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FUNDAMENTALS OF A SUSTAINABLE U.S. BIOFUELS POLICY

INTRODUCTION

Each year, billions of dollars in federal subsidies and tax breaks go to domestic ethanol producers in the hope that biofuels will become a major plank of an energy security and fuel diversification program for the United States. Biofuels, an alternative to traditional gasoline, are often considered an environmentally friendly way to reduce dependence on foreign oil and to lower greenhouse gas emissions. However, whether the current U.S. biofuels program is worth the high costs of implementation or even benefits the environment is still up for debate.

Like many previous energy policies, the new U.S. biofuels program is creating unintended consequences that need to be addressed. In this report, we endeavor to provide an overview of some of the economic, logistical, and environmental challenges to a broader expansion of biofuels in the U.S. transportation fuel system, and we offer a range of policy recommendations to avoid some of the negative unintended consequences of pursuing this ambitious program.

GOALS AND DRAWBACKS OF THE U.S. BIOFUELS PROGRAM

It was hoped that biofuels could provide a ready substitute if the price of oil were to rise too sharply, shielding the economy from the negative impact of a disruption of oil. The Energy Policy Act of 2005 (EPA 2005) set new regulatory targets for the amount of biofuel to be added to the U.S. gasoline supply. Initial stages focused on corn-based ethanol from the U.S. Midwest. The U.S. biofuels program is mandated to expand to include “advanced” biofuels from cellulosic waste, but a commercially viable process for the wide-scale production of cellulosic biofuels has yet to be launched.

The EPA 2005 required 7.5 billion gallons of renewable fuel to be produced annually by 2012 in what is known as the Renewable Fuel Standard (RFS). In an apparent push to accelerate ethanol use, the Energy Independence and Security Act of 2007 (EISA) subsequently set production targets for renewable fuels at 9 billion gallons annually for 2008, expanding to 36 billion gallons per year by 2022.¹ Corn ethanol production, under the 2007 bill, is to be capped at 15 billion gallons per year, or close to 1 million barrels per day (b/d), in 2015. The bill specifies that 16 billion gallons per year should come from cellulosic ethanol by 2022.

To date, 2009 mandates for advanced biofuels, such as those made from cellulosic materials or other non-food crops, do not appear to be achievable and will be rolled into 2010 mandates. Yet 2010 mandates may be similarly difficult to meet. From January through September 2009, the United States produced an average of 678,000 b/d of ethanol, or the equivalent of 10.4 billion gallons at an annualized rate, mainly from corn.

Not all of the ethanol is a direct substitute for gasoline, however. About 6 billion gallons per year (or 400,000 b/d) of ethanol are needed in the United States to replace the potentially carcinogenic gasoline additive methyl tertiary-butyl ether (MTBE). Thus, production levels of 678,000 b/d of ethanol only net

¹ “Renewable fuel” is defined as motor vehicle “fuel that is produced from renewable biomass and that is used to replace or reduce the quantity of fossil fuel present in a transportation fuel.” Renewable fuel therefore includes conventional biofuel and advanced biofuels like cellulosic biofuel, waste-derived ethanol, and biodiesel. RFS2 includes the first definition of and requirement to use “renewable biomass.” Further, it creates land use restrictions limiting renewable biomass to existing agricultural land prior to Dec. 19, 2007, and excludes “new” land from being used in the production of feedstocks for advanced renewable fuels. (*Title II – Energy Security through Increased Production of Biofuels, SEC.201. Definitions.* Energy Independence and Security Act of 2007. H.R.6.)

about 278,000 b/d of ethanol that actually displace gasoline rather than replace MTBE, which was a natural gas-based product. What's more, ethanol has a lower energy content than traditional gasoline, so more fuel is required to travel the same distance. All told, ethanol is only displacing the equivalent of about 185,000 b/d of gasoline. This figure compares with average gasoline demand of 9 million b/d. Thus, ethanol production is not yet significantly replacing gasoline per se, but is replacing additives removed from the fuel system on environmental grounds.

In addition, the cost of displacing this gasoline is very high. Based on the latest available U.S. Government Accountability Office data, which is for the year 2008, the U.S. government spent \$4 billion in subsidies to replace about 2 percent of the U.S. gasoline supply. The average cost to taxpayers for these "substituted" traditional gasoline barrels was roughly \$82 per barrel, or \$1.95 per gallon (gal) on top of the gasoline retail price.

While ethanol production raises serious supply and cost issues, our study supports the premise that corn ethanol is a more environmentally safe additive than MTBE, which has been found to contaminate groundwater, in the sense that ethanol is easily degraded in the environment and, in contrast to MTBE, human exposure to ethanol itself presents minimal adverse health impacts. However, scientific research demonstrates the addition of ethanol to gasoline in amounts higher than 10 percent will impede the natural attenuation of BTEX (benzene, toluene, ethylbenzene, and xylenes) in groundwater and soil, posing a great risk for human exposure to these toxic constituents present in underground storage tank leaks.

