UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

March 5, 2019

EPA-SAB-19-002

The Honorable Andrew R. Wheeler
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, D.C. 20460

Subject: SAB review of *Framework for Assessing Biogenic* CO_2 *Emissions from Stationary Sources* (2014)

Dear Administrator Wheeler:

The EPA Science Advisory Board (SAB) was asked by the EPA Office of Air and Radiation to review and comment on its *Framework for Assessing Biogenic* CO_2 *Emissions from Stationary Sources* (2014) ("2014 Framework"). The 2014 Framework considers the scientific and technical issues associated with accounting for emissions of carbon dioxide (CO_2) from biogenic feedstocks used at stationary sources.

The purpose of the 2014 Framework was to develop a method for calculating the adjustment, or Biogenic Assessment Factor (BAF), for CO_2 emissions associated with the combustion of biogenic feedstocks at stationary facilities by accounting for the biological carbon cycle effects associated with growth, harvest, and processing of these feedstocks. The BAF is an accounting term developed by EPA to adjust stack emissions to reflect a feedstock's *net* carbon emissions after accounting for subsequent sequestration of carbon in regrown biomass or soil, and after considering emissions that might have occurred with an alternate fate had the biomass not been used for fuel.

The SAB notes that EPA's 2014 Framework may be used to develop BAFs for multiple regulations and associated climate objectives (e.g., total emissions versus temperature, etc.); it therefore must be able to accommodate a wide range of potential time and spatial scales and all relevant GHGs. Lack of specificity in the BAF objectives to be addressed under the Framework has made it difficult for the SAB to address many of the charge questions fully.

EPA's 2014 Framework is a revision of its 2011 Framework, which the SAB previously reviewed. The SAB notes that the 2014 Framework incorporated some of the SAB's prior advice and advanced the analytical foundation for making determinations about the net contribution of biogenic feedstocks to

CO_2 in the atmosphere. Specifically, the 2014 Framework has incorporated the SAB's prior advice as follows:

- It adopted an alternative fate approach (i.e., a counterfactual evaluation of what the net biogenic atmospheric contribution might have been if the feedstocks were not used for energy) to the collection and use of waste-derived feedstocks, including avoided methane (CH_4) emissions.
- It included a discussion of the trade-offs inherent in the selection of a temporal scale for considering net emissions.
- It developed representative BAFs by feedstock and region rather than facility-specific BAFs.
- It included a review of existing approaches to addressing leakage, the phenomenon by which efforts to reduce emissions in one place affect market prices that shift emissions to another location.
- It offers an approach to construct an anticipated baseline that allows assessment of the additional CO_2 emissions to, or uptake from, the atmosphere that can be attributed to biogenic feedstocks as a result of changes in biomass feedstock demand.

The 2014 Framework does not, however, provide the regulatory context, specific BAF calculations for that context, or the implementation details the SAB previously requested. 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. The BAF is a *construct* designed to evaluate the importance of the stack emissions of CO_2 at a given time relative to their climate impacts at some point in the future when some of the emitted CO_2 may have been sequestered by regrowth of biogenic feedstocks. As such, the computation of the BAF for a feedstock in a region depends upon the climate impact of concern and the future point in time that is of interest, which is a choice that depends upon the specific regulation or policy that will rely on that BAF. If the objective of interest for the BAF computation is defined by short term processes, then the relevant time-period for the BAF computation needs to include relevant details on short term climate phenomena, which might be less important if the objective of interest is much longer term. In addition to identifying the relevant analytic time frame, knowing the objectives of interest would provide other information necessary to the assessment of the science underpinning the BAFs, such as the scale of demand for biogenic feedstocks, the anticipated time frame for that demand and eligible feedstocks to meet it, relevant spatial scope, and importance of including each type of GHG in the analysis.

While the SAB agreed with many of the recommendations developed by the Biogenic Carbon Emissions Panel in previous drafts of the report, it disagreed with the extended time frame recommended for BAF computation. There was much discussion between the SAB and the Biogenic Carbon Emissions Panel over the significance of the time horizon used to calculate BAFs. The Panel recommended that a general principle for determining the time horizon for BAF calculations should be to select a time horizon that fully accounts for the temporal dynamics for all feedstocks to accommodate the Agency's preference for a regulatory or policy neutral approach. During quality reviews the SAB disagreed with this recommendation noting that for regulatory initiatives that focus on objectives that reflect shorter time horizons, a general model with a long time horizon may not adequately capture the net carbon dioxide emissions relevant to the nearer-term outcomes. The SAB favors selecting the time horizon for calculating the BAF to comport with the objective under consideration, which is generally dependent on the regulation mandating use of that particular BAF. The Panel's previous reports remain available on the SAB webpage.

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 objectives, which would in turn have defined the applicable boundaries regarding upstream and downstream emissions in the feedstock life cycles. The 2014 Framework lacks specificity and is written in a way that is too generic, with too many possibilities that would require assessment of different underlying science. Rather than offering a lengthy menu of calculation options, the EPA Framework needs to define its scenarios and justify those choices. This would enable the SAB to evaluate the science underpinning those decisions and justifications.

Despite this significant limitation, the SAB offers overarching suggestions for moving forward with a framework for assessing the BAFs of biogenic feedstocks. In addition, we offer specific responses to EPA's charge questions when possible and the SAB offers general guidance regarding the calculation of BAFs. EPA's equations were based on emissions (fluxes) with some adjustment terms to account for carbon mass escaping the system between the point of assessment and the point of emissions. In the enclosed report, the SAB recommends an alternative formulation based on changes in terrestrial (non-atmospheric) carbon stocks (or pools) such as the live stocks in biomass, dead stocks, soil stocks, etc., that explicitly incorporates the principle of conservation of mass. While the carbon-stock-based accounting system results in a formula for BAF similar to that of EPA's emissions-based approach, it offers multiple advantages: the component stocks are regularly inventoried and modeled by the scientific community; the different stocks can be aggregated and rearranged as needed or further subdivided; and it is appropriately constrained by conservation of mass and therefore the validity of the results can be assessed using mass balance calculations. Although this alternative formulation provides these benefits, other important modeling issues remain. These include selecting appropriate temporal or spatial boundaries, considering variability among classes of feedstocks, 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.

As an additional caveat, the SAB is aware that the EPA report and this review are focused only on accounting for CO_2 related to the use of biomass for electricity generation. Neither EPA nor the SAB evaluated other concerns like forest conservation, biodiversity, and ecosystem services. We offer this caution about the model boundaries as defined by EPA's method and identified in the SAB review. In addition, we recognize that biodiversity and ecosystem health are valid concerns worthy of a whole different analysis and policy response.

Finally, EPA did not ask the SAB for feedback on its modeling approach. We think this was an oversight, given that modeling is critical to the development of the BAF and different modeling approaches can yield different results. The 2014 Framework employed an integrated model that captures economic and biophysical dynamics and interactions for some of its alternative BAF calculations; however, EPA did not offer explicit justification for its modeling choices derived from articulated criteria. In addition, the sensitivity of BAF responses to some underlying features of the model was not examined by the EPA or the SAB. Thus, we conclude EPA should identify and evaluate its criteria for choosing a model or models and examine the sensitivity of BAF estimates to key modeling features.

The SAB appreciates the opportunity to provide advice on the 2014 Framework and looks forward to your response.

Sincerely,

/S/

Dr. Michael Honeycutt, Chair
Science Advisory Board

Enclosure

NOTICE

U.S. Environmental Protection Agency
Science Advisory Board

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Acronyms and Abbreviations

BACT	Best Available Control Technology
BAF	Biogenic Assessment Factor
BAU	Business as Usual
CH_4	Methane
CO_2	Carbon Dioxide
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
PSD	Prevention of Significant Deterioration
N_2O	Nitrous Oxide
SAB	Science Advisory Board
USDA	U.S. Department of Agriculture

1. EXECUTIVE SUMMARY

The EPA requested the SAB review a revised 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 goal of the 2014 Framework was to evaluate biogenic CO_2 emissions from stationary sources that use biomass feedstocks, given the ability of green plants to remove CO_2 from the atmosphere through photosynthesis. The 2014 Framework and its 2011 predecessor introduced the concept of a Biogenic Assessment Factor (BAF), which is the proposed adjustment for carbon emissions associated with the combustion of biomass feedstocks. The BAF is an accounting term developed in the Framework to denote the offset to stack emissions (using a mathematical adjustment) to reflect net carbon emissions after taking into account the sequestration of carbon in regrown biomass or soil, as well as emissions that might have occurred with an alternative fate had the biomass not been used for fuel.

Importance of Defining the Objective to Be Addressed by a BAF

The questions before the EPA in 2011 and presented for the SAB's review, were whether and how to consider greenhouse gas (GHG) emissions and decisions about best available control technology (BACT) for CO_2 emissions from biomass feedstocks used for electricity generation at stationary facilities. EPA proposed to address this issue by defining a term, Biogenic Assessment Factor, intended to be used to assess effects *relative* to the desired objectives. The 2014 Framework, however, removed the regulatory context, and did not include specific BAF calculations for any regulatory context, or the implementation details the SAB previously requested.

