March 16, 2015

To: The Science Advisory Panel on Biogenic Carbon Accounting
From: Mary Booth, Director, Partnership for Policy Integrity

The following is a critique of certain aspects of the Second Framework for Biogenic C Accounting and the modeling that EPA performed in support the Framework. The gist of these comments is as follows: EPA is charged with evaluating net biogenic emissions from individual facilities, but has conducted economic modeling in the Framework that is not capable of assessing facility-level emissions. Further, the modeling approach appears to incorporate three main assumptions that cause biogenic emissions to be severely underestimated: "avoided" coal emissions appear to be subtracted from biogenic emissions totals; the modeling includes a large anticipatory planting effect that precedes development of a bioenergy market; and the modeling ignores leakage.

Nonetheless, despite giving bioenergy every benefit of the doubt, EPA's modeling still finds that increasing use of bioenergy causes a significant increase in carbon emissions beyond 2030, compared to a no-bioenergy scenario. The SAB should require that EPA use a sound modeling approach that is capable of assessing facility-level emissions. If such modeling is conducted, the net emissions impact of bioenergy will found to be even greater.

Contents

Purpose of the biogenic carbon accounting framework 1

EPA's modeling using FASOM 3

FASOM models regions, not facilities 3

FASOM underestimates biomass emissions by subtracting "avoided" coal emissions 3

FASOM underestimates emissions by including a large "anticipatory planting" effect 4

FASOM underestimates bioenergy emissions by ignoring leakage 6

FASOM underestimates emissions by assuming biopower efficiency will improve significantly 6

Despite its problems, FASOM still finds that bioenergy causes emissions to increase 6

Evidence for FASOM's underestimation of emissions 8

What the EPA model should do to account for faculty-level emissions 9

Purpose of the biogenic carbon accounting framework

When CO_2 became a regulated pollutant under the Clean Air Act, power plants receiving a prevention of significant deterioration (PSD) air permit were required to conduct a best available control analysis (BACT) analysis for CO_2.[1] EPA drafted the initial Framework and convened the special panel of the Science Advisory Board to develop a means of accounting for net emissions from biomass burned in oer plants, taking into account the special characteristics of biomass fuels. While stack emissions from a wood-burning power plant are around 3,000 lb CO_2/MWh, far greater than typical stack emissions at

[1] EPA subsequently deferred consideration of biogenic CO2 for PSD permitting for three years. That deferral is now over, so it would be helpful to have a Framework that can assess facility emissions.

coal or gas plants, "net" emissions from burning wood and other biomass, calculated over time and assuming that bioenergy emissions are offset, are generally lower than stack emissions. It was understood from the beginning that some fuels have greater net emissions than others, and the framework was intended as a means of discriminating among fuels and their relative carbon impact.

The PSD program requires that a BACT analysis take into account the conditions at the particular facility under consideration, its fuels, its boiler technology, its mode of operation, etc, in order to determine how emissions can best be controlled. However, the "reference point" approach initially devised by EPA, which compared standing forest biomass at two points in time, is not capable of assessing net emissions at a particular facility, because it treats all woody biomass as having zero emissions as long as the wood is harvested from a region where growth exceeds harvesting – that is, where net growth is positive. As the Science Advisory Panel report on the first Framework points out, however, EPA is not charged with regulating regional or national forest carbon stocks – the agency must regulate stationary facilities, and simply assessing whether land carbon stocks are rising is inadequate to this task. [2]

The following table illustrates why the EPA's reference point approach cannot be used to assess facility-level emissions. Under EPA's modeling approach, all scenarios where harvesting does not exceed growth would be treated as having zero carbon emissions.

