Aggregate Economic Impacts of the National Bioenergy Policy
A Review

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Dramatically higher fuel prices and massive petroleum imports from politically-unstable countries contributed to a major national initiative to generate renewable fuels, with an emphasis on ethanol and biodiesel. Often, policies are enacted and implemented with huge taxpayer expenditures, but without due diligence of the unintended consequences. Since the 1970s, there have been many studies and reports discussing effects of alternative proposed biofuel policies as well as analyses of implemented energy policies. This briefing paper provides an overview of some of the issues and implications identified in these prior investigations.

U.S. Need for Alternative Fuels

The United States is one of the major consumers of conventional petroleum, with 300 billion gallons of fuel consumed in 2008 (U.S. Energy Information Administration 2009b). Approximately 140 billion gallons are for road and rail systems that are involved in the transportation of goods and people across the nation.

Crude oil and petroleum product imports for the United States totaled 210 billion gallons in 2008 (U.S. Energy Information Administration 2009a), making it the major customer of the Middle East. With the United States' concerns over increasing energy consumption and related environmental quality issues, policies such as the Clean Air Act evolved to mandate use of alternative fuels, with a goal of reducing the dependency on imported oil.

Increased demand for conventional oil, concerns of depleting reserves, and lack of stability in oil-rich nations contributed a major role in price fluctuations and encouraged the search for alternative sources of energy. Similarly, the recent rise in oil prices to $140 per barrel also provided incentive for a biofuel or renewable fuel priority. Unlike the 1970-80s, when high-oil-price periods were relatively short, sustained periods of elevated fuel prices have been experienced during the last few years. Elevated fuel prices were due in part to increased demand from worldwide economic growth, particularly in China and India. Dramatically-higher fuel prices in 2008 were also due to a massive speculative bubble in oil and agricultural commodities associated with new futures market participants, especially corporate and government pension funds, sovereign wealth funds, university endowments, and other institutional investors (Du et al. 2009).

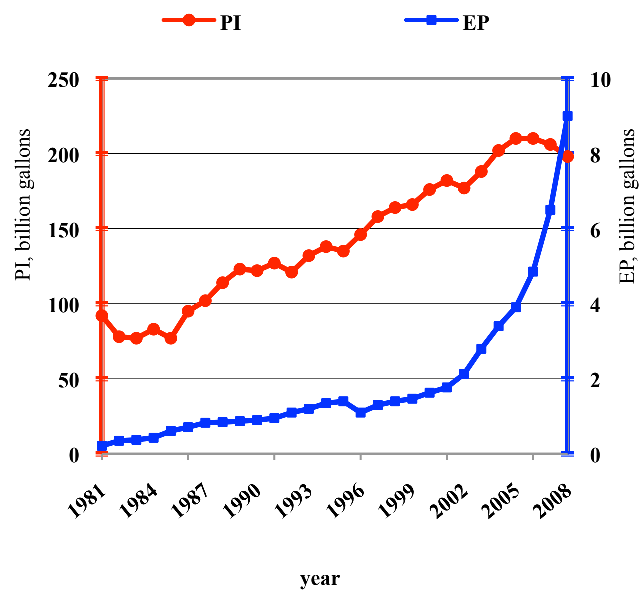
Current biofuel programs have resulted in increased acreages of crops that can be used as feedstocks, creating unintended impacts on soil fertility, depletion of water resources, and increased use of fertilizer and chemical inputs. These issues have refocused attention toward development of more environmentally friendly policies, which include cellulosic fuels, with an aim towards mitigating some of adverse side effects of previous energy policies.

Mandates from U.S. Government on Alternative Fuels

The Energy Independence and Security Act of 2007 mandates a Renewable Fuel Standard target (RFS) of 11 billion gallons of renewable fuels in 2009 and 36 billion gallons annually by 2022, including cellulosic ethanol. Although the RFS calls for a large percentage increase in the use of renewable fuels, they remain a small proportion of the 140 billion gallons of petroleum consumed for mobile uses by the United States in 2008.

Figure 1 shows the proportion of petroleum imports and ethanol production of the United States, measured in billion gallons since 1981. Note the scales are different. Petroleum imports increased from 90 to 190 billion gallons from 1981 to 2008, whereas ethanol production only increased from one to nine billion gallons during the same time period. In 2008, ethanol was less than five percent of petroleum imports.

