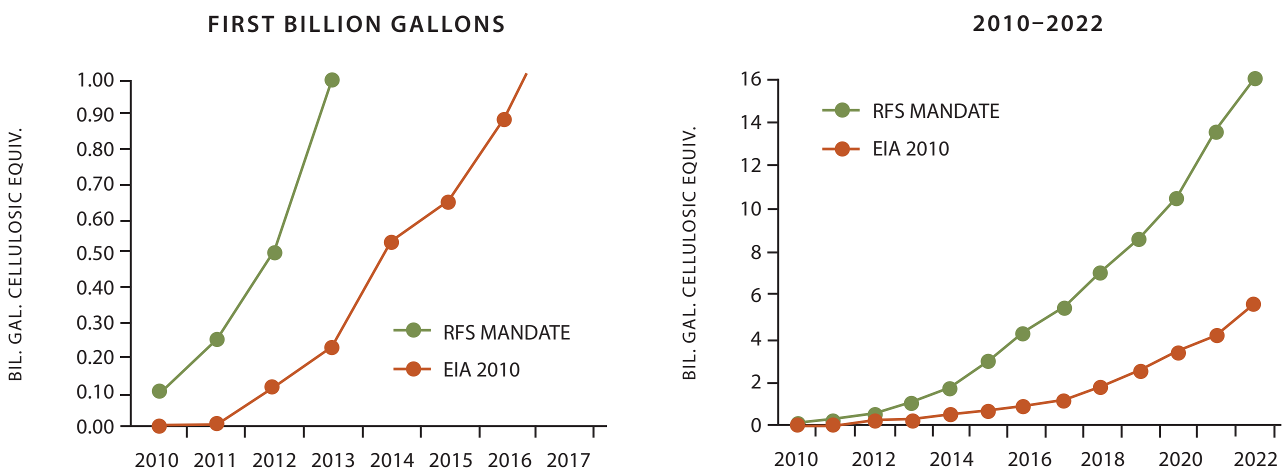
Because different agencies have different kinds of expertise and relationships, a diverse set of programs is not in itself a flaw. But many different pieces have to fall into place to make cellulosic biofuels a reality. While the RFS makes clear that the best biofuels must displace oil, reduce heat-trapping emissions, and enable a transition from food-based biofuels, these criteria and the means to measure them are not always incorporated into the federal programs in a consistent manner.

Current Policies Are Not Launching Cellulosic Biofuels

According to the most recent analysis from the EIA, the United States will produce less than 3 million gallons of cellulosic biofuel in 2010 and about 5 million in 2011, reaching the 100-million-gallon mark only in 2012 (EIA 2009e). This is far lower than the schedule mandated by the RFS, as shown in Figure 4. The RFS mandates that a billion-gallon level be reached in 2013, while the EIA projection is that under current policies this will not happen until 2017.[7] EIA economic models suggest that after the billion-gallon milestone is reached, market forces and RFS mandates will gain traction and cellulosic volumes will start to grow, although they will lag further behind mandated levels. This would mean a shortfall of more than 10 billion gallons in 2022, which implies that

7 Using energy-adjusted ethanol-equivalent gallons (EIA 2009g).

Figure 4. RFS MANDATES FOR CELLULOSIC BIOFUELS VS. PROJECTED PRODUCTION



Comparison of RFS mandates for cellulosic biofuels with projected production levels from EIA 2010g. A delay of three to four years in reaching the first billion-gallon milestone leads to a shortfall of more than 10 billion gallons in 2022.

corn ethanol would likely continue to dominate the biofuels marketplace for decades to come.

This failure to meet the first cellulosic biofuels milestone of the RFS in 2010 is due not just to the technical and logistical challenges of starting a new industry. The cellulosic biofuels business also suffered from terrible timing: the recent financial crisis and turbulence in oil prices scared off potential investors just when investment was most needed. Many of the pilot plants slated for construction with DOE support in the 2008 to 2009 time frame were thus delayed or derailed (Brasher 2009; Reuters 2009).

Delayed scale-up is hardly the worst outcome. Rather, this failure of cellulosic biofuels to live up to the lofty goals articulated by the RFS could undermine the enthusiasm of lawmakers and the public. Without adequate support through the first transition to commercial viability—that is, until the 1-billion-gallon mark has been reached—this promising technology could die on the vine before its potential has even been adequately evaluated. The patience of investors, political leaders, and voters is limited. We need to get cellulosic biofuels out of the lab and into the marketplace. We need to prove that they can deliver—that they can begin the transition to low-carbon fuels in reality and not just in theory.

The disappointing projections for the next few years clearly demonstrate that existing policies are not meeting the challenges of moving beyond food-based fuels and ensuring that biofuels contribute to climate change mitigation. To bring cellulosic fuels to commercial scale will require strategies other than what Congress has put forward to date.

Without adequate support through the first transition to commercial viability, this promising technology could die on the vine before its potential has even been adequately evaluated. We need to get cellulosic biofuels out of the lab and into the marketplace.

CHAPTER FOUR

The Billion Gallon Challenge

To get back on the road to a low-carbon transportation future, we need to give cellulosic biofuels a jump start. The farmers, engineers, and entrepreneurs are ready, but they have been unable to get loans to build commercial-scale facilities. Focusing on the first billion gallons of production capacity is the right target for three reasons. First, a billion gallons a year is a target big enough to put theory into practice at full-scale facilities (based on different technologies and feedstocks) around the country. Second, a billion gallons a year is not so big that adjustments and corrections cannot be made as we learn what works and what potholes and dead ends to avoid. And third, supporting a Billion Gallon Challenge is affordable; it can be paid for with a small portion of the savings to be realized by reforming our currently dysfunctional array of biofuels tax credits (as discussed in the next chapter).

A billion gallons of production a year is a scale sufficient for testing assumptions in the real world. While people have been doing engineering studies and operating pilot plants for years, there are some things you cannot learn until you scale up to commercial production. Producing 1 billion gallons of cellulosic biofuels would require engineers and construction workers to build 10 to 20 commercial-scale biorefineries across the country. Biorefinery workers would need to learn new skills to start the facilities and keep them running smoothly. At the same time, the biorefineries would develop business relationships with farmers, foresters, waste handlers, and other feedstock providers in order to supply millions of tons of cellulosic biomass. And an entirely new supply chain would need to be optimized for collecting, delivering, and storing cellulosic biomass. Many of these challenges can only be successfully addressed when production reaches a meaningful commercial scale. And because there are several promising conversion technologies and different feedstocks that vary by region, one or two pilot plants cannot provide enough information on the diverse options.

A billion gallons a year is still small enough to allow for mid-course corrections. One billion gallons is just 6 percent of the way to meeting the full 16-billion-gallon mandate, and like the first tune-up for a new car, it affords the opportunity to inspect the system for problems that, unless corrected, could lead to major damage. Producing sufficient cellulosic biomass to later supply more than 10 billion gallons of cellulosic biofuels would bring major changes to agriculture. These changes could be beneficial or damaging (see Chapter 2), but until cellulosic biomass markets actually exist it is hard to know what potential problems are most significant. Thus, as commercial production gets underway at facilities all over the country, we will have a much better understanding of the issues, allowing refinement of existing policies or development of new ones so we can stay on the path to a mature and sustainable cellulosic biofuels industry.

A billion gallons of annual cellulosic biofuel production capacity is the right target for focusing our efforts. Once cellulosic conversion technology has reached the billion-gallon mark, further growth would likely be evolutionary rather than revolutionary. At this point, the government would be able to reduce direct support (through tax credits and loan guarantees) and rely instead on performance-based policies that put a price on carbon. In that way, government would be supporting the cleanest fuels on the basis of standards rather than incentives. But the challenges beyond 1 billion gallons are irrelevant until this milestone is within our grasp. The best foundation for the future low-carbon biofuels industry is to produce the first billion gallons promptly and in an environmentally responsible way.

Crossing the Valley of Death

Two of the cellulosic biofuels industry's most urgent problems (which are stalling its launch) are the lack of access to investment capital and the high capital costs for innovators. These are not new or unique problems. As new technology moves from research and development (R&D) to commercialization, it is often challenging to find private financial support for realizing the technology's potential. This phenomenon is often referred to as the "valley of death" because the technology, in a state of being neither here nor there, is highly vulnerable. The capital requirements for early commercialization are often beyond the scope of high-risk R&D funding, while the economics of the commercialized technology are not well enough proven to attract conventional financing (Ford, Koutsky, and Spiwak 2007). It is well known, moreover, that lingering too long in this valley of death can do more than delay the scale-up of the technology. The failure of pioneer companies to get off the ground can discourage subsequent investment and cool the enthusiasm of policy makers to continue supporting what is perceived to be a failed technology.

Complicating matters for the cellulosic biofuels industry, it found itself entering the valley of death just as a perfect storm arrived. Turbulence in the financial markets in 2008 and 2009, volatility of transportation fuel prices, and uncertainty over public policy put cellulosic biofuels technology at great risk of losing momentum before a successful transition from R&D to cost-effective commercialization could occur.

Successive administrations from both political parties have placed strong emphasis on alternative transportation fuels in general and on the potential of cellulosic biofuels in particular to improve energy security and climate change. The best way to realize that potential is a targeted investment in getting cellulosic biofuels from the lab to commercial scale. And as we will describe in Chapter 6, directing government support to the specific problems of cellulosic biofuels commercialization will be more cost-effective and more successful than subsidies spread across the existing biofuels marketplace.

Capital Support for Early Investors. DOE loan-guarantee programs and grants for biorefineries in 2007 and 2008 did not achieve the results they sought as financial turmoil, technological difficulties, and red tape slowed things down, leading some awardees to walk away. Even with grants worth 40 percent of the projected costs, investors were unable to line up private financing in a timely and cost-effective manner to cover the rest (Lemos-Stein 2009). Recently the pace has picked up as additional funding for biorefinery loan guarantees in the Farm Bill[8] has become available and the American Recovery and Reinvestment Act (ARRA) of 2009 added additional funding for programs authorized in earlier bills (DOE 2009b). Meanwhile, the Obama administration has put a priority on expediting the implementation of existing programs (White House 2009a). Even with this renewed emphasis, however, securing financing remains among the biggest obstacles to the commercialization of cellulosic biofuels.

Investment Tax Credits. Early investors in cellulosic biofuels will inevitably face higher capital and start-up costs compared with later entrants. This is reflected in an analysis commissioned by the EIA, which put the capital cost of current technology at $8.75 per gallon of annual capacity (in 2009 dollars), dropping more than 50 percent to $4.34 for next-generation technology and then another 30 percent to $3.05 for mature technology (Marano 2008).[9] The Department of Energy's

8 The 2008 Farm Bill, Sec 9003 (Biorefinery Assistance Program), provides $75 million in FY 2009 and $245 million in FY 2010 for commercial-scale biorefinery loan guarantees. It also authorizes discretionary funding of $150 million per year starting in FY 2009 and continuing through FY 2012 both for demonstration- and commercial-scale biorefineries (Farm Bill 2008).

9 Prices are adjusted from 2002 to 2009 dollars in order to match the DOE result using the Consumer Price Index for All Urban Consumers from the Bureau of Labor Statistics. Industry-specific inflation indexes would be more accurate, but as the goal here is primarily to characterize the extent of cost reductions with technology maturity and to get a rough cost estimate, the CPI conversion is adequate.

analysis showed capital costs for cellulosic ethanol dropping almost 30 percent between 2009 and 2012 (DOE 2009a).[10] Such rapid reduction in capital costs per gallon is expected as the technology matures, practitioners gain experience, and yields improve.