Because the EPA's 2014 Framework report does not identify the specific metric of climate impact (or "objective") with resulting regulations that a BAF estimate should reflect, BAFs that may be developed under the Framework could entail a wide range of objectives, e.g., temporal and spatial domains, total emissions, temperature, etc. While ideally it would be desirable to identify a universal methodology that could be applied to any of a wide range of potential objectives, doing so poses exceptional technical challenges and the concept was not endorsed by the SAB. Thus, the lack of specificity in the 2014 Framework document regarding the objectives that BAFs are expected to address made it very difficult for the SAB to assess whether the types of models, data, and baselines suggested by the Framework are appropriate, and has limited the ability of the SAB to fully address some of the charge questions. We thus preface the SAB's comments with an observation on the consequences of having made this revised 2014 Framework so unspecific with respect to its intended and potential applications. The SAB concluded that evaluation of EPA's plan for a science-based regulatory framework in the absence of defined regulatory objectives is not useful. Rather than assume a specific objective, or evaluate the charge questions across numerous putative objectives of interest, the SAB has focused on providing input on considerations that affect the usefulness and scientific integrity of EPA's approach in general.

[1] https://19january2017snapshot.epa.gov/climatechange/carbon-dioxide-emissions-associated-bioenergy-and-other-biogenic-sources_.html

Region- and Feedstock-Specific Biogenic Assessment Factors, baselines and modeling

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 each facility and the role of market-induced effects on land use, on biomass production and market demand for fiber, and on carbon stocks across space. To obtain a region-specific BAF for feedstocks, it is necessary to address region-specific, feedstock-specific demand for biomass and to assess the impact of this increased demand for biomass on net carbon stocks. Changes in demand for biomass feedstocks should be assessed based on historical data on forest carbon stocks, resource use, and observed information on current and planned expansions to facilities using biomass feedstocks. *There is no single answer to what these BAFs should be, as not all biogenic emissions are carbon neutral nor net additional to the atmosphere, and assuming so is inconsistent with the underlying science.*

Projections of the interactions that must be assessed to compute a BAF can be obtained from diverse model types, from simple empirically and statistically-based models, to complex integrated assessment models that combine biophysical and economic factors. For all model types, sensitivity and uncertainty analyses are needed to adequately interpret the results and understand the dependency of the BAF on the choices and assumptions used as part of its computation.

To compare changes in any system over time there must be a reference scenario (without increased demand for biomass feedstocks) against which to assess the net impacts on the variable of interest. 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 feedstocks for electricity generation. The EPA acknowledged this limitation of its earlier approach and included a future anticipated baseline analysis *along with* a reference point approach in its 2014 Framework. Both the future anticipated baseline and the reference point baseline (with regular updates) are challenging to apply due to data and modeling limitations.

Regardless of the baseline structure chosen (adjusted reference or future anticipated), validation and evaluation of the model used to compute the BAFs will be critical. Model validation is essential to assessing any model's ability to replicate observed phenomenon over time, ensuring that simulations based on the model are sufficiently accurate. Similarly, understanding model sensitivity to input parameters and assumptions is important with respect to assessing model applicability over time. The model selected for estimating BAFs should be reviewed and updated at regular intervals, capturing observed changes in economic and land use conditions that may be due to increased biomass demand or other related conditions, as well as the latest scientific information on biophysical and biogeochemical properties of feedstocks. The appropriate review interval should be selected based on the timeframe of the regulatory objective(s) as well as the timeframe associated with updates to the underlying data.

Charge Question 1

Temporal and Spatial Scales

A sustained increased demand for biomass feedstocks 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 feedstocks for use in stationary facilities can affect carbon stocks by increasing harvesting intensity for standing biomass, diverting biomass feedstocks from other non-energy products and landfills, converting land from other uses to plant new biomass feedstocks for the future, and utilizing biomass residues that might otherwise decay. Each of these responses may differ over time, and thus, the overall effect of all these responses on demand for biomass feedstocks may differ over time. Therefore, the time period selected for estimating the carbon stock or net carbon emissions impacts of an increased demand for biomass feedstocks can strongly affect those estimates. The selection of the time period for assessment is not a purely scientific question and may be primarily driven by the objectives associated with the use of BAFs to be estimated using this Framework. For example, consider an objective to limit peak planetary warming versus an objective of controlling emissions of greenhouse gases in 2050: the same feedstock in the same region could have widely varying impacts on terrestrial carbon stocks because the timeframe defining the endpoint of the relevant analysis would differ. Since BAFs will be computed to serve specific regulatory objectives, there are no scientific criteria by which to pick a single 'right' timeframe for their determination independent of their regulatory context (Ocko et al 2017).

Stationary facilities require a continuous supply of feedstock, thus a landscape approach for accounting of impacts on carbon stocks is more appropriate than a stand-level approach for this application. A landscape approach expands the boundaries of analysis to include all effects and recognizes that there is uptake as well as loss of carbon associated with the production of feedstocks concurrently occurring across the landscape. It is the overall balance of losses and gains that determines carbon stock effects. Moreover, economic considerations will determine the size of the landscape providing feedstocks over time and the potential for land-use changes that can positively or negatively impact carbon stocks.

Stock-Based Accounting Preferred to Emissions-Based Accounting

Carbon accounting associated with determining BAFs should be based on changes in carbon stocks on the land rather than changes in carbon emissions (as used in EPA's 2011 and 2014 Frameworks). A key feature of using carbon stocks is that all terms can be readily aggregated or disaggregated, subject to validation via mass balance, and an existing comprehensive system of empirical measurements is already in place for the US. The stock-based approach comports with the current conventions in carbon accounting, which essentially use input-output tracking of carbon throughout a system with well-defined boundaries. These stocks can be aggregated and rearranged as needed, and they are appropriately constrained by conservation of mass and therefore can be checked and their precision determined using mass balance calculations, in addition to other checks.

Two Cumulative Biogenic Assessment Factor Approaches

The SAB recommends a cumulative carbon accounting metric; however, there are alternative ways to calculate cumulative BAFs. EPA's cumulative BAF (called BAF_T in the 2014 Framework) is one option, reflecting the difference in carbon stocks between the beginning and end of the time horizon, T. One can also calculate a cumulative BAF that is based on the accumulation of annual differences in carbon stocks on the land over the same time horizon, here called $BAF_{\sum T}$. Until the implications of the differences are better understood, we support EPA's cumulative BAF approach, i.e., the difference in carbon stocks between the beginning and the end of the selected time horizon.

Charge Question 2

Scales of Biomass Use and Modeling Approach

Projections for aggregate demand for all biomass changes should be bounded by historical data on resource use, observed information on current and planned expansions to facilities using biogenic feedstocks, and reasonable projections of cost-effective deployment of biomass feedstocks for meeting the energy/feedstock needs of stationary facilities.

In addition, regular retrospective evaluations of observed levels of demand and the mix of feedstocks would enable revisions to EPA's estimates of feedstock demand. Retrospective evaluations of BAF performance will be important for understanding how effective the modeling has been in predicting what occurred. Thus, projections about biomass feedstock demand should be revised based on actual observations, and these updated demands should be used to inform modeling that generates BAFs.

Recommendations

As we have observed above, a sound biogenic carbon accounting approach for estimating BAFs will depend on the specific regulatory objectives for those BAFs, which are yet to be defined. Recognizing this limiting factor in the SAB's ability to review the 2014 Framework, we make the following recommendations.

1. EPA should identify and evaluate its criteria for choosing a model and modeling features that affect BAF results. EPA should explore the sensitivity of BAFs to different modeling approaches, assumptions, transaction costs, and uncertainties in model input parameters.

2. Stationary facilities require a continuous supply of biomass feedstocks, thus a landscape approach is appropriate and likely most reliable for accounting for the impacts of feedstock demand on carbon stocks.

3. The estimate of the direction and magnitude of the impact of using biogenic feedstocks in stationary facilities on terrestrial carbon stocks depends on the time horizon considered. There is no optimal time horizon for evaluating these impacts, and should be determined by the regulatory context mandating use of BAFs.

4. Changes in carbon stocks (e.g., live and dead biomass, soil, products, material lost in transport and waste), should be used to account for biogenic carbon, rather than an emissions (flux-based) approach.

5. The SAB suggests exploration of two cumulative BAF metrics. Until the implications of the different metrics are clear, the SAB recommends using the metric proposed by EPA, i.e., net changes in stock over a specified time.

2. INTRODUCTION

2.1. Background

EPA's Science Advisory Board (SAB) was asked by the EPA Office of Air and Radiation to review and comment on its *Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources* (U.S. EPA 2014).

The purpose of the 2014 Framework was to develop a method for calculating the adjustment, or Biogenic Assessment Factor (BAF), for CO_2 emissions associated with the use of biogenic feedstocks in stationary facilities, taking into account the biological carbon cycle associated with the growth, harvest, and processing of plant biomass. This mathematical adjustment to stack emissions is needed because of the unique ability of biological systems to sequester CO_2 from the atmosphere through photosynthesis in living biomass, to sequester carbon in dead biomass and soil, and to release CO_2 through respiration and biologically-mediated decay of organic matter. These attributes of ecosystems mean that there can be wide variation in the net effect of using biomass feedstocks in stationary facilities on emissions of carbon dioxide to the atmosphere and thus it is scientifically indefensible to assume all bioenergy has no net carbon dioxide emissions to the atmosphere, or the reverse, that all emissions represent a net addition to the atmosphere. The BAF is an accounting term developed in the Framework to estimate the net CO_2 emissions to the atmosphere over a specified period of time associated with burning biomass feedstocks to produce energy. These net emissions reflect the changes in carbon stocks of above and below ground biomass (live and dead), soils, and wastes. The 2014 Framework is a revision of the 2011 Framework (U.S. EPA 2011), which the SAB previously reviewed (U.S. EPA SAB 2012).