Fig 1. Ethanol Production (EP) and Petroleum Imports (PI) of the United States (U.S. Energy Information Administration 2009a)



Review of Studies on Impacts and Consequences

An increase in biofuels demand triggers price increases by increasing demand for agricultural crops. Land is shifted away from corn for food and feed to corn for fuel. Increased corn prices and competition for cropland, in turn, affect other grains and crops. Some of the early studies predicted increases in crop prices as a result of growing crops as feedstock for biofuels. Economic impacts of 12 billion gallons of biofuels produced using corn, grain sorghum, small grains, and crop residues were analyzed after the first energy crisis in the 1970s. Results from one of the early studies indicate that feed grain prices at the farm level would increase by 79 percent and food grain prices by 46 percent (Taylor 1978) with economic conditions prevailing at the time. A similar study concluded that corn prices react most dramatically to alcohol (ethanol) production of 10 billion gallons or more annually, with each additional billion gallons of alcohol per year increasing the price of corn by approximately four percent (Webb 1981).

Net Energy Implications

Scientific debate over the net energy balance of ethanol began back in the mid 70s and has not abated. Some argue that the energy required to grow and convert corn to ethanol is greater than the energy value in ethanol itself. Therefore, the current emphasis on ethanol does not achieve energy security (Pimentel 1991, 2001; Pimentel and Patzek 2005). Recent analysis of the energy value of all of the inputs used in the production and conversion of food and feed into fuel resulted in a negative net energy value (NEV) (Pimentel et al. 2009). However, the estimated NEV of corn ethanol with updated information showed a positive NEV of 1.34 to 1 (Shapouri et al. 2002).

Summing up the national energy implications, including the fossil fuel used to irrigate, fertilize, grow, refine, and transport corn, the energy balance for ethanol is estimated at 1.34 to 1, whereas it is 5 to 1 for gasoline (Rapier 2007). Since the net energy balance of corn ethanol is relatively low with current technology, however, ethanol is not a panacea as an energy source at the present time. Since the net energy balance of corn ethanol is relatively low with current technology, energy per gallon less than petroleum and questions related to global climate change, ethanol is not a panacea as an energy source.

The net energy ratio of soy-based biodiesel is much better than corn ethanol, containing 3.2 times more energy than required for its production (Sheehan et al. 1998). However, soy-based biodiesel production is low per acre of land. Meeting current biofuel mandates from this source with current technology would require doubling or tripling the soybean acreage now cultivated in the U.S.

It appears that with current technology, most of the renewable fuel mandate will be met with corn ethanol. However, because of the energy required to produce biofuels, the net energy gain will be substantially less than the mandate. For example, assuming a net energy gain of 34% (Shapouri et al. 2002), gross production of 36 billion gallons of renewable fuel would represent a net production of only 12.2 billion gallons of fuel, since 23.8 billion gallons of fossil fuel energy would be used in production and conversion.

Economic Implications (cost per net gallon of fuel)

Biofuel crop production depends on substantial use of fossil fuels, including diesel for plowing and transportation and natural gas and coal for production of fertilizers and irrigation. Therefore, the economic implications of biofuels come down to cost per net gallon of ethanol. Reports indicate that it cost approximately $2.53 to produce a gallon of ethanol in 2005, several times higher than required to produce a gallon of gasoline at the time (Taylor and VanDoren 2007). Evaluating the economics of ethanol, while considering investment costs, corn costs, cash operating costs, capital charges, and improvement in technology, indicated that at a one billion-gallon annual capacity with corn at $2.50 per bushel, ethanol would cost $1.30 per gallon. Adding another 1-2 billion gallons of plant capacity would increase the cost to $1.40 per gallon, depending on corn price (Kane and Reilly 1989), which indicates that the present mandate to produce 36 billion gallons of renewable fuels can push the biofuel per gallon price much higher than the per gallon gasoline price. With recent subsidies of $4 billion provided towards the ethanol sector for 2008, the net cost per gallon of ethanol comes to $1.95 per gallon more than that of gasoline's retail price (Dittrick 2010). In a study to estimate the economic costs of corn ethanol on human health and climate change, the total environmental and health costs of producing corn-based ethanol range from $0.72 to $1.45 per gallon and from $0.19 to $0.32 per gallon for cellulosic ethanol compared to $0.71 per gallon of gasoline, based on a University of Minnesota study (2009).

Environmental and Sustainable Implications

There is an on-going debate on environmental benefits and costs of biofuels. Some studies indicate ethanol production would actually increase the total amount of carbon dioxide released into the atmosphere, a result of conversion of forest and conservation grassland and pastures to biofuel crop production. An analysis of carbon emissions from land use changes as a result of biofuel production estimated an increase in emissions by 50 percent and that it would take 167 years of ethanol use to offset the increase of greenhouse gases from initial conversion of forest land (Searchinger et al. 2008).

