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Executive Summary

This Advisory responds to a request from the EPA Office of Air and Radiation for EPA's Science Advisory Board (SAB) to review and comment on 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 framework to adjust the stack emissions from stationary sources using bioenergy based on the induced changes in carbon stocks on land (in soils, plants and forests). To conduct the review, the SAB Staff Office formed the Biogenic Carbon Emissions Panel with experts in forestry, agriculture, greenhouse gas measurement and inventories, land use economics, ecology, climate change and engineering.

The SAB Biogenic Carbon Emissions Panel was asked to review and comment on (1) EPA's characterization of the science and technical issues relevant to accounting for biogenic C02emissions 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 C02 emissions. In the context of EPA's *Framework*, the term "biogenic carbon emissions" refers to emissions of CO_2 from a stationary source directly resulting from the combustion or decomposition of biologically-based materials other than fossil fuels. During the course of deliberations, the SAB Panel reviewed background materials provided by the Office of Air and Radiation and heard from numerous public commenters. This Executive Summary highlights the SAB's main conclusions. Detailed responses to the individual charge questions are provided in the body of the report.

Context

EPA provided very little written description of its motivation for the *Framework* in the document itself. However, through the background information provided and discussion at the public meeting on October 25 – 27, 0211, EPA explained that the context for the report is the treatment of biogenic CO_2 emissions in stationary source regulation. Specifically, under the Clean air Act, stationary sources (e.g. power plants) are often regulated at the point of emissions. In the case of greenhouse gases and this Framework, the question EPA is considering is whether and how to count the biogenic CO_2 emissions from a stationary source.

On June 3, 2010, EPA finalized new thresholds for greenhouse gas emissions that define when Clean Air Act permits under the New Source Review (Prevention of Significant Deterioration program) and Title V operations permits program would be required (also known as the "Tailoring Rule". In the Tailoring Rule, EPA did not exclude biogenic emissions from the determination of applicability thresholds, however in July 2011, EPA deferred for a period of three years the application of permitting requirements to biogenic carbon dioxide (CO_2) emissions from bioenergy and other biogenic stationary sources. In its deferral, EPA committed to conducting a detailed examination of the science and technical issues associated with biogenic CO_2 emissions and submitting its study for review by the Science Advisory Board. The motivation for considering whether or not to adjust biogenic carbon emissions from stationary sources stems from the way the carbon in these feedstocks interacts with the global carbon cycle. Plants take up carbon from the atmosphere to produce products that are consumed by humans and animals for food, shelter and energy. Plants convert raw materials present in the ecosystem such as carbon from the atmosphere and inorganic minerals and compounds from the soil including nitrogen, potassium, and iron and make these elemental nutrients available to other life forms. Carbon is returned to the atmosphere through respiration by plants and animals and by industrial processes, including combustion and by natural decomposition. Thus, the use of biogenic feedstocks results in both carbon emissions and carbon sequestration.

Categorical inclusion or exclusion

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

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

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

Biogenic Accounting Factor (BAF) Calculation

The *Framework* presented an alternative to a categorical inclusion or exclusion by offering an equation for calculating a Biogenic Accounting Factor (BAF) that adjusts the onsite biogenic emissions at the stationary source based on feedstock growth, decomposition, carbon stored in products, leakage and site sequestration effects. In consideration of its own regulatory boundaries, EPA constrained BAF to lie somewhere between 0 (categorical exclusion) and 1 (categorical inclusion) however scientifically, BAF could be below 0 or above 1. In terms of their greenhouse gas implications, some feedstocks could be better than carbon neutral and other feedstocks might do more harm than fossil fuels. In keeping with its regulatory boundaries, EPA's constrained BAF to lie at or above 0 because it was not allowing for the possibility of granting credits to bioenergy if it creates net emissions reductions. EPA did not allow BAF to rise above 1 because it was not considering the possibility of "penalizing" biogenic energy that might be "dirtier" than fossil fuels. As a result of this artificial constraint on BAF, EPA's *Framework* could, inadvertently, encourage the use of biological feedstocks that have higher greenhouse gas emissions than fossil fuels just as it could, inadvertently, discourage the use of biogenic feedstocks that are superior to fossil fuels in terms of their greenhouse gas consequences.

To calculate BAF for biomass from roundwood trees, EPA conjured 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 automatically assigned a BAF of 0. This leads to the nonsensical conclusion that a ton of carbon emitted in one part of the country may be treated differently from a ton of carbon emitted elsewhere. The atmospheric response to an additional ton of carbon is the same, regardless of its geographic origin. Thus, EPA's creation of artificially contrived regions and the assignment of BAF based on geography is not justified scientifically.

While EPA's proposed equation for BAF has overarching problems, the variables in the equation capture many of the factors necessary for estimating the offsite carbon change associated with stationary source biomass emissions from 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. For short recovery feedstocks where carbon recovery and "anyway" emissions are within one to a few years (i.e., agricultural residues, perennial herbaceous crops, mill wood wastes, other wastes), the *Framework* may, with some adjustments and appropriate data, accurately represent direct carbon changes in a particular region. For waste materials (municipal solid waste), the *Framework* needs to consider the mix between biogenic and fossil carbon as well as the potential capture of methane (CH_4) emissions from landfills. Given that CH_4 emissions from landfills are often captured, crediting waste material for avoided emissions (as the *Framework* currently does) may not always be appropriate. For long carbon recovery feedstocks (roundwood), the *Framework* does not capture the carbon outcome given its omission of the time path for carbon recovery following harvest. For these feedstocks, the Framework does not allow determination of the incremental impact of a stationary facility holding everything else the same or establish causality between bioenergy use and observed carbon outcomes. Additionally, the measurement of the carbon impact of the facility is scale sensitive. These issues are discussed in greater detail below.

Leakage is a phenomenon by which efforts to reduce emissions in one place shift emissions to another location or sector The *Framework's* equation for BAF includes a term for leakage, however EPA decided that calculating values for leakage was outside the scope of the *Framework*. 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 the world market and leads to conversion of carbon rich lands to crop production and the release of carbon stored in soils and vegetation.. The use of biogenic feedstocks can also affect the price of fossil fuels by lowering demand for them and thereby increasing their consumption elsewhere. "Good" leakage (called "negative" leakage in the literature) could occur if the use of biomass leads to carbon offsetting activities elsewhere. The latter could arise for example, if increased demand for biomass and higher prices generates incentives for investment in forest management which increases forest carbon sequestration.

