EPA-SAB-12-xxx

The Honorable Lisa P. Jackson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: SAB Review of EPA's Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources (September 2011)

Dear Administrator Jackson:

EPA's Science Advisory Board (SAB) was asked to review and comment on the EPA's *Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources (Framework, September 2011)*. The *Framework* considers the scientific and technical issues associated with accounting for emissions of biogenic carbon dioxide (CO_2) from stationary sources and develops a method to adjust the stack emissions from stationary sources using bioenergy based on the induced changes in carbon stocks on land (in soils, plants and forests). To conduct the review, the SAB Staff Office formed the Biogenic Carbon Emissions Panel with experts in forestry, agriculture, greenhouse gas measurement and inventories, land use economics, ecology, climate change and engineering. The Panel met in October 25-27, 2011 and teleconferenced four times this year.

Assessing the greenhouse gas implications of using biomass to produce energy is a daunting task and the EPA is to be commended for its effort. The context for the *Framework* arose when the EPA established thresholds for greenhouse gas emissions from stationary sources for the purposes of Clean Air Act permits under the New Source Review (Prevention of Significant Deterioration program) and Title V operations program. The Agency had to consider how to include biogenic emissions in determining thresholds for regulation. In July 2011, the EPA deferred for a period of three years the application of permitting requirements to biogenic carbon dioxide emissions from bioenergy and other biogenic stationary sources, while committing to a detailed examination of the issues associated with biogenic CO_2.

The Agency sought a method of "adjusting" biogenic carbon emissions from stationary sources to credit those emissions with carbon uptake during sequestration or, alternatively, avoided emissions from natural decay (e.g., from residues and waste materials). Without a way of adjusting those emissions, the Agency's options would be either a categorical inclusion (treating biogenic feedstocks as equivalent to fossil fuels) or a categorical exclusion (excluding biogenic emissions from determining applicability thresholds for regulation). The purpose of the *Framework* was to propose a method for calculating the adjustment or Biogenic Accounting Factor (BAF) for biogenic feedstocks based on their interaction with the carbon cycle.

In general, the SAB found that the science and technical issues relevant to accounting for biogenic CO_2 emissions are different for each feedstock category and sometimes differ within a category. Forest-derived woody biomass has a much longer rotation period than agricultural feedstocks. While the *Framework* captures most of the elements that would be needed to gauge CO_2 emissions from short-rotation agricultural crops (conventional crops, energy crops and crop residue), its application to forest-derived woody biomass is problematic because it does not capture the relationship between a facility's emissions and the sequestration or offset associated with its particular feedstock. Because forest-derived woody biomass is a long-rotation feedstock, the *Framework* would need to model a "business as usual" scenario along some time scale and compare that carbon trajectory with a scenario of increased demand for biomass. Although this would not be an easy task, it would be necessary to capture the connection between a facility's emissions and the sequestration (offset) associated with its biogenic feedstock. In general the *Framework* should provide a means to estimate the additional effect, as a result of stationary source biogenic emissions, on what the atmosphere/ climate sees over some time period.

In the attached report, the SAB provides some suggestions for an "anticipated baseline" approach while acknowledging the uncertainty and difficulty associated with modeling future scenarios. It would be particularly important to incorporate market effects, specifically the complex interaction between electricity generating facilities and forest markets; market driven shifts in planting, management and harvests; induced displacement of existing users of biomass; land use changes; and the relative contribution of different feedstock source categories (logging residue, pulpwood or roundwood harvest). In developing an anticipated baseline approach, the Agency would need to empirically test alternative modeling approaches with a focus on complexity, accuracy and sensitivity at the relevant time and spatial scales.

For agricultural feedstocks, the variables in the *Framework* capture most of the factors necessary for estimating the carbon change associated with the feedstock, including a factor to represent the carbon embodied in products leaving the stationary source, the proportion of feedstock lost in conveyance, the offset represented by sequestration, the site-level difference in net carbon flux and the emissions that would occur "anyway" from removal or diversion of nongrowing feedstock (e.g., corn stover) and other variables. For short rotation agricultural feedstocks where carbon recovery occurs within one to a few years, the *Framework* can, with some adjustments and appropriate data, represent direct carbon changes in a particular region. As recognized by the Agency, for many waste feedstocks, combustion to produce energy releases CO_2 that would have otherwise been returned to the atmosphere from the natural decay of waste. The Agency chose not to model natural decomposition in the *Framework* but modeling the decay of agricultural and forest residues based on their alternate fate (e.g., whether the materials would have been disposed in a controlled or uncontrolled landfill or subject to open burning) could be incorporated to improve scientific accuracy.

The *Framework* did not discuss the different time scales inherent in the carbon cycle nor did it characterize potential intertemporal tradeoffs associated with the use of biogenic feedstocks. There is no single correct time scale for analysis of climate impacts; the choice is generally considered a policy choice, however it is important that intertemporal tradeoffs be made transparent for policymakers. For forest-derived woody biomass, carbon debts can be created in the short run with increased harvesting but in the long run, climate benefits can accrue if biomass is regrown repeatedly and substituted for coal over successive harvest cycles. Temperature changes are a commonly used assessment endpoint for gauging future climate impacts. While it is clear that the Agency can only regulate emissions (and not temperature), its policy choices about emissions will be better informed if the temporal distribution of temperature impacts is considered.

Finally, the SAB found the task of accounting for biogenic emissions fraught with uncertainties, technical difficulties, data deficiencies and implementation challenges. Clearly there are no easy answers to accounting for the greenhouse gas implications of bioenergy. Some improvements to the *Framework*, as suggested by the SAB, might pose tradeoffs between scientific accuracy and ease of implementation.

Given the challenges associated with improving and implementing the *Framework*, the SAB encourages the Agency to "think outside the box" and look at alternatives to the *Framework* as proposed. The Agency might consider developing default BAFs for each feedstock category based on general information on how their particular harvest and combustion/decay patterns interact with the carbon cycle. Alternatively, the Agency might undertake a comprehensive evaluation of carbon certification systems for procurement of feedstocks, taking into account the same issues that bedevil the calculation of a BAF, specifically leakage, additionality and permanence. While none of these options are flawless, it is important to pursue scientifically sounds methods of accounting for greenhouse gas emissions caused by human activities.

The SAB appreciates the opportunity to provide advice on the *Framework* and looks forward to your response.

Sincerely,

Enclosure

Table of Contents

List of Figures

Acronyms and Abbreviations

Executive Summary

This Advisory responds to a request from the EPA Office of Air and Radiation for EPA's Science Advisory Board (SAB) to review and comment on its *Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources (Framework, September 2011)*. The *Framework* considers the scientific and technical issues associated with accounting for emissions of biogenic carbon dioxide (CO_2) from stationary sources and develops a framework to adjust the stack emissions from stationary sources using bioenergy based on the induced changes in carbon stocks on land (in soils, plants and forests). To conduct the review, the SAB Staff Office formed the Biogenic Carbon Emissions Panel with experts in forestry, agriculture, greenhouse gas measurement and inventories, land use economics, ecology, climate change and engineering.

The SAB Biogenic Carbon Emissions Panel was asked to review and comment on (1) the Agency's characterization of the science and technical issues relevant to accounting for biogenic C02 emissions from stationary sources; (2) the Agency's framework, overall approach, and methodological choices for accounting for these emissions; and (3) options for improving upon the framework for accounting for biogenic $C0_2$ emissions. See Appendix A: Charge to the SAB Panel. In the context of the *Framework*, the term "biogenic carbon emissions" refers to emissions of CO_2 from a stationary source directly resulting from the combustion or decomposition of biologically-based materials other than fossil fuels. During the course of deliberations, the SAB Panel reviewed background materials provided by the Office of Air and Radiation and heard from numerous public commenters. This Executive Summary highlights the SAB's main conclusions. Detailed responses to the individual charge questions are provided in the body of the report.

Context

The Agency provided very little written description of its motivation for the *Framework* in the document itself. However, through the background information provided and discussion at the public meeting on October 25 – 27, 2011, the Agency explained that the context for the report is the treatment of biogenic CO_2 emissions in stationary source regulation. Since January 2011, greenhouse gases are a regulated pollutant under the Clean Air Act New Source Review (NSR) and Title V programs. On June 3, 2010, the EPA finalized new thresholds for greenhouse gas emissions that define when Clean Air Act permits under the New Source Review (Prevention of Significant Deterioration program) and Title V operations program would be required (also known as the "Greenhouse Gas Tailoring Rule"). Under the Clean Air Act, major new sources of certain air pollutants, defined as "regulated New Source Review (NSR) pollutants" and major modifications to existing major sources are required to obtain a permit. The set of conditions that determine which sources and modifications are subject to the Agency's permitting requirements are referred to as "applicability" requirements. Now that greenhouse gases are included in the definition of a "regulated NSR pollutant," a calculation has to be made that determines whether a source meets the "applicability threshold" to trigger permitting requirements. A proposed new source would have to have potential greenhouse gas emissions greater than 75,000 tons per year of carbon dioxide equivalent (CO_2e). For sources that are already considered a major source for regulatory purposes, greenhouse gas emissions greater than 100,000 tons per year CO_2e would trigger the permitting requirement. The question before the Agency, and hence, the motivation for the *Framework*, is whether and how to consider biogenic greenhouse gas emissions in determining these thresholds for permitting.

In the Tailoring Rule, EPA did not initially exclude biogenic emissions from the determination of applicability thresholds, however in July 2011, EPA deferred for a period of three years the application of permitting requirements to biogenic carbon dioxide (CO_2) emissions from bioenergy and other biogenic stationary sources. In its deferral, the Agency committed to conducting a detailed examination of the science and technical issues associated with biogenic CO_2 emissions and submitting its study for review by the Science Advisory Board. The motivation for considering whether or not to adjust biogenic carbon emissions from stationary sources stems from the way the carbon in these feedstocks interacts with the global carbon cycle. Plants take up carbon from the atmosphere to produce products that are consumed by humans and animals for food, shelter and energy. Plants convert raw materials present in the ecosystem such as carbon from the atmosphere and inorganic minerals and compounds from the soil including nitrogen, potassium, and iron and make these elemental nutrients available to other life forms. Carbon is returned to the atmosphere by plants and animals through decomposition and respiration and by industrial processes, including combustion. Thus, the use of biogenic feedstocks results in both carbon emissions and carbon sequestration.

Categorical inclusion or exclusion

The SAB Panel was asked whether it supported the Agency's conclusion that categorical approaches are inappropriate for the treatment of biogenic carbon emissions. A categorical inclusion would treat biogenic carbon emissions as equivalent to fossil fuel emissions while a categorical exclusion would exempt biogenic carbon emissions from greenhouse gas regulation. The decision about a categorical inclusion or exclusion will likely involve many considerations that fall outside the SAB's scientific purview such as legality, feasibility and, possibly, political will. The SAB cannot speak to the legal or implementation difficulties that could accompany any policy on biogenic carbon emissions but this Advisory offers some scientific observations that may inform the Administrator's policy decision.

Carbon neutrality cannot be assumed for all biomass energy a priori. There are circumstances in which biomass is grown, harvested and combusted in a carbon neutral fashion but carbon neutrality is not an appropriate a priori assumption; it is a conclusion that should be reached only after considering a particular feedstock's production and consumption cycle. There is considerable heterogeneity in feedstock types, sources and production methods and thus net biogenic carbon emissions will vary considerably. Only when bioenergy results in <u>additional</u> carbon being sequestered above and beyond the anticipated baseline (the "business as usual" trajectory) displacing fossil fuels over time can there be a justification for concluding that such energy use results in little or no increase in carbon emissions. Of course, biogenic feedstocks do not have to be carbon neutral to be better than fossil fuels in terms of their climate impact.

Given that some biomass could have positive net emissions, a categorical exclusion would remove any responsibility on the stationary source for CO_2 emissions from its use of biogenic material from the entire system (*i.e.*, the global economy) and provide no incentive for the development and use of best management practices. Conversely, a categorical inclusion would provide no incentive for using biogenic sources that compare favorably to fossil energy in terms of greenhouse gas emissions.

Biogenic Accounting Factor (BAF) Calculation

The *Framework* presents an alternative to a categorical inclusion or exclusion by offering an equation for calculating a Biogenic Accounting Factor (BAF) that adjusts the onsite biogenic emissions at the stationary source emitting biogenic CO_2 on the basis of information about growth of the feedstock and/or avoidance of biogenic emissions and more generally the carbon cycle.

Forest-Derived Woody Biomass

The Agency's stated objective was to accurately reflect the carbon outcome of biomass use by stationary sources. For forest-derived woody biomass, the *Framework* did not achieve this objective. To calculate BAF for biomass from roundwood trees, the Agency proposed the concept of regional carbon stocks (with the regions unspecified) and posed a "rule" whereby any bioenergy usage that takes place in a region where carbon stocks are increasing would be assigned a BAF of 0. This decouples the BAF from a particular facility's biogenic emissions and the sequestration (offset) associated with its particular feedstock. Emissions from a stationary facility would be included or excluded from greenhouse gas regulation depending on a host of factors in the region far beyond the facility's control. As The Wilderness Society pointed out in its public comments, the Agency is tasked with regulating emissions from stationary sources, not with regulating emissions from regional forest landscapes (The Wilderness Society, October 18, 2011).

To accurately capture the carbon outcome, an anticipated baseline approach is needed. This requires selecting a time period and determining what would have happened anyway without the harvesting and comparing that impact with the carbon trajectory associated with harvesting of biomass for bioenergy. Although any "business as usual" projection would be uncertain, it is the only means by which to gauge the incremental impact of woody biomass harvesting. The *Framework* discusses this anticipated future baseline approach but does not attempt it. Instead a fixed reference point and an assumption of geographic regions were chosen to determine the baseline for whether biomass harvesting for bioenergy facilities is having a negative impact on the carbon cycle. The choice of a fixed reference point may be the simplest to execute, but it does not properly address the additionality question, i.e. the extent to which forest stocks would have been growing or declining over time in the absence of bioenergy. The Agency's use of a fixed reference point baseline coupled with a division of the country into regions implies that forest biomass emissions could be granted an exemption simply because the location of a stationary facility is in an area where forest stocks are increasing. The reference point estimate of regionwide net emissions or net sequestration does not indicate, or estimate, the difference in greenhouse gas emissions (the actual carbon gains and losses) over time that stem from biomass use. Instead, the *Framework* captures changes over an undefined area, in a sense, substituting space for time. As a result, the *Framework* fails to capture the causal connection between forest biomass harvesting, land carbon change and atmospheric impacts.

Agricultural and Waste Feedstocks

For faster growing biomass like agricultural crops, the anticipated future baseline approach is not necessary because the temporary loss of carbon storage upon harvest is short-lived. For agricultural feedstocks, the *Framework* captures many of the factors necessary for estimating the offsite carbon change associated with use of short rotation (agricultural) feedstocks. These include factors to represent the carbon embodied in products leaving a stationary source, the proportion of feedstock lost in conveyance, the offset represented by sequestration, the site-level difference in net carbon flux as a result of harvesting, the emissions that would occur "anyway" from removal or diversion of nongrowing feedstocks (e.g. corn stover) and other variables. A noticeable omission is the absence of consideration of nitrous oxide (N_2O) emissions from fertilizer use, potentially a major onsite carbon loss that could be induced by a growing bioenergy market.

For short rotation feedstocks where carbon recovery and "anyway" emissions are within one to a few years (i.e., agricultural residues, perennial herbaceous crops, mill wood wastes, other wastes), the *Framework* may, with some adjustments and appropriate data, accurately represent direct carbon changes in a particular region. For logging residues and other waste feedstocks, decomposition cannot be assumed to be instantaneous and the *Framework* could be modified to incorporate the time path of decay of these residues if they are not used for bioenergy.

For waste materials (municipal solid waste), the *Framework* needs to consider the mix between biogenic and fossil carbon when waste is combusted as well as the emissions and partial capture of methane (CH_4) emissions from landfills. In general, when accounting for emissions from wood mill waste and pulping liquor, the EPA should recognize these emissions are part of a larger system that includes forests, solid wood mills, pulp mills and stationary energy sources. Accounting for greenhouse gases in the larger system should track all emissions or forest stock changes over time across the outputs from the system so as to account for all fluxes. Within the larger system, the allocation of fluxes to wood/paper products or to a stationary source is a policy decision. The Agency should consider how its *Framework* meets the scientific requirement to account (allocate) all emissions across the larger system of forests, mills and stationary sources over time.

Leakage

Leakage is a phenomenon by which efforts to reduce emissions in one place affect market prices that shift emissions to another location or sector. The *Framework's* equation for BAF includes a term for leakage, however the Agency decided that calculating values for leakage was outside the scope of the *Framework*. While that decision was expedient, it should be recognized that incorporating leakage, however difficult, may change the BAF results radically. "Bad" leakage (called "positive" leakage in the literature) occurs when the use of biogenic feedstocks causes price changes which, in turn, drive changes in consumption and production outside the boundary of the stationary source, even globally, that lead to increased carbon emissions. One type of positive leakage could occur if land is diverted from food/feed production to bioenergy production which increases the price of conventional agricultural and forest products in world markets and leads to conversion of carbon rich lands to crop production and the release of carbon stored in soils and vegetation. The use of biogenic feedstocks can also affect the price of fossil fuels by lowering demand for them and thereby increasing their consumption elsewhere. "Good" leakage (called "negative" leakage in the literature) could occur if the use of biomass leads to carbon offsetting activities elsewhere. The latter could arise for example, if increased demand for biomass and higher prices generates incentives for investment in forest management, beyond the level needed directly for bioenergy production, which increases net forest carbon sequestration.

The existing literature in the social sciences shows that the overall magnitude of leakage, associated with the use of bioenergy for fuel is highly uncertain and differs considerably across studies and within a study, depending on underlying assumptions. Rather than eschewing the calculation of leakage altogether, the Agency might instead, try to ascertain the directionality of net leakage, whether it is positive (leading to increased carbon emissions elsewhere) or negative (leading to carbon offsetting activities) and incorporate that information in its decision making. Moreover, the Agency should investigate leakage that may occur in other media, e.g. fertilizer runoff into waterways. In cases where prior research has indicated directionality, if not magnitude, such information should be used.

Time scale

The *Framework* seeks to determine annual changes in emissions and sequestration rather than assessing the manner in which these changes will impact the climate over longer periods of time. In so doing, it does not consider the different ways in which use of bioenergy impacts the carbon cycle and global temperature over different time scales. Some recent studies have shown some intertemporal tradeoffs that should be highlighted for policymakers. In the short/medium run there is a lag time between emissions (through combustion) and sequestration (through regrowth) with the use of forest biomass. Some modeling exercises have shown that in long run scenarios (100 years or more) where total emissions are reduced rapidly and limited overall, harvesting of biomass for bioenergy may have minimal effect on peak warming if regrowth is sufficient to compensate for carbon losses that accompany harvest on a cumulative basis (NRC 2011, Allen et al. 2009, Cherubini et al. 2012). By similar reasoning, an intervention in forests or farming that results in an increase in storage of carbon or emissions reductions that endures longer than 100 years (or be "permanent") may reduce the peak climate response. Conversely, interventions that reduce storage of carbon or increase emissions for longer than approximately 100 years may have a negative effect on peak warming response. The recovery of live plant, dead matter, and soil carbon should not be assumed to occur automatically or be permanent; rather regrowth and recovery should be monitored and evaluated for changes resulting from management, market forces or natural causes.

If the climate effect of biogenic carbon use is explored, the degree to which biogenic carbon use curtails fossil carbon use should be assessed and quantified. Given the slow response of the carbon and climate system, if biogenic carbon displaces the use of fossil carbon for longer than

100 years, then there may be a beneficial climate effect. In contrast, if biogenic carbon use does not displace the use of fossil carbon use, then the ultimate climate consequences of biogenic carbon may be overestimated.

