CLEAN AIR TASK FORCE ENVIRONMENTAL WORKING GROUP FRIENDS OF THE EARTH

July 9, 2008

The Honorable Thomas Carper
Chairman, Clean Air and Nuclear Safety Subcommittee
United States Senate Committee on Environment and Public Works
Washington DC 20510

The Honorable George Voinovich
Ranking Member, Clean Air and Nuclear Safety Subcommittee
United States Senate Committee on Environment and Public Works
Washington DC 20510

Dear Chairman Carper and Senator Voinovich:

On April 25, 2008, Texas Governor Rick Perry petitioned the United States Environmental Protection Agency to reduce the Renewable Fuel Standard by 50 percent. The Governor was acting pursuant to Section 211(o) of the Clean Air Act, which authorizes states to petition the EPA to waive or reduce the Renewable Fuel Standard on a year-by-year basis. EPA may grant such requests if it finds that implementing the RFS would "severely harm the economy or environment of a State, region, or the United States," or if it finds the domestic supply of renewable fuels to be inadequate.

The Texas petition states that by increasing the demand for biofuels, the RFS is also increasing the demand for biofuel feedstocks such as corn (for ethanol): "corn prices are up 138 percent globally over the past three years and global food prices have increased 83 percent over that same time period, in part because of the artificial economic forces created by the RFS." According to Governor Perry's petition, higher corn prices have cost the Texas livestock industry billions of dollars and have contributed to "skyrocketing grocery prices."[1]

The Texas petition sparked a debate over the extent to which the 2008 RFS harms the economies of Texas and the United States as a whole. As evidenced by this Committee's decision to hold a hearing on the implementation of the RFS, the standard raises important environmental concerns as well. The Clean Air Task Force, Environmental Working Group, and Friends of the Earth are grateful for this opportunity to describe some of those environmental harms.

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[1] Letter from Governor Perry to Administrator Johnson, Requesting a waiver of a portion of the RFS, April 25, 2008.

I. ENVIRONMENTAL IMPACTS FROM THE RENEWABLE FUEL STANDARD

Full implementation of the RFS would require 36 billion gallons of biofuels to be sold or introduced into commerce in the United States by 2022.[2] Attempting to achieve that target without first developing a fuller understanding of the various effects biofuels have on climate, the environment, and our natural resources is to court disaster. The United States cannot simply rely on the provision in the RFS that requires 21 billion of the mandated 36 billion gallons to be met with "advanced biofuels." As demonstrated by a recent study published in the journal *Science*, nominally "advanced" biofuels like switchgrass-derived cellulosic ethanol can be significantly worse for climate stability than the petroleum-based fuels being replaced.[3] Nor can the United States rely on current lifecycle analyses – which lack the capacity to assess the full range of greenhouse gases or track market-mediated impacts – to ensure that the biofuels used to meet the RFS result in lower greenhouse gas emissions than conventional transportation fuels. The threat from the RFS to climate stability is compounded by other environmental harms associated with biofuel production and consumption, including severely diminished water and soil quality (Section IV), the loss of critical habitat (Section V), and increased ozone pollution in some regions.

Even the annual incremental increases mandated by the RFS take a toll on the environment. For example, biofuel production levels incentivized by the 2008 RFS pose a severe threat to climate stability. As discussed in Section III.C. below, land use changes connected to the incremental increase in biofuel production mandated by the RFS in 2008 will cause approximately 1.3 billion metric tonnes of carbon dioxide-equivalent emissions to be released into the atmosphere. That is the same amount of greenhouse gas emitted in one year by *four hundred* 500MW coal-fired power plants. (*See* Appendix A for analysis.)

II. BIOFUELS AND THE ENVIRONMENT: OVERVIEW

With help from policymakers around the world, interest in biofuels has exploded in recent years. Annual production levels for ethanol doubled globally between 2000 and 2005, while biodiesel production tripled. The European Union instituted ambitious biofuel consumption targets for 2005, 2010, and 2020. China expects to meet fifteen percent of transport fuel demand in 2020 using biofuels. Dozens of ethanol refineries are being built across the United States, fueling record corn plantings. The RFS, as amended in late 2007, will increase domestic production of biofuels almost five-fold, and a growing number of states are exploring ways to develop local bioethanol and biodiesel markets.

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[2] EISA 2007 at §202(a)(1) (amending CAA §211(o)).

[3] T. Searchinger, R. Heimlich, R.A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, T. Yu, "Use of U.S. Cropland for Biofuel Increases Greenhouse Gas Through Emissions from Land Use Change," *Science* (February 8, 2008)..

The main engine behind the surging interest in biofuels is their theoretical potential to strengthen agricultural economies, to expand the options for transport fuel at a time of record oil prices, and to reduce emissions of greenhouse gases and other harmful air pollutants.

This focus on biofuels' theoretical benefits has obscured their actual track record. Numerous recent studies have linked policies like the RFS – *i.e.*, policies that incentivize the production and consumption of biofuels – to increased competition for water, land, and other resources. The studies accuse such policies of playing a significant role in global warming, tropical deforestation, biodiversity loss, water and soil pollution, and the spread of monoculture cropping.

By increasing biofuel production levels in the United States and abroad, the RFS harms the United States' environment in the following ways:

- *Global warming*. Although biofuels are theoretically capable of reducing the climate impact of the transportation sector, the fuels currently incentivized by the RFS are, on net, contributing to global warming. Biofuel production harms climate stability directly and indirectly, by increasing the use of climate-forcing nitrogen-based fertilizers and by encouraging the conversion of forests and other carbon-rich ecosystems into farmland.
- *Water pollution*. The National Agricultural Statistics Service in 2007 reported a 15 million acre increase in corn acres which likely resulted in the application of nearly 2 billion pounds of nitrogen and 870 million pounds of phosphate—a serious increase in the risk of water pollution in agricultural regions. The soil erosion and fertilizer runoff attributable to corn-for-ethanol cultivation are major contributors to the rapid growth of the Gulf of Mexico's "Dead Zone."
- *Habitat destruction*. A key ingredient in making conventional biofuels (*i.e.*, the kinds of biofuels being produced to meet the RFS) is farmland. In order to keep up with policy-driven demand for biofuel feedstocks *and* sustain current food production levels, the agricultural sector, globally, is cultivating millions of hectares of new farmland – a process that often involves clearing critical habitats like forests, wetlands, and grasslands, as well as planting on marginal lands.

III. BIOFUELS AND CLIMATE

Policies like the RFS that encourage biofuel production affect climate change in a variety of ways, through the net greenhouse gas emissions resulting from the production and use of biofuels and through the effects from changes to global agricultural markets. Their net impact on climate is difficult to ascertain, because the analytic tools currently used to assess biofuel policies have some significant remaining gaps in addressing the production process (direct effects) and are not yet capable of quantifying market-mediated (or indirect) effects. It is clear, however, that adverse indirect effects – particularly the release of carbon dioxide (CO2) as forests and wetlands are cleared to accommodate increased demand for farmland – can overwhelm the direct benefits of replacing fossil fuels with fuels made from conventional crops like corn, soy, rapeseed, and oil palms. This is certainly true of the RFS: as described below, analysis submitted with these comments demonstrates that the incremental increase in biofuel production required by the revised RFS for 2008 alone will result in 1.3 billion metric tonnes of additional CO2-equivalent emissions.

