1. EXECUTIVE SUMMARY

The EPA requested the SAB to peer review a revised science-based framework for accounting for biogenic carbon emissions, which the agency defines as "CO_2 emissions related to the natural carbon cycle, as well as those resulting from the combustion, harvest, digestion, fermentation, decomposition, or processing of biologically based materials."[1] The EPA's November 2014 *Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources* is a sequel to its 2011 Framework, which the SAB reviewed in 2012. The goal of the 2011 Framework was to provide the analytical foundation for making determinations about the estimated net atmospheric CO_2 contribution from the production, processing and use of biogenic feedstocks at stationary sources. The goal of the 2014 Framework is to evaluate biogenic CO_2 emissions from stationary sources that use biogenic feedstocks, given the ability of plants to remove CO_2 from the atmosphere through photosynthesis.

Importance of the Policy Context

For its review of the 2011 Framework, the SAB requested and was given a policy context for the biogenic CO_2 accounting framework. The SAB was told that the 2011 Framework was intended to guide the determination of CO_2 emissions from regulated stationary sources under the Clean Air Act, specifically those facilities receiving a prevention of significant deterioration (PSD) air permit that were required to conduct a best available control technology (BACT) analysis for CO_2 emissions. The question before the agency and hence the SAB, was whether and how to consider biogenic greenhouse gas (GHG) emissions in reaching thresholds for permitting and decisions about BACT for CO_2 emissions from bioenergy. The agency has removed this policy context from its 2014 Framework, and the EPA's charge questions seek general guidance on issues related to the choice of temporal, spatial and production scale for determining Biogenic Assessment Factors (BAFs) in a policy-neutral context. This change hampered the ability of the SAB to assess the suitability of the 2014 Framework for use as a science-based regulatory framework. In fact, the lack of information in both Frameworks on how the EPA may use potential BAFs made it difficult to fully evaluate these frameworks. As we stated in our 2012 report and we reiterate here: this SAB review would have been enhanced if the Agency offered a specific regulatory application that, among other things, provided explicit proposed BAF calculations and defined its legal boundaries regarding upstream and downstream emissions in the feedstock lifecycles. A policy context would have provided information on the boundaries regarding upstream and downstream emissions in the feedstock life cycles, the spatial boundaries for assessing emissions associated with a stationary facility; the potential scale of demand for biogenic feedstocks, the time profile for that demand and whether to incorporate the emissions of all greenhouse gases or only CO_2 emissions.

As an example of why the policy context is so important, if the purpose of performing carbon accounting with the proposed Framework is to account for the emissions of all greenhouse gases then it will be important to account for the effect of biogenic feedstocks on non-CO_2 gases such as N_2O and CH_4, and to examine how these effects differ across feedstocks and influence their BAF values. Estimates of the BAFs will also depend on projections of the additional demand for biomass relative to a reference baseline scenario (i.e., a baseline without increased demand for bioenergy). This additional

[1] http://www.epa.gov/climatechange/ghgemissions/biogenic-emissions.html

demand could be generated by various renewable energy and low carbon regional and federal regulations within the US. Outside the U.S., policies such as renewable and low carbon regulations in Europe and other countries that create a demand for biomass exports from the U.S. would also have to be considered and represented in the reference scenario.

Region- and Feedstock-Specific BAF Calculation

As recommended previously by the SAB, BAFs should be feedstock-specific and region-specific and not facility-specific. Facility-specific BAFs are conceptually and practically challenging to estimate due to the absence of well-defined spatial boundaries for feedstock supply to a facility and the potential for market-induced spillover (indirect) effects on land use, biomass production, and diversion from non-energy uses and carbon stocks across space. To obtain a region-specific BAF for a feedstock, it will be necessary to project region-specific, feedstock-specific demand for biomass and to assess the impact of this increased demand for biomass on net carbon stocks. These projections require simulation models that integrate biophysical and economic models and can capture behavioral and biophysical dynamics and their interactions over time.

