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 biological material based on the induced changes in carbon stocks on land (in soils, plants and forests). A panel of experts was formed under the auspices of the SAB to conduct the review. Advice is provided through the chartered SAB. The panel, comprised of experts in forestry, agriculture, greenhouse gas measurement and inventories, land use economics, ecology, climate change and engineering met in a face-to-face meeting and held four teleconferences.

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 whether thresholds for regulation have been met. 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. For instance, forest-derived woody biomass has a much longer rotation period than agricultural feedstocks. The *Framework* includes most of the elements that would be needed to gauge changes in CO_2 emissions; however, the reference year approach employed does not provide an estimate of the additional emissions and the sequestration changes in response to biomass feedstock demand. Estimating additionality is essential, as it is the crux of the question at hand. To do so requires an anticipated baseline approach. 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 estimate carbon cycle changes associated with the biogenic feedstock. In addition, an anticipated baseline would be needed to estimate additional changes in soil carbon stock over time. In general the *Framework* should provide a means to estimate the effect of stationary source biogenic feedstock demand, on the atmosphere over time.

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 capture market and landscape level effects, specifically the complex interaction between electricity generating facilities and forestry markets; market driven shifts in planting, management and harvests; induced displacement of existing uses of biomass; land use changes; and the relative contribution of different feedstock source categories (logging residue, pulpwood or roundwood harvest). A landscape, versus stand or plot, perspective is important because simultaneous management decisions may affect net carbon emissions over time.

For agricultural feedstocks, the variables in the *Framework* capture most of the factors necessary for estimating the carbon change associated with the feedstock use, 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 accumulation occurs within one to a few years, the *Framework* can, with some adjustments to address estimation problems (including an anticipated baseline for soil carbon changes) and careful consideration of data and implementation, represent direct carbon changes in a particular region. As recognized by the Agency, for many waste feedstocks (municipal solid waste, construction and demolition waste, industrial wastes, manure, tire-derived wastes and wastewater), 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 left on site, or subject to open burning) could be incorporated to improve scientific accuracy.

The *Framework* does not discuss the different time scales inherent in the carbon cycle nor does it characterize potential intertemporal tradeoffs associated with the use of biogenic feedstocks. However it is important that intertemporal tradeoffs be made transparent for policymakers. For forest-derived roundwood, carbon debts and credits can be created in the short run with increased harvesting and planting respectively but in the long run, net climate benefits can accrue with net forest growth. While it is clear that the Agency can only regulate emissions, its policy choices about regulating emissions will be better informed with consideration of the temporal distribution of biogenic emissions and associated carbon sequestration or avoided emissions.

Overall, the SAB found that quantification of most components of the *Framework* has uncertainties, technical difficulties, data deficiencies and implementation challenges. These issues received little attention in the *Framework*, but are important considerations relevant to scientific integrity and operational efficiency. Moreover, the Agency should consider consistency between biogenic carbon accounting and fossil fuel emissions accounting. Ideally both fossil fuels and biogenic feedstocks should be subject to the same emissions accounting. While there are no easy answers to accounting for the greenhouse gas implications of bioenergy, further consideration of the issues raised by the SAB and revisions to the *Framework* could result in more scientific rigor in accounting for biogenic emissions. A dissenting opinion, offered in Appendix E, recommends that the Agency abandon the *Framework* altogether and instead choose to exempt biogenic CO_2 emissions from greenhouse gas regulation so long as aggregate measures of land-based carbon stocks are steady or increasing.

Given the challenges associated with improving and implementing the *Framework*, the SAB encourages EPA to consider developing default BAFs by feedstock category and region. Under EPA's *Framework*, facility-specific BAFs would be calculated to reflect the incremental carbon cycle and net emissions effects of a facility's use of a biogenic feedstock. With default BAFs, biogenic emissions from a facility would be based on the weighted combination of default BAFs relevant to a facility's feedstock consumption and location. The defaults might vary by region, prior land use and current land management practices due to the differences these might cause in the interaction between feedstock production and the carbon cycle. They are likely to be more scientifically robust in that they could rely on readily available data. The defaults would also have administrative advantages in that they would be easier to implement and update. Facilities could also be given the option of demonstrating a lower BAF for their feedstocks.

The SAB acknowledges that practical considerations will weigh heavily in the Agency's calculus. In fact, any method that might be adopted or considered, including methods proposed by the SAB, should be subject to an evaluation of the costs of compliance and the carbon emissions savings likely to be achieved as compared to both a categorical inclusion and a categorical exclusion. Uncertainties in the assessment of both the costs and the emissions savings should be analyzed and used to inform the choice of policy.

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

Sincerely,

Enclosure

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Acronyms and Abbreviations

AVOIDEMIT	Avoided Emissions
BAF	Biogenic Accounting Factor
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
DOE	Department of Energy
EPA	Environmental Protection Agency
FASOM	Forestry and Agricultural Sector Optimization Model
GHG	Greenhouse gases
GROW	Growth
GtC/y	Gigatons of carbon per year
GTMM	Global Timber Market Model
GTP	Global Temperature Potential
GWP	Global Warming Potential
GWPbio	Global Warming Potential of biomass
I	Carbon Input
K	Proportion of Carbon Lost per unit of time
LAR	Level of Atmospheric Reduction
LEAK	Leakage
N_20	Nitrous Oxide
NSR	New Source Review
PRODC	Carbon in Products
PSD	Prevention of Significant Deterioration
RPA	Resources Planning Act
SAB	Science Advisory Board
SEQP	Sequestered Fraction
SITE_TNC	Total Net Change in Site Emissions
SRTS	Sub-regional Timber Supply Model
USDA	United States Department of Agriculture

1. EXECUTIVE SUMMARY

Biogenic CO_2 emissions from bioenergy are generated during the combustion or decomposition of biologically-based material. Biogenic feedstocks differ from fossil fuels in that they may be replenished in a continuous cycle of planting, harvesting and regrowth. The same plants that provide combustable feedstocks for electricity generation also sequester carbon from the atmosphere. 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. Biogenic CO_2 is emitted from stationary sources through a variety of energy-related and industrial processes. Thus, the use of biogenic feedstocks results in both carbon emissions and carbon sequestration.

EPA's *Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources (Framework, September 2011)* explores 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 bioenergy based on the induced changes in carbon stocks on land (in soils, plants and forests). The context for the *Framework* is the treatment of biogenic CO_2 emissions in stationary source regulation given the unique feature of plant biomass in providing uptake of carbon dioxide (CO_2) from the atmosphere during the photosynthesis. 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. Since greenhouse gases are included in the definition of a "regulated NSR pollutant," EPA has to make a determination about whether a source meets the "applicability threshold" to trigger permitting requirements. As of January 2011, for facilities already covered by the PSD or Title V programs, greenhouse gas emission increases of 75,000 tons per year (tpy) or more, on a carbon dioxide equivalent (CO_2e) basis, would be subject to technology requirements under the PSD program. As of July 1, 2011, more facilities became subject to regulation based on their greenhouse gas emissions. Specifically new and existing stationary sources (that are not already covered by the PSD or Title V programs) that emit greenhouse gas emissions of at least 100,000 tpy became subject to greenhouse gas regulation even if they do not exceed the permitting thresholds for any other pollutant. 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. The SAB's consensus advice is highlighted in this Executive Summary with more details in the attached report. A dissenting opinion is found in Attachment E.

Categorical inclusion or exclusion

In approaching these questions, EPA considered whether it could a priori categorically include or exclude biogenic emissions in its greenhouse gas accounting. Thus, before doing its own analysis, EPA considered whether it could make a categorical determination. A categorical inclusion would count all biogenic carbon emissions at the combustion source, similar to fossil fuel emissions while a categorical exclusion would exempt biogenic carbon emissions from greenhouse gas regulation. The Agency rejected both extremes and asked the SAB whether it supported their conclusion that a priori categorical approaches are inappropriate for the treatment of biogenic carbon emissions.

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 regulatory complexities 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. Of course, biogenic feedstocks that displace fossil fuels 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 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 dissenting opinion in Attachment E offers support for a categorical exclusion so long as aggregate measures of land-based carbon stocks are steady or expanding.

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) would be used to adjust 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 EPA'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.

To accurately capture the carbon outcome, an anticipated baseline approach is needed, and a landscape level perspective. An anticipated baseline 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. As a result, the *Framework* fails to capture the causal connection between forest biomass growth and harvesting and atmospheric impacts and thus may incorrectly assess net CO_2 emissions of a facility’s use of a biogenic feedstock.

A landscape, versus stand or plot, perspective is important because land-management decisions are simultaneous, e.g., harvesting, planting, silvacultural treatments. Thus, there are concurrent carbon stock gains and losses that together define the net implications over time. A landscape level analysis, and BAF calculation, will capture these.

Agricultural and Waste Feedstocks

For faster growing biomass like agricultural crops, the anticipated future baseline approach is still necessary to reflect changes in dynamic processes, e.g., soil carbon, “anyway” emissions, and landscape changes. For agricultural feedstocks in general, 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. In addition to the anticipated baseline, a noticeable omission is the absence of consideration of nitrous oxide (N_2O) emissions from fertilizer use, potentially a major onsite greenhouse gas loss that could be induced by a growing bioenergy market.