A. NET IMPACT OF BIOFUELS ON CLIMATE: BACKGROUND

Direct effects are climate-relevant events (typically emissions) that explicitly result from the use or production of biofuels. The most obvious direct impact biofuels have on climate is a reduction in the amount greenhouse gases emitted from the tailpipes of automobiles that run on biofuel, as compared to those powered by petroleum. When biofuels made from plant matter are combusted, the CO2 emitted is the same CO2 absorbed by the plant matter before it was harvested and made into fuel – a correlation that has given rise to the misconception that biofuels are "carbon neutral". However, the climate benefit from reduced tailpipe emissions is undermined by other effects directly tied to the production of biofuels. According to a recent University of Sheffield (UK) study, biodiesel made from rapeseed grown on dedicated European farmland accounted for nearly the same amount of CO2-equivalent emissions per kilometer driven as petroleum diesel. The main reason biodiesel performed so poorly is that rapeseed farming, like commercial-scale corn farming, relies heavily on nitrogen-based fertilizers which, in turn, give off nitrous oxide – a powerful global warming agent.[4]

Regardless of whether biofuels' direct impact on climate is beneficial or negligible, it pales in scope when compared to the indirect impacts that occur as a variety of markets adjust to fluctuations in the demand for biofuels. Because the vast majority of commercial biofuels are made from sugars and oils extracted from commonplace crops, policies that expand the market for biofuels tend to also increase demand for agricultural crops and such inputs as water, fertilizer, and land.

Biofuel policies' indirect impact on climate is closely related to their effect on food prices, and is just as troubling. The demand for crops has roiled food markets because the most widely cultivated "energy crops" are also food and feed staples like corn, soy, sugarcane, rapeseed, and oil palm. The vast majority of ethanol produced in the United States comes from corn, and will continue to for some time. Demand from recently-built corn-ethanol refineries contributed to a dramatic spike in the price of corn, pushing up the cost of corn-intensive foods including dairy, eggs, and meat from corn-fed livestock. The sharp rise in the price of corn and other cereals also touched off street protests in dozens of countries including Mexico, Egypt, Haiti, and Indonesia. A 2007 OECD report found that, "Given the high ambitions of the EU, the US, China, Brazil, and others" with respect to biofuel production, "it is certain that without a serious change in policy the 'food-versus-fuel' debate will become more acute in coming years."[5]

In addition, four recent studies confirm that almost regardless of *where* biofuel production is expanded or *what kind* of energy crop is cultivated, tropical forests and grasslands ultimately will

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[4] Johnson, Eric and Russell Heinen, "Petroleum diesel vs biodiesel: The race is on," *Chemistry & Industry*, April 23, 2007. 22-23. *See also* Mortimer, N.D., *et al*., "Evaluation of the Comparative Energy, Environmental and Socio-Economic Cost and Benefits of Biodiesel – Draft Report for Department of Environment, Food and Rural Affairs," June 2002. 28-30. <http://www.ienica.net/policy/sheffield.pdf>.

[5] Doornbosch, Richard and Ronald Steenblik, / OECD, *Biofuels: Is the Cure Worse Than the Disease?* September 2007. 34. <http://media.ft.com/cms/fb8b5078-5fdb-11dc-b0fe-0000779fd2ac.pdf>.

be cleared to make room for farmland. When farmers respond to subsidy-enhanced biofuel demand by diverting crops like corn, soy, or rapeseed from food markets to energy markets, farmers elsewhere in the world satisfy the unmet demand for food and feed products by clearing and cultivating enough new farmland in and attempt to reestablish food market equilibrium. In an increasingly globalized food market, the make-up food often will be grown wherever land and other agricultural inputs are the cheapest. The result is the conversion of forests, wetlands, grasslands, and other areas in tropical countries – a process that typically leads to substantial releases of soil- and plant-carbon as land is cleared, drained, and/or burned to make it suitable for farming or grazing. According to Berkeley professors Alex Farrell and Michael O'Hare, "There is no way around this effect unless we un-make the global economy."[6]

Although the land use-related effect that biofuels have on climate have been termed "indirect," it dominates other climate-relevant impacts. The studies' authors and several other prominent researchers have determined that the negative climate impacts from converting forest or grassland to farmland can overwhelm even the most optimistic assessments of the annual climate benefit derived from biofuels made from energy crops grown on what was formerly food-producing farmland. The four studies are:

- An article in *Science* by Searchinger, Ralph Heimlich, Richard Houghton, and several researchers from Iowa State on the indirect – but dominant – climate impact associated with an expansion in ethanol produced from US-grown corn and switchgrass. The authors concluded that as compared to regular gasoline, ethanol made from corn and switchgrass would increase GHG emissions by 93% and 50%, respectively.[7]

- A companion study by Searchinger and Heimlich that uses the same methodology to conclude that the net GHG emissions associated with the use of biodiesel made from US-grown soybeans would be 75-158% higher than the emissions from conventional diesel.[8]

- A second article in *Science* by Joseph Fargione and researchers from the University of Minnesota about the "biofuel carbon debt" incurred when forests, grasslands, etc in the US and the tropics are directly converted into energy crop farms. "Our analyses suggest that biofuels, if produced on converted land, could for periods of time, be much greater net emitters of greenhouse gases than the fossil fuels that they typically displace."[9]

- A memo by University of California-Berkeley professors Alex Farrell and Michael O'Hare released in January 2008, essentially previewing the findings in Searchinger *et al*. In addition, Farrell and O'Hare found that if the indirect emissions associated with biofuels were

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[6] Memo from Alex Farrell and Michael O'Hare to John Courtis, "Greenhouse gas (GHG) emissions from indirect land use change (LUC)" (January 12, 2008) (http://www.arb.ca.gov/fuels/lcfs/011608ucb_luc.pdf)

[7] T. Searchinger, *et al.*, "Use of U.S. Croplands for Biofuels Increased Greenhouse Gases Through Land Use Change," Science Express (Feb.
7, 2008).

[8] T. Searchinger and R. Heimlich, Estimating Greenhouse Gas Emissions From Soy-Based U.S. Biodiesel When Factoring in Emissions From Land Use Change (February 7, 2008) (http://www.catf.us/projects/climate/biofuels/Searchinger_Heimlich-Biodiesel_Greenhouse_Gas_Emissions_and_Land_Use_Change.pdf).

