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 biophysical effects are expected to occur. Here we refer to the biophysical 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 biophysical effects over time, we recommend using the emissions time horizon as described by the 2014 Framework in Appendix B (page B3). This time horizon T_i could be specific to the feedstock *i* and would be defined as the length of time it would take for the biophysical effect of increased demand for feedstock *i* 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 time 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.

Another important consideration is the time horizon over which changes in carbon emissions are expected to influence the climate and lead to changes in temperature. A widely accepted goal is to limit warming to 2º C. Some modeling exercises have shown that the probability of limiting warming to 2º C in the 21st century depends upon cumulative emission by 2050 (Meinshausen et al. 2009). This suggests that an early phase of elevated emissions from forest biomass could reduce the odds of limiting climate warming. Conversely, another study has demonstrated that peak warming in response to greenhouse gas emissions is primarily sensitive to cumulative greenhouse gas emissions over a period of approximately 100 years, and, so long as cumulative emissions are held constant, is relatively insensitive to the emissions pathway within that time frame (Allen et al. 2009). Thus, an increase or decrease in storage of forest carbon must endure longer than 100 years to have an influence on the peak climate response so long as cumulative emissions from all sources are held constant. With one study showing that cumulative emissions by 2050 are the most critical and another showing that cumulative emissions over 100 years are the most important, there is no single correct scientific answer to the time period over which cumulative changes in carbon emissions affect the climate.

If containing global warming within a specific time horizon such as 100 years is the principal objective, then the timing of emissions during that period becomes relevant because the radiative forcing of a unit of emissions differs depending on the length of time it is in the atmosphere. Due to a time delay between biogenic emissions from the smokestack and carbon sequestration in soils and long rotation feedstocks, the global warming potential (GWP) of a unit of gross emissions in the denominator of the BAF is not the same as the GWP of a unit of net biogenic emissions in the numerator of the BAF within a given time horizon of 100 years. In this case, it may be appropriate to convert gross emissions and net emissions from biogenic sources to their GWP 100 equivalent values using a radiative forcing calculation so that their radiative forcing effects within a fixed time period can be compared.

Since there is no single correct scientific answer to the selection of a time scale for analyzing biogenic carbon emissions, we simply conclude: the time scale should be long enough to capture both short term and long term biophysical impacts on the carbon stocks, including direct and indirect effects.

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 biophysical 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 biophysical impacts on the CO2 stocks. The 2014 Framework refers to an assessment horizon which may be specified by a particular policy. We recommend using the emissions horizon rather than the assessment horizon described in the 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, particularly the first two paragraphs.

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 would not differ across policies based on legislatively set horizons for those policies.

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)?

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)?

We are proposing a reformulation of the BAF that reflects the change in CO2 stocks in the atmosphere over the projection period with the use of bioenergy at the stationary facility compared to the reference case. Our proposed reformulation is based on carbon pools rather than carbon fluxes, as explained below. 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?”

To answer this question, Appendix A offers an alternative framework based on carbon pools rather than carbon flows. A key feature is that all terms can be readily aggregated or disaggregated and are still subject to mass balance.

$$NBE^i = \sum_{t=0}^{T} TC^i{}_{Policy} - TC_{\mathrm{Ref}}$$

Where $TC^i_{policy}(t)$ = the total stock of land carbon in the policy case in year t with increased demand for feedstock i
$TC_{Ref}(t)$ = the total stock of land carbon in the reference case in year t

While our equation is consistent with EPA's, we propose a modification that would account for the change in CO2 stocks 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^i as the net difference 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 ratio.

The denominator of the BAF should also be measured in terms of the change 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 $PE^i(t)$ to be all of the emissions from feedstock i to the atmosphere from the stationary source from time 0 up through time t. This represents the gross addition to the carbon stock in the atmosphere by the stationary source at time t.

The amount of carbon stock in the atmosphere from time 0 to the time horizon T is represented by

$$PGE^i = \sum_{t=0}^{T} PE_t^i$$

We now define BAF^i for a given time horizon T as

$$BAF^i = NBE^i / PGE^i$$

The numerator represents the difference 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 difference in C the atmosphere sees over the projection period. 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^i. 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 provide further clarification on how this proposed approach differs from that presented in the 2014 Framework below. The BAF in the 2014 Framework is defined in terms of the difference in emissions between the reference case and the policy case as follows

$NBE(t) = \Delta TC_{policy}(t) - \Delta TC_{ref}(t)$

where ΔTC is the change in carbon stocks at time t and equal to the net emissions at time t This implies that

$$NBE(T) = \sum_{t=0}^{T} \Delta TC_{policy}(t) - \Delta TC_{ref}(t) = \mathrm{TC}_{policy}(T) - TC_{ref}(T)$$

Here $NBE(T)$ is the sum of the difference in emissions over time which equals the difference in stocks in year T. The BAF as defined in the 2014 Framework is then:

$BAF = NBE(T)/PGE(T)$ where $PGE(T)$ is gross emissions at time T (this is different from the our proposed alternative definition of PGE given above in which it is the accumulation of gross emissions each year $t=0,\ldots T$.

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, 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 accompanying the implementation of this Framework that would foster 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 Forest Inventory and Analysis (FIA) data, 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 regrowth, regeneration and continued sequestration, 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?

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 forecast. 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 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. 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.

It is important to examine landowner responses to increased demand for biogenic feedstocks. Assumptions about landowner behavior are a significant feature of the Forestry and Agricultural Sector Optimization Model (FASOM), the model that EPA used for its case studies in the 2014 Framework. FASOM is a large, dynamic non-linear programming (simulation) model that maximizes the net present value of the sum of producer and consumer surplus across the U.S. agricultural and forestry sectors to solve for market equilibria over time. An earlier peer review of FASOM by Industrial Economics stated that FASOM had not been subjected to model validation exercises such as a test of whether it can reproduce historical outcomes (James Neumann, December 20, 2011). For FASOM in particular, its assumptions about anticipatory planting and other land use changes should be re-examined in light of actual "real world" data ex post. As a deterministic, dynamic simulation model, FASOM assumes that agents operate with perfect foresight and know, with certainty, all relevant information for the next 100 years. While expectations about future prices certainly drive investment behavior, this assumption implies that any increase in demand for biomass feedstocks automatically translates into anticipatory investments that perfectly satisfy that demand in the future. This strong assumption virtually guarantees a particular outcome (a low BAF for feedstocks with long rotations) because investment behavior will always plan to meet future demand and hence compensate for any removal of carbon from the land. Given the importance of this "anticipatory planting" assumption, it should therefore be subjected to tests against historical data.

If the anticipatory effect observed in reality is found to be much smaller than being projected by FASOM then alternative modeling approaches should be considered in which agents are assumed to behave more myopically with shorter planning horizons and having adaptive rather than rational expectations.

The BAF accounting equation divides the changes in carbon stocks into separate components to attribute changes in carbon due to changes in forest biomass, soils and leakage. However, the use of a market-equilibrium model like FASOM makes it practically intractable to separate the changes due to the direct effect of harvesting bioenergy from those due to market and price induced consequences of that harvest. As a result emissions due to leakage are inseparable from those due to direct changes in forest stock or soil carbon. The EPA should make this explicit in its presentation of the calculation of the BAF and the Framework should be more transparent about underlying assumptions and boundaries of their analysis.