For short rotation feedstocks where carbon accumulation 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 to address estimation problems (including an anticipated baseline for soil carbon changes, residue disposition and land management) and careful consideration of data and implementation, accurately represent direct carbon changes in a particular region. For logging residues and other feedstocks that decay over longer periods, 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. This time path should consider the alternative fate of these residues, which in some cases may involve removal and burning to reduce risks of fire or maintain forest health.

For waste materials (municipal solid waste), the *Framework* should consider the alternate disposition of waste material (what would happen if not used as feedstock) in an anticipated baseline (counterfactual) framework. This anticipated baseline should include 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 generate 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. It will also differ by feedstock and location. 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. In some cases even net directionality may be hard to establish. In cases where prior research has indicated directionality, if not magnitude, such information should be used to explore supplementary policy approaches to prevent positive leakage at the source or to control it where it occurs. In addition, the Agency should be alert to leakage that may occur in other media (e.g., fertilizer runoff into waterways) and the need for targeted policies to prevent or abate it. However, consistency with the treatment of fossil fuels is something to consider (discussed below).

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. Nor does it consider temporal differences of climate effects on the environment. Some recent studies have shown some intertemporal tradeoffs that should be highlighted for policymakers. In the short/medium run, at the stand level, there can be a lag time between emissions (through combustion) and sequestration (through regrowth) with the use of forest biomass. At the landscape level, there can be concurrent debts and credits with harvesting and planting. The impacts of the temporal pattern on climate response depend on the framework used. Some modeling exercises have shown that the probability of limiting warming to or below 2°C in the twenty-first century is dependent upon cumulative emissions by 2050 (Meinshausen et al. 2009). This suggests that an early phase of elevated emissions from forest biomass could reduce the odds of limiting climate warming if warming is limited to 2°C. Other modeling exercises by the same research team have shown that in long run scenarios (100 years or more) in which total emissions were fixed, climate response is relatively insensitive to the emissions pathway (Allen et al. 2009). Other studies have shown that 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; Cherubini et al. 2012). This suggests that 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 accumulation of live plant, dead matter, and soil carbon should not be assumed to occur automatically or be permanent; rather growth and accumulation should be monitored and evaluated for changes resulting from management, market forces or natural causes.

If the climate effect of biogenic feedstocks is explored, the degree to which biogenic feedstocks curtails fossil fuel use should be assessed and quantified. Given the slow response of the carbon and climate system, if biogenic feedstocks displace the use of fossil fuels for longer than 100 years, then there may be a beneficial climate effect. In contrast, if the use of biogenic feedstocks does not displace fossil fuels, then any presumed beneficial climate consequences of biogenic carbon may be overestimated.

Spatial Scale

The use of unspecified “regions” as fuelsheds in combination with a reference year baseline is a central weakness of the *Framework* with respect to forest-derived feedstocks. The EPA 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.

Implementation details

The EPA's *Framework* was lacking in implementation details. Implementation is crucial and some of the Agency's current proposals will be difficult to implement. Data availability and quality, as well as procedural details (e.g., application process, calculation frequency) are important considerations for assessing the feasibility of implementation and scientific accuracy of results.

Consistency with fossil fuel emissions accounting

For comparability, there should be consistency between fossil fuel and biogenic emissions accounting. Fossil fuel feedstock emissions accounting from stationary sources under the Clean Air Act are not adjusted for offsite greenhouse gas emissions and carbon stock changes. Unlike fossil fuels, however, biogenic feedstocks have carbon sequestration that occurs within a relevant timeframe. While EPA's primary goal is to account for this offsetting sequestration, its biogenic emissions accounting should be consistent with emissions accounting for fossil fuels for other emissions accounting categories—including losses, international leakage, and fossil fuel use during feedstock extraction, production and transport. Including some accounting elements for biomass and not for fossil fuels would be a policy decision without the underlying science to support it.

Recommendations for Revising BAF

The Agency faces daunting technical challenges if it wishes to implement the *Framework's* facility-specific BAF approach. If the EPA decides to retain and revise a facility-specific *Framework*, the SAB recommends consideration of the following improvements.

- Develop a separate BAF equation for each feedstock category as broadly categorized by type, region, prior land use and current management practices. Feedstocks could be categorized into short rotation dedicated energy crops, crop residues, forest residues, municipal solid waste, trees/forests with short accumulation times, trees/forests with long accumulation times and agricultural residue, wood mill residue and pulping liquor.
    - For long-accumulation feedstocks like roundwood, 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 and landscape level effects, 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).
    - For residues, consider alternate fates (e.g., some forest residues may be burned if not used for bioenergy) and information about decay. An appropriate analysis using decay functions would yield information on the storage of ecosystem carbon in forest residues.
    - 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 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, including

avoided methane emissions, 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 or possibly negative BAFs in the case where methane emissions are avoided.

- 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.

Default BAFs

Given the conceptual and scientific deficiencies of the *Framework* described above, and the prospective difficulties with implementation, the SAB recommends consideration of default BAFs by feedstock category and region. Under EPA's *Framework*, facilities would use individual BAFs designed to capture the incremental carbon cycle and net emissions effects of their use of a biogenic feedstock. With default BAFs by feedstock category, facilities would use a weighted combination of default BAFs based on their particular bundle of feedstocks. The defaults are likely to be more scientifically robust in that they could rely on readily available data and reflect landscape and aggregate demand effects, including previous land use. Default BAFs might also vary by region and current land management practices due to differences these might cause in the interaction between feedstock production and the carbon cycle. The defaults would also have administrative advantages in that they would be easier to implement and update. Default BAFs for each category of feedstocks would differentiate among feedstocks using general information on their role in the carbon cycle. An anticipated baseline would allow for consideration of prior land use, management, alternate fate (what would happen to the feedstock if not combusted for energy) and regional differences. They would be applied by stationary facilities to determine their quantity of biogenic emissions that would be subject to the EPA's Tailoring Rule. Facilities could also be given the option of demonstrating a lower BAF for the feedstock they are using. This would be facilitated by making the BAF calculation transparent and based on data readily available to facilities. Properly designed, a default BAF approach could provide incentives to facilities to choose feedstocks with the lower greenhouse gas impacts.

The SAB also explored certification systems as a possible way to obviate the need to quantify a specific net change in greenhouse gases associated with a particular stationary facility. Carbon accounting registries have been developed to account for and certify CO_2 emissions reductions and sequestration from changes in forest management. Theoretically, for the EPA's purposes, a certification system could be tailored to account for emissions of a stationary facility after a comprehensive evaluation. Ultimately, the SAB concluded that it could not recommend certification without further evaluation because such systems could also encounter many of the same data, scientific and implementation problems that bedevil the *Framework*.

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 intended to account for biogenic carbon uptake and release associated with biomass that is combusted for energy purposes. As such, this *Framework* does not consider, nor is it intended to consider, all greenhouse gas emissions associated with the production and use of biomass energy. Comprehensive accounting for both biogenic and fossil fuels would extend through time and space to estimate the long-term impacts on net greenhouse gas emissions. To estimate net impact that can be attributed to bioenergy, the EPA would need to calculate the net change in global emissions over time resulting from increased use of biomass feedstocks as compared to a future without increased use of biogenic feedstocks. To capture this difference, the boundaries of analysis would need to include all factors in the life cycle of the feedstock and its products although computing global emissions changes for individual facilities has its own daunting challenges.

The boundaries imposed by EPA's regulatory authority necessarily restrict its policy choices, however 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 equal marginal costs. Given the Agency's authority under the Clean Air Act, the most cost-effective economy-wide solution is not within its menu of choices. The Agency's regulation of stationary sources does not include other users of biomass (e.g. consumers of ethanol) that also have impacts on the carbon cycle as well as downstream consumers of products produced by these facilities. Note that EPA can only regulate end-of-stack emissions and thus has to design a system that fits within its regulatory authority.

The Agency has taken on a difficult but worthy task and forced important questions. Practical considerations will, no doubt, weigh heavily in the Agency's calculus. In fact, any method that might be adopted or considered, including methods proposed by the SAB, should be subject to an evaluation of the costs of compliance and the carbon emissions savings likely to be achieved as compared to both a categorical inclusion and a categorical exclusion. Uncertainties in the assessment of both the costs and the emissions savings should be analyzed and used to inform the choice of policy. 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.

2. INTRODUCTION

Greenhouse gas (GHG) emissions from the largest stationary sources became subject to regulation under the Prevention of Significant Deterioration (PSD) and Title V Operating Permit Programs of the Clean Air Act in January 2011. To target these regulations, EPA enumerated specific conditions under which these Clean Air Act permitting requirements would apply. Initially, only sources currently subject to the PSD permitting program or Title V (i.e., those that are newly-constructed or modified in a way that significantly increases emissions of a pollutant other than greenhouse gases) would be subject to permitting requirements for their greenhouse gas emissions. For these projects, only greenhouse gas emission increases of 75,000 tons per year (tpy) or more, on a carbon dioxide equivalent (CO_2e) basis, would be subject to technology requirements under the PSD program. As of July 1, 2011, more facilities became subject to regulation based on their greenhouse gas emissions. Specifically, new and existing stationary sources (that are not already covered by the PSD or Title V programs) that emit greenhouse gas emissions of at least 100,000 tpy are subject to greenhouse gas regulation even if they do not exceed the permitting thresholds for any other pollutant. For these facilities, the PSD and Title V requirements would be triggered. The PSD program imposes "best available control technology" requirements to control greenhouse gas emissions. Title V generally does not impose technology requirements but rather requires covered facilities to report an overall compliance plan for meeting the requirements of the Clean Air Act.