[9] J. Fargione, et al., Land Clearing and the Biofuel Carbon Debt, Science Express (February 7, 2008).

properly accounted for, the carbon intensity of California's existing gasoline would be as much as 33% higher than current estimates due to the amount of ethanol that is already blended into the gas.[10]

B. IMPLEMENTING THE RFS: CLIMATE CONSIDERATIONS

The emerging research on biofuels and climate described above raises the threshold question of *whether* EPA should continue to implement the RFS.[11] We believe that EPA should suspend the mandate. However, if EPA fails to suspend the RFS in light of the recent Texas petition, it must address several problems that concern *how* the Agency is implementing the standard.

First, as mentioned above, unless EPA is afforded additional time to develop analytic tools that assess the full range of climate effects associated with production practices and market-mediated impacts like downstream land-use changes, the Agency will have to rely on models that provide limited insight into how biofuel policies influence climate. Researchers are working on lifecycle analyses that address these concerns, but their models will not be ready in the current timeframe requiring the EPA to promulgate rules this year. According to the timeframe set forth in the amended RFS, however, EPA must begin making certifications as early as this year that renewable fuel produced at new facilities have lifecycle greenhouse gas emissions that are 20 percent better than gasoline or diesel, and that "advanced" and cellulosic biofuels are at least 50 percent and 60 percent better, respectively.[12] If the climate safeguards that Congress built into the RFS when it passed EISA 2007 are to have any effect, EPA must be given an opportunity to rely upon tools that assess the full range of climate-relevant impacts associated with increased production and consumption of all kinds of biofuels.

Second, even if EPA was capable of adequately assessing the net climate impact of commercially available biofuels and determining on that basis which fuels are most worthy of federal support, the Agency is largely constrained from doing so by language in EISA 2007. The 2007 amendment to the RFS directs EPA to ensure that "any such renewable fuel produced from new facilities that commence construction after the date of enactment of this sentence … achieves at least a 20 percent reduction in lifecycle greenhouse gas emissions compared to [the average lifecycle GHG for the gasoline or diesel that would be replaced]."[13] According to the Renewable Fuels Association, more than 13 billion gallons of ethanol capacity had been built or was under construction when EISA 2007 was enacted.[14] Consequently, less than 2 billion gallons of conventional biofuels like corn-based ethanol or soy-based biodiesel will be subject to the climate safeguards. The other 13 billion gallons – fully 36 percent of the total amount of biofuels mandated by the RFS in 2022 – will not have to meet the standard's climate safeguards.

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[10] Farrell/O'Hare Memo, *supra* note 5.
[11] In light of these concerns, several of the undersigned groups have urged that EPA *not* implement the RFS mandate for 2008. *See* Comments on "EPA's Notice of Receipt of a Request from the State of Texas for a Waiver of the Portion of the Renewable Fuel Standard," file June 23, 2008. The comments can be downloaded at: <http://www.catf.us/projects/climate/biofuels/CATF_EWG_FOE_Comments_on_TX_RFS_Waiver_Petition-062308.pdf>
[12] *See* EISA 2007 at §§201, 202(a)(1), (a)(2)(B)(i)(II), (a)(2)(B)(i)(III) (amending CAA §211(o), (o)(1))
[13] EISA 2007 at §§201, 202(a)(1) (amending CAA §211(o))
[14] *See* RFA, U.S. Fuel Ethanol Industry Biorefineries and Production Capacity <http://www.ethanolrfa.org/industry/locations/>.

Given the substantial threat to climate posed by such fuels,[15] it is highly unlikely that full RFS implementation will help reduce global warming. Further, if it is not feasible to produce the "advanced" biofuels in the mandated amounts by the target dates (and experts are skeptical that the schedules can be met), EISA authorizes the use of corn ethanol to fill the mandate, greatly increasing its adverse effects.

C. NET IMPACT OF THE 2008 RFS ON CLIMATE

Pursuant to amendments contained in the Energy Policy Act of 2005, EPA set the 2008 RFS at 5.4 billion gallons of renewable fuel.[16] The standard was revised again with the passage of the Energy Independence and Security Act of 2007, which substantially enlarged annual production targets and established the long-range goal of 36 billion gallons of renewable fuel by 2022.[17] The RFS for 2008 of 9.0 billion gallons represents a 3.6 billion gallon increase over the preexisting target for 2008.

The Clean Air Task Force contracted Agricultural Conservation Economics (ACE) principal Ralph Heimlich to assess the net impact on GHG emissions that can be attributed to that 3.6 billion gallon increase. ACE applied the same model-driven approach that Heimlich and his co-authors described in their above-referenced February 2008 *Science* article, titled "Use of U.S. Cropland for Biofuel Increases Greenhouse Gas Through Emissions from Land Use Change."[18] See Appendix B. According to their *Science* article,

> Most prior studies have found that substituting biofuels for gasoline will reduce greenhouse gasses because biofuels sequester carbon through the growth of the feedstock. These analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland to replace the grain (or cropland) diverted to biofuels.

Heimlich and his co-authors corrected for that "accounting error" by factoring in emissions from land use changes, using tools developed by the Food and Agriculture Policy Research Institute (FAPRI) (to model the acreage and location of new cropland that would be cultivated to accommodate increased biofuel production) and research by the Woods Hole Research Center (to calculate the amount of CO2 that would be released per acre from the various ecosystems projected to be converted into cropland). The land use-related emissions were then used to adjust the output from GREET, the most commonly used lifecycle analysis.

[15] *See* Searchinger, T. *et al.*, Use of U.S. Cropland for Biofuel Increases Greenhouse Gas Through Emissions from Land Use Change, *Science* (February 8, 2008) (attached as Appendix B); T. Searchinger and R. Heimlich, "Estimating Greenhouse Gas Emissions From Soy-Based U.S. Biodiesel When Factoring in Emissions From Land Use Change" (February 7, 2008) (http://www.catf.us/projects/climate/biofuels/Searchinger_Heimlich-Biodiesel_Greenhouse_Gas_Emissions_and_Land_Use_Change.pdf).

[16] 72 Fed. Reg. 66171, 66172 (November 27, 2007).

[17] EISA 2007 at §202(a)(2) (amending CAA §211(o)); 73 Fed. Reg. 8665, 8666 (February 14, 2008).

[18] Searchinger, T. *et al.*, Use of U.S. Cropland for Biofuel Increases Greenhouse Gas Through Emissions from Land Use Change, *Science* (February 8, 2008).

For the *Science* article, Heimlich and his co-authors projected the amount of land that would be cultivated and the corresponding amount of CO2 that would be released if US corn ethanol production were to increase by 56 billion liters (approximately 15 billion gallons).

In the memorandum appended to these comments (see Appendix [C]), ACE used the same approach to calculate the GHG emissions associated with an incremental increase of 3.5 billion gallons (*i.e.*, slightly less than the 2008 RFS increase). Structural constraints within the FAPRI model required ACE to analyze an increase from 15 billion gallons to 18.5 billion gallons (rather than from 5.4 billion to 9.0 billion) and to assume the increase was to occur in 2011 (rather than 2008). These data accommodations have no substantial effect on the outcome, however, because the calculations are based on a reasonably static *rate* of emissions per gallon of corn ethanol produced.