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

Causality and Additionality

EPA's stated objective was to accurately reflect the carbon outcome of biomass use by stationary sources. To accurately capture the carbon outcome, this requires selecting a time period and determining what would have happened anyway without the harvesting and comparing that impact with the carbon trajectory associated with harvesting of biomass for bioenergy within that time frame. Although any "business as usual" projection would be uncertain, it is the only means by which to gauge the incremental impact of biomass harvesting. The *Accounting Framework* discusses this approach, calling it an "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 use of a fixed reference point baseline coupled with a division of the country into regions implies that forest biomass emissions could be considered carbon neutral simply because forest stocks are increasing in a particular region from the base year. This is not justified scientifically because from a mass balance perspective, a reduction in the rate of increase of carbon stocks is equivalent to an increase in emissions; rather it is an artifact based on the choice of baseline and the assumption of unspecified geographic regions. 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 are associated with biomass use. Instead, the *Framework* captures changes over an undefined space, in a sense, substituting space for time. As a result, the *Framework* fails to capture the causal connection between biomass harvesting and atmospheric impacts.

By forgoing the anticipated future baseline approach, the *Framework* fails to capture the difference in CO_2 concentrations the atmosphere sees over some time frame as a result of stationary source use of forest biomass. For faster growing biomass like agricultural crops, the incorporation of a time frame is not necessary. For wood harvested specifically for energy use (roundwood) and logging residues, the *Framework* does not incorporate a) the time path of carbon accumulation in forests (before or after energy emissions from harvested roundwood) or b) the time path of the "anyway" emissions that would have occurred on the land if logging residue were not used for energy production. By not incorporating a time interval, the *Framework* fails to capture the contribution to climate change made by temporary carbon losses. Thus for long recovery feedstocks where carbon recovery occurs over decades, the *Framework* does not capture the carbon outcome, defined as "what the atmosphere sees." EPA might consider adopting a GWP index to represent feedstocks with long recovery times. As pioneered by Cherubini *et al.* (2011), GWP_{bio} incorporates a time dimension into the calculation, taking into account the fact that sequestration in new growth is spread over a time interval of years. GWP_{bio} is a unit-based index that uses CO_2 impulse response functions from C cycle models in the elaboration of atmospheric decay functions for biomass-derived CO_2 emissions. GWP_{bio} is expressed as a function of the rotation period of the biomass.

Scale

The use of a regional scale is a central weakness of the *Framework*. EPA employed regions as an artificial construct to avoid the need for site-specific chain of custody carbon accounting with separate streams for each feedstock and as an alternative to capturing changes in carbon stocks over time. 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. However, it makes the estimate of the BAFs sensitive to the choice of the spatial region. As shown in EPA's own case study, the choice of the appropriate regional scale has significant implications for the emissions attributed to a facility.

Recommendations for Revising BAF

To implement the *Framework*, EPA faces daunting technical challenges. Although the SAB would prefer an alternative to the calculation of a BAF (as described below), if EPA decides to revise the *Framework*, the SAB recommends the following improvements.

- Develop a separate BAF equation for each feedstock category. Feedstocks could be categorized into short rotation dedicated energy crops, crop residues, forest residues, long rotation trees and waste materials.
- Separate out feedstocks which could be classified as "anyway" emissions so that their BAF would automatically be either set to 0 or modeled as a decay function.
- Develop an equation for perennial energy crops and short rotation woody biomass.

- Use an anticipated baseline approach for long recovery feedstocks like roundwood.
    - For forest biomass from roundwood harvested for bioenergy, omit the regional scale and incorporate a time dimension, modifying certain factors in the BAF equation to include the timescale over which carbon is decomposed or released back to the atmosphere. Consider employing integrated forest sector models and/or Cherubini's $GWP_{bio.}$
    - Modify the variable that represents the proportion of emissions that are offset by sequestration during feedstock growth (LAR) so that it is scale insensitive.
- Develop an equation for municipal solid waste to take into account the mix of biogenic waste with fossil fuel waste as well as the possibility of methane capture in landfills.
- Consider information about the directionality of leakage as well as leakage into other media.

Alternatives to BAF

In a perfect world with full information and unlimited policy choices, carbon limits (or prices) would be implemented economy-wide and not selectively enacted for particular sources or sectors. Economic research has shown that the most cost-effective way to reduce greenhouse gas emissions (or any other pollution) is to regulate or tax across all sources until they face a marginal cost of emissions reduction that equals the marginal benefit of emissions reduction and is equal across sources. In EPA's less perfect world with limited authority under the Clean Air Act, the most efficient economy-wide solution is not within its menu of choices. EPA's regulation of stationary sources will exclude other users of biomass (e.g. consumers of ethanol) that have equivalent impacts on the carbon cycle as well as downstream consumers of products produced by these facilities.

In this second-best world with limited policy instruments that can be applied only to limited sources, it would be desirable for EPA to ascribe all changes in greenhouse gas emissions (both upstream and downstream of the stationary source) caused by the operation of the stationary facility to that source. Ideally, these emissions would need to be determined on a facility-specific basis however facility-specific calculations face some daunting practical challenges, including chain of custody accounting and estimation of market mediated effects or "leakage."

Given the choices facing EPA, one hybrid approach for EPA to consider would be a categorical inclusion with opt-out provisions. Stationary sources would be subject to a categorical inclusion unless they opted out by certifying that their biomass was sustainably harvested and produced using best management practices. By making the stationary source responsible for demonstrating "sustainability", the source would be linked to its land base. This would remove the perverse situation of a responsible bioenergy facility, using feedstock produced in a highly sustainable manner, being penalized because it happens to be located in a region where other, less sustainable forest activities are causing carbon stocks to decline. It would also avoid the problem of a bioenergy facility that uses biomass harvested in an unsustainable manner benefiting from operating in a region where carbon stocks happen to be growing. A certification system may not control for market-mediated effects or leakage and it may increase complexity and costs of accounting for the carbon emissions of a stationary source. The SAB cannot offer an opinion on the legal feasibility of such an approach. Certification systems have been successfully employed in Europe and, to a lesser extent, in the U.S. via the Sustainable Forestry Initiative.

Given the conceptual deficiencies, described above, and prospective difficulties with implementation, the SAB urges the Agency to "think outside the box" about policy options that go beyond categorical inclusion, exclusion or calculating a BAF for each facility. We offer the following three options for the Agency's consideration:

1. Consider developing a generic BAF for each feedstock category.
2. Consider certification systems.
3. Consider offset systems.

Option 1: Consider developing a generic BAF for each feedstock category. An alternative to revising the *Framework* and calculating a BAF for each stationary facility is to develop general BAFs for each category of feedstocks, differentiating among feedstocks using general information on how their harvest and combustion interacts with the carbon cycle. EPA might need to develop a separate BAF equation for each of the other categories of feedstocks, using forest growth models to plot carbon paths that track regrowth following harvest. Many more case studies would be needed to develop an accounting focused on feedstocks rather than the facility. These generic BAFs would be applied by stationary facilities to determine their quantity of biogenic emissions that would be subject to EPA's tailoring rule.

Option 2: Consider certification systems in a hybrid approach. A categorical inclusion with an opt-out provision whereby facilities could opt out by certifying that their biomass was sustainably harvest and produced using best management practices. Such "sustainability" would need to be certified by an authority using valid scientific measurements. Requiring stationary facilities to use only "certified" feedstocks would be administratively simpler than quantifying a specific net change in greenhouse gases associated with a particular stationary facility. Certification apparoach can avoid the arbitrary scale issues and can perhaps avoid or reduce leakage.