The EPA's charge to the SAB (Appendix A) requests advice and recommendations on its revised 2014 Framework, which was developed with consideration of the SAB's 2012 recommendations as well as the latest information and input from the scientific community and other stakeholders. The EPA asked the SAB to review and offer recommendations on specific technical elements of the 2014 Framework for assessing the extent to which the production, processing, and use of biogenic feedstocks at stationary facilities results in net emissions of CO_2 to the atmosphere so that it could be quantified through calculation of a BAF.

To conduct the present review, the SAB Staff Office reconstituted the Biogenic Carbon Emissions Panel (Appendix B), which had reviewed the 2011 Framework. That panel met multiple times between March 2015 and August 2017. The Panel presented a draft report (February 2016) to the SAB for quality review. The SAB quality review was conducted in March 2016; this quality review resulted in requested revisions from the Panel. The revised draft report (June 2017) was reviewed by the Board in 2017. The 2017 revision of the report was not approved by the SAB based on the deliberations of the quality review. The present report is a product of SAB's direct efforts and utilizes portions of the Panel's report. Previous drafts of the Panel's report are retained on the SAB website and available here.

The 2014 Framework does not provide the regulatory context, specific BAF calculations for that context, or the implementation details the SAB requested in its review of the 2011 Framework. That is, EPA's Framework report does not identify the specific metric of climate impact (or "objective") that a BAF estimate should reflect, and further notes that BAFs that may be developed under the Framework could entail a wide range of objectives, depending on the regulation or policy-specific approach that would require use of a BAF. (For example, some regulations may impose objectives related to different time horizons than others; similarly, under some regulations the BAF may need to address a temperature impact objective, while other regulations may impose a net CO_2 emissions objective.) Lack of specificity in the Framework document regarding the objectives to be estimated makes it very difficult for the SAB to assess whether the suggested types of models, data, and baselines are appropriate. While it would, in this situation, be desirable to identify a universal modeling methodology that could be applied to any of a wide range of potential objectives, this poses significant new analytical and data challenges on the Framework, and the SAB is not endorsing such an approach. Thus, we note as a preface to this set of SAB comments that a consequence of having made the 2014 Framework so general in its potential applications it has limited SAB's ability to fully address the charge questions presented to it for this review.

3. OVERARCHING COMMENTS

This section addresses issues that lie outside the scope of EPA's charge questions, but which the SAB considered critical to place the responses to the charge questions in context. The charge questions are narrowly focused on specific technical aspects in the structure of the 2014 Framework. However, the SAB had important general advice regarding the Framework. This section outlines that advice.

3.1. Defining Objectives through the Regulatory Context

For its review of the 2011 Framework, the SAB requested and was given a regulatory context for use of BAFs that would result from 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 and 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 the use of bioenergy in stationary facilities.

The agency has removed this regulatory context from its 2014 Framework, and the EPA's charge questions seek guidance on issues related to the choice of temporal, spatial and production scale for determining BAFs in a regulatory-neutral context. In the absence of a specific regulatory context, which would define the objectives that a BAF must estimate, the SAB limited its review to providing general comments about how to consider the questions posed. More specific answers to the questions posed will vary with the objective (as defined by the regulatory context), most notably the appropriate time period over which to determine the net biogenic emissions, and to a lesser degree, the appropriate geographical scale for consideration.

A regulatory context with explicit objectives would clarify if the procedures for determining the BAF will need to account for the emissions of all greenhouse gases that alter the climate. If this is the case, then it will be important that the analytic methods described by the Framework account for the effect of biogenic feedstocks on non-CO_2 gases such as N_2O and CH_4 and to examine how the emission or uptake of these gases differ across space, time, and feedstocks. Given the large difference in the mean residence time of these gases in the atmosphere, their relative importance can vary widely over different time horizons. If climate impact over 20 or 40 years is the objective, then methane and carbon particulate emissions could be very important, while if the objective's period of concern is hundreds of years, their importance will drop significantly (Shoemaker, et. al., 2013). Non-CO_2 gases are particularly important for feedstocks grown with nitrogen fertilizer and for waste materials from landfills.

As an additional caveat, the SAB is aware that the EPA report and this review are focused only on accounting for carbon dioxide related to the use of biomass in stationary facilities for energy generation. Neither EPA nor the SAB evaluated other concerns like forest conservation, biodiversity, and ecosystem services. If, for example, biomass pellets were sourced from old growth forests, this would pose unique risks that would not be reflected in a BAF calculated for net effects on carbon dioxide. We offer this caution about the model boundaries as defined by EPA's method and identified in the SAB review. In addition, we recognize that biodiversity and ecosystem health are valid concerns worthy of a different analysis and regulatory response.

Recommendation

- BAFs will vary depending on their specific objective, which will depend upon the regulatory context, particularly in selection of the time horizon and geographic scope. Thus, future efforts to define specific biogenic accounting factors should be conducted in a regulatory-specific context, with the objectives and relevant time frame specified.
- It is inappropriate to use default assumptions, including assuming there are no net emissions or that all emissions are additive.

3.2. <u>Baseline Approach</u>

To compare change in any system over time, there must be a baseline scenario against which to assess changes, in this case, changes due to demand for biogenic feedstocks; a baseline allows different scenarios to be compared. In the 2011 Framework, the EPA assesses the estimated net change in land-based biogenic CO_2 fluxes and/or carbon stocks between two points in time, with the first time point called the reference point. In the 2012 SAB report, we noted temporal problems with the reference point baseline approach. The EPA has acknowledged this in its 2014 Framework and included a future anticipated baseline analysis alternative along with a reference point baseline approach. The 2014 framework notes that the choice of baseline (reference point or anticipated) depends on the question to be answered and the specific context in which the framework is applied.

The SAB's 2012 advice on the anticipated baseline approach explored the use of complex modeling in order to try to capture interactions among the market, land use, investment decisions, and emissions and ecosystem feedbacks, and to construct a counter-factual scenario that does not include increased bioenergy use. In the case of long rotation feedstocks, biomass feedstock demand can affect carbon stocks in many ways including the age of trees harvested, the diversion of forest biomass from traditional forest product markets to bioenergy, and the rates of reforestation and deforestation. Estimating the net effect of these changes on carbon stocks requires a model that integrates market demand and supply conditions with biophysical conditions that determine growth of forest biomass, losses via decomposition, carbon sequestration and fluxes due to harvests and land use change and incorporates the spatial variability in these effects across the U.S. The complexity of such a modeling approach can make it difficult to parameterize and validate, and thus poses a significant challenge for use in any context. Extra effort will be needed to provide the public with thorough sensitivity analyses of parameters and model assumptions, and explicit recognition of model uncertainties in resulting BAF estimates.

Also, consistent with the SAB's 2012 recommendations, the EPA has now moved toward a "representative factor" approach that would include an assessment of the biogenic landscape attributes (type of feedstock, region where produced). The EPA initially considered calculating a BAF for an individual stationary facility; however, the data needs for a facility-specific approach are daunting if they are to be accurate (e.g., case-specific measurements and calculations of carbon stocks and chain-of-custody carbon accounting, integration of land use changes on a broader landscape level). EPA's use of a representative factor approach is an advance in its accounting methodology, although overly-broad feedstock categories may not reflect important extant or likely future variation in feedstock production or processing (e.g., roundwood in the Southeast, logging residues in the Pacific Northwest, and corn stover in the Corn Belt). The overall approach is a positive development, but caution is required to ensure such inclusiveness does not produce unintentionally negative outcomes, e.g. feedstocks with large net emissions to the atmosphere lumped together with those with more limited net emissions. The EPA should evaluate the "representativeness" of the factors and refine the approach over time with additional data.

As stated in the SAB's 2012 report, there are tradeoffs between ease of implementation (transaction costs), generalizability (getting it right at every location), accuracy (getting the overall stock change correct), and regulatory effectiveness (ensuring that the regulatory objectives are being met). The SAB continues to recognize the difficulty of undertaking the recommended anticipated future baseline approach, and practicality should be an important consideration in the agency's decision making. While the reference point baseline approach has significant limitations as noted in the SAB's 2012 report, these might be mitigated if regular updating with empirical data to capture regional carbon stock changes (increases or decreases) were employed. All methods considered should be subject to an evaluation of the costs of implementation and compliance and weighed against any increase in accuracy that they might yield. Ultimately it is critical that there is a balance among these considerations.

Recommendation

- The EPA should identify and evaluate its criteria for choosing a model and its underlying assumptions with regards to how these criteria and assumptions affect the robustness and reliability of calculated representative BAFs. In addition, the EPA should periodically update and validate the selected model to incorporate the latest scientific knowledge while ensuring that the model outputs are consistent with empirical observations (e.g. shifts in measured carbon stocks as determined the Forest Inventory Analysis program). Any model chosen should be subject to sensitivity analysis to evaluate its efficacy under different conditions and to identify data needs and prioritize future research.