As described in the appended memorandum, increasing US corn ethanol production by 3.5 billion gallons would *increase* net CO2-equivalent emissions by 1,311 million metric tonnes. By way of comparison, that is almost equal to the amount of CO2 that nearly four hundred 500MW coal-fired power plants would emit over the course of a year.

D. THE EUROPEAN PRECEDENT

Assessing the real-time climate impact of biofuel policies is difficult, but the scale of those impacts (as well as the complicated nexus between policies that promote biofuels and activities that accelerate global warming) can become apparent over time. The 2003 EU Biofuels Directive, which is similar in several respects to the US RFS, established successively larger biofuel consumption targets for 2005, 2010, and 2020. European biodiesel is usually made from domestically grown rapeseed oil, which also happens to be a popular cooking oil. By diverting more and more of the annual rapeseed harvest to biodiesel refineries, the Directive inadvertently created a demand for anything that could fill the void in the market for cooking oils. Part of that demand has been met by Malaysian and Indonesian palm oil, much of which is produced at plantations carved from forests and peatlands.

The bog-like peatlands of Southeast Asia store enormous quantities of soil carbon. According to a 2006 report issued by Wetlands International and the Dutch engineering firm Delft Hydraulics, almost 12 million hectares of Indonesian peatland have been drained and cleared – often to make room for palm oil plantations. In the process, approximately two billion metric tons of CO2 are released annually, making peatlands destruction a leading source of global warming emissions. After accounting for these emissions – which equal eight percent of global CO2 emissions from fossil fuel use – researchers determined that Indonesia's CO2 emissions were the third highest in the world, behind only the United States and China.[19]

The carbon release is large enough, in fact, to easily negate any of the purported carbon benefits that might be achieved if European motorists were to meet the Directive's biofuel-for-petroleum substitution targets. Biofuelwatch, an industry watchdog based in Britain, calculates that the

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[19] Wetlands International and Delft Hydraulics, *Assessment of CO2 emissions from drained peatlands in SE Asia*, December 7, 2006. Summary, 29-30. <http://www.wetlands.org/publication.aspx?ID=51a80e5f-4479-4200-9be0-66f1aa9f9ca9>.

average net CO2 emissions caused by producing Southeast Asian palm oil for biodiesel are between two and eight times larger than the emissions that are avoided by substituting the biodiesel for petroleum-based diesel.[20] The Wetlands/Delft report estimates that between 10 and 30 metric tons of CO2 are released for every metric ton of palm oil produced.[21]

Consequently, in a somewhat predictable expression of policy regret, the EU announced it is working on a set of proposals that would ban the importation of biofuel feedstocks that contribute to global warming, and require that feedstocks used to comply with the Directive provide "a minimum level of greenhouse gas savings."[22] According to an article in *The New York Times* published on July 8, 2008,

> European governments had sought to lead the rest of the world in the use of biofuels, aiming to derive 10 percent of Europe's transportation fuels from biofuels by 2020. But the allure has dimmed amid growing evidence that the kind of goals proposed by the European Union are contributing to deforestation, which speeds climate change, and helping force up food prices.[23]

Furthermore, European policymakers are struggling to justify the Directive's targets in light of a study recently issued by the British government that raises "fresh doubt [about] fuels made from crops as a way to the fight climate change."[24]

IV. BIOFUELS AND WATER QUALITY

Increasing the amount of cropland planted with corn will likely increase water pollution unless producers substantially ramp up their use of conservation and pollution prevention practices. According to the USDA Economic Research Service's 2006 Agricultural Resource and Environmental Indicators report, about 130 pounds of nitrogen and 58 pounds of phosphate are applied to corn acres in the United States. The 15 million acre increase in corn acres reported by the National Agricultural Statistics Service in 2007, then, likely resulted in the application of nearly 2 billion pounds of nitrogen and 870 million pounds of phosphate—a serious increase in the risk of water pollution in agricultural regions. Moreover, thanks largely to the ethanol mandate and excessively wet weather, pollution levels flowing to the Gulf of Mexico will be even higher and will expand the so-called "Dead Zone" to an unprecedented 10,000 square miles (or roughly the size of Massachusetts).

The suffocation of marine life every spring through summer is so extensive and grave in the Dead Zone that many scientists fear a "regime shift" may occur where the entire ecosystem's

[20] Jim Roland-Biofuelwatch, "An estimation of the expected CO2 emissions caused by producing South East Asian palm oil for biodiesel, compared with the avoided diesel emissions," February 2007 (internal citation omitted). <www.biofuelwatch.org.uk/SE_Asia_palm_biodiesel_analysis.doc>.
[21] Wetlands Intl/Delft, 30.
[22] *See, e.g.,* Member states in push to revise renewable plans, *EurActiv* (June 10, 2008) (http://www.euractiv.com/en/energy/member-states-push-revise-renewables-plans/article-173208)
[23] James Kanter, Europeans Reconsider Biofuel Goal, *New York Times* (July 8, 2008) <http://www.nytimes.com/2008/07/08/business/worldbusiness/08fuel.html?ref=business>.
[24] *Id*.

food chain is rapidly reorganized, which is difficult or impossible to reverse. This is a high environmental price to pay for a biofuels policy that is straining family food budgets for the poorest Americans, harming the environment, and doing next to nothing to lower gas prices.

Though many environmental and conservation groups warned of the environmental consequences that a five-fold increase in the RFS would have, attempts to set minimum environmental performance standards for biofuels production and to provide EPA to adjust the mandate in the face of adverse environmental effects were thwarted. What follows are some of the ramifications of this short-sighted and dangerous food-to-fuel policy.

A. CORN & SOYBEANS ARE THE TOP DEAD ZONE POLLUTERS

The U.S. Geological Survey (USGS)[25] in February 2008 estimated that agricultural fields – primarily corn and soybean fields – in just 9 states[26] in the Mississippi River Basin contributed 75 percent of the fertilizer and manure pollution creating the Dead Zone in the Gulf of Mexico every spring. These 9 states received $14.3 billion of the $34.8 billion in federal crop subsidies between 2003 to 2005, or 41% of all of taxpayer support for production agriculture.[27] A good start to addressing this problem would be the implementation of a mandatory and comprehensive nutrient management plan that would require all commodity crop subsidy recipients to lower their nutrient pollution while optimizing production, easements and the restoration of riparian buffers. While still optimizing yield, farmers can lower excess fertilizer and manure inputs and prevent nutrient pollution by making conservation practices commonplace.

B. NITROGEN & SOIL POLLUTION ASSOCIATED WITH THE RFS MANDATE ARE HIGH

To supply enough corn to meet a 15 billion gallon corn ethanol mandate would require approximately 37 million acres, or 40 percent, of the entire U.S. 2007 corn crop (which was 90 million acres). Producing 36 billion gallons of corn starch-based ethanol would require virtually the entire U.S. corn crop. That means either all other uses of corn (for meat and dairy production or for exports to developing countries) will have to do without that much corn *or* corn farmers will expand their fields into natural areas or currently unused farmland that are now providing wildlife habitat and clean water.