Replacing 50 percent of gasoline consumption with cellulosic ethanol would require about seven times the amount of land currently used for corn production (Rapier 2006). Production of the quantity of biomass necessary to replace 50 percent of gasoline consumption could reduce a large proportion of land that might be used for growing food, fiber, and timber. At present, second-generation biofuel technologies, namely cellulosic technologies are not commercially viable at current oil prices. Future aggregate economic effects of replacing fossil fuel gasoline with cellulosic ethanol are speculative, therefore, to the extent that the cellulosic ethanol conversion technology that might become commercially viable in the future is not known.

Some world organizations argue that the global rush for biofuels might not be sustainable. Biofuels can affect food prices, increase competition for land and water, increase deforestation, and damage soil and water resources (Taylor and Lacewell 2009a, Vidal 2008). Water availability, whether for crop production or refining, is one of the potential challenges facing biofuels. A report for an ethanol plant in Nevada revealed that it would require 1.3 billion gallons of water for its cooling towers (Woody 2009). This situation has created a divide between special interest groups, where some are making money selling their water rights and others are concerned about the aggregate effect on society's water resources. Gerbens-Leenes et al. (2009) stated that an increase in the demand for food along with a shift from fossil fuels to bioenergy would place additional pressure on world water resources and would require anywhere from 1,400 to 20,000 gallons of water for a gallon of biofuel. A report on an energy-water nexus by the U.S. Government Accountability Office (2009) states that the total amount of water used for irrigation to produce a bushel of corn ranges from 38 to 865 gallons, depending on the region. The report also states that since next generation biofuels have not been grown on a commercial scale, their effects on water resources are not fully known. It is also reported that 96 percent of the corn used in ethanol production is non-irrigated (Aden 2007), but higher crop prices due to expanded corn ethanol production increases the demand for irrigation water. This debate over total water use continues.

Another potential concern of expanded biofuel production is land use and nutrient loss. With the 2010 renewable fuel standard to blend and sell 12.95 billion gallons of renewable fuels (U.S. Environmental Protection Agency 2010), there will be additional pressure on land resources to meet the RFS targets. A recent analysis found that meeting the energy standards set forth by the biofuel policy would expand cropland requirements by 5 million acres by 2015 (Malcolm et al. 2009). A similar effect was found in a separate analysis (Taylor and Lacewell 2009a). Increased fertilizer use due to expanded crop production would result in increased nitrogen losses to surface and groundwater by 1.7 and 2.8 percent, respectively, while soil runoff would increase by 1.6 percent. By including nitrogen cleanup cost in ground and surface water, the indirect costs increase even more.

Examples of Unintended Consequences

Biofuel policies have led to large shifts of food crops into ethanol and biodiesel production. Rapid increase in production and demand for biofuels expanded, in particular, the demand for corn and shifted land away from corn for food and feed, stimulating an increase in corn prices. Analysis of the present biofuels policies indicates that an increase in per bushel corn price of $0.88 is associated with going from zero to 15 billion gallons of annual ethanol production. Further expansion of biofuels production from the United States Department of Agriculture (USDA) baseline of 15 billion gallons to 35 billion gallons is estimated to result in an increase in corn price by an additional $1.55 per bushel. Soybean price also increases an additional $1.15 per bushel over the initial $0.74 per bushel price increase due to going from zero to 15 billion gallons, partly due to production of biodiesel as well as in response to a shift in cropland from soybeans to other major biofuels crops (Taylor and Lacewell 2009a). These results support a 2008 study that estimated increased biofuel demand caused a 39 percent increase in price of corn and 22 percent increase in price of wheat (Rosegrant 2008).

Increases in biofuel production can be expected to raise the demand for primary plant nutrients. Corn yields strongly depend on the quantity of nitrogen fertilizer applied. Therefore, greater application of nitrogen fertilizer can be a consequence of expanded renewable fuels. Increased food and feed demand across nations amplified the demand for inputs that translated into higher prices, particularly fertilizers. Expansion of biofuel production from the USDA baseline of 15 to 35 billion gallons was estimated to increase consumption of N, P, and K from four to eight percent, three to seven percent, and four to nine percent, respectively. A similar trend was also observed in the price levels for these nutrients, which increased from three to six percent for N, 2.5 to six percent for P, and 2.5 to six percent for K (Taylor and Lacewell 2009a). This analysis supports reports indicating a price increase of 32 percent for N, 93 percent for P, and 100 percent for K as a consequence of increased crop production (Huang 2009).