3.3. Alternative Fate Approach for Waste-Derived Feedstocks

In 2012, the SAB recommended that the EPA consider alternative fates (i.e., if not used as fuel for electricity generation or process heat) of waste-derived feedstocks diverted from the waste stream, e.g., whether these feedstocks might decompose over a long period of time, whether they would be deposited in anaerobic landfills, whether they would be diverted from recycling and reuse, etc. In the 2014 Framework, the EPA has conducted extensive alternative fate calculations; however, the agency drew a narrow boundary around point source emissions and neglected other significant considerations that affect the GHG footprint of alternative municipal solid waste management scenarios. Specifically, the EPA neglected to quantify a potential alternative fate of municipal solid waste through landfill-derived methane combustion. Under the Clean Air Act New Source Performance Standards, the EPA requires landfills above a certain size to, at a minimum, collect and control landfill gas (e.g., through flaring or use). As such, a baseline of direct venting is misleading, although almost all these facilities are likely to produce large emissions of methane, even when in compliance with current regulations (Lamb et al 2016: www.epa.gov/lmop/basic-information-about-landfill-gas). The relative rankings of BAFs across waste treatment options assessed in the 2014 Framework might change considerably if a more complete accounting were undertaken (e.g., energy recovery from landfill-derived methane and combustion of waste, and carbon storage associated with landfills).

3.4. Temporal and Spatial Considerations in Biogenic Assessment Factor Calculations

The goal of the EPA Framework reviewed is to account for effects of biomass feedstocks used for energy generation at stationary facilities on terrestrial carbon stocks. BAFs are a carbon accounting method based on expected future changes in carbon stocks (measured in tons of carbon). They are designed to assess the net contribution of CO_2 from a stationary facility that uses biomass feedstocks, due to shifts of terrestrial carbon to and from the atmosphere over a specified period of time. The time scale selected will vary depending on regulatory-defined objectives (e.g., reduction of GHG emissions in 2050 or 2100, or limiting global temperature change resulting from greenhouse gas emissions). Over the selected time period, all greenhouse gas impacts (not just CO_2) – both positive and negative – should be accounted for (as completely as is feasible).

Stationary facilities require a continuous supply of feedstock, thus a landscape approach for accounting of impacts on carbon stocks is more appropriate than a stand-level approach for the application EPA defines (stationary facility for energy production). A landscape approach expands the boundaries of analysis to include all effects and recognizes that there is uptake as well as loss of carbon associated with the production of feedstocks concurrently occurring across the landscape. It is the overall balance of losses and gains that determines carbon stock effects. Moreover, economic considerations will determine the size of the landscape providing feedstocks over time and the potential for land-use changes that can positively or negatively impact carbon stocks. As noted by Cintas et al. (2016), "assessment at the landscape scale integrates the effects of all changes in the forest management and harvesting regime that take place in response to – experienced or anticipated – bioenergy demand. Taken together, these changes may have a positive, negative or neutral influence on the development of forest carbon balances." Landscape level accounting of effects of forest-based feedstocks on carbon stocks can result in a net gain or loss of carbon stocks in the near to medium term; a carbon debt could be followed by a carbon dividend or the other way around.

BAFs are a carbon accounting tool for assessing CO_2 emissions from facilities that consume biomass feedstocks for production of energy and are not life cycle assessments of net greenhouse gas emissions or their climate change effects. The distinction is that not all indirect systemic effects are considered in the BAF, nor are all GHG effects included. We also underscore our caution that the net accumulation of forest and soil carbon over time should not be assumed to occur automatically or to be permanent; rather, growth and accumulation should be monitored and evaluated for changes resulting from management, regulatory efforts, market forces, or natural causes. If such monitoring demonstrates changes that are not included in the model used to develop the BAF, the BAF should be updated to align with the empirical data.

Recommendation

- Stationary facilities require a continuous supply of feedstock, thus a landscape approach is appropriate and likely most reliable for accounting for the impacts of feedstock demand on carbon stocks.

4. RESPONSES TO EPA'S CHARGE QUESTIONS

4.1. Temporal/Spatial Scale for Biogenic Accounting

Charge Question 1: What criteria could be used when considering different temporal scales and the tradeoffs in choosing between them in the context of assessing the net atmospheric contribution of biogenic CO_2 emissions from the production, processing, and use of biogenic material at stationary sources using a future anticipated baseline?

There are several key factors that impact the dynamic nature of the BAF for a specific feedstock and region. The first is that the increased demand for biomass feedstocks in a region could potentially be met by a variety of sources obtained from the agricultural and forestry sectors, including annual and perennial agricultural crops, short rotation woody biomass and pulpwood, and crop and forest residues. Any increase in demand might involve using a larger proportion of an existing resource or diversion from non-energy products and landfills, converting land from other uses to growing biomass feedstocks, changing use of existing feedstocks, utilization of residues that would otherwise decay over some period of time. The effect of increased demand for biomass feedstocks on carbon stocks will depend on the mix of these feedstocks demanded and the scale of demand for these feedstocks.

Second, different biomass sources have different effects on carbon stocks over different timeframes. The plant systems, e.g., forests, agronomic systems, producing feedstocks differ in their rate of growth/regrowth, yield, potential to sequester carbon in biomass and soils, decay rates after harvest, and the type of land-use change that accompanies their production. These effects continue after the feedstock has been consumed by a stationary facility. We therefore recommend computing a cumulative BAF over the relevant time horizon. This cumulative BAF would be based on the difference in carbon stocks between a scenario without change (either computed using a reference point or anticipated baseline) and the increased biomass feedstock demand scenario and would vary with the time horizon selected by the objective in the relevant regulations.

Key principles for calculating changes in the net carbon stocks should include: (1) the positive and negative impacts of demand for biomass over time, (2) a system-wide (landscape and economy) approach to account for direct and indirect effects, and (3) consistency across each region. Selecting different time horizons for different feedstocks being used to meet the same regulatory objective would be inappropriate as it would yield inconsistent effects.

Determining the scale of appropriate regions for calculating BAFs will require balancing similarity in the biophysical characteristics, similar growing conditions (growing season length, vegetation type) and economic factors, biomass demand, with ensuring that the edge to volume ratios of the regions are small enough to ensure minimizing incentives to manipulate the movement of biomass feedstocks among regions due to differing BAFs.

To fully account for all positive and negative terrestrial effects over time, we recommend using the "emissions horizon" that is determined to be relevant by the specific regulatory objective. As defined by the EPA, this "emissions horizon is the period of time during which the carbon fluxes resulting from actions taking place today actually occur …" (U.S. EPA 2014). If the objective associated with a given BAF is to have an effect on greenhouse gas emissions by a certain date, then that date is the appropriate time horizon under which that BAF should be calculated. Accordingly, there is no single time horizon that will effectively address all potential BAF needs since feedstock net effects are time-dependent and different BAF objectives may target different time horizons. Accordingly, the SAB does not support a single time horizon as appropriate for estimating BAFs.

The Panel suggested that the time horizon should be the length of time it would take for the effect of increased demand for biogenic feedstock on the carbon cycle to reach a steady-state. This occurs when the difference in carbon stocks between the increased biomass feedstock demand scenario and the business-as-usual scenario is no longer changing or when the difference is approaching an asymptote. This could result in a very long time horizon being selected for the BAF calculation, potentially hundreds of years if all feedstocks across all regions were to be included. The selection of such a time horizon would mean that for regulatory objectives with shorter time horizons (e.g., meeting a 2050 emissions target), the accounting would not align with relevant effects of biomass feedstock use at stationary sources on the regulatory objective. Whether it would be appropriate to use a model that can estimate effects over a much longer time horizon to estimate a BAF requiring a shorter time horizon will depend on whether that model can produce reasonable estimates of impacts at the nearer term point in time as well.

Several factors determine the difference in carbon stocks between the business-as-usual scenario and the increased biomass feedstock demand scenario. A major factor is the "speed" with which carbon stocks respond after harvest; this can be influenced by several factors: the speed with which a feedstock regrows and can be harvested again, the mix of feedstocks produced, and the rate at which soil carbon stocks change. Thus, the mix of feedstocks used can influence the shape of the curve and when it reaches equilibrium.

Previous studies have shown that estimates of the effects of biomass harvest on carbon stocks depend on the spatial scale of consideration (stand level or landscape level), the initial conditions of carbon stock on the land (e.g., managed forestland, old growth forestland, or agricultural land), the management practices used, and the time horizon over which effects are measured (Walker et al., 2010; Jonker et al., 2014; Mitchell et al., 2012; Galik and Abt, 2012a, b; Ter-Mikaelian et al., 2015). Harvest of an existing forest stand for use as a feedstock results in an immediate reduction of carbon on the site; the amount of carbon lost at the stand level is directly related to the intensity of the disturbance. At a stand level, harvest followed by regrowth (most US forests regenerate without intervention/planting) usually results in a cycle of loss followed by gain. The amount of carbon regained on the site can vary: in some cases, all is regained, in others only part is regained, and in others, more can be gained than is released.

