DATE

EPA-SAB-19-xxx

The Honorable Andrew Wheeler
Acting 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 Acting 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, for carbon emissions associated with the combustion of biogenic feedstocks by taking into account the biological carbon cycle effects associated with growth, harvest, and processing of these feedstocks. The BAF is an accounting term developed by EPA for use in the Framework. The BAF is a mathematical adjustment to denote the offset to stack emissions. It reflects a biogenic feedstock's net carbon emissions after taking into account its sequestration of carbon in regrown biomass or soil and emissions that might have occurred with an alternate fate had the biomass not been used for fuel.

The 2014 Framework is a revision of the 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 has adopted an alternate 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 includes a discussion of the trade-offs inherent in the selection of a temporal scale for considering net emissions.
- It has developed representative BAFs by feedstock and region rather than facility-specific BAFs.

- It includes 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 policy 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 inherently 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 will have been sequestered by regrowth of the biogenic feedstocks. As such, that construct depends upon the future point of interest, which is explicitly a policy decision. Policies designed to affect change in emissions or impacts in the short term will need to be evaluated over the short term, and thus, the relevant time-period for the BAF computation will be that same short term. Feedstocks will have different BAF values depending on the policy-driven relevant time-period.

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 used for the analysis. There was extended 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 policy neutral approach. During quality reviews the SAB disagreed with this recommendation noting that for policy initiatives that consider shorter time horizons it may be inappropriate to use a BAF calculated to incorporate nearly all carbon stock effects over time. The SAB favors selecting the time horizon for calculating the BAF to comport with the policy time horizon under consideration. The Panel's previous reports remain available on the SAB webpage.

In addition to the relevant time frame, a policy context would have provided other information necessary to the assessment of the science underpinning the BAFs, such as the scale of demand for biogenic feedstocks and the anticipated time frame for that demand and eligible feedstocks to meet it. As we stated in our 2012 report and we reiterate here: this SAB review would have been enhanced if the Agency offered a specific regulatory application that, among other things, provided explicit proposed BAF calculations and defined 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 SAB to evaluate the science underpinning those decisions and justifications. Since the policy context is expected to alter the choices various actors will make and these choices will alter the assumptions included in the models used to predict biomass-associated emissions and sequestration, it is not possible to evaluate the proposed model assumptions in the absence of a policy context. For proper scientific evaluation, the Framework needs to be applied in a specific policy context with specific BAF calculations and clearly defined boundaries for EPA's regulatory authority. EPA should provide this application to SAB for review. If multiple policy contexts are under consideration, EPA should provide multiple sets of applications, calculations, and boundary assertions for review.

Despite this significant limitation, the SAB offers overarching suggestions for moving forward with a framework for assessing the BAFs of biogenic feedstocks. In addition to specific responses to EPA's charge questions, 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 offers 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 similar formula for BAF as the EPA's emissions-based approach, it offers multiple advantages: it is typically inventoried and modeled by the scientific community; it can be aggregated and rearranged as needed or further subdivided; and it is appropriately constrained by conservation of mass and therefore can be assessed using mass balance calculations. Although this alternative formulation provides these benefits, other important modeling issues l 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 carbon dioxide related to the use of biomass for electricity 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 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 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,

Enclosure

NOTICE

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TABLE OF CONTENTS

List of Figures

Acronyms and Abbreviations

AVOIDEMIT	Avoided Emissions
BACT	Best Available Control Technology
BAF	Biogenic Assessment Factor
BAU	Business as Usual
CH4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
DOE	Department of Energy
EPA	Environmental Protection Agency
FASOM	Forestry and Agricultural Sector Optimization Model
GHG	Greenhouse Gas
GROW	Term in EPA's BAF equation representing net feedstock growth (or removals)
GWP	Global Warming Potential
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 to review a revised science-based framework for accounting for biogenic carbon emissions, which the agency defines as "CO_2 emissions related to the natural carbon cycle, as well as those resulting from the combustion, harvest, digestion, fermentation, decomposition, or processing of biologically based materials."[1] The goal of the 2014 Framework is to evaluate biogenic CO_2 emissions from stationary sources that use biogenic 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 adjustment for carbon emissions associated with the combustion of biogenic feedstocks to reflect net emissions to the atmosphere. The BAF is an accounting term developed in the Framework to denote the offset to stack emissions (mathematical adjustment) that reflects net carbon emissions after taking into account the sequestration of carbon in regrown biomass or soil and emissions that might have occurred with an alternate fate had the biomass not been used for fuel.