Food Prices Increase Due to Feed Grain Demand

The potential conflict between food and fuel, mainly attributed to corn ethanol, has implications for food prices around the world. According to the International Monetary Fund (2008), world food prices have increased by 45 percent since 2006, mainly due to increased consumption and new biofuel mandates in the U.S. and European Union (EU). A report by the National Corn Growers Association (NCGA) states that of a total of 9.82 pounds of mixed feed ration per pound of beef only 2.6 pounds of corn is required for one pound of beef. Similarly, of a total of 3.84 pounds of mixed ration, two pounds of corn is required for one pound of chicken. With corn priced at $4.00 per bushel, this translates into 18.6 cents of corn in one pound of beef and 14.3 cents of corn in one pound of chicken (Cooper 2007). This value per pound indicates that there are eventual effects of higher corn prices on consumer food prices. However, it should be noted that dressed weights are about 63 percent of live weight for beef cattle (Ward et al. 2010) and 75 percent of live weight for chicken (Lessler and Ranells 2007). This results in a dressed weight of 788 pounds for beef with a total of $216 in corn feed costs alone. This translates into 27.5 cents of corn in one pound of beef, much higher than the 18.6 cents reported by NCGA. Similarly, with a dressed weight of 4.2 pounds for chicken, 17.7 cents of corn is required to produce a pound of chicken. These numbers indicate that there will be a much higher impact on rising corn prices than anticipated. According to The International Monetary Fund, world food prices have raised by 43 percent during 2007-08; however, U.S. production of corn-based ethanol accounts for only 3 percent of that increase (Schafer 2008).

Government Subsidies Create Investments in Conversion Facilities

Various policy tools have been introduced around the world to support a biofuel program. Government subsidies and tariffs are among the most frequent support programs implemented to promote the biofuel industry. For example, the United States provides a tax refund for ethanol of $0.51 per gallon to ethanol blenders, $1.00 per gallon to biodiesel blenders, and imposes a $0.54 per gallon duty on imported ethanol from Brazil. These policies are intended to encourage the expansion of the domestic production capacity of existing refineries and development of new refineries to meet the RFS target. Policies that would increase the ethanol blend from E10 to E15 are also under consideration. Since 2007, United States Department of Energy has offered up to a total of $1 billion in biomass research for bioenergy. The biodiesel subsidy expired at the end of 2009 and all biodiesel conversion facilities stopped production. There is continuing debate on extension of the biodiesel subsidy.

The United States uses several support schemes to promote the use of biofuels, including market price support, volumetric support, and subsidies. In 2006, the U.S. biofuel industry received total government support approximating $6.3 to $7.7 billion, which is projected at approximately $13 billion in 2008 and almost $16 billion by 2014 (Koplow 2007). In aggregate, during the 2006-12 periods, total undiscounted subsidies for ethanol are estimated between $68 and $82 billion, while biodiesel subsidies total an additional $9 to $11 billion. According to the estimates of Yacobucci and Capehart (2008), reaching the renewable fuel standard would cost the United States a total of approximately $181 billion by 2022.

Implications for Water, Fertilizers, and Pesticides

Corn, the primary crop used in ethanol production, is a resource-intensive crop and demands considerable amounts of water, fertilizers, and pesticides. Farmers in 2007 applied 11.4 billion pounds of nitrogen fertilizer, 4.1 billion pounds of phosphorous, and 4.6 billion pounds of potash for corn crop production (U.S. Department of Agriculture 2009). With limited phosphorous and potash reserves in the world, increasing production costs might change the possibility of energy independence to nutrient dependence. Furthermore, most of the nitrogen fertilizer is manufactured from natural gas. Presented in figure 2 is the trend in nutrient production and imports from 1976-2008.