GROWTH: Tons forest biomass accumulation per year	HARVEST: Tons forest biomass harvested and burned per year	Net forest biomass accumulation	Is harvesting "sustainable" (i.e., doesn't exceed growth)?	Treatment under EPA's "reference point" baseline comparing C stocks at two points in time	ACTUAL EMISSIONS: Net CO_2 emitted from biomass burning (tons)
10	1	9	Yes	zero carbon emissions	1
10	2	8	Yes	zero carbon emissions	2
10	3	7	Yes	zero carbon emissions	3
10	4	6	Yes	zero carbon emissions	4
10	5	5	Yes	zero carbon emissions	5
10	6	4	Yes	zero carbon emissions	6
10	7	3	Yes	zero carbon emissions	7
10	8	2	Yes	zero carbon emissions	8
10	9	1	Yes	zero carbon emissions	9
10	10	0	Yes	zero carbon emissions	10
10	11	-1	No	some carbon emissions	11
10	12	-2	No	some carbon emissions	12
10	13	-3	No	some carbon emissions	13

Table 1. For a hypothetical region that is accumulating ten tons of biomass a year, removal of different amounts of biomass produces varying emissions. However, under EPA's modeling approach, all scenarios where harvesting does not exceed growth would be treated as having zero carbon emissions.

[2] http://yosemite.epa.gov/sab/sabproduct.nsf/0/57B7A4F1987D7F7385257A87007977F6/$File/EPA-SAB-12-011-unsigned.pdf Page 4

In its evaluation of the first Framework, the SAB panel recommended that EPA abandon the reference point approach and develop an approach that compares a bioenergy scenario against a "future anticipated baseline" (counterfactual) scenario, which assesses additional carbon emissions and sequestration under a bioenergy scenario with emissions/ sequestration under a counterfactual scenario. For instance, harvesting residues are left to decompose instead of being burned for fuel, or trees are harvested for pulpwood or left to continue growing instead of being harvested for fuel. An alternate means of producing energy, such as continuing to burn coal or building wind turbines instead of a biomass plant, can also be included in these scenarios.

Despite the SAB's strong exhortations to EPA to abandon the reference point modeling, however, the approach has been retained in the Second Framework. EPA should reject this approach completely, as it is not useful for EPA's purposes and its inclusion renders the Framework unnecessarily complex and lengthy.

EPA's modeling using FASOM

EPA's modeling in support of the second Framework was conducted using the Forest and Agricultural Sector Optimization Model (FASOM), a complex economic model that postulates a huge variety of factors and human behaviors to produce an estimate of net biogenic emissions on a regional scale.[3] While FASOM is capable of modeling using the counterfactual approach, it still has a variety of problems that render it nearly useless for EPA's need to assess net biogenic emissions from individual power plants that burn wood and other biomass. These problems include several assumptions that appear to be "baked in" to the model, irretrievably compromising its results.

FASOM models regions, not facilities

All the modeling conducted for EPA was done at a regional level – EPA has not included any assessment or example of how modeling could be done for an individual facility. Appendix K explains that FASOM runs illustrate "*how landscape CO_2 balances (emissions flux net of carbon sequestration in biogenic feedstocks and soils) could respond to changes in land management associated with alternative biogenic feedstock demand projections*."[4] However, as the Framework states, modeling conducted at the regional level may obscure the impacts of external drivers on biogenic carbon fluxes. [5]

FASOM underestimates biomass emissions by subtracting "avoided" coal emissions

As stated in model documentation, FASOM calculates emissions from bioenergy after subtracting out putative "avoided" emissions from fossil fuels. The documentation (Page 7-37) for FASOM[6] states:

"For replacement of gasoline with ethanol, the avoided CO2 emissions in FASOMGHG are 5.49 kg CO2eq/gallon of gasoline replaced on an energy-equivalent basis (assuming that 1.6 gallons of ethanol are required to replace 1 gallon of gasoline). The analogous value for diesel is a reduction in emissions of 6.50 kg CO2eq/gallon of diesel replaced. ***Bioelectricity is assumed to reduce CO2 emissions by***

[3] Appendix J of the technical support documents accompanying the Framework provides background on FASOM and shows the geographic regions that it models on page J-20.
[4] Page K-13.
[5] Page 29.
[6] http://www.cof.orst.edu/cof/fr/research/tamm/FASOMGHG_Model_Documentation_Aug2010.pdf

625,515.27 metric tons CO2eq per 100MW generation capacity *(using 9.198 TBtu of feedstock per year) for nonresidue crops and 628,998.13 metric tons CO2eq per 100MW generation capacity for residue crops relative to the use of coal."*