It is necessary, however, to level the playing field between early investors and the later investors that benefit from the hard-won lessons of the pioneers. To do that we propose a 30-percent investment tax credit that would phase out as the technology matures. After the first billion gallons, the credit would be reduced by 6 percentage points for each subsequent billion gallons of installed capacity. Thus, the second billion gallons would get 24 percent, the third billion 18 percent, and so on; after the industry reaches a capacity of 5 billion gallons, the investment tax credit would be fully phased out. These percentages are consistent with expected reductions in capital costs over time.

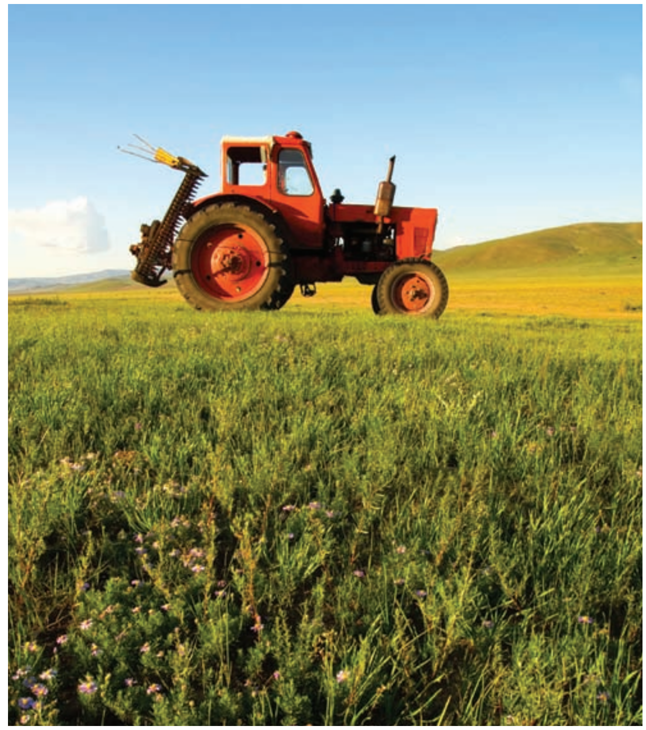
Loan Guarantees. As long as the challenging financing situation continues, loan guarantees are among the most valuable source of government support to assist emerging technologies in getting off the ground. Such support is potentially less "addictive" than large ongoing tax credits paid per gallon of fuel produced; this is because as technology develops and early investors begin to earn a return, private financing becomes more readily available and the need for loan guarantees is reduced. To support the rapid development and expansion of cellulosic biofuels technology, it may be necessary to provide loan guarantees to essentially all the facilities making up the first billion gallons. Beyond this threshold, loan guarantees would be quickly scaled back as the production volumes increase. The loan guarantees should then be reserved for a small fraction—the most innovative—of facilities that pioneer new technologies.

Other Support. In addition to investment tax credits, the DOE and USDA should aggressively use R&D grant programs to speed the commercialization of cellulosic biofuels. Existing DOE programs in basic science, as well as in the development and deployment of biochemical, gasification, and pyrolytic conversion technologies, should be adequately funded to provide the knowledge that could make future cellulosic biofuels technologies successful. USDA investments in cellulosic biomass crop development, and in easing the infrastructural hurdles it could face, would ensure the availability of cost-effective and sustainable cellulosic biomass in the volumes needed to support a growing cellulosic biofuels program.

Wrapping Up the Billion Gallon Challenge. The special capital support essential to crossing the valley of death should quickly become inappropriate as the cellulosic biofuels industry reaches a more mature phase. Thus it ought to be clear to companies from the outset that the support in the Billion Gallon Challenge will phase out at a predictable rate as the milestones are reached and the industry grows strong enough to stand on its own. However, while the 1-billion-gallon capacity would be the first important milestone—having allowed the industry a reasonable period for evaluating the success and failures of the program and for making adjustments—at that point it would likely be too early to abruptly withdraw all support. By contrast, reducing the level of support by 6 percentage points for each additional billion-gallon milestone would provide a gradual transition that investors could plan for and that would be balanced by reduced costs as production technology matures and becomes cost-competitive. Support would expire entirely after 5 billion gallons of capacity is reached, which is about where the corn ethanol industry was in 2006 (RFA 2009). At 5 billion gallons a year, multiple conversion technologies and feedstocks will have been commercialized at 50 to 100 facilities around the country.

Even after the whole Billion Gallon Challenge has been fully phased out, long-term policies should continue to differentiate between clean and dirty fuels by putting a price on carbon. Technology-neutral performance standards such as a low-carbon fuel standard (see the box on p. 31) could then support the cleanest fuels in a cost-efficient manner. A key step to building a bridge from our current policy to a clean energy future, when all fuels will be judged by performance, is to introduce performance-based incentives into our biofuels policy. That is the subject of the next chapter.

10 The DOE has a target of $4.61 per gallon annual production capacity in 2009, dropping to $3.28 in 2012. Both figures are in 2009 dollars (adjusted from 2007 dollars using CPI, as in the previous footnote). These figures are lower than the EIA estimates because DOE values are targets reflecting the theoretical cost of a full-scale facility using 2,000 tons of biomass a day, while the EIA figures reflect the probable sizes at which plants will actually be built. The latter start at a smaller size and only reach full scale for mature technology (DOE 2009a).



CHAPTER FIVE

Biofuels Performance Tax Credit

At the same time that we invest in next-generation biofuels, we need to make the most of conventional biofuels—to establish a market signal that cleaner fuels are more valuable than polluting fuels. Current policy nods in this direction through the different fuel categories in the RFS as well as through tax credits that are larger for cellulosic biofuels than for corn ethanol. But the way these policies are structured does not give fuel suppliers an economic incentive to clean up their fuels.

The best example of missing incentives is corn ethanol. While the EPA's life-cycle analysis confirms that some conversion technologies are much cleaner than others, current policy provides no incentive to make investments accordingly. Essentially all of corn ethanol production is exempt from the life-cycle global warming requirements of the RFS through its grandfathering provision. And an existing ethanol tax credit (VEETC) is applied to all fuel ethanols, regardless of how clean or dirty they are. VEETC is duplicative of the mandated levels in the RFS, essentially paying oil companies and other fuel providers merely for following the law, and they cost tax payers billions of dollars a year with little if any benefit.

We believe that current biofuel tax credit programs should be replaced with a unified tax credit that pays for benefits above and beyond what is required by the RFS. Specifically, we propose a Biofuels Performance Tax Credit of $10 per million Btu based on the extent to which the biofuel replaces oil and reduces global warming emissions. The maximum tax credit works out to $1.15 per gallon of gasoline replaced, but to qualify for it a biofuel would need to have zero global warming emissions on a full life-cycle basis. All biofuels would be eligible, generally getting partial payment in proportion to how much their global warming emissions performance improves over today's baseline corn ethanol.[11] The exact formula is:

$$\text{Biofuels Performance Tax Credit} = \$10 \times \frac{\text{Btu per gallon}}{\text{1,000,000 Btu}} \times \frac{\text{Emissions per Btu}}{\text{Baseline Emissions per Btu}}$$

Thus a fuel that reduced full life-cycle global warming emissions by half compared with today's typical corn ethanol would get $5/million Btu. Table 4 (p. 26) illustrates how the Biofuels Performance Tax Credit payments compare with existing tax credits for several particular ethanol-based biofuels. The table shows that the best cellulosic ethanol, which the EPA found could be carbon-neutral on a full life-cycle basis, would receive the whole $10/million Btu, which works out to

11 The baseline corn ethanol would be natural-gas-fired dry-mill corn ethanol with dry distillers grains (EPA 2010c).

$0.77/gallon, given that ethanol has 77,000 Btu per gallon.[12] Typical corn ethanol would receive no tax credit unless producers adopt clean technologies, in which case they would qualify for a tax credit of up to $0.20/gallon, depending on the technologies involved. Such variable credits for the same fuel would provide a clear financial incentive for corn ethanol producers to invest in technology to reduce their life-cycle emissions.

Table 4. COMPARING TAX CREDITS FOR ETHANOL BIOFUELS

FUEL	GLOBAL WARMING EMISSIONS REDUCTION VS. TYPICAL CORN ETHANOL	BIOFUELS PERFORMANCE TAX CREDIT	EXISTING TAX CREDIT
Best-Case Cellulosic Ethanol	100%	77¢/gallon	$1.01/gallon
Typical Cellulosic Ethanol	85%	65¢/gallon	$1.01/gallon
Cleaner Corn Ethanol	Up to 27%	Up to 20¢/gallon	45¢/gallon
Typical Corn Ethanol	0%	0	45¢/gallon

Actual payouts are based on feedstock and facility-specific details. The better performance of cellulosic ethanol is recognized with a higher tax credit. But even within different types of corn ethanol, cleaner fuels qualify for higher tax credits, thereby providing an incentive for ethanol producers to do better.

Because the Biofuels Performance Tax Credit is based on energy content (Btu are a measure of how much heat a fuel produces when it burns), it is larger for fuels that have more energy per gallon. This proportioning makes good sense, as these fuels displace more oil. Table 5 illustrates how the Biofuels Performance Tax Credit payments for diesel-replacement fuels compare with existing tax credits.[13]

Table 5. COMPARING TAX CREDITS FOR DIESEL-REPLACEMENT BIOFUELS

FUEL	GLOBAL WARMING EMISSIONS REDUCTION VS. TYPICAL CORN ETHANOL	BIOFUELS PERFORMANCE TAX CREDIT	EXISTING TAX CREDIT
Waste Grease Biodiesel	89%	$1.03/gallon	$1.00/gallon
Soybean Biodiesel	44%	50¢/gallon	$1.00/gallon

Given that biodiesel has 50 percent more energy per gallon than ethanol, it displaces more oil and receives a higher tax credit at the same level of heat-trapping emissions performance.

Administration of the Biofuels Performance Tax Credit would require accurate and up-to-date life-cycle assessments of different biofuel types. The EPA has done much of this foundation work already, and it has developed a tracking mechanism for biofuels—Renewable Fuel Identification Numbers (RINs)—which is used to demonstrate compliance with the RFS. But the EPA would need to augment the RIN system so that current life-cycle emissions of individual facilities are auditable by the IRS. Initially, this effort could build on the EPA's existing analyses, which are based on the types of energy and technology in use at specific facilities. In addition, the EPA should develop procedures for fuel producers to submit facility-specific data; in that way, it could obtain a more accurate assessment and give credit for any additional improvements and efficiencies they were able to achieve.

12 77,000 Btu per gallon is used to reflect the energy content of low-heating-value denatured ethanol (EPA 2010a). This value is used rather than the heat content of pure ethanol (76,400 Btu) for consistency with the RFS Renewable Identification Number (RIN) credit system—especially to facilitate the implementation of the tax credits by the IRS using RFS RINs.

13 For consistency with the RFS and ease of implementation, we used the equivalence values from the final RFS rule for energy content of different fuels. These equivalence values are specified in the RFS as 1.3 for butanol, 1.5 for biodiesel (mono alkyl ester), and 1.7 for non-ester renewable diesel (EPA 2010a).

Cleaning Up Corn Ethanol

Corn ethanol is the largest source of biofuel in the United States, and it will likely remain so for at least the next decade. But as discussed in Chapter 2, the global warming emissions of corn ethanol are significant, especially because of its large impacts on land use. One could argue that in light of these emissions, no corn ethanol should qualify for any government support. However, the significant indirect emissions from land use should not cause us to lose sight of the opportunities to clean up corn ethanol's direct emissions.