Importance of the Policy Context

The questions before the agency in 2011 and in 2014 and presented for the SAB's review, were whether and how to consider biogenic greenhouse gas (GHG) emissions and decisions about best available control technology (BACT) for CO_2 emissions from bioenergy. The BAF is defined by its use for policy goals and thus evaluation of this construct for a science-based regulatory framework in the absence of a policy context is not useful. Rather than assume a policy context or evaluate the charge questions across numerous putative policy contexts, the SAB focused on providing a summary of the fundamental science underlying the development of science-based policies for assigning CO_2 emission factors to bioenergy feedstocks.

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. Projections of these interactions can be obtained from diverse model types, from simple empirically and statistically-based models, to complex integrated assessment models that integrate biophysical and/or economic factors. The more complex the model, the greater the dependence of outputs on input assumptions; thus, sensitivity and uncertainty analyses are needed to adequately interpret the results from complex models. Often, simple models are best.

In general, the BAF for a class of feedstock should be estimated for the average effect of the last increment of demand for that feedstock. Changes in demand for biomass feedstocks should be assessed

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

based on historical data on forest carbon stocks, resource use, and observed information on current and planned expansions to facilities using biogenic 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.

To compare changes in any system over time there must be a reference scenario (without increased demand for bioenergy or other uses of the feedstock) against which to assess the net impacts on the variable of interest, in this case carbon stocks. In 2012, the SAB recommended a future anticipated baseline approach to capture the *additional* CO_2 emissions to, or uptake from, the atmosphere created by any increased use of biomass for energy. 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. The reference point approach, if adjusted at regular intervals (e.g., every 5 to 10 years) to account for any additional regional sequestration, would address the SAB's earlier concerns, allowing for the more direct establishment of a baseline while capturing additional increases in carbon stocks.

Regardless of the model structure chosen (reference baseline or future anticipated baseline), validation and evaluation of the model will be critical. Model validation is essential to assessing the model's ability to replicate observed phenomenon over time. 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 using observed changes in economic and land use conditions that may be due to increased biomass/fiber 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 policy as well as the timeframe associated with updates to the underlying data.

In the 2014 Framework, the EPA has offered illustrative simulations of future biophysical and economic conditions employing the Forestry and Agricultural Sector Optimization Model (FASOM) to determine the incremental GHG emissions of increased biomass feedstock demand compared to a "business as usual" approach (i.e., the reference baseline scenario without demand for bioenergy). Such models have not been validated for this application, and heavy reliance on them is unwarranted.

Alternate Fate Approach for Waste-Derived Feedstocks

In 2012, the SAB recommended that the EPA consider the alternate fate of feedstocks diverted from the waste stream, whether they might decompose over a long period of time, whether they would be deposited in anaerobic landfills, whether they are diverted from recycling and reuse, etc. In the 2014 Framework, the agency has conducted extensive alternate-fate calculations. However, by drawing a narrow boundary around point-source emissions, the agency neglected significant considerations that affect the greenhouse gas footprint of alternative solid waste management scenarios including:

- the potential alternate fate of municipal solid waste, e.g. electrical energy generation by capturing landfill gas and associated fugitive emissions or direct combustion.
- carbon storage associated with landfills, and a landfill baseline that is inconsistent with regulatory practice.
- waste treatment options might change if current energy recovery uses were considered.
- methane emissions for woody mill residuals.

A more complete analysis is required to ensure that the net greenhouse gas emissions are well defined.