This scenario assumes co-firing biomass in coal plants. It is legitimate to discount emissions from the amount of coal that is displaced at a plant that is cofiring – for instance, if one wanted to assess the change in emissions when a 100 MW coal plant switches to burning 95 MW worth of coal and 5 MW worth of biomass, the new total emissions are now calculated as

(100 MW coal emissions) – (5 MW coal emissions) + (5 MW biomass emissions)

(with the "net" bioenergy emissions being calculated according to the source of the biomass, its regrowth rate if any, facility efficiency, and the timeframe over which the assessment is conducted.)

However, it is ***not*** legitimate to assume displacement of coal for a new, standalone wood-burning power plant. In this case, subtracting out "avoided" coal emissions from bioenergy emissions produces a dramatic underestimate of facility emissions. Since biomass plants operate at an efficiency of about 22 - 24%, and coal plants at an efficiency of 33%, biomass plants actually emit close to 50% more carbon at the stack than coal plants, per megawatt-hour (MWh) generated. Therefore, subtracting out 625,515.27 metric tonnes "avoided" coal emissions per 100 MW of bioenergy generation (as stated in the FASOM documentation) *significantly* underrepresents the actual emissions coming out the stack of a wood-burning power plant, accounting for only about 48% of the 1,204,587 tonnes of CO_2 actually emitted from burning wood in this scenario.

It makes no more sense to subtract "avoided" coal emissions when calculating net emissions from a wood-burning power plant than it does to subtract avoided coal emissions from natural gas emissions if a choice were made to build a natural gas plant. In fact, given the similar subsidization of bioenergy as wind and solar, and the treatment of bioenergy as having zero emissions under EPA's Clean Power Plan (see slides 4 and 5 at http://www.pfpi.net/wp-content/uploads/2015/02/PFPI-webinar-Role-of-Biomass-in-EPAs-Clean-Power-Plan.pdf), bioenergy is as likely to substitute for wind and solar as it is for coal. Yet the subtraction of avoided coal emissions appears to be baked into the FASOM model, meaning that every modeling run that EPA conducted in support of the Framework dramatically underestimates emissions from bioenergy. We are not sure if EPA understands that FASOM does this – Table L-1 on page L-6 matches FASOM terms with BAF equation terms, but there is no BAF term for avoided fossil emissions, and the subtraction of coal emissions from bioenergy emissions is not mentioned anywhere in the Framework.

FASOM underestimates emissions by including a large "anticipatory planting" effect

Anticipatory planting is a major driver in FASOM; essentially, the model allows effects to precede causes. Appendix L explains:

"The intertemporal optimization approach used in these illustrative case studies captures ***investment behavior under anticipated changes in feedstock demand; thus, land management responds in advance of an anticipated change.*** *This approach allows for a depiction of land use investment/management over the long term, which provides an improved projection of landscape-level*

biogenic CO2 emissions under anticipated changes in biogenic feedstock consumption than static (one-time) models or recursive dynamic models that do not react to future expectations."[7]

The carbon sequestration associated with anticipatory planting, combined with the underestimation of bioenergy emissions due to the subtraction of avoided coal emissions, means that some of EPA's modeling runs show a significant reduction in carbon emissions with use of bioenergy. This is a highly counterintuitive result given that burning biomass for energy emits more CO_2 than fossil fuels, and that facility-specific modeling such as that conducted using the U.S. Forest Service Forest Vegetation Simulator finds that offsetting these excess emissions takes years to decades, depending on the feedstock.

The effects described for FASOM strain credulity. For instance, describing one of the scenarios where emissions are essentially offset immediately, Appendix L states:

"Initially, emissions intensity is negative and relatively large in magnitude, reflecting a net increase in carbon sequestration on the landscape driven by land-owner investment decisions (anticipatory planting) and harvest timing decisions in response to the anticipated long-term demand shift for roundwood-derived biomass. That is, landowners plant new trees and delay harvests in an effort to meet this long-term increase in demand."[8]

In fact, it seems just as likely (if not more likely) that landowners will shorten their harvest intervals in response to increased demand and rising prices!