To consider intertemporal tradeoffs, it is useful to look at predictions of temperature increases over time. An example of a climate-relevant framework for exploring intertemporal effects is found in Cherubini et al. (2012) which shows, as an example, that if biomass is harvested and the carbon is fully reabsorbed within a 100 year time scale, the global temperature increase averaged over that 100 year period is roughly 50% of the temperature increase caused by an equivalent amount of fossil carbon emitted in year 0. If we were to translate this ratio to the Agency's proposed *Framework*, we might conclude, then, that the BAF for this scenario should be adjusted to half its initial value, meaning biogenic emissions are roughly 50% as damaging as fossil fuels. However the high point of temperature increase created by biogenic emissions occurs early in the 100 year cycle and is back to nearly zero by the time the carbon is completely reabsorbed. Estimates of the temperature time path for a biogenic emission relative to the impact of the temperature time path for an initial emission without carbon recovery may reveal difficult tradeoffs. Given this particular example of carbon recovery over 100 years, for the first 20 years the average temperature increase comparing a biogenic emission and recovery with an emission alone is 0.97; for years 21 to 100, the average increase is 0.37; and for years 101 to 500, the increase is 0.02. As this example shows, there are difficult intertemporal trade-offs that should be presented to policymakers, and a scientific perspective does not point to a single, correct answer. Moreover, the Agency needs to investigate options for assessing delayed effects over time using different metrics, particularly temperature changes (not just emissions) and make these tradeoffs transparent. A comprehensive treatment of climate effects would incorporate carbon uptake from a number of mechanisms in addition to feedstock regrowth (i.e., oceanic uptake, mineral weathering) in a framework that considers fossil fuel emissions and biogenic emissions in a parallel fashion.

The example of 100 year carbon recovery in a forest is a simplified example for a single forest stand. The same type of metric could be used to compare temperature changes associated with increased biomass energy use for one year or a period of years for a landscape or nation – taking into account the land carbon change over time with increased biomass energy use. This would involve comparison of a business as usual case to an increased biomass use case. A simpler metric that compares radiative forcing between cases could also be used (Cherubini's GWPbio).

Spatial Scale

The use of unspecified "regions" is a central weakness of the *Framework* with respect to forest-derived feedstocks. The Agency used a variable for the Level of Atmospheric Reduction (LAR) to capture the proportion of potential gross emissions that are offset by sequestration during feedstock growth, however the calculation of LAR captures landscape wide changes rather than facility-specific carbon emissions associated with actual fuelsheds. As a result, the estimates of the BAFs are sensitive to the choice of the spatial region as shown in the Agency's own case study.

Recommendations for Revising BAF

To implement the *Framework*, the Agency faces daunting technical challenges, especially if a facility-specific BAF approach is retained. If the Agency decides to revise the *Framework*, the SAB recommends consideration of the following improvements.

- Develop a separate BAF equation for each feedstock category. Feedstocks could be categorized into short rotation dedicated energy crops, crop residues, forest residues, perennial crops, municipal solid waste, trees/forests with short recovery times, trees/forests with long recovery times and agricultural and forest residues. .
    i. For long-recovery feedstocks like woody biomass, use an anticipated baseline approach to compare emissions from increased biomass harvesting against a baseline without increased biomass demand. For long rotation woody biomass, sophisticated modeling is needed to capture the complex interaction between electricity generating facilities and forest markets, in particular, market driven shifts in planting, management and harvests, induced displacement of existing users of biomass, land use changes, including interactions between agriculture and forests and the relative contribution of different feedstock source categories (logging residuals, pulpwood or roundwood harvest).
    ii. For residues, consider incorporating information about decay after an appropriate analysis in which storage of ecosystem carbon is calculated based on decay functions.
    iii. For materials diverted from the waste stream, consider their alternate fate, whether they might decompose over a long period of time, whether they would be deposited in anaerobic landfills, whether they are diverted from recycling and reuse, etc. For municipal solid waste, consider the mix of biogenic and fossil carbon when waste is combusted. For feedstocks that are found to have relatively minor impacts, the Agency may need to weigh ease of implementation against scientific accuracy. After calculating decay rates and considering alternate fates, the Agency may wish to declare certain categories of feedstocks with relatively low impacts as having a very low BAF or setting it to 0.

- Incorporate various time scales and consider the tradeoffs in choosing between different time scales.

- For all feedstocks, consider information about carbon leakage to determine its directionality as well as leakage into other media.

Alternatives to BAF

Economic research has shown that the most cost-effective way to reduce greenhouse gas emissions (or any other pollution) is to regulate or tax across all sources until they face a marginal cost of emissions reduction that equals the marginal benefit of emissions reduction and is equal across sources. Given the Agency's authority under the Clean Air Act, the most efficient economy-wide solution is not within its menu of choices. The Agency's regulation of stationary sources will exclude other users of biomass (e.g. consumers of ethanol) that have equivalent impacts on the carbon cycle as well as downstream consumers of products produced by these facilities.

If the Agency is to ascribe all changes in greenhouse gas emissions (both upstream and downstream of the stationary source) caused by the operation of the stationary facility to that source, these emissions would need to be determined on a facility-specific basis however facility-specific calculations face some daunting practical challenges.

Given the conceptual deficiencies, described above, and prospective difficulties with implementation, the SAB urges the Agency to "think outside the box" about options that go beyond categorical inclusion, exclusion or calculating a BAF for each facility. Section VII does not respond to charge questions from the Agency. Rather, it presents options for the Agency's consideration while recognizing that all options carry their own uncertainties, technical difficulties and implementation challenges. If improving and implementing the *Framework* proves to be too cumbersome and inefficient, the Agency may wish to explore other options, two of which are suggested below.

Option 1: Consider developing a generic BAF for various feedstock categories. An alternative to revising the *Framework* and calculating a BAF for each stationary facility is to develop general (default) BAFs for each category of feedstocks, differentiating among feedstocks using general information on their role in the carbon cycle. This option would be similar to the "carbon intensity factors" described by The Wilderness Society in their public comments (The Wilderness Society October 18, 2011). The Agency might need to develop a separate BAF equation for each of the categories of feedstocks and conduct many more case studies. These generic or default BAFs might vary by region due to biological and market differences across the U.S. They would be applied by stationary facilities to determine their quantity of biogenic emissions that would be subject to the Agency's Tailoring Rule. Facilities could be given the option of demonstrating a lower BAF for the feedstock they are using.

Option 2: Consider certification systems. This option would require stationary facilities to use only "certified" feedstocks based on a certification (to be developed) of carbon neutrality or low carbon impacts. Such certification would need to be audited by an authority using valid scientific measurements. Since certification would be based on feedstocks (and not facilities), it would obviate the need to quantify a specific net change in greenhouse gases associated with a particular stationary facility. A certification approach can also be done at a fuelshed level thus avoiding the arbitrary scale issues. However certification systems are not without their own implementation difficulties and costs. Protocols would be needed to address potential problems associated with leakage, permanence and additionality while remaining science-based, clearly relevant, and practical to implement.

The SAB cannot offer an opinion on the legal feasibility of any of these options. Certification systems have been successfully employed in Europe and, to a lesser extent, in the U.S. via the

Sustainable Forestry Initiative (SFI) although SFI does not address carbon on source lands. Carbon accounting registries have been developed to account for and certify CO_2 emissions reductions and sequestration from changes in forest management and could be tailored to account for emissions of a stationary facility after a comprehensive evaluation.

Conclusion

With the increasing threat of global climate change, it is important to have scientifically sound methods to account for greenhouse gas emissions caused by human activities. As the Agency has recognized, the greenhouse gas implications of bioenergy are more complex and subtle than the greenhouse gas impacts of fossil fuels. Unlike fossil fuels, forests and other biological feedstocks can grow back and sequester CO_2 from the atmosphere. Given the complicated role that bioenergy plays in the carbon cycle, the *Framework* was written to provide a structure to account for net CO_2 emissions. The *Framework* is a step forward in considering biogenic carbon emissions.

The focus of the *Framework* is on point source emissions from stationary facilities with the goal of accounting for any offsetting carbon sequestration that may be attributed to the facility's use of a biogenic feedstock. To create an accounting structure, the Agency drew boundaries narrowly in accordance with its regulatory domain. These narrow regulatory boundaries are in conflict with a more comprehensive carbon accounting that considers the entire carbon cycle upstream and downstream as well as temporally and spatially. By staying within boundaries drawn narrowly around the stationary source, the *Framework* does not address all sources and sinks. A more comprehensive accounting would extend through time and space to show the long-run effects of biogenic feedstocks on the carbon cycle. It would also expand downstream—to emissions from by-products and co-products, e.g. ethanol combustion or ethanol by-products, as well as upstream to the use of fertilizer to produce the biogenic feedstock.

The Agency has taken on a difficult but worthy task and forced important questions. In this Advisory, the SAB offers suggestions for how to improve the *Framework* while encouraging the Agency to think about options outside its current policy menu. While the task of accounting for biogenic carbon emissions defies easy solutions, it is important to assess the strengths and limitations of each option so that a more accurate carbon footprint can be ascribed to the various forms of bioenergy.

1. The Science of Biogenic CO_2 Emissions

Charge Question 1: In reviewing the scientific literature on biogenic CO2 emissions, EPA assessed the underlying science of the carbon cycle, characterized fossil and biogenic carbon reservoirs, and discussed the implications for biogenic CO2 accounting.

1.1. Does the SAB support EPA's assessment and characterization of the underlying science and the implications for biogenic CO2 accounting?

EPA has done an admirable job of reviewing the science behind the carbon cycle and greenhouse gas emissions and their relationship to climate change, extracting some of the critical points that are needed to create the proposed *Framework*. At the same time, there are several important scientific issues that are not addressed in the EPA document, as well as scientific issues that are briefly discussed but not sufficiently explored in terms of how they relate to the *Framework*. In the following section, we describe a series of deficiencies with the EPA assessment and characterization of the science behind biogenic CO_2 accounting, and suggest some areas where the treatment of the existing scientific understanding of ecosystems and the carbon cycle could be strengthened.

Time scale

One fundamental deficiency in the EPA report is the lack of discussion of the different time scales inherent in the carbon cycle and the climate system that are critical for establishing an accounting system. This is a complicated subject because there are many different time scales that are important for the issues associated with biogenic carbon emissions. At the global scale, there are multiple time scales associated with mixing of carbon throughout the different reservoirs on the Earth's surface. When carbon dioxide is released into the air from burning fossil fuels, roughly 45% stays in the air over the course of the following year. Of the 55% that is removed, roughly half is taken up by the ocean, mostly in the form of bicarbonate ion, and the other half is taken up by the terrestrial biosphere, primarily through reforestation and enhanced photosynthesis. The airborne fraction (defined as the fraction of emissions that remains in the air) has been remarkably constant over the last two decades.

There is considerable uncertainty over how the magnitude of ocean and terrestrial uptake will change as the climate warms during this century. If the entire ocean were to instantly reach chemical equilibrium with the atmosphere, the airborne fraction would be reduced to 20% to 40% of cumulative emissions, with a higher fraction remaining in scenarios with higher cumulative emissions. In other words, the ocean chemical system by itself cannot remove all the CO_2 released in the atmosphere. Because carbon uptake by the ocean is limited by the rate of mixing between the shallow and deeper waters, this complete equilibration is expected to take thousands of years. Over this century, if global CO_2 emissions continue to rise, most models predict that ocean uptake will stabilize between 3 to 5 GtC/y, implying that the fraction of emissions taken up by the ocean will decrease. For the terrestrial biosphere, there is a much wider envelope of uncertainty; some models predict that CO_2 uptake will continue to keep pace with the growth in emissions, while other models suggest that CO_2 uptake will decline, even becoming a net source of CO_2 to the atmosphere if processes such as release of carbon from the tundra or aridification of the tropics were to occur.

Over the time scale of several thousand years, once ocean equilibration is complete and only 20% to 40% of cumulative emissions remains in the atmosphere, dissolution of carbonate rocks on land and on the ocean floor will further reduce the airborne fraction to 10% to 25% over several thousand years to ten thousand years. This last remnant of anthropogenic CO_2 emissions will stay in the atmosphere for more than 100,000 years, slowly drawn down by silicate weathering that converts the CO_2 to calcium carbonate, as well as slow burial of organic carbon on the ocean floor. The size of this "tail" of anthropogenic CO_2 depends on the cumulative emissions of CO_2, with higher cumulative emissions resulting in a higher fraction remaining in the atmosphere.

Another important time scale for considering accounting systems for biogenic carbon emissions is the period over which the climate responds to carbon dioxide and other greenhouse gases. One climate modeling study has demonstrated that peak warming in response to greenhouse gas emissions is primarily sensitive to cumulative greenhouse gas emissions over a period of roughly 100 years, and, so long as cumulative emissions are held constant, is relatively insensitive to the emissions pathway within that time frame (Allen et al. 2009). What this means is that an intervention in forests or farming that results in either an increase or decrease in storage of carbon or emissions reductions must endure longer than 100 years to have an influence on the peak climate response. Conversely, if these changes last less than 100 years, harvesting of biomass for bioenergy resulting in release of carbon dioxide will have a relatively small effect on peak warming. While the harvesting of trees for bioenergy can result in a carbon debt, depending on the spatial scale considered, this does not reflect potential climate benefits at longer time scales if biomass is regrown repeatedly and substituted for coal over successive harvest cycles (Galik and Abt 2012).

Time scales are also important for individual feedstocks and their regeneration at a more local scale. Given that EPA's objective is to account for the atmospheric impact of biogenic emissions, it is important to consider the turnover times of different biogenic feedstocks in justifying how they are incorporated into the *Framework*. The fundamental differences in stocks and their turnover times as they relate to impact on the atmosphere is not well discussed or linked. If a carbon stock is cycling quickly on land, turning over and regrowth is sufficient to compensate for carbon losses from harvesting, it may have a beneficial impact when it displaces fossil fuel over successive cycles of growth and harvest (assuming this temporal displacement exceeds 100 years). If the carbon stock, or some part of it, turns over more slowly, if regrowth is not assured or if feedstocks are not being used to continuously displace fossil fuels, the impact on climate worsens.

There is a continuum of carbon stock size and turnover among the biogenic feedstock sources included in the *Framework*, but there is little background discussion of the variation in the stock and turnover and how that informs the accounting method. The *Framework* sets up categories of feedstocks based on their source, but these groupings do not translate into differential treatment

in the *Framework*. The science section could walk through the carbon stocks covered by the scope of the *Framework* and their relevant turnover times.
A set of studies by Cherubini and co-authors (Cherubini et al. 2011, 2012) provides a possible framework for estimating the atmospheric carbon outcome from biomass harvesting by framing the issue in terms of global warming potentials (GWPs) and global temperature potentials (GTPs) for harvested biomass assuming a suite of carbon uptake mechanisms (such as oceanic uptake) in addition to regrowth in fuelsheds. The difference between GWP and GTP is that GWP is the time integral of the radiative forcing from a pulse emission of CO_2 (in this case, from harvested biomass) and subsequent sequestration by biomass growth, whereas GTP is the actual temperature response to the CO_2 release from harvested biomass. In this context, the GTPbio, discussed by Cherubini (2012), is a more accurate metric for the actual climate response. The idea of the GTPbio is simple: it represents the increase in global average temperature over a given period due to a transient increase in carbon dioxide in the atmosphere (between the initial biomass combustion or respiration and the ultimate regrowth of the carbon stock) relative to the temperature response to a release of an equivalent amount of fossil CO_2 at time 0 (expressed as a fraction between 0 and 1). To calculate a GTPbio value, a time scale must be specified. The calculation for GTPbio is the ratio of the <u>average</u> temperature increase with biogenic emissions followed by reabsorbtion by biomass regrowth over, say, 100 years divided by the <u>average</u> temperature increase from the initial emission alone <u>over</u> 100 years. For short recovery time feedstocks, such as perennial grasses, GTPbio would be a very small fraction due to fast carbon recovery times (ignoring leakage effects). For feedstocks with long recovery times, one must compute the change in global temperature over time, accounting for the decline in temperature change as carbon is reabsorbed.

The example of 100 year carbon recovery in a forest is an artificial simplified example for a single forest stand. The same type of metric could be used to compare temperature changes associated with increased biomass energy use for one year or a period of years for a landscape or nation – taking into account the land carbon change over time associated with increased biomass energy use. This would involve comparison of a business as usual case to an increased biomass use case. A simpler metric that compares radiative forcing between cases could also be used, e.g. Cherubini's GWPbio.

What remains an issue with the GTPbio approach is the appropriate time horizon or, more specifically, the weight to place on temperature increases that occur in the short term versus temperature increases that occur later. Consider a scenario in which biomass is harvested, but the carbon stock is replaced within a 100 year time scale. The GTPbio for a 100-year regrowth and a 100 year time horizon is roughly 0.5, meaning that the time-integrated global average temperature increase within that 100 year period is 50% of the temperature increase caused by an equivalent amount of fossil carbon (or straight CO_2 release without regrowth of biomass). However, using the average temperature increase for the biogenic case over 100 years masks the fact that although there will be an initial increase in temperature near the beginning of the 100 year period the reabsorption of carbon in the forest will bring the effect on ground temperature to nearly zero by year 100, giving an average temperature that was 50% of the average fossil temperature increase over 100 years. In fact the temperature effect for the biogenic case falls below zero slightly before 100 years because oceans initial absorb extra CO_2 in response to the initial biogenic emission (see Figure 1, adapted from Cherubini 2012, Figure 5a). The temperature effect equilibrates to zero as the ocean CO_2 is balanced. A more precise picture of intertemporal effects is shown in Figure 1, adapted from Cherubini et al. (2012).

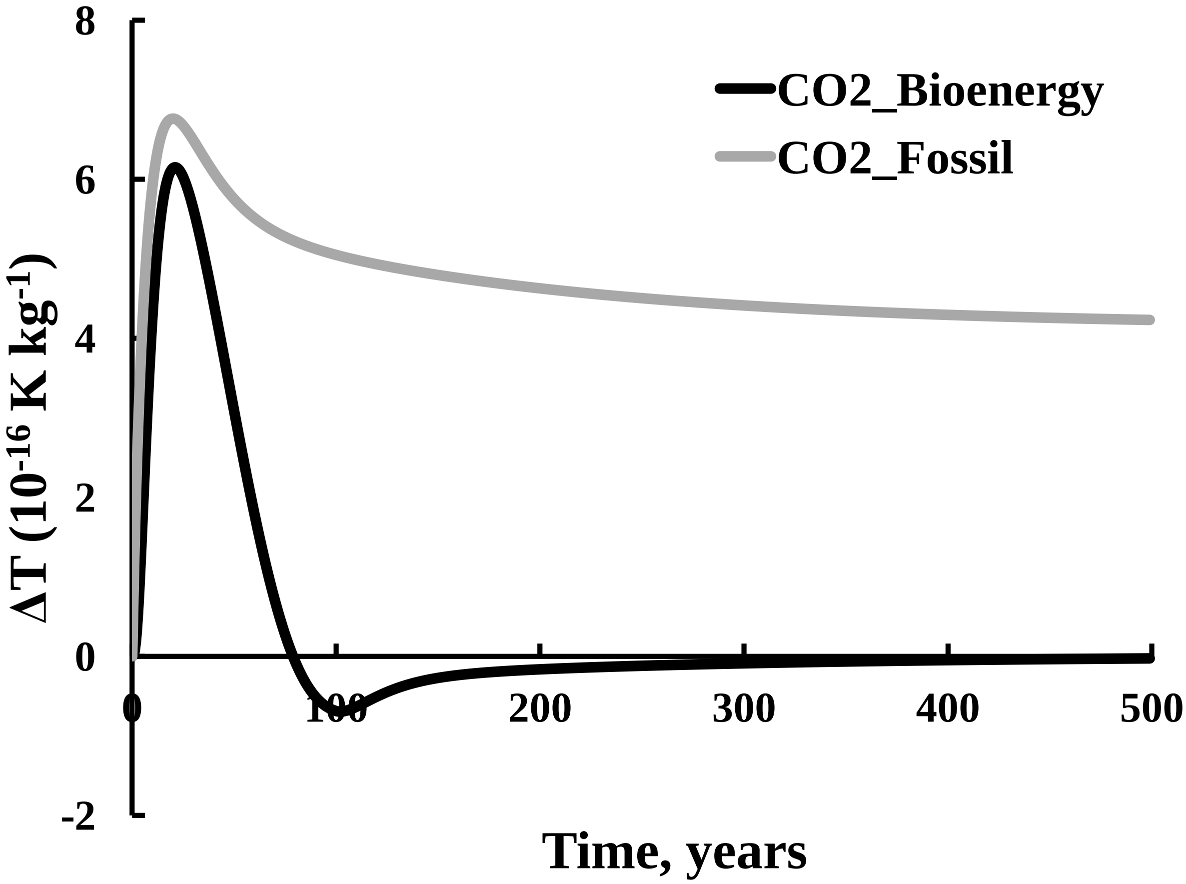

Figure 1: Surface temperature change from biogenic emissions with 100 year carbon recovery and fossil emissions.

