Appendix K: Future Anticipated Baseline Construction: Methodology and Results

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1. Introduction

This appendix describes a methodology for constructing alternative future anticipated baseline scenarios that can be used to evaluate the potential net atmospheric contribution of biogenic carbon dioxide (CO_2) from increased consumption of biogenic feedstocks at stationary sources. The purpose of this analysis is to illustrate how landscape CO_2 balances (emissions fluxes net of carbon sequestration in biogenic feedstocks and soils) could respond to changes in land management associated with alternative biogenic feedstock demand projections, and how baseline formation can affect emissions projections estimates.

Biogenic feedstock consumption will likely grow over time as the demand for renewable electricity increases (driven in part by state renewable portfolios, clean energy standards or other policies and incentives). Thus, it is important to consider anticipated growth in stationary source biogenic feedstock demand in addition to current consumption levels. Using a compilation of different energy sector datasets as inputs to a dynamic land use model, several potential future anticipated baseline scenarios are constructed to project biogenic CO_2 emissions from the U.S. forest and agricultural sectors as well as emissions intensity values for biogenic feedstock consumption for electricity generation at stationary sources. These potential future baseline scenario projections are developed to show a range of potential future conditions, illustrating how baseline scenario projections can be sensitive to different macroeconomic inputs.

The first section of this appendix discusses how current biogenic feedstock consumption estimates are combined with regional energy market projections to generate six alternative future anticipated baseline scenarios, representing alternative biogenic feedstock demand trajectories. Next, the U.S. Forest and Agricultural Sector Optimization Model with Greenhouse Gases (FASOM-GHG) is used to simulate future biogenic CO_2 emissions fluxes estimated for each alternative baseline scenario. These projected emissions trajectories are then compared with a projected future with no biogenic feedstock consumption for electricity generation. Then, results from the alternative future baseline scenarios are used to project cumulative landscape emissions associated with each baseline's biogenic feedstock consumption. This appendix concludes with a discussion of key findings, uncertainties, and limitations. Two baseline scenarios from this appendix are then used for further application and analysis in the future anticipated baseline case studies (Appendix L).

2. Methodology for Projecting U.S. Biogenic Feedstock Consumption Scenarios

A prospective analysis of CO_2 emissions from biogenic feedstock consumption at stationary sources requires two primary pieces of information: current and anticipated future biogenic feedstock usage. The primary data sources used to estimate current facility-level biomass energy consumption are EIA-923 Annual Electric Utility data from December 2009.[1] This information serves as the basis for developing projections using data derived from the Energy Information Agency's (EIA's) Annual Energy Outlook (AEO) models from 2012. This section provides the methodology and presents estimated current and future biogenic feedstock consumption under five alternative future scenarios. One of the outcomes for this section is a table representing current biogenic feedstock consumption for both forest- and agriculture-derived feedstock types delineated according to regions appropriate for use in the FASOM-GHG model.

2.1. Estimates of Current Consumption

To arrive at the biogenic feedstock consumption estimates used for this analysis, three basic steps were required. In Step 1, the December 2009 version of the Form EIA-923 survey representing current facility-level data was queried for total biogenic feedstock consumption at industrial, electricity, and commercial stationary sources. Step 2 involved filtering the data to remove biogenic feedstocks such as black liquor and municipal solid waste, which are not included in the FASOM-GHG model. Finally, in Step 3, common plant ID codes were obtained for each EIA-923 power generation unit by matching the units to EPA's Emissions & Generation Resource Integrated Database (eGrid) 2009 database to obtain latitude and longitude coordinates. These coordinates were then used to map the stationary sources to the 11 primary FASOM-GHG agroforestry regions.

2.1.1. Step 1: Querying EIA-923 Feedstock Consumption Data

EIA-923 contains detailed monthly and annual electric power data on electricity generation, fuel consumption, fossil fuel stocks, and receipts at the stationary source level (EIA, 2012). The dataset contains information on the feedstock type used as well as the different generation processes. Specifically, the data splits plants into three sectors: electricity, industrial, and commercial. Electricity sector entities use biogenic feedstocks to generate electricity for an external electric grid. Industrial sector entities, such as pulp and paper mills, use biomass for internal industrial production processes and electricity generation purposes with residual bioelectricity sold back to the grid. Finally, commercial sector entities are primarily small-scale electric generators, burning

[1] The EIA-923 database is updated annually. The 2009 dataset is used for this analysis to represent starting conditions for the "2010" simulation period in FASOM-GHG.

biomass to supply electricity to a single installation. A hospital with a boiler that co-fires biomass is a good example of a commercial plant.[2]

In addition to categorizing biogenic feedstock demand by the electricity and industrial sectors, EIA-923 further disaggregates consumption by specific biogenic feedstock sources, as shown in Table K-1. Biomass-derived energy can come from a multitude of feedstocks, including raw biomass sources, waste streams, by-products of silvicultural practices and/or agricultural cultivation, or by-products of industrial processes.

Table K-1. Description of Biomass Sources in EIA-923.

	EIA 923 Code	Biomass Description
Solid Renewable Fuels	AB	Agricultural crop by-products/straw/energy crops
	MSB	Municipal solid waste—biogenic component
	OBS	Other biomass solids
	WDS	Wood/wood waste solids (paper pellets, railroad ties, wood chips, etc.)
Liquid Renewable Fuels	OBL	Other biomass liquids
	BLQ	Black liquor
	SLW	Sludge waste
	WDL	Wood waste liquids excluding black liquor

Figure K-1 provides estimates of current biogenic feedstock consumption by biomass sources for each of the three sectors with the industrial sector further disaggregated to differentiate pulp and paper from other industrial entities. Electric utilities consumed the most biomass in 2009, more than 40 million short tons, with the largest share coming from wood solids and municipal solid waste. Pulp and paper mills are the second largest consumers of biomass for energy, with the majority of consumption coming from black liquor and wood solids that are forest-derived industrial by-products of pulp and paper production processes.

[2] This analysis focuses on the major biomass consuming industries, thus, commercial facilities such as hospitals and schools are dropped from the underlying dataset and this analysis.