There are other examples of unrealistic assumptions about forest management incorporated into the FASOM runs. The scenario examining use of logging residues for fuel in the Pacific Northwest is especially strange and deserving of comment. The narrative for the scenario states

"*Early in the simulation horizon, the model projects that the additional biomass requirement leads to increased forest harvest emissions. An increase in logging residue demand leads to a net increase in roundwood harvests for other products* ***in order to meet the additional residue demand****. Then, afforestation and forest management responses to the feedstock requirement lead to an increase in biogenic carbon sequestration (hence, large negative values for GROW), resulting in negative landscape factors from 2020–2040. Over the long term, however, this effect flips as harvest emissions outweigh growth in landscape-level biogenic carbon sequestration."*[9]

In fact, harvesting for wood products is generally *not* driven by a need to generate tops and limbs for biomass fuel, but the model acts as if it is, while ignoring another, more plausible scenario – that if residues are insufficient to meet emerging demand for biomass, whole-tree harvesting might be increased in response. The assumption that "afforestation" is likely to occur in the Pacific Northwest to meet emerging demand for bioenergy is the final unrealistic piece of this scenario.
Other examples also produce odd results. For instance, as summarized in Appendix L, the model finds that cutting roundwood and residues in the Southeast ultimately drives greater carbon sequestration, meaning that net emissions are close to zero or even negative; yet burning corn stover causes net

[7] Page L-3.
[8] Page L-11.
[9] Page L-15.

emissions, because burning stover ultimately causes more wood to be burned, which degrades forest carbon stocks.

FASOM underestimates bioenergy emissions by ignoring leakage

Leakage may occur with increasing use of biomass as demand pulls in wood that was previously going to other uses like pulpwood or sawtimber. Now these other users must find a new supply of wood, increasing the total number of trees harvested. In its last assessment, the SAB requested more analysis and discussion by EPA of bioenergy implications for leakage and soil carbon. However, this has not occurred, especially not in the modeling runs EPA conducted, which ignore leakage. The Framework states,[10]

The framework includes an equation term for leakage; however, the illustrative calculations presented in the appendices do not explicitly quantify leakage or provide a method to do so.

However, this is a large and consequential omission, especially considering the capacity of FASOM for modeling anticipatory planting, which is the opposite of leakage.

FASOM underestimates emissions by assuming biopower efficiency will improve significantly

Also apparently baked into FASOM's calculations, according to the modeling documentation, is the assumption that it will take *substantially* less fuel to generate the same amount of electricity in the future. The documentation states

"For electricity production, assumed technology improvements are such that less feedstock is required over time to produce the same electricity output. This is true for both coal and biomass feedstocks. Electricity generation using coal or any of the biomass feedstocks included in FASOMGHG is assumed to have technological improvements over time at an assumed rate of a 5% reduction in feedstock required for every 5-year model period after 2010 until needing only 75% as much feedstock in the 2035 model period as in the 2010 model period. Feedstock requirements are then assumed to remain constant at 75% of 2010 requirements for all model periods after 2035."[11]

There is no basis for this assumption. Bioenergy is a wet fuel and burning it reduces boiler efficiency compared to drier fuels. Assuming this will change in the future is like assuming there will some change in the laws of thermodynamics.

Despite its problems, FASOM still finds that bioenergy causes emissions to increase

It is important to note that that despite all the ways that the FASOM runs massively underestimate actual carbon emissions – by subtracting coal emissions, by ignoring leakage, and by assuming that anticipatory forest planting is widespread – **the model still finds a net emissions increase when bioenergy is deployed**.

[10] Page 19.
[11] FASOM model documentation, page. 6-14.

An excerpt from Figure K-5 shows the increase in bioenergy projected under the different modeling scenarios, with the red line representing the Energy Information Administration's Reference Case scenario. The green line shows "low cost renewables" scenario.

