Appendix M: Summary of Illustrative Forestry and Agriculture Results

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1. Introduction

This appendix presents the application of the retrospective reference point and future anticipated baseline approaches to estimate illustrative biogenic assessment factors (*BAF)* for specific feedstocks in specific regions. Although both baseline methodologies produce illustrative assessment factors for the same feedstock-region combinations, the methods differ in structure, and the assumptions are not harmonized between the two methods.

Three case studies are presented below: Southeast roundwood, Pacific Northwest logging residues, and Corn Belt corn stover. Both baselines are applied within specific case study constructs to generate illustrative values for the framework equation terms and assessment factors. Sensitivities to regional scale, feedstock demand, equation term impacts, and time frame were also estimated, and those results are included below.

This appendix uses examples from each baseline approach to produce illustrative equation term values for three of the landscape biogenic attribute terms (*GROW, AVOIDEMIT*, and *SITETNC*) from the biogenic assessment factor equation as presented in the main report (Part 2).

$$\boldsymbol{NBE} = (\boldsymbol{PGE})(\boldsymbol{GROW} + \boldsymbol{AVOIDEMIT} + \boldsymbol{SITETNC} + \boldsymbol{LEAK})(\boldsymbol{L})(\boldsymbol{P}) \qquad \textbf{(EQ. M.1)}$$

For simplicity, feedstock carbon losses during storage, transport, and processing (L) are held constant at 1.1, feedstock carbon embodied in products (P) is also constant at 1, and leakage associated with feedstock production (*LEAK*) is not calculated in the illustrative term calculations here. The *BAF* is calculated by dividing *NBE* by *PGE*:

$$\boldsymbol{BAF = NBE/PGE} \qquad \textbf{(EQ. M.2)}$$

For both the retrospective reference point and future anticipated baseline approaches, the interpretation of the assessment factor is the same. The assessment factor represents the ratio of net biogenic emissions to potential gross emissions. In other words, the assessment factor reflects the extent to which biogenic CO_2 emissions from stationary source consumption are counter-balanced by landscape-level biological carbon cycle processes.

For example, an assessment factor of 0.2 indicates that 80% of biogenic CO_2 emissions are counter-balanced by landscape-level carbon sequestration, and 20% contributes to atmospheric CO_2 concentrations. Similarly, a negative assessment factor suggests a carbon sink (e.g., from improved carbon management on the landscape). That is, where the assessment factor < 0, additional biogenic feedstock consumption leads to a net increase in landscape-level carbon sequestration.

2. Retrospective Reference Point Baseline: Southeast Roundwood

In this section, results are generated using a retrospective reference point baseline in which the net change in various carbon pools on the feedstock production landscape between two points of time in the past to how these pools have changed over that period. The values for this case study presented in Table M-1 represent the net biogenic CO_2 emissions from a hypothetical electricity facility with an electricity generating unit (EGU) that uses roundwood from the Southeast region as a biogenic feedstock. This case study also examines alternative scenarios as sensitivities evaluating the regional aggregation, roundwood removals level, *BAF* equation term inclusion, land base, and temporal scale.

Table M-1. Biogenic Assessment Factors Derived from a Reference Point Baseline for the Southeast Roundwood Case Study.

Scenario	Time Scale	Growth (billion cu ft)	Removals (billion cu ft)	Growth to Removals Ratio (GROW) (removals–growth)/ removals)	Avoided Emissions (AVOIDEMIT) (avoided long term sequestration)/ ton removals	Net Landscape Emissions (SITETNC) (other site emissions)/ton removals	Potential Gross Emission (PGE) (million tCO_2e)	Assessment Factor (BAF)[2]
Southeast	2006–2010	7.60	4.38	−0.74	0	−0.024	0.42	−0.84
South Central	2006–2010	9.58	5.38	−0.78	0	−0.020	0.42	−0.88
Combined SE/SC	2006–2010	17.16	9.76	−0.76	0	−0.022	0.42	−0.86
SE x2 Increased Removals	2006–2010	7.60	5.38	−0.41	0	−0.020	0.42	−0.48
SE x3 Increased Removals	2006–2010	7.60	6.38	−0.19	0	−0.017	0.42	−0.23
SE x5 Increased Removals	2006–2010	7.60	9.38	0.19	0	−0.010	0.42	0.20
SE x10 Increased Removals	2006–2010	7.60	14.38	0.47	0	−0.007	0.42	0.51
Without Net Landscape Emissions	2006–2010	7.60	4.38	−0.74	0	NA	0.42	−0.81
Change Time Frame[1]	1966–1976	5.99	3.03	−0.98	0	−0.024	0.42	−1.10
Change Time Frame	1977–1986	5.59	3.67	−0.52	0	−0.024	0.42	−0.60
Change Time Frame	1987–1996	5.96	4.46	−0.34	0	−0.024	0.42	−0.40
Change Time Frame	1997–2006	7.31	4.31	−0.70	0	−0.024	0.42	−0.79