Today, 80 percent of corn ethanol comes from natural gas-fired facilities and 15 percent from facilities fired with coal (EPA 2010b). Retrofitting these facilities with the most efficient technology could dramatically reduce the emissions of corn ethanol. For example, a typical natural-gas-fired corn ethanol facility has emissions from fuel production of about 3 kilograms (kg) of heat-trapping gases per gallon of ethanol produced; a coal-fired facility emits 5 kg per gallon. Adopting up-to-date corn ethanol production technology could reduce these emissions by 30 percent, or almost 1 kg per gallon.[14] Using biomass in place of natural gas as a heat source could reduce net emissions from fuel production to under 1 kg per gallon. Add an efficient biomass-fired combined-heat-and-power system, and facility emissions could fall to less than half a kilogram per gallon.

All told, technology improvements could reduce emissions at existing natural-gas-fired corn ethanol facilities by 1 to 2.5 kg per gallon and by just under 5 kg per gallon at a coal-fired facility. These improvements would not eliminate the impacts of corn ethanol production on land use, but by reducing conversion emissions at existing facilities the overall emissions could be reduced significantly. Looking at the entire life cycle (based on the EPA 2012 analysis), the cleanest corn ethanol is cleaner than the gasoline baseline. With lower estimates of land-use changes, such as in CARB's analysis or the EPA's 2017 and 2022 analyses, the emissions of corn ethanol would be significantly lower than gasoline (EPA 2010c).

We cannot afford to ignore or postpone the opportunities to make conventional biofuels less polluting. Cleaning up the nearly 15 billion gallons of corn ethanol production capacity in existence or under construction could reduce global warming emissions by 20 million to 30 million metric tons per year. The Biofuels Performance Tax Credit would provide a clear incentive for corn ethanol producers to achieve these reductions—an incentive that is lacking in current policy. Moreover, by reducing the emissions of conventional biofuel facilities, they would be able to compete in the future in a world that puts a price on carbon (for example, under a low-carbon fuel standard).

The Biofuels Performance Tax Credit treats all fuels fairly and encourages the most cost-effective implementation of emissions-reduction technology across the biofuels sector. If a corn ethanol facility reduced emissions by 10 percent, it would get the same incremental tax credit as a cellulosic biofuel producer going from 70 percent to 80 percent lower than typical biofuel. If another facility made a bigger improvement cost-effectively, it would get a bigger benefit. The magnitude of these incentives would easily be large enough to persuade fuel producers to upgrade. For a typical corn ethanol facility with a 100-million-gallon-a-year capacity, upgrading to a biomass-fired heat system could result in a tax credit of $20 million a year, enough to pay for the retrofit in less than two years (Plevin and Mueller 2008).

Complementary Support for the Most Environmentally Friendly Fuels

While performance-based policies for biofuels can support cleaner fuels and production methods, carbon accounting

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14 Up-to-date corn ethanol technology refers to fractionation, membrane separation, and raw-starch hydrolysis, which reduce the energy needed to produce ethanol and generate additional coproducts as well (EPA 2010c).

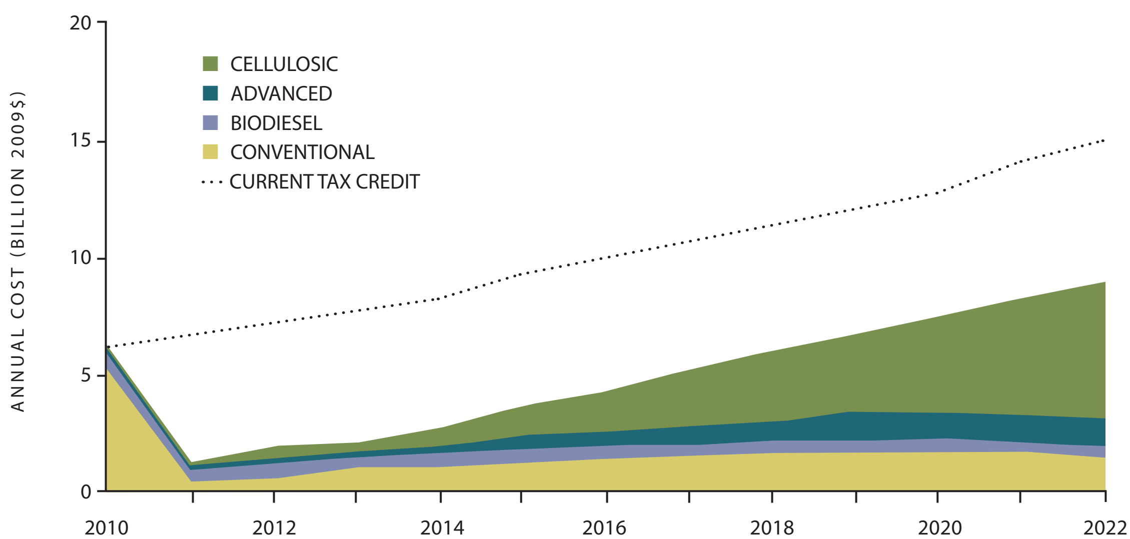
alone is inadequate to address the full range of sustainability issues. Because the environmental impact of biofuels is strongly tied to feedstock production, support for best practices in cellulosic biomass production should entail sustainable practices in forestry, low irrigation-water use in agriculture, soil quality improvements through adoption of agricultural best-management practices, and preservation of wildlife habitat. A thoughtful implementation of the Biomass Crop Assistance Program from the 2008 Farm Bill would be a good place to start. Tax credits are another possibility; an innovative proposal by Loni Kemp relies on conservation measurement tools developed by the Natural Resources Conservation Service to determine an environmental score on which a performance-based biofuels tax credit would be based (Kemp 2009). Support for sustainable biomass production beyond carbon accounting, though outside the scope of this report, would be an important complement to carbon-based policies.

The Cost of the Biofuels Performance Tax Credit

Because the Biofuels Performance Tax Credit would pay for improvements over the status quo—as opposed to paying for compliance with the RFS—it would be much more affordable than today's tax credits. In fact, as discussed in more detail in the next chapter, it would save billions of dollars a year. This is illustrated in Figure 5, which compares the cost of the Biofuels Performance Tax Credit with that of extending current tax credits. The real cost of either option depends on what types of biofuels are produced and the emissions reductions they achieve, which depend, in turn, on whether the cellulosic biofuels industry is successful at reaching the RFS targets. The costs shown in Figure 5 are based on RFS-mandated fuel levels. If actual fuel production were lower, the costs of either set of tax credits would also be lower, but the savings from the Biofuels Performance Tax Credit would remain largely unchanged.

Figure 5. BIOFUELS PERFORMANCE TAX CREDIT VS. CURRENT TAX CREDITS

(RFS Volumes)



Cost of the Biofuels Performance Tax Credit compared with that of extending current tax credits, assuming that biofuel production tracks RFS volume mandates. All costs are in net present value discounted by Treasury rates. Assumptions about initial and final average emissions performance of different biofuels, which determine their eligibility for the Biofuels Performance Tax Credit, are specified in Appendix B.

Mascoma: Meeting Cellulosic Challenges

People have understood for more than a century that alcohol can be distilled from wood and other kinds of cellulosic biomass. However, because the yields were low and the costs high, the processes were implemented at a commercial scale only during the world wars, when there were severe shortages of other fuels (Katzen and Schell 2006).

One of the most basic reasons for the low yields and high costs has been the recalcitrant nature of cellulosic biomass—the sugars in wood and other cellulosic materials are tightly bound together and largely inaccessible to the enzymes that would convert them into alcohol (Yang and Wyman 2008; Himmel et al. 2007). Cows tackle this problem by chewing up the grass, chewing cud, and sending the materials through four separate stomachs, where microbes act sequentially to break down the cellulose. The challenge to us humans is to build chemical/mechanical systems that mimic all this chewing and digesting, in a cost-effective and energy-efficient way, so as to convert cellulose first into different kinds of sugar and then convert the sugars into alcohol.

A second challenge is to consolidate the multiple chemical/mechanical processes, which increase cost and decrease yield. Revolutionary new techniques in biology make it possible to consolidate several of these steps into a single organism—a living-factory "superbug" that could make all the intermediate enzymes for ultimately producing the alcohol. R&D is currently under way to drastically reduce the costs and improve the yields of the biological processes involved. The U.S. Department of Energy, for example, has been funding the relevant basic science through its Genomics:GTL Roadmap (also called the Genomic Science Program). Now that the scientific efforts are yielding useful results, high-tech companies are starting to apply them by developing low-cost biofuel production methods.

Mascoma is one of these companies. Founded at Dartmouth College (Hanover, NH) in 2005, Mascoma has focused on developing key solutions to cellulosic biomass recalcitrance and consolidated bioprocessing.

The company has tackled cellulosic biomass recalcitrance by developing an advanced pretreatment process that breaks down the physical and chemical defenses of the plant material and exposes the underlying cellulose so it can be converted to sugar. Mascoma has also recently announced advances in several key technical areas that provide proof of concept for consolidated bioprocessing (Mascoma 2009). It has been scaling up this technology and optimizing it for different cellulosic biomass feedstocks at a facility in Rome, NY.

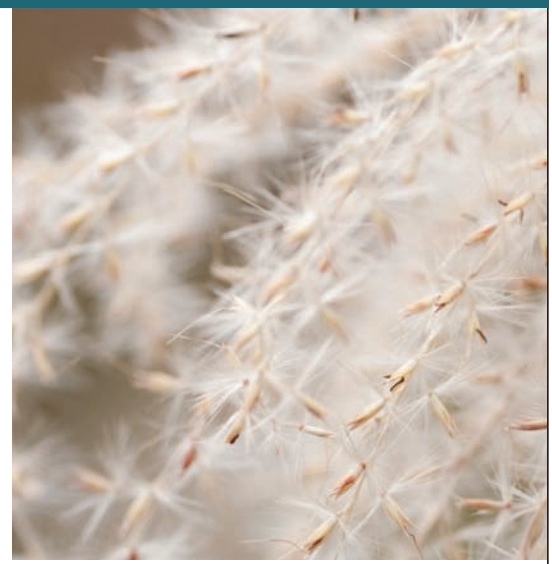
Meanwhile, Mascoma is developing a commercial-scale biorefinery to convert forest biomass into 40 million gallons of ethanol at a site in Kinross, MI. It has received $49.5 million in support from the Department of Energy and the state of Michigan (Michigan 2008). This facility is going into a region (Michigan's Upper Peninsula) where pulp and paper mills have been shutting down; thus it is reusing existing infrastructure and revitalizing communities built around the timber industry. In this enterprise, Mascoma is working with JM Longyear, a privately held landowner whose operations have been certified by the Forest Stewardship Council (SmartWood 2008). According to the Michigan Economic Development Corporation, the project will create 150 construction jobs, 50 full-time direct jobs at the facility, and 500 to 700 indirect economic-spinoff jobs in the region. This first full-scale plant could also serve as a model, designed to be quickly replicable wherever sufficient investment capital is available.

Even though the Biofuels Performance Tax Credit would be less expensive than the status quo, as biofuel volumes grow and producers adopt the cleanest technologies, the absolute cost of the Biofuels Performance Tax Credit will certainly rise. To prevent costs from escalating over time, however, the eligibility criteria for the tax credit could be revised every three years, raising the bar in reasonable increments as the industry's performance improved. This would give producers an incentive to make improvements promptly, spurring a race to the top to claim the biggest tax credits, which would be attractive though not excessive.