EPA's staged-approach to regulating greenhouse gases from stationary sources sought to focus on the nation's largest greenhouse gas emitters and hence "tailored" the requirements of these Clean Air Act permitting programs to cover power plants, refineries, and cement production facilities that meet certain conditions while exempting smaller sources like farms, restaurants, schools and other facilities. The question before the agency, and hence, the motivation for this SAB review, is whether and how to consider biogenic greenhouse gas emissions in determining whether facilities meet certain thresholds (as defined above) for Clean Air Act permitting. Biogenic CO_2 emissions from bioenergy are generated during the combustion or decomposition of biologically based material.

It is in this context that the EPA Office of Air and Radiation requested the 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). Because of the unique role of biogenic feedstocks in the overall carbon cycle, EPA deferred for a period of three years the application of permitting requirements to biogenic CO_2 emissions from bioenergy and other biogenic stationary sources. In its deferral, EPA committed to conduct a detailed examination of the science and technical issues associated with biogenic CO_2 emissions and submit its study for review by the Science Advisory Board. 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 was asked to review and comment on (1) the agency's characterization of the science and technical issues relevant to accounting for biogenic CO_2 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 CO_2 emissions (See Appendix A: Charge to the SAB Panel).

The Biogenic Carbon Emissions Panel held a face-to-face meeting in October 25 – 27, 2011, and teleconferenced four times during 2012. 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 Advisory provides the SAB's main conclusions. Highlights are provided in the Executive Summary and detailed responses to the individual charge questions are provided in the body of the report.

3. RESPONSES TO EPA's CHARGE QUESTIONS

3.1. The Science of Biogenic CO_2 Emissions

Charge Question 1: 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 CO2 accounting.

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, the SAB describes a series of deficiencies with the EPA characterization of the science behind biogenic CO_2 accounting and suggests some areas where the science 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 gigatons per year (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. Excess 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. The importance of the timing of emissions depends on whether one uses a global warming limit or a cumulative emissions limit. Some modeling exercises have shown that the probability of limiting warming to 2 °C or below in the twenty-first century is dependent upon cumulative emissions by 2050 (Meinshausen et al. 2009). This suggests that an early phase of elevated emissions from forest biomass could reduce the odds of limiting climate warming if warming is limited to 2 °C. Another 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 as long as cumulative emissions from all sources are constant. 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 even at the landscape level (Mitchell et al. 2012), this may 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 the 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 impacts on the atmosphere are not well discussed or linked. If a carbon stock is cycling quickly on land 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 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.

Appendix B discusses a set of studies by Cherubini and co-authors (Cherubini et al. 2011; 2012) that provide examples for estimating the temporal distribution of atmospheric impacts from biomass harvesting by framing the analysis in terms of global warming potentials (GWPs) and global temperature potentials (GTPs) for harvested biomass. Figure B-1 in Appendix B, adapted from Cherubini et al. (2012), depicts mean surface temperature changes for a simple contrived comparison of biogenic emissions from a single stand over hundreds of years as compared to comparable fossil emissions. While much is assumed regarding global activity (emissions, landscape responses, investment behavior), Figure B-1 demonstrates the importance of the time horizon and the weight to place on temperature increases that occur in the short term versus temperature increases that occur later. As shown in Figure B-1, a 50-year time horizon (or less) 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 increases 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 when choosing a time horizon, 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.

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. Ideally both fossil fuels and biogenic fuels should be subject to the same emissions accounting to fully capture the difference between the two types of fuels in terms of their greenhouse gas emissions. For biogenic feedstocks, the most important source of non-CO_2 emissions is likely to be N_2O produced by the application of fertilizer (Crutzen, et al. 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.

3.2. Biogenic CO_2 Accounting Approaches

Charge Question 2: 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(a). 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(b). 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 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 full implementation difficulties that could accompany any policy on biogenic carbon emissions but some scientific observations that may inform the Administrator's policy decision are offered below.

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 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, the EPA may face difficult tradeoffs between ease of implementation and other goals (e.g., maximizing scientific accuracy by modeling the decomposition of logging residues). While an alternative approach of default Biogenic Accounting Factors (BAFs) is offered for the agency's consideration (see Section 4), the SAB cannot advise the Agencyon the legal feasibility of any approach.

2(c). 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 Panel at the public meeting, the EPA agreed that this question is redundant with other charge questions and therefore does not require a separate response.

2(d). 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 also is 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.

3.3. Methodological Issues

Charge Question 3: 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(a). 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. The *Framework* includes 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 SAB concurs with the *Framework* that 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. In addition, given that methane (CH_4) is a more potent greenhouse gas than CO_2, the *Framework* should account for CH_4 emissions from landfills in cases where the methane is not captured. The SAB recognizes that EPA may address methane in other regulatory contexts.

When accounting for emissions from waste sources including logging residue, wood mill waste and pulping liquor, the EPA should recognize that these emissions are part of a larger system where they can be co-products with commercial products. For logging residue, wood mill waste and pulping liquor the larger system includes forests, solid wood mills, pulp mills and stationary energy sources. Accounting for greenhouse gases in the larger system needs to track all biomass emissions or forest stock changes and needs to assure they are allocated over time across the outputs (product and co-products) from the system so as to account for all fluxes. Within the larger system, the allocation of fluxes to wood/paper products or to emissions from a stationary source can be supported by scientific reasoning but is ultimately a policy decision. The Agency should consider how the *Framework* meets the scientific requirement to account for (allocate) all emissions to products and co-products across the larger system of forest, mills and stationary sources over time.

For roundwood, the calculation of BAF would need to account for the time path of carbon accumulation and emissions from logging residue and apply a landscape perspective. The landscape perspective is important because of simultaneous management decisions that emit and sequester greenhouse gases concurrently and therefore define the net implications over time. The *Framework* recognizes some of the challenges associated with defining the spatial and temporal time scale and in choosing the appropriate baseline. Ultimately, however, the *Framework* chooses an approach that disregards any consideration of the time scales over which biogenic carbon stocks are accumulated or depleted and does not actually estimate carbon stock changes associated with biomass use. Instead the *Framework* attempts to substitute a spatial dimension for time 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.

<u>Level of Atmospheric Reduction (LAR)</u>: 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.

<u>Loss (L)</u>: This term is included in the *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 *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., 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 of carbon released, one would need to track the stores as well as the fluxes associated with product 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 prorating 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 be a convenient assumption, it should be explained and justified. To improve scientific accuracy, the EPA could explore some sample calculations (as described below), taking into account regional differences in decay rates. Once this information is gathered and analyzed, the 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 in both forest and agricultural systems. 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 C 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 ecosystem 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 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 input because a higher proportion of the forest or agricultural system is contributing inputs. For example, if there is 1 unit of residue/slash generation per harvest, then an annual harvest on a system 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 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, then the forest system 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 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 subtract 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.

<u>Total Net Change in Site Emissions (SITE_TNC)</u>: This term 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 SITE_TNC 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(f), 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.

<u>Sequestration (SEQP)</u>: 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 (LEAK): The *Framework* includes this term for leakage but is silent on the types of leakage that would be included and how leakage would be measured. EPA representatives said the *Framework* did not provide 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 or increase carbon stored in soils and vegetation. The use of these feedstocks could 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 and Khanna 2012). Leakage effects will vary by feedstock and location and 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 3.4 [in response to question 4(f)], the latter could arise, for example, if increased demand for biomass and higher prices generate 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 and 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 increase 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 example, 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, assessing 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). Existing models would need to be expanded to include the multiple lignocellulosic 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). Other feedstock-use combinations would also need to be evaluated. If the magnitude of leakage is plagued with too much uncertainty, if possible, its direction should at least be stated and recognized in making policy choices. Depending on the level of uncertainty, supplementary policies might be possible 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 3.4.

3(b). 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 an accounting approach. In fact, the lack of information on EPA's policy context and the 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, including how the Agency regulates point sources for greenhouse gases and other pollutants. The document should make 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. The *Framework* also should describe the EPA's 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 the 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* would need 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 equal marginal costs. 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 the 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 also have equivalent impacts on the carbon cycle as well as downstream emissions from consuming the products produced by these facilities. Note that biogenic emissions accounting would still be an issue even under an economy-wide emissions policy.

3(c). 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. However, an anticipated baseline is needed for soil carbon, residue disposition and land management changes. For forest biomass, the *Framework* needs to incorporate the time path of carbon accumulation in forests (after energy emissions from harvested roundwood) and forest investment and multi-stand decisions. 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* states, 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(d). 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 biomass is decomposed or carbon is 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.

3.4. 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.

Question 4(a). 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 accumulation feedstocks, where carbon accumulation 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 to address estimation problems (including an anticipated baseline for soil carbon changes, residue disposition and land management) and careful consideration of data and implementation, the *Framework* can accurately represent carbon changes offsite. However, for long accumulation feedstocks where carbon accumulation and "anyway" emissions occur over decades [i.e., wood harvested specifically for energy use (roundwood) and logging residue], the *Framework* does not accurately account for changes in carbon stocks offsite for several reasons discussed below in response to charge question 4(b).