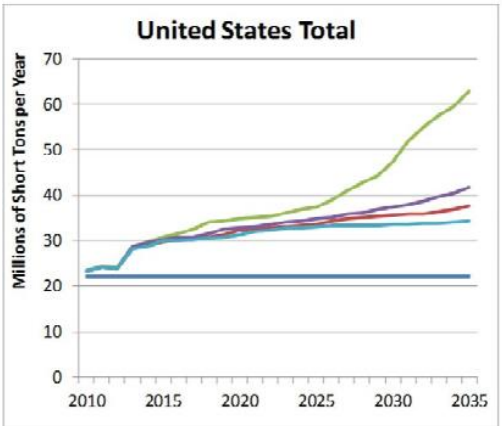

Figure 1.(Excerpt from Figure K-5). Growth of bioenergy under the scenarios modeled by FASOM.

Figure K-7, reproduced below, shows that ramping up bioenergy under the AEO Reference Case produces 22% greater cumulative emissions in 2035 than emissions under the "zero biomass" baseline.

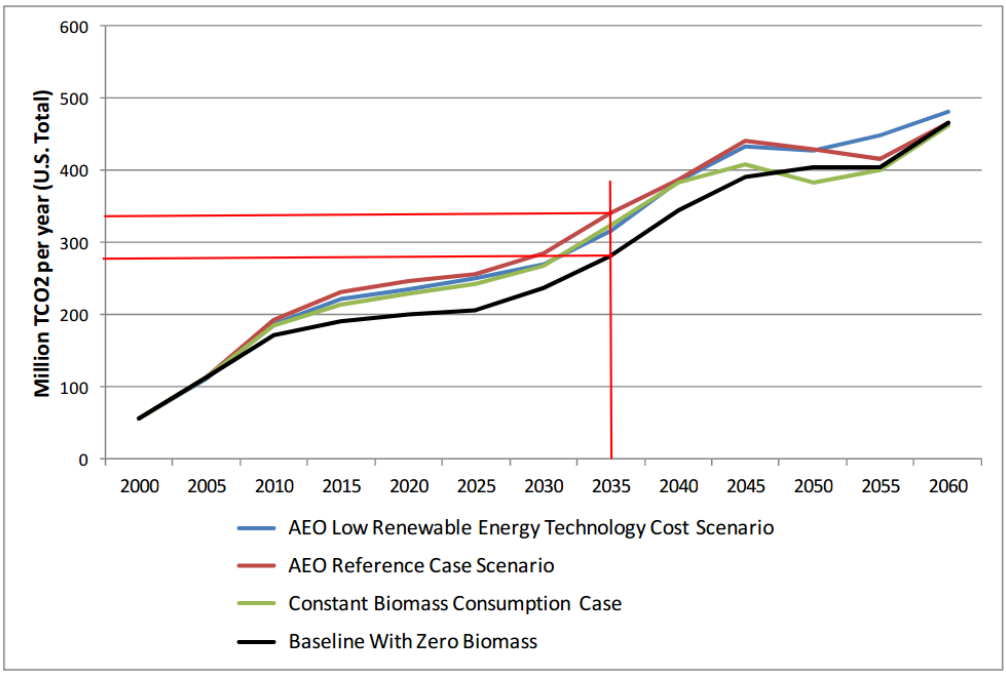

Figure K-7. Cumulative Emissions Over Time by Biomass Scenario.

Figure 2. (Figure K-7). Cumulative emissions over time for the bioenergy scenarios modeled by FASOM. Emissions under the reference case scenario are 22% greater in 2035 than under the zero biomass case.

Evidence for FASOM's underestimation of emissions

Since the Framework only reproduces modeling results, it is not possible to analyze the degree to which the factors identified above contribute to FASOM underestimating emissions. However, the overall magnitude of the underestimate can be seen qualitatively in Figure K-8, reproduced below. This figure shows emissions intensity, which is defined as the ratio of net emissions (after carbon resequestration and offsetting is taken into account) to gross emissions from combustion of the feedstock.[12] Low numbers indicate that carbon emitted by burning biomass has been resequestered; high numbers indicate that carbon is still "out there" in the atmosphere.