Temporal Scale (Charge Question 1)

A sustained increased demand for bioenergy by stationary facilities in a region is likely to trigger changes in carbon stocks through one or more pathways that could generate a new (steady-state) equilibrium stock of carbon that may be higher or lower than the current stock of carbon on the land. The demand for biomass for bioenergy can affect carbon stocks by increasing harvesting intensity for standing biomass, diverting biomass from other non-energy products and landfills, converting land from other uses to plant new biomass feedstocks for the future, and utilizing residues that might otherwise decay. Each of these responses may differ over time, and thus, the overall effect of all these responses together on demand for biogenic feedstocks may differ over time. Therefore, the time period selected for the analysis can strongly affect the assessed impact of an increased demand for bioenergy by stationary facilities on carbon stocks and net emissions of carbon dioxide to the atmosphere. The selection of the time period for assessment is not a scientific question, but rather is closely associated with the policy objectives being addressed by the application of a BAF to a stationary source. For example, if the goal is to limit peak planetary warming versus a goal 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 analysis would differ. Since BAFs are defined by the policy objectives, there are no scientific criteria by which to pick a single ‘right’ timeframe for their determination (Ocko et al 2017). Computing a cumulative BAF over any period of time requires accounting for the positive and negative impacts on stocks over time to determine the net biogenic effect. A cumulative BAF is preferable to an instantaneous (or annual) BAF because the use of biogenic feedstocks can trigger changes in carbon stocks that manifest beyond the period in which the feedstock is consumed by a stationary facility.

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 it is appropriately constrained by conservation of mass and therefore can be assessed using mass balance calculations. In theory, a stock-based formulation should yield the same BAF as an emissions-based approach, but the stock-based approach is simpler and more transparent.

Two Cumulative Biogenic Assessment Factor Approaches

There are two alternative approaches to calculating a cumulative BAF and the implications of these different approaches should be further considered. Until the implications of the differences are better understood, we support EPA’s cumulative BAF (which we designate as BAF_T) approach, i.e., the difference in carbon stocks *at the end of the time horizon T*. A second approach was developed by members of the Biogenic Carbon Emissions Panel which takes into account the time course of CO_2 emissions by accumulating the annual differences in carbon stocks on the land *over the time horizon T*. By accumulating annual differences across the projection period, the alternative cumulative BAF metric (designated as $BAF_{\sum T}$) 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. (See Figures 1 and 2)

Scales of Biomass Use and Modeling Approach (Charge Question 2)

In general, the BAF for the feedstock in a region should be estimated for the average effect of the last increment of demand for biomass from that feedstock in that region. 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 biogenic energy resources consistent with policy.

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 changes. Retrospective evaluations of BAF performance will be important for understanding how effective the modeling has been, regardless of the complexity of the deployed models. Thus, projections about biomass demand should be revised based on actual outcomes, and these updated demands should be used to inform modeling that generates BAFs.

Recommendations

1. Full development of a biogenic carbon accounting approach requires a specific-policy objective to which BAFs will be deployed. With that specificity, the accounting can be refined to ensure maximum effectiveness relative to that objective, while minimizing transaction costs.

2. 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.

3. The direction and magnitude of the impact of a feedstock on terrestrial carbon stocks depends on the time horizon considered. There is no single optimal time horizon.

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

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

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 is to develop a method for calculating the adjustment, or BAF, for CO_2 emissions associated with the use of biogenic feedstocks, 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 bioenergy 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 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 material at stationary sources results in a net atmospheric contribution of biogenic CO_2 emissions that 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. This 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.

3. OVERARCHING COMMENTS

This section addresses issues that lie outside the scope of EPA's charge questions.

3.1. Policy Context

For its review of the 2011 Framework, the SAB requested and was given a policy context for the biogenic CO_2 accounting framework. The SAB was told that the 2011 Framework was intended to guide the determination of CO_2 emissions from regulated stationary sources under the Clean Air Act, specifically those facilities receiving a prevention of significant deterioration (PSD) air permit 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 bioenergy.