[1] The change in time frame sensitivities could only be conducted on timberlands, rather than all working lands (which is the land base used for all other assessment factor calculations above) because the FIA database only had information available this far into the past for timberlands.

2.1. Key Insights from the Retrospective Reference Point Baseline Application to Southeast Roundwood

- The current estimated assessment factor for Southeast roundwood is less than 0 at −0.84. Except in the increased removals sensitivities where timber removals are increased and eventually exceed growth (which is held constant), these assessment factors remain negative, indicating a net increase in landscape-level carbon sequestration.
- Aggregating to a larger region (Southeast and South Central) or removing site land use and management biogenic CO_2 change from the equation (*SITETNC*) has little impact on the assessment factor in this instance.

- Although growth and removals have varied over the past half-century, the assessment factor would remain negative if calculated over different historical time periods.

3. Future Anticipated Baseline: Southeast Roundwood

The case studies presented in Table M-2 in this section begin with regional biomass consumption trajectories from the AEO Reference case and then require an additional 1 million short dry tons of roundwood feedstock consumption in the Southeast. This additional biomass requirement is phased in linearly, beginning with 250,000 short dry tons in the 2015 simulation period, reaching 1 million tons in 2030. The feedstock requirement was phased in over time under the conservative assumption that it could take time for a new facility or demand point to build up a steady supply source of one particular feedstock given regional market dynamics. The additional biomass requirement is then held constant for the remainder of the simulation horizon[1] and must be met by roundwood only.

Instead of calculating the net change in carbon pools on the landscape between two points in time, the future anticipated baseline approach calculates the cumulative net change between two alternative scenarios. The first row in Table M-2 labeled "Incremental Demand vs. AEO Ref" presents the estimated "marginal" *BAF* as discussed in Appendix L.[2] The "AEO Reference case vs. Zero Biomass" results in the tables below compare the AEO Reference case with a Zero Biomass scenario; thus, the values presented correspond to the "average" effects explained in Appendix L but include an *L* factor of 1.1. All other scenarios use the "average user" approach described in Appendix L, which takes the relative difference between the Incremental Demand and Zero Biomass scenarios. Like the reference point section, this case study also examines alternative scenarios as sensitivities evaluating regional aggregation, roundwood demand level, *BAF* equation term inclusion, land base, and temporal scale.

There are two primary differences in the presentation of biogenic assessment values in this appendix. The first difference is the use of the term "relative" to describe the fact that future anticipated baseline biogenic attribute term values are the difference between two alternative cases over a set time period. *Relative growth*, for example, is the difference between the Zero Biomass case and the alternate case in the sum of all tree carbon growth fluxes (in CO_2) for the 50-year period between 2010 and 2060. The second is that the sensitivities related to increased roundwood use are based on incremental demand levels for the feedstock rather than the increased removals evaluated in the reference point sensitivities.

[1] The 2012 Annual Energy Outlook projections do not extend past 2030; thus, biomass consumption shock is held constant after this simulation period.

[2] Comparison of the 1 million ton increased feedstock consumption scenario to the AEO Reference baseline scenario can be interpreted as the *marginal* effect of a new source of consumption that is fueled by a single feedstock, relative to the AEO Reference anticipated baseline.

Table M-2. Biogenic Assessment Factors Derived from a Future Anticipated Baseline Approach for the Southeast Roundwood Case Study.