Option 3: Consider offsets. An offset is a reduction in emissions of carbon dioxide or other greenhouse gas made in order to offset an emission made elsewhere. The use of offsets could accompany either Option 1 or Option 2 above or even a calculated BAF for each facility (using the *Framework*). If offsets were allowed, it would make possible a variety of gains from trade that facilities could use to lower costs. For example, a fossil or biogenic CO_2 emitter could contract with land owners to offset their emissions through forest protection and regrowth or carbon accumulation in soils.

Conclusion

As EPA has recognized, the greenhouse gas implications of bioenergy are more complex and subtle than the greenhouse gas impacts of fossil fuels. In recognition of the complicated role that bioenergy plays in the carbon cycle, the *Framework* provides a structure to account for net climate impacts. The focus of the *Framework*, however, is on point source emissions from stationary facilities. As a result, the *Framework's* boundaries are drawn only so far as to account for any offsetting carbon sequestration that may be attributed to the facility's use of a biogenic feedstock. These narrow regulatory boundaries 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. As far as the climate is concerned, it makes no difference if land use change is used to offset CO_2 that was of fossil origin or of biogenic origin. 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. While the *Framework* , to some degree, extends carbon accounting upstream, a more comprehensive carbon accounting would extend downstream—to emissions from by-products, co-products, or products such as ethanol combustion or ethanol by-products such as dried distillers grains (DDGs) that are sold as livestock feed and will soon become CO_2 (or CH_4). It would also extend upstream and account for the carbon emissions due to the use of fertilizer to produce the biogenic feedstock.

The *Framework's* main contribution is to lay the groundwork for future developments in accounting for biogenic emissions while forcing important questions.

Charge Question 1

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

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

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

1) Timescale

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

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

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

Another important timescale for considering accounting systems for biogenic carbon emissions is the period over which the climate responds to carbon dioxide and other greenhouse gases. Several different climate modeling studies have demonstrated that the peak warming in response to greenhouse gas emissions is primarily sensitive to cumulative greenhouse gas emissions over a period of roughly 100 years, and is relatively insensitive to the emissions pathway within that time frame. What this means is that an intervention in forests or farming that results in a change in storage of carbon or emissions reductions must endure for significantly longer than 100 years in order to have any real influence on the peak climate response.

Timescales are also important at a more local scale. Given the EPAs 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 accounting framework. The fundamental differences in stocks and their turnover times as they relate to impact on the atmosphere is not well discussed or linked into the current framework. (Page 6 raises the issue but does not delve into what it means for biogenic carbon accounting).
If a carbon stock is cycling quickly on land, turning over and being replaced fully in less than 100 years (as discussed above), it may have a beneficial impact when it is consumed for energy, displacing the combustion of fossil fuel. If the carbon stock, or some part of it, turns over more slowly, i.e., much longer than 100 years, the timing of release begins to matter.
There is a continuum of carbon stock size and turnover among the biogenic feedstock sources included in this framework, but there is little background discussion of the variation in the stock and turnover and how that informs the accounting method. The current framework sets up categories of feed stocks based on their source, but these grouping have little to do with their carbon stock and turnover or how they are accounted for in the current framework. The science section could walk through the carbon stocks covered by the scope of the accounting framework and their relevant turnover times.

The timescale over which land carbon may change, coupled with the scientific understanding of the timescale of the climate system response, could have been used in the report to support the EPA accounting method against criticisms from several environmental groups who point to the idea of a carbon debt when biomass is harvested and taken from a forest. The idea of a carbon debt is technically correct, but fails to recognize that the climate response is based on cumulative emissions over 100 years. This means that the climate system is not sensitive to the imbalance in the carbon cycle that might occur over decades from harvesting of biomass for bioenergy facilities. The carbon debt is a serious problem if the time for regrowth is much more than 100 years. However, the annual accounting method proposed by the EPA does not fit well with this framework. A scientifically rigorous evaluation of the biomass harvest on the carbon cycle must consider what the impact will be on the 100 year timescale. Annual accounting of carbon stocks is likely to give inaccurate assessments of the overall carbon cycle impacts.

A subtle but important point for estimating carbon outcome and "what the atmosphere see" is that the measurement should be in the form of change in global warming potential on say the commonly used 100 year basis. For short recovery time feedstocks such as perennial grasses the difference in global warming potential is almost identical to CO_2 emissions minus carbon change on the land (CO_2 eq). For feedstocks with long recovery time one must compute the change in global warming potential by calculating the cumulative radiative forcing of the initial CO2 emission minus the carbon change on the land (CO_2 eq) (using an integral convolution) to 100 years, then dividing by the integral of radiative forcing for a simple CO_2 emission to 100 years. This estimate of GWP in CO_2 equivalents will be less than an estimate using CO_2 emission minus carbon change on the land (CO_2 eq) over 100 years. The more detailed calculation of change in GWP_{100} properly takes into account absorption of the initial CO_2 emission by oceans and terrestrial CO_2 fertilization.

2. 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 timescales. 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. A short list of relevant publications is provided in the Reference section.

3. Space for time substitution

A discussion of the literature on the value and limitations of space for time substitutions should be discussed as it is a fundamental part of the *Accounting Framework* presented. The implications for different baseline conditions on space-time substitution should also be part of this methods review.

4. Non-CO_2 Greenhouse Gases

The *Framework* does not incorporate greenhouse gases other than CO_2. This fails to account for the difference between biomass feedstocks in terms of their production of other greenhouse gases. The most important of these is likely to be N_2O produced by the application of fertilizer (Crutzen 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 this is a life cycle comparability/fairness issue with fossil fuels this needs to be explicitly discussed. If we are not counting certain emissions from fossil fuels either because they are counted elsewhere or outside the mandate, then how do those compare to the emissions from biogenic fuels that are counted elsewhere or outside the mandate? How significant are they compared to those emitted and counted?

Charge Question 2

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.

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

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

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

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

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 implementation difficulties that could accompany any policy on biogenic carbon emissions but below are some scientific observations that may inform the Administrator's policy decision.

The notion that biomass is carbon neutral arises from the fact that the carbon released as CO2 upon combustion was previously removed from the atmosphere as CO2 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 biomas are attributed to a stationary source, assuming carbon neutrality of biomass necessarily implies that the net sum of carbon emissions from all sources and sinks is zero, including all supply chain and market-mediated effects. Therefore, carbon neutrality cannot be assumed for all biomass energy a priori (Rabl et al., 2007; 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 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.

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

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

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

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

Charge Question 3

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

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

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.

