Comments on the SAB Panel Draft Report Regarding EPA's Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources (2014)

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We offer these comments on the draft panel report related to accounting of greenhouse gas emissions from bioenergy. We write to express concerns about this report and recommend that the full SAB initiate a process to make appropriate changes.

Introduction: This report focuses on how to count the carbon consequences of bioenergy, particularly the harvest of wood for power plants, and it is of great importance to climate change and to the world's forests. Harvesting additional trees from forests to burn for electricity will tend to increase carbon dioxide in the atmosphere for decades. At this time, however, Europe is importing large quantities of wood pellets crafted from trees harvested in the United States to burn in power plants based on an accounting error that treats all biomass as carbon neutral. Carbon neutral means that that the carbon dioxide emitted by burning biomass is not counted. European utilities that are required to reduce emissions can therefore switch from coal or gas to wood and mistakenly treat that change as a full reduction of carbon from the fuel itself.

The potential implications of miscounting bioenergy from wood for the world's forests and climate change are large because vast quantities of wood are needed to produce even modest quantities of electricity. Some modeling by the US Energy Information Agency has estimated that if biomass is treated as carbon neutral, power plants will respond to modest carbon prices by producing an additional 4% of electricity from biomass by 2035. If that biomass comes from wood, it would require roughly 70% of all existing U.S. wood harvest. Globally, supplying 3% of the world's existing primary energy demand from bioenergy would require roughly a doubling of the world's commercial tree harvest.

The SAB's bioenergy report is also important because of the likelihood that other countries would follow flawed U.S. rules. If the U.S. counts the harvest of trees as carbon free or low carbon, many other countries with extensive forests are likely to do the same either to fuel their own power plants or to export wood pellets to developed countries.

The European accounting error results from what now a well-known misapplication of national greenhouse gas reporting guidelines under the UN Framework Convention on Climate Change (Searchinger et al. 2009). Those guidelines do not treat bioenergy as carbon neutral. Instead, the basic principle of those guidelines is that for national accounting purposes bioenergy harvests of wood can be counted as emissions from land use change in the land use count. For example, when US forests are cut and burned in another country, the emissions are counted in the U.S. even though they mostly occur in Europe. On a global basis, therefore the emissions balance out. However, when a country has a regulatory scheme that does not apply to emissions from land use change, or if it imports wood, it must count the emissions when the biomass is burned to avoid creating a false incentive or it must count reductions in terrestrial carbon as a cost of bioenergy. This principle applies to EPA regulatory schemes such as the Clean Power Plant.

The panel report does not treat biomass as automatically carbon free but addresses two primary topics that could have the effect of badly miscalculating the carbon consequences of bioenergy. One concerns the time frame by which to judge bioenergy. Bioenergy initially increases greenhouse gas emissions, but over time, it has the potential to reduce net emissions (counting in the benefits of reduced fossil fuel consumption) if and when forest growth rebuilds carbon stocks. From a climate perspective, the value of actions that increase and then reduce emissions through bioenergy should be identical to the value of any other actions that do so (such as increasing coal use before switching eventually to solar). Although the panel report expresses inconsistent views about this timing question, some of its language would de facto treat most forest harvests for bioenergy as carbon free, and none of its treatment of timing addresses the relevant questions. Strangely there is a whole academic field focused on valuing how emissions and mitigation change over time through the "social cost of carbon," but the report ignores this field entirely even though it is actually being used by the government.

The other major problem with the report is its endorsement of analyzing impacts on forests of bioenergy demand through the use of what are necessarily highly complex and extremely uncertain economic and land use models that have never yet been validated. The report does so without analysis of whether any such models have sufficient empirical support and validation to generate reliable estimates or could plausibly develop that support in the near future. At this time, as a separate EPA-sponsored peer review of the FASOM model makes clear, models of this type rely on large numbers of assumptions, adopt large numbers of parameters that lack proper econometric support, and end up imposing decision rules with little to no empirical basis to avoid awkward-looking results. The danger is that poorly designed or manipulated models can claim without proper justification that additional demand for wood actually increases the quantity of carbon in forests – like some FASOM modeling. Such results imply not only that harvesting trees for energy is good for the climate, but also that the country's vast commitment to paper recycling is bad because it reduces demand for wood. If the U.S. embraces this kind of modeling, other countries are likely to develop models that justify extensive harvests of their forests.