This integrated region-specific approach is particularly appropriate for land that is managed to maximize the returns to land by its owner for commercial purposes. Since demand for bioenergy can be met by a wide range of agricultural and forest feedstocks that have long life-spans, a dynamic, integrated model that includes both the agricultural and the forestry sectors, competition between land use activities, investment decisions that consider potential future returns (especially for slower growing, long rotation feedstocks) and a large number of spatially distinct regions (while keeping the model tractable) would be appropriate. An integrated model would allow for land use to change in response to changes in the relative returns to land. This model can be used to construct an anticipated baseline that simulates the future “without” increased bioenergy scenario and to compare it with the projected effects of an increased demand for biomass on CO_2 emissions. The Forestry and Agricultural Sector Optimization Model (FASOM) used by the EPA for its illustrative BAF estimates in the 2014 Framework has the above features. The model can incorporate the effects of export and import of biogenic feedstocks on crop and forest biomass production and land use in the US. In general, the land base covered by the model is the one that responds to market signals. For feedstocks obtained from land managed with other objectives, ecological models may suffice to assess the effects of using those feedstocks for bioenergy on carbon stocks.

In general, the BAF of a feedstock should be estimated for the average effect of the last increment of demand for that feedstock to reflect the feedstock’s impact on carbon emissions at the margin. To be consistent with reality, changes in aggregate demand for biomass feedstocks should be bounded by historical data on resource use, observed information on current and planned expansions to facilities using biogenic feedstocks, and information about existing and projected establishment of stationary facilities likely to use biogenic feedstocks. Since BAFs will differ for different levels of demand for a feedstock, modeling exercises could also be undertaken to determine feedstock-specific demands and BAF thresholds for different levels of the demand for a feedstock.

Since the BAF for a feedstock could differ depending on the method of production (for example, the soil carbon implications of corn stover will depend on the type of tillage practice used and the amount of residue harvested), it will be appropriate to have the BAF for a feedstock in a region vary by feedstock

production method. To the extent that BAFs depend on technology and emissions control regulations at a stationary electricity-generating facility in a region, they could be made technology specific.

In sum, the BAF can vary by feedstock, by region, by feedstock management practices and by the technology and emissions controls used at the electricity-generating facility.

Future Anticipated Baseline Approach

The BAF is an accounting term developed in the Framework to denote the offset to total emissions (mathematical adjustment) that reflects a biogenic feedstock's net carbon emissions after taking into account its sequestration of carbon, in biomass or soil, or emissions that might have occurred with an alternate fate had it not been used. It is a ratio of the feedstock's net biogenic carbon emissions compared to total carbon emissions and its value can change over time. To compare changes in any system over time there must be a reference scenario (without demand for bioenergy) against which to assess changes due to increased demand for bioenergy, so that two distinct scenarios can be compared. In our 2012 SAB report, the SAB stated that the reference point baseline approach is inadequate in cases where feedstocks accumulate over long time periods because it does not estimate the *additional* effect of a stationary facility's combustion of biomass on carbon emissions over time. The reference point baseline approach takes a given initial carbon stock level and simply compares "before" and "after" carbon levels over time without attributing carbon stock changes to particular causes. In 2012, the SAB recommended a future anticipated baseline approach to capture the *additional* CO_2 emissions to or uptake from the atmosphere created by any increased use of biomass for energy (i.e., the "increased biomass feedstock demand scenario"). The EPA acknowledged this limitation of its earlier approach and now includes a future anticipated baseline analysis along with a reference point approach in its 2014 Framework. The SAB remains concerned that the reference point approach has important limitations and should not be the preferred approach.