Municipal solid waste biomass is either disposed of in a landfill or combusted in facilities at which energy is recovered. Smaller amounts of certain waste components (food and yard waste) may be processed by anaerobic digestion and composting. The CO_2 released from the decomposition of biogenic waste in landfills, compost facilities or anaerobic digesters could reasonably be assigned a BAF of 0 but applying a 0 to all municipal solid waste does not take into account the fact that when waste is burned for energy recovery, both fossil and biogenic CO are released. The *Framework* should take into account the mix of biogenic waste with fossil fuel waste since the combustion of municipal solid waste results in the production of both biogenic and fossil carbon. In addition, the *Framework* should account for the fact that CH_4 emissions from landfills are sometimes captured already.

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

Level of Atmospheric Reduction (LAR): The 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. The term also combines two very separate concepts, regrowth of feedstock (GROWTH) and avoided emissions (AVOIDEMIT) from the use of residues that would have been decomposed and released carbon emissions anyway. These two terms are not applicable together for a particular feedstock and representing them as additive terms in the accounting equation can be confusing. Additionally, the value of LAR, for forest biomass, is sensitive to the size of the region for which growth is compared to harvest.

Loss (L): This is included in the *Accounting Framework* to explicitly adjust the area needed to provide the total feedstock for the stationary facility. It is a term used to include the emissions generated by the feedstock lost during storage, handling and transit. This is based on the strong assumption that most of the carbon in the feedstock lost during transit is immediately decomposed and therefore released to the atmosphere, an assumption that lacks scientific justification. 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 is 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 the loss that would be counted. The *Accounting Framework* tacitly assumes an infinitely long horizon that results in the release of all the carbon stored in the lost feedstock.

Products (PRODC). The removal of products from potential gross emissions is justified scientifically, however, the scientific justification for treating all products equally in terms of their impact on emissions is not clear. In the case of some products (e.g., fuels like ethanol and paper) the stored carbon will be released rapidly while in the case of 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 with no scientific foundation. For products that release their stored carbon rapidly, the consequences for the atmosphere are the same as those associated with the carbon stored in the underlying feedstock; thus a distinction between the two is not scientifically justified. To precisely estimate the stores of products so as to estimate the amount released, one would need to track the stores as well as the fluxes associated with products pools. The stores of products could be approximated by modeling the amount stored over a specified period of time; the exact time period would have to be a policy decision.

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

Avoided Emissions (AVOIDEMIT): This term refers to transfers of emissions within the system or to emissions that occur regardless, although in different places (i.e., at the point source or at the field site). Since the concept reflected in “avoided emissions” is actually “equivalent field-site emissions” it would be clearer to refer to it by a term that reflects the actual concept being used. As with the Loss term, the assumption of instantaneous decomposition or total combustion of the crop or forest residue needs scientific support. Some of the materials that are harvested might take decades to centuries to fully decompose. To be scientifically-based the hypothetical store of harvested fuel stock would have to be tracked. To approximate these stores one could compute the average amount remaining after a period of years. The number of years considered would be a policy decision; the longer the period, the less would be counted. The *Framework* tacitly assumes an infinite number of years.

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

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

The use of biogenic feedstocks could lead to leakage by diverting feedstocks and land from other uses and affecting the price of conventional forest and agricultural products which can lead to indirect land use changes that release carbon stored in soils and vegetation. The use of these feedstocks can also affect the price of fossil fuels by lowering demand for them and increasing their consumption elsewhere. These leakage effects could be positive (if they lead to carbon emissions elsewhere) or negative (if they lead to carbon uptake activities). The latter, could arise for example, if increased demand for biomass and higher prices generates incentives for investment in forest management that increases forest carbon sequestration. Some research has shown that when a future demand signal is strong enough, expectations about biomass demand for energy (and thus revenues) can reasonably be expected to produce anticipatory feedstock production changes with associated changes in land management and land-use (e.g. Sedjo forthcoming; Rose, McCarl, Latta, forthcoming). 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 is questionable. While first principles in environmental economics show the efficiency gains from internalizing externalities by attributing direct environmental damages to responsible parties that are directly responsible for them, 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. Moreover, leakage caused by the use of fossil fuels is not included in assessing fossil emissions generated by a stationary facility. Thus, the technical basis for attributing leakage and inherent inconsistency involved in including leakage and the different sources of leakage that will be included in this *Framework* needs to be assessed. Including some types of leakage (for e.g., due to agricultural commodity markets) and not others (such as those due to fossil fuel markets) and for biomass and not fossil fuels would be a policy decision without the underlying science to support it.

The empirical assessment of the magnitude of leakage and the method for attributing it to different stationary sources would need to be based on complex global economic modeling that involves comparisons of production, consumption and land use decisions with the use of a biogenic feedstock to those in a baseline scenario without the use of this feedstock. Thus it would use an anticipated baseline. This approach would introduce an inconsistency between the anticipated baseline that is needed to assess leakage and reference point baseline proposed for assessing LAR. The existing literature in the social sciences that is assessing the magnitude of leakage shows that its overall magnitude is highly uncertain and differs considerably across studies and within a study depending on underlying assumptions.

The use of a regional scale for assessing LAR implies that there could be cross-regional leakage; its presence and magnitude will be a function of the characteristics of the regions created (size and composition). The more regions created from a given area, the more leakage will occur from each region. If this leakage is not accounted for elsewhere in the *Framework*, for e.g., increased harvesting of biomass for pulp and paper manufacture in one region due the operations of a stationary facility in a different region, then this leakage could have an atmospheric outcome. With many regions involved, it would become extremely difficult to determine which of the multiple regions generated a particular leakage observed. Where many regions are involved simultaneously, disturbances may make identifying the unique leakage from a particular region almost impossible to determine. In sum, the precision associated with qualitatively estimating negative leakage accurately may involve huge errors that could be so great as to overwhelm any usefulness of the development of high quality data for other interrelated parts of the assessment. If the magnitude of leakage cannot be calculated, however, its direction should at least be stated and incorporated in some fashion. A default assumption that leakage is zero is neither helpful nor accurate.

Thus, on balance, the *Framework*, while including many important elements suffers from significant estimation and implementation problems. Some of these implementation issues with estimating BAF and leakage that will be discussed further in response to charge question 4.

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

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

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

Specifically, if the policy context is changed, for example, if carbon accounting is needed to support a carbon cap and trade or carbon tax policy, then the appropriateness of the *Framework* needs to be evaluated relative to alternative approaches such as life cycle analysis for different fuel streams. Modifying how certain factors are measured or included may not be sufficient. In fact, a different *Framework* would probably make sense 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.

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

In this second-best world with limited policy instruments that can be applied only to limited sources, it would be desirable for EPA to ascribe all changes in greenhouse gas emissions (both upstream and downstream of the stationary source) caused by the operation of the stationary source to that source. Ideally, these emissions would need to be determined on a facility-specific basis but facility-specific calculations would require a chain of custody accounting and involve other daunting challenges such as estimating leakage effects.