Adapted from Cherubini, F., Guest, G. and Strømman, A. H. (2012), Application of probability distributions to the modeling of biogenic CO2 fluxes in life cycle assessment. GCB Bioenergy. doi: 10.1111/j.1757-1707.2011.01156.x

Cherubini et al. (2012) have shown that if biomass is harvested and the carbon is reabsorbed within a 100 year time scale, the global average temperature increase over that 100 year period is 50% of the temperature increase caused by an equivalent amount of fossil carbon. We might conclude that biogenic emissions are roughly 50% as damaging as fossil fuels, however the high point of temperature increase created by biogenic emissions occurs early in the 100 year cycle and is back to zero by the time the carbon is reabsorbed. For the case where carbon is recovered within 100 years Cherubini et al. (2012) have shown that at 20 years, the average temperature increase (over 20 years) from biogenic fuel is 97% of the temperature increase caused by an equivalent amount of fossil carbon; for years 21 to 100 years, the average increased is 0.37 and for years 101 to 500, the increase is 0.02.

Thus, choosing a 100-year time horizon would obscure the longer-term climate consequences of bioenergy. The GTPbio value would continue to decline for time horizons beyond 100 years since there is no net temperature increase after 100 years! The choice of weighting of temperature effects at different time horizons could be influenced by the estimated damages associated with the temperature increased as well as the social rate of time preference for avoiding damages. The discussion by Kirschbaum (2003, 2006) of the impact of temporary carbon storage (the inverse of temporary carbon release from biomass harvesting for bioenergy) points out that the exact climate impact of temporary CO_2 storage (or emissions) depends on the type of impact, as some depend on peak temperature, whereas others, such as melting of polar ice sheets, depend more on time-averaged global temperature. There is no scientifically correct answer here for choosing a time horizon to estimate GTPbio, although the *Framework* should be clear about what time horizon it uses, and what that choice means in terms of valuing long term versus shorter term climate impacts. If a high value is placed on the longer term temperature impact, then the effect of the initial biogenic emission would be near zero.

Disturbance

Because ecosystems respond in complicated ways to disturbances (e.g. harvesting, fire) over long periods of time, and with a high degree of spatial heterogeneity, the state of knowledge about disturbance and impacts on carbon stocks and turnover should be reviewed within the context of relevant time scales and spatial extents. This is highly relevant to producing accurate estimates of biogenic emissions from the land. There is also insufficient treatment given to the existing literature on the impact of different land management strategies on soil carbon, which is important for understanding how carbon stocks may change over many decades.

Non-CO_2 Greenhouse Gases

The *Framework* does not incorporate greenhouse gases other than CO_2. This fails to account for the difference between biomass feedstocks in terms of their production of other greenhouse gases. The most important of these is likely to be N_2O produced by the application of fertilizer (Crutzen, Mosier, Smith, & and Winiwarter, 2007). In particular, if the biomass feedstock is from an energy crop that results in different N_2O emissions vis-a-vis other crops, should this be counted? Is it negligible? This issue is not introduced in the science section. N_2O is relatively long-lived (unlike methane) and therefore the climate impacts of heavily fertilized biomass (whether in forests or farms) are greater than non-fertilized biomass. There is a substantial literature on N_2O from fertilizer use that was not discussed in the *Framework*. If the decision to not count non-CO_2 greenhouse gases stems from a need to render the carbon accounting for biogenic sources parallel with fossil fuels, this needs to be explicitly discussed.

2. Biogenic CO_2 Accounting Approaches

Charge Question 2: Evaluation of Biogenic CO2 Accounting Approaches

In this report, EPA considered existing accounting approaches in terms of their ability to reflect the underlying science of the carbon cycle and also evaluated these approaches on whether or not they could be readily and rigorously applied in a stationary source context in which onsite emissions are the primary focus. On the basis of these considerations, EPA concluded that a new accounting framework is needed for stationary sources.

2.1. Does the SAB agree with EPA's concerns about applying the IPCC national approach to biogenic CO_2 emissions at individual stationary sources?

Yes. The IPCC national approach is an inventory of global greenhouse emissions (*i.e.*, all emissions are counted). It is comprehensive in quantifying all emissions sources and sinks, but does not describe linkages among supply chains. In other words, it is essentially a "production-based inventory" or "geographic inventory" rather than a "consumption-based inventory" (Stanton et al. 2011). Moreover, it offers a static snapshot of emissions at any given time, but it does not expressly show changes in emissions over time. As such, the IPCC national approach does not explicitly link biogenic CO_2 emission sources and sinks to stationary sources, nor does it provide a mechanism for measuring changes in emissions as a result of changes in the building and operation of stationary sources using biomass.

2.2. Does the SAB support the conclusion that the categorical approaches (inclusion and exclusion) are inappropriate for this purpose, based on the characteristics of the carbon cycle?

A decision about a categorical inclusion or exclusion[1] will likely involve many considerations that fall outside the SAB's scientific purview such as legality, feasibility and, possibly, political will. The SAB cannot speak to the legal or implementation difficulties that could accompany any policy on biogenic carbon emissions but below are some scientific observations that may inform the Administrator's policy decision.

The notion that biomass is carbon neutral arises from the fact that the carbon released as CO_2 upon combustion was previously removed from the atmosphere as CO_2 during plant growth. Thus, the physical flow of carbon in the biomass combusted for bioenergy represents a closed loop that passes through a stationary source. Under an accounting framework where life cycle emissions associated with the production and use of biomass are attributed to a stationary source, assuming carbon neutrality of biomass implies that the net sum of carbon emissions from all

[1] / Note that the Panel sought and got clarification from EPA that this question refers to "a priori" categorical inclusion and exclusions as inappropriate.

sources and sinks is zero, including all supply chain and market-mediated effects. Carbon neutrality cannot be assumed for all biomass energy a priori (Rabl et al. 2007, E. Johnson 2009, Searchinger et al. 2009). There are circumstances in which biomass is grown, harvested and combusted in a carbon neutral fashion but carbon neutrality is not an appropriate a priori assumption; it is a conclusion that should be reached only after considering a particular feedstock production and consumption cycle. There is considerable heterogeneity in feedstock types, sources, production methods and leakage effects; thus net biogenic carbon emissions will vary considerably.

Given that some biomass combustion could have positive net emissions, a categorical exclusion would remove any responsibility on the stationary source for CO_2 emissions from its use of biogenic material from the entire system (*i.e.*, the global economy) and provide no incentive for the development and use of best management practices. Conversely, a categorical inclusion would provide no incentive for using biogenic sources that compare favorably to fossil energy in terms of greenhouse gas emissions.

The commentary above merely reflects some scientific considerations. The SAB recognizes that, in reality, EPA may face difficult tradeoffs between ease of implementation and other goals. While some options are offered in Section 7 for the Agency's consideration, the SAB cannot offer an opinion on the legal feasibility of any approach.

2.3. Does the SAB support EPA's conclusion that a new framework is needed for situations in which only onsite emissions are considered for non-biologically-based (i.e., fossil) feedstocks?

Through discussions with the Agency at the public meeting, EPA agreed that this question is redundant with other charge questions and therefore does not need to be answered here.

2.4. Are there additional accounting approaches that could be applied in the context of biogenic CO_2 emissions from stationary sources that should have been evaluated but were not?

Several other agencies are developing methods for assessing greenhouse gas emissions by facilities that could inform the approach developed by the EPA. These include the DOE 1605(b) voluntary greenhouse gas registry targeted to entities which has many similar characteristics to the approach proposed by EPA for stationary sources. There is also the Climate Action Registry developed in California that uses a regional approach to calculate baselines based on inventory data and may inform the delineation of geographic regions and choice of baselines in the EPA approach. USDA is also developing in parallel an accounting approach for forestry and agricultural landowners. It would be beneficial if the EPA and USDA approaches could be harmonized to avoid conflicts and take advantage of opportunities for synergy.

3. Methodological Issues

Charge Question 3: Evaluation of methodological issues. EPA identified and evaluated a series of factors in addition to direct biogenic CO_2 emissions from a stationary source that may influence the changes in carbon stocks that occur offsite, beyond the stationary source (e.g., changes in carbon stocks, emissions due to land-use and land management change, temporal and spatial scales, feedstock categorization) that are related to the carbon cycle and should be considered when developing a framework to adjust total onsite emissions from a stationary source.

3.1. Does SAB support EPA's conclusions on how these factors should be included in accounting for biogenic CO_2 emissions, taking into consideration recent advances and studies relevant to biogenic CO_2 accounting?

The SAB's response to this question differs by feedstock. On balance, the *Framework* includes many important factors but some factors suffer from significant estimation and implementation problems.

For agricultural feedstocks, the factors identified by EPA to adjust the CO_2 emissions from a stationary source for direct off-site changes in carbon stocks are appropriate but suffer from significant estimation and implementation problems. These include factors to represent the carbon embodied in products leaving a stationary source, the proportion of feedstock lost in conveyance, the offset represented by sequestration, the site-level difference in net carbon flux as a result of harvesting, the emissions that would occur "anyway" from removal or diversion of non-growing feedstocks (e.g. corn stover) and other variables. In some cases, energy crops like miscanthus and switchgrass, have significant potential to sequester carbon in the soil and be sinks for carbon rather than a source (Anderson-Teixeira et al. 2009). In other cases, the production of bioenergy could result in by-products like biochar which sequester significant amounts of carbon. A large value of the SITE_TNC and/or SEQP variables in the accounting equation could result in a negative BAF for such feedstocks. The *Framework* should clarify how a negative BAF would be used and whether it could be used by a facility to offset fossil fuel emissions. Restricting BAF to be non-negative would reduce incentives to use feedstocks with a large sequestration potential.

For waste materials (municipal solid waste, manure, wastewater, construction debris, etc.), the *Framework* assigns a BAF equal to 0 for biogenic CO_2 released from waste decay at waste management systems, waste combustion at waste incinerators or combustion of captured waste-derived CH_4. The *Framework* further states that for any portion of materials entering a waste incinerator that is harvested for the purpose of energy production at that incinerator, biogenic CO_2 emissions from that material would need to be accounted according to the *Framework* calculations. Municipal solid waste biomass is either disposed of in a landfill or combusted in facilities at which energy is recovered. Smaller amounts of certain waste components (food and yard waste) may be processed by anaerobic digestion and composting. The CO_2 released from the decomposition of biogenic waste in landfills, compost facilities or anaerobic digesters could reasonably be assigned a BAF of 0 but applying a 0 to all municipal solid waste does not take into account the fact that when waste is burned for energy recovery, both fossil and biogenic CO_2 are released. The *Framework* should take into account the mix of biogenic waste with fossil carbon containing waste since the combustion of municipal solid waste results in the production of both biogenic and fossil carbon. In addition, given that methane is so much more important than CO_2, the *Framework* should account for CH_4 emissions from landfills in cases where the methane is not captured.

In general, when accounting for emissions from wood mill waste and pulping liquor, the EPA should recognize these emissions are part of a larger system that includes forests, solid wood mills, pulp mills and stationary energy sources. Accounting for greenhouse gases in the larger system is optimal when all biomass emissions or forest stock changes are allocated over time across the outputs from the system so as to account for all fluxes. Within the larger system, the allocation of fluxes to wood/paper products or to a stationary source is a policy decision. The Agency might consider how their *Framework* meets the scientific requirement to account (allocate) all emissions across the larger system of forest, mills and stationary sources over time.

For forest-derived woody biomass, the calculation of BAF would need to account for the time path of carbon recovery and emissions from logging residue. The *Framework* recognizes some of the challenges associated with defining the spatial and temporal time scale and in choosing the appropriate baseline but ultimately chooses an approach that disregards any consideration of the time scales over which biogenic carbon stocks are accumulated or depleted. Instead the *Framework* substitutes a spatial dimension for time in assessing carbon accumulation and creates an accounting system that generates outcomes sensitive to the regional scale at which carbon emissions attributed to a stationary source are evaluated.

Below are some comments on particular factors.

Level of Atmospheric Reduction (LAR): The term refers to the proportional atmospheric carbon reduction from sequestration during feedstock regrowth (GROW) or avoided emissions (AVOIDEMIT) from the use of residues that would have been decomposed and released carbon emissions “anyway”. The scientific justification for constraining the range of LAR to be greater than 0 but less than 1 is not evident since it is possible for feedstock production to exceed feedstock consumption. These two terms are not applicable together for a particular feedstock and representing them as additive terms in the accounting equation can be confusing. Additionally, the value of LAR, for forest biomass, is sensitive to the size of the region for which growth is compared to harvest.

Loss (L): This is included in the *Accounting Framework* to explicitly adjust the area needed to provide the total feedstock for the stationary facility. It is a term used to include the emissions generated by the feedstock lost during storage, handling and transit based on the strong assumption that most of the carbon in the feedstock lost during transit is immediately decomposed. It is therefore important to separate the use of this Loss term for estimating the area needed to provide the feedstock and for estimating the carbon emissions released by the operation of the stationary source. To more accurately estimate the actual loss of carbon due to these losses, one would need to model the carbon storage and fluxes associated with the feedstock lost, which are likely to be a function of time. The number of years considered would be a policy decision; the longer the period, the larger the proportion of loss that would be counted. The *Accounting Framework* tacitly assumes an infinitely long horizon that results in the release of all the carbon stored in the lost feedstock.

Products (PRODC). The removal of products from potential gross emissions is justified scientifically, however, the scientific justification for treating all products equally in terms of their impact on emissions is not clear. For some products (e.g., fuels like ethanol and paper), the stored carbon will be released rapidly while for other products, such as furniture, it might be released over a longer period of time. The *Framework* implicitly assumes that all products have infinite life-spans, an assumption without justification or scientific foundation. For products that release their stored carbon rapidly, the consequences for the atmosphere are the same as for combustion of the feedstock. To precisely estimate the stores of products so as to estimate the amount released, one would need to track the stores as well as the fluxes associated with products pools. The stores of products could be approximated by modeling the amount stored over a specified period of time.

A second way in which PRODC is used is as a means of pro-rating all area based terms such as LAR, SITE-TNC and Leakage. This is potentially problematic because it makes the emissions embodied in co-products dependent on the choice of regional scale at which LAR is estimated. As the size of the region contracts, LAR tends towards zero and the amount of gross emissions embodied in PRODC increases and exacerbates the implications of the scale sensitivity of the LAR value.

Avoided Emissions (AVOIDEMIT): This term refers to transfers of emissions that would occur “anyway” from removal or diversion of non-growing feedstocks like corn stover and logging residues. In the *Framework*, feedstocks may be mathematically credited with avoided emissions if the residues would have decayed “anyway.” Specifically AVOIDEMIT is added to GROW in the numerator in determining the LAR or proportion of emissions that are offset by sequestration or avoided emissions. As with the Loss term, there is an implicit assumption of instantaneous decomposition that appears to be a simplifying assumption. While this may a convenient assumption, it should be explained and justified. To improve scientific accuracy, EPA could explore some sample calculations (as described below), taking into account regional differences in decay rates. Once this information is gathered and analyzed, EPA may then need to make a decision that weighs scientific accuracy against administrative expediency and other factors.

Since the concept reflected in “avoided emissions” is actually “equivalent field-site emissions,” it would be clearer to refer to it this way since emissions are not so much avoided as they are shifted to another venue. With residues left in the forest, some of the materials might take decades to fully decompose. For accuracy, the hypothetical store of carbon would have to be tracked. To approximate these stores, one could compute the average amount of carbon remaining after a period of years.

The scientific theory behind losses and stores of ecosystem carbon was developed by Olson (1963) and could be applied to the fate of residues and slash. The store of carbon in an ecosystem depends upon the amount of carbon being input (I) and the proportion of carbon lost per time unit referred to as the rate-constant of loss (k). Specifically the relationship is I/k. In the case of residues or slash that are burned in the field or in a bioenergy facility, the store of carbon is essentially zero because most of the input is lost within a year (k> 4.6 per year assuming at least 99% of the material is combusted within a year). On the other hand, if the residue or slash does not lose its carbon within a year, the store of carbon would be greater than zero, and depending on the interval of residue or slash creation could be greater than the initial input. Appendix B provides more information on the fate of residue after harvest and landscape storage of carbon. For example, if slash is generated every 25 years (I=100 per harvest area/25=4 per year) and the slash is 95% decomposed within 25 years (k=0.12 per year), one cannot assume a store of zero because the average landscape store in this case would actually be 33% of the initial input (4/0.12=33.3). If the input occurred every 5 years (I=100 per harvest/5=20 per year) for the same decay rate-constant, then the landscape average store would be 167% of the initial input (20/0.12=167). Moreover, it cannot be assumed that because the rate-constant of loss k is high, that the stores will always be low. That is because the input (I) is a function of the interval of residue or slash generation; the shorter the interval of generation, the higher the effective landscape input because a higher proportion of the landscape is contributing inputs. For example, if there is 1 unit of residue/slash generation per harvest, then an annual harvest on a landscape basis creates 1 unit of material; if there is 1 unit of residue/slash generation per harvest, then a harvest every 10 years creates an average landscape harvest of 0.1 units (1 unit/10 years = 0.1 unit per year). This relationship means that if residue or slash is generated annually and 95% is lost to decomposition in that period, that the landscape could store 33% of the initial input (I/k=1/3). For the values of k usually observed in agricultural setting (50% per year), an annual input would lead to a landscape store in excess of 145% of the initial input (I/k=1/0.69). Burning of this material would cause a decrease in carbon stores analogous to that of reducing mineral soil stores as accounted for in SITE_TNC, but this loss is not accounted for in the proposed *Framework*.

There are several ways in which losses from residue/slash decomposition could be used in the *Framework*. One is to track the annual loss of carbon from decomposition. This would be analogous to tracking the regrowth of feedstock annually, but in this case it would be the annual decomposition loss. The annual decomposition loss would then be credited as equivalent to combustion as fuel. The advantage of this system is that it would track the time course of release. The disadvantage is that it increases transaction costs. An alternative based on a fuelshed (or other larger area) would be to calculate the average fraction of residue or slash that would remain over the harvest interval and subtracting that from the amount harvested. The difference between the amount harvested and the amount that would have remained is an index of the equivalent amount of release via decomposition. For example, if 10 metric tons of either residue or slash is created per year in a fuelshed and 65% of the slash would have decomposed on average over a given harvest interval, then decomposition would have been equivalent to a release of 65% of the amount of fuel used (6.5 metric tons). This would mean that 3.5 metric tons that would have been stored was lost by combustion; hence 6.5 metric tons would be credited in the current calculation of LAR. However, if 35% of the slash would have decomposed on average over the harvest interval, then use of 10 metric tons as fuel would reduce carbon stores of residues and slash by 6.5 metric tons. This would result in a so-called "avoided emissions" credit of 3.5 metric tons.

In addition to considering actual decomposition losses, the *Framework* needs to consider the starting point of residue and slash harvest. The carbon released by combustion will be a function of the starting point, with systems that start with residues and slash having a different timeline of release than those that newly create residue and slash. The former will have the release rate linearly related to the harvest interval, whereas the latter will likely have a curvilinear relationship that is a function of the rate-constant of loss (k).

Instead of a simplifying assumption of instantaneous decomposition, a more accurate calculation could be developed that determines a loss rate-constant appropriate to the material and climate to estimate the amount of carbon that could have been stored had the material not been burned. This amount could be approximated by using the relationships developed by Olson (1963) and reducing the number of calculations involved. When approximations are used, they should be checked against more precise methods to determine the magnitude of possible approximation errors. Several mechanisms could be used to simplify the estimation of these numbers ranging from calculators that require entry of a few parameters (e.g., average amount of residue or slash generated, the area of source material, the interval of harvest) to look-up tables that are organized around the parameters used to generate them. While there is some uncertainty regarding the loss rate-constants, these sorts of parameters are routinely used in scientific assessments of the carbon cycle and their uncertainty is not much greater than any other parameter required by the *Framework*.