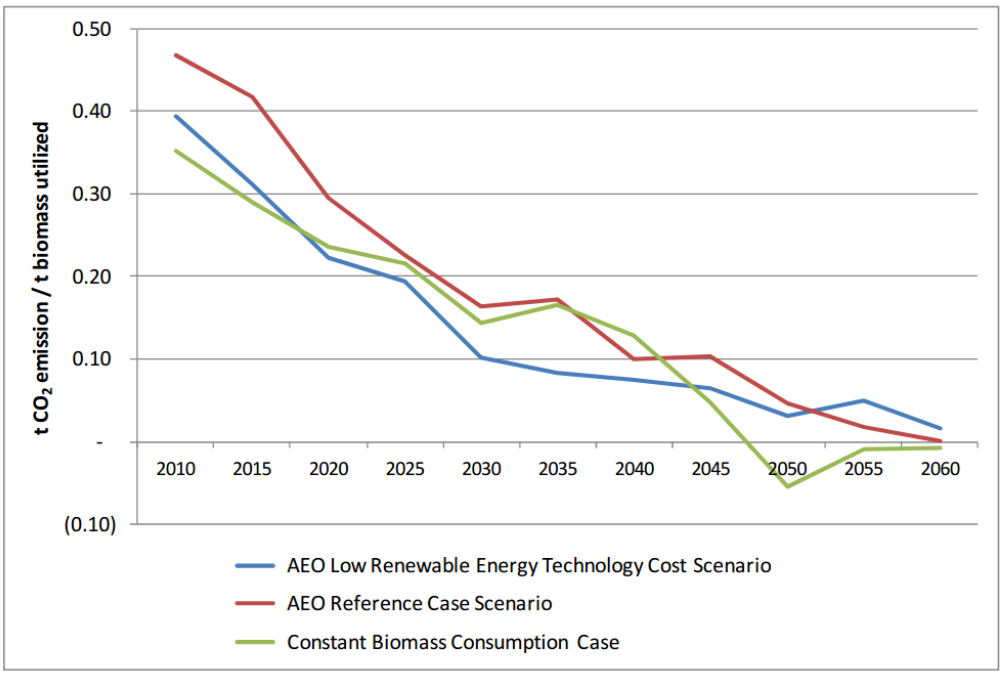

Figure K-8. Emissions Intensity of Biomass Energy Relative to the Zero Biomass Scenario (Cumulative Additional Emissions Divided by Cumulative Biogenic Carbon from Additional Biogenic Feedstocks).

Figure 3 (Figure K-8). Emissions intensity (the ratio of net emissions to gross emissions) for FASOM modeled scenarios.

Figure 3 reveals that under FASOM, emissions are actually lowest when bioenergy generation is highest. The red line, corresponding to the reference case scenario, finds cumulative emissions are already more than half re-sequestered at the beginning of the modeling scenario, and increasing bioenergy capacity brought online has minimal effect The blue line, which in this graph corresponds to the low-cost renewables scenario where bioenergy is anticipated to grow the most, starts out with a *lower* emissions intensity than even the reference case. As these model runs do not include black liquor,[13] the one fuel for which EPA has postulated a relatively fast carbon debt payoff period (see

[12] Page K-17.
[13] See pages K-3, K-22

Appendix D of the Framework), the near-immediate carbon debt payoff in the model is due to a variety of complex interactions, as modeled by FASOM and explained in Appendix K:[14]

1) A shift in land use/management early in the simulation horizon that increases tree carbon uptake over the long term (afforestation of cropland and pastureland);
2) Declining market effects of initial biomass demand shocks;
3) Improved agricultural productivity over time due to exogenous yield growth assumptions and endogenous yield growth responses to the biomass requirements (including regional crop mix changes); and
4) A shift in biogenic feedstock composition (as seen in Figure K-9).