As will be discussed in Section 6.3, given the sub-optimal choices facing EPA, one hybrid approach would be a categorical inclusion with opt-out provisions. Stationary sources would be subject to a categorical inclusion unless they opted out by certifying that their biomass was sustainably harvested and produced using best management practices. By making the stationary source responsible for demonstrating "sustainability", the source would be linked to its land base.

This would remove the perverse situation of a responsible bioenergy facility, using feedstock produced in a highly sustainable manner, being penalized because it happens to be located in a region where other, less sustainable forest activities are causing carbon stocks to decline. It would also avoid the problem of a bioenergy facility that uses biomass harvested in an unsustainable manner benefiting from operating in a region where carbon stocks happen to be growing. This may, however, increase complexity and costs of accounting for the carbon emissions of a stationary source and require the development of certification systems that can certify that biomass used by a facility was harvested sustainably. Caution is also advised that such an approach could create global leakage effects that may overwhelm any carbon reduction achieved. The case could occur in which a facility using sustainably produced biomass has an apparent benefit on a regional scale but net negative effects on a global scale. The SAB cannot offer an opinion on the legal feasibility of a categorical inclusion with opt-out provisions based on certified feedstocks but we commend it to the Agency's attention for consideration.

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

As stated above, for agricultural biomass from energy crops and crop residues, the factors included in the *Framework* capture most of the direct off-site adjustments needed to account for the changes in carbon stocks caused by a facility using agricultural feedstocks although they do not account for leakage. For forest biomass, the *Framework* needs to incorporate a) the time path of carbon recovery in forests (after energy emissions from harvested roundwood) or b) the time path of the "anyway" emissions that would have occurred on the land if logging residue were not used for energy production. For municipal solid waste biomass, the *Framework* needs to consider other gases and CH_4 emissions from landfills when municipal solid waste is used for energy production. Given that methane emissions from landfills are often captured, crediting waste material for avoided emissions of methane may be inappropriate. The carbon impact of using waste for energy production should be measured relative to the CH_4 emissions, if any, that would be released during decomposition in a landfill. Note that the *Framework* should account for the fact that CH4 emissions from landfills are sometimes captured already. N_2O emissions, especially from fertilizer use, should also be considered. Furthermore, the inclusion of non-CO_2 greenhouse gases in general should be consistent between biogenic and fossil fuel accounting. For instance, there are also transportation related emissions losses in the delivery of natural gas.

3.4. Should any factors be modified or eliminated?

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

Charge Question 4

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 $C0_2$ emissions from stationary sources.

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

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

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

4.2. Is it scientifically rigorous?

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

The following issues require additional scientific support.

Timescale: One deficiency in the EPA report is the lack of discussion and proper consideration of the different timescales 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 timescales that are important for the issues associated with biogenic carbon emissions.

An important timescale for considering accounting systems for biogenic carbon emissions is the period over which the climate responds to carbon dioxide and other greenhouse gases. Several different climate modeling studies have 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 is relatively insensitive to the emissions pathway within that time frame.[1] What this means is that an intervention in forests or farming that results in a change in storage of carbon must endure for significantly longer than 100 years in order to have any real influence on the peak climate response.

If a carbon stock is cycling quickly on land, turning over and being replaced fully in less than 100 years then it may be beneficial to use biogenic carbon to displace the combustion of fossil fuel. If the carbon stock, or some part of it, turns over more slowly, i.e., much longer than 100 years, the timing of release begins to matter. Examples of the former are forest harvest and regrowth, even including accelerated harvests, and energy crops. Examples of the latter are land conversion to a significantly difference average carbon stock. The fundamental differences in stocks and their turnover times as they relate to impact on the atmosphere is not well discussed or linked into the current framework. Differences among feedstocks in their turnover times could justify how different feedstocks need to be incorporated into the *Framework*. At the moment, there is little background discussion of the variation in the stock and turnover and how that informs the accounting method. A fuller discussion of timescale of turnover of biogenic carbon stocks could inform the *Framework*, perhaps justifying the groupings of feedstocks based on their carbon cycling and likely impact on the atmosphere; those that have little or no impact, have partial impact, or can have significant impact.

Scientific understanding of the timescale 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 the time for regrowth is much more than 100 years. This means that the climate system is not sensitive to the imbalance in the carbon cycle that might occur over decades from harvesting of biomass for bioenergy facilities. A scientifically rigorous evaluation of the biomass harvest on the carbon cycle must consider the temporal characteristics of the cycling. Annual accounting of carbon stocks is likely to give highly distorted assessments of the overall carbon cycle impacts.

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

The *Accounting Framework* subtracts the emissions associated with products, including ethanol, paper, and timber, from the calculation of emissions from a stationary source, through the PRODC term. While EPA may not have the discretion to treat all emissions equally, distinguishing between immediate emissions from the facility and downstream emissions (as

[1] Allen, M. R., D. J. Frame, C. Huntingford, C. D. Jones, J. A. Lowe, M. Meinshausen and N. Meinshausen. (2009). "Warming caused by cumulative carbon emissions towards the trillionth tonne." Nature **458**(7242): 1163-1166. Allen et al. (2009)

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, there is no difference between these two types of emissions. 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. In addition, the *Accounting Framework* allows different carbon pools to be accounted for at different spatial scales with little justification. 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). On the other hand, impacts due to land use change or removal of residues such as corn stover (as captured in the SITE-TNC variable) which impact soil C pools are accounted for using site specific accounting.

The *Accounting Framework's* use of a regional scale for accounting for the net changes to the atmosphere is an artificial construct developed to (a) avoid the need for site-specific chain of custody carbon accounting with separate streams for each feedstock and (b) as an alternative to capturing changes in carbon stocks over time. The calculation of LAR captures landscape wide changes rather than facility-specific carbon emissions associated with actual fuelsheds. Thus, the *Accounting Framework* captures changes over space, in a sense, substituting space for time. This approach attempts to simplify implementation using available forest inventory data and avoids the need for accounting for changes in carbon stocks specific to the site or feedstock sourcing region (fuelshed) which may be more complex and costly and difficult to verify. However, it makes the estimate of the BAFs sensitive to the choice of the spatial region chosen for accounting purposes. There is no peer reviewed literature to support a decision about the appropriate spatial scale for determining LAR, and as shown by case study #1, there are significant implications of this choice for the emissions attributed to the facility. Specifically, a ton of carbon emitted in one part of the country may be treated differently from a ton of carbon emitted elsewhere.

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

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

For example, for roundwood use, a region may have carbon accumulation with respect to the reference year (and be assigned LAR=1 according to the *Framework*); however, harvest of a 150+ year old forest in the region for energy production would be regarded as a carbon stock gain even though there is less carbon than there would have been otherwise and we would recover only a portion of its carbon within the next 100 years. Likewise, a region which has a slight overall annual loss of carbon (LAR=0), could actually provide roundwood from light thinning of a mid-aged forest, yielding greater regional carbon than there would have been otherwise, where most of the carbon would recover within 100 years. The *Framework*, however, would view the roundwood supply as carbon stock loss. Since we want to estimate the "difference in atmospheric greenhouse gases" over some period we must estimate how carbon recovery differs between a biomass use case and a case without biomass use (business as usual case).