Another environmental challenge is related to the consequences of expanded crop production to create biofuels. Without major reforms in the regulation of farming practices, increased corn-based ethanol production in the Midwest could cause an increase in detrimental environmental impacts, including exacerbating damage to ecosystems and fisheries along the Mississippi River and in the Gulf of Mexico and creating water shortages in some areas experiencing significant increases in fuel crop irrigation.

Some of the consequences of groundwater contamination and crop expansion could be managed by site cleanup and agricultural policy adjustments, respectively.

The role of biofuels in reducing greenhouse gas emissions in the transportation sector is less clear. Studies demonstrate that the production and use of ethanol are not carbon neutral, whether corn-based ethanol or advanced cellulosic fuels are at issue. The preponderance of evidence shows that existing biofuels offer no improvement over traditional gasoline, once land use changes and emissions of nitrous oxide emitted during production are taken into account. Thus, legislation giving preference to biofuels on the basis of greenhouse gas benefits should be avoided.

ANALYZING THE IMPACT OF ETHANOL SUBSIDIES AND TRANSPORTATION COSTS

Subsidies and Tax Credits

Various federal and state incentives, such as blender credits and import tariffs, have been adopted to promote domestic ethanol production. Currently, three major federal policies are relevant to biofuels: a Renewable Fuel Standard; a subsidy for blending biofuel with gasoline; and a tariff on imported ethanol.

The RFS and blending subsidy aim to promote the production and consumption of biofuels in the United States, while the tariff acts to restrict the import of ethanol—in effect ensuring it remains a "homegrown" fuel. In addition, a variety of smaller federal policies help fund research and development (R&D) or grant subsidies to various constituencies related to biofuels, such as farmers, certain ethanol producers, and gasoline station owners who install pumps to sell E-85, a blend of 85 percent ethanol and 15 percent gasoline.

The American Jobs Creation Act of 2004 replaced previously authorized gasoline tax exemptions and credits with the Volumetric Ethanol Excise Tax Credit (VEETC), which gave the credit directly to producers who blend ethanol with gasoline (the so-called "blenders"). The rate of the credit was initially \$0.51/gal, although it was reduced to its current level of \$0.45/gal in the 2008 Farm Bill. VEETC is authorized until the end of 2010.

Approximately \$3.2 billion in tax credits were given to gasoline blenders in 2007. Thus, 76 percent of all funds allocated by the federal government for all U.S. renewable energy developments, as laid out in EPAct 2005, went to gasoline blenders to support the introduction of ethanol into the transport fuel market. The federal government also provides a production income tax credit, in the amount of

\$0.10/gal for the first 15 million gallons of ethanol produced annually (the credit is capped at \$1.5 million per producer per year) to “small” ethanol producers who manufacture less than 60 million gallons per year.

Despite these subsidies, in the first quarter of 2009, more than 25 biofuels facilities closed nationwide in the aftermath of the financial crisis, according to the U.S. House of Representatives Small Business Committee. A survey of ethanol production in March 2009 found that roughly 17 percent of ethanol plant capacity stood idle. Several major ethanol producers went bankrupt early this year, and some facilities were purchased by large oil refining companies. The rising cost of corn feedstock and high costs of ethanol production and transportation, compared to falling gasoline prices, hurt the profitability of ethanol businesses.

Additional appropriations were made to support the biofuels industry through President Barack Obama’s 2009 economic stimulus package. The bill includes \$480 million for integrated pilot and demonstration-scale biorefineries to produce advanced biofuels, bioproducts, and heat and power in an integrated system; \$176.5 million to increase the budget for existing federal assistance for commercial-scale biorefinery projects; \$110 million for fundamental research for demonstration projects, including an algal biofuels consortium; and \$20 million for research related to promoting E-85 fuel and studying how higher ethanol blends (E-15 or E-20) affect conventional automobiles.

Transportation and Distribution Issues

Critics of the fledgling U.S. biofuels industry say corn ethanol is costly, environmentally unfriendly, and inefficient. Supporters argue that it will pave the way for a more general ethanol and biofuels infrastructure, which in turn will create new markets for imported sugarcane-based ethanol and other alternative fuels, including cellulosic ethanol and other advanced biofuels.

Despite substantial efforts by the federal government to promote ethanol production and use, current U.S. production is concentrated in the Midwest. Unfortunately, the distribution system to other parts of the country and along the coasts, where most of the nation’s gasoline is consumed, is not well-developed. This creates difficulty in expanding ethanol use in a cost-effective manner, regardless of the public funds devoted to encouraging production.

Transportation costs, bottlenecks, and other logistical issues also keep many states from significantly increasing ethanol consumption. In fact, the majority of states—especially in areas farthest from the Midwest—have not achieved a 10 percent average ethanol content level (E-10 fuel). For E-10 to be a national average, states with an ethanol surplus would likely have to use more than 10 percent ethanol in their fuel to compensate for other states unlikely to achieve the average, unless tariffs on ethanol imports are removed. In 2008, only nine states had a surplus of ethanol, and all were located in the Midwest (North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Wisconsin, Illinois, and Indiana), and none represented a sizable transportation market.