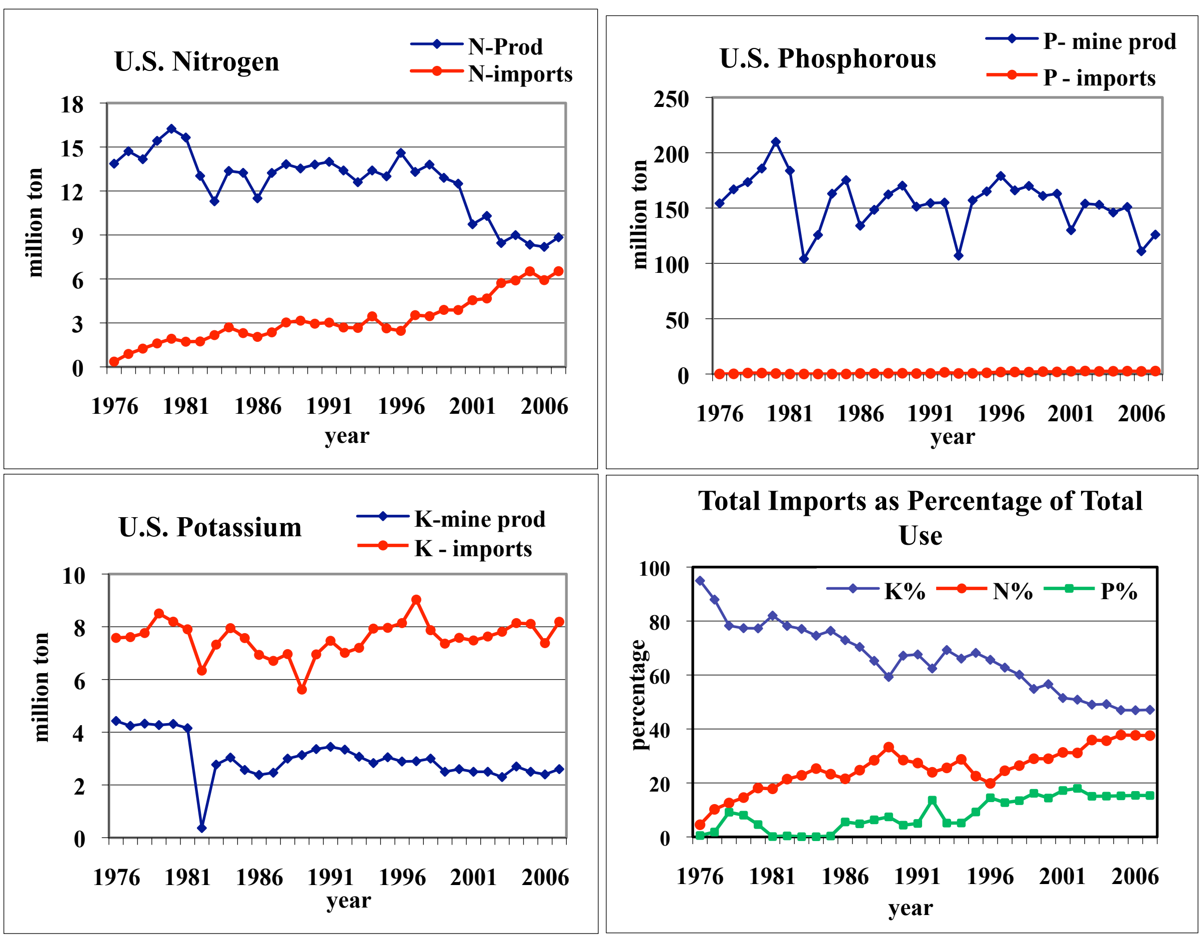


Fig 2: U.S. Production and Import Levels of Major Plant Nutrients
(U.S. Geological Survey 2009)

Water use could be significantly impacted by biofuel production. Growing more acres of water-intensive crops (e.g., corn) and increased water use by ethanol distillation plants exacerbate the environmental situation in regions where fresh water resources are scarce. Irrigated corn for grain uses over one acre-foot of water per acre of land, producing an average yield of 181 bushels per acre (Farm Ranch and Irrigation Survey 2008). This use equates to more than 642 gallons of water for every gallon of ethanol produced, at a conversion rate of 2.8 gallons of ethanol per bushel. For rainfed corn production, much of the water used is precipitation. Total water use can be expected to rise if ever increasing quantities of biofuels are mandated. The amount of water used in biorefineries is modest compared to the water used for irrigated production; however, the effects are incurred more locally. Minnesota distillation plants report an increased efficiency of 38 percent in water use from 1998 to 2005 with a use rate of 3.5 to 6 gallons of water per gallon of ethanol production (Smith et al. 2008). However, some predicted an increase in total water use by ethanol plants by as much as 254 percent from 1998 to 2008, on expectations of increased number of ethanol distillation plants to come online (Keeney and Muller 2006). A study by Argonne National Laboratory on consumptive water use in ethanol production found that the total water required for corn irrigation and ethanol production could range from 10 to 323 gallons of water per gallon of ethanol (Wu et al. 2009). Ethanol plants overlying the Ogallala aquifer region reported an annual water use of 2.6 billion gallons per year (Roberts et al. 2007), worsening an already-serious situation, where a United States Geological Survey (USGS) reports a 234 feet drop in the saturated thickness of the Ogallala aquifer since the beginning of irrigation in the Texas High Plains (McGuire 2009).