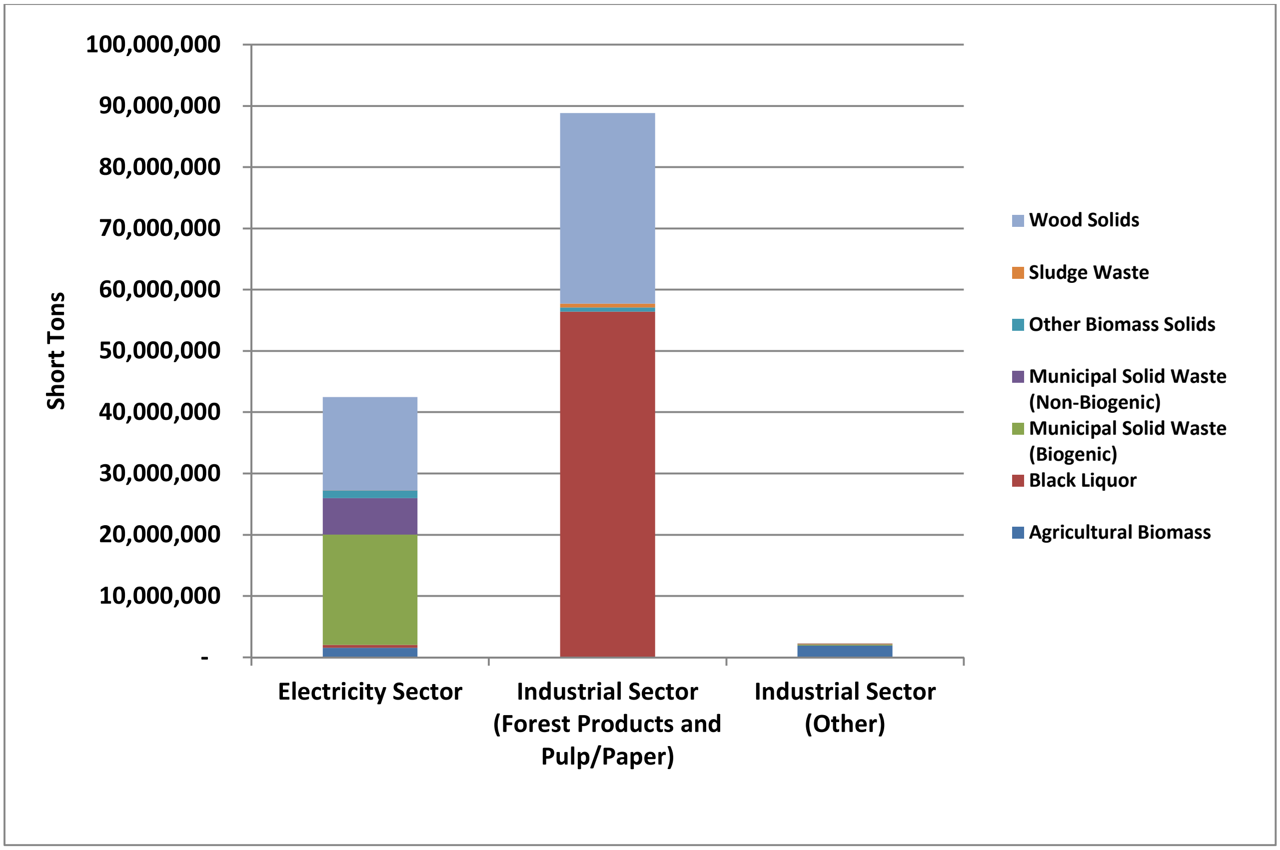

Figure K-1. Biogenic Feedstock Consumption for Energy Generation (Short Tons) by Sector and Source in 2009 (Source: EIA-923).

2.1.2. Step 2: Filtering the Data for FASOM-GHG Biogenic Types

With the EIA-923 biogenic feedstock consumption for 2009 identified, it is now necessary to process the data so that these can be used as part of the FASOM-GHG modeling approach. This means that biogenic feedstocks handled in other parts of the framework and those not included in FASOM-GHG, as well as coinciding stationary sources, must be filtered out of the dataset.

First, municipal solid waste and other waste-derived feedstocks receive a different treatment than forestry and agriculture-derived biogenic feedstocks (see Appendix N). Second, the FASOM-GHG model does not currently depict black liquor, an industrial processing byproduct from pulp and paper milling. Thus, for the purposes of this study, the estimates of current biogenic feedstock consumption are restricted to the following EIA-923 biomass types: agricultural crop by-products, straw, and energy crops (AB); wood and wood waste solids (WDS); and other biomass solids (OBS). This subset of biomass represents forest and agricultural biomass and excludes any liquids or municipal solid waste used for electricity generation; it thus accounts for approximately 37% of all biogenic feedstocks currently consumed for energy generation.[3]

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[3] It is important to remember that because of the data filtering necessary for this specific study, the biogenic feedstock consumption projections provided in subsequent sections are lower than AEO or other bioenergy

Next, stationary sources that use these biogenic feedstocks that have been filtered out of the dataset are removed, eliminating all of the sources in the commercial sector, and resulting in two remaining power generation sectors: the electricity sector and the industrial sector. For the purposes of this study, the electricity sector dataset was created by excluding any stationary source that does not have “electric utility” as the sector name or does not have the appropriate NAICS code 22. The industrial sector dataset excludes any stationary source that does not have “industrial NAICS cogen” or “industrial NAICS non-cogen” as the sector name. This 2009 feedstock consumption estimate represents the base-level value from which all projections presented for the future anticipated baseline approach in this and related appendices (Appendix L) are simulated.

Figures K-2 and K-3 provide a geographic depiction of biogenic feedstock consumption in short tons in the electricity and industrial sectors, respectively, in 2009. Biomass consumption in the electricity sector is primarily confined to the Northeast, Florida, California, and Minnesota. Within the industrial sector, biomass is consumed mostly in the Southeast, Northeast, and Pacific Northwest, where much of the pulp and paper industry is located. These 2009 consumption rates are what determine the “Constant Biomass Consumption case” scenario discussed in subsequent sections.

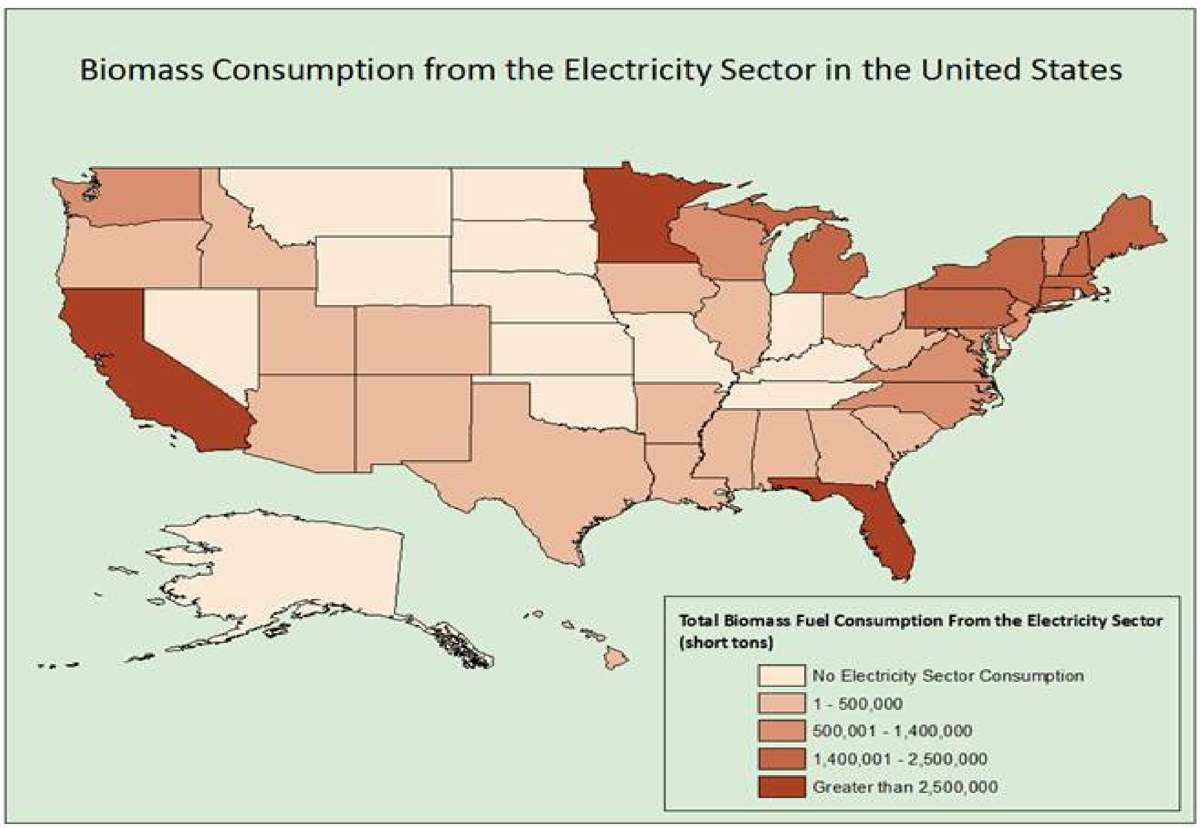

Figure K-2. Biogenic Feedstock Consumption by Electric Utilities in 2009 (Source: EIA-923).

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projections that would include municipal solid waste and other important biogenic feedstock types.