Since stationary facilities require a continuous supply of feedstock, multiple stands will be disturbed asynchronously; the order in which losses and gains occur becomes meaningless at the landscape level because both simultaneously occur. Thus, the operative issue is the overall balance between losses and gains of carbon at the landscape scale. Thus, stand level accounting is not relevant to the calculation of BAFs for biomass feedstocks used at stationary sources. If harvest does not exceed the rate of carbon accumulation, the landscape-level carbon stocks are stable or increasing. However, there could be a net loss of carbon to the atmosphere at the landscape level, compared with the business-as-usual scenario, if trees are harvested at younger ages or if trees that would otherwise have been unharvested are harvested.

Biomass, particularly from forest sources, is also used for producing non-energy products. The demand for biomass feedstocks for energy generation can lead to a diversion of biomass from those products and lead to an immediate reduction in carbon stocks in products. It is also possible that anticipation of future demand for biomass feedstocks by stationary facilities could lead to land conversion, reforestation and retention, or accumulation of carbon stocks in a growing forest. In general terms, the amount of either net loss or net gain of carbon on the landscape is influenced by changes in many factors including those influencing net primary production and removals, and the net effect can be expected to vary over time.

When agricultural feedstocks are harvested annually from land under continuous production, the time lag between harvest, CO_2 emissions from conversion to energy, and regrowth on land is likely to be close to one year, and the harvested carbon will be fully regained, with no net impact on above-ground carbon stocks. The production of these feedstocks may directly affect carbon stocks below-ground by increasing or decreasing soil carbon stocks relative to the use of the land in the business-as-usual scenario. The demand for biomass feedstocks can also affect carbon stocks by leading to a change in the use of land which could either release carbon stored in the land (for example if permanent grasslands are converted to annual agricultural production) or accumulate carbon on the land (for example through reforestation as annual cropland is converted back to forests).

Recommendation

- The estimate of direction and magnitude of the impact of using biogenic feedstocks in stationary facilities on terrestrial carbon stocks depends on the time horizon considered. There is no optimal time horizon for evaluating these impacts, and it should be determined by the regulatory context mandating use of BAF.

Charge Question 1(a): Should the temporal scale for computing biogenic assessment factors vary by policy (e.g., near-term policies with a 10-15 year policy horizon vs. mid-term policies or goals with a 30-50 year policy horizon vs. long-term climate goals with a 100+ year time horizon), feedstocks (e.g., long rotation vs. annual/short-rotation feedstocks), landscape conditions, and/or other metrics? It is important to acknowledge that if temporal scales vary by policy, feedstock or landscape conditions, or other factors, it may restrict the ability to compare estimates/results across different policies or different feedstock types, or to evaluate the effects across all feedstock groups simultaneously.

Charge Question 1(a)(i). If temporal scales for computing biogenic assessment factors vary by policy, how should emissions that are covered by multiple policies be treated (e.g., emissions may be covered both by a short-term policy, and a long-term national emissions goal)? What goals/criteria might support choices between shorter and longer temporal scales?

Charge Question 1(a)(ii). Similarly, if temporal scales vary by feedstock or landscape conditions, what goals/criteria might support choices between shorter and longer temporal scales for these metrics?

Charge Question 1(a)(iii). Would the criteria for considering different temporal scales and the related tradeoffs differ when generating policy neutral default biogenic assessment factors versus crafting policy specific biogenic assessment factors?

Charge Question 1(b). Should the consideration of the effects of a policy with a certain end date (policy horizon) only include emissions that occur within that specific temporal scale or should it consider emissions that occur due to changes that were made during the policy horizon but continue on past that end date (emissions horizon)?

The responses to questions 1(a), 1(a)(i), 1(a)(ii), 1(a)(iii), and 1(b) are combined because these questions all relate to goals or criteria that may affect choices of differing temporal scales for calculating BAFs.

Question 1(a) asks specifically if the temporal scale for computing BAFs should vary by regulatory policy. As noted in the overall response to Charge Question 1 (above), the SAB concludes that the BAF computation should be informed by the regulatory objectives, including with respect to time.

If there are different objectives in multiple regulations mandating use of BAFs (as discussed in charge question 1(a)(i)), there are no overriding scientific principles that can be applied *a priori* to guide alignment in the calculation of BAFs for different objectives.

One could advocate for a host of approaches to selecting a time horizon for evaluation; all would be plausible but not inherently aligned with the objective of the regulations being promulgated. At the extremes one could consider only the carbon accounting over the year in which the biomass was combusted; such an approach would mean that almost all feedstocks would be assigned a BAF close to one, representing no net benefit to reducing atmospheric carbon dioxide concentrations. Conversely one could only consider net impacts on the carbon cycle over several hundred years, which would mean for most feedstocks the BAF would be close to zero (assuming steady demand and unchanged rotation lengths thus allowing stocks to come into equilibrium), indicating all biogenic emissions being net beneficial to the atmosphere. Neither of these approaches would align with the most likely objectives of BAFs; however, neither is inherently correct or incorrect.

The time horizon for consideration of carbon stock changes should be chosen based on the specific objective of a regulation, once it is identified (e.g., minimizing net greenhouse gas emissions over a specified period or temperature increase by a certain date). The SAB makes no assertion regarding the appropriate regulatory use of the BAF and thus supports no specific time horizon selected independent of a regulatory requirement.

Charge Question 1(c). Should calculation of the biogenic assessment factor include all future fluxes into one number applied at time of combustion (cumulative – or apply an emission factor only once), or should there be a default biogenic assessment schedule of emissions to be accounted for in the period in which they occur (marginal – apply emission factor each year reflecting current and past biomass usage)?

Accumulating all effects of the use of a biogenic feedstock over a time horizon is preferred to a marginal or instantaneous ("per period") BAF. (For the purposes of answering this question, the SAB interprets "marginal" to mean "annual" or "per period" so as to distinguish it from the meaning of "marginal" that typically refers to the last unit of emissions or the additional effect of the last unit of biomass.)

As described in the overall response to Charge Question 1 (above), the SAB recommends a cumulative carbon accounting metric; however, there are alternative ways to calculate cumulative BAFs. EPA's cumulative BAF (called BAF_T in the 2014 Framework) applied to stocks is one option, reflecting the carbon stocks at the end of the time horizon—specifically, changes in carbon stocks by time, T. One can also calculate a cumulative BAF that is based on the accumulation of annual differences in carbon *stocks* on the land *over the time horizon until equilibrium is reached*, here called $BAF_{\sum T}$. By accumulating annual differences across the projection period, this alternative cumulative BAF metric attempts to incorporate “residence time” in the sense that it is a proxy for the length of time carbon stays in the atmosphere until it is modified by changing stocks of carbon on the land. While intended to generate a single BAF term at the end of the selected time horizon, either computation can be evaluated at any time of interest. Until the implications of the differences are better understood, we support EPA’s cumulative BAF approach, i.e., the difference in carbon stocks *at the end of the selected time horizon*.

The choice of an appropriate cumulative BAF should be informed by a scientific assessment of the dynamics of additions to atmospheric carbon stocks as well as the complexities and uncertainties of these determinations, ensuring the accounting is accurate and verifiable. Both cumulative BAFs attempt to capture net changes in biogenic carbon 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.

With either approach to evaluating BAFs, caution is advised with projections into the future. A BAF is inherently based on some type of modeling that employs assumptions about the relationship of variables in the future based on current observations. These assumptions may not be robust in the future. Each BAF will need to be assessed periodically to see if changing conditions warrant a revision (Bucholz et al. 2014).

Carbon accounting for biogenic emissions can be framed either using differences in carbon emissions to the atmosphere or using differences in carbon stocks on the land. Conservation of mass dictates that any carbon taken from the land (through increased harvests or other disturbances) will result, in the near-term, in equivalent increases of carbon in the atmosphere, followed by longer-run changes in ocean and land-based carbon. Thus, these approaches are compatible, but examining changes in stocks is operationally more direct and can be done periodically, rather than requiring continuous measurements to be accurate. However, both approaches should account for changes within the boundaries of the analysis, such as import and export of biogenic feedstocks and other associated products.

Long-Term Trends in Biogenic Assessment Factors

The Panel has suggested that cumulative BAFs might approach zero as T is reached. However, that is only true for $BAF_{\Delta t}$ and not the cumulative BAFs – BAF_T and $BAF_{\sum T}$. Mathematically cumulative BAFs are hyperbolic functions once T is reached and have extremely long “tails”, representing a period of net CO_2 emissions to the atmosphere.

An approach to determining a baseline that includes an historical time period could be used to periodically reset a reference baseline based on re-measuring carbon stocks on the landscape using data from existing inventory programs. Carbon stock measurements have been made for more than a half century in the US, offering a robust record of change. This approach could improve the accuracy of the baseline over time; however, as noted above, the preference for use of a reference or future anticipated baseline depends on the objective. Future changes in growth-to-harvest ratios could be used to inform the model assumptions and modify the BAF that would be applicable going forward. This could create long-term incentives for sustainable management of land resources. In any accounting framework that assumes future regeneration and regrowth, it is important to periodically test this assumption against actual data as they become available. If assumptions of future regeneration and regrowth are not supported by observations, adjustments need to be made to models that are used to determine BAFs.

Recommendations

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

- The SAB suggests consideration of two cumulative BAFs—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 BAFs will depend on the understanding of the carbon system and climate response for which there is uncertainty.