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_2e the atmosphere sees." In addition, excluding CH_4 emissions 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.

Question 4(b). Is the Framework scientifically rigorous?

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

Time scale: As discussed previously, one deficiency in the *Framework* is the lack of 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 growth across the landscape 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 as well as the spatial simultaneous decisions made across stands and plots. 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 *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 the 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 uses regional landscape wide carbon changes but does not actually estimate changes attributable to biomass demand (see next discussion). This approach attempts to simplify implementation using available forest inventory data and circumvents the need for accounting for changes in carbon stocks specific to the site or feedstock sourcing region (fuelshed) which may be more complex, costly and difficult to verify. However, as noted, it doesn't provide an actual estimate of carbon changes due to stationary source biomass demand, and 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 a 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 increased harvesting of biomass for bioenergy 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 a particular 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 increased harvesting of biomass. Similarly, a region with increasing carbon stocks may have less stores carbon than would be the case 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 under the *Framework*, 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. To estimate the “difference in atmospheric greenhouse gases” over some period, one must estimate how carbon accumulation 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. Selecting an acceptable risk level is a policy decision but characterizing uncertainty and risks is a scientific question. 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, the EPA should put its 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. 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) Consistency with fossil fuel emissions accounting: Fossil fuel feedstock emissions accounting from stationary sources under the Clean Air Act are not adjusted for offsite GREENHOUSE GAS emissions and carbon stock changes. Does that imply that by default BAFs should be zero as well? No, because, unlike fossil fuels, biogenic feedstocks have carbon sequestration that occurs within a timeframe relevant for offsetting CO_2 emissions from the biomass' combustion. For comparability, however, biomass and fossil fuels emissions accounting should be similar for other emissions categories. These include non-CO_2 GREENHOUSE GAS emissions, losses, leakage, and fossil fuel use during feedstock extraction, production and transport. This issue is also discussed in Section 3.3.1.

(2) 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?

(3) 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 N_2O 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.

(4) 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.

(5) Definition of soil. There is a good deal of variation in the *Framework* as to the definition of "soil." 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. In other places, the *Framework* seems only to 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 definitions of soil carbon mean 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 et al. 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.

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 the 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 et al. 1985; Nave et al. 2010; Richter et al. 1999; Sanchez et al. 2007; Schiffman and Johnson 1989; Selig et al. 2008; Tang et al. 2005; Tolbert et al. 2000).

Question 4(c). Does the Framework 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 the sections 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. In one of the case studies, for example, the Century model is used to model soil carbon 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 suggested or discussed. 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.

Question 4(d). Is it easily updated as new data become available?

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, could be used 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.

The *Framework* uses an annual or five-year interval for updating calculations. For some kinds of data, such as soil and forest carbon stocks, this interval is too short to detect significant changes based on current or feasible data collection methodologies. This implies 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, frequent calculation of the BAF would introduce considerable uncertainty for the facility. 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, the EPA will have to weigh tradeoffs between the accuracy of greenhouse gas accounting and ease of implementation and other transactions costs.

Question 4(e). 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/accumulation 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 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 may be misunderstood. Lastly, many elements of the *Framework* are implicit rather than explicit. For example, the time frame during which changes in atmospheric greenhouse gases will be assessed 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.

Question 4(f). 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(b), 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 on greenhouse gas emissions over time of feedstock use. 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 for soils, residue, waste disposition and land management.

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, shift species composition, change management intensity 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 et al. 1996; Sohngen and Sedjo 1998), which includes anticipatory behavior in response to future forest carbon prices and markets (Sohngen and Sedjo 2006; Rose and Sohngen 2011). The U.S. Energy Information Administration (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 are going to drive forest management decisions, and regional variations in them, 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, in press, 2012). This would be the case if demand is anticipated to increase in the future. Some other modeling studies suggest more limited responses to increased wood energy demand that differ across regions. One such model for the United States 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, landscape 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 decisions incorporate expectations about future prices and market opportunities. 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 not designed for prediction but instead to evaluate potential futures and deviations between futures. 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.

Selection of an appropriate model requires judgment and understanding of the structure and assumptions of alternative models and their strengths and weaknesses. This could be supplemented with one or more approaches to choosing a model. These include validation of existing models at the relevant temporal and spatial scale by a means appropriate to the model type, as well as using more than one model to compare and triangulate outcomes. Note that models of different types (e.g., projections vs. forecasting models) require different types of evaluation.

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 southern United States, 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. The authors 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.

While market effects are important, there is value in making separate estimates of biological land carbon changes alone (without market effects). Specifically, biophysical process response modeling results are a critical input to economic modeling. Ecosystem modeling is not a substitute for economic modeling, which is necessary to estimate behavioral changes driven by biomass feedstock demand that produces the estimates emissions and sequestration changes. Ecosystem modeling would establish carbon storage in the absence of positive or negative leakage and may have lower uncertainty – especially for logging residue – than the estimate with leakage. Appendix D depicts three biological scenarios for the total carbon storage in a forest system, including live, dead, and soil stores of carbon. Graphically, Figure D-2 in Appendix D shows how the storage of carbon in a forest system could respond to a shorter harvest interval. Note that all graphs in Appendix D 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. These carbon responses to management decisions are important inputs for economic modeling of management changes and their carbon consequences. Such modeling could also include the effect of avoided fire emissions on forest land due to biomass removal. This information could indicate what forest conditions and practices could provide higher rates of accumulation, 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 accumulation.

Question 4(g). 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 the EPA is entertaining alternatives and would like the SAB to comment on 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 (and their corresponding LARs) 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 create perverse incentives for landowners. For instance, landowners may be inclined to clear forest land a year or more in advance of growing and using energy crops. Similarly, landowners 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* lacks 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 look-up 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).

3.5. 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 only and may or may not be the appropriate values for an actual biomass-to-energy project. Moreover, the case studies 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. For clarity, it might be useful to start with a specific forestry or agricultural feedstock example as the base case, then add 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 illustrating different pieces of the *Framework*.

Question 5(a). 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 more realistic 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 scenario could be implemented, this particular case study is not realistic because very few 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 uncommon. 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 and measuring changes in soil carbon (which will depend on current use of the land) are not described.

Question 5(b). 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 the 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 4 below, 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.

Question 5(c). 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 realistic situations of biomass development, production, and utilization. For example, Case Study 1 describes the construction of one new plant. What would happen if 10 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 involved parties. 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 emissions 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 the 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.

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.

3.6. 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.

Question 6(a). 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.

Question 6(b). 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 accumulation feedstocks (i.e., agricultural residues, perennial herbaceous crops, mill wood wastes, other wastes), the *Framework* could, with some modifications and careful consideration of data and implementation, 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 and 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 an anticipated baseline and 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 for 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, which attempts to estimate facility-feedstock specific BAFs, 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 the 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 and carbon and methane release through decomposition present a challenge for any accounting system because anticipated future changes in vegetation should, in principle, be factored into BAF. These future changes depend on natural processes such as fires and pest outbreaks that are not easily foreseen, and because of climate change and broader environmental change, we face a system that is hard to predict. Projecting forward based on current or historical patterns is subject to biases of unknown direction and magnitude. More importantly, land use decisions are under the control of landowners, who will be responding to unknown future events. The *Framework* recognizes this issue and chooses to use a Reference Point Baseline, the serious limitations of which have been discussed previously.

Overall, the 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 to offset fossil fuel combustion emissions. Scientifically, a comprehensive greenhouse gas 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 that are sold as livestock feed that ultimately becomes CO_2 (or CH_4). However, doing so would need to consider consistency with fossil fuel emissions accounting and emissions currently regulated (such as by EPA with vehicle greenhouse emissions standards). As for gains from trade, 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. Bioenergy would still need to confront the issue of crediting offset carbon accumulation 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.

Question 6(c). 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 be explained as it relates to Clean Air Act requirements and any recent court rulings. The *Framework* should also make explicit the constraints within which greenhouse gases can be regulated under the Clean Air Act. In doing this, the EPA could be clear that these issues have not been settled but that some assumptions were necessary to make a decision about the *Framework*. The 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 make explicit how it does or does not 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. Though biofuel combustion emissions are already regulated, along with combustion of gasoline, via EPA's vehicle greenhouse gas emissions standards, the 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.

The *Framework* is lacking in implementation details. Implementation is crucial and some of the EPA's current proposals will be difficult to implement. Data availability and quality, as well as procedural details (e.g., application process, calculation frequency) are important considerations for assessing the feasibility of implementation and scientific accuracy of results. Implementation details (e.g., data, technical processes, administrative procedures, timing) need to be laid out, discussed and justified.

Among other things, the discussion should note alternatives, uncertainty and implications via case studies.

Recommendations for Revising BAF

In response to the charge to the SAB, recommendations are offered here for revising the *Framework*. In the next section, the SAB suggests an alternative – default BAFs. If EPA decides to revise the *Framework*, the following recommendations for specific improvements to the document (and methodology) are summarized here. 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, as grown in different regions, on different prior land-use types and with different management practices. 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 as broadly categorized by type, region, prior land use and current management practices. 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 including wood mill residue and pulping liquor.
    - For long-accumulation feedstocks like woody biomass, use an anticipated baseline and landscape 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 uses 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).
    - For residues, consider incorporating information about decay after an appropriate analysis in which storage of ecosystem carbon is calculated based on decay functions.
    - 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. Implementation complexity, cost and scientific accuracy should be considered. For feedstocks that are found to have relatively minor impacts, the 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.