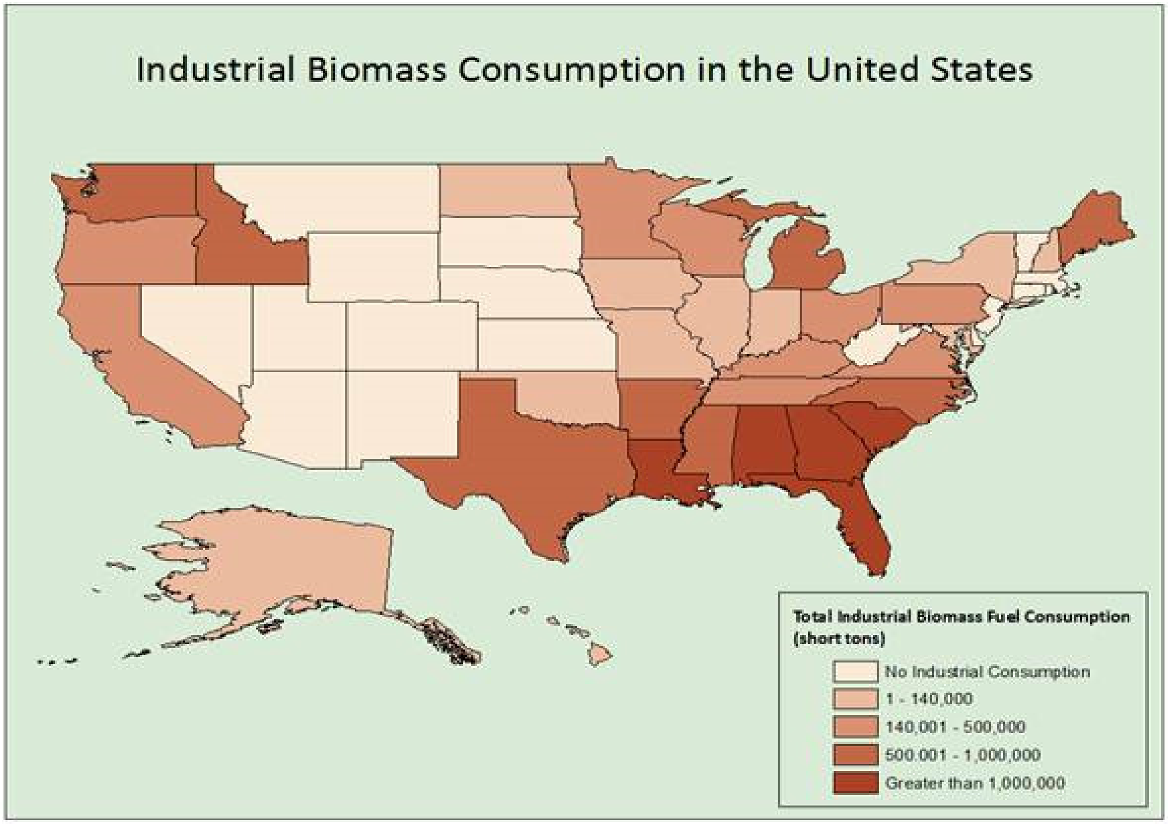

Figure K-3. Total Biogenic Feedstock Consumption for Electricity Generation at Stationary Sources in the Industrial Sector in 2009 (Source: EIA-923).

2.1.3. Step 3: Mapping EIA-923 Data to FASOM-GHG Regions

Once the biogenic feedstock types and sectors were filtered, EIA 923 data were merged with FASOM-GHG regions. EIA-923 data are collected at the stationary source level, but the geographic coordinates are not published. However, EPA's publicly available eGRID 2009 database uses EIA-923 data and includes a common plant ID code to link the data sources as well as latitude and longitude coordinates for the stationary sources included in this analysis. For industrial sector sources, only forest product and paper manufacturing facilities are included. Figure K-4 displays the EIA-923 biogenic feedstock consumption data at the eGRID stationary source locations overlaid with a map of the FASOM-GHG regions.[4]

[4] **Region Definitions for Figure K-4:** CB = Corn Belt; GP = Great Plains; LS = Lake States; NE = Northeast; PNWE = Pacific Northwest East; PNWW = Pacific Northwest West; PSW = Pacific Southwest; RM = Rocky Mountains; SE = Southeast; SC = South Central; SW = Southwest

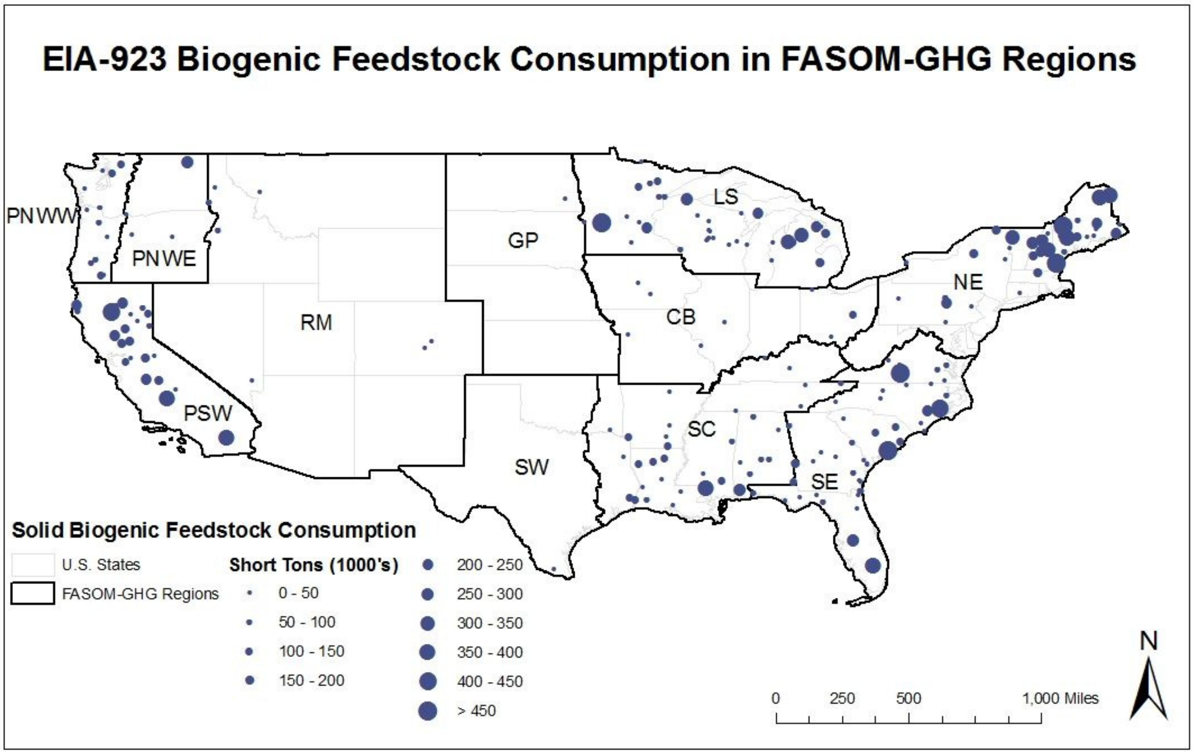

Figure K-4. Map of EIA-923 Biogenic Feedstock Consumption at Electric and Industrial Plants and FASOM-GHG Region.

Table K-2 provides the results of the data processing exercise by sector and FASOM-GHG region in addition to percentages of agricultural versus nonagricultural biogenic feedstock categories consumed within the combined electricity and industrial sectors. The majority of biogenic feedstocks used (once forest and agricultural biomass sources have been filtered out of the EIA-923 data)—96.7% of U.S. solid biomass feedstock consumption—originates from nonagricultural sources. Thus, forest-derived biomass in solid and liquid form makes up the majority of biomass consumption at stationary sources in the filtered EIA-923 dataset. Forest biomass includes the categories “Roundwood” and “Logging Residues,” plus a set of “Forest Derived Industrial Products or Processing By-products,” as defined in Appendix D. Agricultural feedstocks include the categories “Conventional Agricultural Crops”, “Dedicated Energy Crops,” and “Agricultural Crop Residues,” which are also defined and discussed in Appendix D.