We estimate that about 500,000 tons of nitrogen fertilizer may be lost from the commercial fertilizer and manure used on the cornfields feeding the 15 billion gallon corn ethanol mandate. To reach the 15 billion gallon mandate, about 180 million tons of soil may be lost which is about

[25] Alexander, Richard B. Richard A. Smith, Gregory E. Schwarz, Elizabeth W. Boyer, Jacqueline V. Nolan, and John W. Brakebill. Differences in Phosphorus and Nitrogen Delivery to the Gulf of Mexico from the Mississippi River Basin. February 2008. http://water.usgs.gov/nawqa/sparrow/gulf_findings/

[26] Five of these nine states are in the top 10 Crop Subsidy-Receiving States in the Country (Iowa is the no. 1 subsidy-receiving state, Illinois is no. 3, Indiana=7, Arkansas=9, Missouri=9. Two more states are in the Top 15 Subsidy-Receiving States (Ohio=12, Michigan=14). The last two are in the Top 25 Subsidy-Receiving States (Tennessee=21, Kentucky=25). Environmental Working Group, EWG Farm Bill 2007 Policy Analysis Database, Washington, DC.

[27] Environmental Working Group, EWG Farm Bill 2007 Policy Analysis Database, Washington, DC.

10 percent of the 1.7 billion tons of soil that erode annually nationwide.[28] Additional soil degradation will also occur as a result of increases in crop production to produce the remaining 21 billion gallons of biofuels for the RFS, including crops for biodiesel and conventional ethanol.

C. THE RFS MANDATE WILL WORSEN THE DEAD ZONE & MAKE IT IMPOSSIBLE TO CLEAN UP WITHOUT UNIMAGINABLE CHANGES

Corn is the most fertilizer- and energy-intensive crop of all the commodity crops. Therefore, according to Donner and Kucharick (2008), achieving a mere 15 billion gallons per year mandate for corn ethanol would cause a 10 to 18 percent increase in nitrogen export to the Gulf of Mexico. If 36 billion gallons of conventional corn ethanol were somehow produced in a manner that met the greenhouse gas requirements in the bill, then the nitrogen export to the Gulf would still be 34 percent higher.[29]

Instead, to shrink the Dead Zone to 5000 square kilometers (km^2) nitrogen loadings to the Gulf need to be reduced by 40 to 45 percent. Thus, Donner and Kucharick conclude that the corn ethanol mandate makes it "practically impossible" to reach the goals of reducing the Dead Zone without extreme shifts in food production and agricultural management. The scientists' project that a revolutionary shift in diet away from meat consumption and construction of 22,000 km^2 of wetlands next to all corn and soybean lands may be necessary to shrink the Dead Zone.

D. PUBLIC ENVIRONMENTAL INVESTMENTS ARE BEING LOST THANKS TO THE RFS MANDATE

In 2007, corn was planted on an additional 14 million acres largely in response to the demand for more corn from the RFS mandate and continued strong demand from overseas. Morris estimates that about two of the 14 million acre increase came from Conservation Reserve Program (CRP) land.[30] Thus, millions of taxpayer dollars worth of investments in clean water, wildlife habitat, and carbon sequestration from retiring environmentally sensitive cropland into 10-15 year conservation contracts have been lost to the high price of corn driven up, in part, by the RFS mandate.

Calls for early, no penalty, early outs for farmers from the CRP will only lead to greater losses while exacerbating the other negative effects. In fact, taking 7 million acres out of CRP is equivalent in carbon emission to putting 2.1 million new cars on the road each year.

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[28] US Department of Agriculture. National Resources Inventory. 2003 Annual NRI. Soil Erosion. http://www.nrcs.usda.gov/TECHNICAL/land/nri03/nri03eros-mrb.html

[29] Donner, Simon D. and Christopher J. Kucharick. Corn-based ethanol production compromises goal of reducing nitrogen export by the Mississippi River Published online on March 10, 2008, 10.1073/pnas.0708300105 PNAS | March 18, 2008 | vol. 105 | no. 11 | 4513-4518. http://www.pnas.org/cgi/content/abstract/105/11/4513

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V. BIOFUELS AND CRITICAL HABITAT

As global biofuel production competes for arable land, farmers and governments are converting native forests and grasslands to agricultural lands**.** Lands directed into biofuel production will either directly or indirectly cause deforestation and the loss of other natural ecosystems, resulting in biodiversity loss and threatening the existence of species.

In the United States, demand for corn has caused Conservation Reserve Program land to be taken out and directed towards ethanol production. CRP is fundamental for wildlife conservation and biodiversity enrichment. Much of the land enrolled in CRP is within the Great Plains region. Across the Great Plains, approximately 99 percent of the original prairie grassland has been lost.[31] Over a decade ago, 55 grassland species in the United States were threatened or endangered and 728 were candidates for endangerment.[32]

In Brazil, increased acreage for soybean biodiesel and sugarcane ethanol is devastating the *Cerrado*, Brazil's biodiverse savanna. A great number of species exist solely in the Cerrado. Additionally, as soy and sugarcane acreage increases, other land users are forced to seek new lands, which is leading to the destruction of the Brazilian rainforest. The Brazilian Amazon is home to the 10 percent of the world's mammals and 15 percent of the world's known land-based plant species; it is also estimated that as many as 300 species of tree can be found in a single hectare.[33]

In Southeast Asia, deforestation is occurring to expand palm oil plantations – in part to meet international, policy-driven demand for biodiesel. Close to 48 percent of currently productive palm oil plantations in Malaysia and Indonesia are on land that was recently converted from forest.[34] Widespread deforestation in Sumatra, Borneo, and other islands that are part of Malaysia and Indonesia has caused severe damage to the biodiversity of the area. The small island of Borneo alone contains at least 222 mammals (44 endemic), 420 *resident* birds (37 endemic), 100 amphibians and 394 fish (19 endemic), with new species discovered each year.[35] Deforestation has resulted in iconic mammals, such as the Sumatran tiger, the Sumatran orangutan, the Asian elephant and the Sumatran rhinoceros to become endangered or critically endangered.

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VI. CONCLUSION

In light of the severe environmental harms associated with the RFS-driven increase in biofuel production, the undersigned groups urge Congress to suspend the mandate. Any renewable fuels policy must include minimum environmental standards that protect climate, soil, air and water quality for *all* renewable fuels; regularly assess the effects and successes of policies; and provide a clear mechanism for adjusting mandates to prevent adverse effects.

