

SUPPORTING ONLINE MATERIAL

SOM Text

Combustion emissions per unit of energy: The Intergovernmental Panel on Climate Change provides default factors for greenhouse gas emissions per unit of energy from stationary installations using different forms of energy. Emissions rates from some biomass sources, such as wood and wood waste, are modestly higher than those for coal, oil or natural gas[p. 217 in (S1)]. Nearly all life-cycle assessments either explicitly or implicitly treat the emissions from combustion of ethanol and biodiesel as the same for gasoline and fossil diesel per unit of energy (S2, S3). Many do so in practice by assuming that there are no emissions from the combustion of the biofuels on the theory that they are necessarily canceled out by the carbon absorbed through the growth of the plants that become the biofuel.

Higher production/refining emissions typically found for biofuels: The production/refining emissions for gasoline and diesel consist of the emissions involved in mining the crude oil, refining it into gasoline or diesel and the associated transportation. The production emissions for biofuels are those from the growing of the biofuel feedstock (not counting land use effects or carbon uptake), the refining process and the associated transportation. The average production emissions for gasoline or diesel are typically estimated at roughly 20% of total emissions from their use (S2, S3). For this reason, this 20% represents the maximum potential savings from any biofuel with a more efficient production/refining process not counting the effects of land use change.

Nearly all life-cycle analyses of the greenhouse gas emissions from biofuels count only these “production emissions” while assuming that the tailpipe emissions from consuming the biofuel in the vehicle are fully offset by the carbon absorbed by the plant feedstocks. In such a comparison, if the production emissions for the biofuel and petroleum based fuels were the same, the greenhouse gas emissions from biofuels would be estimated at 80% lower than those for petroleum. In fact a summary of 27 life-cycle analyses of ethanol from different starch sources and 25 analyses of biodiesel from different vegetable oils found that nearly all estimated less than 80% savings and therefore that these production emissions are higher for biofuels than for the petroleum products they replace [Tables 5.1 & 5.2 in (S4)]. Farrell et al (S5) [supporting materials, Table S3 in (S5)], came to the same conclusion in evaluating several studies of corn-based ethanol.

Some life-cycle analyses of ethanol from cellulose or Brazilian sugarcane emissions estimate savings relative to petroleum greater than 80% and even more than 100% in some cases, but even these studies do not truly estimate lower production/refining emissions [Tables 5.1 & 5.3 in (S4)]. These higher savings occur because much of the energy that fuels the refining process comes from the sugarcane or

cellulose, and often this biomass also provides an electricity energy co-product. The analyses assume that the emissions from this biomass energy use, just like the emissions from the ultimate consumption of the fuel, are cancelled out by the carbon absorbed with the growth of the biomass. As our paper discusses, that offset only occurs if this carbon derives from biomass that is “additional,” in that it would not otherwise remain or become sequestered in plants or soils. In other words, these calculations do not alter the result that the actual emissions from the production process are still higher. Instead, they calculate implicitly that these production/refining emissions may themselves be cancelled out by additional carbon in the biomass feedstock that is used to energize the production process, or to generate energy co-products.

Exclusion of emissions from consumption of biomass for energy in Kyoto Protocol and European Union and U.S. climate legislation: The original reporting under the IPCC revised 1996 guidelines (S6), recommends that countries report emissions for the United Nations Framework Convention on Climate Change from the consumption of biomass for information purposes only and not as national totals although non-CO₂ emissions from this consumption, such as methane or nitrous oxide, do count toward national totals. The accounting rules for Annex I countries under the Kyoto Protocol (S7), which in large part reference these IPCC guidelines, state on page 23: “Consistent with the Revised 1996 IPCC Guidelines . . . CO₂ emissions from biomass and emissions from multilateral operations, should be reported in the appropriate tables, but not included in the national totals.”

The principal climate legislation in the European Union, the Emissions Trading Scheme, caps greenhouse gas emissions from major energy and industrial facilities and allows trading of emissions. But as specified in Annex I, it does not cover emissions from agriculture or land use change (S9). Annex IV then provides, “The emission factor for biomass shall be zero.”

As passed by the U.S. House of Representatives in July, 2009, the American Clean Energy and Security Act of 2009 (S10), Sections 721-728, establishes a cap for greenhouse gas emissions from energy use. Factories and power plants are responsible for holding allowances to match their emissions from energy use. Sellers of transportation fuels must also hold allowances for the emissions their fuels will cause when consumed. The level of allowances declines over time and will require large reductions in emissions by 2050 by these various “covered” entities. Section 722 specifies which emissions are covered, and in the case of all liquid transportation fuels, applies only to those from fossil origin and therefore not biofuels. For electricity generation or industrial power, emissions from use of “renewable biomass” do not count. The definition of renewable biomass (§ 126) places some restrictions on harvesting material from special value, publicly owned lands in the United States but allows the use of virtually any private forest material or the harvesting of any planted bioenergy crop regardless of the private area planted.

The bioenergy provisions of the bill were the subject of negotiations between the bill's lead sponsor, Congressman Henry Waxman, and the Chairman of the Agriculture Committee, Collin Peterson. When they released the language that resulted from their negotiations, they sent a letter to the Speaker of the House, Congresswoman Nancy Pelosi, showing awareness of an accounting problem. The letter stated, "we also agree on the need to account for the carbon footprint of biofuels and biomass used for electricity and power generation through the carbon accounting system in the global warming pollution program or an equally effective mechanism" (S11).