The *Framework* should provide guidance on how logging residue will be distinguished from forest feedstock since that will influence the BAF for that biomass and create incentives to classify as much material as possible as residue and slash despite the fact that some of the "residue/slash" material such as cull trees would be "regenerated" via feedstock regrowth.

Total Net Change in Site Emissions (SITE_TNC) is the annualized difference in the stock of land-based carbon (above and below ground, including changes in standing biomass and soil carbon) that results on the site where the feedstock is produced.

The estimates of this term will be site-specific and will depend on the knowledge about previous history of land use at that site, the specific agricultural or forestry management practices utilized and the length of time over which they have been practiced. To the extent that the use of bioenergy leads to a change in these practices relative to what would have been the case otherwise, it will be important to use an anticipated baseline approach to determine the stock of land based carbon in the absence of bioenergy and to compare that to the stock with the use of bioenergy. As discussed below in response to charge question 4.6, this anticipated baseline could be developed at a regional or national scale and include behavioral responses to market incentives. Alternatively, look-up tables could be developed based on estimates provided by existing large scale models such as CENTURY or FASOM for feedstock based and region specific SITC_TNC estimates.

It should be noted that soil carbon sequestration is not a permanent reduction in CO_2 emissions. The *Framework*, however, treats permanent reductions in emissions, for example, due to a reduction in the LOSS of biomass to be equivalent to reductions due to an increase in soil carbon sequestration which could be temporary. Since soil carbon sequestration is easily reversible with a change in land management practices, the implementation of this *Framework* will need to be accompanied by frequent monitoring to determine any changes in soil carbon stocks and to update the BAF value for a facility.

Sequestration (SEQP). This term refers to the proportion of feedstock carbon embodied in post-combustion residuals such as ash or biochar. Including sequestration in the *Framework* is appropriate, however, the approach taken is subject to the same problems as those described for Products. There is no scientific literature cited to support the idea that all the materials produced by biogenic fuel use do not decompose. This is the subject of ongoing research, but it seems clear that these materials do decompose. The solutions to creating a more realistic and scientifically justified estimate are the same as for the Products term (see above).

Leakage. The *Framework* includes a term for leakage but is silent on the types of leakage that would be included and how leakage would be measured. EPA said it was not providing a quantification methodology for leakage because assessing leakage requires policy- and program-specific details that are beyond the scope of the report, however there are several conceptual and implementation issues that merit further discussion in the *Framework*.

The use of biogenic feedstocks could lead to leakage by diverting feedstocks and land from other uses and affecting the price of conventional forest and agricultural products which can lead to indirect land use changes that release carbon stored in soils and vegetation. The use of these feedstocks can also affect the price of fossil fuels by lowering demand for them and increasing their consumption elsewhere (also referred to as the rebound effect on fuel consumption); this would offset the greenhouse gas savings from the initial displacement of fossil fuels by bioenergy (Chen & Khanna, in press, 2012). These leakage effects could be positive (if they lead to carbon emissions elsewhere) or negative (if they lead to carbon uptake activities). As will be discussed in Section 4.6, the latter, could arise for example, if increased demand for biomass and higher prices generates incentives for investment in forest management that increases forest carbon sequestration. Some research has shown that when a future demand signal is strong enough, expectations about biomass demand for energy (and thus revenues) can reasonably be expected to produce anticipatory feedstock production changes with associated changes in land management and land-use (e.g. Sedjo and Sohngen, in press, 2012). Thus price changes can lead to changes in consumption and production decisions outside the boundary of the stationary source, even globally.

While the existence of non-zero leakage is very plausible, the appropriateness of attributing emissions that are not directly caused by a stationary facility to that facility has been called into question (Zilberman et al. 2011) While first principles in environmental economics show the efficiency gains from internalizing externalities by attributing direct environmental damages to responsible parties, they do not unambiguously show the social efficiency gains from attributing economic or environmental effects (such as leakage) that occur due to price changes induced by its actions to that facility (Holcombe & Sobel, 2001). Moreover, leakage caused by the use of fossil fuels, is not included in assessing fossil emissions generated by a stationary facility. Liska and Perrin (2009) show that military activities to secure oil supplies from the Middle East lead to indirect emissions that could double the carbon intensity of gasoline. Thus, the technical basis for attributing leakage to stationary sources and inherent inconsistency involved in including some types of leakage and for some fuels makes the inclusion of leakage as a factor in the BAF calculation a subjective decision. Including some types of leakage (for e.g., due to agricultural commodity markets) and not others (such as those due to the rebound effect in fossil fuel markets) and for biomass and not fossil fuels would be a policy decision without the underlying science to support it.

Empirically, the assessment of the magnitude of leakage is fraught with uncertainty. Capturing leakage would entail using complex global economic models that incorporate production, consumption and land use decisions to compare scenarios of increased demand for biogenic feedstocks with a baseline scenario without increased demand. Global models that include trade across countries in agricultural and forest products can aid in determining the leakage effects on land use in other countries. Global models of the forestry sector include Sedjo and Sohngen (2012) and Ince et al. (2011). A review of such models can be found in Khanna and Crago (2012). Existing models would need to be expanded to include the multiple feedstocks considered in this *Framework* that can compete to meet demand for bioenergy to determine net leakage effects. Methods would then need to be developed to assign leakage factors to individual feedstocks. The existing literature assessing the magnitude of leakage from one use of a biogenic feedstock (corn ethanol) shows that its overall magnitude in the case of leakage due to biofuel production is highly uncertain and differs considerably across studies and within a study depending on underlying assumptions (Khanna et al. 2011, Khanna and Crago, 2012). If the magnitude of leakage is plagued with too much uncertainty, its direction should at least be stated and recognized in making policy choices. Supplementary policies could be developed to reduce leakage due to changes in land use, such as restrictions on the types of land that could be used to produce the biogenic feedstocks and the types of biogenic feedstocks that could be used to qualify for a BAF less than 1. Some of these implementation issues with estimating BAF and leakage will be discussed further in Section 4.

3.2. Does SAB support EPA's distinction between policy and technical considerations concerning the treatment of specific factors in an accounting approach?

A clear line cannot be drawn between policy and technical considerations. In fact, the lack of information on EPA's policy context and menu of options made it more difficult to fully evaluate the *Framework*. Because the reasonableness of any accounting system depends on the regulatory context to which it is applied the *Framework* should describe the Clean Air Act motivation for this proposed accounting system, how it regulates point sources for greenhouse gases and other pollutants, making explicit the full gamut of Clean Air Act policy options for how greenhouses gases could be regulated, including any potential implementation of carbon offsets or certification of sustainable forestry practices, as well as its legal boundaries regarding upstream and downstream emissions. Technical considerations can influence the feasibility of implementing a policy just as policy options can influence the technical discussion. The two need to go hand in hand rather than be treated as separable.

The *Framework* explicitly states that it was developed for the policy context where it has been determined that a stationary source emitting biogenic CO_2 requires a means for "adjusting" its total onsite biogenic emissions estimate on the basis of information about growth of the feedstock and/or avoidance of biogenic emissions and more generally the carbon cycle. However, in the discussion on the treatment of specific factors it states in several places that this treatment could depend on the program or policy requirements and objectives. Certain open questions described as "policy" decisions (e.g. the selection of regional boundaries, marginal versus average accounting, inclusion of working or non-working lands, inclusion of leakage) made the evaluation of the *Framework* difficult. Clearly, the policy context matters and EPA's reticence in describing the policy context and in taking positions on open questions (as well as lack of implementation details) meant that the *Framework* was inadequately defined for proper review and evaluation.

Specifically, if the policy context is changed, for example, if carbon accounting is needed to support a carbon cap and trade or carbon tax policy, then the appropriateness of the *Framework* needs to be evaluated relative to alternative approaches such as life cycle analysis for different fuel streams. Modifying how certain factors are measured or included may not be sufficient. In fact, a different *Framework* would likely be needed if a national or international greenhouse gas reduction commitment exists. Furthermore, the BAFs developed for regulating the emissions from stationary sources would likely conflict with measures of greenhouse gas emissions from bioenergy used in other regulations such as California's cap and trade system for regulating greenhouse gases.

Economic research has shown that the most cost-effective way to reduce greenhouse gas emissions (or any other pollution) is to regulate or tax across all sources until they face a marginal cost of emissions reduction that equals the marginal benefit of emissions reduction and is equal across sources. The most cost-effective solution would involve setting carbon limits (or prices) on an economy-wide basis and not selectively for particular sources or sectors. Given EPA's limited authority under the Clean Air Act, the most efficient economy-wide solution is not within its menu of policy choices. EPA's regulation of stationary sources will exclude other users of biomass that have equivalent impacts on the carbon cycle as well as downstream emissions from consuming the products produced by these facilities and upstream emissions from producing biomass feedstocks.

In this second-best world with policy instruments that can be applied only to limited sources, it would still be desirable for EPA to ascribe all changes in greenhouse gas emissions (both upstream and downstream of the stationary source) caused by the operation of the stationary source to that source. These emissions would need to be determined on a facility-specific basis and require a chain of custody accounting both for upstream and downstream emissions.

3.3. Are there additional factors that EPA should include in its assessment? If so, please specify those factors.

As stated above, for agricultural biomass from energy crops and crop residues, the factors included in the *Framework* capture most of the direct off-site adjustments needed to account for the changes in carbon stocks caused by a facility using agricultural feedstocks although they do not account for leakage. For forest biomass, the *Framework* needs to incorporate the time path of carbon recovery in forests (after energy emissions from harvested roundwood). As discussed in Section 3.1, EPA should consider the time path of the "anyway" emissions that would have occurred on the land if logging residue were not used for energy production and weigh the benefits of scientific accuracy against the administrative simplicity of assuming instantaneous decomposition. For municipal solid waste biomass, the *Framework* needs to consider other gases and CH_4 emissions from landfills. Given that methane emissions from landfills are sometimes not captured, crediting waste material for avoided emissions of methane may be inappropriate. As the *Framework* has stated, the carbon impact of using waste for energy production in combustion facilities should nonetheless be subjected to a biogenic accounting framework. It should be gauged relative to the CH_4 emissions, if any, that would be released during decomposition in a landfill. N_2O emissions, especially from fertilizer use, should also be considered. Furthermore, the inclusion of non-CO_2 greenhouse gases in general should be consistent between biogenic and fossil fuel accounting. For instance, there are also transportation related emissions losses in the delivery of natural gas.

3.4. Should any factors be modified or eliminated?

For reasons discussed above, factors such as PRODC, AVOIDEMIT and SEQP could be improved by incorporating the time scale over which carbon is decomposed or released back to the atmosphere. LAR needs to be modified to be scale insensitive and to address additionality. Factors can be separated by feedstocks according to their relevance for accounting for the carbon emissions from using those feedstocks. For example, GROW and leakage may not be relevant for crop and forest residues.

4. Accounting Framework

Charge Question 4: EPA's Accounting Framework is intended to be broadly applicable to situations in which there is a need to represent the changes in carbon stocks that occur offsite, beyond the stationary source, or in other words, to develop a "biogenic accounting factor" (BAF) for biogenic $C0_2$ emissions from stationary sources.

4.1. Does the Framework accurately represent the changes in carbon stocks that occur offsite, beyond the stationary source (i.e., the BAF)?

For agricultural biomass, the variables in EPA's proposed equation for BAF represent the basic factors necessary for estimating the offsite carbon change associated with stationary source biomass emissions, including changes in storage of carbon at the harvest site. For short recovery feedstocks, where carbon recovery and "anyway" emissions are within one to a few years (i.e., agricultural residues, perennial herbaceous crops, mill wood wastes, other wastes), with some adjustments and appropriate data, the *Framework* can accurately represent carbon changes offsite. However, for long recovery feedstocks where carbon recovery and those "anyway" emissions that occur over decades (i.e., wood harvested specifically for energy use (roundwood) and logging residue), the *Framework* does not accurately account for carbon stocks changes offsite for several reasons discussed below in response to charge question 4.2.

The *Framework* also does not consider other greenhouse gases (e.g. N_2O from fertilizer use and CH_4 emissions from landfills). Excluding CH_4 because it is not "CO_2" is not a legitimate rationale. It would need to be included to estimate the "difference in CO_2 (equivalent)" the atmosphere sees. In addition, excluding CH_4 from landfills is inconsistent with the *Framework's* desire to account for displaced on-site changes in CO_2. For the same reasons, the basis for excluding N_2O emissions from biomass production is unclear. It also needs to be included to estimate the net changes in atmospheric greenhouse gases. Accounting for N_2O from fertilization would be consistent with tracking changes in soil carbon which are a response to agricultural management systems, which includes fertilizer decisions.

4.2. Is it scientifically rigorous?

The SAB did not find the *Framework* to be scientifically rigorous. Specifically, we identified a number of deficiencies that need to be addressed.

The following issues require additional scientific support.

Time scale: As discussed in Section 1, one deficiency in the *Framework* is the lack of discussion and proper consideration of the different time scales inherent in the carbon cycle and the climate system that are critical for establishing an accounting system. This is a complicated subject because there are many different time scales that are important for the issues associated with biogenic carbon emissions.

Scientific understanding of the time scale over which the climate system responds to cumulative emissions implies that the carbon release caused by harvesting and combusting biomass at stationary sources is a serious problem if carbon storage, on average, is reduced over long periods of time. So long as rates of regrowth are sufficient to compensate for carbon losses from harvesting over the long run, the climate system is less sensitive to the imbalance in the carbon cycle that might occur in the short run from harvesting of biomass for bioenergy facilities. A scientifically rigorous evaluation of the impact of biomass harvest on the carbon cycle should consider the temporal characteristics of the cycling. Annual accounting of carbon stocks, while helpful in tracking net carbon emissions, is likely to give an inaccurate assessment of the overall climate and atmospheric carbon cycle impacts.

The *Framework* also does not consider the length of time it takes ecosystems to respond to disturbances, such as those due to the harvesting of biomass, nor does it consider the spatial heterogeneity in this response. This has implications for the accuracy with which the impact of different land management strategies on carbon stocks in soil and vegetation is estimated.

The *Accounting Framework* subtracts the emissions associated with products, including ethanol, paper, and timber, from the calculation of emissions from a stationary source, through the PRODC term. While EPA may not have the discretion to treat all emissions equally, distinguishing between immediate emissions from the facility and downstream emissions (as these products will inevitably be consumed within a short period of time) does not make sense scientifically. From the perspective of the carbon cycle and the climate system, all these facilities extract biomass from the land, and the vast majority of that biomass is converted to carbon dioxide, adding to cumulative emissions and, hence, a climate response.

Spatial scale: There is no peer reviewed literature cited to support the delineation of spatial scales for biogenic CO_2 accounting and different carbon pools to be accounted for at different spatial scales. For example, the atmospheric impact of feedstocks is gauged on a regional basis in terms of its impact on forest carbon stocks (except for case study 5) while impacts due to land use change are accounted for at the site level.

The *Framework's* use of a regional scale for accounting for the net changes to the atmosphere is an artificial construct developed to (a) avoid the need for site-specific chain of custody carbon accounting with separate streams for each feedstock and (b) as an alternative to capturing changes in carbon stocks over time. The calculation of LAR captures landscape wide changes rather than facility-specific carbon emissions associated with actual fuelsheds. Thus, the *Framework* captures changes over space, in a sense, substituting space for time. This approach attempts to simplify implementation using available forest inventory data and avoids the need for accounting for changes in carbon stocks specific to the site or feedstock sourcing region (fuelshed) which may be more complex and costly and difficult to verify. However, it makes the estimate of the BAFs sensitive to the choice of the spatial region chosen for accounting purposes. As shown by case study #1, there are significant implications of this choice for the emissions attributed to the facility.

Additionality: A key question is whether the harvesting of biomass for bioenergy facilities is having a negative impact on the carbon cycle relative to emissions that would have occurred in the absence of biomass usage. This requires determining what would have happened anyway without the harvesting and comparing the impact with the harvesting of biomass for a bioenergy facility in order to isolate the incremental or additional impact of the bioenergy facility. However, while the *Framework* discusses the "business as usual" or "anticipated future baseline" approach, it implements a reference point approach that assesses carbon stocks on a regional basis at a given point in time relative to a historic reference carbon stock.

For forest carbon stocks, the choice of a fixed reference point may be the simplest to execute, but it does not actually address the question of the extent to which forest stocks would have been growing/declining over time in the absence of this bioenergy facility. The use of a fixed reference point baseline implies that forest biomass emissions could be considered carbon neutral if forest stocks are increasing. This is simply an artifact based on the choice of the baseline that will be used. The problem is thus: a region with decreasing carbon stocks may in actuality have more carbon than what would have happened without the facility using biomass. Similarly, a region with increasing carbon stocks may have less than would have happened without the facility using biomass. By default, this approach creates "sourcing" and "non-sourcing" regions. Thus, a carbon accumulating region is a "source" of in situ carbon that can be given to support biomass use, and a carbon losing region is a "non-source" of carbon and cannot support biomass use. The reference year approach provides no assurances at all that a "source" region is gaining carbon due to biomass use, or that a "non-source" region is losing carbon due to biomass use.

For example, for roundwood use, a region may have carbon accumulation with respect to the reference year (and be assigned LAR=1 according to the *Framework*); however, harvest of a 150+ year old forest in the region for energy production would not be counted in a facility's greenhouse gas emissions even though there is less carbon storage than there would have been otherwise and only a portion of the forest's carbon would be recovered within the next 100 years. Likewise, a region which has a slight overall annual loss of carbon (LAR=0), could actually provide roundwood from light thinning of a mid-aged forest which would yield greater carbon sequestration through enhanced growth rates of remaining trees. In such a region, the *Framework*, however, would view the harvested roundwood from thinning as carbon stock loss. Since we want to estimate the "difference in atmospheric greenhouse gases" over some period we must estimate how carbon recovery differs between a biomass use case and a case without biomass use (business as usual case).

Assessing uncertainty: The *Framework* acknowledges uncertainty but does not discuss how it will be characterized and incorporated to assess the potential uncertainty in the estimate of the BAF value. Characterizing the uncertainty and risks is a scientific question. Selecting an acceptable risk level is a policy decision. There are numerous drivers that can change biogenic carbon stocks, even in the absence of biomass harvesting for energy. These include changes in economic conditions, domestic and international policy and trade decisions, commodity prices, and climate change impacts. There is considerable uncertainty about the patterns of future land use, for example, whether land cleared for bioenergy production will stay in production for decades to come. The potential impact of these forces on biogenic carbon stocks and the uncertainty of accounting need to be considered further. Ideally, EPA should put their BAF estimates into context by characterizing the uncertainties associated with BAF calculations and estimating uncertainty ranges. This information can be used to give an indication of the likelihood that the BAFs will achieve the stated objective. The uncertainty within and among variables for any estimate may vary widely between feedstocks and across regions. Finally, it should be pointed out that while parameter uncertainty is important to consider throughout the *Framework*, alternative policy options (e.g., categorical inclusion and exclusion) do not have parameter uncertainty yet their effect on atmospheric carbon is also uncertain.

Leakage: The *Framework* states that the likelihood of leakage and the inclusion of a leakage term will be based on a qualitative decision. There is essentially no guidance in the document about how leakage might be quantified and no examination of the literature regarding possible leakage scenarios (consider Murray et al. 2004). A number of statements/assumptions were made regarding the area and intensity of wood harvest increases to accommodate biomass access. There was no examination of the scientific literature on wood markets and therefore no science-based justification for these statements/assumptions.

Other areas: Other areas that require more scientific justification include assumptions regarding biomass losses during transport and their carbon implications, the choice of a 5 year time horizon instead of one that considered carbon cycling, and the decision to include only CO_2 emissions and exclude other greenhouse gas emissions need more science based justification. Additionally, assumptions about the impacts of harvests on soil carbon and land use changes on carbon sequestration need to be more rigorously supported.

Inconsistencies: Below are some inconsistencies within the *Framework* that should be resolved or justified:

(1) Biogenic and fossil fuel emissions accounting for losses: The *Framework's* handling of carbon losses during handling, transport, and storage introduces an inconsistency between how fossil emissions are counted at a stationary source and how biomass emissions are counted. For biomass emissions the *Framework* includes emissions associated with loss of feedstock between the land and the stationary source. For natural gas the emissions attributed to the stationary source do not include fugitive greenhouse gas emissions from gas pipelines. Why would loss emissions be included for biomass when they are not included for natural gas?