2.1. Estimates of Future Consumption

EIA’s AEO focuses on factors that influence the U.S. energy system in the long run (energy demand, supply, and prices). AEO projections assume that current laws and regulations remain unchanged throughout the projections, unless explicitly changed for a policy scenario case (for instance, certain AEO scenarios include GHG mitigation policies, including CO_2 emissions allowance fees). These laws and regulations include mandatory state renewable or clean energy standards, which are applied to the underlying model used to produce the AEO (the National Energy Modeling System) to the extent possible.

Table K-2. EIA-923 Biogenic Feedstock Consumption by Sector and FASOM-GHG Region as well as Regional Proportion Derived from Woody Biomass (EIA-923, 2009).

FASOM Region	Electric Fuel Consumed (short tons)			Percentage Derived from Woody Biomass
	Nonelectric Stationary Sources	Electric Stationary Sources	Total	
CB	192,185	73,292	265,477	95%
GP	3,477	4,308	7,785	0%
LS	525,588	3,151,535	3,677,123	99%
NE	470,644	5,336,594	5,807,238	100%
PNWE	8,437	290,853	299,290	100%
PNWW	437,863	326,206	764,069	100%
PSW	312,445	3,629,679	3,942,124	95%
RM	91,502	229,078	320,580	100%
SC	2,170,840	363,043	2,533,883	96%
SE	1,739,475	2,556,641	4,296,116	92%
SW	162,325	0	162,325	0%
U.S. Total	6,114,781	15,961,229	22,076,010	97%

The AEO projections also include key macroeconomic factors that significantly influence the energy market, including population and gross domestic product (GDP). According to the AEO website, the AEO Reference case "provides the basis for examination and discussion of energy production, consumption, technology, and market trends and the direction they may take in the future. It also serves as a starting point for analysis of potential changes in energy policies." In addition to the Reference case, EIA presents a number of other alternative cases to illustrate uncertainties associated with the Reference case projections.

The same exercise is done in this study. To account for uncertainty in future anticipated biogenic feedstock consumption, multiple anticipated future baseline scenarios are developed that calibrate directly to AEO 2012 scenarios (discussed below). The 2012 AEO projections used in this report are carried out until 2035, and all biogenic feedstock consumption beyond this period is held constant in FASOM-GHG simulation periods beyond 2035.

AEO scenario projections are used to build biogenic feedstock consumption trajectories off of the 2009 feedstock consumption values calculated for this analysis. There are numerous AEO scenarios available from EIA, with deviations in economic growth assumptions, policy variables, and fuel prices (the AEO 2012 report included 29 total scenarios): the discussion here focuses on the following four baseline scenarios: Reference, High Economic Growth, Low Economic Growth, and Low Renewable Technology Cost. In addition to the AEO scenarios, a fifth baseline scenario was developed in which 2009 biogenic feedstock consumption levels are held constant. The Reference case is the baseline AEO (2012) scenario, which assumes real GDP grows at a 2.4% average annual rate from 2008 to 2035, buoyed by a 1.5% per year growth in productivity in nonfarm businesses and 0.6% growth in non-farm employment. All other AEO baseline scenarios pivot off this Reference baseline scenario by changing specific assumptions. The High Economic Growth baseline assumes that real GDP grows by 3%, supported by productivity growth of 2.4% and employment growth of 1.2%. The Low Economic Growth baseline assumes that real GDP grows by 1.8%, supported by productivity growth of 1.5% and employment growth of 0.5%. The Low Renewable Energy Technology Cost baseline assumes annual levelized cost for non-hydropower renewables is 10% lower than the Reference baseline in 2010 and drops 35% by 2035 compared to Reference baseline values.

To generate biogenic feedstock consumption projections for each AEO baseline scenario, index variables were created using 2009 as the base year; these values reflect the rate of growth in projected renewable electricity consumption by Electricity Market Module (EMM) region in quadrillion British thermal unit (Btu). For industrial sector stationary sources, growth rates are equal to the change in industrial sector renewable energy consumption by EMM region. For electricity sector stationary sources, the change in total renewable electricity generation by EMM region is used. Note that this assumes that the proportion of biomass energy to total renewable energy would stay constant over time. Thus, it does not factor in potential declining costs of alternative renewable energy technologies such as wind, solar, or geothermal, and such declining costs could reduce the share of renewables coming from biogenic feedstocks.

These projections are multiplied by EIA-923 electricity consumption data (i.e. total 2009 biomass consumption for each facility) to produce facility-level biogenic feedstock projections from 2009 to 2035. This facility-level data is then mapped to FASOM-GHG regions using the eGRID latitude and longitude coordinates. This methodology provides a justifiable set of unique biogenic feedstock consumption projections calibrated to standard energy market projections.

2.1.1. AEO Baseline Scenario Projections

This section provides graphical representation of the current and future alternate estimates of biogenic feedstock consumption derived above at the regional scale. The biogenic feedstock consumption baseline projections are shown in Figure K-5. The results in this figure include both industrial and electricity sector biogenic feedstock consumption as well as the combined total. Of the five scenarios, the Low Renewable Energy Technology Cost case (in which renewable fuels are lower cost), exhibits the largest amount of biogenic feedstock consumption in 2035, with growth accelerating after 2025. It is important to note that in this case biogenic feedstock consumption growth is driven by growth in renewables generally. Because these projections are derived from 2009 numbers, the renewable portfolio is fixed in 2009 and is not allowed to change. The High and Low Economic Growth cases represent potential upper and lower bounds for the AEO Reference baseline scenario because they include exogenous shifts on renewable demands without any endogenous changes in underlying technology.

Shifting focus to the individual sector graphs in Figure K-5, high demand growth is seen for the Low Renewable Technology Cost case in the electricity sector after 2025. This growth occurs because large capacity exists for increases in renewable electricity generation in that sector. This exponential rise is contrasted with the relatively modest rise seen for the industrial sector graph. The industrial sector does not have as much capacity for fuel increase because many of the industrial facilities included in this dataset already use biogenic feedstocks as a primary fuel source, such as pulp and paper mills.

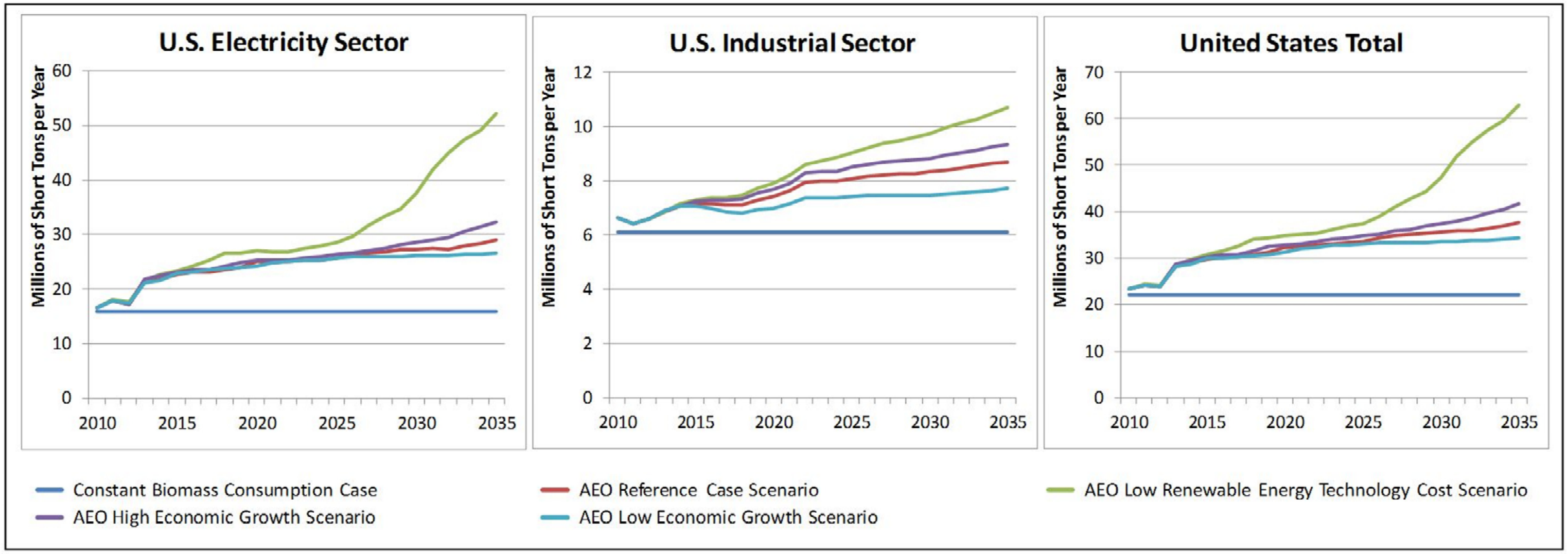

Figure K-5. Biogenic Feedstock Consumption Projections by Sector.