Estimated Bioenergy Impacts

Bioenergy policy has and will have several implications for the U.S. economy, including increased crop prices, additional pressure on less-productive land to expand crop production, and increased demand for fertilizer and water resources. Biofuel mandates and subsidies also result in distortions in the agriculture economy that can cause increased food prices (Taylor and Lacewell 2009a). Though small in percentage terms, such increases in food prices can have a substantial effect on consumer wellbeing when aggregated over the U.S. or world population. Aggregate economic impacts of the biofuel policy of 35 billion gallons indicate a net loss in consumer surplus (well-being) amounting to $30.8 billion. However, net farm income increased by $54.7 billion annually, and the economic well-being of the food sector decreased by $66.7 billion annually (Taylor and Lacewell 2009a). Producers are the “winners” and consumers are the ”losers.”

Other economic impacts of alternative fuels include effects on fertilizer prices, domestic consumption, crop prices, cropped acres, and erosion rates. An analysis by Taylor and Lacewell (2009a) indicates the crop price impact of expanding biofuel production to 35 billion gallons annually would result in a price increase of $2.43 per bushel for corn and $1.83 per bushel for soybeans. Expanded production of ethanol to the set renewable fuel standard target by 2025 is projected to result in an approximate nine percent increase in the price of the primary plant nutrients and a 12 percent increase in their consumption (Taylor and Lacewell 2009a).

The estimated effect of first generation biofuel production of 35 billion gallons on cropping acreage resulted in a net addition of 16.4 million cropped acres. The estimated additional cropped acreage included 7 million acres from matured conservation reserve program (CRP) land (Taylor and Lacewell 2009b). A similar analysis on the effect of expanding biofuel production on cropland estimated a projected increase of 8.6, 1.7, and 2.8 percent of cropping acres in the Northern Plains, Corn Belt, and Great Lake States, respectively (Malcolm et al. 2009). Expanded production is also expected to affect erosion rates, which averaged 21 tons per acre on CRP acres before enrollment and 1.6 tons per acre after enrollment. With an estimated 7 million CRP acres returning to crop production and relatively-high erosion rates associated with the cultivation of first generation biofuel crops, total amount of soil erosion is expected to increase by 174 to 206 million tons annually compared to 31 to 60 million tons with all land remaining in CRP. Though the net positive effect of expanded biofuel production due to returning CRP land would be $1.6 billion annually, it comes at the expense of 145 million tons of increased erosion, amounting to $11.13 per ton of soil (Taylor and Lacewell 2009b).

Conclusions

The Biofuel industry is growing rapidly and is having a significant impact on energy, climate, natural resource utilization, and the economy. Present policies encouraging biofuels production are having some negative impacts by accelerating depletion of land and water resources, as well as impacting food security and climate. Most of the issues center on where and how biofuels are produced. To protect the U.S.'s sensitive natural resources base, these input-intensive crops must be grown in ways that do not degrade land and water resources. Some of the biofuel crops that require heavy applications of fertilizer derived from fossil fuels are not sustainable options. Biofuel policies must go beyond production mandates and focus on environmental, social, and economic performance. Instead of just having volumetric mandates, policies should aim at sustainability goals including land, water, climate, and other economic considerations.

Given the importance of food and fuel to the wellbeing of people, carefully-designed integrated food and energy policies must be considered to avoid unintended consequences. These policies should carefully examine the long-run resource impact of alternative bioenergy policies, an absence of which could become a major roadblock to the nation's energy policy. Both short-term and long-term policy options that lead to the sustainable use of biomass into energy must be examined; otherwise, nations could be scalping the planet for material to feed the engines. Not included in these studies is the issue of national security and need for a dependable domestic mobile energy source, just one more critical aspect of a balanced energy policy.

References

Aden, A. 2007. "Water Usage for Current and Future Ethanol Production." *Southwest Hydrology* 6(5):22-3.

Cooper, G. 2007. "Understanding the Impact of Higher Corn Prices on Consumer Food Prices." Unnumbered Report. National Corn Growers Association, Chesterfield, MO.

Dittrick, P. 2010. "US Biofuels Policies Flawed, Baker Institute Study Finds." *The Oil and Gas Journal* 108(2):38.

Du, X., C. L. Yu, and D. Hayes. 2009. "Speculation and Volatility Spillover in the Crude Oil and Agricultural Commodity Markets: A Bayesian Analysis." Paper presented at the 2009 Annual Meeting, July 26-28, Agricultural and Applied Economics Association, Milwaukee, WI.