Substitution of Space for Time in Measuring Carbon Stock Changes: The *Framework* uses a single year's carbon accumulation – for an entire region – to compute the BAF offset for the current annual biomass combustion emissions. This approach is based in part on the idea that we can estimate carbon recovery over many years from current year harvest using information from one year of carbon accumulation over a wide area (a region). However the BAF is sensitive to the chosen size and composition of the region, particularly if the reference point baseline is used.

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 "carbon outcome" and the BAF value. 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 impact. 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 needs to be considered further. Ideally, EPA should put their BAF estimates into context by characterizing the uncertainties associated with BAF calculations and estimating uncertainty ranges. This information can be used to give an indication of the likelihood that the BAFs will achieve the stated objective. The uncertainty within and among variables for any estimate may vary widely between feedstocks and across regions. If a regional BAF is to be used, and there is not scientifically justifiable reason for doing so, at the very least, the uncertainty evaluation should be able to assess if an assigned BAF value for one feedstock in one area can be confirmed to be significantly different than a BAF estimated and assigned in another case. If there is no significant difference then they should be assigned one common value. In addition, uncertainty information would allow policy makers to assign BAF values after deciding on their aversion to the risk of assigning values that are too high or too low. Characterizing the uncertainty and risks is a scientific question. Selecting an acceptable risk level is a policy decision.

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 science in the document about how leakage might be quantified and no examination of the literature regarding non-hypothetical leakage scenarios (consider Murray et al 2004). Any discussion/decisions regarding a leakage term should be based on quantitative assessment and science. 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 cyclind, and the decision to include only CO_2 emissions and exclude other greenhouse gas emissions need more science based justification. Additionally, assumptions about the impacts of forest harvests on soil carbon and land use changes on carbon sequestration need to be more rigorously supported.

Inconsistencies: We found a number of inconsistencies within the proposed framework that should be resolved or justified:

(1) Adjustments for fossil fuel emissions: Fossil fuel CO_2 emissions from stationary sources under the Clean Air Act are currently not adjusted for offsite greenhouse gas emissions or 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. There are also relevant non-CO_2 greenhouse gas emissions associated with biogenic energy feedstocks (discussed below). What about greenhouse gas emissions generated during fossil fuel and biomass feedstock production and transport? It is practical to be consistent in the handling of these greenhouse gas emissions within the *Framework*—either excluding or including them for both fossil and biomass feedstocks. Including them would imply the need for a lifecycle analysis for both.

(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 land management system, soil, and climatic conditions. However, it does account for the non-CO2 greenhouse gas changes that are jointly produced with the soil carbon changes, as well as influence both the below and above ground carbon stock changes associated with 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.

4.3. Does it utilize existing data sources?

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

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

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

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

The *Framework* includes a term for leakage but eschews the need to provide any methodology for its quantification. Mysteriously, example calculations are carried out for leakage in one of the case studies. However, leakage can be positive or negative, and while many publications speculate about certain types of leakage, no data are presented, nor are data sources for different types of leakage discussed and suggested. The *Framework* does provide an example calculation of leakage in the footnote to a case study, but this does not a substitute for a legitimate discussion of the literature and justification and discussion of implications of choices. In addition, such data are unlikely to be available at the scales required. The implications and uncertainties caused by using some indicator or proxy to estimate leakage need to be discussed. If leakage cannot be estimated well is it possible to put an error range on the leakage value (e.g., a uniform distribution) and assess the impact of this uncertainty on the overall uncertainty in the BAF value? For some cases, such as the conversion of agricultural land to biomass production from perennial crops, leakage may be described as likely increasing net emissions. In cases such as this where prior research has indicated directionality, if not magnitude, usch information should be used. As previously noted, there is also a consistency issue with the reference year approach because leakage estimates implicitly assume an anticipated baseline approach of some sort.

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

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

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

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

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

Lastly, if BAF is not under the control of the facility, it would introduce considerable uncertainty for the facility if the BAF were recalculated frequently. If the goal of a policy using this framework was to reduce greenhouse gas emissions, an overly costly or burdensome accounting framework might not achieve that goal.

However, if the accounting is infrequent, shifts in the net greenhouse gas impact may not be captured.

4.5. Is it simple to implement and understand?

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

Much more detailed information is required about how the *Framework* would be implemented. For example, the specific data sources and/or models to be used and frequency of updating calculations and crediting as discussed under other sub-questions. To assess the adequacy of data, more information is needed on implementation and the degree of uncertainty acceptable for policymakers to assign BAF values.

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

As mentioned in response to Charge Question 4.2, the *Framework* uses a reference year baseline approach to determining BAF. In the case of long recovery feedstocks such as the use of wood biomass for energy, this makes the estimation of LAR scale specific and prevents the determination of any incremental or additional impact of the bioenergy facility on emissions. An alternative approach to gauge the difference in greenhouse gas emissions associated with the use of forest-derived woody biomass would be to adopt the anticipated baseline approach of estimating a “business as usual” trajectory of emissions and comparing it with a trajectory that incorporates bioenergy. The anticipated baseline approach should be applied to determine changes in forest stocks due to the use of forest material for bioenergy as well as to determine the changes in land use and soil carbon for all types of feedstocks.

In developing this anticipated baseline for forest materials, it is important to distinguish between three broad categories of wood biomass for energy: (a) logging residues from roundwood harvested solely for timber or pulp, (b) roundwood harvested solely for bioenergy and (c) mixtures of logging residues (a) and roundwood (b) where it is difficult to distinguish between logging residue and pulpwood harvested for energy. Sathre (2011) argues that as long as wood biomass for fuel has low value relative to other products it is unlikely that forest sites will be harvested solely for fuel. Wood being removed for fuel from these operations can be considered logging residue for estimating BAF. However, it may be necessary to specify guidelines for distinguishing logging residue from pulpwood harvested for bioenergy.

In the case of logging residues, it is arguably reasonable to assign them a BAF equal to zero because they could be considered “anyway” emissions over a time period relevant for attaining climate stabilization, e.g 100 or somewhat more years. More accuracy could be achieved by projecting the emissions from decay of those residues over time and comparing that to the biomass use case in which those residues are used for energy generation. For temperate climates, emissions from logging residue can be over 80% to near 100% within 100 years (Schlamadinger et al. 1995) (Palosuo et al. 2001). Factors that determine the extent of decay of logging residue (emissions versus C addition to soil) and the rate of decay include temperature, precipitation and type of decay fungi. Decay in very dry conditions is very slow, particularly for large logs. Conifers in the west tend to be decayed by brown rot fungi which do not break down lignin (about one-third of wood carbon). Hardwoods tend to be decayed by white rot fungi which break down all wood including lignin. (Jessie Glazer, personal communication). Forest Service FIA plot re-measurement data on dead and down wood for the East is currently being analyzed to estimate rates of wood decay and may help in estimating logging residue decay.

