1. RESPONSES TO CHARGE QUESTIONS ON TEMPORAL SCALE

Charge Question 1

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?**

The selection of a temporal scale for biogenic carbon accounting should be based on the time horizon over which effects are expected to occur. Here we refer to the effects, both positive and negative, of a change in the demand for bioenergy. Selection of the temporal scale should include consideration of growth and harvest cycles, short- and long-term soil carbon changes, and direct and indirect effects on the land. These effects may work on different temporal scales across feedstocks, but the longest of these as measured for any feedstock production system should set the end point of the temporal scale used for biogenic carbon accounting for all feedstocks.

To fully account for all positive and negative terrestrial effects over time, we recommend using the "emissions horizon" as described by the 2014 Framework. As defined by EPA, this "emissions horizon" is the period of time during which the carbon fluxes resulting from actions taking place today actually occur …" ((Environmental Protection Agency, 2014, pp. B-3). In the context of an anticipated baseline approach, this emissions horizon would be the length of time it would take for the effect of increased demand for a feedstock on the carbon cycle to reach a state in which the difference in CO2 stocks between the policy case and the reference case is no longer changing. Defining the emissions horizon to be long enough to achieve a state where the difference in CO2 stocks between the policy case and the reference case is no longer changing will ensure that all positive and negative changes in stocks attributable to increased use of a bioenergy feedstock will be accounted for. This time horizon should be standardized by selecting the longest time period among the various feedstock horizons and applying it to all feedstocks.

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.**

As discussed above, the temporal scale should be chosen to capture all effects on CO2 stocks, both direct and indirect – thus it should not vary by policy or landscape conditions.

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?

Temporal scales should not vary by policy. They should, instead, be chosen to capture all effects on the CO2 stocks. The 2014 Framework refers to an assessment horizon which may be specified by a particular policy. We recommend using the broader definition of the emissions horizon rather than the assessment horizon described in the 2014 Framework.

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?

Please see the overall response to Question 1 above.

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?

No, the criteria for selecting a temporal scale should simply be based on the period of time over which effects are expected to occur.

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)?

No, based on the same principle that all effects should be considered (both short-term and long-term, both direct and indirect) during the emissions horizon, the effects of a policy should not be limited to an arbitrary policy horizon that may be shorter than the emissions horizon. It should include all changes in stocks that occur during the emissions horizon.

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)?

Cumulating all effects of the use of a biogenic feedstocks over a time horizon is preferred to a marginal or instantaneous ("per period") BAF. (For the purposes of answering this question, we are interpreting "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).

We are recommending a formulation of the BAF that differs from EPA's various BAF formulas. We propose a BAF based on the accumulation of annual differences in carbon *stocks* on the land over the time horizon rather than annual differences in *emissions (fluxes)*. The rationale for this follows.

Carbon accounting for biogenic emissions can either be framed using differences in carbon in the atmosphere or using differences in carbon stores on the land. Since carbon that is not stored on the land is emitted to the atmosphere, conservation of mass dictates that any carbon taken from the land (through increased harvests in the policy case) will result in equivalent increases of carbon in the atmosphere. Thus these approaches are compatible.

The use of biogenic feedstocks can affect the time sequence of emissions in the policy case relative to the time sequence of emissions in the reference case. These each affect the time sequence of C on the land in the policy and reference cases. Moreover, near term removal of biomass can have feedback effects on biomass growth potential in the future and affect the entire trajectory of C on the land in the future. The effects of biogenic feedstock removal and use on what the atmosphere sees may play out over many years to many decades and it is the sequence of increased biogenic emissions collectively which determine the time path of carbon changes on the land.

At any point in time, over a projection period, the effect on the atmosphere (what the atmosphere sees) from the sequence of biogenic emissions will be the difference in carbon stocks on the land. We must consider all of these differences in carbon stocks at each point in time over a long period of time and not just the difference in carbon stocks at a single point in time in order to capture the full effect of the use of biogenic feedstocks over a time period.

This proposed modification to EPA's approach accounts for the residence time of emissions which is an integral part of radiative forcing. For each year that a ton of CO2 emissions resides in the atmosphere, it contributes to radiative forcing or the difference between incoming sunlight absorbed by the Earth and energy radiated back into space. For biogenic feedstocks evaluated in an anticipated baseline framework, the difference between the time path of CO2 emissions between the policy and the reference cases should take into account the residence time of emissions if the BAF is to be a plausible indicator of the contribution of biogenic emissions to radiative forcing. This can be captured by using a measure of BAF that takes into account the entire sequence of differences in the store of carbon on the land over time. This modification to the BAF formula, as explained further below, would yield something like the notion of "ton-years" to account for differences in carbon stocks *each year*.