On a practical level, it will be difficult for any state to exceed 10 percent ethanol-blended fuels. One reason is that automobile manufacturers will not extend warranties on engines or parts in vehicles that use more than 10 percent ethanol content in fuel, except for flex-fuel vehicles (FFV) specifically designed to run on E-85 fuel. This is problematic because E-85 FFVs represented only 3 percent of the car fleet as of March 2009, and more than one-third of the nation’s limited number of E-85 retail pumps are in Minnesota, Iowa, and Illinois, states near major ethanol production centers. Even in states that offer E-85 fuel, only a small fraction of retail outlets offer E-85. Moreover, most citizens in those states do not drive FFVs. Thus, the potential to exceed 10 percent ethanol—even in the Midwest—is greatly constrained.

Some advocates are pressing Congress to mandate that all new cars manufactured in America be fitted as FFVs. Should such a bill pass, considering the fact that the vehicle fleet turns over slowly and not all vehicles sold in the United States are produced in the United States, it would take well over a decade for FFVs to comprise a majority of the American car fleet.

Thus, at this juncture, most cars on U.S. roads will continue to require fuel that contains no more than 10 percent ethanol, creating the so called E-10 “blending wall,” and greatly restricting ethanol use throughout the United States beyond 10 percent. Furthermore, retail fueling stations are unlikely to go to the expense of adding a tank to sell E-85 fuel unless there are a large number of drivers willing to buy it, creating a classic chicken-and-egg problem.

The Environmental Protection Agency (EPA) recently delayed a decision on whether to increase

the amount of ethanol that can be blended into gasoline. The agency said more testing was needed to know if a 15 percent ethanol level would be harmful to vehicles, but added that a decision could be made by mid-2010. Fuels containing more than 10 percent ethanol have high evaporative qualities, making it challenging for car makers to meet state and federal emissions standards in non-FFVs. In addition, car components—including fuel tanks, pumps, lines, injectors, and calibrations—must be adjusted because the unique chemical properties of ethanol can corrode seals and other engine parts. Thus, any regulation must recognize that the entire gasoline pool cannot be changed to 15 percent ethanol unless all cars on the road can use it without risk of damage to individual vehicles. Enforcing such a change could prove costly.

As noted above, most ethanol is produced in the Midwest—the nation’s Corn Belt. In 2007, the United States produced 155.2 million barrels of ethanol, of which 96.4 percent came from the Midwest. By 2008, total U.S. ethanol production had increased to 219.9 million barrels, of which 205.7 million barrels were from nine midwestern states. Even so, only 80 percent of the fuel blended in the Midwest averaged 10 percent ethanol.

The other 41 states did not achieve an average of 10 percent ethanol level. In fact, as of 2008, motor fuel use in no region of the United States averaged 10 percent ethanol. In the Northeast, about 60 percent of the fuel attained an average of 10 percent ethanol; the South, 42 percent; the West Coast, 63 percent; and the Northwest, only 36 percent. The regions farthest from the Midwest are using less ethanol than central states primarily due to the high transportation costs that make ethanol economically uncompetitive compared to unblended gasoline.

Gasoline is produced at refineries in the Midwest and along the coasts near urban areas that consume the largest volumes. It is transported very cheaply around the United States via pipeline from refineries to local distribution centers (where trucks are loaded for short-range delivery to local gasoline stations) or directly to major industry consumers. In the United States, an estimated 160,868 miles of liquid petroleum pipelines transport “hazardous liquids” (mainly crude oil and refined petroleum products). This extensive pipeline network means that traditional gasoline can be transported across the country for pennies per barrel. By contrast, no ethanol is shipped via this same economical liquid petroleum pipeline network in the United States due

to fuel quality and pipeline integrity concerns, as well as economic barriers.

Pipeline transportation of ethanol in the United States has been researched and tested on a relatively small scale. However, questions remain about the viability of the construction of a vast ethanol pipeline network comparable to the existing gasoline transportation system. At first, it was deemed impossible due to ethanol’s water solubility and tendency to mix with any water present in the pipelines (water is used to clean pipelines and can also enter the system during fuel entry and exit). An ethanol-only pipeline could reduce the chance of water blending, at a high cost, but still there would be the risk of water contamination during ethanol transfer between modes of transportation. The corrosive effects of water-carrying ethanol have resulted in the general reluctance of pipeline owners to share their facilities for the transport of ethanol.

Still, Brazilian state oil firm Petrobras has been shipping ethanol in multiproduct pipelines for several years without adverse effects on infrastructure or conventional car engines in Brazil. Special procedures separate ethanol from other products to prevent contamination.

Even if U.S. pipeline owners could be persuaded to try these methods, the geography of pipelines in the United States works against batching ethanol into existing pipeline infrastructure. Most U.S. refined product pipelines are either not in the right place or flowing in the wrong direction. Specifically, existing infrastructure mainly ships product from southern U.S. coastal states northward toward the Midwest instead of in the opposite direction. Thus, there are few existing pipelines that flow product out of the Midwest that could be tapped for ethanol shipments, should a feasible way to batch and separate the ethanol shipments become available.