Breaking down the scenario projections by FASOM-GHG regions allows insights into the regional distribution of growth in biomass consumption. Regional baseline scenario projections are provided in two groups of graphs at the end of this appendix. Figure K-10 (located in the addendum of this appendix) shows the biogenic feedstock consumption projections for each baseline scenario grouped by FASOM-GHG region. In general, the Low Renewable Technology Cost case represents the maximum growth path for any given FASOM-GHG region. However, the magnitude of the effect of this growth rate varies greatly between regions, with large growth in the Southeast (SE) and Lake States (LS) regions, relative to other baseline scenarios. This variation is further seen in the Rocky Mountains (RM) and Pacific Southwest (PSW) regions, where the high economic growth case yields the greatest amount of biogenic feedstock consumption for a number of years within the projection. This illustrates the regional variability in biogenic feedstock consumption projections presented in the alternative future anticipated baseline scenarios.

Figure K-11 presents the same data showing the biogenic feedstock consumption projections for each FASOM-GHG region grouped by AEO scenario. The top four consumers of biogenic feedstocks for all the cases are the PSW, Northeast (NE), LS, and SE. However, for the Reference case and High Economic Growth case, the PSW has the highest feedstock consumption, whereas the Low Renewable Energy Technology Cost case shows the SE biogenic feedstock consumption expanding rapidly. This Low Renewable Technology Cost case shows there is large capacity potential for renewable energy expansion in the SE, given a reduction in the price of renewables generally, or policies that encourage renewable energy development. With few existing state energy policies requiring or incentivizing renewable energy in the SE, much of the additional renewable capacity potential exists in these states.

3. Biogenic Feedstock Consumption Baseline Scenario Projections: Results and Analysis

This section analyzes the GHG emissions and terrestrial carbon sequestration estimates produced from the alternative baseline scenarios created in the previous section. The purpose of this analysis is to 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. This evaluation considers total soil and feedstock-related biogenic CO_2 emissions from agricultural and forestry land management decisions across multiple future anticipated baselines. A detailed discussion of the emissions fluxes evaluated in this analysis is found in Appendix L. Results illustrate how baseline scenario formation can have a large impact on emissions projections.

FASOM-GHG is used to simulate market equilibrium in the forest and agricultural sectors by maximizing net economic surplus (consumer and producer) over 17 5-year periods (2000–2080), along with a terminal period valuation. Several key assumptions made for this baseline scenario formulation are highlighted below (the basic structure and key underlying datasets of the FASOM-GHG model are described in the Supplemental Information section of the future anticipated baseline case studies appendix, Appendix L):

- For the alternative baseline scenarios, constraints are imposed requiring that a specific volume of biomass be consumed for electricity generation on a regional basis. These regional constraints are all that vary across simulation runs, and serve as the primary basis of comparison for examining GHG implications of changes in biomass energy demand.
- For biofuels production, all alternative baseline scenarios assume that the RFS2 legislation binds and the mandated levels of biofuel are supplied. Feedstock-specific constraints are imposed and are based on the supplemental control case assumptions from the EPA Regulatory Impact Analysis of the RFS2.[5]
- Other than biofuel feedstock restrictions, there are no constraints on feedstock choices for bioenergy across the alternative baseline scenarios, allowing the model to choose an optimal feedstock portfolio to achieve regional biomass requirements.
- Agricultural productivity rates are linear growth rates in agricultural productivity growth and demand growth; these parameters are calibrated to USDA (2009) projections of yield and demand growth for key commodities forestry data (yields, species mix, etc.) are from USFS, calibrated to the forest inventory and assessment (FIA) and other relevant forestry sector datasets.

In addition to FASOM-GHG details included in Appendices J and L, further details regarding the model structure, regional detail, commodity representation, and GHG accounting can be found in Beach et al. (2010).

The discussion of results below focuses on four baseline scenarios. Two of the four AEO baseline scenarios discussed above are used—the Reference baseline and the Low Renewable Technology Cost baseline. The Low and High Economic Growth baseline scenarios were not simulated in FASOM-GHG as these do not deviate greatly from the AEO Reference case scenario. The AEO Reference and Low Renewable Technology Cost baseline scenarios provide a reasonable range of potential biomass energy expansion. In addition to these AEO-based baseline scenarios, two other counterfactual baseline scenarios are also simulated: one with constant 2009 biogenic feedstock consumption (as derived above—this scenario is referred to as the Constant baseline scenario throughout the remainder of this analysis) and another with no biogenic feedstock consumption at stationary sources ("Zero Biomass Consumption" scenario). The difference between the Zero Biomass Consumption baseline scenario and each of the other baseline scenarios (alternate AEO-based and Constant scenario) indicates the additional calculated emissions associated with that level of biogenic feedstock consumption compared to no biogenic feedstock consumption. The purpose of simulating both the Constant and Zero Biomass baseline scenarios is to respond directly to the SAB review of the previous accounting framework, which noted (Swackhamer and Khanna, 2011):

> *Estimating additionality, i.e., the extent to which forest stocks would have been growing or declining over time in the absence of harvest for bioenergy, is essential, as it is the crux of the*

[5] This includes growth in domestic (U.S.) biofuel production up to approximately 30 billion gallons in the 2020 simulation period (including 15 billion gallons of corn ethanol, 13.7 billion gallons of cellulosic ethanol, and 1.3 billion gallons of biodiesel, produced primarily from soybean oil).

question at hand. To do so requires an anticipated baseline approach… [the] Framework would need to model a "business as usual" scenario along some time scale and compare that carbon trajectory with a scenario of increased demand for biomass… In general the Framework should provide a means to estimate the effect of stationary source biogenic feedstock demand, on the atmosphere, over time, comparing a scenario with the use of biogenic feedstocks to a counterfactual scenario without the use of biogenic feedstocks.

With this in mind, baseline scenarios are constructed so that business-as-usual (BAU) projections, which include anticipated growth in biogenic feedstock consumption, can be compared relative to alternative baseline scenarios that include no new growth in biogenic feedstock demand (the Constant scenario), and no future consumption of biomass. Thus, this appendix considers a range of possible anticipated future baselines and alternative counterfactuals, allowing for a detailed assessment of potential biogenic emissions estimates for illustrative purposes.

The following sections continue with more detail describing the baseline scenario results, with a brief look at periodic net emissions and cumulative net emissions for each of the scenarios. Finally, the model results for additional emissions in each AEO baseline scenario are presented and discussed at both the national and regional levels.

3.1. FASOM-GHG Simulation Results

This section presents and compares results for the various baseline scenarios. First net CO_2 emissions are presented followed by cumulative net emissions, and finally additional emissions relative to a counterfactual scenario in which no biogenic feedstocks are consumed at stationary sources.