Forest management credits under Kyoto Protocol: Nearly all developed countries have abundant re-growing forests that were harvested prior to 1990 and are sequestering carbon (S12). Because these re-growing forests primarily result from human activities prior to 1990, they would not normally be entitled to carbon credits as human-induced sinks (S12, S13). However, under the "Marrakesh Accords" for implementing the Kyoto Protocol, developed (*Annex I*) countries subject to commitments to reduce emissions under the Protocol may take credit for this re-growing carbon, at least during the first commitment period of 2008-12, as "forest management," but only up to levels set at 15% of the estimated annual carbon re-growth (S14). This percentage was explicitly based on the theory that 15% of the forest growth could be attributable to ongoing forest management efforts (S11, S13). By itself, this credit does not alter the consequences of causing emissions from further land use activities. However, countries may take additional credits for this carbon gain from "forest management" to the extent needed to offset their emissions from land use change and forestry (the emissions covered by Article 3, paragraph 3 of the Kyoto Protocol) up to 9 megatons per year [¶ 6, 10, 11 (S14)]. As a result, even if the production of bioenergy in these developed countries increases emissions from land use change or forestry, most developed countries are likely to be able to offset them with additional, otherwise unused, forest management credits. As a practical matter, at least during the first commitment period, this system means that emissions from land use change effectively do not count against compliance with the national emissions targets because each new ton of emissions entitles a country to use an additional ton of carbon credits.

Use of forests for electricity on additional carbon: Roughly a quarter of anthropogenic emissions of carbon dioxide are removed from the atmosphere by the terrestrial carbon sink, of which the re-growth of forests cut in previous decades plays a major role (S15, S16). Any gain in carbon stored in regenerating forests contributes to the sink, so activities that keep otherwise regenerating forests to constant levels of carbon reduces that sink relative to what would have occurred without those activities.

The net effect of harvesting wood for bioenergy is complicated and requires more analysis. Each ton of wood consumed in a boiler instead of coal does not significantly alter combustion emissions. However, some of the wood in standing timber is typically not utilized and is left to decay in the forest or nearby, causing additional emissions. Much of the carbon in roots will also decompose. Replanting may accelerate release of

carbon from forest soils. As the forest regenerates following cutting, it may sequester carbon faster or slower than would have occurred in the absence of the harvesting, depending on the previous forest's age, site quality and forest type. Over long periods, the carbon stocks of the forests with and without the harvest for biofuels may be equal. For this reason, how different emissions are valued over time plays an important role in estimating the net carbon effects of harvesting wood for use as a bioenergy. [For one discussion of the time issues, see (S17)].

Calculations of greenhouse gas emissions for liquid biofuel mandates: Both the European Union (EU) and the United States, along with many other countries, have instituted blending requirements for transportation fuel distributors that require a minimum percentage of biofuels (S18). For biofuels to meet this blending requirement in both the EU and United States, they must reduce greenhouse gas emissions by specified levels by comparison with gasoline or diesel--levels that vary by year and type of biofuel. These emissions are based on life-cycle analyses. In the United States this life-cycle analysis includes a broad array of potential emissions from land use, including nitrous oxide emissions generated by growing a bioenergy crop, and emissions from land use change. As the Environmental Protection Agency has proposed to implement this requirement, these emissions from land use change do not distinguish between direct land use change and indirect land use change, i.e., they do not differ depending on where the bioenergy crop is grown, but represent the EPA's estimate of the emissions from the incremental land-use changes that will occur as a result of producing the required levels of biofuels of a particular feedstock (S19).

Crediting biomass for energy use versus life-cycle analysis: The life-cycle analyses for biofuels proposed for use by the U.S. Environmental Protection Agency (S19) and adopted by the California Air Resources Board (S20) attempt to calculate the total change in life-cycle emissions that results from a switch between petroleum fuel and the particular biofuel. That kind of analysis includes emissions from the energy used in the production process. For purposes of determining if the use of biomass for energy should receive a carbon credit, as we recommend, emissions that are otherwise regulated under a cap should not be counted again. For example, the tractor fuel used to produce a biofuel crop in the United States, or the natural gas or coal used to refine it, creates emissions that would also be subject to a cap under the climate change bill passed by the U.S. House of Representatives (S10). Because these emissions require compensating reductions elsewhere in energy use to meet the cap, they do not need to be included in the calculation of the carbon effects of the biomass generation and use. Put another way, the cap puts a price on these regulated emissions, so there is no false incentive to switch to bioenergy to avoid legal responsibility for them.

For regulatory programs that do not limit or cap emissions from land use, however, the net land use consequences of biomass for energy have to be assessed to determine the extent of any greenhouse gas credit for the use of this biomass. As we propose, this crediting should focus on the extent to which the generation of the biomass

in “additional carbon,” i.e., a net gain in carbon that would not otherwise be stored in terrestrial ecosystems anyway. This analysis should credit the carbon absorbed by the plant that becomes the fuel (or that helps to fuel the refining process if the emissions from that refining process are under the cap) and also credit any increase in ongoing carbon sequestration. But the calculation must deduct any loss in carbon stocks, and any loss in ongoing carbon sequestration. If the generation of the biomass uses land that otherwise supported carbon uptake in the form of food (whether crops or livestock forage) or timber products, this carbon would not be sequestered, but the calculation must then estimate the “leakage.” The leakage involves the change in emissions from land use (and other unregulated emissions) elsewhere, such as the loss of carbon involved in conversion of forest or grassland to crops, that will occur to replace the product elsewhere. In this analysis, non-CO₂ emissions need to be included, such as nitrous oxide from fertilizer use, to the extent they are non-regulated emissions. These additionality and leakage considerations are now a conventional part of the crediting of land-based emissions reductions under the Clean Development Mechanism established by the Kyoto Protocol and by other proposed methods for crediting land-based offsets. When bioenergy products are generated abroad, the biomass has to be evaluated in the same way.

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