Another solution would involve the construction of a dedicated ethanol pipeline distribution network. One U.S. pipeline currently transporting ethanol successfully is Kinder Morgan’s existing oil pipeline in Florida. The pipeline moves pure ethanol from Tampa Bay to Orlando to be blended with gasoline. A batch pipeline with ethanol and oil protects against corrosion. So far, the Kinder Morgan pipeline has been the exception, not the rule, and concerns about the sustained level of scaled-up production has created a chicken-and-egg barrier to ethanol pipeline development and financing.

If direct connections between the distillery and the blending terminal could be facilitated by

pipelines, the cost of ethanol transport would be considerably lower, on the order of only \$0.02/gal, compared with between \$0.20/gal and \$0.30/gal. Given that most existing and planned ethanol processing and distillation occur in the Midwest, this can create large price differentials across the United States. It has been argued, therefore, that the development of pipeline capacity that could be dedicated to the transport of ethanol could potentially drive down regional price differentials and improve the competitiveness of ethanol. The commercial viability of a pipeline, however, depends crucially on a sufficient throughput volume to drive down cost.

To justify the construction of a major pipeline, ethanol processing and distillation capacity must be sufficiently large to provide an economy of scale benefit. But economies of scale similar to gasoline and other petroleum products do not exist for non-capital costs related to the construction of ethanol manufacturing facilities. Generally speaking, the two largest expenses for an ethanol producer are the cost of the feedstock and the cost of electricity and natural gas. An ethanol producer will not enjoy any per-unit cost reductions associated with scaling-up activity on these fronts, as the market rates must be paid for both feedstock and operating fuel. Generally, scaling-up activity increases demand for the feedstock, which will tend to push up feedstock prices (especially if it is an industry-wide phenomenon) and thereby diminish any scale economies. This phenomenon has already taken place with the rising cost of corn in the United States.

If the scale economies associated with expanding production capacity are indeed minimal, the chances that investors will choose to build larger facilities are reduced, given the difficulties of amassing large amounts of biomass in one place. The prevalence of smaller-sized plants reduces the likelihood that a sufficient production volume will be amassed in a central location to justify pipeline development. In fact, recent projections by the Washington, DC-based Renewable Fuels Association indicate that the number of ethanol refineries will rise substantially by 2011, but the average size of production facilities will only increase slightly, to little more than 4.4 thousand b/d or about 67 million gallons per year. By comparison, oil refineries typically produce hundreds of thousands of barrels of petroleum products each day. Given the relatively small scale of new developments, a gathering system

would be needed to aggregate ethanol production volumes to a central location if pipeline development is to become economically viable.

As a result of these barriers to ethanol transport by pipeline in the United States, there are three primary modes of transportation for ethanol: truck, rail, and barge. As of 2005, rail handled 60 percent of total ethanol transportation, trucks handled 30 percent, and barges handled 10 percent. The lack of large-scale ethanol pipeline infrastructure increases distribution costs for ethanol to be used as either an additive to gasoline or as a substitute fuel, especially in the main gasoline consumption regions along the U.S. coasts. Problematically, rail, tank, and barge transport for ethanol mean that oil-based fuel is consumed in ethanol distribution, constraining the amount of gasoline, and thereby oil, that ethanol can truly displace.

Current government support is *required* for ethanol produced in the Midwest to be an attractive option to blenders in most other parts of the country. The farther the end-use market is from the Midwest, the more the price of ethanol to the blender increases, reflecting higher transportation costs from the major producing regions to U.S. coastal regions. In addition, the *relative* price of ethanol to gasoline also increases. The reason for this is twofold: the price of ethanol is generally higher the farther the geographic distance from the Midwest, reflecting transportation cost differentials; and the price of gasoline is generally lower along U.S. coastal regions because it is closer to gasoline production and import delivery points.

The relative price of ethanol to gasoline is important because it determines the competitiveness of the two fuels. Given that ethanol has a lower heating value than gasoline—hence yielding lower fuel efficiency—ethanol's price must be no more than roughly two-thirds of the price of gasoline to make it competitive in the marketplace to sell a blended mixture. Only if ethanol is cheaper than gasoline will blenders make a profit by adding ethanol to their fuel. Thus, the closer the relative price of ethanol-to-gasoline is to 100 percent, the less profitable an option it becomes to blend ethanol into gasoline. Without government subsidies, the average ethanol price compared to gasoline will not be commercially competitive in most regional markets in the United States to incentivize blenders to add ethanol to gasoline.

Coastal regions farthest from the Midwest could easily import ethanol through existing

port infrastructure. The relatively low ethanol production costs in Brazil and production potential in the Caribbean and Central America could make importing ethanol a lower cost option. So, for example, blenders in Texas and other Gulf Coast states can either import ethanol via rail and truck from domestic inland locations such as Iowa, or they can import ethanol via ship from foreign locations such as Brazil or Guatemala. This could substantially help Gulf Coast states successfully meet a 10 percent ethanol content level. Notably, the per-unit cost of transport in the latter case is much lower than the U.S. Midwest option, given relative distances and transport costs.