3.1.1. Net Emissions Flux per Time Period

For each 5-year period, an annual emission or sequestration value was calculated using the FASOM-GHG equations and parameters (presented in the supplemental section at the end of Appendix L), then a total net emissions flux for that 5-year period was calculated by aggregating the individual fluxes. Figure K-6 illustrates projected CO_2 emissions flux trajectories across the different baseline scenarios using atmospheric GHG accounting (a positive value represents net emissions, while a negative value represents net carbon sequestration on the landscape). Note that the difference between scenarios is not as significant as the change in net emissions between periods (i.e., over time). The cyclical shape of these trajectories is driven by periodic shifts in forest management; harvest emissions and forest biomass growth can vary period-to-period, leading to high net emissions totals in some periods and net sequestration in others. Land use change emissions can also contribute to this cycle. Assumptions related to management practices for the various feedstocks considered are described in Appendix H. Periods with high agricultural land use conversion (such as pasture or forest conversion to cropland) can result in increased emissions, while afforestation can increase terrestrial carbon uptake.

Differences between baseline scenario projections are subtle, as the overall shape of these trajectories is similar. However, the absolute difference in annual emissions could be significant (for instance, this difference ranges 3–5 million tCO_2e per year for the 2010 simulation period).

Furthermore that each biogenic feedstock consumption scenario results in an immediate increase in emissions in the 2010 time step, coinciding with the first year of the biogenic feedstock demand shock applied to each alternative baseline scenario. Thus, biomass demand initially increases emissions relative to the Zero Biomass demand scenario, driven by changes in management in response to the new feedstock demand.

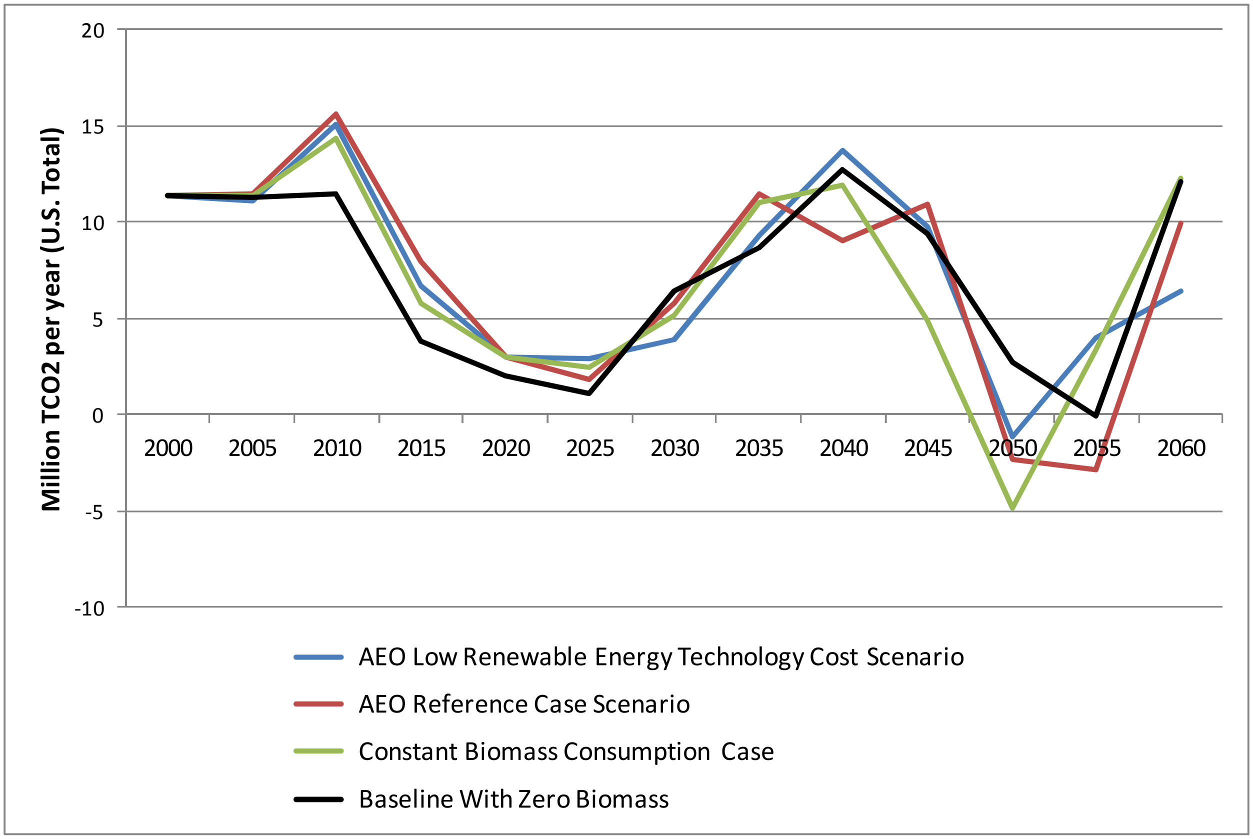

Figure K-6. Terrestrial Carbon Flux from U.S. Forest and Agricultural Sectors (Excluding Non-CO_2 Emissions, Emissions from Fossil Fuel Consumption, and Carbon Stored In Wood Products).

3.1.2. Cumulative Net Emissions

Although the periodic net emissions flux trajectories are similar over time, minor differences in annual fluxes can result in large differences in cumulative emissions over time. Total emissions for each 5-year period are converted to a cumulative emissions total over the time horizon, displayed in Figure K-7.

In 2035 (when biogenic feedstock demand peaks), cumulative emissions for the AEO Reference baseline scenario are 22% higher than cumulative emissions for the Zero Biomass baseline. However, over time, projected cumulative emissions for the Zero Biomass baseline begin to converge with the alternative biogenic feedstock demand baselines. There is little difference between the Zero and Constant Biogenic Feedstock baseline scenarios toward the end of simulation horizon, and less than 7% difference across all scenarios. Thus, after immediate and medium-term emissions effects of increased biogenic feedstock demand, physical carbon stocks begin to recover and the cumulative difference in emissions from Zero Biomass to the alternative baselines begins to subside. One implication of these results is that the choice of time scale is important and can have a large impact on the cumulative emissions difference between scenarios (i.e., with a shorter timeframe used for this illustration, the observed convergence would not occur).