Farm and Ranch Irrigation Survey (FRIS). 2008. *Estimated Quantity of Water Applied and Primary Method of Distribution by Selected Crops Harvested: 2008 and 2003*. Publication. USDA-FRIS. Available at http://www.agcensus.usda.gov/Publications/2008/FRIS/index.asp. Accessed December 10, 2009.

Gerbens-Leenes, W., A.Y. Hoekstra, and T.H. van der Meer. 2009. "The Water Footprint of Bioenergy." *Proceedings of the National Academy of Sciences of the United States of America* 106(25):10219-23.

Huang, W.-Y. 2009. "Factors Contributing to the Recent Increase in U.S. Fertilizer Prices, 2002-08." Agricultural Resources Situation and Outlook Number AR-33. U.S. Department of Agriculture, Economic Research Service, Washington, DC.

International Monetary Fund (IMF). 2008. "Impact of High Food and Fuel Prices on Developing Countries." Frequently Asked Questions. IMF External Relations Department. Available at http://www.imf.org/external/np/exr/faq/ffpfaqs.htm. Accessed February 15, 2010.

Kane, S., and J.M. Reilly. 1989. "Economics of Ethanol Production in the United States." Agricultural Economic Report 607. U.S. Department of Agriculture-Economic Research Service, Washington, DC.

Keeney, D., and M. Muller. 2006. "Water Use by Ethanol Plants: Potential Challenges." Unnumbered Report. The Institute for Agriculture and Trade Policy (IATP). University of Minnesota, Minneapolis, MN.

Koplow, D. 2007. "Biofuels – At What Cost? Government Support for Ethanol and Biodiesel in the United States." Unnumbered Report prepared for The Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD). IISD, Cambridge, MA.

Lessler, J., and N. Ranells. 2007. "Grower Guidelines for Poultry and Fowl Processing." Unnumbered Report Prepared as part of a Grant to the Chatham County Center of North Carolina Cooperative Extension. Raleigh, NC.

Malcolm, S.A., M.P. Aillery, and M. Weinberg. 2009. "Ethanol and a Changing Agricultural Landscape." Economic Research Report 86. U.S. Department of Agriculture, Economic Research Service, Washington, DC.

McGuire, V.L. 2009. "Changes in Water Levels and Storage in the High Plains Aquifer, Predevelopment to 2007." U.S. Geological Survey Fact Sheet 2007–3029. Available at http:// pubs.usgs.gov/fs/2007/3029/pdf/FS20073029.pdf. Accessed November 10, 2010.

Pimentel, D. 1991. "Ethanol Fuels: Energy Security, Economics, and the Environment." *Journal of Agricultural and Environmental Ethics* 4(1):1-13.

Pimentel, D. 2001. *Biomass Utilization, Limits of.* Ed. R.A. Meyers. Encyclopedia of Physical Science and Technology, Vol. 2, 3rd Edition. San Diego, CA: Academic Press, pp.159-71.

Pimentel, D., A. Marklein, M. Toth, M. Karpoff, G. Paul, R. McCormack, J. Kyriazis, and T. Krueger. 2009. "Food Versus Biofuels: Environmental and Economic Costs." *Human Ecology* 37(1):1-12.

Pimentel, D., and T.W. Patzek. 2005. "Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower." *Natural Resources Research* 14(1):65-76.

Rapier, R. 2006. "Report: Brazilian Ethanol is Sustainable." R-Squared Energy Blog. Available at http://www.consumerenergyreport.com/2006/10/10/report-brazilian-ethanol-is-sustainable/. Accessed December 10, 2009.

Rapier, R. 2007. "Ethanol/Alternative Fuel." Frequently Asked Questions. R-Squared Energy Blog. Available at http://www.consumerenergyreport.com/2007/08/18/ethanolalternative-fuel-faq/. Accessed December 10, 2009.

Roberts, M.G., T.D. Male, and T.P. Toombs. 2007. "Potential Impacts of Biofuels Expansion on Natural Resources: A Case Study of The Ogallala Aquifer Region." Environmental Defense Fund. Available at http://www.edf.org/documents/7011_Potential%20Impacts%20of%20Biofuels%20Expansion.pdf. Accessed November 20, 2009.

Rosegrant, M.W. 2008. "Biofuels and Grain Prices: Impacts and Policy Responses." Testimony to the U.S. Senate Committee on Homeland Security and Governmental Affairs. International Food Policy Research Institute, Washington, DC.

Schafer, E. 2008. "Food and Fuel." Press Release No. 0130.08. U.S. Department of Agriculture, Washington, DC.

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(5867):1238-40.

Shapouri, H., J.A. Duffield, and M. Wang. 2002. "The Energy Balance of Corn Ethanol: An Update." Agricultural Economic Report 813. U.S. Department of Agriculture, Office of Energy Policy and New Uses, Washington, DC.