Scenario	Time Scale	*Relative* Growth & Removals[3]		*Relative* Carbon Fluxes			*Relative* Annual Total Carbon Flux & Biogenic Emissions		Assessment Factor (BAF) (ratio of net biogenic emissions to potential gross emissions)
		Relative Growth (million tCO_2e)	*Relative* Removals (million tCO_2e)	*Relative* Net Growth (GROW) (relative growth–relative removals) (million tCO_2e/ton biogenic feedstock use)	*Relative* Avoided Emissions (AVOIDEMIT) (million tCO_2e/ton biogenic feedstock use)	*Relative* Net Landscape Emissions (SITETNC) (million tCO_2e/ton biogenic feedstock use)	*Relative* Potential Gross Emissions (PGE) (sum of all relative carbon fluxes/50 years) (million tCO_2e/year)	*Relative* Net Biogenic Emissions (NBE) (emissions from harvest & use of feedstock per year) (million tCO_2e /year)	
Incremental Demand vs. AEO Reference	2015–2060	-15	-10	-0.36	0.00	-0.04	1.4	-1	-0.43
AEO Ref vs. Zero Biomass	2015–2060	−22	27	0.01	0.00	0.00	12.1	0	0.01
Incremental Demand vs. Zero Biomass	2015–2060	−37	17	−0.03	0.00	0.00	13.4	0	−0.04
South Central	2015–2060	−75	18	−0.19	0.00	−0.05	6.2	-1	−0.26
Combined SE/SC	2015–2060	−112	35	−0.08	0.00	−0.02	19.6	-2	−0.11
SE x2 Incremental Demand	2015–2060	−51	94	0.06	0.00	0.03	14.8	1	0.10
SE x3 Incremental Demand	2015–2060	−51	26	−0.03	0.00	0.15	16.2	2	0.13
SE x5 Incremental Demand	2015–2060	33	27	0.06	0.00	−0.02	18.9	1	0.05
SE x10 Incremental Demand	2015–2060	−15	141	0.10	0.00	0.15	25.8	6	0.27
Without Onsite Emissions Change	2015–2060	−37	17	−0.03	0.00	0.00	13.4	0	−0.03
Change Time Frame	2015–2030	−7	56	0.22	0.00	0.06	4.5	1	0.31

While the *BAF* value as calculated from the equations is technically equal to the sum of *GROW, AVOIDEMIT*, and *SITETNC* in the absence of losses (*L*), the *BAFs* shown above may be slightly as it is assumed that *L= 1.1*. Furthermore, the values provided in the table are rounded to the nearest integer or hundredth particularly in the *AVOIDEMIT* term, which was projected to have a very small magnitude for most case studies (0.003 or less).

[3] Note that CO_2 accounting is atmospheric so sequestration is negative and emission is positive.

3.1. Key Insights from the Future Anticipated Baseline Application to Southeast Roundwood

- Because the future anticipated baseline compares alternative scenarios instead of comparing two points in time, many of the variables have different interpretations than they do under the reference point baseline.

    - Instead of representing forest growth between two points in time, *Growth* represents the relative difference in cumulative tree carbon growth fluxes in CO_2 between the two scenarios (in this case, the case study incremental demand scenario and the Zero Biomass utilization case). Positive values represent net emissions from the landscape for the case study scenario relative to the Zero Biomass utilization scenario. Negative values represent a net increase in sequestration on the landscape for the case study scenario.
    - *Removals* similarly represent the relative difference in cumulative tree carbon harvest in the two scenarios, with positive values representing an increase in harvest emissions (in CO_2e) for the case study relative to the Zero Biomass utilization case.
    - Instead of simply representing the ratio of growth to removals, the anticipated future baseline treats *GROW* as difference between growth and removals in order to represent relative net growth.

- The "Incremental Demand vs. AEO Ref" case represents the marginal effect of additional roundwood consumption relative to the AEO reference case. This anticipated additional demand leads to investments in new and replanted tree stands early in the simulation horizon, which increases carbon sequestration overall and reduces total emissions relative to the AEO Reference Case, resulting in a negative BAF (-0.43).
- The increased demand scenarios represent increases in incremental demand relative to the 1 million tons of incremental demand in the Southeast case study scenario (i.e., because the case study has a 1 million ton increase in demand relative to the AEO Reference, the "SE x2 Incremental Demand" case reflects a 2 million ton increase). These sensitivities have little impact on the assessment factor, but it should be noted that they are not directly equivalent to the increased removal scenarios in the reference point baseline table (which increases total biomass removed from the regional landscape proportionally to the increase biogenic feedstock demand).