The current tariff on imported fuel ethanol is \$0.54/gal plus a 2.5 percent ad valorem tax. Ethanol from United States–Dominican Republic–Central America Free Trade Agreement (CAFTA) countries is not subject to the tariff. So far, CAFTA countries have used duty-free access to import Brazilian hydrous ethanol and export anhydrous ethanol to the United States. Only Nicaragua has a substantial domestic ethanol industry based on domestically grown sugarcane. The Caribbean Basin Initiative (CBI) provides another way for imported ethanol to get into the country duty-free, but it only allows importation to expand to a maximum of 7 percent of U.S. domestic ethanol production. Given the production cost differentials between sugarcane ethanol and corn-based ethanol, these tariffs ensure that corn-based ethanol gets the priority share of the market.

Most estimates place ethanol production costs using sugarcane as the primary feedstock at the equivalent of roughly 30 percent of the average production costs using corn as the primary feedstock. This means that imports of sugarcane-based ethanol have a competitive advantage in certain U.S. coastal markets.

If U.S. government support for U.S. manufactured, corn-based ethanol were removed, it is likely that U.S. domestic production would fall dramatically because Brazilian imports could land economically in U.S. coastal markets for just over \$1.00/gal, which would represent a \$0.60/gal savings over unsubsidized domestic ethanol prices. Arguably, this would make importing ethanol much more attractive than producing ethanol domestically in the Midwest and shipping it to coastal areas. Current U.S. tariffs and subsidies ensure that domestic ethanol will be more competitive than shipping foreign ethanol inland. Innovation

will have to drive down domestic production and transportation costs if domestic ethanol is to compete longer term for the large coastal U.S. markets and make ethanol commercial throughout the United States. If the tariff on imports were removed, prices for corn would have to fall below \$3.00 per bushel to allow U.S. domestic corn-based ethanol to compete against sugarcane-based ethanol imports along large, fuel-consuming coastal regions of the United States.

POTENTIAL SUPPLY FROM LATIN AMERICA AND THE CARIBBEAN

The United States could very likely meet its target of 36 billion gallons of ethanol by 2022 largely through imports from Latin America. Of course, this would mean that ethanol would no longer be homegrown. Other countries will also be competing for Latin American supplies, though areas in Asia and Africa have a rich ethanol potential as well. Therefore, while the reality is that the United States will likely import from a number of regions—as will Europe—the bottom line is that there is sufficient ethanol production capability within the Western Hemisphere to supply most of the ethanol that the United States has mandated over at least the next decade.

The Baker Institute estimates that Latin America could supply somewhere between 22 to 89 billion gallons of ethanol per year, if a larger push were made to utilize more of the available arable land in the region for sugarcane growth. Given that ethanol contains about 65 percent of the energy content of gasoline and that a barrel of oil consists of 42 gallons, these outputs translate into about 0.93 to 3.78 million b/d of crude oil equivalent. The United States alone consumes more than 21 million b/d, while Central and South America consume about 6 million b/d. Together, ethanol production from these countries could displace more than 10 percent of Western Hemisphere crude oil demand.

Brazil is now the world's largest ethanol exporter and the second-largest producer of ethanol with output at 6.9 billion gallons (out of world production of 20.4 billion gallons) in 2008, a significant increase from 2004, when only 3.8 billion gallons were produced. Much of the increased production has come from increasing the acreage devoted to sugarcane cultivation. But productivity of sugarcane has also increased substantially over time, reaching an average of 65 metric tons per hectare (t/ha), the

equivalent of about 29 tons per acre (tn/ac). In some regions in São Paulo, yields have reached 100 to 110 t/ha (45 to 49 tn/ac), representing a 33 percent increase since the mid-1970s. Plans are to increase production in São Paulo by 50 percent between 2008 and 2010.

It took Brazil many years and substantial subsidies, which have been phased out, to reach current production levels. Brazil's approach to promoting ethanol use was to mandate that gasoline be mixed with 10 percent ethanol and that this should be increased to 25 percent by 1980. In addition, the government provided loans for the construction of ethanol plants and guaranteed the price of ethanol. Following an oil price spike in 1980, the government required Petrobras, the state-owned oil company, to supply ethanol to filling stations. In order to promote the substitution of ethanol for gasoline, the Brazilian government also introduced subsidies for automakers for the production of vehicles that could run on E-100, or pure ethanol fuel. The market for these cars collapsed along with oil prices in the 1980s. However, the market for vehicles using ethanol was restored in the early 2000s with the introduction of FFVs that can operate using either ethanol or gasoline. FFVs now account for roughly 85 percent of new car sales in Brazil. Still, the program was expensive. One estimate put Brazilian government subsidies from 1979 to the mid-1990s at more than \$16 billion in 2005 dollars.