1. Short background on bioenergy accounting

Burning biomass for energy emits carbon into the environment just like burning fossil fuels, and typically emits more carbon than burning fossil fuels because of various lower efficiencies. If and when bioenergy reduces emissions, that can only occur because another process offsets these emissions. The first requirement of any offset is that it be additional. Using forest residues or waste can provide an offset. If residues would otherwise be burned in the field, the emissions of burning those wastes instead for energy are offset by the reduction of the emissions in the field. Plant growth absorbs carbon and can also provide an offset. However, only additional plant growth can serve as an offset.

Thus, the mere fact that trees grew and absorbed carbon does not make them a carbon neutral source of energy because that plant growth occurred anyway and already reduced carbon in the atmosphere. Using this biomass for bioenergy by itself cannot reduce carbon further. Similarly, the mere fact that trees would grow back does not automatically provide an offset. Tree growth can begin to offset bioenergy emissions only if and when trees regrowing after a harvest grow at faster rates than trees would grow without the harvest.

Another way of viewing the precise issue is to recognize that burning fossil fuels takes carbon otherwise stored in the ground and puts it in the air. But burning biomass also puts carbon into the air that would typically otherwise be stored in plants and soils.

A large number of papers have analyzed the consequences of harvesting trees for electricity in a wide range of forests under a wide range of forest regimes and have found that doing so increases greenhouse gas concentrations for decades. Bernier & Pare (2012); Holtsmark (2011); Hudiburg, T. et al. (2011); Mckechnie et al. (2011); Mitchell et al. (2012); Zanchi et al. (2011); Walker et al. (2010). In these studies, the assumption is that bioenergy results in additional harvest of trees. The EPA has made the same assumption when estimating the greenhouse gas consequences of paper recycling (ICF 2010). ("The net increase in forest carbon storage from recycling or source reduction is equal to the additional amount of carbon contained in wood that is not harvested as a result of increased recycling or source reduction."). This assumption of additional harvest works even if the trees harvested are from a commercial forest and would otherwise be harvested and used for wood products so long as the wood diverted to bioenergy would be replaced by additional harvesting of forests elsewhere with the same overall efficiency.

The reasons these harvests increase emissions for decades are intuitively understandable. First and most obviously, when trees are cut and burned for bioenergy, there is an immediate release of carbon stored, just like burning fossil fuels. Second, although the trees may grow back, the trees that were cut would also often continue to grow if not cut, and additional sequestration is lost. In fact, middle-aged forests (often harvested for wood) would typically continue to absorb more carbon dioxide than young forests for an extended period of time. During this time, the carbon debt increases. Third, there are great carbon inefficiencies in using wood. Less than two-thirds of the biomass in trees is likely to be used, leaving roots and some branches and leaves to decompose, which emit carbon without any displacement of fossil fuels. [1] Soil carbon losses add to these initial carbon releases. In the power plant itself, the lower burning temperature and greater carbon intensity of wood than both coal and natural gas lead to more carbon releases per kilowatt hour. The combined results mean far more carbon is released immediately or in a few years than would alternatively be released by burning coal.

If forests are allowed to grow back (and not all the carbon dioxide is necessarily reabsorbed), this regrowth will generally require decades before carbon stocks near the carbon stocks the forests would otherwise contain. During the interim, carbon in the atmosphere is higher than using fossil fuels. This timing pattern is why timing considerations are so important. There are parts of the panel report that argue that the only result policymakers should focus on is the carbon in the atmosphere after 100 years. With such a focus, so long as forest regrowth might result in net reductions in carbon after 100 years, users of bioenergy should be credited as though it had in fact reduced emissions in the initial year. There would therefore be no consequences to increasing emissions for decades and no discounting of reductions that would only occur after 100 years.

2. Timing

2A. Valuing emissions and mitigation over time

The issue of timing is basically as follows. Governments are imposing requirements to reduce emissions in specific years, such as requirements in the Clean Power Plan for utilities to reduce emissions. That requirement typically means reducing emissions up the smokestack that year, for example, by switching to solar or wind or gas rather than coal. Much bioenergy would increase emissions for decades but potentially reduce emissions in later years if forests regrow. The question is how policy should value such a measure that starts by increasing emissions even for decades compared to another action that actually reduces emissions in the first year.

The question of how to value emissions and mitigation is the same issue for bioenergy and for climate policy in general. For example, if the government credits a power plant switching to biomass with immediate reductions based on expected results after 100 years, the government should similarly credit a power plant's

1 For example, Wang et. al. 2011 estimated that 32% of all carbon in loblolly pine forests is contained in

proposal to increase emissions for decades by using more coal so long as it provides equivalently enforceable promises to reduce emissions by year 100.