Charge Question 1(d). What considerations could be useful when evaluating the performance of a future anticipated baseline application on a retrospective basis (e.g., looking at the future anticipated baseline emissions estimates versus actual emissions ex post), particularly if evaluating potential implications for/revisions of the future anticipated baseline and alternative scenarios going forward?

It is appropriate to periodically revise the modeling and the BAFs. The goal of such revisions would be to update underlying economic and biophysical assumptions and modeling trends in light of new data to reduce uncertainty and to increase accuracy of future projections.

A retrospective comparison would compare model-projected behavior to newly available historical observations and estimates, such as regional feedstock demand, land-use changes (e.g., reforestation, management intensity, forest rotations characteristics and conversion of land to other land uses including dedicated energy crops), and forest carbon measurements and estimates (both level and composition). It would be important to re-examine parameters, functional forms, and other assumptions of the modeling approach as part of an *ex post* evaluation.

4.2. <u>Scales of Biomass Use</u>

Charge Question 2: What is/are the appropriate scale(s) of biogenic feedstock demand changes for evaluation of the extent to which the production, processing, and use of biogenic material at stationary sources results in a net atmospheric contribution of biogenic CO2 emissions using a future anticipated baseline approach? In the absence of a specific policy to model/emulate, are there general recommendations for what a representative scale of demand shock could be?

Charge Question 2(a). Should the shock reflect a small incremental increase in use of the feedstock to reflect the marginal impact, or a large increase to reflect the average effect of all users?
Charge Question 2(b). What should the general increment of the shock be? Should it be specified in tons, or as a percentage increase?

The responses to questions 2(a) and 2(b) are combined below because both questions relate to the size of the simulated change in demand for biomass feedstocks. The complexities are large and any predictions on scale of demand shock can only be done effectively in a regulatory context as they are very challenging to define otherwise.

If the EPA's goal is to obtain a region-specific BAF for a feedstock, it will be necessary to project region-specific and feedstock-specific demand for biomass. 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 reflect the methods used to produce that feedstock. To the extent that BAFs depend on technology and emissions control regulations at a stationary facility in a region, they could also be defined in terms of specific technologies.

Charge Question 2(c). Should the shock be from a business as usual baseline, or from a baseline that includes increased usage of the feedstock (i.e., for a marginal shock, should it be the marginal impact of the first ton, or the marginal impact of something approximating the last ton)?

In the absence of a specific regulation to model, the SAB cannot offer general recommendations for a representative scale of demand shock.

Charge Question 2(d). Should shocks for different feedstocks be implemented in isolation (separate model runs), in aggregate (e.g., across the board increase in biomass usage endogenously allocated by the model across feedstocks), or something in between (e.g., separately model agriculture-derived and forest-derived feedstocks, but endogenously allocate within each category)?

Charge Question 2(e). For feedstocks that are produced as part of a joint production function, how should the shocks be implemented? (e.g., a general increase in all jointly produced products; or, a change in the relative prices of the jointly produced products leading to increased use of the feedstock, and decreased production of some other jointly produced products, but not necessarily an overall increase in production).

The responses to questions 2(d) and 2(e) are combined because both questions relate to modeling biomass feedstocks in isolation or jointly.

In the absence of a mandate for use of specific feedstocks or incentives for specific types of bioenergy which might be prescribed in a regulatory framework, and which would inform the feedstock-specific demand that should be modeled, a reasonable approach is to model the aggregate demand for feedstocks. This approach assumes facilities are constantly seeking their least-cost alternative. An aggregate demand could be imposed on the model and used to determine demand for different feedstocks in different regions. This would allocate demand across feedstocks as well as within each category to simulate a given target aggregate demand determined by the market's ability to draw from the least cost combination of feedstocks.

Charge Question 2(f). How should scale of the policy be considered, particularly for default factors? (e.g., can a single set of default factors be applied to policies that lead to substantially different increases in feedstock usage)?

Default BAFs would likely vary by the scale of demand. In fact, a single set of default BAFs is unlikely to be robust across a wide range of scales of demand. The scale of demand is likely to influence the mix of feedstocks that is viable to produce because it can be expected to affect the market price of biomass. Low levels of demand for biomass may be met relatively easily by crop residues, forest residues and mill residues; high levels of demand could lead to dramatically increased harvests of forest biomass or production of dedicated energy crops. The BAF of a feedstock in a region can be expected to vary depending on the scale of the demand i.e., a 1-million-ton increase in biomass demand or a 1-billion-ton increase in biomass demand.

In the absence of information about the scale of demand, BAFs could be determined for different threshold levels of aggregate demand for biomass feedstocks and consequent feedstock/region-specific demand.

Charge Question 2(g). Would the answers to any of the above questions differ when generating policy neutral default factors, versus generating factors directly tied to a specific policy?

While the methodological framework for different policies could be similar, we expect differences as follows: (1) BAFs that are tied to a particular regulatory approach, versus a particular period of time, would be based on simulating the aggregate and feedstock-specific demand that is expected to emanate from that regulation, while regulatory neutral factors would be based on various exogenously specified quantities of demand for biomass and corresponding endogenously determined levels of feedstock specific demand, and (2) different regulations may require different production and use practices, and thus result in different biogenic factors. Isolating the extent to which expected increase in demand for biomass and its consequences for CO_2 emissions can be attributed to a specific regulation (when there are multiple regulations inducing a shift to renewable energy) is likely to be complicated and challenging to convert into regulatory-specific BAFs. It could also create unintentionally negative incentives for feedstock choice to comply with various regulations.

Charge Question 2(h). What considerations could be useful when evaluating the performance of the demand shock choice ex post, particularly if evaluating potential implications for/revisions of the future anticipated baseline and alternative scenarios going forward?

It is likely that the observed feedstock demand in response to a specific regulation will differ from the forecast because the regulation can be expected to increase demand for feedstocks with lower BAF and decrease demand for feedstocks with a high BAF. Since feedstock-specific demand and the feedstock BAFs are likely to be jointly determined, while the approach proposed above determines them sequentially, divergence between model simulated demand for feedstocks and observations is inevitable.

An evaluation using actual data would also allow revisions to the EPA's estimates of feedstock demand changes (as discussed in response to Question 1d) based on updated data. To improve the performance of the model for assessing BAFs retrospectively, quantities of biomass feedstock (by feedstock category) harvested could be updated with actual observations. New data should improve the estimate of the portion of total biomass demand that is attributable to stationary facilities. This information could be used to improve BAFs.

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APPENDIX A: CHARGE TO THE SAB

February 25, 2015

MEMORANDUM

To: **Holly Stallworth, Designated Federal Official**
Science Advisory Board Staff Office

From: **Paul Gunning, Director**
Climate Change Division

Subject: **Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources and Charge Questions for SAB peer review**

The purpose of this memorandum is to transmit the revised *Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources,* related documentation and charge questions for consideration by the Science Advisory Board (SAB) during your upcoming peer review.

In January 2011, the U.S. Environmental Protection Agency (EPA) announced a series of steps it would take to address biogenic CO_2 emissions from stationary sources. EPA committed to conduct a detailed examination of the science and technical issues related to assessing biogenic CO_2 emissions from stationary sources and to develop a framework for evaluating those emissions. The draft study was released in September 2011 and subsequently peer reviewed by the SAB Ad-Hoc Panel on Biogenic Carbon Emissions (SAB Panel). The final peer review report was published September 2012.

To continue advancing the agency's technical understanding of the role that biomass use can play in reducing overall greenhouse gas emissions, the EPA released a second draft of the technical report, *Framework for Assessing Biogenic Carbon Dioxide for Stationary Sources*, in November 2014. This revised report presents a methodological framework for assessing the extent to which the production, processing, and use of biogenic material at stationary sources results in a net atmospheric contribution of biogenic CO_2 emissions. The revised report takes into account the SAB Panel's peer review recommendations on the draft 2011 Framework as well as the latest information and input from the scientific community and other stakeholders.

The revised framework addressed many of the SAB Panel's key concerns and recommendations by incorporating: an anticipated baseline approach analysis, including an alternative fate approach for waste-derived feedstocks and certain industrial processing products and byproducts; an evaluation of tradeoffs from using different temporal scales; an improved representation of the framework equation; and illustrative case studies demonstrating how the framework equation can be applied, using region-feedstock combinations to generate regional defaults per different baseline approaches and temporal scales.

We ask the SAB to review and offer recommendations on specific technical elements of the revised framework for assessing the extent to which the production, processing, and use of biogenic material at stationary sources results in a net atmospheric contribution of biogenic CO_2 emissions, as identified in the charge accompanying this memo. We look forward to the SAB's review.

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

Attachments:
1) *Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources*
2) Technical Appendices
3) Response to the 2011 SAB Panel Peer Review Advisory

Peer Review Charge on the Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources

To improve the quality, utility, and scientific integrity of the Framework, EPA is providing this study, *Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources* (November 2014) and related materials to the Science Advisory Board (SAB). The revised report takes into account the SAB Biogenic Carbon Emissions Panel's ("SAB Panel") peer review recommendations[2] on the draft 2011 Framework[3] as well as the latest information and input from the scientific community and other stakeholders. The "Response to SAB" document included in the materials provided for this review discusses and responds to the SAB Panel key points and recommendations, serving as a guide to how the revised framework incorporates their recommendations. This charge narrowly focuses on a few specific remaining questions that were not explicitly addressed in the initial SAB Panel peer review report.