(2) Inconsistency in the consideration of land management and the associated greenhouse gas flux accounting: The *Framework* accounts for soil carbon stock changes, which are a function of the land management system, soil, and climatic conditions. However, it does not account for the non-CO_2 greenhouse gas changes like N2O? that are jointly produced with the soil carbon changes. Soil carbon changes influence both the below and above ground carbon stock changes associated with changes in the land management system.

(3) Reference year and BAU baseline use: The *Framework* proposes using a reference year approach: however, it implicitly assumes projected behavior in the proposed approach for accounting for soil carbon changes and municipal waste decomposition.

(4) Definition of soil. There is a good deal of variation in the *Framework* as to what soil is: at one point it appears to be defined as all non-feedstock carbon such as slash, surface litter, and dead roots as well as carbon associated with mineral soil, but in other places, the *Framework* seems to only consider the carbon associated with mineral soil. Unfortunately this inconsistency in the use of the term soil creates confusion regarding interpretation and implementation. When soil is defined as non-feedstock carbon (that is all forms of dead carbon) and then implemented as mineral soil carbon (one form of dead carbon), it is impossible to ensure a mass balance as dead material above- and below ground is accounted for in one place, but then not elsewhere. Inconsistent use of soil carbon means that statements regarding the impact of management cannot be unequivocally assessed. For example, if the broader definition of soil is being invoked, then the statement that management of forests can reduce soil carbon could be justified (Harmon, Ferrell and Franklin 1990, Johnson and Curtis 2001). However, if the narrower definition of mineral soil carbon is being invoked, then there is very little empirical evidence to justify this statement (Johnson and Curtis 2001); and in fact there is evidence that forest management can at least temporarily increase mineral soil carbon (refs). It is not clear how soil carbon is being used in the *Framework*.

Soil carbon should be defined and used consistently throughout the document. If defined broadly, then consistent use of subcategories would eliminate much confusion. For example, if organic horizons such as litter are part of the soil, then consistently referring to total soil, organic soil horizons, and mineral horizons would be essential. Had that been done, the confusion about the impact of forest management on soil carbon would have been eliminated as management can greatly influence organic horizons, but have little effect on mineral horizons. If defined narrowly to only include mineral soil, then EPA should develop a terminology for the other carbon pools (e.g., organic horizons, aboveground dead wood, and belowground dead wood) that ensures that mass balance is possible.

To define soil carbon, EPA should consider the merits of an aggregated soil term versus subcategories based on source of the carbon, the controlling processes, and their time dynamics. While the aggregated term "soil" is simple, it potentially combines materials with very different sources, controlling processes, and time dynamics, creating an entity that will have extremely complex behavior. It also creates the temptation of a broad term being used for a subcategory. Separating into woody versus leafy materials would account for different sources and to some degree time dynamics. In contrast, separating into feedstock versus non-feedstock material (as appears to be done in the *Framework*) creates a poorly defined boundary as woody branches would be soil if they are not used, but could be viewed as not being soil if they are. A feedstock-based system also does not separate materials into more uniform time dynamics (if leaves and wood are not harvested, then materials with lifespans that differ an order of magnitude are combined). Controlling processes, be they management or natural in nature, differ substantially for above- versus belowground carbon; hence they should be divided.

Underlying the need for a clear definition of soil in the document is the complexity of soil outcomes that differ based on conditions. Some noteworthy omissions from forest soil science might have informed the *Framework's* treatment of soil carbon in forest ecosystems (Alban and Perala 1992, Mattson and Swank 1989, Binkley and Resh 1999, Black and Harden 1995, Edwards and Ross-Todd 1983, Gilmore and Boggess 1963, Goodale et al. 2002, Grigal and Berguson 1998, Homann et al. 2001, Huntington 1995, Johnson and Curtis 2001, Laiho et al. 2003, Mroz 1985, Nave et al. 2010, Richter 1999, Sanchez et al. 2007, Schiffman and Johnson 1989, Selig 2008, Tang 2005, Tolbert et al. 2000).

4.3. Does it utilize existing data sources?

First, and most importantly, the *Framework* does not provide implementation specifics. Therefore, it is difficult to assess data availability and use. These issues are discussed here and in Sections 4.4 and 4.5 that follow.

A more meaningful question is "Are the proposed data sets adequate to account for the effects of biogenic carbon cycling on CO_2 emissions from a facility?" The *Framework* does use existing data, but the data are not adequate to attribute emissions to a facility. For example, the *Framework* mentions the use of the USDA Forest Service's Forest Inventory and Analysis (FIA) data at some unspecified scale. However, carbon stock change data are likely not very accurate at the scale of the agricultural or forest feedstock source area for a facility.

The *Framework* requires data and/or modeling of land management activities and their effects on CO_2 emissions and stock changes. For example for agricultural systems, data are required on the type of tillage and the effect of such tillage on soil carbon stocks for different soil types and climatic conditions. Such data are not likely to be available at the required scales. For example, in one of the case studies, the Century model is used to model soil C stocks. Is the use of this particular model proposed as a general approach to implement the *Framework*? Since this model generally addresses soil carbon only to a depth of 20 centimeters, does that represent a boundary for the *Framework*? Recent work has shown that such incomplete sampling can grossly misestimate changes in soil carbon for agricultural practices such as conservation tillage (Baker et al. 2007, Kravchenko and Robertson 2011). Which version of the model? Would EPA run this model and select parameters appropriate for each feedstock production area for each facility? How robust are the predictions of this model for the range of soils, climatic conditions, and management practices expected to be covered by the *Framework*? Could some other model be used that produces different results for a given facility?

The *Framework* implies that data are required from individual feedstock producers. Collecting such data would be costly and burdensome. Additionally, to the extent that feedstocks are part of commodity production and distribution systems that mix material from many sources, it is not likely to be feasible to determine the source of all feedstock materials for a facility.

The *Framework* includes a term for leakage but eschews the need to provide any methodology for its quantification. Example calculations are carried out for leakage in one of the case studies without any explanation for their source. However, leakage can be positive or negative, and while many publications speculate about certain types of leakage, no data are presented, nor are data sources for different types of leakage discussed and suggested. The *Framework* does provide an example calculation of leakage in the footnote to a case study, but this does not a substitute for a legitimate discussion of the literature and justification and discussion of implications of choices. In addition, such data are unlikely to be available at the scales required. The implications and uncertainties caused by using some indicator or proxy to estimate leakage need to be discussed. If leakage cannot be estimated well is it possible to put an error range on the leakage value (e.g., a uniform distribution) and assess the impact of this uncertainty on the overall uncertainty in the BAF value? For some cases, such as the conversion of agricultural land to biomass production from perennial crops, leakage may be described as likely increasing net emissions. In cases such as this where prior research has indicated directionality, if not magnitude, such information should be used. As previously noted, there is also a consistency issue with the reference year approach because leakage estimation will require an anticipated baseline approach of some sort.

In summary, it is not clear that all of the data requirements of the *Framework* can be met. Furthermore, even if the data are acquired, they may not be adequate to attribute emissions to a facility.

4.4. Is it easily updated as new data become available?

The details of implementing the *Framework* are not clear, as discussed for other sub-questions. Thus it is also not clear how feasible it would be to update the calculations. However, if many of the data requirements cannot be met currently, as stated above, it is very likely that many of the data will not be easy to update.

In principal it would be feasible to update the calculations as new data become available. Some kinds of data, such as those from FIA are updated periodically, thus it would be feasible to update the analysis. However, as discussed for other sub-questions, it is not clear exactly what data and resolution are required and whether all the required data are readily available.

An annual or five-year time frame is suggested for updating calculations. For some kinds of data, such as soil and forest carbon stocks, these time frames are too short to detect significant changes based on current or feasible data collection methodologies; implying that statistical or process models would be used to estimate short-term changes for reporting purposes.

Lastly, if BAF is not under the control of the facility, it would introduce considerable uncertainty for the facility if the BAF were recalculated frequently. This would particularly be the case if a leakage factor were included in the BAF and would need to be updated frequently with changes in market conditions. However, if the accounting is infrequent, shifts in the net greenhouse gas impact may not be captured. Clearly, EPA will have to weigh tradeoffs between the accuracy of greenhouse gas accounting and ease of implementation and other transactions costs.

4.5. Is it simple to implement and understand?

It is neither. While the approach of making deductions from the actual emissions to account for biologically-based uptake/recovery is conceptually sound, it is not intuitive to understand because it involves tracking emissions from the stationary source backwards to the land that provides the feedstock rather than tracking the disposition of carbon from the feedstock and land forwards to combustion and products. The *Framework* also appears to be difficult to implement, and possibly unworkable, especially due to the requirements for the many kinds of data required to make calculations for individual facilities. Additionally, the factors (variable names) in the *Framework* do not match those used in the scientific literature and are therefore not intuitive. Lastly, many elements of the *Framework* are implicit rather than explicit. For example, we assume that there should be a time frame during which changes in atmospheric greenhouse gases will be assessed, but this time frame is not explicit. The time frame for specific processes is often implicit, such as the emissions of CO_2 from biomass that is lost in transit from the production area to the facility; this loss is assumed to be instantaneous.

Much more detailed information is required about how the *Framework* would be implemented. It would be helpful to know the specific data sources and/or models to be used. To assess the adequacy of data, more information is needed on implementation and the degree of uncertainty acceptable for policymakers to assign BAF values.

4.6. Can the SAB recommend improvements to the framework to address the issue of attribution of changes in land-based carbon stocks?

The *Framework* uses a reference year baseline approach to determining BAF in combination with a regional spatial scale. As mentioned in response to charge question 4.2, this approach is not adequate in cases where feedstocks accumulate over long time periods because it does not allow for the estimation of the incremental effect of feedstock harvesting on greenhouse gas emissions over time. To gauge the incremental effect on forest carbon stocks due to the use of forest-derived woody biomass, specifically, the value of the LAR, an anticipated baseline approach is needed. This involves estimating a “business as usual” trajectory of emissions and forest stocks and comparing it with alternate trajectories that incorporate increased demand for forest biomass over time. The anticipated baseline approach should also be applied to determine soil carbon for all types of feedstocks.

An anticipated baseline approach must incorporate. market effects even when direct effects of the use of biogenic feedstocks on carbon emissions are being estimated. The projected baseline level of forest carbon stocks will need to be compared with the level in the case when there is demand for roundwood for bioenergy to assess the change in forest stocks due to the demand for bioenergy. The case with demand for bioenergy should consider the possibility that investment in long lived trees could be driven by expectations about wood product prices and biomass prices, leading landowners to expand or retain land in forests, plant trees, invest in faster growing species and adjust the timing of harvests. The role of demand and price expectations/anticipation is well developed in the economics literature (e.g., see Muth 1992) and also in the forest modeling literature (Sedjo and Lyon 1990, Adams 1996; Sohngen and Sedjo 1998), which includes anticipatory behavior in response to future forest carbon prices and markets (USEPA 2005; Sohngen and Sedjo 2007; Rose and Sohngen 2011). The U.S. Energy Information Agency (EIA) has projected rising energy demands for biogenic feedstock based on market and policy assumptions, which could be met from a variety of sources, including energy crops and residues, but also short rotation woody biomass and roundwood (EIA 2012; Sedjo 2010; Sedjo and Sohngen 2012). The extent to which price expectations and anticipation of future demand for bioenergy is going to drive forest management decisions, and regional variations in it, would need to be empirically validated. One study shows forest carbon change in a decade (and thereafter) that exceeds the modeled increased cumulative wood energy emissions over the decade (Sedjo and Tian, forthcoming). Other models suggest more limited responses to increased wood energy demand that differ across regions. One such model indicates a large response in the South, in the form of less forest conversion to non-forest use, but much less response in the North and West (USDA FS 2012, Wear 2011).

To capture both the market and biological responses to increased biomass demand, a bioeconomic modeling approach is needed with sufficient biological detail to capture inventory dynamics of regional species and management differences as well as market resolution that captures economic response at both the intensive (e.g. changing harvest patterns, utilization or management intensity) and extensive margins (e.g. land use changes). While several models have these features [USDA Forest Service Resources Planning Act (RPA) models in Wear 2011, Sub-regional Timber Supply in Abt et al. in press 2012, Forest and Agricultural Sector Optimization Model (FASOM) in Adams et al. 2005 and the Global Timber Market Model (GTMM) in Sohngen and Sedjo, 1998], they differ in scope, ecological and market resolution, and how future expectations are formed. FASOM and GTMM employ dynamic long term equilibria that adopt the rational expectations philosophy that markets will incorporate the knowledge embedded in models and adjusts so that the “anticipated baseline” assumes perfect foresight. In stochastic dynamic equilibrium models rational expectations has the somewhat weaker assumption that on average agent’s expectations are realized. In the RPA and SRTS models agents respond to current supply, demand, price signals so that expectations are assumed to be driven by current market conditions. While the rational expectations approach has internal logical consistency and can better simulate long-term structural change, it is an empirical question which approach is more accurate in the short to medium run (10-15 years). These models should incorporate the multiple feedstocks (including crop and logging residues) from the agricultural and forest sectors that would compete to meet the increased demand for bioenergy.

Energy policies can influence the mix of feedstocks used, such as the use of logging residues and the level of projected traditional wood demand, and thus the impact of woody bioenergy demand on timber markets (Daigneault et al. in press 2012). A lower level of timber demand from pulp and paper mills and sawmills, for example, will lead to lower harvest levels and fewer available logging residues. If only residues are allowed to qualify as renewable, then the woody bioenergy industry is explicitly tied to the future of the traditional wood industries. However, if roundwood is used for bioenergy, then the market outcome is more complicated. A lower level of traditional harvest could lead to fewer available residues (which could raise the price of residues and set a physical upper limit on residue supply), but could also lead to higher inventory levels and lower roundwood prices, which would favor increased roundwood utilization for bioenergy. Modeling the interaction across traditional wood consumers, bioenergy consumers, changes in the utilization and mix of products and the displacement of one wood consumer by another as markets evolve will be difficult, but could have a significant impact on the estimate of the carbon consequences of bioenergy use.

As with any modeling, uncertainties will need to be assessed. Models that include price expectations effects or the impact of current year prices would need to be validated. However, validation means different things for different kinds of models. For an econometric model, reproducing history is a form of validation, as is evaluating errors in near-term forecasts. Simulation models are not forecast models. They are designed to entertain scenarios. Validation for simulation models is evaluating parameters and judging the reasonableness of model responses—both theoretically and numerically—given assumptions. Evaluation will help improve representation of average forest and agricultural land management behavior. Evidence affirming or indicating limitations of the effect of prices on investment in retaining or expanding forest area across various U.S. regions may be found by a review of empirical studies of land use change. In order to choose a model, EPA could empirically test the two kinds of models using a “backcasting” approach where the validity of each model’s projections could be compared to actual data for a historical time period.

The anticipated baseline approach could be based on a national/global scale model or a regional scale after weighing the strengths and weaknesses of the two approaches. An example of a regional scale model is that by Galik and Abt (2012) where they tested the effects of various scales on greenhouse gas outcomes and found that in the South market impacts (negative leakage) had a significant impact on forest carbon impacts, but the results were dependent on time period evaluated and were particularly sensitive to scale. They evaluated carbon consequences of bioenergy impacts from stand level to state level and found that as scale increased, market responses mitigated forest carbon impacts. In addition to being sensitive to scale, another disadvantage of the regional scale models is that they would not account for leakage across different regions. However, regional models can incorporate greater heterogeneity in forest growth rates, their carbon impacts and in the price responsiveness of forest management decisions. The SAB has not conducted a detailed review of these models to suggest which model and which scale would be the most appropriate. EPA could select a scale and a model for implementing the *Framework* after validating its performance. Projections from one model could be compared to those from other models by historical backcasting

While market effects are important, there could be value in making separate estimates of biological land carbon changes alone (without market effects). This would establish carbon storage in the absence of positive or negative leakage and will likely have much lower uncertainty – especially for logging residue – than the estimate with leakage. Appendix C depicts three biological scenarios for the total carbon storage in a forest landscape, including live, dead, and soil stores of carbon. Graphically, Figure 5 shows how the storage of carbon in a forest landscape could respond to a shorter harvest interval. Note that all graphs in Appendix C show the biological response and do not account for management changes that could be induced through markets or policies.

Modeling physical land carbon responses over time (without market effects) would show how carbon storage varies by such factors as length of harvest rotations, initial stand age and density, thinning fraction, and growth rates. This information could indicate what forest conditions and practices could provide higher rates of recovery, information that might be helpful for EPA in designing its policy response so that incentives could be provided to favor harvest in areas with a higher likelihood of carbon recovery.

4.7. Are there additional limitations of the accounting framework itself that should be considered?

A number of important limitations of the *Framework* are discussed below:

Framework ambiguity: Key *Framework* features were left unresolved, such as the selection of regional boundaries (the methods for determining as well as implications), marginal versus average accounting, inclusion of working or non-working lands in the region when measuring changes in forest carbon stocks, inclusion/exclusion of leakage, and specific data sources for implementation. As a result, the *Framework's* implementation remains ambiguous. The ambiguity and uncertainty in the text regarding what are stable elements versus actual proposals also clouded the evaluation. If EPA is entertaining alternatives and would like the SAB to entertain alternatives, then the alternatives should be clearly articulated and the proposed *Framework* and case studies should be presented with alternative formulations to illustrate the implementation and implications of alternatives.

Feedstock groups: The proposal designates three feedstock groupings. However, it is not clear what these mean for BAF calculations, if anything. The *Framework* does not incorporate the groupings into the details of the methodology or the case studies. As a result, it is currently impossible to evaluate their implications.

Potential for Unintended consequences: The proposed *Framework* is likely to create perverse incentives for investors and land-owners and result in unintended consequences. For investors, the regional baseline reference year approach will create regions that are one of two types —

either able to support bioenergy from forest roundwood (up to the gain in carbon stock relative to the reference year), or not. As a result, a stationary source investor will only entertain keeping, improving, and building facilities using biomass from regions designated as able to support bioenergy. However, as noted previously, regions losing carbon relative to the reference year, could actually gain carbon stock in relative terms due to improved biomass use and management to meet market demands. In addition, the definitions of regions would need to change over time. The designation of regions as able or not to support bioenergy that comes from the reference year approach will create economic rents and therefore financial stakes in the determination of regions and management of forests in those regions.

The proposed *Framework* could also potentially create perverse incentives for land-owners. For instance, land owners may be inclined to clear forest land a year or more in advance of growing and using energy crops. Similarly, land owners may be more inclined to use nitrogen fertilizers on feedstocks or other lands in conjunction with biomass production. Such fertilization practices have non-CO_2 greenhouse gas consequences (specifically N_2O emissions) that are not presently captured by the *Framework*. It should be noted that agricultural intensification of production via fertilization is a possible response to increased demand for biomass for energy. If onsite N_2O emissions are not accounted for, the carbon footprint of agricultural feedstocks could be significantly underestimated.

Assessment of Monitoring and Estimation Approaches: The *Framework* is also missing a scientific assessment of different monitoring/estimation approaches and their uncertainty. This is a critical omission as it is essential to have a good understanding of the technical basis and uncertainty underlying the use of existing data, models, and lookup tables. A review of monitoring and verification for carbon emissions from different countries, both from fossil and biogenic sources, was recently released by the National Research Council that may provide some guidance (National Research Council, 2010).

5. Case Studies

Charge Question 5: EPA presents a series of case studies in the Appendix of the report to demonstrate how the accounting framework addresses a diverse set of circumstances in which stationary sources emit biogenic CO_2 emissions. Three charge questions are proposed by EPA.

Overall Comments

In general, case studies are extremely valuable for informing the reader with examples of how the *Framework* would apply for specific cases. While they illustrate the manner in which a BAF is calculated, the data inputs are illustrative and may or may not be the appropriate values for an actual biomass-to-energy project. Moreover, they are simplistic relative to the manner in which biomass is converted to energy in the real world. For all case studies in the *Framework*, additional definition of the context is needed, along with examples of how the 'data' are collected or measured, and a discussion of the impacts of data uncertainty. Overall, the case studies did not fully cover the relevant variation in feedstocks, facilities, regions, etc. of potential BAFs that is required to evaluate the methodology. From a clarity and 'teaching' point of view, it might be useful to start with a specific forestry or agricultural feedstock example as the 'base case', and then add in the impacts of the more detailed cases, e.g., additional losses, products, land use changes. This may be more useful than a series of completely separate examples, each including different pieces of the *Framework*.