In addition, if the only focus of policy is increased radiative forcing after 100 years, efforts to mitigate methane emissions today would be essentially meaningless as almost no methane emitted today would remain after 100 years. Federal and international governments have large programs to reduce methane emissions. With almost no discussion, the implications of some portions of the panel report are that these efforts should be abandoned.

There is, not surprisingly, a very large literature dealing with the significance of timing of emissions and their mitigation. Much of this literature is expressed through estimates of the "social cost of carbon," which represents the cost of emissions and value of mitigation, and how it changes over time. (According to google scholar, there are 218 papers with the "social cost of carbon" in the title alone, and 4,820 somewhere in the text.) The federal government already uses social cost of carbon for regulatory purposes (EPA, The Social Cost of Carbon, https://www3.epa.gov/climatechange/EPAactivities/economics/scc.html), and as discussed below, its formula discounts future emissions reductions when expressed in today's dollars There are many factors that determine this SCC, and plausible reasons, grounded in scientific estimates of thresholds and many uncertainties to adjust present calculations so as to provide yet greater value to earlier mitigation. A striking feature of the panel report is that it ignores this literature.

Neither does the panel recognize that its recommendations are inconsistent with the way the United States reports bioenergy emissions under the UN Framework Convention on Climate Change or discuss the implications. These rules require that biogenic emissions be reported as emissions from land use change, which includes harvest of trees, in the year in which they occur, but if that is not done, they must be reported when burned. To be consistent, either the EPA must count the emissions from smokestacks or count the emissions from tree removal when they occur.

2B. *The panel recommendations*.

The panel report provides inconsistent and mutually exclusive approaches to addressing emission and removal timing.

2B1. Report language encouraging focus only on the effect on radiative forcing after 100 years.

The panel report contains a few pages arguing, in effect, that the proper focus for evaluating any trajectory of emissions and mitigation is the net emissions after 100 years. Under this approach, if bioenergy increases emissions for decades by 100 tons or even more, but reduces emissions by 100 tons in the year 100, it should be treated analogously with a measure that reduces emissions by 100 tons in year one.

The rationale is that newer climate models estimate that peak atmospheric temperatures are a function of cumulative carbon emissions. Reductions at any time within 100 years would therefore equivalently reduce peak emissions after 100 years.

This reasoning is inconsistent with a broad literature, often expressed in technical terms, but which we explain more simply.

- Even if peak temperatures and damages are the same after 100 years, earlier emissions cause damages in the first 100 years. During the entire regrowth period, there is additional carbon dioxide in the atmosphere trapping heat, melting glaciers, raising sea levels, adding to ocean acidity. Unless these are assigned no value, earlier mitigation must therefore have higher value than later mitigation.

- Even if subsequent sequestration reabsorbs this carbon, damages from the first decades of additional warming do not suddenly disappear. The physical consequences of earlier warming for oceans, permafrost and forests will continue. Any weakened economic growth from the earlier damages will also reduce long-term economic growth.

- The level of emissions matters, not merely the pattern, particularly with regard to damage thresholds. It is likely that damages do not always increase gradually with temperature but instead exhibit thresholds that cause more rapid increases in damages. Once specific but uncertain levels of cumulative warming are reached, consequences may follow that cannot be fully offset by subsequent emissions reductions. The risk of crossing these uncertain levels implies substantially higher value for earlier rather than later emissions. This value can be expressed in part as the estimated value of avoiding this risk. There is also an option value based on the increased flexibility that early reductions provide to adopt more urgent mitigation pathways if increasing evidence shows the need for it.

- One rational approach to this concern is to establish a fixed target for warming, such as 2°C, which translates into a fixed cap on anthropogenic emissions. (Typical cumulative emissions estimates for this target are on the order of 1,000 gigatons from 2000 to 2050. [Meinshausen et al. 2009]). At this time, societies appear to be on a trajectory to exceed this cap before 2050. If this target represents a belief that 2°C may represent a significant damage threshold, then emissions reductions that happen in time to help avoid this threshold have more value than emissions reductions that happen subsequently. Bioenergy activity that actually increases emissions by 2050 could have negative value by this measure regardless of future reductions.