The revised 2014 framework report identifies key scientific and technical factors associated with assessing biogenic CO_2 emissions from stationary sources using biogenic feedstocks, taking into account information about the carbon cycle. It also presents a methodological framework for assessing the extent to which the production, processing, and use of biogenic material at stationary sources for energy production results in a net atmospheric contribution of biogenic CO_2 emissions.

The revised framework and the technical appendices address many of the SAB Panel's key concerns and recommendations by incorporating: an anticipated baseline approach analysis (Appendices J-L); an alternative fate approach for waste-derived feedstocks (Appendix N); and certain industrial processing products and byproducts (Appendix D Addendum); an evaluation of tradeoffs from using different temporal scales (Appendix B); an improved representation of the framework equation (Appendix F); and illustrative case studies demonstrating how the framework equation can be applied, using region-feedstock combinations to generate regional defaults per different baseline approaches and temporal scales (Appendices H-N).

[2] The final peer review report from the SAB Panel on the draft 2011 framework was published on September 28, 2012 (Swackhamer and Khanna, 2011). Information about the SAB peer review process for the September 2011 draft framework is available at http://yosemite.epa.gov/sab/sabproduct.nsf/0/2F9B572C712AC52E8525783100704886.

[3] The 2011 *Draft Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources* is available at www.epa.gov/climatechange/ghgemissions/biogenic-emissions.html.

As explained in the revised framework introduction and accompanying SAB response document, the revised framework maintains the policy neutral approach from the 2011 draft Framework. It is a technical document that does not set regulatory policy nor does it provide a detailed discussion of specific policy and implementation options. Ultimately, the framework provides a methodological approach for considering, and a technical tool (the framework equation) for assessing, the extent to which there is a net atmospheric contribution of biogenic CO_2 emissions from the production, processing, and use of biogenic material at stationary sources. The revised framework details technical elements that should be considered as appropriate per specific policy applications or biogenic carbon-based feedstock assessments. Therefore, this charge excludes policy and regulatory recommendations or legal interpretation of the Clean Air Act's provisions related to stationary sources.

The revised report does not provide any final values or determinations: it offers indications of different biogenic feedstock production effects per research and analyses conducted, including illustrative example results per specific case study parameters. As discussed by the previous SAB Panel, this report also finds that biophysical and market differences between feedstocks may necessitate different technical approaches. Even using a future anticipated baseline approach, forest- and agriculture-derived feedstock characteristics, and thus analyses and results, may vary per region and per feedstock, and may be influenced by land use change effects. Illustrative analyses conducted for specific waste-derived feedstock case studies using a counterfactual anticipated baseline, as recommended by the SAB Panel, yielded minimal or negative net emissions effects.

This charge focuses on questions that remain regarding whether there are more definitive technical determinations appropriate for parameterizing key elements of the revised framework, regardless of application to a specific policy or program. Specifically, we ask that the SAB Panel examine and offer recommendations on future anticipated baseline specification issues in the context of assessing the extent to which the production, processing, and use of forest- and agriculture-derived biogenic material at stationary sources for energy production results in a net atmospheric contribution of biogenic CO_2 emissions – such as appropriate temporal scales and the scale of biogenic feedstock usage (model perturbations or 'shocks') for analyzing future potential bioenergy production changes.

Technical approaches, merits and challenges with applying a future anticipated baseline

Establishing a baseline creates a point of comparison necessary for evaluating changes to a system.[4] Baseline specification can vary in terms of what entity or groups of entities are being analyzed (e.g., industries, economic sectors), temporal and spatial scales, geographic resolution, and, depending on context, environmental issues/attributes (EPA, 2010).[5] The choice of baseline approach can also depend on the question being asked and the goal of the analysis at hand. For example, some GHG analysis may require a baseline against which historic changes of landscape carbon stocks can be measured. Other applications may necessitate a baseline against which the estimated GHG emissions and sequestration associated with potential future changes in related commodity markets and policy arenas. Analyses of the estimated GHG emissions and sequestration effects from changes in biomass use have used different

[4] Definitions for baseline vary, including "the reference for measurable quantities from which an alternative outcome can be measured" (IPCC AR4 WGIII, 2007) or "the baseline (or reference) is the state against which change is measured. It might be a 'current baseline,' in which case it represents observable, present-day conditions. It might also be a 'future baseline,' which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines" (IPCC AR4 WGII, 2007).

[5] Guidelines for Preparing Economics Analyses (NCEE), Chapter 5: http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-05.pdf/$file/EE-0568-05.pdf

baseline approaches, as well as a wide range of different temporal scales and alternative scenario parameters (Sohngen and Sedjo, 2000; Fargione, 2008; UNFCCC, 2009; Walker et al., 2010; Cherubini et al, 2011; Galik and Abt, 2012; Latta et al., 2013; Walker et al., 2013; AEO, 2014; U.S. EPA, 2014; Miner et al., 2014).

The draft 2011 framework had discussed three different potential baseline approaches – reference point, future anticipated and comparative – and used the reference point baseline in its hypothetical case study applications of the Framework. The SAB Panel in its review stated that "the choice of a fixed reference point may be the simplest to execute, but it does not actually address the question of the extent to which forest stocks would have been growing/declining over time in the absence of a particular bioenergy facility" (SAB Advisory, p. 29). The SAB Panel expressed concern that the reference point baseline does not address the important question of additionality, or what would have been the trajectory of biogenic CO_2 stocks and fluxes in the absence of an activity or activities using biogenic feedstocks for energy, especially in the context of forest-derived feedstocks.[6] "Estimating additionality, i.e., the extent to which forest stocks would have been growing or declining over time in the absence of harvest for bioenergy, is essential, as it is the crux of the question at hand. To do so requires an anticipated baseline approach" (SAB Letter, p. 2).

Through public comments to the SAB Panel during the 2011-2012 SAB peer review process, various stakeholders expressed divergent perspectives on the appropriate baseline for the draft 2011 framework report.[7] The revised 2014 framework retains the reference point baseline and adds the anticipated baseline in order to retain adaptability for potential applications, and discusses both approaches at length in the revised report and several technical appendices. However, as the SAB Panel was clear in its previous review of the reference point baseline, EPA has no outstanding technical questions for the SAB Panel on that baseline approach. This charge focuses specifically on remaining technical questions that EPA has on the future anticipated baseline approach.

Part 1 – Future anticipated baseline approach and temporal scale

It is important to consider possible treatments of time and the implications of these treatments in developing strategies for long-term and short-term emissions assessment, because the choice of treatment may have significant impacts on the resultof an assessment framework application. For the intended use of the revised Framework – assessing the extent to which the production, processing, and use of biogenic material at stationary sources results in a net atmospheric contribution of biogenic CO_2

[6] The difference in net atmospheric CO_2 emissions contributions with and without changes in biogenic feedstock use is known as additionality (Murray et al., 2007). Additionality can be determined by assessing the difference in potential net atmospheric CO_2 emissions of a specific level of biogenic feedstock use over a certain period of time (in many cases the business-as-usual [BAU] baseline) versus the net atmospheric CO_2 emissions contributions that would have occurred over the same time period with a different level of biogenic feedstock use (counterfactual scenario), holding other factors and assumptions consistent between scenarios.

[7] The American Forest and Paper Association (AF&PA) supported the reference point baseline (e.g., comments submitted October 2011, March 2012) applied historically (January 2012, March 2012). The National Alliance of Forest Owners (NAFO) stated if certain feedstocks weren't categorically excluded, then the historical reference point baseline should be used (e.g., March 2012, August 2012). The U.S. Department of Agriculture stated preference for a historic baseline approach (May 2012). The Environmental Defense Fund (EDF) (January 2012, May 2012) and NCASI (October 2011, March 2012) both supported the retrospective reference point approach, though also both offered recommendations if an anticipated baseline approach was included (EDF for future anticipated and NCASI for counterfactual). Others, such as Green Power Institute (March 2012), the National Resource Defense Council (NRDC, August 2012), Becker et al. (August 2012), Biomass Energy Resource Center et al. (February 2012), and a group scientists letter to EPA (June 2014) all support some form of the anticipated baseline approach (future anticipated and/or counterfactual).

emissions – there are different elements of time to consider when using a future anticipated baseline approach. These elements can include:

- Emissions horizons, assessment or policy horizons, and reporting periods (i.e., fluxes related to feedstock production may occur over many years to decades, whereas reporting may be the current year and policies may cover only a few years or decades), and
- Differences in temporal characteristics of different feedstocks (i.e., annual crops, short rotation energy crops, and longer rotation forestry systems).
- Changes in biophysical and economic conditions over time may affect or differ from those in future anticipated baseline and scenario estimates.