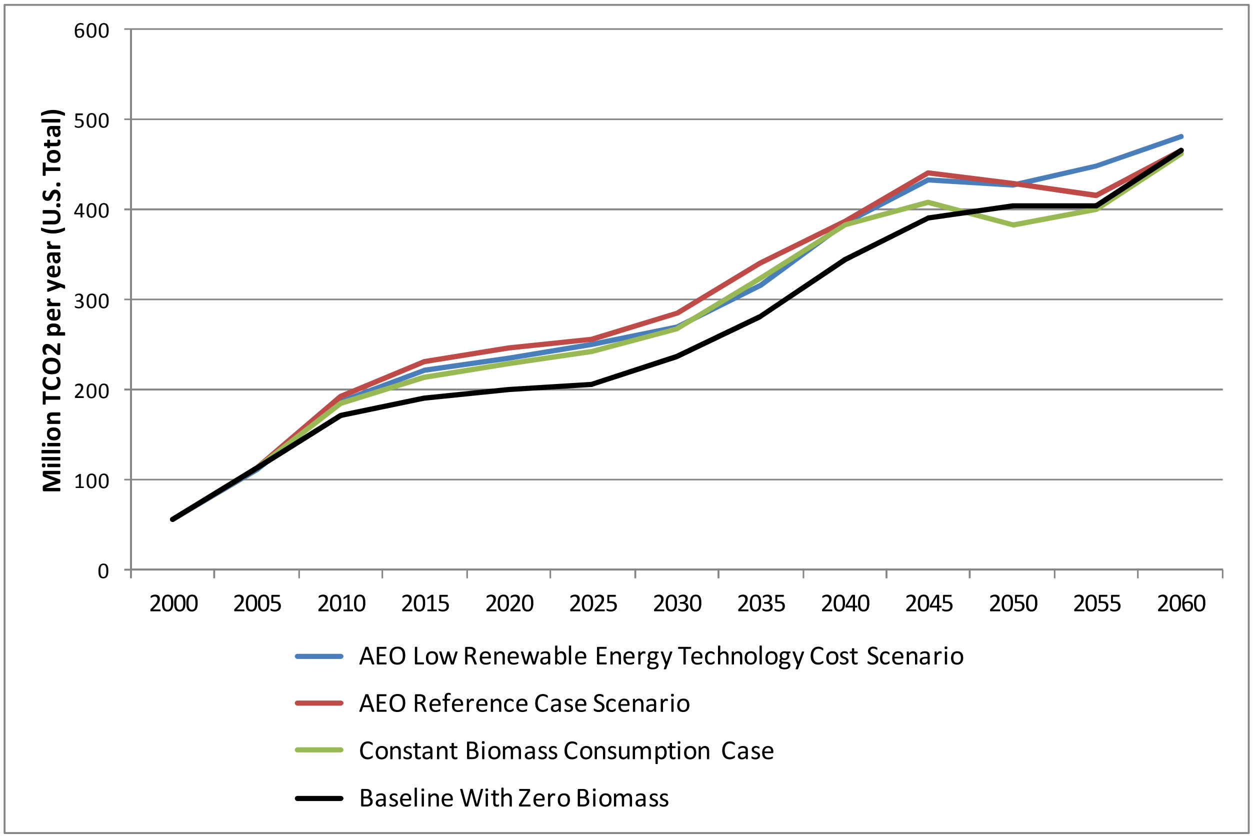

Figure K-7. Cumulative Emissions Over Time by Biomass Scenario.

3.1.3. Additional Estimated Emissions

Additional biogenic CO_2 consumption and landscape-level emissions are calculated relative to the Zero Biomass baseline scenario. This is done in order to capture all additional emissions effects of biomass consumption under an anticipated future baseline projection relative to an alternative future in which there is no biomass consumption. Thus, all additional current and expected growth in biogenic feedstock consumption and the relative change in terrestrial CO_2 emissions are captured. This approach allows one to consider changes in emissions for relative changes in future biomass demand (captured by the Constant [no growth in consumption], AEO Reference, and AEO Low Renewable Technology Cost Baselines).

Emissions intensities for additional biogenic feedstock consumption relative to the Zero Biomass baseline scenario are computed (as this includes all biogenic feedstock users). An emissions intensity is the ratio of net biogenic emissions (net of emissions and landscape-level sequestration) to net biogenic CO_2 in biomass consumed for energy (tCO_2 equivalent emissions/ tCO_2 equivalent in consumed biogenic feedstocks). In this context, emissions intensity represents the ratio of emissions relative to a unit of biogenic feedstock used for energy (i.e., the portion of biogenic feedstock carbon emitted to the atmosphere). A value of 0 implies no net emissions, meaning that biogenic CO_2 emissions from the use of biogenic feedstocks in energy production would be balanced with carbon uptake in the feedstock and on the landscape where the feedstock was produced. A value of 0.5 would imply that half of the biogenic CO_2 emissions are displaced by carbon uptake on the landscape. This metric provides insight into potential emissions intensity of biogenic feedstock consumption by current and future stationary sources under these specific anticipated baseline scenarios and related parameters. This metric does not take into account stationary source process emissions, including combustion efficiencies, feedstock losses during processing, or other possible components related to feedstock procurement or processing.

For the three alternative biogenic feedstock consumption baseline scenarios (Constant, AEO Reference baseline, and AEO Low Renewable Technology Cost Baseline), cumulative additional emissions are calculated as the difference from the Zero Biomass baseline scenario and each alternative scenario for each period of the simulation horizon. Cumulative additional biogenic CO_2 from biogenic feedstock consumption is calculated by converting annual biogenic feedstock consumption requirements for each scenario to a cumulative value, and then converting to CO_2 equivalence (assuming that each dry ton of feedstock is 50% carbon). This cumulative additional emissions value is then divided by total CO_2 equivalence of biogenic feedstock consumption to derive the emissions intensity per unit of biogenic feedstock (Figure K-8).

In general, emissions intensity projections show that biogenic CO_2 emissions are not entirely displaced by terrestrial carbon sequestration early in the simulation horizon. When compared with the Zero Biomass baseline, additional emissions per-unit of additional biogenic CO_2 consumption ranges 0.35–0.47 ton CO_2e once the biogenic feedstock requirements are imposed in 2010. Note, however, that emissions intensity declines steadily over time for each baseline scenario, approaching a net carbon balance of 0 for the AEO Reference and AEO Low Renewable Technology Cost cases. Emissions intensity reaches values below 0 for the Constant Biomass case, indicating that cumulative biogenic CO_2 emissions are more than balanced by emissions changes on the landscape. This decline in emissions intensity is driven by several factors:

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).

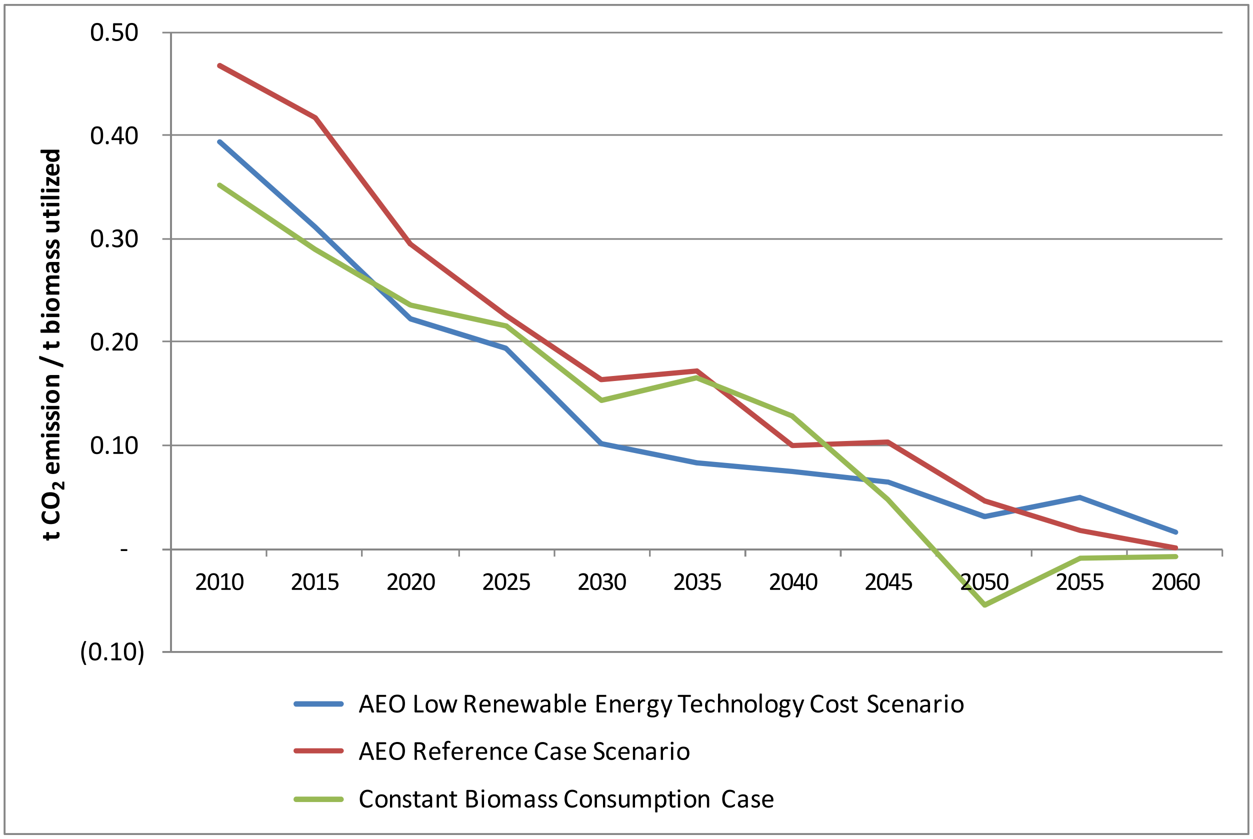

Figure K-8. Emissions Intensity of Biomass Energy Relative to the Zero Biomass Scenario (Cumulative Additional Emissions Divided by Cumulative Biogenic Carbon from Additional Biogenic Feedstocks).