- Beyond damages, many general economic principles come into play. One is the time value of money. It reflects the value of present consumption and the expectation that future societies will be wealthier. (That growth will occur unless climate change in the interim has such severe effects that it undermines economic growth, which would be yet another reason to favor earlier mitigation.) These economic factors increase the value of mitigation today relative to future mitigation.

All of this thinking, expressed in various forms in the literature, contradicts the reasoning of the panel report and is unaddressed.

To support its reasoning, the panel report also cites papers by Kirschbaum (2003) and Cherubini (2012), which take different paths to argue for some benefits for bioenergy. Among other problems, the panel appears unaware that both the Kirschbaum and Cherubini papers use pulse-emission models that contradict the cumulative emissions model of future warming because the pulse-emissions model do not account for climate/carbon cycle feedbacks (Joos et al. 2013; National Research Council 2016). The pulse-emission models assume that emissions today actually cause less warming, for example, 50 years from now than emissions 50 years from now because oceans and forests would take up much of the carbon released today by that future year. In that way, these pulse-emission models by themselves suggest a value to delaying mitigation. But if the "cumulative emissions" models are correct – and the panel correctly argues that they are better science – then emissions in year one have the same warming effect in year 50 and also cause warming in the interim, so the basis of these other papers is wrong.

2B2. Timing approaches based on harvest cycles.

Patterns of forest removal and growth: Notwithstanding the "100-year" language above, the report's basic approach to timing is quite different. It is based on patterns of wood removal and regrowth in (mostly) managed forests that are harvested in part for the same quantity of bioenergy consistently for decades using the same management regime. Eventually, as earlier tracts regrow, the potential exists to reach an equilibrium in which the loss of carbon from harvesting each new tract is balanced by the carbon gained from the regrowth of the earlier tracts. (This equilibrium does not mean that carbon stocks are unchanged from before bioenergy management, only that there is no further change.) The panel recommends that this time period, which could be decades serve as the time period within which to judge bioenergy. In scenario 1 of Appendix D, for example, this equilibrium period occurs at 90 years. The panel argues that this period is the relevant "policy horizon." Having done that, the panel then provides three different ways of valuing this pattern.

The basic problem with all of these approaches is that the panel is confusing two separate questions. The panel approach describes how much carbon will be physically added to the air and when (under specific assumptions about which forests are harvested for bioenergy, how they are harvested, and how long). But the timing question is the entirely separate question of how we value these different amounts of carbon at different times. That question depends on the impacts on climate, climate damages, economic factors that influence the value of money across time, risks, and the differential costs of the mitigation.

Valuing carbon within forest cycles: Having established a timeline, the panel report does go on to identify three separate ways of evaluating emissions within that timeline, and these approaches at least do bear on timing considerations.

- One approach might be to care only about the effect of bioenergy use on carbon in the last year. This approach ignores all the prior impacts on climate. The problem with this approach is that for no articulated reason, it ignores all the damages that occur within the first 90 years, and all of the other factors that bear on timing.
- Another approach would be, in effect, to judge bioenergy by the average net carbon removed relative to the gross carbon removed from the forest over the period (e.g. 90 years). The problem with this approach is that it does not value earlier emissions higher than later emissions in contrast to the many reasons to do so.
- To the credit of the panel report, the third approach, the integrative approach, is the principal recommendation, and it is better. This approach starts by counting all the additional net "carbon years," in which the total amount of carbon removed from the forest in each year is summed. The ratio of these net carbon years to the gross carbon years would be the amount used.

This third approach is in effect a form of time discounting. It recognizes, in effect, that the additional carbon in the atmosphere each year has a cost, and it compares this net cost (recognizing forest regrowth) relative to the total cost without any forest regrowth. These are important factors in a proper timing consideration.

Despite this fact, the overall report retains several problems. First, there is no explanation of why this recommended approach is appropriate, and it is of course contradicted by the limited explanation of timing consideration that is in the report. The report should include a proper consideration of timing questions in which these issues are one factor. Second, although the timing valuation has some merit, there is no particular reason to tie it to the period chosen based on harvest regime.

There are also large practical problems. The whole timing approach recommended requires judging bioenergy harvests in year one based on an assumption that those harvests will continue for bioenergy in the same manner, and in the same amount over the 90 year period (or other period to equilibrium). There is no reason to believe that will occur. For many uses, bioenergy (even based on flawed carbon assumptions) would only be an interim strategy, such as co-firing coal until the plant retires. There is also no particular reason to believe that biomass would be supplied from the same forest, using the same harvest regime, for this whole period. The approach therefore requires a series of fictional assumptions about the course of actions for decades to judge any bioenergy.