4. DEFAULT BAFs BASED ON FEEDSTOCK CATEGORIES

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 facility-specific BAF approach embodied in the *Framework*, the SAB encourages the EPA to "think outside the box" and look at alternatives to the *Framework* and its implementation as proposed. One promising alternative is default BAFs for each feedstock category. Given the conceptual and scientific deficiencies of the *Framework*, and the prospective difficulties with implementation, the SAB recommends consideration of default BAFs by feedstock type, region, land management and prior land use. Under EPA's *Framework,* facilities would use individual BAFs designed to capture the incremental carbon cycle and net emissions effects of their use of a biogenic feedstock. With default BAFs, facilities would use a weighted combination of default BAFs relevant to their feedstock consumption and location.

The defaults BAFs would rely on readily available data and reflect landscape and aggregate demand effects, including previous land use. The defaults would also have administrative advantages in that they would be easier to implement and update. Default BAFs for each category of feedstocks would differentiate among feedstocks using general information on their role in the carbon cycle. An anticipated baseline would allow for consideration of prior land use, management, alternate fate (what would happen to the feedstock if not combusted for energy) and regional differences. Default BAFs might vary by region, prior land use and current land management practices due to differences these might cause in the interaction between feedstock production and the carbon cycle. They would be applied by stationary facilities to determine their quantity of biogenic emissions that would be subject to the Agency's Tailoring Rule. Case studies should be used to evaluate default BAFs applicability to heterogeneous facilities. Facilities could also be given the option of demonstrating a lower BAF for the feedstock they are using. This would be facilitated by making the BAF calculation transparent and based on data readily available to facilities. Default BAFs should be carefully designed to provide incentives to facilities to choose feedstocks with the lower greenhouse gas impacts.

The SAB also explored certification systems as a possible way to obviate the need to quantify a specific net change in greenhouse gases associated with a particular stationary facility. Carbon accounting registries have been developed to account for and certify CO_2 emissions reductions and sequestration from changes in forest management. Ultimately, however, the SAB concluded that it could not recommend certification without further evaluation. Moreover, such systems could encounter many of the same data, scientific and implementation problems that bedevil the *Framework.*

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APPENDIX A: Charge to the Panel

<u>MEMORANDUM</u>

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.

- 2(a). Does the SAB agree with EPA's concerns about applying the IPCC national approach to biogenic CO2 emissions at individual stationary sources?
- 2(b). 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?
- 2(c). 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?

2(d). Are there additional accounting approaches that could be applied in the context of biogenic CO2 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.

3(a). Does SAB support EPA's conclusions on how these factors should be included in accounting for biogenic CO2 emissions, taking into consideration recent advances and studies relevant to biogenic CO2 accounting?

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

3(c). Are there additional factors that EPA should include in its assessment? If so, please specify those factors.

3(d). 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.

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

4(b). Is it scientifically rigorous?

4(c). Does it utilize existing data sources?

4(d). Is it easily updated as new data become available?

4(e). Is it simple to implement and understand?

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

4(g). 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.

5(a). Does the SAB consider these case studies to be appropriate and realistic?

5(b). Does the EPA provide sufficient information to support how EPA has applied the accounting framework in each case?

5(c). 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.

6(a). Does the report – in total – contribute usefully to the advancement of understanding on accounting for biogenic CO2 emissions from stationary source?

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

6(c). Does the SAB have advice regarding potential revisions to this draft study that might enhance the utility of the final document?

APPENDIX B: Temporal Changes in Stand Level Biogenic Emissions Versus Fossil Emissions

Cherubini et al. (2011) analyzes temperature increases on the basis of GWP (global warming potential) whereas Cherubini et al. (2012) analyzes climate impacts using GTP (global temperature potential). GWP is the time integral of the change in 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 integral of actual temperature response to a pulse emission of CO_2 and subsequent sequestration by biomass growth. Both studies use a simple contrived comparison of biogenic emissions from a single stand over hundreds of years to comparable fossil emissions. Much is assumed regarding for instance global activity and emissions, and climate and carbon cycle dynamics. Also, importantly, landscape responses and investment behavior are not reflected which represent concurrent and related emissions and sequestration that affect net global emissions changes.

Both studies incorporate a suite of carbon uptake mechanisms (such as oceanic uptake) in addition to regrowth in forest stands. 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 accumulation feedstocks, such as perennial grasses, GTPbio would be a very small fraction due to fast carbon accumulation times (ignoring leakage effects). For feedstocks with long accumulation times, one must compute the change in global temperature over time, accounting for the decline in temperature change as carbon is reabsorbed.

Cherubini et al. (2011, 2012) provide an artificial simplified example for a single forest stand. The same type of metric could be used to compare temperature changes or changes in radiative forcing associated with increased biomass energy use for one year or more 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 the cumulative radiative forcing of biogenic feedstocks to the cumulative radiative forcing of fossil fuels over time could also be used, e.g.. Cherubini's GWPbio. However the broader literature should be considered regarding the climate implications of alternative emissions pathways (see charge question 1 response) while considering uncertainty in global emissions, climate response and the carbon cycle.

Figure B-1 demonstrates the importance of the 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 instantaneous temperature change 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 B-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 B-1, adapted from Cherubini et al. (2012).

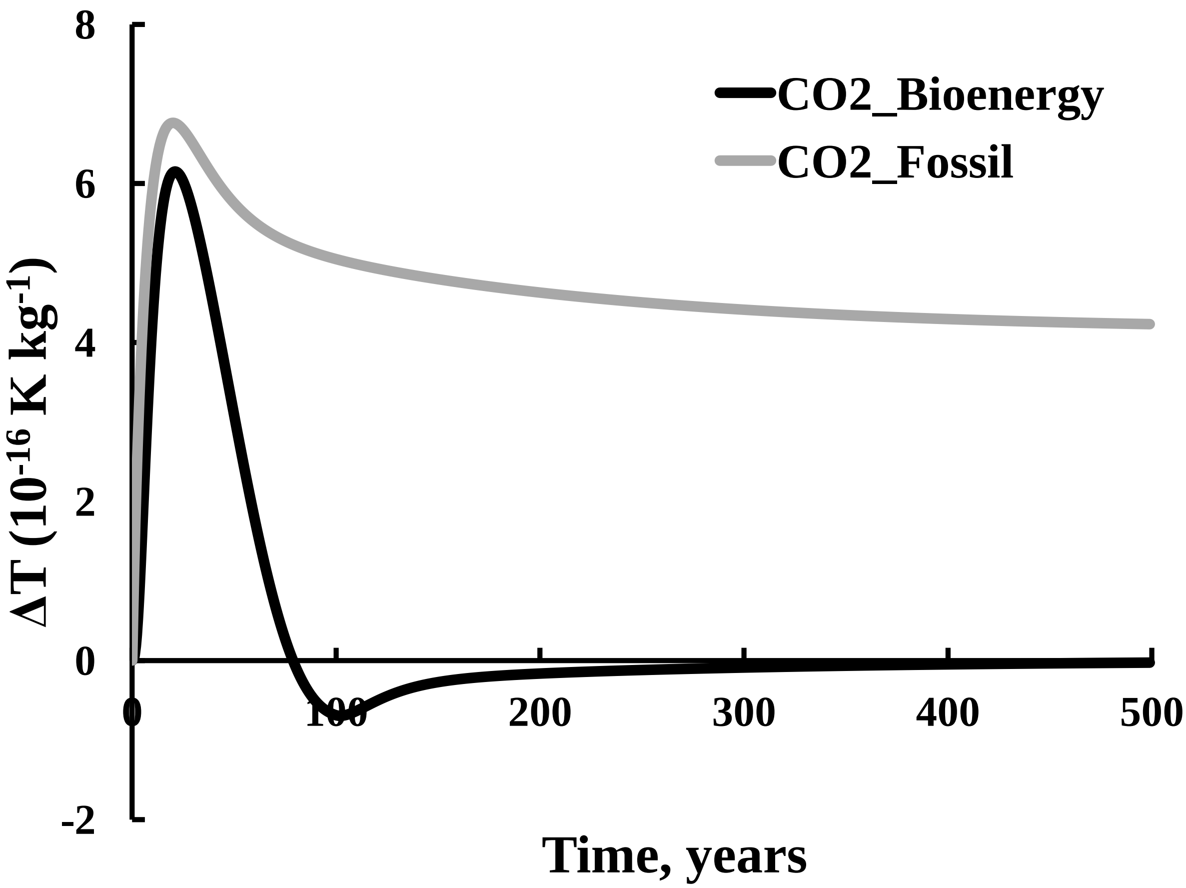

Figure B-1: Surface temperature change from biogenic emissions versus fossil fuel over time. Adapted from Cherubini et al. (2012) and reprinted with copyright permission.

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.

A current practice for international reporting under IPCC guidelines and international treaty negotiations is to use greenhouse gas emissions and sink values that represent the cumulative radiative forcing for greenhouse gases over a 100 year period with uniform weighting over 100 years. Greenhouse gas values are reported in tons CO_2 equivalent where one ton of CO_2 equivalent is an index for the cumulative radiative forcing for a pulse emission of one ton of CO_2 over 100 years. The CO_2 equivalent for a ton of other greenhouse gases is given by how many times more radiative forcing it produces over 100 years compared to CO_2 (e.g., 21 times for CH_4) (EPA 2012).