Although the Biofuels Performance Tax Credit would add incentives that are lacking in the RFS, a more efficient, flexible, and affordable approach would be to replace the RFS altogether with a policy—for example, the Low-Carbon Fuel Standard described in the box to the right—that includes such incentives. California has already implemented a standard of this kind and 11 Northeast and Mid-Atlantic states are in the process of following suit. When the federal government adopts this policy, or some other approach that provides comparable incentives, it will be time to phase out the Biofuels Performance Tax Credit.

Low-Carbon Fuel Standard

One promising strategy for simultaneously addressing our petroleum addiction and global climate change is a Low-Carbon Fuel Standard (LCFS). Under a well-designed LCFS, fuel suppliers must reduce the life-cycle emissions (on an average per-Btu basis) of the fuels they sell. But rather than being constrained to particular technologies or fuels, the suppliers are free to choose how they meet the emissions targets. For example, they could blend lower-carbon biofuels, such as cellulosic ethanol, into gasoline; sell low-carbon biofuels for use in flex-fuel vehicles (which can run on blends up to 85-percent ethanol); or reduce emissions from the refining process. Market mechanisms allow for trading credits, thereby providing additional flexibility and lowering the cost of compliance. For example, fuel suppliers can purchase credits from utilities that provide low-carbon electricity to plug-in hybrids or battery-powered electric vehicles.



By allowing compliance flexibility, the LCFS supports innovation in transportation fuels while contributing both to energy security and climate protection. The standard can:

- **Promote improvements in the supply chain.** Using life-cycle accounting of emissions provides an incentive for improvements anywhere along the supply chain for fuels. For instance, an ethanol production facility that uses coal for process heat creates much more global warming pollution than one that uses biomass. Because the ethanol from the biomass-based facility will have lower life-cycle emissions, under an LCFS this will result in more credits for that ethanol supplier and ultimately a more profitable operation.

- **Protect against high-carbon fuels.** The LCFS creates an incentive to use clean fuels and a matched disincentive to use especially polluting fuels. Coal-to-liquids technology, for example, produces almost twice as much life-cycle global warming pollution as gasoline (NAS 2009). Under the LCFS, any fuel supplier that sells this fuel needs to either shift to lower-carbon fuels or purchase credits from others in order to meet the standard. In this way, the dirty fuels incur the price for their higher pollution. In effect, an LCFS creates a level playing field where all fuels can compete according to their overall benefits and costs.

- **Create choices and spur innovation.** The LCFS does not rely on assumptions about the technical or commercial feasibility of any particular technology. Whether or not cellulosic ethanol, plug-in hybrids, or hydrogen fuel cells, for example, prevail in the marketplace will depend on their ability to deliver cost-effective low-carbon fuel rather than on government mandates to use them. But as investors consider these technologies, they have the certainty that there will be a steadily growing market for low-carbon fuels, regardless of the price of oil. This will spur investment and let the marketplace decide the ultimate winners.

CHAPTER SIX

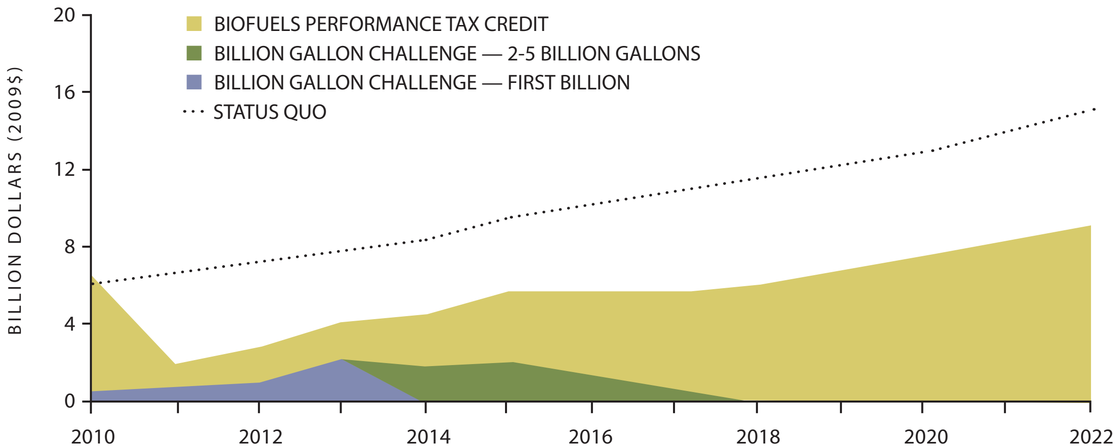
Greater Benefits at Lower Costs

Getting our biofuel policies back on track could yield many benefits. Support of the fledgling cellulosic biofuels industry through the Billion Gallon Challenge would create economic opportunities and launch truly low-carbon biofuels. Reformation of our tax credits with the Biofuels Performance Tax Credit would provide all biofuels producers with an incentive to clean up while saving taxpayers money.

The savings from the Biofuels Performance Tax Credit would be more than $5 billion per year (in 2009 dollars), while the cost of providing loan guarantees and tax credits to support the first billion gallons of cellulosic biofuels capacity would be only about $4 billion spread over several years. Overall, the cost of the Billion Gallon Challenge from 2011 to 2014 would be about a quarter of the savings from the Biofuels Performance Tax Credit over the same period. If the RFS cellulosic mandate were not met and the Billion Gallon Challenge were met after 2013, the costs would be spread over a longer period and the savings would be even greater. These savings would come from trimming the wasteful tax credits and from using *any* tax credits only to pay for improvements beyond the requirements already established by the RFS.

Support of the fledgling cellulosic biofuels industry through the Billion Gallon Challenge would create economic opportunities and launch truly low-carbon biofuels. Reformation of our tax credits with the Biofuels Performance Tax Credit would provide all biofuels producers with an incentive to clean up while saving taxpayers money.

Figure 6. YEAR-BY-YEAR COST COMPARISON OF THE OPTIONS



The cost schedule above assumes that biofuel volumes match the RFS schedule. The yellow area shows the cost of tax credits, transitioning from present tax credits to the Biofuels Performance Tax Credit starting in 2011. The blue area shows the cost of support for investment capital for the first billion gallons. A delayed schedule would reduce the rate of spending but the cumulative total would remain the same. The green area shows the cost of support for investment capital as support tapers off through 5 billion gallons. Details on cost calculations are presented later in this chapter.

Figure 6 shows that the savings from reforming the tax credits with the Biofuels Performance Tax Credit would be much larger than the costs of the Billion Gallon Challenge. The figure assumes that production levels for all biofuels follow the RFS mandates after 2010. If the cellulosic biofuels mandates were reduced, the Billion Gallon Challenge expenses would be spread over a longer time and the savings would be larger.

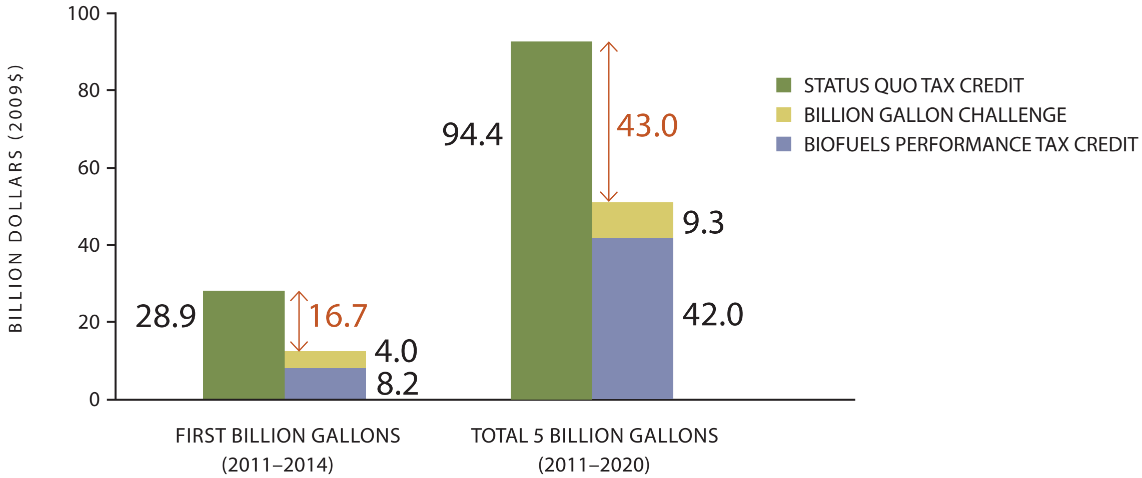
Figure 7 compares the cumulative costs (in 2009 dollars) of the Billion Gallon Challenge and the Biofuels Performance Tax Credit with the cost of extending the current tax credits, assuming that production tracks the RFS mandates. In the four-year period from 2011 to 2014, the Biofuels Performance Tax Credit would save more than $20 billion. Investing less than a quarter of this amount, $4 billion, to support the Billion Gallon Challenge would still save taxpayers more than $16 billion compared with the status quo. Over the 10 years from 2011 to 2020, the Biofuels Performance Tax Credit would cost less than half that of the status quo tax credit. The cost of supporting the Billion Gallon Challenge and then phasing it out over the next 4 billion gallons would be less than a quarter of the money saved.

Comparing the Costs Facility by Facility

To understand the cumulative impact of the different types of support we have proposed, it helps to look at the value of all the parts together at a single facility. Consider a 50-million-gallon-a-year facility that starts construction in 2011 and begins production in 2013, thus contributing to the first-billion-gallons milestone.

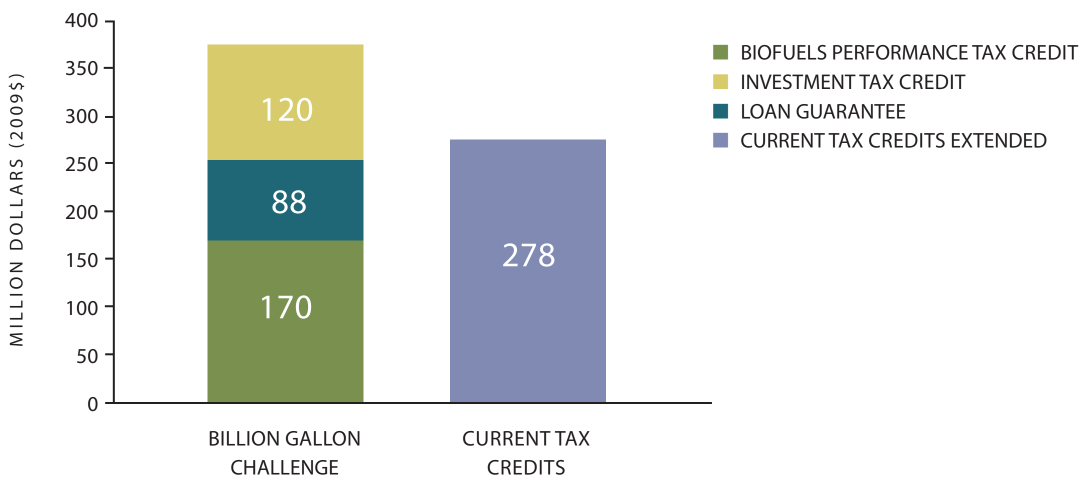
As shown in Figure 8, even though the special production tax credit for cellulosic biofuels has been replaced with a smaller Biofuels Performance Tax Credit, the benefit of the loan guarantees and the investment tax credit more than make up for the loss. More important, the investment tax credit and loan guarantee are structured in a way that assists developers in raising money to build their facilities. That is, the value of the investment tax credit and loan guarantee are predictable at the time that financing is arranged, while existing biofuels tax credits are contingent on uncertain future extensions. Helping cellulosic biofuel entrepreneurs raise money is crucial to getting through the "valley of death" described earlier. The current tax credit for cellulosic biofuels is not helping the biofuels industry because it cannot get up to scale to start collecting the credit.