The SAB's 2012 advice on the anticipated baseline approach recognized that sophisticated modeling is needed to capture the interaction between the market, land use, investment decisions, emissions and ecosystem feedbacks and to construct a counter-factual reference scenario. For some of its alternative BAF calculations, EPA's 2014 Framework employs a future anticipated baseline approach consistent with our earlier recommendations. In the 2014 Framework, the EPA has offered illustrative simulations of future biophysical and economic conditions employing the Forestry and Agricultural Sector Optimization Model (FASOM) to determine the incremental GHG emissions of increased biomass feedstock demand compared to a "business as usual" approach (i.e., the reference baseline scenario without demand for bioenergy). The EPA's case studies applied the future anticipated baseline approach on a regional basis to Southeastern roundwood, Corn Belt corn stover and Pacific Northwest logging residues, however none of its charge questions were feedstock specific.

Modeling Approach

The EPA used the FASOM model for its illustrative BAF estimates in the 2014 Framework. While this model has the appropriate features for calculating region-specific, feedstock-specific BAFs, the agency should provide more details regarding its plans to conduct model validation, evaluation, justification, and sensitivity analysis. Regardless of the model chosen, model validation and evaluation will be critical. Model validation is informative about the model's ability to replicate observed phenomenon at

the starting point of the study period. Model validation should also be conducted to understand the model sensitivity to input parameters and assumptions as well as to provide insight into the time frame for BAF updates within different policy frameworks. Illustrative analyses in Appendix E show that the BAFs are fairly robust to assumptions that affect both the reference scenario and the increased biomass demand scenario because they are based on the difference of the two scenarios and any trends they share are cancelled out. BAFs are also somewhat insensitive to the magnitude of the loss of carbon caused by harvests. This is due to the fact the BAFs are ratios (of the net biogenic carbon effect to the gross emissions by the facility) and increased loss of carbon is related to the emissions from feedstock combustion: while more harvest can mean more net loss of carbon, it also means more gross emissions.

Model evaluation can usefully elucidate the role of model features, such as spatial scope and resolution, linked agricultural and forest markets and land use change, economic dynamics (time frame, anticipatory planting/management), commodity resolution (where the ability to model feedstock types is affected), and biological dynamics (agricultural crops and productivity, forest biology, forest management practices) in influencing the BAF obtained. For example, a feature of intertemporal optimization models like FASOM that could have implications for BAF estimates is that landowners are assumed to make investment decisions based on expected current and future economic returns and engage in anticipatory planting and management if economical to do so given expected future biomass demand. This assumption could imply that an increase or decrease in demand for biomass feedstocks translates into increased or decreased investments in feedstock production that satisfy expected demand in the future. Accordingly, an increase in demand for a long-rotation feedstock may lead to a low BAF with the analytic assumption of long planning horizons. This assumption, along with other model features listed above, should be evaluated when justifying alternative modeling approaches; thus assessing the actual planning horizon of landowners is important. Other assumptions that should be examined include those related to productivity growth, the dynamics of carbon in various pools, the modeling of agriculture-forest land competition, and the disaggregation and characterization of biomass feedstocks. Over time, the model selected for estimating BAFs should be reviewed and updated periodically using observed changes in economic and land use conditions due to increased biomass demand, and the latest scientific information on biophysical and biogeochemical properties of feedstocks.

Alternate Fate Approach for Waste-Derived Feedstocks

In 2012, the SAB recommended that the EPA consider the alternate fate of waste-derived feedstocks diverted from the waste stream, whether they might decompose over a long period of time, whether they would be deposited in anaerobic landfills, whether they are diverted from recycling and reuse, etc. In the 2014 Framework, the agency has conducted extensive alternate fate calculations (in Appendix N); however, the EPA drew a narrow boundary around point source emissions and neglected other significant considerations that affect the greenhouse gas footprint of alternative municipal solid waste (MSW) management scenarios. Other greenhouse gases are particularly relevant in the case of waste-derived feedstocks. This illustrates one of the problems caused by the 2014 Framework's sole focus on CO_2. Specifically, the EPA neglected to recognize and quantify a potential alternate fate of MSW, in particular, its current use for electrical energy generation by capturing landfill gas or direct combustion. EPA also failed to consider carbon storage associated with landfills, and selected a landfill baseline that is inconsistent with regulatory practice. The relative rankings of BAF values across waste treatment options in the 2014 Framework would change considerably if current energy recovery uses were