In the case of roundwood harvested solely for bioenergy, it is more important to incorporate the temporal dimension since their emissions remain in the atmosphere for some time before being captured by biomass regrowth. The anticipated baseline would be a projection of forest emissions in the absence of an increment in roundwood use for bioenergy while accounting for both natural and human disturbances in forests. This would require making assumptions about average growth rates, natural disturbances and landowner behavior. Integrated forest sector models such as the Forest Service RPA Forest Sector models or FASOM could be used to project cases with and without increased roundwood use for energy. This type of analysis would estimate both direct emissions from wood energy use and well as direct land carbon change (on land providing biomass) and indirect land carbon change (a form of negative leakage). U.S. forest and agricultural land carbon change could be estimated by models such as FASOM and the Forest Service RPA models include effects of changes in forest management intensity and forest land area. Indirect land use changes outside the US would require a using a global model. There would be many sources of uncertainty but alternate runs may be able to put boundaries on this uncertainty. Historically revenue provided for wood from forests has resulted in substantial investment to expand and increase forest growth and, based on this record, is an effect contained in projections by numerous forest sector models.

In the case of long recovery feedstocks, Cherubini (2011) provides a method to estimate the global warming potential (GWP_{bio}) of biomass harvested from a forest of given age and regrown to the same age. GWP_{bio} is the ratio of (a) cummulative radiative forcing (over a certain period) associated with an initial emissions minus absorption by forest regrowth and oceans divided by (b) cumulative radiative forcing of the initial emission alone with absorption by oceans). This could be a metric for LAR. This estimate would be appropriate if one could reasonably assume that the human caused disturbance of forest site will be limited after biomass harvest in the biomass use case, and the age of the timber at the time of harvest is known. In addition the estimate assumes for the BAU case that there would have been near term harvest for timber that would have limited growth. The estimate would need to be adjusted to assess variations in this assumption. Cherubini's method may be able to use FIA data on age of forest areas harvested to estimate an average GWP_{bio} / LAR. In addition to using Cherubini's method, FIA data might be used to see what recovery is made by actual FIA plots that have been harvested and remeasured.

One concern about the anticipated baseline approach is the uncertainty associated with a projection given potential future changes in markets, policies, technologies, and biophysical circumstances. Note that what is of interest here is the difference between two projections, i.e. whether carbon emissions increase or decrease as a result of using feedstock X. To the extent that each projection is driven by the same factors, the uncertainty of concern is only the uncertainty reflected in the delta between two projections. Presumably this would be lower than the uncertainty about a single projection. Unlike the reference year approach, the BAU baseline approach can provide an actual estimate of greenhouse gas change. The reference year approach does not even attempt to estimate changes, and will be prone to errors in either direction.

A general issue in being able to make LAR or BAF estimates for wood from forests is to identify combinations of limited conditions or plausibly assumed conditions for the BAU case and the biomass use case over time that allow a constrained estimate. Given a constrained estimate – such as the Cherubini method – we can assess the effect of varying the assumptions on LAR or BAF..

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

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

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

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

Potential for Unintended consequences: The proposed *Framework* is likely to create perverse incentives for investors and land-owners and result in unintended consequences. For investors, the regional baseline reference year approach will create regions that are one of two types — either able to support bioenergy from forest roundwood (up to the gain in carbon stock relative to the reference year), or not. As a result, a stationary source investor will only entertain keeping, improving, and building facilities using biomass from regions designated as able to support bioenergy. However, as noted previously, regions losing carbon relative to the reference year, could actually gain carbon stock in relative terms due to improved biomass use and management to meet market demands. In addition, the definitions of regions would need to change over time.

The designation of regions as able or not to support bioenergy that comes from the reference year approach will create economic rents and therefore financial stakes in the determination of regions and management of forests in those regions.

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

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

Charge Question 5

Case Studies

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.

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

Overall Comments

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

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

The case studies did not incorporate "real-world" scenarios which would have served as models for other situations that may involve biogenic carbon emissions. More would have been learned about the proposed *Framework* by testing it in multiple, unique case studies with "real world" data development and inclusion. The current set of case studies did not fully cover the relevant variation in feedstocks, facilities, regions, etc. of potential BAFs that would be required to evaluate the methodology. Among other things, additional case studies for landfills, switchgrass, waste, and other regions are necessary, as well as illustrations of the implementation of feedstock groups, and framework alternatives.

For example, Case Study 4 considers a scenario where corn stover is used for generating electricity. While it is possible that this particular scenario could be implemented, for the present time and maybe into the future, this particular case study does not mirror a "real world" case in that very few if any electrical generation facilities would combust corn stover or agricultural crop residues only. A more likely scenario might be a co-firing facility with a fossil fuel at low percentages. Additionally, the assumptions made in this case about biomass yield and the rate of growth of yield are not realistic. The yield of corn stover is expected to vary considerably across the region expected to supply biomass to a facility and to grow over time and not be uniform as assumed in the Framework.

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

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

There remained considerable uncertainty in many of the inputs. In addition, some sensitivity/uncertainty analysis would be useful. The results of this analysis may guide EPA in further model development. For example, if the BAF is determined to be zero, or not statistically different from zero in most case studies, then this could pave the way for a simpler framework. As discussed in Section XS, a simpler framework based on categorization of feedstocks could be designed to identify cases where biomass to energy generally results in a BAF of 0, 1 or something in between.

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

The major recommendation is additional case studies be performed and that these case studies be designed to describe actual or proposed biomass to energy projects where the framework would be used based on "real-world" situations of biomass development, production, and utilization.

For example, Case Study 1 describes the construction of one new plant. What would happen if ten new plants were to be proposed for a region? In each case study, we would like to see development of the required data and an assessment of whether data development can be standardized and/or simplified. And how would the introduction of multiple facilities at the same time impact the accounting for each facility? We support the suggestion in the report that look-up tables be developed. However, only by trying to develop these look-up tables can EPA assess whether this is workable.

All terms/values used to determine the BAF need to be referenced to actual conditions throughout the growth/production/generation processes that would occur in each case study including how these values would actually be implemented by one or more parties/entities involved.

Examples of needed case studies could be perennial herbaceous energy crop, 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 and assessments across alternative regions that represent distinctly different types.

For example it would be very useful to consider the application of this framework to a cellulosic ethanol plant fueled with coal or gas, and consider the emission of CO_2 from fermentation (not combustion) and the production of ethanol which is rapidly combusted to CO_2 in a non-stationary engine. There are three major sources of CO_2 emissions (list them here), but only one is included in this framework, only two may be considered under the clean-air action, but all three are emissions to the atmosphere. This lack of internal consistency makes the evaluation difficult.