Sincerely,

Jonathan Lewis
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Clean Air Task Force

Sandra Schubert
Director of Government Affairs
Environmental Working Group

Kate McMahon
Energy and Transportation Policy Campaigner
Friends of the Earth

Cc:
Chairwoman Barbara Boxer
Ranking Member James Inhofe
Senator Joseph Lieberman
Senator Hillary Clinton
Sen. Johnny Isakson
Sen. Bernard Sanders
Sen. Lamar Alexander

Appendix A

Results for 3.6 Billion Gallon RFS from U.S. Ethanol Production

CAA 211(o)(7) authorizes states to petition EPA to waive or reduce the RFS, and authorizes EPA to do so if it finds that implementing the mandate would "severely harm the economy or environment of a State, region, or the United States." EPA has received an RFS waiver petition from Texas, which has alleged that the RFS is severely harming its livestock industry. Other states are considering whether to send in their own petitions pointing to other instances of economic harm.

The statute allows EPA to waive or reduce the mandate for only one year at a time. The issue is whether the RFS for 2008 (9 billion gallons of renewable fuel) is causing severe environmental harm relative to the previous RFS for 2008 of 5.4 billion gallons, prior to passage of the EISA in December 2007. What is the environmental impact of expanding corn ethanol and soy biodiesel production by a total of 3.6 billion gallons (i.e., the incremental increase for 2008 under EISA).

This analysis addresses one aspect of the environmental impact of increased renewable fuel production through biofuels: changes in net GHG emissions attributable to substituting biofuels for fossil fuels, including attendant land use change on a global basis from diversion of the crop feedstock to biofuel production. Searchinger et al. (2008) demonstrated that prior engineering studies of the relative GHG emissions from fossil and biofuels failed to adequately account for effects of indirect land use change in the full life cycle of biofuels production. When carbon sinks presently in place in the form of forests and grasslands throughout the world are disrupted to convert additional land for crop production to replace diverted biofuel feedstocks, net GHG emissions per megajoule of energy in the fuels increase from 74 for ethanol (20 percent *less than* for gasoline) to 177 grams of CO2 equivalent emissions per megajoule (93 percent *higher than* for gasoline). This “carbon debt” would eventually be retired by continued use of ethanol, but ethanol production would cause net greenhouse gas emissions until corn ethanol had been used for 167 years. This is equivalent to 67,734 grams per additional liter of ethanol produced (256,402 grams per gallon), or 351.4 metric tonnes per additional hectare brought into production around the world. Applying the net emissions differences derived by Searchinger et al (2008) to the additional 3.6 billion gallons of ethanol required under the EISA RFS target is estimated to produce an additional 923.1 million metric tonnes of CO2 equivalent greenhouse gas emissions globally relative to use of fossil fuels (3.6 billion gallons x 256.4 MT/gallon). This “linear” estimate is summarized in table 1.

However, the Searchinger et al result is based on a full target level of 30 billion gallons of renewable fuels by 2016, or a 15 billion gallon increase in ethanol over levels expected in the 2016 baseline. There are several reasons why a smaller increase instituted today could produce different results from the Searchinger et al findings related to the nature of agricultural production. First, the amount of potential arable land is limited, so that higher levels of biofuels produced from agricultural feedstocks will require an increasing proportion of this fixed asset. Second, bringing in increasingly marginal land resources will likely reduce yield per unit area, requiring more land to meet higher biofuel levels. Third, there is a secular upward trend in crop yield assumed over time, so that meeting higher biofuel goals at later periods requires less land since overall crop yields are assumed to be rising. The second and third factors work in opposite directions to each other.

To investigate how emissions factors might change for lower biofuel targets closer in time to the present (i.e, 2011 versus 2016), the same methods used by Searchinger et al (2008) were used to analyze diversion of corn for ethanol amounting to an increase of 3.5 billion gallons in 2011 (from a baseline of 15 billion gallons to 18.5 billion gallons) derived from the same FAPRI-CARD ethanol modeling (S. Tokgoz et al, 2007) used in Searchinger et al (2008). Cropping changes associated with that scenario amount to an additional 3.8 million hectares of land brought into production (compared with 10.8 million hectares for the 2016 scenario at 15 billion additional gallons). Applying carbon loss estimates relating to land types converted over the last 20 years by region compiled by Woods Hole Research Center (Houghton, 1999, 2003; Houghton and Hackler 2006; Ajtay et al, 1979; Olson et al, 1983; Whittaker and Likens, 1973; Houghton et al, 1991; Houghton and Hackler, 1999; Houghton, 2005) results in estimated CO2 equivalent emissions from land use change caused by cropland development of 1,311.1 million metric tonnes (compared with 3,801.2 million MT for the 2016 scenario). Dividing the smaller emissions by the smaller area change gives a rate of emissions per hectare of 343.4 in 2011 (less than the 351.4 metric tonnes per hectare for the 2016 scenario). However, the rate of emissions per added gallon of ethanol rises to 370,887 grams in 2011 (versus 256,402 g/gallon in 2016). The emissions per hectare are lower n 2011 because of the mix of crop conversions necessary to achieve the higher commodity production, but the emissions per gallon are higher because the secular trend increase in crop yields is less in 2011 than in 2016, but the amount of production necessary to produce each unit of ethanol and meet other crop demands is the same. Because conversion of forest and grassland allows cropping to occur over a long period, we assume that these emissions would be amortized over 30 years.

Table 1—Estimated GHG emissions from land use change due to ethanol production, three scenarios

Item	unit	Linear estimate	2011 Scenario	2016 Scenario
Scenario Production	million gallons	9,000	18,582	29,632
Baseline Production	million gallons	5,400	15,047	14,807
Change in Production	million gallons	3,600	3,535	14,825
Change in Crop Area	million hectares	na	3.8	10.8
Change in CO2- equivalent emissions	million metric tonnes	923	1,311	3,801
Change in emissions per area converted	metric tonnes/hectare	na	343.4	351.4
Change in emissions per unit of ethanol	Grams/gallon	256,402	370,888	256,402
Amortized change in emissions (30 years)	million metric tonnes/year	31	44	127
Percent of 2006 transportation emissions	percent	1.5%	2.2%	6.3%

Based on data from the Energy Information Administration, the U.S. used 21.9 billion gallons of motor gasoline in 2006, which emitted 2,010 million metric tonnes of CO2 equivalent greenhouse gases. Replacing 3.6 billion gallons of gasoline with ethanol (16.4 percent) is estimated to add between 1.5 and 2.2 percent to total annual greenhouse gas emissions on an amortized basis, although most of the changes in land use accompanying diversion of corn to ethanol would occur in the first few years of that period.

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Sciencexpress Report

Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change

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Most prior studies have found that substituting biofuels for gasoline will reduce greenhouse gasses because biofuels sequester carbon through the growth of the feedstock. These analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland to replace the grain (or cropland) diverted to biofuels. Using a worldwide agricultural model to estimate emissions from land use change, we found that corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gasses for 167 years. Biofuels from switchgrass, if grown on U.S. corn lands, increase emissions by 50%. This result raises concerns about large biofuel mandates and highlights the value of using waste products.