APPENDIX C: Fate of Landscape Residue after Harvest and System 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 C-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 *Framework*.

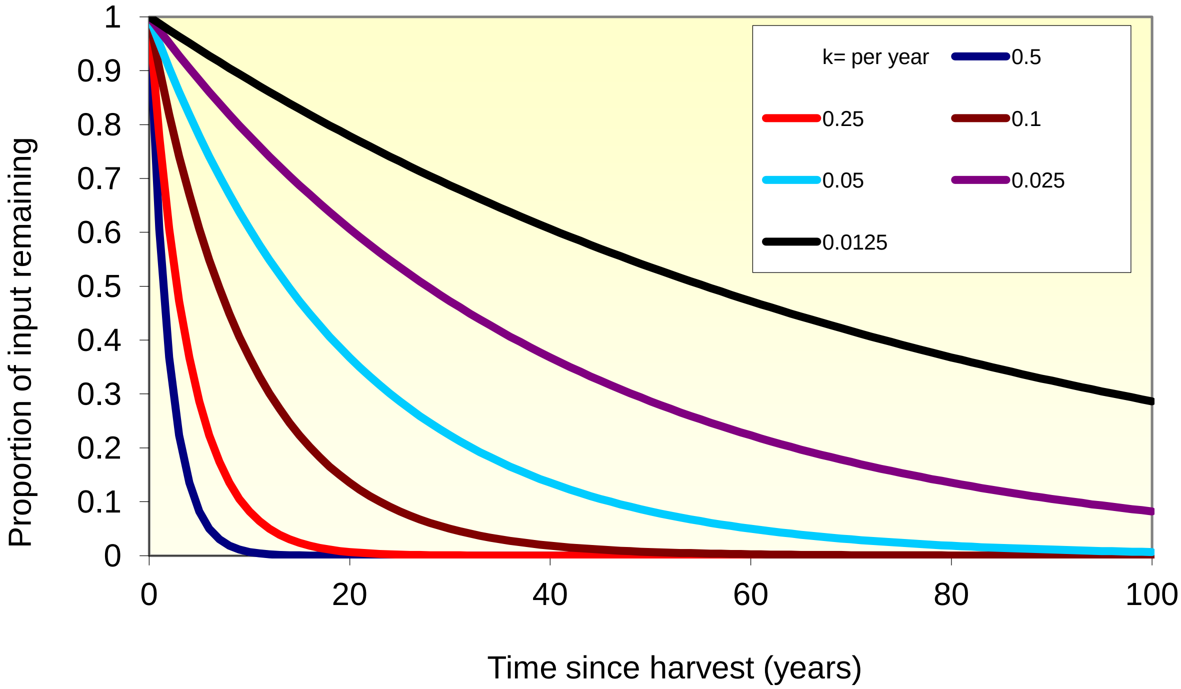

Figure C-1: Fate of residue/slash left after harvest as function of k and time since harvest.

The amount of carbon stored on average in a forest system 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 forest 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 forest 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 store relative to the input is presented in Figure C-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.

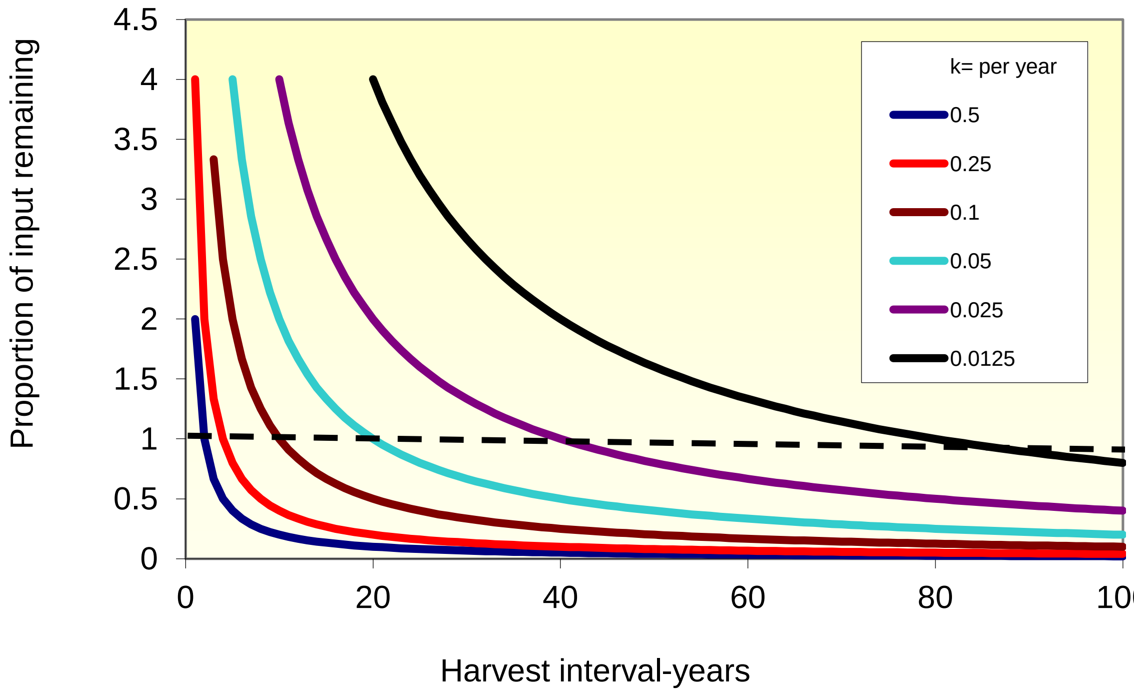

Figure C-2: Landscape average store of residue/slash as function of k and harvest interval.

APPENDIX D: Carbon Balances over Time in an Existing Forest System

To determine whether a forest harvest system for existing forest acreage 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). Note the discussion that follows refers only to existing managed forests (and their stored carbon) and not broader landscape effects such as the expansion or contraction of forest area. At the forest system 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 4-6 which are based on the online Forest Sector Carbon Calculator used in the forest system landscape mode (http://landcarb.forestry.oregonstate.edu/default.aspx) .

In Figure D-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 D-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 D-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 existing forest 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), where *I* is the input of carbon to the pools and *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 forest system-level (not to mention the broader agriculture-forest landscape level), (2) all forest carbon pools can exhibit either debts, gains, or remain relatively constant, (3) most systems of forest 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.

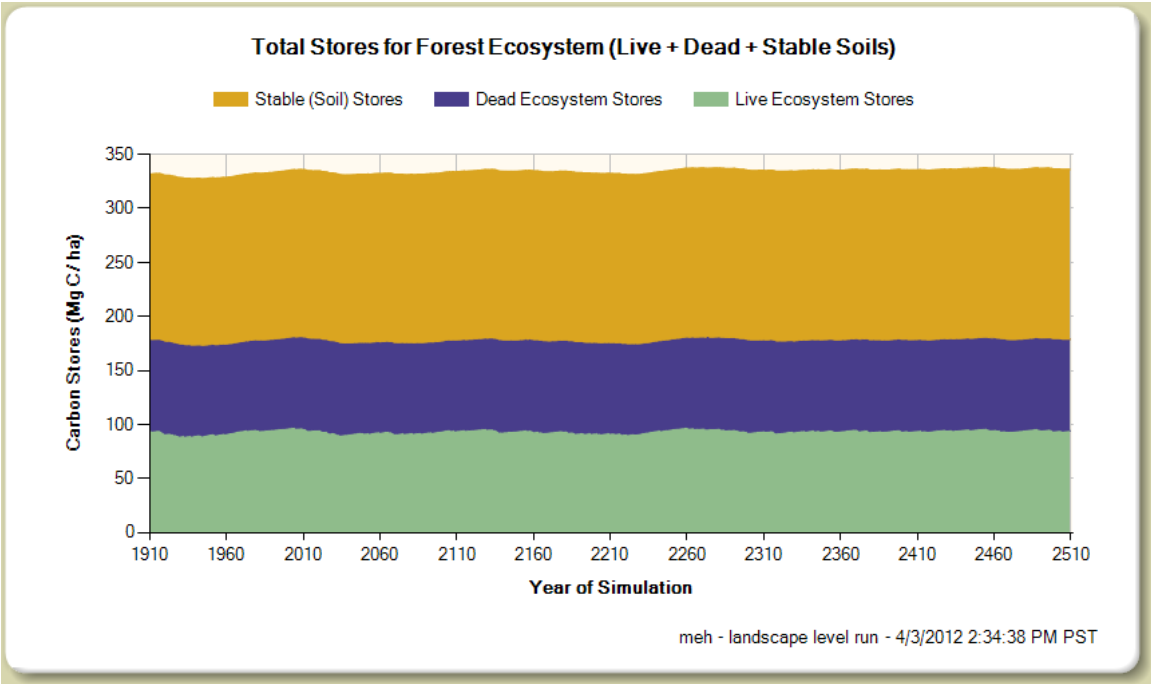

Figure D-1: Changes in carbon stores of major forest ecosystem pools when a 50 year clear-cut harvest system is established and continued. The result is a continued carbon balance.