While the potential in Brazil is well known, Cuba could also become a major ethanol exporter if it could recapture its historical comparative advantage by returning acreage that has been diverted to other uses back to sugarcane cultivation. In Nicaragua and Brazil, growers have been getting agricultural yields of 75 to 80 t/ha (33 to 36 tn/ac) of sugarcane, and distillers have been achieving yields of 70 to 80 liters per metric ton (L/t) of sugarcane, roughly 17 to 19 gallons per ton (gal/tn). At 75 t/ha and 75 L/t (5,625 L/ha, or 600 gal/ac), Cuba would need 1.33 million hectares (3.3 million acres) to produce 2 billion gallons of ethanol. Moreover, agricultural productivity is continually improving as new plant varieties and new cultivation practices are developed through research and innovation. In some regions of Brazil, yields of 84 t/ha (37 tn/ac) and 82 L/t (20 gal/tn) of sugarcane (6,888 L/ha, or 750 gal/ac) have been achieved, and even higher yields have been achieved in some areas of São Paulo. If similar yields were reached in Cuba, ethanol production

could reach 2 billion gallons with only 1.1 million hectares (2.7 million acres) of harvested land.

Regarding the energy security emphasis of expanding domestic ethanol production in the United States, it is worth noting that imported ethanol would come largely from countries that are not current suppliers of crude oil. As a result, imported ethanol could at least diversify the U.S. foreign energy supply portfolio and thus contribute to energy security. In addition, ethanol produced in developing countries could be an engine for growth for countries that are not endowed with conventional oil resources, helping U.S. regional allies. Still, these benefits would have to be weighed against the risks that increased ethanol production in Latin America and the Caribbean could come at the expense of forest land or rainforest or could face political risk from worker unrest or resource nationalism.

Beyond the possibility of gaining more ethanol from abroad, the U.S. refining industry, among others, is attempting to address some of the logistical and economic barriers to ethanol transportation by developing alternative, renewable fuels from source material other than corn, such as cellulosic materials and other crops. ExxonMobil Corporation recently announced a new joint venture with Synthetic Genomics, Inc., to develop advanced biofuels from photosynthetic algae. In its brochure regarding the algae program, ExxonMobil states that "algae yield greater volumes of biofuel per acre of production than crop plant-based biofuels sources. Algae could yield more than 2,000 gallons of fuel per acre of production per year" as compared to corn (about 400 gal/ac) or sugarcane (600-750 gal/ac). The fuel produced from the proposed process would have properties compatible to existing gasoline and diesel fuel and therefore could be blended directly into the existing fuel pipeline distribution system. Tanks for growing the algae, while potentially a not-in-my-backyard headache, could be located closer to regional centers with high gasoline consumption, and algae could be grown in tanks or ponds in areas that are not suitable for crop and food production. Chevron and other companies are also working on research to convert agricultural waste and other non-food crops into renewable transportation fuels.

ENVIRONMENTAL ISSUES RELATED TO BROADER USE OF BIOFUELS

Meeting the mandated increased production of biofuels will inevitably result in increased agricultural activity, such as tilling more acres and higher agrichemical application. These changes will lead to adverse environmental impacts that range from local groundwater degradation to eutrophication of distant coastal waters. Runoff from nitrogen fertilizers results in the most apparent example of eutrophication: the Gulf of Mexico's "dead zone," a large area of poorly oxygenated water (hypoxia) near the mouth of the Mississippi River in which some organisms, particularly those living near the sea bed, cannot survive, resulting in limited biodiversity and an altered ecosystem.

Annual row crops, such as those typically used as biofuel feedstocks, are especially prone to cause soil erosion and nutrient runoff to surface water, with corn having one of the highest nutrient application rates and nutrient loading to surface waters. Marginal lands—which may require even greater fertilizer application and may be more susceptible to erosion and runoff—will also be pressed into agricultural service to meet the EISA mandate. This will create the potential for a substantial increase in detrimental impacts to water quality.

Agrichemical runoff includes both fertilizers (nitrogen and phosphorous) and chemicals designed to kill pests (herbicides, fungicides, and pesticides such as atrazine and alachlor for corn and glyphosphate for soybeans). Nitrogen and phosphorous discharge are considered some of the primary contributors to the hypoxic zone in the Gulf of Mexico, which covered more than 20,000 km² (7,700 mi²) in 2007. Although observations show that hypoxic zones have naturally occurred throughout geologic time, the shallow coastal dead zone of the Gulf of Mexico has increased in size since the 1950s, and is believed to have caused a decrease in species diversity, along with slumping yields. Marine species are affected by such factors as altered food supplies, forced migration, habitat reduction, and increased susceptibility to predation.

Pesticides are toxic to humans as well as to other fauna. A 10-year (1992–2001) survey of U.S. streams and groundwater showed that pesticides occurred in more than 50 percent of the wells sampled in shallow groundwater and in 33 percent of deeper wells. Roughly 97 percent of stream waters in

agricultural areas presented pesticide compounds, and particularly high concentrations were found in the Corn Belt. The increase in agriculture to meet the U.S.-mandated 15 billion gallons of fuel ethanol from corn by 2015 will require an expansion of agrichemical applications, including 2.17 million tons of additional nitrogen fertilizer, or about 16 percent of the nitrogen fertilizer used for all crops in the United States. The high fertilizer application rates, especially for row crops in the midwestern United States, contribute an estimated 65 percent of nitrogen loads and the greatest flux of phosphorus to local waterways and the Mississippi River basin.

There are steps that can, and likely should, be taken to reduce the problems of nutrient runoff. A variety of technological options can be used to reduce runoff, including contour farming, terraced farmland, reduced nitrogen application, grassed waterways, restored wetlands, and reduced tillage practices such as no-till or conservation tillage agriculture.