Most life-cycle studies have found that replacing gasoline with ethanol modestly reduces greenhouse gasses (GHGs) if made from corn and substantially if made from cellulose or sugarcane.(*1–8*). These studies compare emissions from the separate steps of growing or mining the feedstocks (such as corn or crude oil), refining them into fuel, and burning the fuel in the vehicle. In these stages alone, as shown in Table 1, corn and cellulosic ethanol emissions exceed or match those from fossil fuels, and therefore produce no greenhouse benefits. But because growing biofuel feedstocks removes carbon dioxide from the atmosphere, biofuels can in theory reduce GHGs relative to fossil fuels. Studies assign biofuels a credit for this sequestration effect, which we call the "carbon uptake" credit. It is typically large enough that overall GHG emissions from biofuels are lower than those from fossil fuels, which do not receive such a credit because they take their carbon from the ground.

For most biofuels, growing the feedstock requires land, so the credit represents the carbon benefit of devoting land to biofuels. Unfortunately, by excluding emissions from land use change, most previous accountings were one-sided because they counted the carbon benefits of using land for biofuels but not the carbon costs – the carbon storage and sequestration sacrificed by diverting land from its existing uses. Without biofuels, the extent of cropland reflects the demand for food and fiber. To produce biofuels, farmers can directly plow up more forest or grassland, which releases to the atmosphere much of the carbon previously stored in plants and soils through decomposition or fire. The loss of maturing forests and grasslands also forgoes ongoing carbon sequestration as plants grow each year, and this foregone sequestration is the equivalent of additional emissions. Alternatively, farmers can divert existing crops or croplands into biofuels, which causes similar emissions indirectly. The diversion triggers higher crop prices, and farmers around the world respond by clearing more forest and grassland to replace crops for feed and food. Studies have confirmed that higher soybean prices accelerate clearing of Brazilian rainforest. (*9*) Projected corn ethanol in 2016 would use 43% of the U.S. corn land harvested for grain in 2004 (*1*)—overwhelmingly for livestock (*10*)—requiring big land use changes to replace that grain.

Because existing land uses *already* provide carbon benefits in storage and sequestration (or, in the case of cropland, carbohydrates, proteins and fats), dedicating land to biofuels can potentially reduce greenhouse gasses only if doing so *increases* the carbon benefit of land. Proper accountings must reflect the net impact on the carbon benefit of land, not merely count the gross benefit of using land for biofuels. Technically, as shown in Table 1, to generate greenhouse benefits, the carbon generated on land to displace fossil fuels (the carbon uptake credit) must exceed the carbon storage and sequestration given up directly or indirectly by changing land uses (the emissions from land use change).

Many prior studies have acknowledged but failed to count emissions from land use change because they are difficult to quantify. (*1*) One prior quantification lacked formal agricultural modeling and other features of our analysis. (*11*, *1*) To estimate land use changes, we used a worldwide model to project increases in cropland in all major temperate and sugar crops by country or region (as well as changes in dairy and livestock production) in response to a possible increase in U.S. corn-ethanol of 56 billion liters above projected levels for 2016. (*12*, *13*) The model's historical supply and demand elasticities were updated to reflect the higher price regime of the last three years and to capture expected long-run equilibrium behavior. (*1*) The analysis identifies key factors that determine the change in cropland.

• New crops do not have to replace all corn diverted to ethanol because the ethanol by-product, dry distillers grains, replaces roughly one third of the animal feed otherwise diverted.

• As fuel demand for corn increases, and soybean and wheat lands switch to corn, prices increase by 40%, 20% and 17% for corn, soybeans, and wheat respectively. These increases modestly depress demand for meat and other grain products beside ethanol, so a small percentage of diverted grain is never replaced.

• As more American croplands support ethanol, U.S. agricultural exports decline sharply (corn by 62%, wheat by 31%, soybeans by 28%, pork by 18% and chicken by 12%).

• When other countries replace U.S. exports, farmers must generally cultivate more land per ton of crop because of lower yields.

Farmers would also try to boost yields through improved irrigation, drainage, and fertilizer (which have their own environmental effects), but reduced crop rotations and greater reliance on marginal lands would depress yields. Our analysis assumes that present growth trends in yields continue but that positive and negative effects on yields from biofuels balance out.

We calculated that an ethanol increase of 56 billion liters, diverting corn from 12.8 million hectares of U.S. cropland, would in turn bring 10.8 million hectares of additional land into cultivation. Locations would include 2.8 million hectares in Brazil, 2.3 million hectares in China and India, and 2.2 million hectares in the U.S.

Greenhouse emissions will depend on the type of lands converted. We assigned the new cropland in each region to different types of forest, savannah or grassland based on the proportion of each ecosystem converted to cultivation in the 1990s, and assumed that conversion emits 25% of the carbon in soils (*14*, *15)*, and all carbon in plants, which must be cleared for cultivation. For mature forests, in carbon equilibrium, we only calculated emissions from the initial conversion. For growing forests, we attributed emissions to biofuels equal to the carbon those lost forests would no longer sequester over thirty years (adjusted for disturbances like fire). Our estimates of the carbon content of ecosystems compare roughly to figures cited by the IPCC. (*16)* Our analysis does not reflect the full opportunity costs of using lands for biofuels, which include the additional carbon lands *could* store if managed optimally (e.g., through reforestation), but only the carbon lands would otherwise store in their existing use. Our method yielded an average GHG emission of 351 MT per converted hectare (CO_2 equivalent).

We allocated the total emissions for all converted land into emissions per mega joule of fuel, and factored them into the GREET model (Table 1). GREET provides a commonly used lifecycle analysis of greenhouse gas emissions from the different stages of biofuel and gasoline production (*4*–*6*), and its default assumptions calculate that replacing gasoline with corn-ethanol reduces GHGs by 20% in the 2015 scenario excluding land use change. (*6*, *17*) As land generates more ethanol over years, the reduced emissions from its use will eventually offset the carbon debt from land use change, which mostly occurs quickly and is limited in our analysis to emissions within 30 years. We calculated that GHG savings from corn ethanol would equalize and therefore "pay-back" carbon emissions from land use change in 167 years, meaning greenhouse gasses increase until the end of that period. Over a 30-year period, counting land use change, GHG emissions from corn ethanol nearly double those from gasoline (Table 1). (We chose 30 years because near-term reductions are important and difficult to avert long-term climate change (*18*) and because ethanol is typically viewed as a bridge to more transformative energy technologies.)

As part of our sensitivity analysis, we found that even if corn-ethanol caused *no* emissions *except* those from land use change, overall GHGs would still increase over a 30 year period. (*1*) We also hypothesized a scenario in which (1) increased ethanol and higher prices spur enough yield increases beyond current trends to supply 20% of the replacement grain; (2) emissions per hectare of converted land are only half of our estimates, and (3) improved technology allows corn ethanol to reduce greenhouse gasses compared to gasoline by 40% excluding land use change. In that scenario, the payback period would last 34 years, which means emissions modestly increase over a 30 year period. (*1*)

A smaller ethanol increase of 30.6 billion liters had similar results, with emissions from land use change per MJ of ethanol 10% lower. (*1*) Far larger biofuel increases could change the magnitude of results in unclear ways.