The agency has removed this policy context from its 2014 Framework, and the EPA's charge questions seek general guidance on issues related to the choice of temporal, spatial and production scale for determining BAFs in a policy-neutral context. In the absence of a specific policy context, this review was limited to providing general comments about how to consider the questions posed. Answers to the specific questions posed will vary with the policy 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 and the regulated entity.

A policy context would be helpful to clarify if the proposed procedures will account for the emissions of all greenhouse gases that alter the climate. If this is the case, then it will be important to account for the effect of biogenic feedstocks on non-CO_2 gases such as N_2O and CH_4, to examine how the emission or uptake of these gases differ across space, time, and feedstocks, and to examine how these gases influence BAFs. 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 the climate impacts over 20 or 40 years is of concern then methane and black carbon emissions could be very important, while if the 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.

Recommendation

- Biogenic carbon accounting will vary depending on the policy 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 policy-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. Baseline Approach

To compare change in any system over time, there must be a baseline or reference scenario against which to assess changes due to an incremental and sustained demand for biogenic feedstocks, allowing different scenarios to be compared. The EPA assesses the estimated net change in land-based biogenic CO_2 fluxes and/or carbon stocks between two points in time. 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 approach. The limitations of a reference point approach can be reduced by deploying a shifting reference point (updated at regular intervals using empirical data (e.g. every 5 or 10 years)), which is designed to capture increased regional carbon stocks.

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, bioenergy demand can affect carbon stocks in many ways including the ages at which trees are harvested, the diversion of forest biomass from traditional forest product markets to bioenergy, and the rates of afforestation and deforestation. The complexity of such a modeling approach makes it difficult to parameterize and validate. The lack of empirical data regarding many of these relationships and the resulting uncertainties pose a significant challenge to use of this type of model in a regulatory context. 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. Employing models of this complexity is likely beyond the capabilities of many practitioners.

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 were daunting if they were to be accurate (e.g., case-specific measurements and calculations of carbon stocks and fluxes 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 perverse outcomes, e.g. feedstocks with large positive 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 2012, there are tradeoffs between ease of implementation (transaction costs), precision (getting it right at every location versus overall accuracy), and policy effectiveness (ensuring that the policy objectives are being met). We continue to recognize the difficulty of undertaking an anticipated baseline approach, and practicality should be an important consideration in the agency's decision making. All methods considered should be subject to an evaluation of the costs of implementation and compliance and weighed against any increase in accuracy and precision that they might yield. Ultimately it is critical that there is a balance between accuracy and minimization of implementation costs.

Recommendation

- The EPA should identify and evaluate its criteria for choosing a model (simple or complex) and its underlying assumptions with regards to how both affect BAFs. In addition, the EPA should periodically update and validate the selected model to incorporate the latest scientific knowledge while ensuring that the model outcomes 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. Alternate Fate Approach for Waste-Derived Feedstocks

In 2012, the SAB recommended that the EPA consider alternative fates (i.e., if not used as fuel) 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 alternate 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 alternate 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). 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). For example, one public commenter provided an example showing the effect on BAFs of incorporating methane emissions for woody mill residuals (National Council for Air and Stream Improvement 2015).

3.4. Temporal and spatial considerations in Biogenic Assessment Factor Calculations

The goal of the Framework reviewed by the SAB is to account for effects of biogenic feedstocks on terrestrial carbon stocks. BAFs are a carbon accounting method based on expected future changes in carbon stocks (measured in tons of carbon) due to the use of biogenic feedstocks by a stationary facility. They are designed to assess the net contribution of CO_2 from a stationary facility that uses biogenic feedstocks, due to shifts of terrestrial carbon to the atmosphere over a specified period of time. The time scale selected will vary depending on policy objectives (e.g. a mitigation of climate change in 2050 or 2100, or minimizing global temperature change resulting from greenhouse gas emissions). Over the selected time period, all greenhouse gas impacts – 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. 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 credits that determine 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 emissions from facilities that burn biomass 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. 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, policy, 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 required for accounting for the impacts of feedstock demand on carbon stocks.