The explanation for Figure K-9 in the Framework (not reproduced) shows that under the highest bioenergy demand scenario, less wood is burned because *"Over time, as greater amounts of biogenic feedstocks are required for the AEO Reference and Low Renewable Technology Cost Baseline scenarios,* ***the portfolio shifts to a higher proportion of agricultural feedstocks,*** *which decreases overall emissions intensity."*

Thus according to this model, the higher the biomass requirement, the more net emissions decrease, because landowners are planting trees (and lengthening rotations) in response to anticipated bioenergy markets for their wood, and, burning crop residues for energy has become feasible and cost-effective. However, the latter assumption contradicts EPA's own conclusions that crop residues are not a particularly feasible solution. We summarized EPA's treatment of crop residues in our comments on the Clean Power Plan:[15]

Crop residues are dirty and contain relatively high amounts of potassium and other elements that foul emissions controls. Collection, processing, and storage of these materials is expensive, a fact that EPA acknowledges in its IPM modeling by attaching not only a $12/dry ton surcharge on all types of biomass for transport, but also a $20/ton surcharge for storage of crop residue-derived biomass fuels, since they can only be collected at certain times of the year and must be stored in quantity until they are needed.[16]

Currently, agricultural residues comprise 3.9 percent of the biomass burned by the electrical, commercial, and industrial bioenergy sectors, as reported by the EIA for 2013.[17]

What the EPA model should do to account for faculty-level emissions

There are a few simplifying steps that can be taken that will reduce the clutter associated with EPA's modeling approach and replace it with a framework that is capable of assessing net facility emissions.

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[14] Page K-18
[15] Available at http://www.pfpi.net/wp-content/uploads/2015/01/PFPI-comments-on-111d_Dec-1-2014.pdf
[16] U.S. Environmental Protection Agency. Documentation for EPA Base Case v.5.13 Using the Integrated Planning Model. Page 11-2.
[17] Biomass use was totaled for the following fuel categories: AB, BLQ, OBL, OBS, WDL, WDS, in the U.S. Department of Energy, The Energy Information Administration (EIA) EIA-923 Monthly Generation and Fuel Consumption Time Series File, 2013 December.

1. **Model against an "anticipated future baseline" or counterfactual scenario that represents net and gross emissions graphically.**
    a. As the SAB has already pointed out, this is the only approach that estimates emissions impacts from individual wood-burning power plants, which is the whole point of the Framework.

As an example of this kind of facility-level counterfactual modeling, consider the following graphs, which are output from a simple model that compares net emissions from a 20 MW biomass plant, versus 20 MW of generation from a coal or gas plant. It assumes that the biomass fuel is forest residues that would decompose and emit CO_2 (not methane[18]) if they were not collected and burned for energy. The scenario used a decomposition constant of 0.05, representative of decomposition constants provided in the Framework in Appendix L, page L-28.