Although these estimates face several uncertainties, the general finding flows from three reliable projections. First, farmers will replace most of the grain diverted from food and feed by ethanol because the demand for overall food and feed – as opposed to any particular grain -- is inelastic. (*19*) Second, increases in cropland will provide most replacement grain because they are cost-effective and fast, the yield effects of biofuel demands are both positive and negative, and the world has many convertible acres – up to 170 million hectares in Brazil alone (*20*–*21*) and perhaps 2.8 billion hectares worldwide. (*22*) Most significantly, the potential emissions per hectare of land conversion greatly exceed the annual greenhouse reductions per hectare of biofuels. According to GREET and at 2015 yields, a hectare of corn for ethanol reduces GHGs by 1.8 MT/ha/yr (CO_2 eq.), but each hectare of forest converted has up-front emissions of 604 to 1146 MT (varying by type and maturity), and each hectare of grassland or savannah from 75 to 305 MT. (*1*) If new cropland replaces any significant fraction of diverted cropland, the payback period for these up-front emissions will be long (even without counting foregone annual sequestration). This result makes intuitive sense because potential biofuel benefits originate in the annual carbon uptake from growing a feedstock, but growing that feedstock will typically require the up-front release of carbon previously sequestered on land over decades.

This analysis has implications for other biofuels. Cellulosic ethanol could use wastes that do not trigger land use change. But if American corn fields of average yield were converted to switchgrass for ethanol, replacing that corn would still trigger emissions from land use change that would take 52 years to pay back and increase emissions over 30 years by 50%. (*1*)
Ethanol from Brazilian sugarcane, based on estimated GHG reductions of 86% excluding land use changes, (*7*) could pay back the upfront carbon emissions in 4 years if sugarcane only converts tropical grazing land. However, if displaced ranchers convert rainforest to grazing land, the payback period could rise to 45 years. (*1*) The extraordinary productivity of Brazilian sugarcane merits special future analysis.

Even if hopes for dramatic yield improvements (*23*) or use of reserve lands (*8*) generated excess croplands in Europe or the U.S., biofuels would still not avoid emissions from land use change. Truly excess croplands would revert either to forest or grassland and sequester carbon. Using those lands instead for biofuels sacrifices this carbon benefit, which could exceed the carbon saved by using the same land for biofuels. (*24*) In addition, even as cropland declined in Europe in recent years, changing technology and economics led cropland to expand into forest and grassland in Latin America. (*25*). Higher prices triggered by biofuels will accelerate forest and grassland conversion there even if surplus croplands exist elsewhere. Most problematically, even with large increases in yields, cropland must probably consume hundreds of millions more hectares of grassland and forest to feed a rising world population and meat consumption (*22, 26*), and biofuels will only add to the demand for land.

This study highlights the value of biofuels from waste products (*27*) because they can avoid land use change and its emissions. To avoid land use change altogether, biofuels must use carbon that would reenter the atmosphere without doing useful work that needs to be replaced, for example, municipal waste, crop wastes and fall grass harvests from reserve lands. Algae grown in the desert or feedstocks produced on lands that generate little carbon today (*28*) might also keep land use change emissions low, but the ability to produce biofuel feedstocks abundantly on unproductive lands remains questionable.

Because emissions from land use change are likely to occur indirectly, proposed environmental criteria that focus only on direct land use change (*8*) would have little effect. Barring biofuels produced directly on forest or grassland would encourage biofuel processors to rely on existing croplands, but farmers would replace crops by plowing up new lands. An effective system would have to guarantee that biofuels use a feedstock, such as a waste product or carbon-poor lands that will not trigger significant emissions from land use change.

Counteracting increases in biofuels with controls or disincentives against land conversion would not only face great practical challenges but also have harsh social consequences. In our analysis, a diversion of 12.8 million hectares, otherwise generating 10% of the world's feed grain by weight, would reduce world consumption of meat 0.9% by weight and dairy products 0.6% (fluid milk equivalents). (*1*) This effect, of which around half reflects poorer diets in developing countries, depresses emissions and has a greenhouse gas "benefit" but probably not a desirable one. Effective controls on land conversion would constrain the major source of new supply to meet increased biofuel demands, resulting in less additional cropland and higher prices as markets seek equilibrium. In that event, more greenhouse "benefits" would stem in reality from reduced food consumption.

Using good cropland to expand biofuels will probably exacerbate global warming. As a corollary, when farmers use today's good cropland to produce food, they help to avert greenhouse gasses from land use change.

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29. Table 1 is calculated with GREET 1.7(4) using default assumptions for the 2015 scenario and as described in (*17*). Gasoline is a combination of conventional and reformulated gasoline. Ethanol rows are based on E-85, and adjusted to isolate effects of ethanol by proportionately removing emissions of gasoline. Land use change emissions are amortized over 30 years, and for biomass assume use of U.S. corn fields of average yield to produce switchgrass at 18 MT/ha (*27*) with no feed by-product. Emissions from burning ethanol are slightly higher than feedstock uptake credit because some carbon is emitted as more potent greenhouse gasses than CO_2. By GREET estimates, 3.04 MJ provides power for 1 kilometer.
30. Acknowledgments: We appreciate the valuable suggestions by Tim Male and Mark Delucchi. This material is based in part upon work supported by the National Aeronautics and Space Administration under Grant Number NNX06AF15G issued through the

Terrestrial Ecology Program, and by the William and Flora Hewlett Foundation.

Supporting Online Material
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References

17 October 2007; accepted 28 January 2008
Published online 7 February 2008; 10.1126/science.1151861
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Table 1. Comparison of corn ethanol and gasoline greenhouse gasses with and without land use change by stage of production and use (Grams of GHGs CO_2 eq. per MJ of energy in fuel) (*29*).

Source of Fuel*	Making Feedstock	Refining Fuel	Vehicle Operation (Burning Fuel)	Net Land Use Effects		Total GHGs*	% Change in Net GHGs vs. Gasoline
				Feedstock Uptake from Atmosphere (GREET)	Land Use Change †		
Gasoline	**+4**	**+15**	**+72**	**0**	–	**+92**	–
Corn Ethanol (GREET)	**+24**	**+40**	**+71**	**-62**	–	**+74**	-20%
						+135 without feedstock credit	**+47%** without feedstock credit
Corn Ethanol + Land Use Change	**+24**	**+40**	**+71**	**-62**	**+104**	**+177**	**+93%**
Biomass Ethanol (GREET)	**+10**	**+9**	**+71**	**-62**	–	**+27**	-70%
Biomass Ethanol + Land Use Change	**+10**	**+9**	**+71**	**-62**	**+111**	**+138**	**+50%**

*Figures in total may not sum perfectly due to rounding in each column.
†Amortized over 30 years