Sheehan, J., V. Camobreco, J. Duffield, M. Graboski, and H. Shapouri. 1998. "Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus." National Renewable Energy Laboratory (NREL) Report SR-580-24089. NREL, Golden, CO.

Smith, T.M., S. Suh, and J. Schmitt. 2008. "Environmental and Economic Assessment of Ethanol Production Systems in Minnesota." Final Report to the Minnesota Pollution Control Agency. Minnesota Pollution Control Agency, St. Paul, MN.

Taylor, C.R. 1978. "National Economic Impacts of Using Crop Residues and Grain to Produce Alcohol." Unnumbered Report prepared for the U.S. Congress Office of Technology Assessment, Washington, DC.

Taylor, C.R., and R.D. Lacewell. 2009a. "Aggregate Economic Effects of Corn Ethanol and Soy-Based Biodiesel Production." BioEnergy Policy Brief, BPB 070209. Available at https://sites.auburn.edu/academic/ag/group/bioenergy. Accessed December 10, 2009.

Taylor, C.R., and R.D. Lacewell. 2009b. "Effects of Corn Ethanol and Soy-Based Biodiesel Production on Soil Erosion and Return of Conservation Reserve Program Land to Crop Production." BioEnergy Policy Brief, BPB 070409. Available at https://sites.auburn.edu/academic/ag/group/bioenergy. Accessed December 10, 2010.

Taylor, J., and P. VanDoren. 2007. "Ethanol Makes Gasoline Costlier, Dirtier." The CATO Institute. Available at http://www.cato.org/pub_display.php?pub_id=7308. Accessed November 20, 2010.

University of Minnesota. 2009. "Cellulosic Ethanol May Benefit Human Health and Help Slow Climate Change." News Release. *Science Daily*. Available at http://www.sciencedaily.com/releases/2009/02/090202174934.htm#. Accessed November 10, 2009.

U. S. Department of Agriculture (USDA). 2009. "U.S. Fertilizer Use and Price." Data. USDA-ERS. Available at http://www.ers.usda.gov/Data/fertilizeruse/. Accessed November 20, 2010.

U.S. Energy Information Administration (EIA). 2009a. "U.S. Imports of Crude Oil and Petroleum Products." Data. U.S. EIA.

Available at http://tonto.eia.doe.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbl_m.htm. Accessed February 10, 2010.

U.S. Energy Information Administration. 2009b. "U.S. Product Supplied of Crude Oil and Petroleum Products." Data. U.S. EIA. Available at http://tonto.eia.doe.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_a.htm. Accessed February 10, 2010.

U.S. Environmental Protection Agency (EPA). 2010. "EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond." EPA Report 420-F-10-007. Office of Transportation and Air Quality, Washington, DC.

U.S. Geological Survey (USGS). 2009. "USGS Minerals Information: Commodity Statistics and Information." Data. U.S. Department of Interior. Available at http://minerals.usgs.gov/minerals/pubs/commodity/. Accessed January 20, 2010.

U.S. Government Accountability Office (GAO). 2009. "Energy-Water Nexus: Many Uncertainties Remain about National and Regional Effects of Increased Biofuel Production on Water Resources." GAO Report 10-116. U.S. GAO, Washington, DC.

Vidal, J. 2008. "Change in Farming Can Feed World - Report." News Release. *The Guardian*. Available at http://www.guardian.co.uk/environment/2008/apr/16/food.biofuels. Accessed November 10, 2009.

Ward, C. E., T. C. Schroeder, and D. M. Fuez. 2010. "Fed Cattle Pricing: Live and Dressed Weight." Oklahoma Cooperative Extension Service Report WF-556. Division of Agricultural Sciences and Natural Resources, Stillwater, OK.

Webb, S.B. 1981. "The Impact of Increased Alcohol Production on Agriculture: A Simulation Study." *American Journal of Agricultural Economics* 63(3):532-7.

Woody, T. 2009. "Alternative Energy Projects Stumble on a Need for Water." News Release. *The New York Times.* September 30, 2009.

Wu, M., M. Mintz, M. Wang, and S. Arora. 2009. "Consumptive Water Use in the Production of Ethanol and Petroleum Gasoline." Argonne National Laboratory Report ANL/ESD/09-1. Center for Transportation Research, Chicago, IL.

Yacobucci, B. D., and T. Capehart. 2008. "Selected Issues Related to an Expansion of the Renewable Fuel Standard (RFS)." Congressional Research Service (CRS) Report RL34265. CRS, Washington, DC.