considered. The 2014 Framework clearly includes methane associated with municipal solid waste feedstocks but it omits current electrical energy recovery from both landfills and combustion, as well as carbon storage associated with landfills. While we recognize that inclusion of electrical energy offsets would be inconsistent with the system boundaries described by EPA in the 2014 Framework, failure to account for these offsets has the potential to lead to inferior technology choices in consideration of all greenhouse gas emissions. In addition, when non-CO_2 greenhouse gases (such as methane) are a part of any projections of carbon emissions into the future, as may be the case for waste feedstocks, estimation of the BAF could be modified to account for the cumulative effect of these gases as with CO_2. For example, the BAF could be modified to account for methane emissions for woody mill residuals.

Temporal Scale and the Future Anticipated Baseline Approach (Charge Question 1)

Charge question 1 and its subparts pertain to the temporal scale and the anticipated baseline approach to calculating a BAF. The 2014 Framework is an improvement over the 2011 Framework with respect to the treatment of temporal issues and the development of the future anticipated baseline approach.

A sustained increased demand for bioenergy by stationary facilities in a region is likely to trigger changes in carbon stocks through one or more pathways that could generate a new (steady-state) equilibrium stock of carbon that may be higher or lower than the current stock of carbon on the land. The demand for biomass for bioenergy can affect carbon stocks by increasing harvesting intensity for standing biomass, diverting biomass from other non-energy products and landfills, converting land from other uses to plant feedstocks for biomass in the future, and utilizing residues that might otherwise decay. The overall impact of all these responses to the increase in demand for biogenic feedstocks by stationary facilities on carbon stocks between the increased biomass feedstock demand scenario and the reference scenario could vary over time, depending on factors such as the mix of feedstocks demanded, the scale of demand, the ease of land conversion from one use to another. The use of each of these sources of biomass for bioenergy may differ in the direction of their impact on carbon stocks depending on whether one focuses on the near term or the long term. To capture these time varying impacts of a feedstock on carbon stocks, the Panel recommend an approach for computing a cumulative BAF that accounts for nearly all the positive and negative impacts on emissions over time to determine the net biogenic effect. A cumulative BAF that aggregates changes in carbon stocks over time is preferable to an instantaneous (or annual) BAF because the use of biogenic feedstocks can trigger changes in terrestrial carbon stocks that can last longer than the period in which the feedstock is consumed by a stationary facility. The SAB expressed concern that for some types of policy initiatives that consider shorter time horizons it may be inappropriate to use a BAF calculated to incorporate all or nearly all carbon stock effects over time. SAB members would favor selecting the time horizon for calculating the BAF to comport with the policy time horizon under consideration. To accommodate such cases, the presented methods enable a BAF to be calculated for any selected time horizon. The selection of a time horizon for calculating the BAF is an issue for which it was not possible to reach full consensus between the Panel and the chartered SAB. The Panel recognizes that policy-makers may choose a different time horizon than the one recommended by the Panel. If so, that would imply leaving out expected future carbon stock changes relevant to climate change. In such a case, the carbon accounting implications should be calculated and clearly communicated.

To ensure comparability of BAFs across all feedstocks and regions we recommend using the same time horizon, T, for all feedstocks and regions. The scientifically appropriate temporal scale would be

determined by modeling the mechanisms by which increased demand for bioenergy by all stationary facilities in a region affects carbon stocks. The net biogenic effect will be the difference in carbon stocks between the increased biomass feedstock demand scenario and the reference scenario. By selecting a shorter time horizon that does not capture all effects, the cumulative effects on carbon stock would be truncated, and could be over-estimated or under-estimated relative to those at the steady-state level. This could result in an upward or downward bias to the cumulative BAF of all feedstocks. Selecting different time horizons for different feedstocks would also be an arbitrary choice that is inconsistent with the fact that carbon emissions generated by all feedstocks are equivalent in their impact on the climate.