RESPONSES TO EPA'S CHARGE QUESTIONS

3.5. <u>Temporal/spatial Scale for Biogenic Accounting</u>

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 a couple of factors that impact the BAF over time. The first is that the increased demand for bioenergy in a region could potentially be met by a variety of feedstocks obtained from the agricultural and forestry sectors, including annual and perennial agricultural crops, short rotation woody biomass and pulpwood, and crop and forest residues. The additional biomass might come from several sources: diversion from non-energy products and landfills, converting land from other uses to plant feedstocks for biomass, utilization of residues that would otherwise decay over some period of time. The effect of increased demand for biomass on carbon stocks will depend on the mix of these feedstocks demanded and the scale of demand for these feedstocks.

Second, feedstocks differ in their rate of 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 the reference (baseline) scenario and the increased biomass feedstock demand scenario and would vary with the time horizon selected by the policy context.

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 approach to account for direct and indirect effects, and (3) consistency across regions. Selecting different time horizons for different feedstocks would be inappropriate since carbon emissions generated by differing feedstocks are equivalent in their impact on the climate.

To fully account for all positive and negative terrestrial effects over time, we recommend using the "emissions horizon" as described by the 2014 Framework applied to a specific policy 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 goal is to have an effect on greenhouse gas emissions by a certain date, then the impacts aggregated by that date are the relevant metric, and that date is the appropriate time horizon. Accordingly, there is no single time horizon that will effectively address all policies or feedstocks since feedstock effects are time-dependent and desired outcomes for policy changes target different time horizons. The SAB does not support a single time horizon as appropriate for determining BAFs, because the computed values can vary significantly over differing time horizons.

Some suggest 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 reference scenario is no longer changing or when the difference is approaching an asymptote. This could result in a very long time horizon being selected, 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 policy objectives with shorter time horizons (e.g., meeting an emissions target by 2050), the accounting would not align with relevant effects of biomass energy on the policy outcome.

Several factors determine the difference in carbon stocks between the reference scenario and the increased biomass feedstock demand scenario. A major factor is the "speed" with which carbon stocks respond after harvest; this is determined, for example, by 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. For example, if the mix of feedstocks consists of agricultural and short rotation trees then it is likely that stocks will establish new regional equilibrium relatively quickly.

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, 2012; 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 in a regulated manner (i.e., completely asynchronously), and 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. 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 reference 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 bioenergy can lead to a diversion of biomass from those products to energy use and lead to an immediate reduction in carbon stocks in products. It is also possible that anticipation of future demand for biomass by stationary facilities can 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 that 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 reference scenario. The demand for bioenergy 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 impact of a feedstock on terrestrial carbon stocks depends on the time horizon considered. A cumulative BAF is preferred because it will capture and integrate all expected negative and positive carbon effects over the policy-relevant time period.

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. The 2014 Framework refers to an "assessment horizon" which may be specified by a particular policy. As described in the overall response to Charge Question 1 (above), the SAB supports the use of time horizons that are defined by a specific policy objective. If there are multiple objectives, there are no overriding scientific principles that can be applied *a priori* to guide alignment among multiple objectives. It may be useful to consider a time horizon that represents the most conservative policy with respect to minimizing net greenhouse gas emissions, but such a guiding framework is the purview of policy, not science.

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 policy 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, indicating all biogenic emissions being net beneficial to the atmosphere. Neither of these approaches would align with the most likely policy uses of a biogenic accounting framework; however, neither is inherently correct or incorrect.

The time horizon, T, for consideration of carbon stock changes should be chosen based on the policy objective (e.g., minimizing net greenhouse gas emissions or temperature increase by a certain date). The SAB makes no assertion regarding the appropriate policy use of the BAF and thus supports no specific time horizon selected independent of a policy goal.