Figure 7. CUMULATIVE COST COMPARISON OF THE OPTIONS



Projected costs in constant 2009 dollars, assuming biofuel production matches the RFS mandates. Current tax credit costs assume that tax credits are maintained at current levels. Future costs are discounted at nominal Treasury bond rates.

Figure 8. FUNDING FOR A 50-MILLION-GALLON CELLULOSIC FACILITY



Comparison of proposed policy with current tax credits from the perspective of an investor in a 50-million-gallon facility. On the left, the net present value of the Biofuels Performance Tax Credit (assuming an 80-percent reduction in life-cycle global warming emissions compared with typical corn ethanol over 10 years) is added to the value of the investment tax credit and loan guarantee. On the right is the net present value of the current tax credits over 10 years, assuming they are extended. Net present values of the investment tax credit and loan guarantee are calculated at a 7 percent nominal discount rate, while the Biofuels Performance Tax Credit and current tax credits are discounted at an 8.7 percent rate (7 percent + 1.7 percent expected inflation).

Another salient comparison is the cost of failing to build the cellulosic biofuel facility and relying on corn ethanol instead. Supporting the same 50 million gallons of capacity from an existing corn ethanol facility at the current 45¢/gallon, VEETC has a net present value of $124 million over 10 years while doing nothing to launch cellulosic biofuels technology and delivering no reductions in heat-trapping emissions. This enormous incentive goes to support a facility that has taken no technology risk, has customers that are required by law to buy the product it produces, and is not even obligated to meet the minimal global warming reduction standards for conventional biofuel in the RFS. Under our reformed Biofuels Performance Tax Credit, the corn ethanol facility could receive tax credits with a net present value of more than $50 million over 10 years only if it adopted the most efficient conversion technologies. This would provide an economic incentive for grandfathered ethanol facilities to undertake improvements that would reduce their emissions and make the most from existing investments in today's biofuels.

Reducing Emissions

The Billion Gallon Challenge would spur reduced emissions of heat-trapping gases from transportation by speeding the transition to cellulosic biofuels. According to the most recent EIA projections (assuming present policies are unchanged), there will be less than 6 billion gallons of cellulosic biofuels production in 2022, versus the 16 billion gallons mandated by the RFS (EIA 2009c). Under that standard, each gallon of cellulosic ethanol must reduce emissions by at least 60 percent compared with gasoline, which comes to more than 4 kg of CO_2e per gallon. So if the Billion Gallon Challenge got the RFS back on track and met the 2022 mandates, the extra 10 billion gallons would reduce emissions in 2022 by more than 45 million metric tons of CO_2e per year.

In addition to the Billion Gallon Challenge, the Biofuels Performance Tax Credit would provide an incentive for corn ethanol producers to exceed the minimum requirements of the RFS. The EPA's analysis of the RFS showed that by moving from today's typical corn ethanol technology to the most advanced technology, emissions from fuel production could be reduced by some 1 to 2.5 kg CO_2e per gallon of ethanol. Given that we are already producing 10 billion gallons of corn ethanol a year, and will soon be producing 15 billion, reducing emissions at these facilities by an average of 1.5 kg per gallon could reduce emissions by 22 million metric tons a year. We could do this just by deploying the latest energy-efficient technology at fuel-production facilities already built.

Together the Billion Gallon Challenge and Biofuels Performance Tax Credit could reduce emissions in 2022 by as much as 100 million metric tons of CO_2e per year—equivalent to taking 15 million of today's cars and light trucks off the road that year.

Finally, the Biofuels Performance Tax Credit could also provide incentives for advanced and cellulosic biofuels producers to exceed the minimum requirements of the RFS. While the RFS requires advanced biofuels to reduce emissions by 50 percent and cellulosic fuels to reduce emissions by 60 percent, the EPA analysis shows that much larger emissions reductions are possible. If the Biofuels Performance Tax Credit motivated advanced and cellulosic biofuels producers to exceed the minimum standards by 20 percent, this would reduce emissions by 1.5 kg CO_2e per gallon of ethanol-equivalent fuel. With 21 billion gallons of advanced and cellulosic biofuels mandated by 2022, reductions of 31 million metric tons per year would occur.

Putting all of the above together, the Billion Gallon Challenge and Biofuels Performance Tax Credit could reduce emissions in 2022 by as much as 100 million metric tons of CO_2e per year—equivalent to taking 15 million of today's cars and light trucks off the road that year.[15]

Creating a New Industry

Investing in the development of new technology creates and sustains jobs, while existing tax credits such as VEETC, which pay people to do what they are already doing, create no new jobs. By contrast, the Biofuels Performance Tax Credit provides

15 Assuming that today's new car and truck fleet has an average on-road fuel economy of 21 miles per gallon and that vehicles are driven an average of 12,000 miles annually with emissions per gallon of 11.29 kg CO_2e per gallon (from the 2005 gasoline baseline in the RFS) (EPA 2010a).

Fulcrum Bioenergy and BlueFire Ethanol: Converting Waste into Energy

Waste products have been identified as sources of renewable fuels that dramatically reduce global warming emissions without displacing forests or food production. Several companies are trying different technical approaches to converting municipal solid waste or construction and demolition waste into fuels.

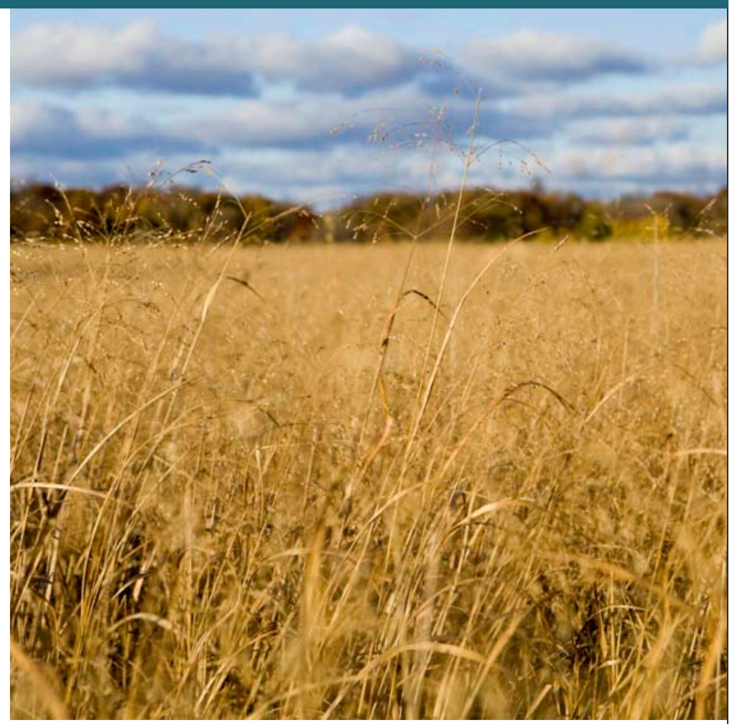
Fulcrum Bioenergy is a Pleasanton, CA-based company that is planning to build one of the first facilities to convert municipal solid waste into fuel at an industrial scale (more than 10 million gallons a year) at a site outside Reno, NV. Fulcrum uses gasification, which breaks down cellulosic biomass into carbon monoxide and hydrogen, which are subsequently converted into ethanol with the aid of catalysts (Fulcrum 2008). BlueFire Ethanol of Irvine, CA, uses a different approach—acid converts the cellulose into sugar, which is then fermented to make ethanol—and the company plans to build two facilities, producing 20 million gallons of ethanol a year, in Southern California and Mississippi (BlueFire 2008).

It is expected that these approaches will be optimized to handle the variable nature of waste as a feedstock, and that the projects will have the capacity to produce clean fuel while reducing landfill requirements. And because the garbage tends to be where the people are, the fuel can be produced close to consumers, thereby saving on transportation costs and associated emissions. But while using garbage for fuel avoids competition with agricultural and forest land, there is the potential to create a market for trash that could compete with and potentially undermine recycling. So care must be taken to implement this technology at the back end of the recycling process.

Even with serious recycling measures, however, there is still a significant fraction of waste that currently goes to landfills but could instead be converted into fuel. Los Angeles County produces some 24 million tons of waste materials a year. After diverting about half through recycling and other programs, local authorities still need to dispose of 12 million tons of nonrecyclable waste a year. With old landfills filling up, and no convenient locations for new ones, Los Angeles is planning to take dramatic measures, such as moving its waste several hundred miles by train to landfills with sufficient room.

In light of these difficulties, Los Angeles has been evaluating measures to convert waste into fuel, into other materials, or directly into energy by burning it (ARI 2007). To get a sense of the scale of the available resource, consider that the United States generated 250 million to 500 million tons of municipal solid waste in 2008 (WBJ 2009). Industry estimates put the total potential liquid-fuel production derivable from this resource at 10 billion to 21 billion gallons a year. The EPA also evaluated the urban waste available for liquid-fuel production in its draft RFS rules, and it arrived at the much lower estimate of 2.2 billion gallons a year in 2022 (EPA 2009a). But because the EPA made several highly restrictive assumptions in its analysis, this number may reasonably be viewed as a lower limit. In any case, the potential is clearly in the billions of gallons.

University of Minnesota: Sustainable Biofuels from Prairie Grass



A few sources of cellulosic biomass seem to offer the potential to have our cake and eat it too, and Professor David Tilman and his colleagues at the University of Minnesota have been working for decades in pursuit of one of them. The researchers seek to understand how diverse mixtures of perennial native prairie grasses can produce high cellulosic biomass yields on low-productivity soil.

They have found that "polycultures"—many species of plants growing together—can increase yields while using less fertilizer and fewer pesticides. This phenomenon reduces fossil fuel inputs, which consequently lowers groundwater pollution and global warming emissions. In 2006, the Tilman team's work on the ecology of prairie grass ecosystems was translated into terms relevant for biofuel production, with impressive results. Because of the relatively high yields, this approach offers the potential to produce biofuel in a manner that minimizes competition with land used for food production, does not encourage habitat destruction, and reduces global warming emissions. There may also be additional benefits from the accompanying ecosystem services, such as improved soil fertility and cleaner ground and surface waters (Tilman, Hill, and Lehman 2006).

Now this small-scale, painstaking scientific work is being expanded on about 100 acres of marginal land across six sites in Minnesota (Kintisch 2008). Related work is also under way in seven midwestern states including Iowa, where a plot of 100 acres of Iowa tallgrass prairie is being tested for its potential to provide cellulosic biomass (Ericson 2007).

Prairie restoration is just one example of how abandoned or degraded land can potentially produce biofuels without displacing farms or forests. Christopher Field, a biologist/ecologist at the Carnegie Institution and Stanford University, has studied this issue. Field and colleagues used global land-cover databases to assess the potential to produce biofuel or other kinds of bioenergy from crops grown on abandoned lands that were previously used for agriculture and are not currently forested. Their analysis put the scale of the resource within the United States at 125 million to 165 million acres, with a productive capacity of 321 million tons of cellulosic biomass per year (Field, Campbell, and Lobell 2008). This figure is an upper limit rather than a projection of what is technically or economically feasible, but just 10 percent of it would amount to more than 3 billion gallons of cellulosic ethanol.

incentives to pursue emissions reductions beyond the minimums required under the RFS and ensures that these incentives are available to all producers of biofuels. Under the Biofuels Performance Tax Credit, the most advanced corn ethanol facilities would receive a tax credit of 20¢/gallon. For a large corn ethanol facility with a capacity of 100 million gallons of annual production, this would be worth 20 million dollars a year. But to claim this benefit the facility must invest in improvements, which means better performance (both technological and economic) and new jobs.