Among the case studies, we suggest that there be two on municipal solid waste. One case study should be on waste combustion with electrical energy recovery. Here, as described in the report, a BAF of zero is appropriate and this case study is quite simple. EPA should also perform a case study on landfill disposal of municipal solid waste. Here it is important to recognize that landfills are repositories of biogenic organic carbon in the form of lignocellulosic substrates (e.g., paper made from mechanical pulp, yard waste, food waste). There is literature to document carbon storage and EPA has recognized carbon storage in previous greenhouse gas assessments of municipal solid waste management. There are potentially also avoided CH_4 decomposition emissions that need to be accounted for.

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) whether the results make sense and achieve appropriate results with respect to biogenic CO_2 emissions (2) the ease with which data were developed and the model implemented, and (3) whether the results are robust and useful in recognition of the uncertainty in the various input parameters, and (4) whether the model results lead to unintended consequences as discussed in response to charge question 4.7.

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

Charge Question 6

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.

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

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

Yes, the *Framework* contributes to advancing 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. The report covers many of the complicated issues associated with the accounting of biogenic CO_2 emissions from stationary sources and acknowledges that choices made in the *Framework* to address them 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 a scientific justification.

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

Clearly the *Framework* offers a mechanism to adjust total on-site emissions. For short recovery feedstocks, where carbon recovery and "anyway" emissions are within one to a few years (i.e., agricultural residues, perennial herbaceous crops, mill wood wastes, other wastes), the Framework could, with some modifications, accurately represent the direct carbon changes offsite however leakage, both positive and negative, remains a troublesome matter if left unresolved. However, the *Framework* offers no scientifically sound way to define a region for measuring LAR for forest biomass. 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 scientific foundation for using regional changes in carbon stocks to assign a BAF to the source.

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

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

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

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

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

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

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

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

Recommendations for Revising BAF

Overall, the SAB would prefer an alternative to the calculation of the BAF, given the daunting technical and implementation challenges associated with implementing the *Framework*. If EPA decides to revise the *Framework*, below we offer a summary of recommendations for specific improvements in the calculation of BAF.

1. Develop a separate BAF equation for each feedstock category. Many of the issues raised in previous responses regarding the treatment of specific factors included in the *Framework* are specific to particular feedstocks. The clarity of the *Framework* would be improved by differentiating among feedstocks based on how their management and use interacts with the carbon cycle. Feedstocks could be categorized into short rotation dedicated energy crops, crop residues, forest residues and long rotation trees. A BAF equation should be developed for each of these categories of feedstocks, preferably separating out "anyway" emissions feedstocks from those that have significant emissions.
    - Use an anticipated baseline approach for long recovery feedstocks like roundwood, employing integrated forest sector models and/or Cherubini's $GWP_{bio.}$(as discussed in Section 4.6).

    - Develop an equation for municipal solid waste to take into account the mix of biogenic waste with fossil fuel waste in combustion facilities as well as the possibility of methane capture in landfills (as discussed in Section 3.1).

2. Consider information about the directionality of leakage and leakage into other media (as discussed in Section 3.1).

3. Omit the regional scale and incorporate a time dimension (as discussed in Sections 3.1, 4.2 and elsewhere). Certain factors in the BAF equation should be modified to include the timescale over which carbon is decomposed or released back to the atmosphere. The variable that represents the proportion of emissions that are offset by sequestration during feedstock growth (LAR) needs to be modified to be scale insensitive and to address additionality.

Alternatives to BAF

Given the conceptual deficiencies and prospective difficulties with implementation, the SAB encourages EPA to "think outside the box" to search for an alternative to a categorical inclusion , exclusion or a facility-specific BAF. We offer the following three options for the Agency's consideration:

1. Develop a generic BAF for each feedstock category.
2. Consider certification systems.
3. Consider offset systems.

Option 1: Develop a generic BAF for each feedstock category. An alternative to revising the *Framework* and calculating a BAF for each stationary facility is to develop general BAFs for each category of feedstocks, differentiating among feedstocks using general information on how their harvest and combustion interacts with the carbon cycle. Feedstocks could be categorized into short rotation dedicated energy crops, crop residues, forest residues, long rotation trees and waste materials. Special attention should be given by which feedstocks could be classified as "anyway" emissions so that their BAF would automatically be either set to 0 or modeled as a decay function. For longer recovery feedstocks, EPA would need to use forest growth models to plot carbon paths that track regrowth following harvest or adopt a calculation of GWP_{bio} (as discussed in Section 4.6). Many more case studies would be needed to develop an accounting focused on feedstocks rather than the facility. These generic BAFs would be applied by stationary facilities to determine their quantity of biogenic emissions that would be subject to EPA's tailoring rule.

Option 2: Consider certification systems in a hybrid approach. This hybrid approach combined a categorical inclusion with an opt-out provision whereby facilities could opt out by certifying that their biomass was sustainably harvest and produced using best management practices. Such "sustainability" would need to be certified by an authority using valid scientific measurements. Requiring stationary facilities to use only "certified" feedstocks would be administratively simpler than quantifying a specific net change in greenhouse gases associated with a particular stationary facility. Certification apparoach can avoid the arbitrary scale issues and can perhaps avoid or reduce leakage. By making the stationary source responsible for demonstrating "sustainability", the source would be linked to its land base. This would remove the perverse situation of a responsible bioenergy facility, using feedstock produced in a highly sustainable manner, being penalized because it happens to be located in a region where other, less sustainable forest activities are causing carbon stocks to decline. It would also avoid the problem of a bioenergy facility that uses biomass harvested in an unsustainable manner benefitting from operating in a region where carbon stocks happen to be growing.

Option 3: Consider offsets. The use of offsets could accompany either Option 1 or Option 2 above or even a calculated BAF for each facility (using the *Framework*). An offset system would allow sources (e.g. a stationary energy producer) to contract with sinks (e.g. landowner) to offset their emissions through forest protection and regrowth or carbon accumulation in soils. Plants would need to meet a required BAF on an annual basis by acquiring carbon uptake credits equal to their emissions. Since the atmosphere is indifferent between emissions reductions and carbon accumulation, an offset need not be on a specific piece of land or even associated with the specific point source. Offsets would need to be certified by an authority using valid scientific measurements. Point sources could acquire certified storage credits, irrespective of their relationship to the point source. For example, a landfill, a forest product producer, or biomass waste energy generator could acquire credits for new production of lumber or paper products to offset carbon in forest products that went through them or to offset land fill emissions or stack emissions. Allowing flexibility in who could acquire these credits would encourage market forces to seek these out. As firms compete to acquire certified carbon uptake or storage a market will develop for these certified credits that will provide incentives for maintaining uptake/stocks consistent with requirements for credits. Measurement and certification can be based on observed carbon uptake or stock accumulation. These certifications can be over periods that make sense and need not be made daily or annually. If concern exists that stocks of soil carbon cannot be reliably estimated except over longer periods, then certifications may be limited to period of 5 or 10 years. A certification system would also allow stationary source fossil emitters to compete for biogenic credits.

References --- to be compiled