2C. Potentially rational approaches to timing

Here we describe some of the potentially plausible approaches to timing considerations that might be consistent with economic theory.

- Government SCC: Since 2010, the U.S. government has used estimates of the social cost of carbon as a shadow price of carbon in regulatory impact analyses under Executive Order 13563. These social cost of carbon estimates, which have been previously employed by EPA in numerous applications including the Clean Power Plan, are based on economic analysis using a set of climate change integrated assessment models. Interagency guidance mandates the use of four time series of the social cost of carbon, which are associated with three different consumption discount rates. The four time series reflect the mean estimates of the social cost at a 5%, 3% and 2.5% annual consumption discount rate, and the 95th percentile at a 3% consumption discount rate. Over 2020–2030, the average annual growth rates of these time series (based on the May 2015 Technical Support Document) are 3.4%, 2.1%, 1.7%, and 2.3%, respectively, and this growth slows in subsequent decades. Thus, were bioenergy to be valued in a manner consistent with broader U.S. government regulatory policy, the carbon discount rate would be between 0.7% and 1.6% annually between 2020 and 2030, and increase in subsequent decades. Applying the U.S. government estimates as best we can to the hypothetical emissions profile in case study one in Appendix D, we estimate that the BAF would be between 0.25 and 0.32. (These figures are actually comparable to the integrated BAF recommended by the panel although that might not be true for other scenarios, and this approach is based on a clear economic rationale.)

- Adjusted SCC: There are many considerations not emphasized in the U.S. government social cost of carbon analysis that would increase the difference between earlier and later emissions by altering the rate of growth in the SCC. For example, Cai et al. (2015) show that the potential for ‘tipping points’ in the climate system lends an added ‘insurance’ value to emissions reductions that occur before tipping points are crossed. This added early value increases the carbon discount rate. An even more recent paper found that when factoring in the ways in which crossing some tipping points increases the risk of others, the optimal climate strategy required elimination of emissions by 2050, which would therefore dramatically increase the costs of actions that increase emissions within that time-frame (Cai et al. 2016). A related, although not identical value, would be the option value to be able to respond to information about harsh effects with additional mitigation, a value undermined by efforts that actually increase carbon in initial years.

The international goal of limiting warming to below 2°C and as close as possible to 1.5°C also implies a far higher value of emissions reductions that occur before this target is breached. It too implies high costs from bioenergy activities that increase emissions in this time. It is hard to see how bioenergy uses that actually increase carbon in the atmosphere by 2030 and 2050 are consistent with U.S. commitments to reduce emissions by these dates. Early emissions reductions therefore have the value of supporting U.S. leadership and promoting international reciprocity.

- Counting emissions and offsets when they occur: All policies that assign lifetime values in advance to bioenergy projects shift risk in a variety of ways from those undertaking the project to society at large. An alternative, straightforward approach that would avoid this shifting of risk would be to count emissions and reductions when they occur (e.g., Melilio et al., 2009). This is precisely the approach implicit in either a carbon tax or a "cap and trade" system. Any regulated entity required to reduce emissions can still increase emissions and buy credits from some other source and then provide its own emissions reductions or even sell credits in the future. Any entity facing a tax can still increase emissions in year one and pay the tax and reap the benefit of paying a smaller tax later when emissions decline. The fact that any such entity would likely apply a meaningful discount rate to this approach, which in effect values emissions reductions earlier more than later, is just one way of understanding why earlier emissions reductions should generally be viewed as more valuable than later reductions.

  This approach would also assure that carbon accounting practiced by the EPA is consistent with the way the U.S. reports emissions under the UN Framework Convention on Climate Change, which requires that forest carbon stock reductions due to bioenergy be counted in the year they occur.

3. Panel's Endorsement of economic models

The other major issue raised by the panel report is its endorsement of the use of economic models to analyze the carbon implications of removing forest biomass. There certainly are economic effects in increased demand for forest biomass – and they could either increase or decrease the carbon impacts – but the initial question is whether economic models are capable at this time of capturing these effects with sufficient reliability. A primary focus of the SAB on many environmental issues is the reliability of different kinds of environmental evidence. The SAB panel report includes no discussion of the reliability or potential of these models. At this time, potential models yield widely different results, and can be easily programmed to yield a huge span of results. Unless and until they are shown to be reliable, the SAB should not endorse them.