The SAB Panel in its previous peer review noted that "this is a complicated subject because there are many different time scales that are important for the issues associated with biogenic carbon emissions" (Advisory, page 13). They discussed multiple temporal scales associated with mixing of carbon throughout the different reservoirs on the Earth's surface at the global scale (Advisory, page 13) and climate responses to CO_2 and other greenhouse gases (Advisory, page 15), implications of temporal scales greater and shorter than 100 years, and those related to the growth cycles of different feedstock types (Advisory, page 15). The SAB Panel specifically highlighted considerations for using a 100-year or longer temporal scale for evaluating climate impacts and radiative forcing[8] as well as decay rates and carbon storage in forest ecosystems in the main text as well as in Appendices B-D. However, in its recommendations, including those for developing default BAFs per region, the SAB Panel did not offer recommendations per what temporal scale to use in the specific context of the Framework for its intended use and scope. Instead, the SAB Panel stated that "there is no scientifically correct answer when choosing a time horizon, although the *Framework* should be clear about what time horizon it uses, and what that choice means in terms of valuing long term versus shorter term climate impacts (Advisory, page 15) and recommended that a revised framework "incorporate various time scales and consider the tradeoffs in choosing between different time scales" (Advisory, page 43).

Multiple stakeholders have also weighed in on temporal scales, some with specific recommendations on what temporal scale should/could be used for framework assessments, others with no specific recommendations but emphasizing the importance of time. In various comments submitted during the 2011-2012 SAB process, NAFO supported a 100-year timeframe (March 2012). The National Council for Air and Stream Improvement (NCASI) in October 2011 comments suggested "the need for considerable flexibility in setting the temporal scales for determining the stability of forest carbon stocks. There are a range of circumstances that can cause transient trends in carbon stocks that can obscure the more relevant long-term picture."

Other groups, such as The Wilderness Society (TWS), NRDC, EDF and others, submitted comments supporting consideration of shorter temporal scales. In its comments and example calculations, TWS (in October 2011 comments) implied support for shorter temporal scales, and stated in later comments that

[8] EPA acknowledges that the long-term climate impacts of shifting from fossil fuel to biogenic energy sources is an important topic for climate change mitigation policy and also recognizes the extensive work being conducted by EPA and throughout the research community on this question. However, EPA's focus here is on a narrower, more targeted goal of developing tools to assess the extent to which there is a net atmospheric contribution of biogenic CO_2 emissions from the production, processing, and use of biogenic feedstocks at stationary sources. This more narrowly defined assessment is anticipated to be a better fit for the types of program and policy applications in which this framework may potentially be applied.

the SAB "text appears biased toward ignoring effects that occur within a 100-year period" (May 2012). NRDC (August 2014) implied support for shorter temporal scales: "even if near-term carbon emissions increases are eventually 'made up' by regrowth over the very long term, the carbon emission from these types of biomass actually exceed those from fossil fuels for decades. This puts use of these types of biomass fuels in conflict with the urgent need for near-term carbon emissions reductions. The time profile of the carbon emission from biogenic fuel sources matters because it is critical to limit near-term global GHG emissions." This perspective was similar to that shared by Becker et al. in their August 2012 comments. EDF (January 2012) suggested a very short temporal scale (in the context of supporting a retrospective reference baseline). Others, such as the Biotechnology Industry Organization (October 2011) simply asked for "clarification on the methodology used to identify the time scale of carbon cycles."

Per the various recommendations above, the revised framework report and the technical appendices include a more detailed discussion of intertemporal tradeoffs inherent in various options for treating emissions over time in the context of assessing biogenic CO_2 emissions from stationary sources. Specifically, the revised report has: a section on key temporal scale considerations (pages 33-38); an appendix dedicated to temporal scale issues (Appendix B), which includes further discussion of temporal scales in the context of future anticipated baselines and decay rates for feedstocks that would have otherwise decayed if not used for energy, and; an appendix describing the background of and modeling considerations for constructing an anticipated baseline approach (Appendix J). Also, illustrative calculations using the future anticipated baseline estimates use future simulations and thereby explicitly incorporate temporal patterns of different feedstocks (e.g., feedstock growth rates, decay rates) into the analysis and shows how results can vary per temporal scale used (as seen in Appendices K and L). The revised framework does not recommend specific temporal scales for framework applications, but rather identifies different elements of and considerations concerning time to provide insights into the potential implications of using different temporal scales.

EPA seeks guidance on the following issues regarding appropriate temporal scales for assessing biogenic CO_2 emissions using a future anticipated baseline, using the above referenced components of the revised framework report as the starting point for the SAB Panel's discussion. As the previous SAB Panel recommended developing default assessment factors by feedstock category and region that may need to be developed outside of a specific policy context, and as the framework could be also be used in specific policy contexts, the questions below relate to the choice of temporal scale both within and outside of a specific policy context.

Part 1 – Future anticipated baseline approach and temporal scale

1. What criteria could be used when considering different temporal scales and the tradeoffs in choosing between them in the context of assessing the net atmospheric contribution of biogenic CO2 emissions from the production, processing, and use of biogenic material at stationary sources using a future anticipated baseline?

   a. Should the temporal scale for computing BAFs vary by policy (e.g., near-term policies with a 10-15 year policy horizon vs. mid-term policies or goals with a 30-50 year policy horizon vs. long-term climate goals with a 100+ year time horizon), feedstocks (e.g., long rotation vs. annual/short-rotation feedstocks), landscape conditions, and/or other metrics? It is important to acknowledge that if temporal scales vary by policy, feedstock or landscape conditions, or other factors, it may restrict the ability to compare estimates/results across different policies or different feedstock types, or to evaluate the effects across all feedstock groups simultaneously.

i. If temporal scales for computing BAFs vary by policy, how should emissions that are covered by multiple policies be treated (e.g., emissions may be covered both by a short-term policy, and a long-term national emissions goal)? What goals/criteria might support choices between shorter and longer temporal scales?
ii. Similarly, if temporal scales vary by feedstock or landscape conditions, what goals/criteria might support choices between shorter and longer temporal scales for these metrics?
iii. Would the criteria for considering different temporal scales and the related tradeoffs differ when generating policy neutral default BAFs versus crafting policy specific BAFs?

b. Should the consideration of the effects of a policy with a certain end date (policy horizon) only include emissions that occur within that specific temporal scale or should it consider emissions that occur due to changes that were made during the policy horizon but continue on past that end date (emissions horizon)?
c. Should calculation of the BAF include all future fluxes into one number applied at time of combustion (cumulative – or apply an emission factor only once), or should there be a default biogenic assessment schedule of emissions to be accounted for in the period in which they occur (marginal – apply emission factor each year reflecting current and past biomass usage)?
d. What considerations could be useful when evaluating the performance of a future anticipated baseline application on a retrospective basis (e.g., looking at the future anticipated baseline emissions estimates versus actual emissions *ex post*), particularly if evaluating potential implications for/revisions of the future anticipated baseline and alternative scenarios going forward?

Part 2 – Scales of biomass use when applying future anticipated baseline approach

EPA seeks guidance on technical considerations concerning how to select model perturbations (‘shocks’) for future anticipated baseline simulations estimating the net atmospheric contribution of biogenic CO2 emissions from the production, processing, and use of biogenic material at stationary sources, using the above referenced components of the revised framework report as the starting point for the SAB Panel’s discussion. As the SAB Panel recommended developing default assessment factors by feedstock category and region that may need to be developed outside of a specific policy context, and as the framework could be also be used in specific policy contexts, the questions below relate to the choice of model shocks both within and outside of a specific policy context.

2. What is/are the appropriate scale(s) of biogenic feedstock demand changes for evaluation of the extent to which the production, processing, and use of biogenic material at stationary sources results in a net atmospheric contribution of biogenic CO2 emissions using a future anticipated baseline approach? In the absence of a specific policy to model/emulate, are there general recommendations for what a representative scale of demand shock could be?
    a. Should the shock reflect a small incremental increase in use of the feedstock to reflect the marginal impact, or a large increase to reflect the average effect of all users?

b. What should the general increment of the shock be? Should it be specified in tons, or as a percentage increase?
c. Should the shock be from a business as usual baseline, or from a baseline that includes increased usage of the feedstock (i.e., for a marginal shock, should it be the marginal impact of the first ton, or the marginal impact of something approximating the last ton)?
d. Should shocks for different feedstocks be implemented in isolation (separate model runs), in aggregate (e.g., across the board increase in biomass usage endogenously allocated by the model across feedstocks), or something in between (e.g., separately model agriculture-derived and forest-derived feedstocks, but endogenously allocate within each category)?
e. For feedstocks that are produced as part of a joint production function, how should the shocks be implemented? (e.g., a general increase in all jointly produced products; or, a change in the relative prices of the jointly produced products leading to increased use of the feedstock, and decreased production of some other jointly produced products, but not necessarily an overall increase in production).
f. How should scale of the policy be considered, particularly for default factors? (e.g., can a single set of default factors be applied to policies that lead to substantially different increases in feedstock usage)?
g. Would the answers to any of the above questions differ when generating policy neutral default factors, versus generating factors directly tied to a specific policy?
h. What considerations could be useful when evaluating the performance of the demand shock choice *ex post*, particularly if evaluating potential implications for/revisions of the future anticipated baseline and alternative scenarios going forward

Appendix B: Members of the Biogenic Carbon Emissions Panel

CHAIR
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PANEL MEMBERS
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Dr. Morton Barlaz, Professor, Civil, Construction, and Environmental Engineering, Engineering, North Carolina State University, Raleigh, NC

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