    - In the initial time periods, the net emissions fluxes related to increased biogenic feedstock demand oscillate between positive and negative net emissions (note only cumulative values are included here, so this time path effect is not shown). These fluctuations occur as the market and related land use activities adjust to increased demand levels (e.g., large volumes of new plantings in the initial periods).

- However, as markets and related land uses adjust to new demand levels over time, equilibrium is reached and the assessment factor trends down to hover around or at 0.
- Thus, increasing the demand for Southeast roundwood for bioenergy use in this specific case study, and almost all of the related sensitivities, results in a small or 0 assessment factor.[4]

- In the sensitivity that shortens the analysis time frame from 50 years (2015–2060) to 20 years (2015–2030), the assessment factor for Southeast roundwood is 0.3, whereas the 50-year case study base case was 0.01. This shows that this baseline approach is quite sensitive to the analysis time frame chosen.

4. Retrospective Reference Point Baseline: Pacific Northwest Logging Residues

The values for this case study presented in Table M-3 represent the reference point-derived net biogenic CO_2 emissions from a hypothetical electricity facility with an EGU that uses logging residues from the Pacific Northwest region as a biogenic feedstock. This case study also examines an alternative scenario as sensitivity evaluating the equation term inclusion.

Table M-3. Biogenic Assessment Factors Derived from a Reference Point Baseline for the Pacific Northwest Logging Residues Case Study.

Scenario	Time Scale	Growth (billion cu. ft.)	Removals (billion cu. ft.)	Growth to Removals Ratio (GROW) (removals–growth)/ removals)	Avoided Emissions (AVOIDEMIT) (avoided long term sequestration)/ ton removals	Net Landscape Emissions (SITETNC) (other site emissions)/ton removals	Potential Gross Emission (PGE) (million tCO_2e)	Assessment Factor (BAF)
PNW	2006–2010	N/A	N/A	0	−0.98	1.0	0.42	0.02
Without Net Landscape Emissions	2006–2010	N/A	N/A	0	−0.98	NA	0.42	−0.98

[4] Emissions from land management (*SITETNC*) have minimal influence on the assessment factor result. Evidence for this can be seen where the value of *SITETNC* is not included in the calculation; the assessment factor for Southeast Roundwood remains the same.

4.1. Key Insights from the Retrospective Reference Point Baseline Application to Pacific Northwest Logging Residues

- In this case study, it is assumed that logging residues have an alternative fate of decay on the forest floor, which would result primarily in emissions to the atmosphere. Because residues are not specifically cultivated but rather removed for bioenergy consumption, the assessment factor in this instance depends on the value of avoided emissions.
- Logging residues in this instance receive a slightly positive assessment factor because when logging residues are left on the landscape, a small portion of carbon is retained in soil carbon. Removal of the logging residues, therefore, has a small negative impact on soil carbon levels.
- Very little data are available on logging residues removal volumes and related impacts on landscape emissions. Thus, emissions fluxes associated with land management changes (*SITETNC*) are considered 0 for logging residues under this baseline approach. Therefore, omitting this term in calculating an assessment factor has no impact.

5. Future Anticipated Baseline: Pacific Northwest Logging Residues

The case study results from Table M-4 in this section begin with regional Biomass Consumption trajectories from the AEO Reference case and then require an additional 1 million short dry tons of logging residue feedstock consumption in the Pacific Northwest. The additional biomass requirement is phased in using the same method described in the roundwood case study section and likewise must be met by logging residues only.

The first row in Table M-2 labeled "Incremental Demand vs. AEO Ref" present "marginal" *BAF* as discussed in Appendix L. The remaining results are cumulative relative to Zero Biomass baseline. The incremental demand scenario includes 1 million tons more logging residues from the Pacific Northwest demanded by 2030 than AEO Reference case.

Table M-4. Biogenic Assessment Factors Derived from a Future Anticipated Baseline Approach for the Pacific Northwest Logging Residues Case Study.