We recognize that policy-makers may choose a different time horizon from the T that incorporates nearly all effects over time. If so, that would imply leaving out expected future carbon stock changes relevant to climate change. In such a case, the carbon accounting implications should be calculated and clearly communicated. BAF calculations will require integrated economic-biophysical modeling to estimate expected changes in carbon stocks over time from increasing biomass demand for energy.

In the absence of a policy construct, concern about many potential impacts of biogenic feedstocks were raised by commenters, including effects on forest conservation, biodiversity and ecosystem services. The SAB considers these out of scope for the Framework and thus for this review because the SAB was charged narrowly with reviewing the scientific appropriateness of the Framework for quantifying the adjustment to smokestack carbon emissions from stationary facilities using biogenic feedstocks. The SAB recommends EPA make the boundaries of the assessment more clear in the Framework by specifying a policy context, providing example BAF calculations, and clearly defining boundaries for EPA's regulatory authority.

As an additional caveat, the SAB is aware that this report is focused on greenhouse gases only. In considering the use of biomass for electricity generation, we only considered the risks of adding carbon to the atmosphere in accordance with our charge from the EPA. We did not evaluate other concerns like forest conservation, biodiversity and ecosystem services. If, for example, biomass pellets were ever sourced from old growth forests, that would pose unique risks that would not be reflected in a BAF calculated for greenhouse gases. We offer this caution about the boundaries of our review along with a recognition that biodiversity and ecosystem health are valid concerns worthy of a whole different analysis and policy response.

Stock-Based Accounting Preferred to Emissions-Based Accounting

Before discussing two cumulative BAFs, we first propose a shift to carbon accounting based on changes in carbon stocks on the land rather than changes in carbon emissions (as used in EPA's 2011 and 2014 Frameworks). The SAB's proposed alternative formulation offers a prototype equation with terms for stocks in biomass (i.e., live stocks, dead stocks, soil stocks, product stocks and waste stocks). A key feature of using carbon stocks is that all terms can be readily aggregated or disaggregated and are still subject to mass balance. The new stock-based framework presented in Appendix B and graphically illustrated in Appendices C and D would be scale and process invariant as it could be used for a stand, plot, fuel shed, landscape, or region (see Appendix E for how the stand and landscape levels relate to each other). It would comport with the current conventions in carbon accounting, which essentially use input-output tracking of carbon throughout the system with well-defined boundaries. In contrast to the 2014 Framework equation, which mixed together net fluxes and correction terms, a stock-based

approach is based on the stocks in terrestrial pools. These stocks can be aggregated and rearranged as needed or further subdivided, but regardless will still follow conservation of mass and are subject to mass balance. In theory, a stock-based formulation should yield the same BAF as an emissions-based approach but the stock-based approach is simpler and more transparent. We conclude a BAF formulation based on carbon stocks is preferred over an emissions-based approach. While this alternative formulation provides benefits, there are still general issues that remain in estimating a BAF, including selecting appropriate temporal or spatial boundaries, considering variability within a class of feedstocks, the possibility of irreversible land use change, accounting for non-CO_2 greenhouse gases such as nitrous oxide and methane, and quantifying stocks and fluxes that are difficult to measure or estimate.

Two Cumulative BAF Approaches

We recommend consideration of two alternative approaches to calculating a cumulative BAF (Appendix B). The first is EPA's cumulative BAF (which we designate as BAF_T) that computes the difference in carbon stocks *at the end of the time horizon T*. The second alternative was developed by members of the Biogenic Carbon Emissions Panel. It considers the time course of CO_2 emissions by accumulating the annual differences in carbon stocks on the land *over the time horizon T*. By accumulating annual differences across the projection period, the alternative cumulative BAF metric (which we designate as $BAF_{\sum T}$) attempts to incorporate "residence time" in the sense that it is a proxy for the amount of time carbon stays in the atmosphere until it is modified by changing stocks of carbon on the land. Mathematically, the $BAF_{\sum T}$ formulation can be thought of as "ton-years" to account for changes in carbon stocks *year to year*.