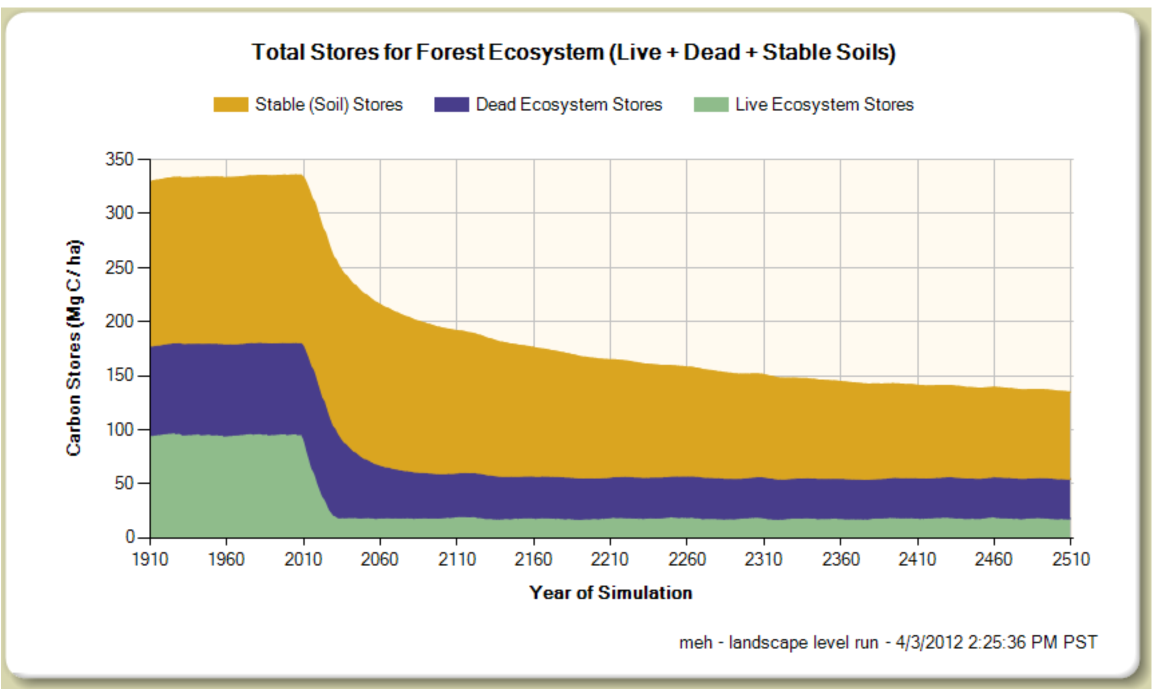

Figure D-2: Changes in carbon stores of major forest ecosystem pools when a 50 year clear-cut harvest system is replaced by a 25 year clear-cut harvest system in 2010. The result is a carbon debt.

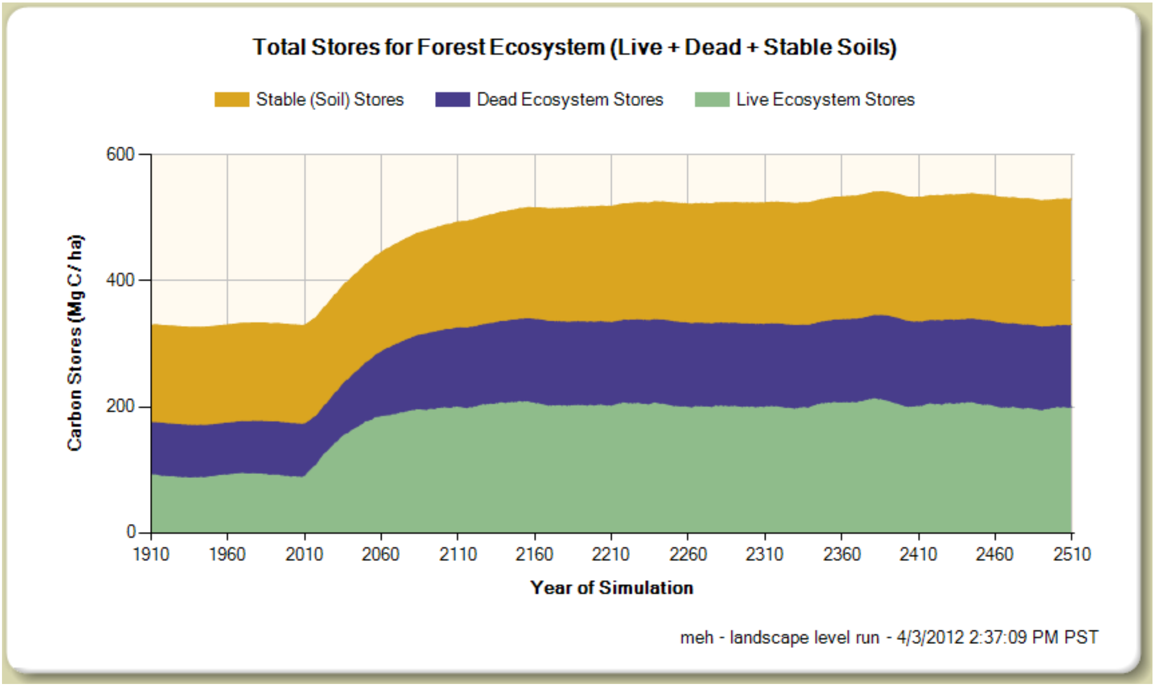

Figure D-3: Changes in carbon stores of major forest ecosystem pools when a 50 year clear-cut harvest system is replaced by a 100 year clear-cut harvest system in 2010. The result is a carbon gain.

APPENDIX E: Dissenting Opinion from Dr. Roger Sedjo

Introduction

EPA's Science Advisory Board (SAB) was asked to review and comment on the EPA's Accounting Framework for Biogenic CO2 Emissions from Stationary Sources (Framework September 2011). The motivation for the Accounting Framework "is whether and how to consider biogenic greenhouse gas emission in determining thresholds … for Clean Air Act permitting" (p. 4). To my knowledge the SAB Report has been complete and is being submitted to the broader SAB process. The comments below (and page numbers cited) relate to the SAB Report draft of 6-15-12 (SAB 2012).

I take fundamental issue with many of the elements of the SAB Report. Although I largely agree with the Report's criticisms of the absence of supporting science for many of the Framework's suggested approaches, I find unconvincing and unscientific much of the Report's attempt to salvage large elements Framework's approach. My comments focus largely, but not entirely, to forest issues in the Report not only because that is the area of my greatest expertize but also because the defects in the Framework approach are most egregious in forestry.

The EPA considered whether to categorically include biogenic emission in its greenhouse gas accounting or whether to categorically exclude biogenic emissions (p 6-7). The Agency rejected both extremes and asked the SAB whether it supported their conclusion that categorical approaches are inappropriate for treatment of biogenic carbon emissions. However, I do not believe that this issue was properly vetted within the SAB process. Although the statement that "carbon neutrality cannot be assumed for all biomass energy a priori" (p 7) is correct, it misrepresents the serious position developed by the Intergovernmental Panel on Climate Change (IPCC 2006) and commonly used included a critical qualification regarding the condition of land cover generally and forest stock specifically. This requirement is missing from the simplistic evaluation statement. This position is supported in the Appendix to this piece, (USDA appendix by Hohenstein, 2012), which notes that the major IPCC rationale does not claim "a priori" neutrality. The IPCC, which suggested this approach, makes carbon neutrality contingent on an aggregate monitoring approach that focuses on the changes in aggregate land use and forests. Thus, the definitive development of the wide spread exclusion of biogenic and wood does not, in fact, involve an a priori assumption of neutrality. Rather it involves a qualification (for wood) that the forest stock be constant or expanding. I should note here that consideration of that important qualification was largely absence from the evaluation by the SAB and, in my judgment, aggressively discouraged by the organizers from the SAB discussion.

Finally, if the proposed Accounting Framework were capable of providing reliable accounting, one might give it serious consideration as an alternative to the IPCC approach in achieving the EPA objectives. However, as is acknowledged by the Report (e.g., p. 15), the proposed Accounting Framework is replete with problems as are the calculations of the elements necessary for calculating the Biological Accounting Factor (BAF). The acknowledged scientific weaknesses in the EPA document are identified throughout the SAB Report.

This paper demonstrates below that the SAB Report has not adequately addressed some of these issues and has not found ways to estimate in a scientifically acceptable way the values of some of the requisite components of the BAF.

Defects in the Accounting Framework

Questions raised in the Report about the Framework run from the appropriateness of the proposed use of the same accounting framework for the various feedstocks, which are different, to issues dealing with the appropriate baseline and questions concerning the relevant timescale. The SAB Report essentially embraces a variant of the BAF approach, which was developed in the Framework, even though the Report points to numerous important weaknesses of the BAF approach. The BAF is a simple accounting model that tries to identify and measure the various components and impacts of carbon emissions and accumulations from biomass energy sources. Ultimately, the Report essentially embraces the general BAF approach but applies it differently to individual biogenic feedstocks. However, the Report acknowledges throughout that a number of the components of the BAF cannot be adequately measured.