BAFs are a carbon accounting tool used to measure expected future changes in carbon stocks due to increases in demand for bioenergy over some period of time. Therefore, BAFs should be science based and developed in service of a policy objective, ensuring that they help align actions and outcomes. If the BAF is calculated over a timeframe different from that of the policy objective, a mismatch between the carbon cycle impacts and those desired is likely. In the service of simplicity, a single time horizon may be selected to serve multiple objectives, in which case the tradeoffs need to be explored to ensure the most parsimonious temporal framework is selected and thus dis-benefits to the environment and public health are minimized.

The demand for biomass for bioenergy can affect carbon stocks by increasing harvesting intensity for standing biomass, diverting biomass from other non-energy products and landfills, converting land from other uses to plant feedstocks for biomass in the future, and utilizing residues that might otherwise decay or be incorporated into soils. To capture these time varying impacts of a feedstock on carbon stocks, we recommend an approach for computing a cumulative BAF that accounts for the positive and negative impacts on emissions over time to determine the net biogenic effect. To ensure comparability of BAFs across all feedstocks and regions, we recommend an approach that computes a cumulative BAF using the same policy-informed time horizon, T, for all feedstocks and regions.

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 (BAF_T) is one option that reflects 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* to T, here called $BAF_{\sum T}$.

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, thus the simpler the model the more confidence that can often be placed in it (Bucholz et al. 2014). Each BAF will need to be assessed periodically to see if changing conditions warrant a revision.

Carbon accounting for biogenic emissions can either be framed 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 water 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

Some have 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. 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.

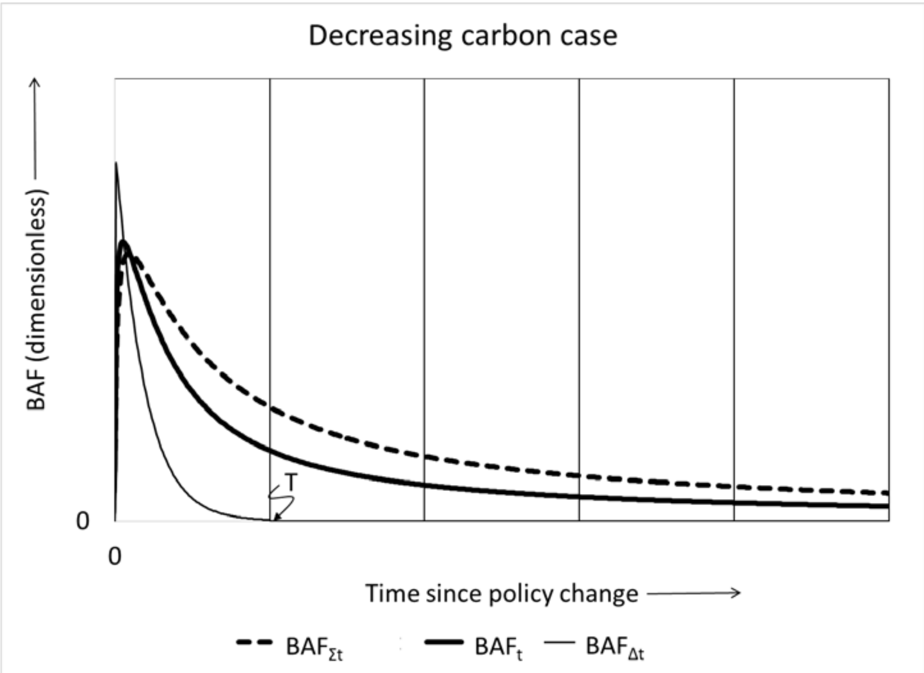

Figure1: Illustration of Long-Term Trend in BAF for a case of decreasing carbon stocks

Figure 1 illustrates the long-term trends in BAFs for the case of decreasing carbon. This is the case in which harvest in a forest landscape is increased to provide biogenic feedstock through more frequent harvesting, or more intensive harvesting over time, or a diversion of harvested wood to bioenergy. As a result of increased use of bioenergy, removals of carbon from the land are higher than that for the reference scenario. The time at which annual changes approach zero is indicated by T. Once T is reached, the $BAF_{\Delta t}$ approaches a value of zero, but BAF_t and $BAF_{\Sigma t}$ are ≈25-35% of their peak value, respectively. Doubling the value of time used for evaluation (i.e., 2 x T) would lead to a BAF being selected that is half that at time T. Thus, the systems that lose carbon will have a positive cumulative BAF for a considerable period of time.