5.1 Does the SAB consider these case studies to be appropriate and realistic?

The case studies did not incorporate "real-world" scenarios which would have served as models for other situations that may involve biogenic carbon emissions. More would have been learned about the proposed *Framework* by testing it in multiple, unique case studies with "real world" data development and inclusion. Additional case studies for landfills and waste combustion, switchgrass, waste, and other regions would be useful, as well as illustrations of the implementation of feedstock groups, and *Framework* alternatives.

For example, Case Study 4 considers a scenario where corn stover is used for generating electricity. While it is possible that this particular scenario could be implemented, this particular case study does not mirror a "real world" case in that very few if any electrical generation facilities would combust corn stover or agricultural crop residues only. A more likely scenario might be supplementing a co-firing facility with a low percentage of corn stover. Additionally, the assumption of uniform corn stover yields across the region is not realistic. Variation should be expected in the yield of corn stover across the region.

In another example, Case Study 5 calculates the net biogenic emissions from converting agricultural land in row crops to poplar for electricity production. This case study is also not representative of "real world" agricultural conditions as switching from one energy crop to another is not realistic. The formula provided for estimating the standing stock of carbon in the aboveground biomass in the poplar system is not intuitive. The methods for determining biomass yield as well as for measuring changes in soil carbon, which will depend on current use of the land (whether it is conventionally tilled or under a perennial grass), are not described.

5.2. *Does the EPA provide sufficient information to support how EPA has applied the accounting framework in each case?*

There remained considerable uncertainty in many of the inputs. In addition, some sensitivity/uncertainty analysis would be useful. The results of this analysis may guide EPA in further model development. For example, if the BAF is determined to be zero, or not statistically different from zero in most case studies, then this could pave the way for a simpler framework. As discussed in Section 7, a simpler approach could be designed to develop default BAFs for categories of feedstocks based on how their management and use interacts with the carbon cycle.

5.3. *Are there alternative approaches or case studies that EPA should consider to illustrate more effectively how the framework is applied to stationary sources?*

Additional case studies should be designed based on actual or proposed biomass to energy projects to capture "real-world" situations of biomass development, production, and utilization. For example, Case Study 1 describes the construction of one new plant. What would happen if ten new plants were to be proposed for a region? And how would the introduction of multiple facilities at the same time impact the accounting for each facility?

All terms/values used to determine the BAF need to be referenced to actual conditions throughout the growth/production/generation processes that would occur in each case study including how these values would actually be implemented by one or more parties/entities involved. Regional look-up tables could be valuable and EPA could learn a great deal by trying to develop look up tables.

Additional case studies could be developed for perennial herbaceous energy crops, annual energy/biomass sorghums, rotations with food and energy crops, cropping systems on different land and soil types, municipal solid waste and internal reuse of process materials. Each of these feedstocks should be assessed across alternative regions so that the variation in carbon changes across regions could be gauged.

For example it would be very useful to consider the application of the *Framework* to a cellulosic ethanol plant fueled with coal or gas, and consider the emission of CO_2 from fermentation (not combustion) and the production of ethanol which is rapidly combusted to CO_2 in a non-stationary engine. While such an operation is associated with three major sources of CO_2 emissions (listed here), only one is included in the *Framework*; only two may be considered under EPA's regulatory authority, yet all three are emissions to the atmosphere. It would be useful for EPA to at least describe the emissions that are excluded from consideration so that biogenic carbon emissions from stationary sources can be viewed in context.

At least two case studies are needed on municipal solid waste. One case study should be on waste combustion with electrical energy recovery. EPA should also perform a case study on landfill disposal of municipal solid waste. Here it is important to recognize that landfills are repositories of biogenic organic carbon in the form of lignocellulosic substrates (e.g., paper made from mechanical pulp, yard waste, food waste). There is literature to document carbon storage and EPA has recognized carbon storage in previous greenhouse gas assessments of municipal solid waste management.

In Case Study 3 the data used in Table 3 to describe the ‘paper co-product’ will vary with the grade of paper. The ‘carbon content of product’ may vary between 30% to 50% depending on the grade and the amount of fillers and additives. Also, some significant carbon streams in a mill can go to landfills and waste water treatment. The submitted comments from NCASI include a useful example of the detail/clarity that could be used to enhance the value of the Case Studies.

After completion of the case studies, there should be a formal evaluation of (1) the ease with which data were developed and the model implemented, (2) whether the results are robust and useful in recognition of the uncertainty in the various input parameters, and (3) whether the model results lead to unintended consequences as discussed in Section 4.7.

Case studies could be developed to assess and develop a list of feedstocks or applications that could be excluded from accounting requirements as “anyway” emissions. A sensitivity analysis using case studies could be used to develop reasonable offset adjustment factors if they are needed to adjust anyway feedstocks for impact on long term stocks like soil if needed.

6. Overall Evaluation

Charge Question 6: Overall, this report is the outcome of EPA's analysis of the science and technical issues associated with accounting for biogenic CO_2 emissions from stationary sources.

6.1. Does the report-in total-contribute usefully to advancement of understanding of accounting for biogenic CO_2 emissions from stationary sources?

Yes, the *Framework* contributes to advancing the understanding of accounting for biogenic emissions and addresses many issues that arise in such an accounting system. It is thoughtful and far reaching in the questions it tackles. Its main contribution is to force important questions and offer some ways to deal with these. It covers many of the complicated issues associated with the accounting of biogenic CO_2 emissions from stationary sources and acknowledges that its choices will have implications for the estimates of CO_2 emissions obtained. These include those raised by SAB and discussed above, related to the choice of baseline, region selection and the averaging of emissions/stocks over space and time. However, the solutions offered in many cases, particularly those related to the use of harvested wood for bioenergy, lack transparency or a scientific justification.

6.2. Does it provide a mechanism for stationary sources to adjust their total onsite emissions on the basis of the carbon cycle?

Clearly the *Framework* offers a mechanism to adjust total on-site emissions. For short recovery feedstocks (i.e., agricultural residues, perennial herbaceous crops, mill wood wastes, other wastes), the *Framework* could, with some modifications, accurately represent the direct carbon changes offsite. Leakage, however, both positive and negative, remains a troublesome matter if left unresolved. Moreover, the *Framework* offers no scientifically sound way to define a region. The definition of the regional scale can make a large difference to the estimate of emissions from a facility using wood as a biomass. Moreover, if there is no connection between actions of the point source and what happens in the region, there is no foundation for using regional changes in carbon stocks to assign a BAF to the source.

The *Framework* also does not make a clear scientific case for use of waste or what is called "anyway" emissions. Scientifically speaking, all biogenic emissions are "anyway" emissions. Even most woody biomass harvested from old growth forests, would, if left undisturbed eventually die, decompose, returning carbon to the atmosphere. The appropriate distinction is not whether the product is waste or will eventually end up in the atmosphere anyway, but whether the stationary source is leading to an increase or a decrease in biogenic carbon stocks and associated change in GWP. To do this, the *Framework* must consider the time period for "anyway" emissions and that this may vary across different types of waste feedstocks.

An important limitation of the proposed *Framework* is that the accounting system replaces space for time and applies responsibility to things that happen on the land, to a point source, for which the agent who owns that point source has no direct control. The proposed approach would estimate an individual point source's BAF based on average data in a region in which it is located. Any biogenic carbon accounting system that attempts to create responsibility or give credit at a point source for carbon changes upstream or downstream from the point source must relate those responsibilities and credits to actions under control of the point source. However, the *Framework* does not clearly specify a cause and effect relationship between a facility and the biogenic CO_2 emissions attributed to it. In particular, If the BAF is assigned to a plant when it is approved for construction, as the BAF is currently designed, those emissions related to land use change will have nothing to do with that actual effect of the point source on land use emissions because the data on which it is based would predate the operation of the plant.

The dynamics of carbon accumulation in vegetation and soils present a challenge for any accounting system because in principle it implies that BAF estimates such as those proposed by EPA should be based on anticipated future changes in vegetation. These future changes depend on natural processes such as fires and pests that are not easily foreseen, and because of climate change and broader environmental change we face a system that is certainly not stable, and so projecting forward based on current or historical patterns is likely to generate significant errors and biases of unknown direction and magnitude. More important, however, is that land use decisions are under control of landowners, whose actions would need also to be projected. The *Framework* recognizes this issue and chooses to use a Reference Point Baseline. The limitations of this approach for adjusting the CO_2 emissions from biogenic sources have been discussed above. As discussed in response to the next charge question, an alternative to using this approach would be to develop an accounting system based on observable and measured changes rather than projections as discussed in response to the charge question that follows.

EPA's regulatory boundaries, and hence the *Framework*, are in conflict with a more comprehensive carbon accounting that considers the entire carbon cycle and the possibility of gains from trade between sources, among sources or between sources and sinks. For example, by restricting its attention to the regulation of point source emissions, EPA's analysis does not allow for the possibility that a fossil CO_2 emitter could contract with land owners to offset their emissions through forest protection and regrowth or carbon accumulation in soils. As far as the climate is concerned, it makes no difference if land use change is used to offset CO_2 that was of fossil origin or of biogenic origin, however, by staying within boundaries drawn narrowly around the stationary source, the *Framework* eclipses a more comprehensive approach to greenhouse gas reductions that would address all sources and sinks and take advantage of gains from trade. Scientifically, a comprehensive carbon accounting would extend downstream—to emissions from by-products, co-products, or products such as ethanol combustion or ethanol by-products such as distillers dried grains (DDGs) that are sold as livestock feed and will soon become CO_2 (or CH_4).

6.3. Does the SAB have any advice regarding potential revisions that might enhance the final document?

Overall, the *Framework* would be enhanced by including a description of its regulatory context and specifying the boundaries for regulating upstream and downstream emissions while implementing the regulation. The motivation for the *Framework* should have been explained as it relates to Clean Air Act requirements. The *Framework* should also make explicit the constraints within which greenhouse gases can be regulated under the Clean Air Act. In doing this, EPA could be clear that these issues have not been settled but that some assumptions were necessary to make a decision about the *Framework*. EPA could also stipulate that further development of a regulatory structure might require changes to the accounting system. While the SAB understands the EPA's interest in describing an accounting system as a first step and potentially independent of the regulatory structure, the reader needs this background in order to understand the boundaries and context for the accounting structure and to evaluate the scientific integrity of the approach.

Similarly, the *Framework* is mostly silent on how possible regulatory measures under the Clean Air Act may relate to other policies that affect land use changes or the combustion/oxidation of products from the point sources that will release carbon or other greenhouse gases. For example if a regulatory or incentive system exists to provide credits for carbon offsets through land use management then under some conditions it would be appropriate to assign a BAF of 1 to biogenic emissions given that the carbon consequences were addressed through other policies.

The *Framework* does not describe how it will address emissions downstream from a point source such as in the case of a biofuels or paper production facility where the product (biofuels, paper) may lead to CO_2 emissions when the biofuels are combusted or the paper disposed of and possibly incinerated. For example, if paper products are incinerated the incinerator may well be a point source that comes under Clean Air Act regulation. However, biofuels used in vehicles would not be subject to regulation as a point source. EPA needs to make clear the implicit assumptions on how biogenic carbon will be treated upstream and downstream from the point source if this *Framework* is used to regulate CO_2 emissions under the constraints imposed by the Clean Air Act for regulating stationary sources.

Recommendations for Revising BAF

Many of the issues raised in previous responses regarding the treatment of specific factors included in the *Framework* are specific to particular feedstocks. The clarity of the Framework would be improved by differentiating among feedstocks based on how their management and use interacts with the carbon cycle. Feedstocks could be categorized into short rotation dedicated energy crops, crop residues, forest residues and long rotation trees. A BAF equation could be developed for each of these categories of feedstocks.

If EPA decides to revise the *Framework,* the following recommendations for specific improvements are summarized below.

- Develop a separate BAF equation for each feedstock category. Feedstocks could be categorized into short rotation dedicated energy crops, crop residues, forest residues, perennial crops, municipal solid waste, long rotation trees and waste materials.

   i. For long-recovery feedstocks like woody biomass, use an anticipated baseline approach to compare emissions from increased biomass harvesting against a baseline without increased biomass demand. For long rotation woody biomass, sophisticated modeling is needed to capture the complex interaction between electricity generating facilities and forest markets, in particular, market driven shifts in planting, management and harvests, induced displacement of existing users of biomass, land use changes, including interactions between agriculture and forests and the relative contribution of different feedstock source categories (logging residuals, pulpwood or roundwood harvest).
   ii. For residues, consider incorporating information about decay after an appropriate analysis in which storage of ecosystem carbon is calculated based on decay functions.
   iii. For materials diverted from the waste stream, consider their alternate fate, whether they might decompose over a long period of time, whether they would be deposited in anaerobic landfills, whether they are diverted from recycling and reuse, etc. For municipal solid waste, consider the mix of biogenic and fossil carbon when waste is combusted. For feedstocks that are found to have relatively minor impacts, EPA may need to weigh ease of implementation against scientific accuracy. After calculating decay rates and considering alternate fates, EPA may wish to declare certain categories of feedstocks with relatively low impacts as having a very low BAF or setting it to 0.

- Incorporate various time scales and consider the tradeoffs in choosing between different time scales.

- For all feedstocks, consider information about carbon leakage to determine its directionality as well as leakage into other media.

7. Alternative Approaches for the Agency's Consideration

There are no easy answers to accounting for the greenhouse gas implications of bioenergy. Given the uncertainties, technical difficulties and implementation challenges associated with implementing the *Framework*, the SAB encourages EPA to "think outside the box" and look at alternatives to the *Framework* and its implementation as proposed. The following alternatives are offered for the Agency's consideration, while recognizing the difficulties associated with each one. The SAB cannot offer any opinion on the legality of these options.

1. *Consider developing default BAFs for each feedstock category.* As already discussed, the clarity of the *Framework* would be improved by differentiating among feedstocks based on how their management and use interacts with the carbon cycle. Many of the issues raised in previous responses regarding the treatment of specific factors included in the *Framework* are specific to particular feedstocks To develop default BAFs, feedstock groups could be differentiated based on general information on how their particular harvest and combustion patterns interacts with the carbon cycle. Special attention should be given to whether and which feedstocks could be classified as "anyway" emissions for ease of administration (if that is valued over scientific accuracy). For longer recovery feedstocks, EPA would need to use forest growth models to plot carbon paths that track regrowth following harvest and compare those to the path under a no-bioenergy case. A shortcoming of the feedstock specific BAF is that it would disregard facility specific factors such as Loss and PRODC. Case studies would be needed to develop an accounting approach focused on feedstocks and to determine its potential for widespread applicability to heterogeneous facilities..Facilities could have the option of demonstrating a lower BAF than the default value based on their specific production conditions.

2. *Consider certification systems for procurement of forest-derived woody biomass.* This approach would be based on a new type of certification, not traditional forest certification, but certification specific to the effect of using forest resources for bioenergy on greenhouse gas balances. Certifications systems would have the advantage of being tied to the feedstock's fuelshed or actual sourcing area. A certification approach would involve a quantifiable and verifiable accounting for net greenhouse gas changes of the system (using a specified baseline determination for consistency), while accounting for additionality and permanence. For biogenic carbon accounting, "additionality" means that carbon sequestration has increased as a result of using the biomass as compared to the case without using the biomass for energy. Maintaining land carbon above a fixed point baseline is not sufficient to assure additionality.

Although most certification schemes are designed for forest management, certification might also be applied to agricultural feedstocks to the extent that their use poses carbon deficits. A certification approach would make the stationary source responsible for providing information on certification of feedstocks. This information, in turn, would relate to harvest and regrowth rates of forests in the fuelshed from which its biomass was procured. In so doing, the source would be linked to its land base.

Administratively, certification systems can be very complex. Because much of the forest biomass is likely to be used for other purposes, e.g., lumber, pulp, wood pellets and a variety of other products, certification systems would need to involve the use of complex protocols to differentiate between wood removed for traditional forest products, which would not be counted against the stationary bioenergy facility and wood removed for energy purposes.

There is precedent for systems to certify forest carbon accumulation where the goal is to estimate the amount of land carbon increase that is caused (and maintained) by a carbon payment. Such systems have mechanisms that seek to assure carbon increase is additional to what would have occurred without carbon payment (additionality) while accounting for probable natural loss in judging permanence. In addition to these factors, it is important to account for leakage due to price effects. Leakage may be generated by either positive or negative responses to forest activities. Protection in one area may simply deflect logging to other areas. Also, harvests in one place may generate market forces elsewhere to invest in forest management to take advantage of anticipated future markets. Murray et al. (2004) have estimated positive leakage in U.S. forests of 10-90%. In the absence of a comprehensive global monitoring approach, leakage is likely to be significant (Sedjo and Macauley 2011, Sohngen and Brown 2004). Furthermore, since leakage can be either positive or negative, there can be uncertainty even with respect to the sign of net leakage.

Addressing issues of additionality, leakage and permanence increases complexity and costs of accounting for the carbon emissions of a stationary source. Voluntary and regulatory carbon certification programs have been developing methodologies for tracking forest carbon for forest management for a number of years (Reserve, 2012). The Climate Action Reserve (CAR, Reserve 2012), American Carbon Registry (Registry, 2012) and Verified Carbon Standard (Verified Carbon Standard Association) all have forest management methodologies that address additionality, baseline, leakage, and permanence issues in various ways (Galek, Mobley, & and Richter, 2009). However, only CAR has seen a significant number of projects developing in the U.S. (more than 40) using this protocol. The California Air Resources Board has approved CAR's forest protocols for the offsets program under their new regulations (California Air Resources Board, 2012) Protocols on soil carbon in agricultural systems are in active use in Canada and in early stages of development for the US (Coren, 2012).

To capture the major pathways by which wood-based feedstocks interact with the carbon cycle, a biogenic carbon certification system would seek to estimate 1) the amount of land carbon increase that occurs over time because woody biomass is taken for fuel, 2) the amount of logging residue decay emissions avoided over time because logging residue is taken for fuel, or 3) the amount of waste wood emissions avoided over time because waste wood is used for fuel. Note, that this approach requires an estimate of the total biomass removed, the portion that is used for bioenergy and an estimate of the portion that would not otherwise be removed in the absence of a biomass market. With the exception of a forest dedicated to biomass production, estimates are likely to be different for different types of forests depending on the product mix and even for the same type of forest at different ages.

Certification that a certain feedstock has a certain "carbon recovery" could potentially be done by the owner at the source of the feedstock and/or a buyer of feedstock via specification standards. Some degree of source certification of feedstock specifications may be needed. It would be most practical if all material from a given source or type of source could be assigned the same "carbon recovery" (e.g. all mill residue, all logging residue, large categories of roundwood). As an example, the Massachusetts Executive Office of Energy and Environmental Affairs (2012) has released draft Renewable Portfolio Standard regulations that indicate how wood feedstocks may be certified to have certain carbon recovery performance. They identified three categories of wood biomass and how their carbon decay (recovery) profiles can be used to meet feedstock performance requirements (Massachusetts 2012).

Mill residue could be recognized by its physical source. A key criterion for material to be recognized as logging residue is that it is produced at the time of harvest with sawlogs or pulpwood. Would it be realistic to recognize up to a certain fraction of biomass sales from a land area as logging residue based on sales receipts of all material removed? Could the permissible fraction of biomass that can be identified as logging residue be based on historical timber product output (harvest) estimates of logging residue generated per unit of roundwood removal or some other survey based means?

For roundwood it may be possible to physically recognize three different sources that will have notably different biogenic accounting values: 1) biomass from forest thinnings removals limited e.g. to a certain percentage basal area removal, 2) biomass from clearcuts on working land where forest plans or other information indicate rotation age is limited and carbon recovery would occur within that time period (if the land remains in forest), and 3) other forest land with no definable rotation age. The Massachusetts draft regulations use one category of wood from forest thinning. These are just suggestions. There could be much better categories that could be identified on the ground while allowing for estimation of differing generic BAF values for a wide area. The key goal is to be able to identify and specify sources with notably differing BAF values so there can be an incentive to preferentially use sources with lower BAF values.