For its part, the Billion Gallon Challenge could build a whole new industry, stimulating job creation in science and engineering, construction and operations, and the agricultural sector. Moreover, cellulosic biofuels technology could initiate entirely new uses for existing biomass crops and even establish markets for waste materials, such as garbage, that currently have little or no economic value. Thus these policies would do more than increase demand for existing corn and soybeans; they could launch economic opportunities that do not currently exist.

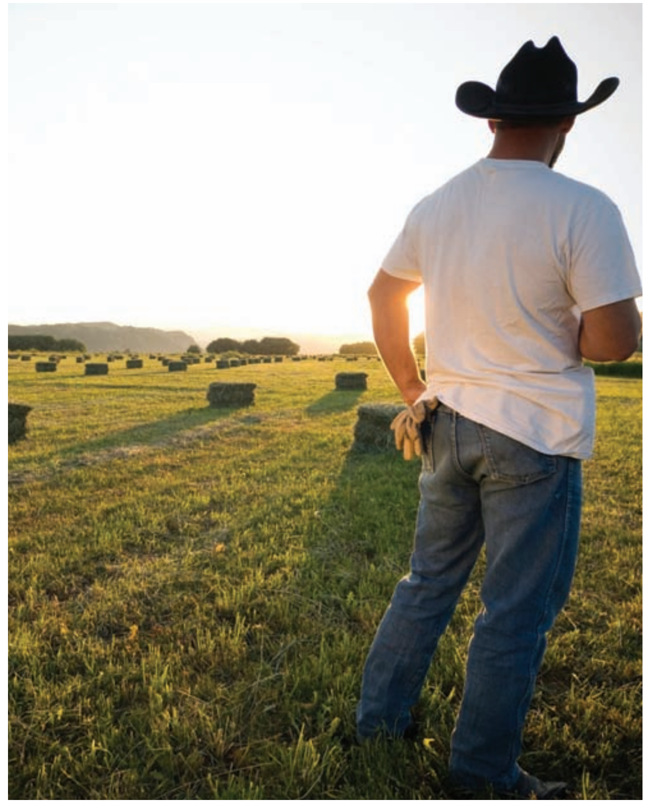
Biofuels tax credits today can apply to biofuels produced anywhere in the world. The tax credits and loan guarantees in the Billion Gallon Challenge, by contrast, would be available only to facilities in the United States, putting more of our tax dollars to work in providing American jobs.

The United States as Technology Leader

The Billion Gallon Challenge and the Biofuels Performance Tax Credit would be investments in helping to make the United States a leader in a clean energy technology—*cellulosic biofuels* technology. This country has substantial and sustainable cellulosic biomass resources, which could help the transition to a clean energy future. And it has the brainpower, ingenuity, and natural resources to avoid putting food and fuel in competition and causing other unintended consequences. By giving American innovators the support they need to meet the Billion Gallon Challenge, and by easing the way with the Biofuels Performance Tax Credit, we could ensure such technological leadership, stimulate the economy, and reduce global warming.

CHAPTER SEVEN

Conclusion



Scientists, engineers, farmers, foresters, and numerous other professionals are ready to begin the transition from today's conventional biofuels to the next generation. Using sustainable biomass from diverse sources, we could produce low-carbon cellulosic biofuels while providing new economic opportunities in rural communities all over the country. But this critical transition is stalled, a victim of inadequate policies and the global economic downturn, which have dried up investments. The result is that billions of dollars go to redundant tax credits, which pay oil companies and other fuel blenders merely to comply with existing law. Meanwhile, the most promising biofuels—made from cellulosic biomass—are unable to reach commercial levels of production.

The good news, however, is that we could get cellulosic biofuels back on track and save taxpayers money by making two policy adjustments:

- We should replace the current tax credits as they expire with a smarter Biofuels Performance Tax Credit. This would provide a clear incentive to makers of biofuels—all biofuels, whether existing or next-generation—to clean up, while generating more than $50 billion in savings over the next 10 years (compared with extending the current tax credits).

- Using a small portion of the tax credit savings, we could jump-start the stalled cellulosic biofuels industry with a Billion Gallon Challenge. This program would provide capital assistance and loan guarantees designed to get the first billion gallons of cellulosic biofuel out of the lab and into the market within the next five years.

Meeting the Billion Gallon Challenge would get us on the path to realizing the energy-security, climate-protection, and economic-development potentials of biofuels. An annual capacity of a billion gallons of cellulosic biofuels means production at 10 to 20 full-scale facilities around the country, where we would learn by experience how to reduce the cost of the technology and make biofuels out of a variety of sustainable feedstocks.

Diverse and sustainable sources of biomass including prairie grasses from the Great Plains, wood waste from our forests, and nonrecyclable garbage from our cities can generate clean biofuels and provide new economic prospects. Meeting the Billion Gallon Challenge would enable us to vastly expand biofuels production without sacrificing food production or the environment. We would be building the business case for the next round of private investment and ensuring American technology leadership in the clean fuels of the future. The opportunity to realize our country's clean energy potential is at hand, so let us embrace the challenge.

APPENDIX A.

Life-Cycle Accounting for Biofuels

Burning fuel in our cars and trucks generates CO_2 and other heat-trapping emissions, which are released directly from the vehicles' tailpipes. However, the story does not end there. The production of transportation fuels generates such emissions at all stages of the process: extraction, refining, and transporting the fuel to market. Accounting for the full life-cycle global warming emissions of different transportation fuels allows a comparison of their full climate impacts.

In the case of petroleum, the full life cycle accounts for the global warming emissions released at the oil well, the tankers and pipelines that move the oil to the refinery, emissions at the refinery where the oil is converted into gasoline, and the pipelines and delivery trucks that bring the gas to your corner gas station. These "upstream emissions" are about 20 percent of the total life-cycle emissions, with the balance coming from the tailpipe (EPA 2010a).

The life cycle of biofuels follows the same general logic, though the individual sources of emissions can be quite different. Consider corn ethanol, for example. To grow corn requires farmland, so we need to account for any emissions associated with securing that farmland. Growing the crop entails fertilizers, pesticides, and tractor fuel, each of which has emissions associated with its production and use. In addition to the emissions released during the manufacture of the fertilizer, some of the product will break down in the soil, releasing N_2O—a powerful heat-trapping gas—into the atmosphere. Harvesting and transporting the corn to a biorefinery produces further emissions from the tractors, trucks, and trains involved. The biorefinery also has emissions from the fuel used in heating and powering the conversion process, and from other inputs such as the enzymes and chemicals used to make and purify the ethanol. The ethanol is then moved by train, boat, or truck through the fuel distribution system to local gas stations.

A key feature of life-cycle analysis is that it accounts for efficiency and emissions reductions along the fuel's entire supply chain, regardless of the fuel type. Thus, investments in energy-efficient technology can reduce life-cycle emissions at petroleum refineries, say, as well as at biorefineries. Similarly, choosing low-carbon energy sources to power the facilities can reduce emissions. For example, production of corn ethanol requires heat, which can be provided by coal, natural gas, or renewable biomass. Using natural gas in place of coal will substantially reduce the life-cycle emissions of corn ethanol, and using low-carbon biomass as a source of heat and power provides an even bigger reduction.

While parts of the biofuels life cycle are closely parallel to the fossil fuels life cycle, biofuels life-cycle analysis has some unique elements. It does not generally include tailpipe CO_2 emissions, as the carbon in the fuel is understood to be balanced out by CO_2 absorbed by the plants as they grow. If producing the biofuels changes the ability of the affected ecosystems to absorb and sequester carbon, however, then the carbon emitted by burning the biofuels may not be balanced by the environment's uptake of carbon. Changes in land use, especially the conversion of forests to agriculture, can actually have a major impact on the capacity of that land to absorb and store carbon.

A simplified example may help to illustrate the situation. If you could power your car with the leaves that fall from the trees in your yard each autumn, the resulting CO_2 from the tailpipe would be offset by the CO_2 taken out of the atmosphere as new leaves grow the following spring. In this case the assumption that emissions would be balanced by regrowth may be a reasonable approximation of the truth. But if you cut down the tree and use it for fuel without planting a new tree in its place, then the tailpipe emissions from using that tree's leaves for fuel would add to global warming just like tailpipe emissions from gasoline. If you replace the tree with corn plants and use their harvest for fuel in subsequent years, the new corn crop each year would absorb some CO_2 from the atmosphere. This yearly amount would offset some gasoline emissions, but it would be a long time before the cumulative offsets added up to as much as was lost from cutting down the tree.

Thus, to accurately calculate the carbon costs and benefits of using plants to replace fossil fuels, we need to account for releases of carbon stored in plants and soils, and for changes in the amount of carbon taken up as one type of land use substitutes for another.[16]

Land-Use Changes

When previously unused land is converted to biofuels production, the global warming emissions associated with this change are relatively easy to understand and can be directly compared with the annual life-cycle savings from substituting the biofuels for fossil fuels. For example, if abandoned cropland is brought back into cultivation and used to produce biofuels, the emissions associated with the land-use conversion are minimal compared with the benefits of thus displacing fossil fuels. On the other hand, clearing a rainforest to grow soybeans for biodiesel releases more carbon from the soil and trees than the resulting biodiesel would displace in 300 years (Fargione et al. 2008; Gibbs et al. 2008).

Land-use changes also result when food production is converted to biofuels production. This happens even if the crop is unchanged—for example, when corn is diverted from food or animal feed to ethanol production. When corn leaves the food market, the footprint of agriculture gets that much larger because the demand for food remains the same. To make up for the lost food and animal feed, agricultural production must become more intensive, with increased use of fertilizers and irrigation, and it also gets more expansive as land is converted to agriculture from other uses. The emissions associated with the intensification and expansion of agriculture are very large (Searchinger et al. 2008).

Measuring these emissions is complicated because agricultural markets are global and affected by many different factors. But these questions are not unique to the subject of biofuels, and agricultural economists have developed models that describe how agricultural markets respond in general to changes in supply and demand. In some studies, they have used these models specifically to predict how biofuel production volumes could affect crop production worldwide. By combining the models with what is known about land-use changes and the carbon stored in different types of land, academic researchers and regulatory agencies—including the U.S. EPA and the California Air Resources Board—have been able to calculate the impacts that such changes, when carried out to support biofuels production, have on global warming emissions. The scientists conclude that the indirect emissions from making food crops into fuels is one of the largest sources of emissions associated with these fuels.

16 While land is also needed for gasoline production, the required acres per gallon are so much lower than for biofuels that they do not significantly affect the gasoline life-cycle analysis.

APPENDIX B.

Assumptions

Cost Assumptions

To model a program involving a new industry requires assumptions about costs, risks, and how they develop over time. We did not attempt to make highly detailed assumptions, however, preferring simple and conservative ones instead. In general we erred on the side of overestimating the likely cost of the programs we proposed; in that way we could ensure that the cost savings we projected were conservative. We assumed in particular that cellulosic biofuel technologies will have capital costs for the first billion gallons of $8/gallon of capacity and that these costs will decline by 5 percent with each subsequent billion-gallon milestone. Thus, after the 5-billion-gallon mark has been reached, the costs will have dropped by 25 percent to $6/gallon. These estimates, consistent with those of the EIA and DOE, steer a middle course that is broadly representative of the variety of potential production technologies (DOE 2009a; Marano 2008).