Scenario	Time Scale	*Relative* Growth & Removals		*Relative* Carbon Fluxes			*Relative* Total Carbon Flux & Biogenic Emissions		Assessment Factor (BAF) (ratio of net biogenic emissions to potential gross emissions)
		Relative Growth (million tCO_2e)	*Relative* Removals (million tCO_2e)	*Relative* Net Growth (GROW) (relative growth–relative removals) (million tCO_2e/ton biogenic feedstock use)	*Relative* Avoided Emissions (AVOIDEMIT) (million tCO_2e/ton biogenic feedstock use)	*Relative* Net Landscape Emissions (SITETNC) (million tCO_2e/ton biogenic feedstock use)	*Relative* Potential Gross Emissions (PGE) (sum of all relative carbon fluxes/50 years) (million tCO_2e/year)	*Relative* Net Biogenic Emissions (NBE) (emissions from harvest & use of feedstock per year) (million tCO_2e /year)	
Incremental Demand vs. AEO Ref	2015-2060	15	-1	0.21	0.00	0.09	1.4	0.4	0.33
AEO Ref vs. Zero Biomass	2015–2060	−13	1	−0.14	0.00	−0.02	1.7	-0.3	−0.18
Incremental Demand vs. Zero Biomass	2015–2060	−14	16	0.02	0.00	0.03	3.1	0.1	0.04
Without Net Landscape Emissions	2015–2060	−14	16	0.02	0.00	0.00	3.1	0.0	0.02

While the *BAF* value as calculated from the equations is technically equal to the sum of *GROW, AVOIDEMIT,* and *SITETNC* in the absence of losses (*L*), the *BAFs* shown above may be slightly as it is assumed that *L= 1.1*. Furthermore, the values provided in the table are rounded to the nearest integer or hundredth particularly in the *AVOIDEMIT* term, which was projected to have a very small magnitude for most case studies (0.003 or less).

5.1. Key Insights from the Future Anticipate Baseline Application to Pacific Northwest Logging Residues

- In the "Incremental Demand vs. AEO Ref" case, there is an increase in forest harvests to respond to the additional demand for forest residues. This increase in harvest leads to a slight increase in net emissions and a resulting BAF of 0.33.
- In the "AEO Ref vs. Zero Biomass" case, a change in silviculture causes a response in *Growth* (probably for long-term stability of the market) but very little change in harvest because residues from existing harvest can be used to meet nearly all of the biogenic demand. This leads to negative values for both "relative net growth" and "relative net landscape emissions" terms and thus a negative assessment factor.
- In the incremental demand case, another million tons of biogenic feedstock are used (nearly doubling AEO Reference demand levels), which leads to both an increase in harvest and a stronger silvicultural response (although muted by the higher harvest). Given the aggregate harvest of approximately 1 billion tons CO_2e over the 2015 through 2060 time

period, the harvest increase of 16 million tons is relatively minor. This leads to positive yet small "relative net growth," "relative net landscape emissions," and assessment factors.

6. Retrospective Reference Point Baseline: Corn Belt Corn Stover

The values for this case study presented in Table M-5 represent the reference point-derived net biogenic CO_2 emissions from a hypothetical electricity facility with an EGU that uses corn stover from the Corn Belt region as a biogenic feedstock. This case study also examines alternative scenarios as sensitivities evaluating N_2O as well as equation term inclusion.

Table M-5. Biogenic Assessment Factors Derived from a Reference Point Baseline for the Corn Belt Corn Stover Case Study.

Scenario	Time Scale	Growth (billion cu. ft.)	Removals (billion cu. ft.)	Growth to Removals Ratio (GROW) (removals–growth)/ removals)	Avoided Emissions (AVOIDEMIT) (avoided long-term sequestration)/ ton removals	Net Landscape Emissions (SITETNC) (other site emissions)/ton removals	Potential Gross Emission (PGE) (million tCO_2e)	Assessment Factor (*BAF*)[1]
Base Case	2006–2010	N/A	N/A	0	0	0.0026	0.44	0.0029
With N_2O	2006–2010	N/A	N/A	0	0	0.0123	0.44	0.0135

6.1. Key Insights from the Retrospective Reference Point Baseline Application to Corn Belt Corn Stover

- In this case study, corn stover production for energy is not considered the motivation for crop production, and the "growth to removals ratio" is assumed to be 0. The assessment factor in this instance depend on the value of "avoided emissions," because the assumed alternate fate of these residues is to decompose or be burned onsite (results here are the former). Therefore, "avoided emissions" are equal to 0.
- When N_2O is included in the "net landscape emissions" calculation, the assessment factor is larger than when N_2O is not included (meaning that only 90% of biogenic CO_2 emissions out the stack are counterbalanced by feedstock growth). This suggests that there are increases in the nitrogen fertilizer application to replenish soil nutrients that were lost by removing corn stover that would have otherwise decomposed onsite.