This analysis is of enormous potential significance. For example, one of the modeling analyses in the draft EPA framework sent to the SAB found that every ton of carbon removed from a southeastern forest for bioenergy resulted in an increase in forest carbon of 1.4 tons. If this analysis were true, not only would forest biomass be better than carbon-free, but paper and cardboard recycling programs in the United States that depress forest product demand would be harmful to the climate. (Both bioenergy demand and paper demand primarily use pulpwood quality wood.) Yet, the EPA itself has encouraged this recycling using its "WARM" model, which assumes that a ton of carbon in reduced pulpwood demand results in a saved ton of forest carbon (ICF 2010).

3A. Nature of economic consequences

The models tend to focus on increased demand in a region, such as the Southeast and analyze potential economic responses to the increase in prices. Because wood and the land that produce it are assets however used, each of these responses of increasing demand for wood also has carbon costs. For the economic model to be reliable, both those responses and their costs must be estimated reliably.

- Increased cutting in target region: The most obvious response is that there is an increase in cutting of existing forests. In this case, the carbon cost lies in the loss of carbon stored in the forest.

- Increased cutting in other regions: A second possible response is a diversion of existing wood harvests to bioenergy from other uses such as pulp & paper, resulting in a replacement through additional harvest of existing trees either in other regions or abroad. The carbon cost is the loss of carbon storage in these other forests.

- Reduction in wood consumption and possible increase use of other materials: A third possible response is that people consume fewer wood products, such as less cardboard packaging or paperboard products. The carbon cost would be the greenhouse gas released if some or most of that reduced consumption were replaced by plastics or other materials, and if some sawn timber is diverted, possibly concrete.

- Increased planting or management: A fourth possible response is that landowners plant more forests or intensify their management of existing forests. However, this response is also not cost free. Land planted to forest will typically alternatively be in some kind of agricultural use. Replacing the food will likely require converting some non-agricultural land to agricultural use elsewhere, and possibly shift some livestock production abroad.

The first response is the response analyzed by purely biophysical models of tree harvest and regrowth. There is no inherent reason to believe that the other responses would have lower carbon consequences. The net consequences of each effect depend primarily on relative "carbon efficiencies." If wood harvested abroad or in other regions is harvested less efficiently than wood harvested in the Southeast, then replacing wood elsewhere will have higher carbon costs. If other packaging or construction material is more carbon intensive than wood products, reductions in wood consumption could lead to more total emissions. If replacing crops or livestock occurs abroad, where it is generally less land and greenhouse gas efficient than in the U.S. (Johnson et al. 2014; Herrero et al. 2013), planting forests on agricultural land in the U.S. could also lead to higher total greenhouse gases in the atmosphere.

One reason some models or papers have found carbon benefits from these economic consequences is that they ignore some of these carbon costs. For example, in the FASOM described above, the modeling assumed no carbon cost in replacing Southeastern wood diverted to bioenergy from other uses, nor of replacing agricultural products. Similarly, one modeling analysis by a member of the panel estimated that nearly all bioenergy wood in the U.S. would be supplied by diversions from other uses of pulpwood, but did not count any of the costs of replacing that wood or its uses (Sedjo 2013).

3B. Reliability of these economic models

In part because of the need to count all costs, the panel report recommends that any model used be appropriately comprehensive and global, and focus on both forestry and agricultural effects. But doing so dramatically increases the complexity of the model and multiplies the consequences of the various uncertainties. (Some modelers at some times suggested they can adopt a simply derived "leakage" factor, but there is no way of deriving a leakage factor simply.) For any analytical tool, the burden should be on that tool to demonstrate its reliability.

There are many reasons for large doubts in this context

- Wide modeling differences: Global land use and agricultural models today generate a very broad range of different results (Robinson et al. 2014; Nelson et al. 2014). Which model therefore should be used and why? Even among members of the panel, papers addressing bioenergy from forest biomass have widely different estimates regarding how much will derive from diversions of wood and how much from additional production. Galik & Abt (2015); Sedjo et al. (2011); Wang et al. (2015).