Certification systems are unlikely to be able to quantify the magnitude of positive or negative leakage due to a single fuelshed's use of forest biomass for bioenergy, since leakage by definition occurs due to changes in land use/biomass production in the aggregate. However, they could qualitatively assess the potential for leakage by examining the type of land and the feedstock being used for producing biomass. Certification systems could be accompanied by other approaches to reduce the potential for leakage. For example, positive leakage in the form of carbon loss when agricultural land is converted to forests might be avoided by not permitting the use of biomass from agricultural land that was converted to forest or energy crops.

There are a variety of schemes that could be employed to implement a certification approach. The simplest approach would be a binary system so that certified feedstocks would be excluded (from counting toward a facility's greenhouse gas emissions in determining applicability to the

Tailoring Rule) and uncertified feedstocks would be included and, hence, treated on par with fossil fuels. In other words, feedstocks would either have a BAF of 0 or 1.

More complicated schemes could be devised so that certification is combined with default BAFs in determining a facility's overall carbon emissions from biogenic feedstocks. In this hybrid approach, a facility could calculate its biogenic emissions based on a mix of feedstock sources using both certified feedstocks and default BAFs. As an example, suppose a facility is using 25% mill residue, 50% logging residue and 25% roundwood thinnings. Assume further that mill residues are determined to have a default BAF of 0, logging residues are certified and roundwood thinnings have a default BAF of 0.4, then its overall carbon emissions could be computed as .25(tons of mill residue)(0) + .5(tons of logging residue)(0) + .25(tons of roundwood thinning)(0.4). As in Option 1 (developing default BAFs), facilities could have the option of demonstrating a lower BAF for feedstocks they are using based on their site-specific feedstock production systems and operations.

Another option would be to use certification only for determining the LAR value that captures the proportion of a feedstock's emissions that are offset by sequestration. Other facility-specific terms like PRODC and Loss would still have to be calculated and plugged into the equation in the *Framework* to determine a facility's overall carbon emissions from biogenic feedstocks.

Obviously EPA would need to conduct a comprehensive evaluation of certification options in far greater detail than shown in the sketchy details given here. As with any scheme, it is likely EPA would face tradeoffs between the scientific accuracy and ease of implementation with more complex schemes yielding more "accurate" biogenic accounting factors and simpler schemes offering ease of implementation.

References

Abt, K.L., Abt, R.C., Galik, C.G. (2012, In Press). Effect of bioenergy demands and supply response on markets, carbon and land use. *Forest Science*.

Adams, D., Alig, R., Callaway, J., Winnett, S., & McCarl, B. (1996). The Forest and Agricultural Sector Optimization Model (FASOM): Model Structure, Policy and Applications. Portland, OR: USDA Forest Service, Pacific Northwest Experiment Station.

Adams, D.; Alig, R.; McCarl, B.; Murray, B. (2005, February). Bruce McCarl Website. Retrieved April 2012, from Texas A & M Agricultural Economics: http://agecon2.tamu.edu/people/faculty/mccarl-bruce/papers/1212FASOMGHG_doc.pdf.

Alban, D.H.; Perala, D.A. (1992). Carbon Storage in Lake States Aspen Ecosystems. *Canadian Journal of Forest Research*, 1107-1110.

Allen, M. R., Frame, D. J., Huntingford, C., Jones, C. D., Lowe, J., Meinshausen, M., et al. (2009). Warming Caused by Cumulative Carbon Emissions toward the Trillionth Tonne. *Nature*, 1163 - 1166.

Anderson-Teixeira, K.; Davis, S.; Masters, M.; Delucia, E. (2009). Changes in soil organic carbon under biofuel crops. *Global Change Biology Bioenergy*, 75-96.

Baker, J., Ochsner, T., Venterea, R., & Griffis, T. (2007). Tillage and soil carbon sequestration—What do we really know? *Agriculture, Ecosystems and Environment*, 118.

Binkley, D.; Resh, S.C. (1999). Rapid changes in soils following Eucalyptus afforestation in Hawaii. *Soil Science Society of America Journal*, 222-225.

Black, T.; Harden, J.W. (1995). Effect of timber harvest on soil carbon storage at Blodgett Exp Forest, California. *Canadian Journal of Forest Research*, 1385 - 1396.

Butler, B. (2008). Family forest Owners of the U.S. Newtown Square, PA: U.S. Forest Service Northern Research Station.

California Air Resources Board. (2012). Compliance Offset Program. Retrieved from http://www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm

Chen, X., & Khanna, M. (in press, 2012). The Market Mediated Effects of Biofuel Policies. Agbioforum.

Cherubini, F., Guest, G., & Stromman, A. (2012). Application of Probability Distributions to the Modeling of Biogenic CO2 Fluxes in Life cycle Assessment. *Global Change Biology Bioenergy*, 1 - 15.

Cherubini, F., Peters, G., Berntsen, T., Stromman, A., & and Hertwich, E. (2011). CO2 Emissions from Biomass Combustion for Bioenergy: Atmospheric Decay and Contribution to Global Warming. *Global Change Biology Bioenergy*, 413 - 426.

Coren, M. J. (2012). Betting on the Farm: Can Soil Carbon Cut Emissions and Improve the World's Farmlands? Retrieved from http://www.ecosystemmarketplace.com/pages/dynamic/article.page.php?page_id=7580&section=home.

Crutzen, P., Mosier, A., Smith, K., & and Winiwarter, W. (2007). N2O Release from Agro-biofuel Production Negates Global Warming Reduction by Replacing Fossil Fuels. *Atmos. Chem. Phys. Discussion*, 11191 - 11205.

Daigneault, A.; Sohngen, B.; Sedjo, R. (2012). An Economic Approach to Assess the Forest Carbon Implications of Biomass Energy. *Environmental Science & Technology*, Forthcoming.

Edwards, N.T.; Ross-Todd, B.M. (1983). Soil carbon dynamics in a mixed deciduous forest following clear cutting with and without residue. *Soil Science Society of America Journal*, 1014-1021.

Energy Information Administration. (2012). Annual Energy Outlook 2012 Early Release Overview. Washington, D.C.: U.S. Department of Energy.

Galek, C., Mobley, M., & and Richter, D. (2009). A Virtual "Field Test" of Forest Management Carbon Offset Protocols: The Influence of Accounting. *Mitigation and Adaptation Strategies for Global Change*, 677 - 690.

Galik, C.S.; Abt, R.C. (2012). The effect of assessment scale and metric selection on the greenhouse gas benefits of woody biomass. *Biomass and Bioenergy*, In Press.

Gilmore, A.R.; Boggess, W.R. (1963). Effects of past agricultural practices on the survival and growth of planted trees. *Soil Science Society of America Proceedings*, 98-101.

Goodale, C.L.; Apps, M.J.; Birdsey, R.A.; Field, C.B.; Heath, L.S.; Houghton, R.A.; Jenkins, J.C.; Kohlmaier, G.H.; Kurz, W.; Liu, S.R.; Nabuurs, G.J.; Nilsson, S.; Shvidenko, A.Z. (2002). Forest carbon sinks in the Northern Hemisphere. *Ecological Applications*, 891 - 899.

Grigal, D.F.; Berguson, W.E. (1998). Soil carbon changes associated with short-rotation systems. *Biological Biogengineering*, 371-377.

Harmon, M., Ferrell, W., & and Franklin, J. (1990). Effects on carbon storage of conversion of old-growth to young forests. *Science*, 699 - 702.

Holcombe, R., & Sobel, R. (2001). Public Policy Toward Pecuniary Externalities. *Public Finance Review*, 29.

Homann, P.S.; Bormann, B.T.; Boyle, J.R. (2001). Detecting treatment differences in soil carbon and nitrogen resulting from forest manipulations. *Soil Science Society of America Journal*, 463-469.

Huntington, T. (1995). Carbon sequestration in an aggrading forest ecosystem in the southeastern USA. *Soil Science Society of America Journal*, 1459-1467.

Ince, P., Kramp, A., Skog, K., Spelter, H., & Wear, D. (2011). U.S. Forest Products Module: A Technical Document Supporting the Forest Service 2010 RPA Assessment. Madison, WI: U.S. Forest Service, Forest Products Laboratory.

Ingerson, Ann and David Moulton, The Wilderness Society. (October 18, 2011). Comments submitted to the Science Advisory Board. Retrieved from Science Advisory Board Website: http://yosemite.epa.gov/sab/SABPRODUCT.NSF/91808E2B275DD22F8525792D006B40BA/$File/Wilderness+Society+comments.pdf

Ingerson, Ann. The Wilderness Society Comments (2011, October 18) for the Biogenic Carbon Emissions Panel Meeting October 25 - 27, 2011. Retrieved April 6, 2012, from Science Advisory Board Website: http://yosemite.epa.gov/sab/SABPRODUCT.NSF/91808E2B275DD22F8525792D006B40BA/$File/Wilderness+Society+comments.pdf

Johnson, D., & Curtis, P. (2001). Effects of forest management on soil C and N storage: meta analysis. *Forest Ecology and Management*, 227 - 238.

Johnson, D.W.; Curtis, P.S. (2001). Effects of forest management on soil C and N Storage: meta analysis. *Forest Ecology and Management*, 227-238.

Johnson, E. (2009). Goodbye to carbon neutral: Getting biomass footprints right. *Environmental Impact Assessment Review*, 29.

Khanna, M.; Crago, C., & Black, M. (2011). Can biofuels be a solution to climate change? The implications of land use change-related emissions for policy. *Interface Focus*, 233-247.

Khanna, Madhu; and Crago, C.L. (In Press, 2012). Measuring Indirect land Use Change with Biofuels: Implications for Policy. *Annual Review of Resource Economics*.

Kravchenko, A., & Robertson, G. (2011). Whole Profile Soil Carbon Stocks: The Danger of Assuming Too Much from Analyses of Too Little. *Soil Science Society of America Journal*, 75.

Laiho, R.; Sanchez, F.; Tiarks, A.; Dougherty, P.M.; Trettin, C.C. (2003). Impacts of intensive forestry on early rotation trends in site carbon pools in the southeastern U.S. *Forest Ecology and Management*, 177-189.

Liska, A., & Perrin, R. (2009). Indirect land use emissions in the life cycle of biofuels: regulations vs science. *Biofuels, Bioproducts and Biorefining*, 318-328.

Massachusetts Executive Office of Energy and Environmental Affairs (2012). Renewable Portfolio Standard – Biomass Policy Regulatory Process; Proposed final regulation. Published April 27, 2012. http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/biomass/renewable-portfolio-standard-biomass-policy.html.

Mattson, K.G.; Swank, W.T. (1989). Soil and detrital carbon dynamics following forest cutting in the Southern Appalachians. *Biology and Fertility of Soils*, 247-253.

Mroz, G.D.; Jurgensen, M.F.; Frederick, D.J. (1985). Soil nutrient changes following whole tree harvesting on 3 Northern Hardwood Sites. *Soil Science Society of America Journal*, 1552-1557.

Murray, B.C.; McCarl, B.A.; Lee, H. (2004). Estimating Leakage from Forest Carbon Sequestration Programs. *Land Economics*, 109-124.

Muth, J. (1992). Rational Expectations and the Theory of Price Movements. In International Library of Critical Writings in Economics, Volume 1 (pp. 3-23). Aldershot, UK: Elgar.

National Research Council. (2010). Verifying Greenhouse Gas Emissions: Methods to Support International Climate Agreements. Washington, D.C.: The National Academies Press.

Nave, L.E.; Vance, E.D.; Swanston, C.W.; Curtis, P.S. (2010). Harvest impacts on soil carbon storage in temperate forests. *Forest Ecology and Management*, 857-866.

Olson, J. S. (1963). Energy Storage and the Balance of Producers and Decomposers in Ecological Systems. *Ecology*, 322 - 331.

Polykov, M., Wear, D., & Huggett, R. (2010). Harvest Choice and Timber Supply Models for Forest Forecasting. *Forest Science*, 344 - 355.

Rabl, A., Benoist, A., Dron, D., Peuportier, B., Spadaro, J., & Zoughaib, A. (2007). How to Account for CO2 Emissions from Biomass in a Life Cycle Analysis. *International Journal of Life Cycle Analysis*.

Registry, A. C. (2012). American Carbon Registry Standards and Methodologies. Retrieved from http://www.americancarbonregistry.org/carbon-accounting

Reserve, Climate Action. (2012). Protocols. Retrieved from http://www.climateactionreserve.org/how/protocols/

Richter, D.D.; Markewitz, D.; Trumbore, S.W.; Wells, C.G. (1999). Rapid accumulation and turnover of soil carbon in a re-establishing forest. *Nature*, 56-58.

Sanchez, F.G.; Coleman, M.; Garten Jr., C.T.; Luxmoore, R.J.; Stanturf, J.W.; Trettin, C.; Wullschleger, S.D. (2007). Soil carbon, after 3 years, under short-rotation woody crops grown under varying nutrient and water availability. *Biomass and Bioenergy*, 793-801.

Sathre, R. a. (2011). Time-dependent climate benefits of using forest residues to substitute fossil fuels. *Biomass and Bioenergy*, 35, 2506-2516.

Schiffman, P.M.; Johnson, W.C. (1989). Phytomass and detrital carbon storage during forest regrowth in the southeatsern U.S. Piedmont. *Canadian Journal of Forest Research*, 69-78.

Schlamadinger, B., Spitzer, J., Kohlmaier, G., & and Ludeke, M. (1995). Carbon Balance of Bioenergy from Logging Residues. *Biomass & Bioenergy*, 221 - 234.

Searchinger, T., Hamburg, S., Melillo, J., & Chameides, W. (2009). Fixing a Critical Climate Accounting Error. *Science*, 326.

Sedjo, R. (2010). The Biomass Crop Assistance Program: Some Implications for the Forest Industry. Washington, D.C. : Resources for the Future.

Sedjo, R., & Lyon, K. (1990). The Long Term Adequacy of World Timber Supply. Washington, D.C.: Resources for the Future.

Sedjo, R., & Sohngen, B. (In Press, 2012). Wood as a Major Feedstock for Biofuel Production in the U.S.: Impacts on Forests and International Trade. *Journal of Sustainable Forests*.

Sedjo, R.; Macauley, Molly. (2011). Forest Carbon Offsets: Possibilities and Limitations. *Journal of Forestry*.

Sedjo, Roger; Tian, Xiaohui. (2012). What is the Carbon Footprint of Wood Biomass Energy. *Journal of Forestry*, Forthcoming.

Selig, M.F.; Seiler, J.R.; Tyree, M.C. (2008). Soil carbon and CO2 efflux as influenced by the thinning of loblolly pine. *Forest Science,* 58-66.

Sohngen, B., & Sedjo, R. (1998). A Comparison of Timber Market Models: Static Simulation and Optimal Control Approaches. *Forest Science*, 24-36.

Sohngen, B., Mendelsohn, R., & Sedjo, R. (2001). A Global Model of Climate Change Impacts on Timber Markets. *Journal of Agricultural and Resource Economics*, 326 - 343.

Sohngen, B.; Brown, S. (2004). Measuring Leakage from Carbon Projects in Open Economies: A Stop Timber Harvesting Project as a Case Study. *Canadian Journal of Forest Research*, 829-839.

Stanton, E., Bueno, R., Ackerman, F., Erickson, P.; Hammerschlag, R., & and Cegan, J. (2011). Consumption-Based Greenhouse Gas Emissions Inventory for Oregon - 2005. Technical Report. Somerville, MA: Stockholm Environment Institute-U.S. Center.

Tang, J.; Qi, Y.; Xu, M.; Misson, L.; Goldstein, A.H. (2005). Forest thinning and soil respiration in a ponderosa pine plantation in the sierra Nevada. *Tree Physiology*, 57-66.

Tolbert, V.R.; Thornton, F.C.; Joslin, J.D.; Bock, B.R.; Bandaranayake, W.; Hoiuston, A.; Tyler, D.; Pettry, D.W.; Green, T.H. (2000). Increasing belowground carbon sequestration with conversion of agricultural lands to production of bioenergy crops. *New Zealand Journal of Forest Science*, 138-149.

USDA Forest Service. (April 2012). The Future of America's Forests and Rangelands - The 2010 Resources Planning Act (RPA) Assessment. Washington, D.C.: USDA, In Press.

Verified Carbon Standard Association. (n.d.). Verified Carbon Standard: A Global Benchmark for Carbon. Retrieved from http://www.v-c-s.org/methodologies/find

Vokoun, M., Wear, D., & Abt, R. (2009). Testing for Change in Structural Elements of Forest Inventories. *Forest Science*, 455 - 466.

Wear, D. (2011). Forecasts of county-level land uses under three future scenarios: a technical document supporting the Forest Service 2010 RPA Assessment. Ashville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station.

Zilberman, D.; Hocman, G.; Rajagopal, D. (2011). On the Inclusion of Indirect Land Use in Biofuel Regulations. *University of Illinois Law Review*, 413-434.

Appendix A: Charge to the Panel

MEMORANDUM

To: Holly Stallworth, DFO
Science Advisory Board Staff Office

From: Paul Gunning, Acting Director
Climate Change Division

Subject: Accounting Framework for Biogenic Carbon Dioxide (CO_2) Emissions from Stationary Sources and Charge Questions for SAB peer review

The purpose of this memorandum is to transmit the draft *Accounting Framework for Biogenic CO_2 Emissions* study and the charge questions for consideration by the Science Advisory Board (SAB) during your upcoming peer review in fall 2011.

In January 2011, the U.S. Environmental Protection Agency (EPA) announced a series of steps it would take to address biogenic CO_2 emissions from stationary sources. In addition to specific regulatory action, EPA committed to conduct a detailed examination of the science and technical issues related to accounting for biogenic CO_2 emissions and to develop an accounting framework for those emissions. The study transmitted today is that examination.

The study identifies key scientific and technical factors that should be considered when constructing any framework for accounting for the impact of utilizing biologically-based feedstocks at stationary sources. It then provides EPA's recommendations on those issues and presents a framework for "adjusting" estimates of onsite biogenic CO_2 emissions (i.e., a "biogenic accounting factor" or BAF) on the basis of information about the carbon cycle.

As indicated in the accompanying materials, advice on these issues will be important as EPA moves through the steps to address biogenic CO_2 emissions from stationary sources. We look forward to the SAB's review.

Please contact me if you have any questions about the attached study and charge.

Charge Questions

EPA is providing this study, *Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources* (September 15, 2011), to the Science Advisory Board (SAB) to review EPA's approach on accounting for biogenic CO_2 emissions from stationary sources, including the scientific basis and methodological components necessary to complete that accounting.

Objective

EPA is charging the SAB to review and comment on (1) EPA's characterization of the science and technical issues relevant to accounting for biogenic CO_2 emissions from stationary sources; (2) EPA's framework, overall approach, and methodological choices for accounting for these emissions; and (3) options for improving upon the framework for accounting for biogenic CO_2 emissions.

This charge does not ask the SAB for regulatory recommendations or legal interpretation of the Clean Air Act statutes related to stationary sources.

Charge Questions

1. *Evaluation of the science of biogenic CO_2 emissions*

In reviewing the scientific literature on biogenic CO_2 emissions, EPA assessed the underlying science of the carbon cycle, characterized fossil and biogenic carbon reservoirs, and discussed the implications for biogenic CO_2 accounting.

- Does the SAB support EPA's assessment and characterization of the underlying science and the implications for biogenic CO_2 accounting?

2. *Evaluation of biogenic CO_2 accounting approaches*

In this report, EPA considered existing accounting approaches in terms of their ability to reflect the underlying science of the carbon cycle and also evaluated these approaches on whether or not they could be readily and rigorously applied in a stationary source context in which onsite emissions are the primary focus. On the basis of these considerations, EPA concluded that a new accounting framework is needed for stationary sources.

- Does the SAB agree with EPA's concerns about applying the IPCC national approach to biogenic CO_2 emissions at individual stationary sources?
- Does the SAB support the conclusion that the categorical approaches (inclusion and exclusion) are inappropriate for this purpose, based on the characteristics of the carbon cycle?
- Does the SAB support EPA's conclusion that a new framework is needed for situations in which only onsite emissions are considered for non-biologically-based (i.e., fossil) feedstocks?

- Are there additional accounting approaches that could be applied in the context of biogenic CO_2 emissions from stationary sources that should have been evaluated but were not?