7. Future Anticipated Baseline: Corn Belt Corn Stover

The first row in Table M-2 labeled "Incremental Demand vs. AEO Ref" present "marginal" *BAF* as discussed in Appendix L. Remaining sensitivity results are cumulative relative to Zero Biomass baseline. The incremental demand scenario includes 1 million tons more corn stover from the Corn Belt demanded by 2030 than the AEO Reference case.

Table M-6. Biogenic Assessment Factors Derived from a Future Anticipated Baseline Approach for the Corn Belt Corn Stover Case Study.

Scenario	Time Scale	*Relative* Growth & Removals		*Relative* Carbon Fluxes			*Relative* Total Carbon Flux & Biogenic Emissions		Assessment Factor (BAF) (ratio of net biogenic emissions to potential gross emissions)
		Relative Growth (million tCO_2e)	*Relative* Removals (million tCO_2e)	*Relative* Net Growth (GROW) (relative growth–relative removals) (million tCO_2e/ton biogenic feedstock use)	*Relative* Avoided Emissions (AVOIDEMIT) (million tCO_2e/ton biogenic feedstock use)	*Relative* Net Landscape Emissions (SITETNC) (million tCO_2e/ton biogenic feedstock use)	*Relative* Potential Gross Emissions (PGE) (sum of all relative carbon fluxes/50 years) (million tCO_2e/year)	*Relative* Net Biogenic Emissions (NBE) (emissions from harvest & use of feedstock per year) (million tCO_2e/year)	
Incremental Demand vs. AEO Ref	2015-2060	NA	NA	0	0	0.08	1.4	0.0\	0,08
AEO Ref vs. Zero Biomass	2015–2060	NA	NA	0	0	0.27	0.8	0.2	0.27
Incremental Demand vs. Zero Biomass	2015–2060	NA	NA	0	0	0.15	2.2	0.3	0.17
With N_2O	2015–2060	NA	NA	0	0	0.15	2.2	0.3	0.17
Without Net Landscape Emissions	2015–2060	NA	NA	0	0	0.00	2.2	0.0	0.00

While the *BAF* value as calculated from the equations is technically equal to the sum of *GROW, AVOIDEMIT,* and *SITETNC* in the absence of losses (*L*), the *BAFs* shown above may be slightly as it is assumed that *L= 1.1*. Furthermore, the values provided in the table are rounded to the nearest integer or hundredth particularly in the *AVOIDEMIT* term, which was projected to have a very small magnitude for most case studies (0.003 or less).

7.1. Key Insights from the Future Anticipate Baseline Application to Corn Belt Corn Stover

In the "AEO Ref vs. Zero Biomass" scenario (with 1 million ton demand increase over the AEO Reference level), the cumulative assessment factor for corn stover is 0.17. This means that approximately 83% of additional biogenic feedstock consumption is replaced by carbon sequestration on the landscape.

- As "relative net growth" defaults to 0 for corn stover, the relatively large assessment factor is driven by "relative net landscape emissions." This flux represents changes in agricultural and forestry land management in response to the long-term increase in the demand for corn stover biomass.
- The estimated *BAF* under the "Incremental Demand vs. AEO Ref" case is smaller than the "Incremental Demand vs. Zero Biomass" case. This implies that the marginal landscape emissions effect of increasing corn stover removals in isolation could be smaller than a total shift in biomass consumption in the Corn Belt (with multiple feedstocks used to meet the additional demand).
- Note that when the N_2O flux is included, calculated "relative net landscape emissions" values increase slightly because of the additional corn stover demand, which increases corn production and nitrogen fertilizer use, thus increasing N_2O emissions relative to the Zero Biomass baseline.
- When "relative net landscape emissions" is not included in the assessment factor, the resulting assessment factor is effectively 0, because the primary terms, "relative net growth" and "relative net landscape emissions," are eliminated.