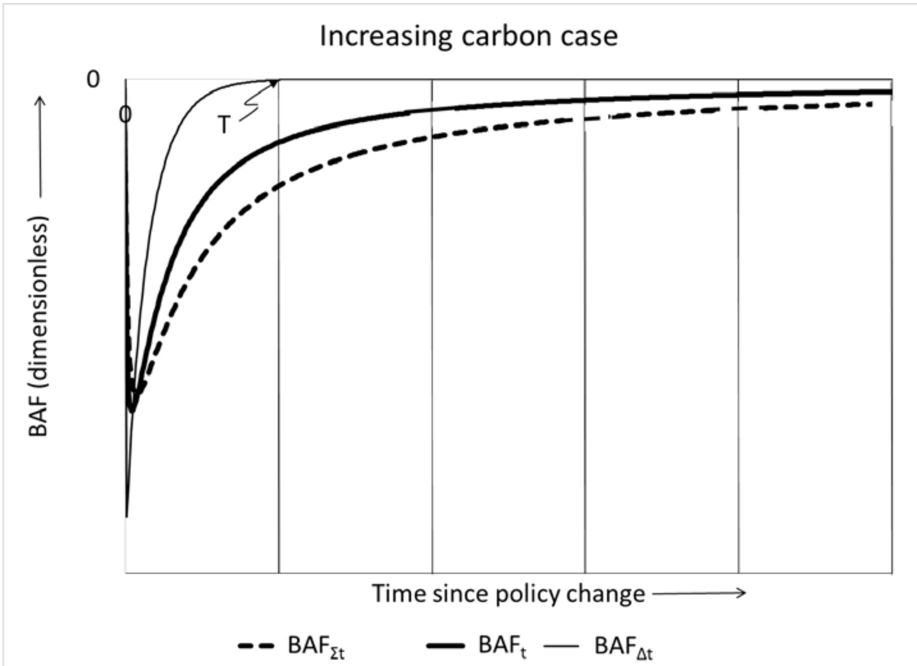

Figure 2: Illustration of Long-Term Trend in BAF for a case of increasing carbon stocks

The same is true for a system that increases carbon stocks as illustrated in Figure 2. Increased input of carbon might occur through the use of a feedstock that grows faster, practices that improve productivity such as irrigation, fertilization, and/or planting on lands that previously had shorter-lived plants. At time T, the $BAF_{\Delta t}$ approaches zero, however, the cumulative BAFs are 25-40% of the maximum value. As with the decreasing case, doubling the time for evaluation (i.e., 2 x T) reduces the cumulative BAFs to roughly half that value because of the hyperbolic nature of the Biogenic Accounting Factor calculation once T is reached.

A shifting projection of the reference baseline that includes a historical time period could be used to reset the baseline periodically based on re-measuring carbon stocks on the landscape, using data from existing inventory programs. This would improve the accuracy of the baseline over time. 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 would 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. Carbon stock measurements have been made for more than a half century in the US offering a robust record of change.

- 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 the anticipated baseline approach.

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.

3.6. <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.

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 policy 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 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 policy 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 whether there is 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 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 policy, versus a particular period of time, would be based on simulating the aggregate and feedstock-specific demand that is expected to emanate from that policy, while policy 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 policies 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 policy (when there are multiple policies inducing a shift to renewable energy) is likely to be complicated and challenging to convert into policy-specific BAFs. It could also create perverse incentives for feedstock choice to comply with various policies.

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 policy will differ from the forecast because the policy 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 outcomes. 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

[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

the estimated GHG emissions and sequestration effects from changes in biomass use have used different 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 outcome of 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

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[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

[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.

October 2011 comments) implied support for shorter temporal scales, and stated in later comments that 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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