To calculate the cost to taxpayers of loan guarantees—we presumed that loan guarantees would be required for all facilities built as part of the first Billion Gallon Challenge—we used a subsidy rate[17] of 35 percent for the first billion gallons; this is what the Obama administration used for USDA loan guarantees in the 2010 budget (OMB 2009a). We assumed that this rate would drop by 2 percent with each subsequent billion gallons of built capacity, so that it would have declined to 25 percent by the end of the 5 Billion Gallon Challenge.[18] The same approach was used in calculating the value of the loan guarantee to the cellulosic biofuel developer.

After the first billion gallons, we expect that subsequent capacity will be increasingly supplied by scale-up and duplication of earlier facilities, so these ventures will increasingly not require loan guarantees once pioneer facilities have proven the technology and the economics and have begun commercial-scale production. Our cost estimates reflect 100 percent of facilities getting loan guarantees in the first billion gallons of capacity, 40 percent for the second billion gallons, and 20 percent for the third, fourth, and fifth billion gallons.

Loan guarantees were assumed to be for 90 percent of the capital cost of the project less any investment tax credits.

The cost of the investment tax credit was counted as a fixed percentage of the capital cost. This treatment would be appropriate for a tax credit convertible immediately into a grant, and it served as a conservative upper limit for our purposes. If the tax credit were claimed against future tax liabilities, the real cost to the government, and the benefit to fuel producers, would be lower than we described. The investment tax credit will phase out by 20 percent for each billion gallons, so that the tax credit of 30 percent for the first billion gallons will drop to 24 percent for the second billion, and so on, until it is phased out entirely after capacity reaches 5 billion gallons.

When projecting cost savings to taxpayers, we followed the guidance of OMB Circular A94 and presented the net present value of savings as discounted, using U.S. Treasury Note rates of appropriate maturities from the circular's Appendix C, updated in December 2009 (OMB 2009b; OMB 1992). Current tax credits and the Biofuels Production Tax Credit are fixed in nominal dollars and thus are discounted using nominal rates, while costs for capital support are presumed to increase with inflation and so are discounted using the real rates.

In the discussion of costs to the facility, we discounted future tax credits using an 8.7-percent nominal discount rate; because this calculation reflects the perspective of an investor rather than taxpayer expenses, Treasury rates would not be appropriate. The 8.7 percent encompasses the 7-percent real rate recommended by the circular, plus a 1.7-percent expected rate of inflation from the spread on real and nominal bond rates of equivalent maturity. We assumed that a loan guarantee

17 The subsidy rate is a ratio, used by the U.S. Office of Management and Budget (OMB), that incorporates the risk of default, the probable value of assets in case of default, and other factors to calculate a comprehensive economic value of the loan guarantee.

18 Twenty-five percent is still a relatively high rate, but the decline reflects lower risk based on the maturity of the industry when it will have reached commercial scale at numerous facilities nationwide.

would be for 90 percent of the remaining cost after subtracting the investment tax credit, and that the value to the investor of the loan guarantee would be equal to its cost to the government (obtained using a subsidy rate of 35 percent). The investment tax credit and loan guarantee were discounted at 7 percent, given that their value is fixed in real dollars.

Biofuels Volume Assumptions

Future fuel-production levels are difficult to predict, and because they depend on the costs of a broad variety of feedstocks, production pathways, and the values of tax credits and other types of support, they are beyond the scope of this analysis. Even if, at this point, we were able to project the impacts in detail of the changes in production caused by our policy prescriptions, there would be numerous scenarios that differed in so many particulars that it would be difficult to isolate the roles of individual factors.

However, to present the implications of our policy prescriptions in a straightforward manner, comparing costs across fixed fuel volumes, we focused on the RFS-mandated levels of fuel consumption (EPA 2010a) and made limited comparisons with the most recent EIA forecasts (EIA 2009e). To do so we had to make several simplifications and assumptions so as to reconcile inconsistencies between the biofuels categories in the RFS and the categories in the EIA forecasts. We treated all conventional biofuel mandates as pertaining to corn ethanol, and we assumed that production of corn ethanol would in all scenarios track exactly with the RFS-mandated levels of conventional biofuel. We treated imported ethanol as sugarcane and assumed it would satisfy the mandates for advanced renewable fuel. We treated liquids from biomass and ethanol from cellulose in EIA forecasts as cellulosic biofuel. We adjusted the volume of liquids from biomass based on energy content for purposes of RFS compliance and for calculating the cost of the Biofuels Performance Tax Credit, but not for calculating the cost of the existing volume-based tax credits.

Biofuels Emissions Assumptions

Because implementation of the Biofuels Performance Tax Credit would be based on the EPA's assessments—of the life-cycle emissions of different feedstocks and the conversion technologies at hundreds of individual facilities—and because these factors are expected to change over time, a detailed analysis of aggregate cost was beyond the scope of this project. Instead, we made highly simplified assumptions about the average changes in emissions of different biofuel categories.

We assumed that initially the different biofuel categories' global warming reductions—compared with the baseline (corn ethanol produced by today's typical natural-gas-fired technology using dried distillers grains)—would be similar to their RFS-mandated reduction levels relative to gasoline. For corn ethanol, the typical natural-gas-fired and coal-fired facilities would not qualify for any tax credit. But because some facilities would have already implemented energy-saving technologies, and therefore have emissions below the baseline, the average global warming emissions for purposes of claiming the tax credit would be 5 percent better than the baseline.

By contrast, we assumed that advanced biofuel and bio-based diesel would be scored at 50 percent below the baseline and that cellulosic biofuel would be scored at 60 percent below the baseline. The EPA did not do a 2012 life-cycle analysis of cellulosic biofuels, and based on later projections 60 percent is arguably an underestimate, but given that early facilities will be less efficient—that is, they will have higher input requirements and lower yields—than later facilities, 60 percent seemed a reasonable starting point.

We further projected that as fuel producers respond to the tax credit, the average emissions relative to the baseline will drop by 2 percent per year for a decade, so that by 2020 the average emissions will be reduced by 20 percent for each category. For corn ethanol, this projection is justified by the EPA analysis of the emissions reductions enabled by advanced technologies (such as biomass-fired combined-heat-and-power systems) at the biorefinery. For cellulosic biofuels, average reductions this large—made possible by choosing feedstocks and developing conversion systems that produce the lowest-carbon fuels—are well within the limits projected by the EPA analysis. For sugarcane ethanol, the EPA shows substantial opportunities to improve life-cycle emissions through increased collection of sugarcane tops and leaves for electricity production. For biodiesel, improvements are achievable through increasing the ratio of waste oil feedstocks to virgin soybean oil feedstocks.

We would not expect the emissions reductions in response to the tax credit to be identical in each sector, but 20 percent seemed like a reasonable average across the broad range of current and future biofuels. The results of the analysis illustrate the likely costs and emissions impacts of the Biofuels Performance Tax Credit over time.

References

ARI (Alternative Resources, Inc.). 2007. *Los Angeles County conversion technology evaluation report: Phase II—assessment. Converting waste into renewable resources.* Prepared for the County of Los Angeles Department of Public Works and the Los Angeles County Solid Waste Management Committee, Integrated Waste Management Task Force's Alternative Technology Advisory Subcommittee. Online at *http://www.socalconversion.org/pdfs/LACo_Conversion_PII_Report.pdf.*

ARRA. 2009. American Recovery and Reinvestment Act of 2009, HR 1. 111th Congress, 1st Session. Online at *http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h1enr.pdf.*

Babcock, B.A. 2010. Mandates, tax credits, and tariffs: Does the U.S. biofuels industry need them all? CARD policy brief 10-PB 1. Ames, IA: Center for Agricultural and Rural Development, Iowa State University. Online at *http://www.card.iastate.edu/publications/DBS/PDFFiles/10pb1.pdf.*

Babcock, B.A. 2008. *Breaking the link between food and biofuels*. Briefing paper 08-BP 53. Ames, IA: Center for Agricultural and Rural Development, Iowa State University. Online at *http://www.card.iastate.edu/publications/DBS/PDFFiles/08bp53.pdf.*

Baker, M.L., D.J. Hayes, and B.A. Babcock. 2008. Crop-based biofuel production under acreage constraints and uncertainty. Working paper 08-WP 460. Ames, IA: Center for Agricultural and Rural Development, Iowa State University. Online at *http://www.card.iastate.edu/publications/DBS/PDFFiles/08wp460.pdf.*

BlueFire. 2008. BlueFire ethanol receives first installment of DOE grant funds. Press release, July 29. Online at *http://bluefireethanol.com/pr/55/.*

Brasher, P. 2009. Biofuels projects have uncertain future. *Des Moines Register*, November 22.

CARB (California Air Resources Board). 2010. *California's Low Carbon Fuel Standard: Supplement to the final statement of reasons.* Sacramento, CA: California Environmental Protection Agency. Online at *http://www.arb.ca.gov/regact/2009/lcfs09/lcfssupprev.pdf.*

CARB (California Air Resources Board). 2009. *Regulations to implement the Low Carbon Fuel Standard: Final statement of reasons.* Sacramento, CA: California Environmental Protection Agency. Online at *http://www.arb.ca.gov/regact/2009/lcfs09/lcfsfsor.pdf.*

CBO (Congressional Budget Office). 2009. *The Troubled Asset Relief Program: Report on transactions through June 17, 2009.* Washington, DC. Online at *http://www.cbo.gov/ftpdocs/100xx/doc10056/06-29-TARP.pdf.*

CRS (Congressional Research Service). 2008. *CRS report for Congress: Biofuels incentives: A summary of federal programs.* Updated July 29. Washington, DC. Online at *http://fpc.state.gov/documents/organization/109550.pdf.*

DOE (U.S. Department of Energy). 2009a. *Biomass multi-year program plan,* B-4. Office of the Biomass Program. Washington, DC.

DOE (U.S. Department of Energy). 2009b. More than $600 million announced for advanced biorefinery projects. Press release, December 4.

EIA (Energy Information Administration). 2009a. *Updated annual energy outlook 2009*. April. Washington, DC: U.S. Department of Energy.

EIA (Energy Information Administration). 2009b. *September 2009 international petroleum monthly.* November 10. Washington, DC: U.S. Department of Energy. Online at *http://www.eia.doe.gov/emeu/ipsr/t21.xls.*

EIA (Energy Information Administration). 2009c. *Annual energy review*. Report DOE/EIA-0384(2008). Washington, DC: U.S. Department of Energy.

EIA (Energy Information Administration). 2009d. *Country analysis briefs, Brazil*. Washington, DC: U.S. Department of Energy. Online at *http://www.eia.doe.gov/emeu/cabs/Brazil/Full.html.*

EIA (Energy Information Administration). 2009e. *Annual energy outlook 2010 early release overview.* December 14. Washington, DC: U.S. Department of Energy. Online at *http://www.eia.doe.gov/oiaf/aeo/index.html.*

EIA (Energy Information Administration). 2008a. *Federal financial interventions and subsidies in energy markets 2007*. April. Washington, DC: U.S. Department of Energy. Online at *http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/index.html.*

EPA (U.S. Environmental Protection Agency). 2010a. *Regulation of fuels and fuel additives: Changes to renewable fuel standard program.* March 26. Federal Register:14669–15320.

EPA (U.S. Environmental Protection Agency). 2010b. *Renewable Fuel Standard program (RFS2) regulatory impact analysis.* February. Washington, DC.