The presence of tile drainage is a very important factor in determining nutrient transport fluxes. Tile drainage involves a network of clay, concrete, or perforated plastic subsurface pipes that hasten removal of excess water, which in turn improves nutrient uptake of plant roots. A study comparing tile-drained and non-drained soils in Iowa showed that the fraction of nitrogen fertilizer lost to surface waters ranged from an average of 8 percent in non-drained fields to 36 percent in tile-drained fields. In the future, if tile-drained lands are used predominantly for growing crops that do not require significant nitrogen fertilizer or that are more effective at taking up fertilizer, the nitrogen losses to surface water can be reduced.

Nutrient runoff can also be significantly reduced with no-till agriculture, which has the added benefit of large reductions in soil loss.

Potential reductions in nutrient runoff and water use raise the question of whether no-till agriculture should be incentivized or even mandated. While pesticides are strictly regulated by the Federal Insecticide, Fungicide, and Rodenticide Act, last amended in 1988, there are no regulations on fertilizer application and storage. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service has established nutrient management standards, which is a set of voluntary best management practices regarding the amount, source, placement, form, and timing of the application of nutrients. Biofuel production in

no-till agriculture is nearly identical to production when conventional techniques are used. Even absent expansion of domestic ethanol production, these agricultural practices carry environmental benefits that should be considered.

Corn ethanol will also consume more water for irrigation. Meeting the mandated 15 billion gallons of fuel ethanol from corn will require 6.3 trillion liters (1.7 trillion gallons) of irrigation water—about 3 percent of all irrigation water used in the United States in 2000 and more than Iowa uses in a year. This value only looks at water for the corn used for ethanol (44 percent of 2007 U.S. corn production) and assumes the current proportion of irrigated corn (20 percent) and a national average water withdrawal rate. In the United States, agriculture accounts for 40 percent of total water withdrawals (water taken from a source) and for as much as 80 percent of total water consumption (water lost from the resource system that will be unavailable for other uses).

The mandated ethanol expansion will not, however, be entirely met with those optimal growth conditions. A comprehensive regional analysis on this topic shows that water appropriation by corn ethanol in the United States in the past three years has increased 246 percent, whereas corn ethanol production has increased only 133 percent. In 2008, 6.1 trillion liters (1.6 trillion gallons) of irrigation water were used for corn ethanol; by extrapolating this trend, meeting the EISA mandate of 15 billion gallons of corn ethanol will require almost 6 percent of water irrigation withdrawals.

Any other major crop in the United States grown for biofuel will use natural resources (land and water) at the same rate as corn, or even more, as is the case of sorghum and soybean. While switchgrass theoretically has no irrigation requirements, its water demands are similar to that for corn. The real advantage of switchgrass is its greater resistance to droughts. Switchgrass has a longer rooting system than corn, which means that during a drought, and the corresponding drop in the water table, switchgrass will be able to reach the deeper water. Still, when switchgrass is grown as a bioenergy crop and yields need to be maximized, farmers can be expected to irrigate and fertilize.

The increased use of ethanol nationwide increases the likelihood of leakage of ethanol into water supplies and the environment, often when ethanol is blended with gasoline in E-10 and E-85 concentrations. Underground storage tanks

commonly found in gas stations and refineries are a principal source of this contamination. These metal containers are prone to corrosion and leaking, giving rise to a nationwide problem referred to as leaking underground storage tanks (LUST). LUST is a quite common phenomenon, with more than 479,000 confirmed releases, of which upwards of 377,000 have already been cleaned up. These releases can vary in magnitude from a few gallons to tens of thousands of gallons.

Releases of ethanol will most likely lead to some altered remediation approaches and possible small-scale environmental damage. But rather than the dangers of direct exposure to ethanol, the greater risk to human health comes from the potential for BTEX mixed with ethanol to travel farther and be more difficult to degrade. Of the BTEX hydrocarbons, benzene is potentially the most toxic and is known to be carcinogenic. A variety of factors inhibit the degradation of benzene in the presence of ethanol, which allows the benzene to spread over a wider area. The footprint of the BTEX-ethanol mixture is wider (a phenomenon known as plume migration) and increases the chances of exposure to more people of target pollutants that are detrimental to human health. The extent to which ethanol will extend plume migration varies with concentrations of ethanol content in the fuel, with levels of 20 percent ethanol fuel blends increasing elongation by around 60 percent, for example, compared to fuels with no ethanol content.

Remediation for LUST occurs at the state and local level. Certain states are developing guidelines for how to deal with LUST via ethanol-blended fuels, but most states that have printed guidelines do not believe E-10 fuel will significantly alter the remediation process. A state with a significant number of E-85 pumps, Minnesota, is currently a leader in developing guidelines for remediation of E-85 spills. Its interim document recognizes how the degradation of BTEX can be delayed, leading to longer plume length, and it warns about the potential of methane generation from ethanol degradation that could lead to explosive conditions and the potential environmental consequences of low oxygen conditions.