- Enormous complexity: The demand and supply interactions that these models in some form attempt to estimate are very high in number and complexity. When a new source of demand occurs for wood or agricultural land, these models attempt to estimate how much prices will prices, how much would these prices result in reductions in pure consumption, how much in switches in consumption and to which products, how much in changes in forestry or agricultural management practices, how much in changes in land use, and where and how. For example, if grazing land is diverted in the US to trees, questions include how much milk and meat would be replaced, where in the world that would occur, how much would be produced with what land, and with what greenhouse gas efficiencies. These estimates require a very large range of uncertain and difficult to derive parameters. Models necessarily try to simplify these interactions to limit the parameters, but the simplifications are not necessarily accurate. Even the purely biophysical uncertainties are daunting. For example, there is no good data on the efficiencies with which wood is harvested in different parts of the world.

- Opaqueness: For at least most of these models, there is little clear documentation on where and how underlying parameters were derived. Even when EPA had a peer review team analyze FASOM, it indicated an inability to analyze most parameters and functions because of lack of clear documentation (as discussed more below).

- Insufficient econometric foundations: Nearly all the models require parameters that have never been econometrically estimated, and which are therefore assumed or are borrowed from other parameters out of necessity rather than because of a clear rationale. A yield response for cassava in Africa may be based on some estimate of corn yield response in the U.S. Of the parameters that are estimated, many are not based on proper econometric methods. In general, de facto cross-price elasticities of demand and supply, which determine how changes in demand or supply of one product influence another, are not empirically estimated but are instead generated through an assumed functional form.

- Dependence on uncertain future demand: Some models predicate forestry decisions on the assumption that bioenergy demand today will also guarantee equivalent bioenergy demand in the future, inducing farmers to plant more trees today. Even apart from climate accounting, bioenergy demand in the future would depend on a range of unknown cost developments. In many countries, bioenergy is viewed only as a transition strategy. Projections of future bioenergy demand (and landowner assumptions about those demands) introduce yet another important uncertainty in those models.

- Potential impacts outside experience range: If treated as a low carbon source of energy, demand for wood for bioenergy could lead to short-term increases in demand greater than the entire existing U.S. wood demand, and therefore outside historical ranges of experience that might be used to make proper economic estimates.

- Lack of validation: Perhaps most importantly, there is a lack of empirical validation of these models. The panel report calls for some kind of retroactive validation, but the panel does not identify any models for which this has been satisfactorily done. At a minimum, for this kind of model, the validation must be done using data independent of the data used to "tune" the model. Validation must also avoid false claims. Some models build a great deal of results from historical data directly into them, and then claim victory if the model's own features do not greatly distort those preset data.

Before a model should actually be used, all important parameters and functions should be derived using proper, and clearly documented econometric methods. There should also be a solid validation. Until there is demonstration of a viable model under these criteria, and why that model is to be trusted rather than another, the SAB should not be recommending use of such model to EPA.

3C. Experiences with the EPA FASOM Model

An EPA peer review of the FASOM model reveals the difficulties in trying to assure that the model is actually reliable (Segerson et al. 2011). The peer review found:

- The model "presents a false sense of precision."
- Many of the model outcomes "are driven by assumptions about future productivity growth" that the review panel found "highly questionable" as well as "assumptions about agricultural land" demand that "are highly suspect."
- The model generates "large fluctuations in outcomes from one 5-year period to the next" that cannot be adequately explained.

Yet these and many other detailed criticisms are less significant than several other features of the peer review.

- One, the panel found that the underlying structure of the model – the portions that are supposed to be based on empirical evidence – do not predict plausible results. As a result, the modelers impose "constraints designed to produce 'reasonable' projections by, for example, restricting regional crop mix or livestock mix," and without these constraints, the model will "yield 'unreasonable' predictions." Even with these correction rules, "A number of the model's predictions do not seem consistent with expectations." This problem casts serious doubts on the reliability of such a model unless it can be independently and rigorously validated against real data experience. It means that the modelers are imposing constraints specifically for the purpose of making the model results appear reasonable, not that any empirically grounded features of the model are themselves generating reasonable results.

- Two, although the peer review report is strongly critical about many model features that the panelists could review, the review panel could not actually review the majority of actual parameters in the model because of a lack of model documentation. "To judge the credibility of the model's results and have confidence in them, one must be able to see and understand fully the model's structure and inputs. The documentation that was provided to the review panel did not allow the panel to gain such an understanding. It provided general information about model structure and some details about model inputs and parameter values. However, much of the documentation provided simply alludes to general data sources from which information was drawn . . . rather than providing specific estimates (for example, of actual or implied elasticities) that can be judged based on other information."