The appropriate biophysical measure of BAF can be informed by the scientific assessment of the dynamics of additions to atmospheric carbon stocks and mechanisms by which changes in atmospheric carbon stock affect the climate (assuming that is the effect of interest). The effect of changes in long run equilibrium carbon stocks can be captured by BAF_T while the transitional effects on carbon stocks are proxied by $BAF_{\sum T}$. Consideration of the effect of timing of biogenic emissions on the climate hinges on the scientific assessment of the mechanisms by which carbon emissions affect global temperature, sea-level rise, oceanic acidification and other natural systems. Climate focused studies conclude that it is cumulative emissions over a very long period that determine the climate response and that different emissions pathways with the same cumulative emissions are likely to produce to a similar global temperature response (Allen, et. al. 2009; Matthews, et. al. 2009; Zickfield et al., 2012). However, we recognize that some policy contexts require an accounting of emissions over a shorter time frame. Effects of rising carbon stocks in the atmosphere on other natural systems, such as ocean acidification, may occur over different time scales (Zickfield et al., 2012. Carbon cycle dynamics and uncertainties (e.g., decay, uptake, feedbacks, and transient climate response) are important issues in choosing between the two cumulative BAFs.

Both cumulative BAFs attempt to capture net biogenic carbon emissions in a biophysical sense only. Although we recommend that the BAF be calculated for a time horizon long enough to account for the large majority of changes in terrestrial carbon stocks, we note that both BAF measures (BAF_T and $BAF_{\sum T}$) should be calculated for varying levels of T to examine their time paths. If the time path of carbon stock changes between the reference scenario and increased biomass feedstock demand scenario is of particular interest, then $BAF_{\sum T}$ will provide this information for any time horizon of interest. The

SAB acknowledges the difficult questions raised by public commenters who pointed out the uncertainties associated with future sequestration (carbon uptake), the possibility of tipping points, irreversibilities and feedback effects and the need to provide incentives for technological change.

The policy urgency of greenhouse gas reductions should be reflected in the selection of policy tools that directly target emissions and the stringency of those policies. Such policy tools include emissions caps, technology standards, efficiency standards, carbon pricing and other approaches. By contrast, we were asked to advise EPA on emissions accounting, specifically scientific considerations that should guide the estimation of the BAF for bioenergy feedstocks. We have presented two versions of the cumulative BAF; both capture the dynamics of carbon stock changes but differ in their temporal emphasis. It is important to note that the BAF is not a complete carbon accounting method and that neither BAF approach offers a complete life cycle assessment of the climate effects of biomass use.

Scales of Biomass Use and the Future Anticipated Baseline Approach (Charge Question 2)

Charge question 2 and its subparts were entirely devoted to very narrow technical considerations concerning how to select model perturbations in biomass demand ("shocks") for the anticipated future baseline simulations to estimate the net atmospheric contribution of biogenic CO2 emissions. Some of these questions were difficult to answer in the absence of information about programmatic goals, legal boundaries, implementation details, and specific BAF calculations. Some questions in this section would have been better framed by specifying a policy context that could be indicative of the likely scale of aggregate demand for biomass, which could, in turn, influence the methods for producing feedstocks. Noting these limitations also limit the value of our responses, the SAB provides thoughts on the questions.

The EPA asked for general recommendations on the scale of demand change that should be used in a model for the future anticipated baseline approach. Typically, biomass demand changes should be modelled in response to particular policy scenarios like the Clean Power Plan or multiple policies likely to be implemented simultaneously that create incentives to use biogenic feedstocks, e.g. the Renewable Portfolio Standard, the Renewable Fuel Standard, etc. One approach would be to model the aggregate demand for biomass and the feedstock and region specific demands for biomass likely to be generated by a specific policy (or policy mix). Alternatively, the aggregate demand for biomass could be specified in a policy neutral context at various incremental levels (e.g., 1 million tons, 2 million tons, 3 million tons) and in each case the feedstock-specific and region-specific demands and corresponding values of the BAF could be determined by the integrated biophysical-economic model.