EPA (U.S. Environmental Protection Agency). 2010c. *RFS2 final rule life cycle analysis supplemental materials.* February. Washington, DC. Online at *http://www.epa.gov/otaq/fuels/renewablefuels/RFS2-FRM-LCA-DocketMaterials.zip.*

EPA (U.S. Environmental Protection Agency). 2009a. *Inventory of U.S. greenhouse gas emissions and sinks: 1990–2007.* Report EPA 430-R-09-004. April 15. Washington, DC. Online at *http://www.epa.gov/climatechange/emissions/downloads09/InventoryUSGhG1990-2007.pdf.*

Ericson, J. 2007. Center researches grass as fuel. *Waterloo/Cedar Falls Courier*, September 2. Online at *http://www.wcfcourier.com/articles/2007/09/02/news/metro/d7744463126b100f8625734a000a14f0.txt.*

FAO (Food and Agriculture Organization of the United Nations). 2008. *The state of food and agriculture. Biofuels: Prospects, risks, and opportunities.* Rome, Italy. Online at *ftp://ftp.fao.org/docrep/fao/011/i0100e/i0100e.pdf.*

Fargione, J., J. Hill, D. Tilman, S. Polasky, and P. Hawthorne. 2008. Land clearing and the biofuel carbon debt. *Science* 319:1235–1238. February 29. Online at *http://www.sciencemag.org/cgi/content/abstract/319/5867/1235.*

Farm Bill. 2008. Food, Conservation, and Energy Act of 2008. H.R. 6124, 110th Congress, 2nd Session. Online at *http://www.usda.gov/documents/Bill_6124.pdf.*

Field, C.B., J.E. Campbell, and D.B. Lobell. 2008. Biomass energy: The scale of the potential resource. *Trends in Ecology & Evolution* 23:65–72.

Ford, G.S., T.M. Koutsky, and L.J. Spiwak. 2007. *A valley of death in the innovation sequence: An economic investigation.* Phoenix Center discussion paper. September. Online at *http://www.phoenix-center.org/Valley_of_Death_Final.pdf.*

Fulcrum. 2008. Fulcrum BioEnergy announces plans to build one of the first commercial-scale ethanol plants using municipal solid waste as feedstock. Press release, July 18. Online at *http://fulcrum-bioenergy.com/documents/SierraBioFuels07-18-08_002.pdf.*

GAO. (U.S. Government Accountability Office). 2009. *Biofuels: Potential effects and challenges of required increases in production and use*. August. Washington DC.

Gibbs, H.K., M. Johnston, J.A. Foley, T. Holloway, C. Monfreda, N. Ramankutty, and D. Zaks. 2008. Carbon payback times for crop-based biofuel expansion in the tropics: The effects of changing yield and technology. *Environmental Research Letters* 3:1–10. Online at *http://www.iop.org/EJ/abstract/-alert=33387/1748-9326/3/3/034001.*

Gibbs, H.K., A.S. Ruesch, F. Achard, M. Clayton, P. Holmgren, N. Ramankutty, and J.A. Foley. No date. Pathways of agricultural expansion across the tropics: Implications for forest conservation and carbon emissions. *Proceedings of the National Academy of Sciences* (USA). In review.

Himmel, M.E., S.-Y. Ding, D.K. Johnson, W.S. Adney, M.R. Nimlos, J.W. Brady, and D. Foust. 2007. Biomass recalcitrance: Engineering plants and enzymes for biofuels production. *Science* 315:804–807. February 9. Online at *http://www.sciencemag.org/cgi/content/abstract/315/5813/804.*

IRS (Internal Revenue Service). 2009. *Memorandum on black liquor: Excise tax credits*. No. 200941011. October 9. Office of Chief Counsel.

Ivry, B., and C. Donville. 2009. Black liquor tax boondoggle may net billions for papermakers. *Bloomberg.com*, April 17. Online at *http://www.bloomberg.com/apps/news?pid=20601109&sid=abDjfGgdumh4.*

JCT (Joint Committee on Taxation). 2009. Tax expenditures for energy production and conservation. JCX-25-09R. April 21. Online at *http://www.jct.gov/publications.html?func=startdown&id=3554.*

Katzen, R., and D.J. Schell. 2006. Lignocellulosic feedstock biorefinery: History and plant development for biomass hydrolysis. In *Biorefineries: Industrial processes and products,* Volume 1, edited by B. Kamm, P.R. Gruber, and M. Kamm. Weinheim: Wiley-VCH, 129–138.

Kemp, L. 2009. *Greener biofuels tax credit: A policy to drive multiple goals.* Shared winner of the climate change category of the Farm Foundation 30-Year Challenge Policy Competition. Online at *http://www.farmfoundation.org/news/articlefiles/1718-Loni%20Kemp.pdf.*

Kintisch, E. Minnesota ecologist pushes prairie biofuels. 2008. *Science* 322:1044–1045. November 14. Online at *http://www.sciencemag.org/cgi/content/summary/322/5904/1044.*

Lemos-Stein, M. 2009. Ethanol grant program shows challenge of new biofuels. *Dow Jones NewsPlus*, March 5. Online at http://checkbiotech.org/node/24963.

Marano, J.J. 2008. *Cellulosic ethanol technology: Data profile.* Report prepared for U.S. Department of Energy, Energy Information Administration. Contract no. DE-AM01-04EI42005.

Marshall, L., and Z. Sugg. 2010. *Fields of fuel: Market and environmental implications of switching to grass for U.S. transport.* WRI policy note, Energy: Biofuels, no. 5. April. Washington, DC: World Resources Institute.

Marshall, L., and Z. Sugg. 2009. *Corn stover for ethanol production: Potential and pitfalls.* WRI policy note, Energy: Biofuels, no. 4. January. Washington, DC: World Resources Institute. Online at *http://pdf.wri.org/corn_stover_for_ethanol_production.pdf.*

Mascoma. 2009. Mascoma announces major cellulosic biofuel technology breakthrough. Press release, May 7. Online at *http://www.mascoma.com/download/Technology%20AdvancesRelease%20-%20050709%20FINAL.pdf.*

Michigan. 2008. Mascoma Corporation announces $49.5 million in U.S. Department of Energy, State of Michigan funding for cellulosic fuel facility. State of Michigan press release, October 7. Online at *http://www.michigan.gov/minewswire/0,1607,7-136-3452-201341--,00.html.*

NAS (National Academy of Sciences). 2009. *Liquid transportation fuels from coal and biomass: Technological status, costs, and environmental impacts.* America's Energy Future, Panel on Alternative Liquid Transportation Fuels. Online at *http://www.nap.edu/catalog.php?record_id=12620.*

Obama, B. 2009. Letter to Governors' Biofuels Coalition. May 27. Online at *http://www.governorsbiofuelscoalition.org/assets/files/President%20Obama's%20Response%20(5-27-09).pdf.*

OMB (U.S. Office of Management and Budget). 2009a. Supplemental materials to the president's 2010 budget. Online at *http://www.whitehouse.gov/omb/budget/Supplemental/.*

OMB (U.S. Office of Management and Budget). 2009b. *Discount rates for cost-effectiveness, lease purchase, and related analyses.* Circular no. A-94, Appendix C, revised December.

OMB (U.S. Office of Management and Budget). 1992. *Guidelines and discount rates for benefit-cost analysis of federal programs.* Circular no. A-94.

Perlack, R.D., L.L. Wright, A.F. Turhollow, R.L. Graham, B.J. Stokes, and D.C. Erbach. 2005. *Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply.* DOE/GO-102005-2135. Oak Ridge, TN: Oak Ridge National Laboratory. Online at *http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf.*

Plevin, R.J., and S. Mueller. 2008. The effect of CO_2 regulations on the cost of corn ethanol production. *Environmental Research Letters* 3. May 15. Online at *http://iopscience.iop.org/1748-9326/3/2/024003/pdf/erl8_2_024003.pdf.*

Reuters. 2009. U.S. advanced biofuel sector finds lenders wary. October 29. Online at *http://www.reuters.com/article/idUSTRE59S5E220091029.*

RFA (Renewable Fuels Association). 2009. *Industry statistics.* Downloaded April. Online at *http://www.ethanolrfa.org/pages/statistics.*

Rosegrant, M.W., S. Msangi, T. Sulser, and R. Valmonte-Santos. 2006. Biofuels and the global food balance. In *Bioenergy and agriculture: Promises and challenges*, edited by P. Hazell and R.K. Pachauri. Washington, DC: International Food Policy Research Institute. Online at *http://www.ifpri.org/sites/default/files/publications/focus14.pdf* .

Searchinger, T., R. Heimlich, R.A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, and T.-H. Yu. 2008. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science* 319:1238–1240. February 29. Online at *http://www.sciencemag.org/cgi/content/abstract/319/5867/1238.*

SmartWood. 2008. Forest management certification assessment report for: J.M.L. Heirs, LLC, in Marquette, MI. November 25. Richmond, VT: SmartWood. Online at *http://www.rainforest-alliance.org/forestry/documents/jmlheirspubsum08.pdf.*

Tilman, D., J. Hill, and C. Lehman. 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. *Science* 314:1598–1600. December 8. Online at *http://www.sciencemag.org/cgi/content/abstract/314/5805/1598.*

Tilman, D., R. Socolow, J.A. Foley, J. Hill, E. Larson, L. Lynd, S. Pacala, J. Reilly, T. Searchinger, C. Somerville, and R. Williams. 2009. Beneficial biofuels—the food, energy, and environment trilemma. *Science* 325:270–271, July 17. Online at *http://www.sciencemag.org/cgi/content/short/325/5938/270.*

USDA (U.S. Department of Agriculture). 2009a. *USDA agricultural projections to 2018.* February 2009. Washington, DC. Online at *http://www.ers.usda.gov/Publications/OCE091/OCE091.pdf.*

USDA (U.S. Department of Agriculture). 2009b. Feed grains database. Downloaded December 1. Online at *http://www.ers.usda.gov/Data/FeedGrains/.*

WBJ (*Waste Business Journal*). 2009. Waste market overview and outlook.

White House. 2009. President Obama announces steps to support sustainable energy options. Departments of Agriculture and Energy, Environmental Protection Agency, to lead efforts. Press release, May 5. Online at *http://www.whitehouse.gov/the_press_office/President-Obama-Announces-Steps-to-Support-Sustainable-Energy-Options/.*

Yang, B., and C.E. Wyman. 2008. Pretreatment: The key to unlocking low cost cellulosic ethanol. *Biofpr [Biofuels, Bioproducts, and Biorefining]* 2(1):26–40. Online at *http://www.biofpr.com/details/journalArticle/107122/Pretreatment_the_key_to_unlocking_lowcost_cellulosic_ethanol.html.*

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THE BILLION GALLON CHALLENGE

GETTING BIOFUELS BACK ON TRACK

Biofuels hold out the promise of alleviating two major problems: oil dependence and global warming emissions from transportation. Yet despite numerous government programs and subsidies, biofuels are not measuring up to their potential.

This report assesses the current state of our biofuels policy landscape and lays out a plan to get biofuels back on track. Its key element is the Billion Gallon Challenge, which if met would commercialize cellulosic biofuels at 10 to 20 commercial-scale facilities around the country. Diverse and sustainable sources of biomass such as prairie grasses from the Great Plains, wood waste from our forests, and nonrecyclable garbage from our cities can generate clean biofuels and provide new economic opportunities.

This report is available on the UCS website at *www.ucsusa.org/smartbioenergy*.

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