- Three, what documentation was provided made clear, "in cases where data are not available, parameter values are assumed (see, for example, p. 6-7), presumably based on expert opinion, although the basis for these assumptions/opinions is not documented." Where a model is based on several "assumptions/opinions," it cannot be viewed as being independently reliable absent some other basis for establishing reliability.

Finally, the review made clear that the model has never been "validated against historical data," let alone with future predictions. This point is fundamental. Proper validation is hard and must be done carefully. Once a model is "calibrated" with actual data, or programmed to fit actual annual data, the fact that its results do not differ substantially from that data is not an indication of its validity. And if a model is calibrated for one year, the fact that its results the next year are not far off provides little if any evidence of reliability. Proper validation must be done using data that is not part of the underlying original model calibration, and in ways that validate the truly predictive parts of the model and not those that are inherently "built in."

Even with these challenges, the FASOM model applies only to the United States. If, for example, pulpwood in the United States is diverted from paper uses to bioenergy, or additional agricultural lands are planted to trees in the U.S., such changes do not imply carbon gains because much of the wood and agricultural products are likely to be replaced abroad. The challenges in predicting U.S. responses compound in predicting global responses.

3D. Significance of these limitations

Limitations of the FASOM model are important because that is the model that EPA has in fact been using to develop its bioenergy accounting framework, but even more important is the inherent nature of the problem. FASOM is not necessarily lacking because of mistakes by its authors but rather because this kind of model requires estimations of very large numbers of very complex relationships that (a) lack good underlying econometric estimation, (b) have inevitable uncertainties even when well econometrically estimated, which multiply the resulting uncertainty in the model greatly when combined with so many other factors. In practice, modelers trying to put together models of this complexity must rely on "assumptions" and unsupported extrapolation from what underlying econometric analyses are available because they cannot otherwise complete their model.

The rationale for using this type of model is that the economic feedbacks may show benefits from forest use for bioenergy not evident in assuming that additional demand for wood will require additional forest harvests. Yet, this point lacks any empirical demonstration using simpler economic analyses that look backward at the impacts of previous changes in wood demand. Unless and until there is convincing economic evidence of such effects in the past, there is no reason to pursue these other forward projecting models.

In fact, there is no physical reason that increased wood demand requires new forest plantings. Forest area within the United States has been remarkably constant over the last several decades. And both within the United States and globally, forests are accumulating large quantities of biomass as part of a forest carbon sink that plays a vital role in holding down climate change (in large part because of fertilization by nitrogen and higher levels of carbon dioxide). Although this growth does not make additional forest harvest for bioenergy carbon free – because such harvests would reduce this carbon sink -- this growth of forest biomass does make it possible for total U.S. or global timber harvests to increase several fold without reducing wood availability.[2] In turn, this growth casts doubt on whether economic forces would push additional forest plantings.

[2] For example, Pan (2011) estimates a net global forest sink of roughly 1 gigaton of carbon, roughly equal to around 2 billion tonnes of dry biomass. From 2008-2009, annual roundwood harvest according to FAOSTAT in oven dry tonnes was 1.65 billion tonnes. These figures imply that wood harvest could more than double without reducing forest carbon stocks. In the U.S., Heath et al. (2011) estimate a net forest

These issues do not mean that economics can have nothing to say in the future about bioenergy. More rigorous, but simpler econometric studies may provide useful and reliable lessons that could help shape policy toward bioenergy in the future. Nor does it mean that global modeling studies, particularly in comparison, may not yield interesting insights about the possible interactions. But without careful evaluation and demonstration that any model of this kind today generates empirically verifiable and reliable results, the SAB should not endorse such an approach.

4. Alternatives

Any accounting system should follow the actual carbon cycle as close as possible to accurately address the climate consequences (while a full analysis should also address other environmental consequences). We cannot here outline such a system in detail. However, a more straightforward approach in general would be to count all the emissions as they are emitted up the smokestack of a power plant. Following the same principles of forest offsets, bioenergy users that are able to directly demonstrate (through efforts of their own or of their suppliers) land management changes to increase carbon stocks beyond what would otherwise occur could then be allowed to count those increases as offsets. Issues regarding such offsets would remain regarding potential displacement of food or timber for some scenarios. Yet, overall such a system would give credits in the years in which they occur, and would avoid assigning credit for carbon accumulation that has merely been predicted by a dubious economic model.

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carbon sink of roughly 300 million tons of carbon, roughly 600 million tons of biomass, which is roughly four-times U.S. annual roundwood harvest of 150 million tons.

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