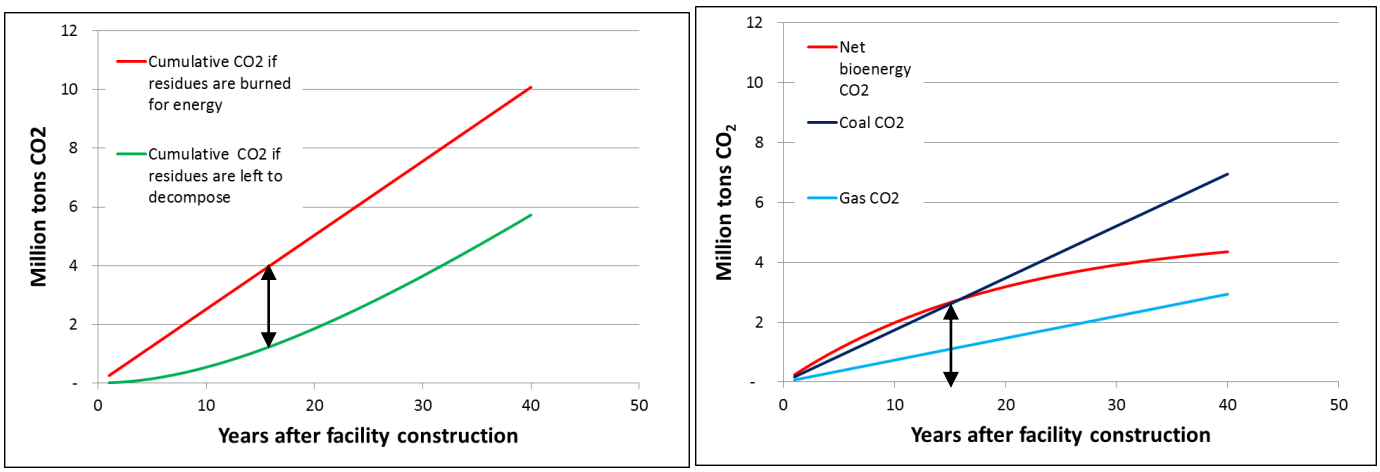

Figure 4. Calculation of net cumulative emissions from bioenergy. The first graph compares emissions from combusting the material, versus letting it decompose. The difference between the red and the green line, designated at Year 15 with the black arrow, is what is graphed as "net bioenergy CO_2" in the second graph.

2. **Model individual facilities and their fuelsheds using a spatially-explicit approach**
    a. Wood-burning facilities generally source their fuel from a certain radius around the plant. This is the area that should be modeled to assess what the facility's impact will be, employing fuelshed-level data to develop a counterfactual scenario for each facility. For a particular fuelshed, a model can use USFS data on typical species composition, growth rates, harvest rates, and the amount of residues generated to assess the type of biomass that a facility will likely use. These data are public and are easy to incorporate into existing models like the Forest Vegetation Simulator. Are forests dense and harvesting common enough that a new bioenergy facility can actually meet most of its fuel demand by burning residues? Will a facility need to harvest whole trees to meet its fuel needs,

[18] The Framework makes it clear that in-woods methane generation from decomposing forestry residues is not an important factor in calculating net GHG fluxes, stating at page 10: *"in the United States, CH4 is not a significant contributor to landscape carbon-based emissions related to the growth and harvest of biogenic feedstocks because most forest- and agriculture-derived feedstocks are produced in upland areas rather than in areas with higher moisture content, such as rice paddies or wetlands (see Figure 4). These areas do not typically generate CH4 emissions (Anderson et al., 2010) or, in some cases, have a small negative net CH4 fluxes (EPA, 2013b)."*

and how long will it take for harvested forests to regrow? This kind of spatially explicit modeling can answer these questions, as well as generating a legitimate counterfactual scenario that represents actual forest management practices in the region of interest.

3. **Use uncertainty about counterfactuals to make modeling estimates more robust.**
    a. One of the objections to modeling against the "future anticipated baseline" is, we don't know what the future holds for a particular forest or region. However, this is not a weakness of modeling – it is actually a strength, when uncertainty is incorporated into a spatially explicit modeling framework. It is true that there is no one "right" answer, because facilities may change their fuel mix from year to year. However, given knowledge about the fuelshed of a particular facility – the typical amount of wood harvested by traditional industries, the typical growth rates, the typical amounts of residues available – it is possible to generate a **range of possibilities** for what a facility's fuel sourcing and net carbon emissions impacts will be, over time. The "right" answer lies somewhere in this range of possibilities, and by modeling several, it is possible to put reasonable siderails on an estimate of facility carbon impacts.

4. **Model over short timeframes.**
    a. Shorter timeframes consistent with the need to reduce emissions in the near-term to address climate warming and ocean acidification. However, modeling over short timeframes also produces more robust estimates that then inform decisions about infrastructure that is very long-lived. Biomass power plants last a long time – there are industrial biomass boilers still opereating that were installed in the 1930's. Decisions made on the basis of net emissions impacts over the next five to fifteen years will influence infrastructure decisions that could last for decades.

    b. Modeling over shorter timeframes also reduces modeling uncertainty when modeling against a counterfactual baseline, particularly when coupled with knowledge about a facility's fuelshed. For instance, if we know that the forests in a fuelshed are held by numerous owners and are typically harvested on a 70-year rotation, this gives us a good idea of what the next 10 – 15 years will hold for these forests.

5. **Include leakage**
    a. Except in very special cases, there is no reason to assume that existing wood demand evaporates when a bioenergy facility increases regional wood demand. Thus, modeling must include the explicit default assumption that leakage occurs on a 1:1 basis.

Thank you for considering these comments.

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