POLICY RECOMMENDATIONS TO IMPROVE THE U.S. BIOFUELS-ALTERNATIVE FUELS PROGRAM

The United States is investing billions of dollars each year in subsidies to domestic ethanol producers in the hope that biofuels will become a major plank of an energy security and fuel diversification program.

However, it is our finding that not all of the mandated targets slated to be implemented under the Energy Independence and Security Act of 2007 are actually achievable in the time frames set forth in that legislation. We encourage Congress to revisit these mandates and revise them to be in line with realizable targets and time frames to create an improved policy that will reduce uncertainty for refiners and allow a more orderly implementation of achievable goals and mandates by the EPA. A reevaluation of the RFS must take into consideration the fact that introduction of E-85 fuel into the U.S. fuel system to increase the average use of ethanol beyond 10 percent ethanol faces major logistical problems. More realistic assessments of the penetration of E-85 must be part of the reevaluation process for RFS mandates.

As noted above, no automobile manufacturer will currently extend an engine or parts warranty for vehicles that use more than 10 percent of ethanol content in fuel, except for vehicles specifically designed to run on E-85 fuel. This means that the majority of cars on the road today in the United States are not under warranty for anything other than gasoline containing 10 percent ethanol or less. E-85 flex-fuel vehicles represented only 3 percent of the car fleet as of March 2009, and the availability of E-85 refueling stations is mainly limited to only one region of the United States. The use of flex-fuel vehicles is not likely to be extensive enough to overcome the barriers to achieving the Energy Independence and Security Act of 2007 mandates for U.S. ethanol market saturation. Moreover, existing mandated targets for advanced biofuels are not currently achievable—scientifically or commercially—and should be revisited.

Furthermore, we note that increased production of renewable fuels, such as corn-based ethanol, is causing unintentional harm to the environment. However, because ethanol easily degrades in the environment and human exposure to ethanol itself presents minimal adverse health impacts, its role as a substitute for potentially carcinogenic gasoline additive MTBE, on balance, represents a positive development. About 6 billion gallons per year (or 400,000 b/d) of ethanol are needed in the United

States to replace MTBE. However, the state and local environmental agencies responsible for site cleanup must take into consideration the fact that the addition of ethanol to gasoline beyond a 10 percent concentration will impede the natural attenuation of BTEX in groundwater and soil, and pose a great risk for human exposure to these toxic constituents, should the fuel leak from underground storage tanks. The EPA can encourage these agencies to follow the lead of states like Minnesota, which is already releasing guidelines for E-85 remediation.

We question the scale to which ethanol can enhance U.S. energy security by replacing oil-based fuel, and recommend that Congress order a cost-benefit analysis that compares the volume of renewable fuel being added to the American transportation fuel system to the cost per gallon to the American taxpayer to achieve this marginal addition of non-fossil-fuel-based supply. We believe that such an assessment would find that the extremely high costs of implementing this program outweigh the indirect benefits to consumers of the small, marginal reductions in U.S. oil imports. Therefore, we do not recommend renewing blenders' credits when they expire at the end of 2009.

We also recommend that Congress and the U.S. administration refrain from giving preferential treatment to corn-based ethanol on the basis of its purported ability to reduce greenhouse gas emissions. There is no scientific consensus on the climate-friendly nature of U.S. produced corn-based ethanol, and it should not be credited with reducing GHGs when compared to the burning of traditional gasoline.

Increases in corn-based ethanol production in the Midwest could cause an increase in detrimental regional environmental impacts, including exacerbating damage to ecosystems and fisheries along the Mississippi River and in the Gulf of Mexico and creating water shortages in some areas experiencing significant increases in fuel crop irrigation. Crops such as corn, which result in high nutrient losses to surface waters, should be discouraged in areas with tile drainage, and crops with high water demands should be grown in areas where rainfall rather than irrigation can meet most of the water needs. We recommend that Congress consider mandates that would encourage no-till agriculture as part of a sustainable renewable fuels program, and that the USDA's Natural Resources Conservation Service revisit regulations on fertilizer application and storage.

Limitations in the economies of scale in ethanol production pose a significant barrier to overcoming

the logistical issues that block the widespread distribution of ethanol in the United States, adding to the greenhouse gases emitted and conventional fuel burned in the transportation of ethanol to end-use markets. Lifting the \$0.54 tariff on imported ethanol from major countries in Central America, the Caribbean, and Latin America would allow key coastal areas of the United States to be more cheaply and sustainably supplied with ethanol while at the same time help build trade and positive relations with important U.S. regional allies. We believe, on balance, that the economic and geopolitical benefits of this trade with select regional suppliers would outweigh any “energy security” costs associated with some larger percentage of U.S. ethanol supplies arriving from foreign sources.

Imported ethanol from these regions is already making its way to U.S. shores through a variety of loopholes, but at a higher cost. As discussed in this report, given the limitations of sustainable production of U.S. domestic corn-based ethanol, tariff policies that block cheaper imports are probably misguided. It is reasonable to ask if protective tariffs are meeting the goals for which they were intended, and who among the market participants—farmers, producers, blenders, or oil refiners—is really reaping the actual profits from the tariffs.

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