3. Evaluation of methodological issues

EPA identified and evaluated a series of factors in addition to direct biogenic CO_2 emissions from a stationary source that may influence the changes in carbon stocks that occur offsite, beyond the stationary source (e.g., changes in carbon stocks, emissions due to land-use and land management change, temporal and spatial scales, feedstock categorization) that are related to the carbon cycle and should be considered when developing a framework to adjust total onsite emissions from a stationary source.

- Does SAB support EPA's conclusions on how these factors should be included in accounting for biogenic CO_2 emissions, taking into consideration recent advances and studies relevant to biogenic CO_2 accounting?
- Does SAB support EPA's distinction between policy and technical considerations concerning the treatment of specific factors in an accounting approach?
- Are there additional factors that EPA should include in its assessment? If so, please specify those factors.
- Should any factors be modified or eliminated?

4. Evaluation of accounting framework

EPA's accounting framework is intended to be broadly applicable to situations in which there is a need to represent the changes in carbon stocks that occur offsite, beyond the stationary source, or in other words, to develop a "biogenic accounting factor" (BAF) for biogenic CO_2 emissions from stationary sources.

- Does the framework accurately represent the changes in carbon stocks that occur offsite, beyond the stationary source (i.e., the BAF)?
- Is it scientifically rigorous?
- Does it utilize existing data sources?
- Is it easily updated as new data become available?
- Is it simple to implement and understand?
- Can the SAB recommend improvements to the framework to address the issue of attribution of changes in land-based carbon stocks?
- Are there additional limitations of the accounting framework itself that should be considered?

5. Evaluation of and recommendations on case studies

EPA presents a series of case studies in the Appendix to demonstrate how the accounting framework addresses a diverse set of circumstances in which stationary sources emit biogenic CO_2 emissions.

- Does the SAB consider these case studies to be appropriate and realistic?
- Does the EPA provide sufficient information to support how EPA has applied the accounting framework in each case?
- Are there alternative approaches or case studies that EPA should consider to illustrate more effectively how the framework is applied to stationary sources?

6. Overall evaluation

Overall, this report is the outcome of EPA's analysis of the science and technical issues associated with accounting for biogenic CO_2 emissions from stationary sources.

- Does the report – in total – contribute usefully to the advancement of understanding on accounting for biogenic CO_2 emissions from stationary source?
- Does it provide a mechanism for stationary sources to adjust their total onsite emissions on the basis of the carbon cycle?
- Does the SAB have advice regarding potential revisions to this draft study that might enhance the utility of the final document?

Appendix B: Fate of Residue after Harvest and Landscape Storage of Carbon

The decomposition of materials left after harvest can be estimated from the negative exponential decay equation (Olson 1963): $C_t=C_0 \exp[-kt]$ where C_t=is the amount at any time t, C_0 is the initial amount, k is the rate-constant of loss, and t is time. Solving this function for a range of rate-loss constants results in the relationship shown in Figure 1 for a range of k that covers the most likely range for decomposition rates of leafy to woody material in North America. In no case does the store instantaneously drop to zero as assumed in the current framework.

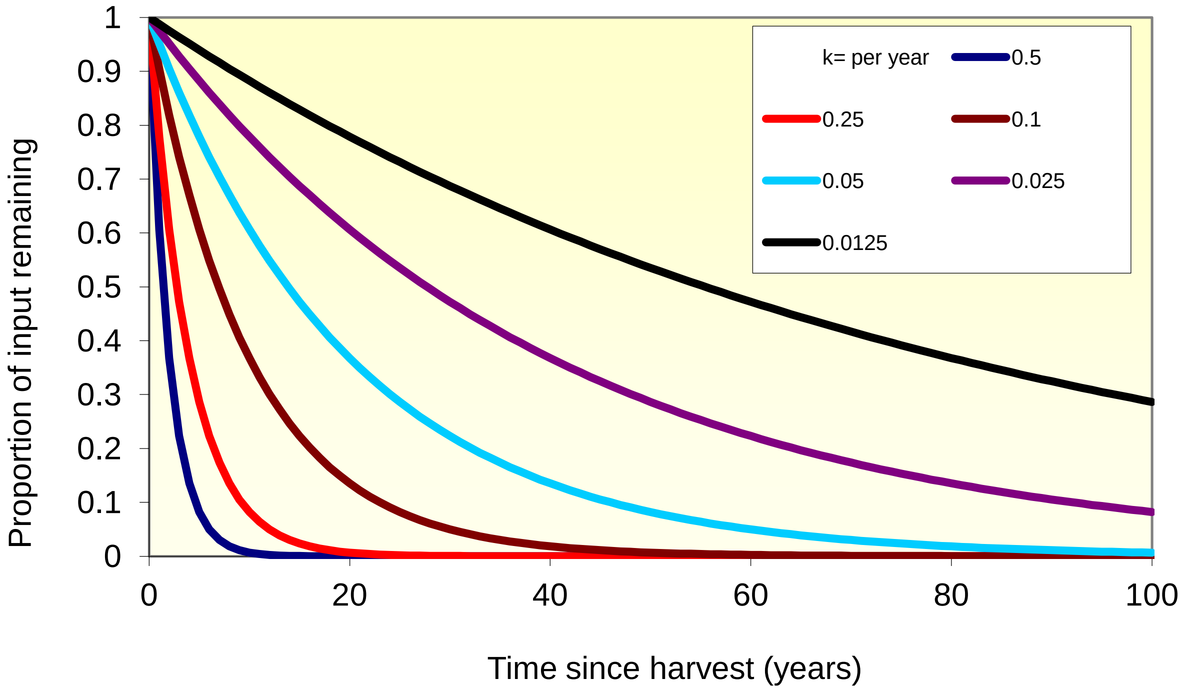

Figure 2: Fate of residue/slash left after harvest as function of k and time since harvest.

The amount of carbon stored on average in a landscape or fuel-shed comprised of units or stands that generate equal amounts of residue or slash is given by: I/k, where I is the average landscape input of residue or slash. To create a relative function independent of the amount of residue or slash created, the input of each harvest unit or stand can be set to either 1 (to give the proportion of the input) or 100 (to give a percent of the input). The average landscape input (I) would therefore be equal to $1/R_H$ or $100/ R_H$ where R_H is the harvest return interval. Using this relationship to solve the average landscape store relative to the input is presented in Figure 2 for the most likely range of decomposition rates for leafy to woody material in North America. This indicates that there are a wide range of possible cases in which the store of residue or slash can exceed the initial input (shown by the horizontal line indicating storage of 1). This means that combusting this material will cause the store to drop by the amount indicated, and this amounts to the net flux of carbon to the atmosphere. To a large degree there is a negative relationship between the harvest interval and k; materials with high values of k (i.e., leafy) are typically harvested with short intervals between harvests and material with low values of k (i.e, large wood) are typically harvested with long interval between harvests. This suggests that the effect of harvesting residues and slash is largely independent of the loss rate-constant.

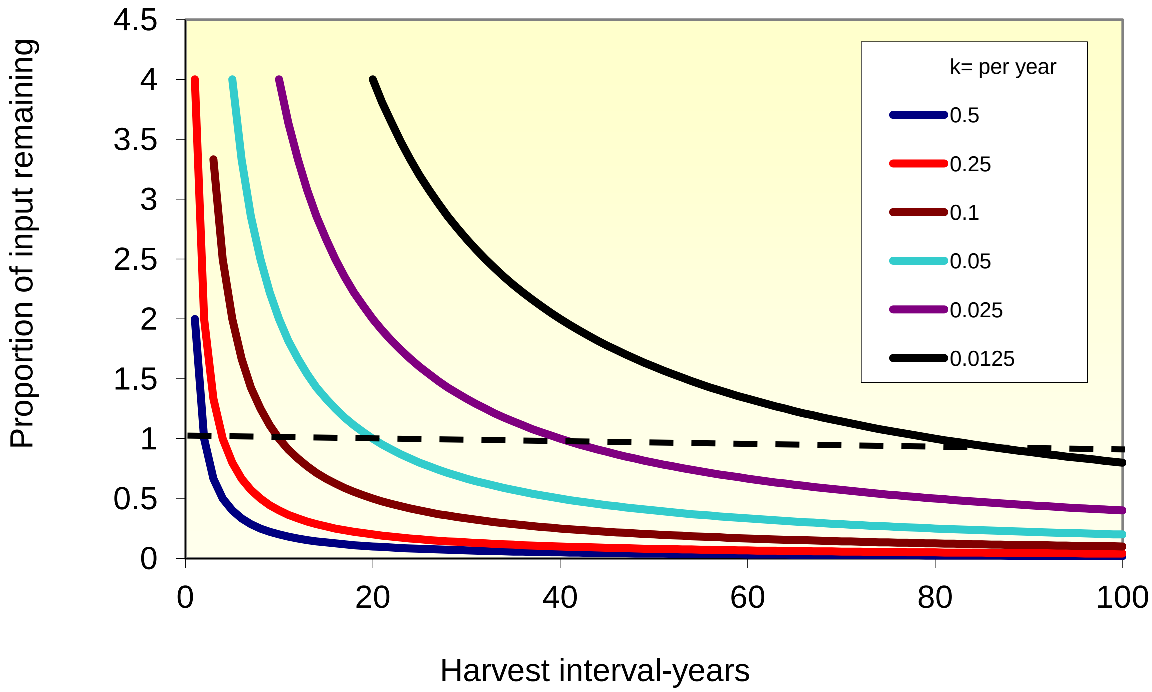

Figure 3: Landscape average store of residue/slash as function of k and harvest interval.

Appendix C: Carbon Debts, Gains and Balances Over Time in a Forest Landscape

To determine whether a harvest system creates a carbon debt or alternatively a gain it is appropriate to examine this problem at the landscape-level (or in the context of biogenic carbon a fuel-shed basis). At the landscape level there are three possible cases: 1) a relatively constant, steady-state store of carbon if the harvest system is continued unchanged, 2) an increase of carbon stores to a higher steady-state if the intensity of harvest declines, and 3) a decrease of carbon stores to a higher steady-state if the intensity of harvest increases. These cases are illustrated in Figures 1-3 which are based on the online Forest Sector Carbon Calculator used in the landscape mode (http://landcarb.forestry.oregonstate.edu/default.aspx) .

In Figure 1 a 50 year clear-cut harvest rotation was practiced until 2010 and then continued for 500 years. This resulted in no carbon debt. If tracked at the stand scale one would see carbon levels rising and falling, but over time the net balance is zero. In contrast, if one converted the 50 year clear-cut harvest rotation system to a 25 year clear-cut harvest rotation system as in Figure 2 there would have been a decline in carbon stores in the ecosystem. This decline would be considered a carbon debt and while not permanent (i.e., forever), it would remain as long as the 25 year management system persists. If the 50 year clear-cut harvest rotation was replaced by a 100 year clear-cut system at year 2010, then there would have been a gain carbon stores (Figure 3). That gain would remain as long as that 100 year clear-cut system of management was maintained. All these simulations all assumed that soil productivity is maintained regardless of harvest interval.

At the landscape level, as opposed to the stand-level, live, dead, and soil stores all acted the same. Each of these pools either remained in balance (i.e., no net gain) or could increase or decrease depending on how the interval of harvest changes. The steady-state store of all three pools is controlled by the I/k relationship developed by Olson (1963). I is the input of carbon to the pools whereas k is the proportion lost from the system in respiration and harvest (the live also has a loss related to mortality of trees). As the harvest interval decreases the input to the pool (I) decreases and the proportion lost via harvest (k) increases. This explains why the ecosystem stores decrease when the harvest interval is shortened and why they increase when the harvest interval is increased. A similar response happens when one takes a larger share of the carbon stores away when there is a harvest.

These dynamics have several important implications that need to be considered in the context of biogenic carbon: 1) long-term carbon debts, gains, and balances are best examined at the landscape-level, 2) all forest carbon pools can exhibit either debts, gains, or remain relatively constant, 3) most systems of management will reach a steady-state if maintained over a long enough period and this steady-state can be maintained as long as the management system is continued, and 4) ultimately reaching a steady-state does not determine if there has been a loss or gain in carbon as this depends on how harvest management changes from one steady-state to the next.

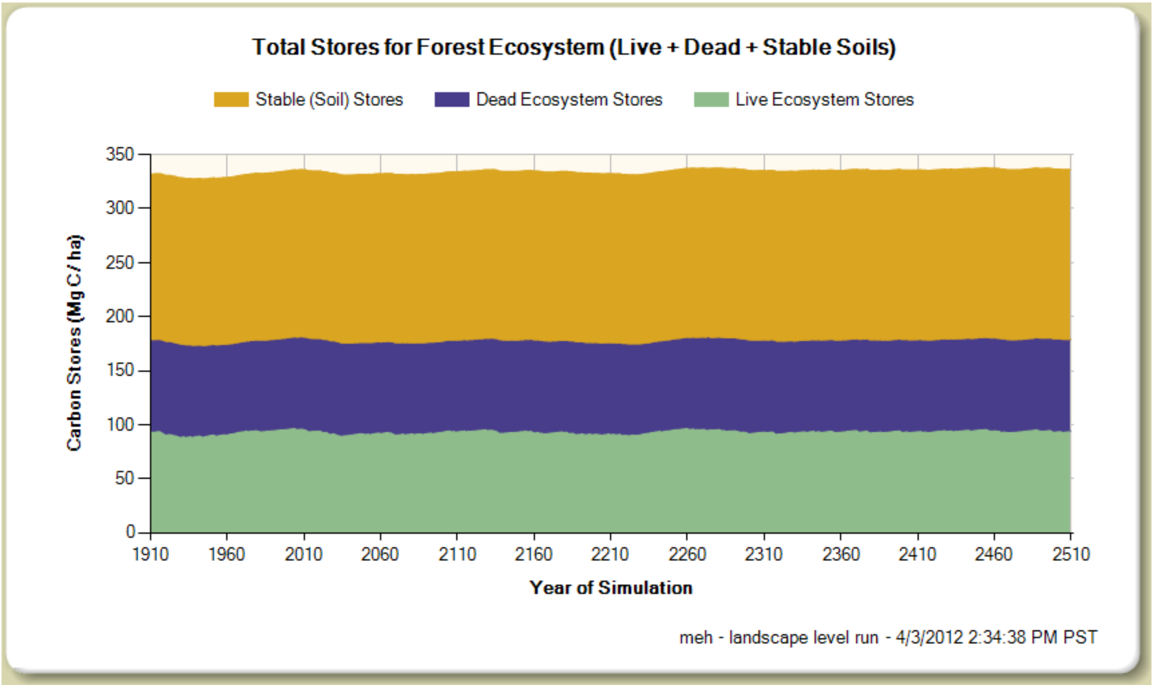

Figure 4: Changes in carbon stores of major forest ecosystem pools when a 50 year clear-cut harvest system is established and continued. The result is a continued carbon balance.

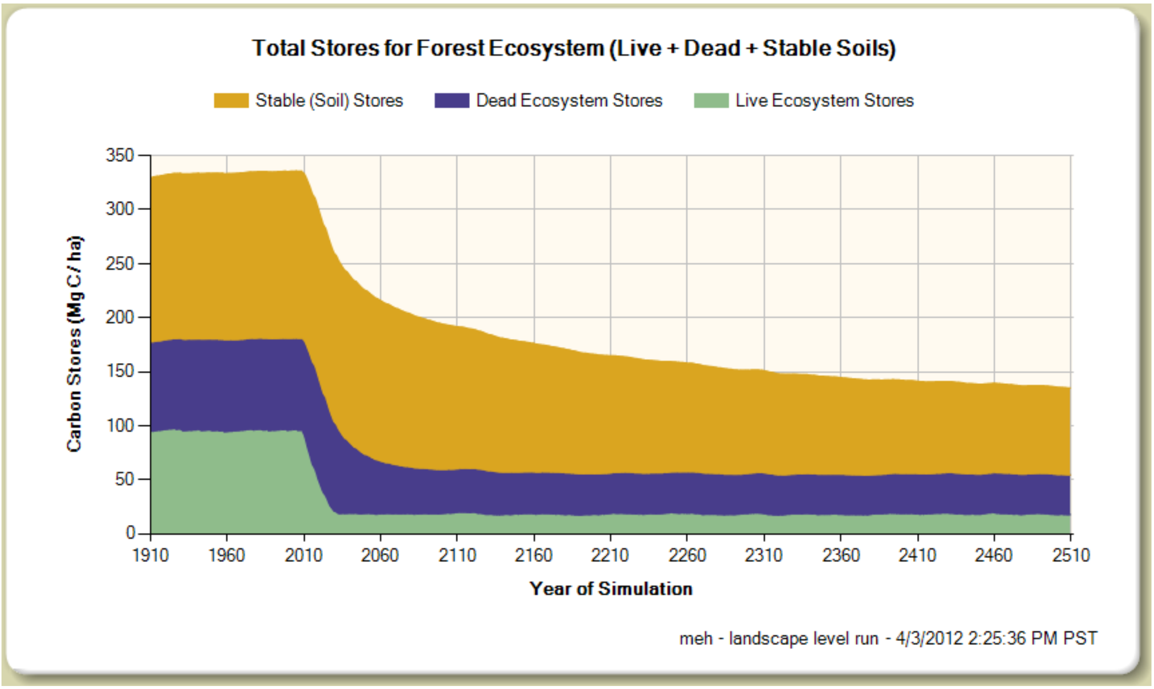

Figure 5: Changes in carbon stores of major forest ecosystem pools when a 50 year clear-cut harvest system is replaced by a 25 year clear-cut harvest system in 2010. The result is a carbon debt.

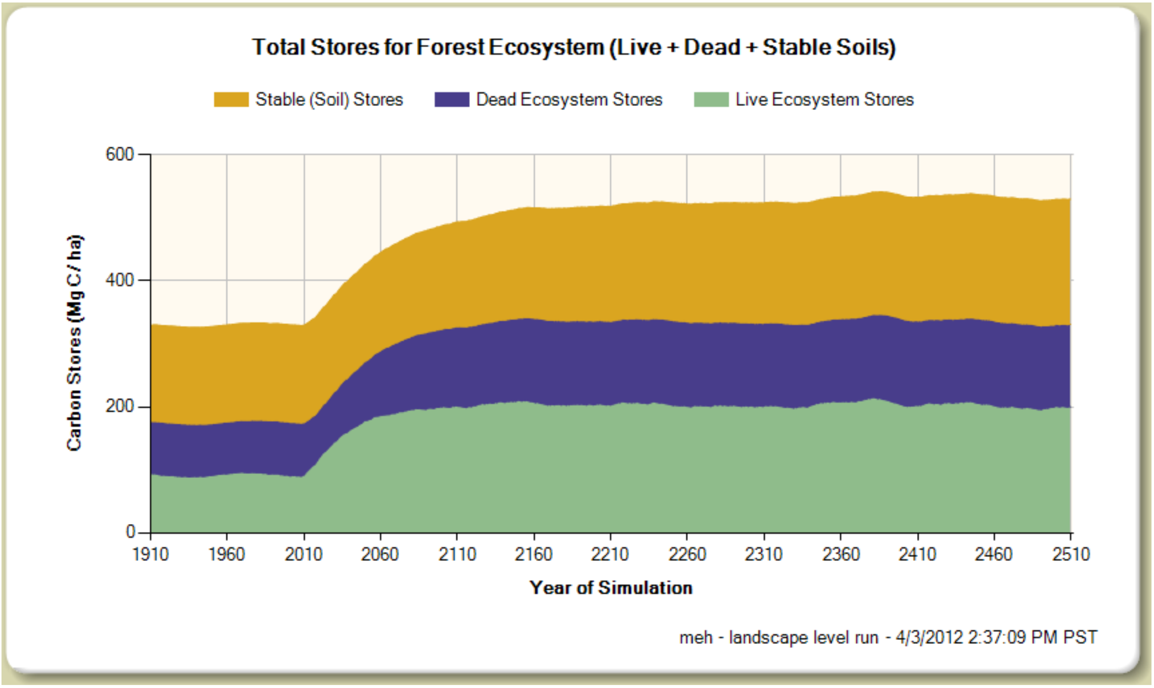

Figure 6: Changes in carbon stores of major forest ecosystem pools when a 50 year clear-cut harvest system is replaced by a 100 year clear-cut harvest system in 2010. The result is a carbon gain.