As noted in the 2014 Framework, conceptually, we seek to answer the following question:

"Is more or less carbon stored in the system over the projection period compared to what would have been stored in the absence of changes in biogenic feedstock use?" (Environmental Protection Agency, 2014, pp. J-6)

To answer this question, Appendix A offers an alternative framework based on differences in carbon stocks between a policy case and a reference case rather than differences in carbon fluxes. A key feature of using land carbon stocks is that all terms can be readily aggregated or disaggregated and are still subject to mass balance.

We define:

$$NBE_{\Sigma T} = \sum_{t=0}^{T} (TC_{Reference} - TC_{Policy})$$

Where:
$TC^{i}_{policy}(t)$ = the total stock of land carbon in the policy case in year *t* with increased demand for a biogenic feedstock; and
$TC_{Reference}(t)$ = the total stock of land carbon in the reference case in year *t*.

While our anticipated baseline based approach is consistent with EPA's, the proposed modification would accumulate the annual differences in carbon stocks on the land [which represent the accumulated annual differences of CO2 in in the atmosphere] over the projection period. To do this, we propose amending both NBE and PGE to reflect the differences in carbon stocks between the policy scenario and the reference scenario. We can interpret $NBE_{\Sigma T}$ as the sum of the annual differences in carbon stock in the atmosphere from time t=0 to T associated with biogenic feedstock use. This term is the numerator of the $BAF_{\Sigma T}$ ratio.

The denominator of the $BAF_{\Sigma T}$ formula should also be measured in terms of the difference in carbon stocks in the atmosphere due to the use of the biogenic carbon at the stationary facility. Specifically, for the denominator we first define PGE_t to be all of the annual emissions from a biogenic feedstock to the atmosphere from the stationary source from time 0 up through time t, where each annual emission is denoted by $PGE_{\Delta t}$. This represents the gross amount of carbon stock in the atmosphere at time t due to stationary source emissions.

The accumulated annual amounts of gross emissions from time 0 to the time horizon *T* is represented by

$$PGE_{\Sigma T} = \sum_{t=0}^{T} PGE_t$$

We now define $BAF_{\Sigma t} = \dfrac{NBE_{\Sigma T}}{PGE_{\Sigma T}}$ for a given time horizon T

The numerator represents the accumulated annual differences in the carbon stock over a total period of time T between the policy case (with increased demand for biogenic carbon) and the counterfactual reference baseline. It also represents the corresponding difference in C the atmosphere sees over the projection period. This ratio takes into account the effect on the atmosphere of periods of time when differences in carbon stocks may be large as well as periods when they may be small.

After subtracting the policy case from the reference case, a loss in carbon stocks in the policy case relative to the reference case would lead to a positive sign for $NBE_{\sum T}$. Conversely a gain in carbon stocks compared to the reference case would lead to a negative sign. If this approach for calculating the BAF is utilized for long rotation feedstocks, it should also be used for all other feedstocks to maintain comparability.

We illustrate this $BAF_{\sum T}$ value graphically in Appendix B and Appendix C in different cases. These cases provide examples with carbon stores in the reference case being larger or smaller than the policy case over the entire time horizon. We also provide examples where total carbon stocks reach a new steady state as well as scenarios in which equilibrium is not reached.

We now clarify how this proposed approach differs from the approaches presented in the 2014 Framework which describes two different ways to calculate the BAF: a cumulative BAF and a per-period BAF (Environmental Protection Agency, 2014, pp. L-9). EPA's cumulative BAF in the 2014 Framework is based on the difference in emissions between the reference case and the policy case as follows:

$$NBE_t = \sum_{t=0}^{T} \Delta TC_{\mathrm{Re}\,ference}(t) - \Delta TC_{Policy}(t) = \mathrm{TC}_{\mathrm{Re}\,ference}(T) - TC_{Policy}(T)$$

where ΔTC is the change in carbon stocks at time t relative to $t\text{-}1$ and equal to the net emissions at time t. Here NBE_t is the NBE at a point in time and equals the sum of the annual changes in emissions. Mathematically, NBE_t adds up to the difference in stocks at time t. This cumulative BAF as defined in the 2014 Framework as:

$BAF_t = NBE_t/PGE_t$ where PGE_t is gross emissions at time t . Note this is different from the our proposed alternative definition of PGE given above in which it is the accumulation of annual gross emissions each year $t=0,\ldots T$. EPA's cumulative BAF is also shown graphically in Appendix C and referred to as BAF_t. If the time period at which the BAF is measured is $t=T$ then $BAF_T = NBE_T/PGE_T$

The per-period BAF in the 2014 Framework is based on the change in emissions at a point in time.

$$\Delta TC_{\mathrm{Re}\,ference}(t) - \Delta TC_{Policy}(t)$$

$$BAF_{\Delta t} = \frac{\Delta TC_{Reference}(t) - \Delta TC_{Policy}(t)}{PGE_{\Delta t}}$$

This is shown graphically in Appendix C as well. Additionally, averages of the per-period BAF at each point in time as well as a moving average of the per-period BAF is also computed and included in the graphs for comparison.

As shown in Appendix C, all BAF values decline as T increases and in some cases may not stabilize as T increases. Thus choice of time scale is critical in defining the value of the BAF. The examples in Appendix C also show that these different measures of BAF can lead to widely different values for any particular case. For the range of examples we present, the stock difference based BAF ($BAF_{\sum T}$) proposed here is generally larger in absolute terms than the cumulative emission based BAF and the Per-Period BAF in cases where the stock of carbon in the reference case is higher than that in the policy case.

With either approach to evaluating BAF, caution is advised with projections into the future. For example, a BAF calculation is based on modeling that implicitly assumes feedstock regrowth following an assumed rotation length and that carbon sequestered in soils would continue indefinitely. Given the uncertainty about the maintenance of our forests and agricultural land use policies and practices, the BAF needs to be updated periodically to reflect latest data and trends and a one-time cumulative BAF may not remain an accurate representation of reality over time. Therefore the model used to determine the BAF needs to be updated and validated periodically to ensure that the underlying information on which it is based is still valid. Additionally, the likelihood of a cumulative BAF being realistic also depends on other policies in place that encourage or, at least, do not discourage long term sustainable land and forest management.

A shifting projection of the reference baseline that includes a historical period could be used to reset the baseline periodically based on re-measuring carbon stocks on the landscape, based on existing inventory programs, effectively improving 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 continually test this assumption against actual data as it becomes available.

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?

The goal of an ex post evaluation would be to make adjustments to the key parameters, functional forms and assumptions that can be improved with hindsight, thus improving the ability to calculate a BAF for the future. There are many reasons why an ex post BAF would differ from an ex ante BAF, many of them beyond any model's ability to anticipate. The recent collapse in oil prices is an example of a macroeconomic event that is dramatically affecting the energy sector but was hardly expected. Neither was the hydraulic fracturing revolution foreseen as recently as 10 years ago. After the fact, these economic changes can be incorporated into a model but the future will always have economic surprises, including surprises from climate change itself such as forest fires, drought and precipitation.

It is important to periodically update the model with the newest data and estimates for historical years but a retrospective evaluation should seek to segregate those exogenous factors from elements of the model that can be improved such as key parameters, functional forms and assumptions. As time passes and BAF calculation projection periods become historic periods there will be opportunities for comparing new observations and estimates of historic carbon fluxes and stocks to BAF-based estimates (the product of BAFs and biomass quantities used) for those same years. However, it is important to note that such a comparison will be imperfect because there is no observed counterfactual. Thus, econometric analysis would be useful to estimate biomass' role in historic carbon emissions and stocks and compare to BAF-based estimates. If the two estimates are vastly different, the analysis could be used to identify the key factors associated with the difference and update BAF calculations.

RESPONSES TO CHARGE QUESTIONS ON THE FUTURE ANTICIPATED BASELINE APPROACH

Charge Question 2

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)?**

   We have lumped these three questions together because they all relate to the size of the simulated "shock" in biomass feedstock demand.

   There are two issues that are relevant to determining the scale of demand for a specific feedstock: the overall demand for biomass from all sources and the competitiveness of the specific feedstock relative to other feedstocks. In the absence of a specific policy that specifies a scale of demand for all biomass, a model could be used to analyze the implications of various exogenously set levels of aggregate demand for biomass for the mix of feedstocks that would meet that demand in an economically viable manner.