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For any given change in total demand for biomass, the demand for individual feedstocks should be determined endogenously within the integrated biophysical-economic model so that it is economically viable and constrained by the joint production function that determines the supply of a feedstock produced jointly with another crop with a market-determined demand. An analysis of the implications of assigning BAFs to feedstocks on the mix of feedstocks demanded and its subsequent implications for BAFs should be conducted to determine the robustness of the BAFs assigned to specific feedstocks.

In addition, a retrospective evaluation of the observed level of demand and mix of feedstocks would allow revisions to EPA's estimates of feedstock demand changes based on updated data. To evaluate the performance of a BAF retrospectively, quantities of biomass feedstock used by stationary sources could be updated and projections about biomass demand could be revised based on actual outcomes. While a BAF may be calculated using a long time horizon (e.g., multiple decades), assuming that forest and land management practices will be maintained over that period, it will need to be updated periodically to incorporate changes in market conditions, land use and land cover and short-term and long-term policies.

Summary of Major Conclusions and Recommendations

The EPA's 2014 Framework has advanced biogenic carbon accounting and offered improvements over its 2011 Framework. As captured in the 2014 Framework, the anticipated baseline approach to calculating BAFs, while subject to implementation difficulties and all the uncertainties associated with modeling the future, represents an advance in biogenic carbon accounting. In the hopes of further advances, the SAB offers the following summary of our conclusions and recommendations.

1. For full scientific evaluation of a biogenic carbon accounting approach, beyond our recommendations for the basic form of the BAF metric, the EPA should specify a specific policy context in which BAFs will be used, propose specific BAF calculations and values, and specify its legal authorities over upstream and downstream emissions as well as the spatial boundaries for assessing emissions associated with a stationary facility. It is also important to have more clarity on underlying expectations about other prevailing land use management, renewable energy and carbon policies both in the US and in other countries that could impact the demand for and choice of feedstocks and their production methods and thus the estimates of their BAF.

2. The SAB recommends a BAF formulation based on changes in carbon stocks (terrestrial pools such as live, dead, soil, products, material lost in transport and waste), rather than an emissions (flux-based) approach, because it comports with conventional carbon accounting, has well-defined boundaries, and follows conservation of mass as well as mass balance.

3. The direction and magnitude of the impact of a feedstock on terrestrial carbon stocks depends on the time horizon considered. A cumulative BAF is preferred because it will capture and integrate all expected negative and positive carbon effects. Based on carbon cycle science, we recommend that the time horizon for calculating a cumulative BAF is the time period over which nearly all (e.g., >95%) of terrestrial effects on the stock of carbon are expected to occur in response to a sustained increase in the demand for bioenergy and the net change in carbon stock stabilizes. Choosing a shorter time horizon will truncate carbon stock effects.

4. The SAB suggests consideration of two cumulative BAF metrics—that proposed by EPA and an alternative metric that takes into account the changes in terrestrial carbon stocks over time. The appropriate cumulative metric for calculating BAF will depend on the understanding of the carbon system and the relevant physical response. We have presented two versions of the cumulative BAF that both capture carbon stock changes but differ in their temporal emphasis with $BAF_{\sum T}$ emphasizing near term changes and BAF_T emphasizing changes at the end of the time period.

5. EPA should identify and evaluate its criteria for choosing a model and modeling features that affect BAF outcomes, including both model structure and assumptions about economic and biophysical parameters. EPA should explore the sensitivity of BAF to different modeling assumptions. EPA should also update and validate the model to incorporate the latest scientific knowledge while ensuring that the model outcomes are consistent with the observed reality.