For example, the Report acknowledges that for important major elements of the Framework, e.g., leakage, there is no satisfactory monitoring or measurement system. Leakage, which can be either positive of negative, may involve the deflection of deforestation and associated emission out of woodshed under consideration or it may involve sequestration associated with offsetting forest management outside of that woodshed. Thus, the values of these major elements are essentially empirical, could be either positive or negative, but have their impacts outside of the area of direct observation. But, without accurate leakage values, the BAF approach proposed cannot accurately estimated for carbon changes. It cannot even determine the sign of the changes with any great accuracy. Thus, although the Reports states that "it is important to have scientifically sound methods to account for greenhouse gas emission caused by human activities" (p 13), it acknowledges that the it is widely acknowledged in the literature that leakage cannot to be readily measured with any accuracy (Murray et al. 2004; Macauley et al. 2009). Nevertheless, in contradiction of this finding the Report suggests that "the Agency … try to ascertain the directionality of net leakage … and incorporate that information into decision making." (p 9-10). This suggestion flies in the face of the concept of "scientifically sound methods."

Indeed, the application of the proposed framework would either need to leave these elements of the BAF empty, as suggested in the USDA letter posted on the SAB website, or nonscientific guesses would need to be imposed, as suggested in parts of the Report. In either case large errors in measurement appear almost inevitable and, rather than providing the regulators with accurate information, would provide misinformation to regulators and would likely redound to errors in the application of regulations. The idea introduced in the Report of default BAFs does not do anything to address their fundamental lack of scientific rigor.
Other thorny issues involve questions of the boundaries of a woodshed and/or a region, which relate to the leakage question, the intermixing of industrial wood and biomass so that significant portions of any harvest are used for each, and the export of biomass for energy, e.g., the large flow of wood pellets to Europe, where their emissions for the production of bioenergy will not be captured in the accounting. Finally, any accounting approach that tries to monitor each biomass using unit is surely going to be time

consuming and expensive, perhaps too expensive to justify the use of the biomass for energy (Sedjo and Sohngen 2012).

An important defect is that the Report embraces a carbon-debt framework. However, this framework is an artifact of an arbitrary decision of how the accounting system is applied. If the forest is sustainability managed, then there is no carbon-debt. Withdrawals equal growth for both biomass and carbon. Accounting debts can occur in some circumstances, however. For a mature forest stand, if the accounting period begins with the harvest of the stand, as in the Manomet Study, a debt is incurred for that stand. Note that net carbon sequestration could be occurring in that forest but on different stands. Most forests are multi-aged and hence will have net growth occurring on some stands while stock reductions occur on other stands.

An additional source of confusion regarding carbon debt is related to the accounting period. If the accounting focuses on a stand and the accounting period begins with the harvest, a debt will be establishment for the forest stand. However, if the accounting begins with the forest establishment, e.g., at tree planting, then the initial post planting growth is building up a stock of carbon that will be released at harvest. Thus, any future debt from that stand will have been offset in advance of the harvest and no intertemporal net carbon debt is incurred.
Thus, although an accounting debt can be found for mature stands, the debt is an artifact of the time period selected and the choice of how narrowly to define the relevant forest stands. Furthermore, a carbon debt will not be occurred for sustainably managed forests. In the aggregate, the U.S. forest system is more than sustainable as demonstrated by the FIA's data going back to a least 1952. Thus, a fully accounting of the entire managed US forest does not find a carbon-debt.

In summary, the Report identifies a host of problems with the proposed Accounting Framework, and reports that "the SAB did not find the Framework to be scientifically rigorous" (p 30). Indeed, although the Framework is said to "include most of the elements that would be needed to gauge changes in CO2 emissions," the problems with the effective of monitoring, measurement and verification of several of the components are daunting.

Alternative Approaches for Accounting for Biogenic Carbon

One wonders why the SAB exerted so much effort to try to save the Accounting Framework, containing as it does, such fundamental defects. It is my understanding that the SAB was asked to review and comment on the Framework, but not necessarily to save it. Indeed, as noted above, EPA's change included the question of "whether … to consider biogenic greenhouse gas emission in determining thresholds … for Clean Air Act permitting" (p. 4).
Nevertheless, despite the identification of very serious defects in the approach, there is a considerable attempt in the SAB process to downplay the problems and ignore the lack of scientific bases for measuring some of the elements, apparently in order to preserve a variant of the approach, no matter how defective.

There are at least two basic ways that one might approach the problem of estimating the net emissions associated with biogenic energy. The highly regarded scientific organization, Intergovernmental Panel on Climate Change (IPCC) has suggested an aggregate approach that would focus on the changes in aggregate land use and forests to determine whether, for example, aggregate forest stocks are expanding or contracting. This approach has been supported by the USDA (Hohenstein 2012) in a response to an earlier draft report by the SAB.

In the context of measuring the total aggregate forest the issue of leakage and anticipatory management within the US does not arise since to total system is evaluated. Where the aggregate is subdivided into a few large international regions, these issues are more easily captured since flows in forest biomass are measured in the international trade statistics and individual woodshed monitoring is not necessary. Indeed, for the US this approach can easily be put in place at low cost since the Forest Service has been undertaking Forest Inventory Assessments (FIA) for over fifty years.

The alternative to the IPCC approach, suggested by the Accounting Framework, involves the individual audit of each separate woodshed associated with a facility and an attempt to estimate the impact of each individual operation on net emissions. Such an approach would be a monitoring nightmare complicated by the fact that wood feedstock could, and likely would on occasion, be brought into one region from other small regions as required, this situation would involve leakage. Leakage could be replete since more regions would almost surely involve more leakage. Not only is the individual wood shed audit approach much more expensive, it also is inadequate since wood sheds are not always well defined and wood will undoubtedly flow across various woodsheds and leakage will occur. However, such detail is entirely unnecessary for purposes of the broad monitoring of biogenic facilities and their effects on atmospheric carbon. The relevant consideration is not the infinitesimal impact of each individual facility. Rather, the concern is with the grand aggregate impact of the bioenergy system on net emissions. If this approach does not properly account for the effects of leakage and anticipatory forest management (reverse leakage), the BAF estimates will have basic errors.

The Framework approach and the SAB Report appear to accept the notion that the Framework Accounting approach is superior to the IPCC approach. However, no evidence of this is provided either in argumentation or in analytical studies. Nevertheless, it is probably indisputable that the costs of the Accounting Framework approach with its estimated BAFs are far higher than those associated with the IPCC approach.

Five Summarizing Points

First, the guidelines provided by the EPA for the SAB Report essentially accept the Framework view and dismisses the IPCC suggested approach with regard to biogenic feedstocks within the land use sector, including forests. This was done despite that fact that there was no serious discussion by our SAB group of the adequacy or viability of the IPCC approach. Indeed the IPCC approach was dismissed by the EPA as inadequate on rather flimsy grounds. I note that my position is supported in the letter by William Hohenstein, Director of the Climate Change Program Office posted at the SAB website. The letter states that USDA "prefers the IPCC accounting framework" approach and takes issue with the rationale used by the SAB Report and its dismissal of the IPCC approached. USDA differs with the assertion of the SAB Report and maintains "the IPCC approach is not equivalent to an a priori assumption that these feedstocks are produced in a carbon neutral manner or an assertion that land use activities contributing feedstocks to the energy sector can be managed without consideration of atmospheric outcome."

Second, an attempt to assess the carbon debt of individual stands fundamentally misses the point since it is the entire forest, not individual stands that are relevant to the carbon footprint as seen by the atmosphere. As such, the attempt to imperfectly apply the BAF to individual forests is costly and irrelevant to the aggregate U.S. carbon footprint.

Third, although the Report acknowledges the dynamic nature of market driven supply systems that would be providing the biogenic energy feedstock, it essentially uses a static approach that largely ignores various market responses and adaptations to changing circumstances. Although the Report acknowledges that investment decisions for trees must predate their utilization by years and indeed decades, this reality is not incorporated into any BAF calculation. Indeed, while investment decisions must be driven by the anticipation of the existence and size of future markets, these considerations are acknowledged for wood biomass in parts of the Report and then disregarded in the application of the approach for regulatory purposes. Thus, the actual approach suggested is essentially static, missing the essential dynamic nature of the supply process. Despite these basic defects, the Report recommendations are treated as if they are scientifically sound.

Fourth, the Report erroneously states that incentives for producing replacement bioenergy crops are absence. Such a result would occur in viable markets only if there were no anticipation of increasing future demand. However, a variety of signals, including requirements of renewal portfolio standards and forecasts of dramatic biomass energy demand increases over the next couple of decades by various authoritative organizations, e.g., EIA.

Fifth, the Report tends to support a very expensive and onerous regulatory accounting system rather than a much more efficient system such as suggested by the IPCC. This support is given without any apparent serious assessment or rationale that the regulatory results of the BAF system will be equal to or superior to those that would result from a much less expensive and less onerous IPCC type approach.

In summary, I find that although the SAB Report provides a useful critique of the Accounting Framework and the BAF approach. However the Report falls into the trap of trying to make a basically defective system functional and tends to support many aspects of that flawed system. In the end the Report largely ignores its own criticisms and supports a fundamentally flawed approach. Thus, since the motivation for the Accounting Framework "is whether and how to consider biogenic greenhouse gas emission in determining thresholds … for Clean Air Act permitting" (p. 4), it can rationally be concluded that biogenic greenhouse gas emission are best not considered in determining thresholds or perhaps considered only of the forest and land use conditions as such that they do not meet minimal IPCC conditions.

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