   In general, the limiting factor in determining the size of the shock is the ability of available data to provide a statistically significant signal. The 2014 Framework provides a good discussion on this topic, although it should be noted that homogeneous feedstocks lend themselves to analysis more readily than a mixture of feedstocks. Regarding the question of marginal versus average impact measurement, marginal changes would likely be impractical because the market and resource impact of a small marginal change would be statistically insignificant. Instead, modeling exercises could be undertaken to determine BAF thresholds (scales of consumption that shift the BAF) so that a "marginal" shift becomes a demand shift large enough to

cross a BAF threshold. Demand shifts should be specified as percentage increases and the "business as usual" baseline should include increased usage of the feedstock, using Department of Energy energy consumption updates to reflect actual consumption. Because baseline demand is constantly evolving, the updated baseline should converge to the reality observed as the feedstock market develops. The key question that remains is whether adding more complicated market dynamics enhances or diminishes our ability to detect a carbon signal.

To isolate the carbon implications of using each feedstock to get a feedstock specific BAF, this could be done either by (a) applying the equilibrium quantity of each feedstock determined in the first step as a shock in demand for that feedstock alone relative to the reference case and analyzing its carbon implications to obtain an average BAF across all users or (b) increase demand for a feedstock by a marginal (incremental) level relative to the equilibrium and simulating its effect on emissions to isolate the effect of the last unit of that feedstock on carbon emissions while keeping demand for all other feedstocks at the equilibrium level. The latter would provide a BAF based on the impact of the marginal unit of feedstock on carbon emissions.

Specifying the increase in demand for bioenergy in percentage terms relative to the reference case would keep the analysis grounded in historical reality and provide the perspective needed to define a marginal increase as compared to a total increase in demand for a feedstock.

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).**

Without information on EPA's policy context, we are left to conjure very hypothetical demand shocks. For example, a mandate for use of specific feedstocks or incentives for specific types of bioenergy production would have a significant effect on the structure of demand shocks to be modelled. The most economically sensible approach is to model the feedstocks together because facilities are constantly seeking their least cost feedstock. In fact, shocks for different feedstocks should be

allocated endogenously by the model across feedstocks and also across forestry and agricultural derived feedstocks. A general shock, e.g. 5 million tons of biomass, could be allocated by a model among feedstocks but the resulting estimate of emissions would be difficult to disentangle among separate feedstock categories for the purpose of calculating a feedstock-specific BAF. We could use the average or marginal approach described above as a way to address this issue.

This question of whether to use a joint production function becomes relevant for feedstocks like corn stover (which is driven by corn production) and forest residue (which is driven by sawtimber harvests). If one of the co-products has higher market value, it is likely that harvest rates are driven primarily by the higher valued co-product and thus the demand shocks simulated in the model should be bound by practical limits on the primary product. For feedstocks that are joint products like crop or forest residues, if the model is used to endogenously determine the demand for those feedstocks then it will determine an economically viable quantity to be produced of that feedstock and avoid possibly perverse results in which the demand for residues drives the demand for the other marketable products.

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)?**

By "scale of the policy," we assume EPA means the quantity of biomass required for a policy change. By "single set of default factors," we assume EPA means default BAFs that would be independent of the size of the demand shock. It is not clear whether EPA is referring to default BAFs that vary by feedstock category but we assume this is the case because no single BAF would apply to all feedstock categories.

BAFs should be based on the scale of demand for a feedstock irrespective of the policy that leads to that scale of 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-specific demand. It would be impractical to isolate the quantity of a feedstock demanded to comply with individual policies (when several policies are implemented simultaneously) and then determine policy-specific BAFs. The BAF will vary greatly, depending on whether a policy requires 1 million ton increase in biomass or a 100 million ton increase in biomass. In addition to determining the quantity of biomass needed, EPA's policy choice will determine what mix of feedstocks will be induced so it is unlikely that a single set of default BAFs could be applied independent of the size of the demand shock.

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?**

No – the same approach should be used in both cases. The only difference would be that BAFs that are tied to a particular policy would be based on simulating the aggregate and feedstock specific demand shock that emanates from that policy specifically 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. The specific value of BAF that is then chosen in the latter case will depend on EPA's expectations of the level of aggregate demand for biomass likely to emerge.

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?**

An ex post evaluation would allow revisions to EPA's estimates of feedstock demand changes (as discussed in response to Question 1d) based on updated data. To evaluate the performance of a BAF retrospectively, quantities of biomass feedstock (by feedstock category) used by stationary sources would be updated and predictions about biomass demand at stationary facilities could be tested against actual outcomes. Ex post, 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 BAF estimates prospectively.