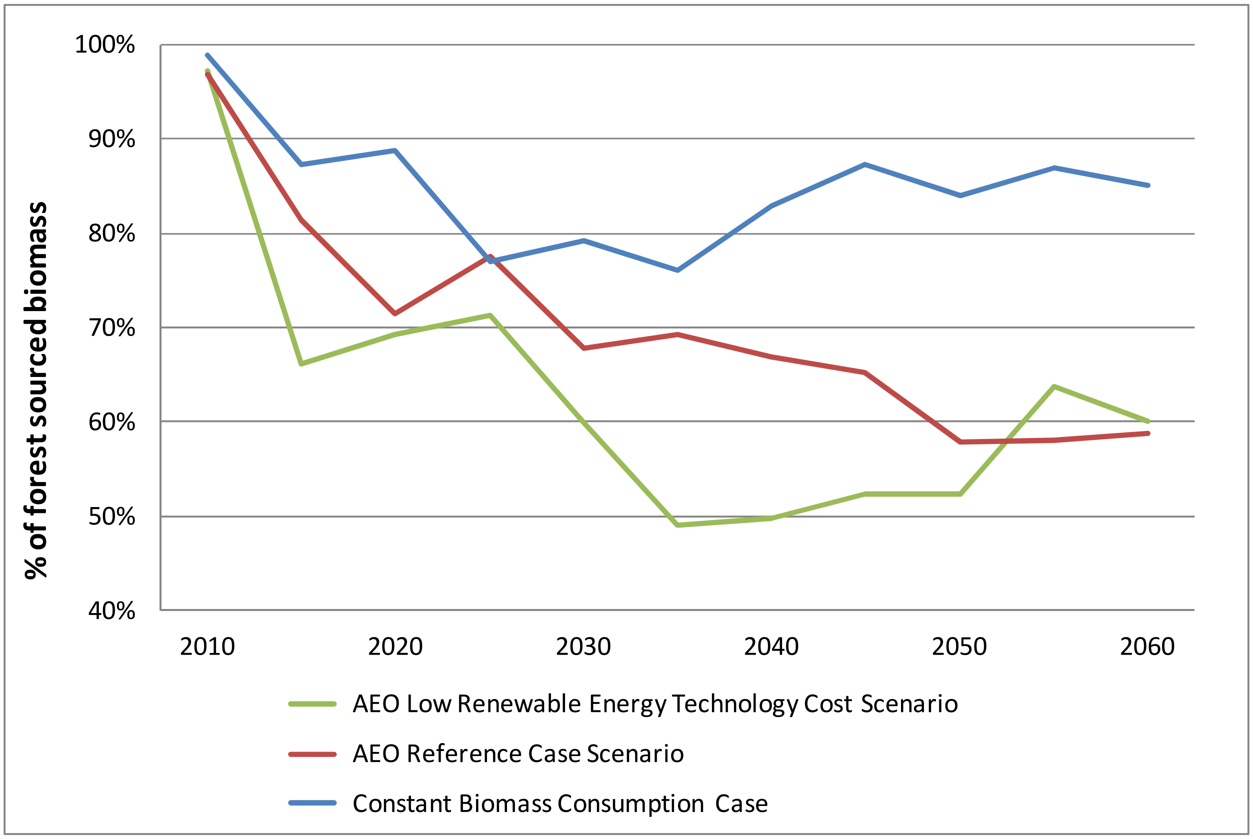

Figure K-9. Proportion of Biogenic Feedstock from Woody Sources by Scenario Relative to the Zero Biomass Scenario.

In general, use of forest biogenic feedstocks for energy generation generates greater direct emissions and less energy output per-unit area than agricultural feedstocks or dedicated energy feedstocks, such as switchgrass (for more discussion, see Latta et al., 2013). Initially, the overall feedstock portfolio is required to be approximately 96% derived from forestry feedstocks to match observed biomass consumption patterns, hence the higher emissions per unit of biomass. However, this constraint is relaxed after the initial time period, giving the model flexibility to choose a biogenic feedstock portfolio mix that minimizes the costs of meeting the total biogenic feedstock requirement. 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.

This decline is more pronounced for the Low Renewable Technology Cost baseline as it adopts a much higher proportion of dedicated energy feedstocks to meet total biogenic feedstock demand. Although the Constant Biomass scenario continues to consume a relatively high proportion of forest-derived feedstocks, total biogenic feedstock requirements do not increase from the base year, so land management, markets, and terrestrial carbon stocks adjust more rapidly, causing emissions to fall.

4. Conclusion

This appendix developed biogenic feedstock demand projections with an initial (2009) value calibrated to observed consumption patterns at electricity and industrial sector stationary sources. Future projections were then calibrated to projected growth rates in renewable energy demand (by sector and region) from the AEO (2012). A range of anticipated future baseline scenarios were created, representing a range of possible biogenic feedstock consumption futures. These projections were mapped to FASOM-GHG agroforestry regions, representing regional biogenic feedstock requirements for simulation analysis.

Emissions trajectories across the alternative future baseline scenarios were compared to a scenario in which no agricultural and forestry biomass is consumed at stationary sources for energy generation. Results of the simulation analysis revealed that emissions from biogenic feedstock consumption are not fully balanced by initial landscape CO_2 uptake. However, over time, emissions intensity decreases, approaching or surpassing a net carbon balance for all alternative anticipated future baseline scenarios assessed here.

In general, these results are consistent with previous studies that have shown that there are GHG consequences associated with biogenic feedstock production, especially immediately following an increase in biogenic feedstock demand (Latta, et al., 2013; Daigneault et al., 2012). However, this analysis shows that carbon dioxide emissions associated with biogenic feedstock production and use are at least partially balanced by changes in sequestration on the landscape and that, over time (in this case decades), an increasing share of these carbon dioxide emissions is balanced at a national level and in most regions as well. When disaggregated regionally, emissions intensity trajectories also approach net carbon balances for most FASOM-GHG regions, with a few clear exceptions (CB, PSW). For the CB and PSW, land use change early in the simulation horizon (afforestation) leads to net sequestration, which causes negative emissions intensity in the near term.

Three of the future anticipated baseline scenarios presented in this appendix are utilized within the case study appendix (Appendix L): Zero Biomass, Constant Biomass (existing sources in 2009), and AEO Reference. Appendix L develops feedstock- and region-specific demand shocks in addition to the AEO Reference case scenario. Emissions projections from these feedstock case study scenarios are then compared to the three alternative baselines above to evaluate the emissions effect of a marginal increase in consumption of one feedstock (comparison to AEO Reference), an average effect relative to current consumption levels (Constant), and an average effect relative to no biogenic feedstock consumption (Zero).

The baselines and estimated values derived in this appendix and in Appendix L are intended to illustrate the functionality of a future anticipated baseline approach method and do not reflect EPA findings in the context of specific policies or programs. As with all modeling studies, there are a number of uncertainties present in the baseline scenario assumptions and parameters adopted for this analysis. These uncertainties include future environmental conditions and the biophysical emissions accounting parameters, future economic or policy conditions, and technological growth (both for agricultural/forestry feedstock yield and commodity-processing technologies). However, model projections provide key insight into the potential market and land use consequences of possible shifts in the demand for biogenic feedstocks at stationary sources. Furthermore, this study does not include full coverage of possible feedstocks from agricultural and forestry production processes. Most notably, FASOM-GHG does not include production of black liquor as an industrial processing by-product of pulp and paper production.

5. References

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6. Supplemental Data and Information

6.1. Graphics

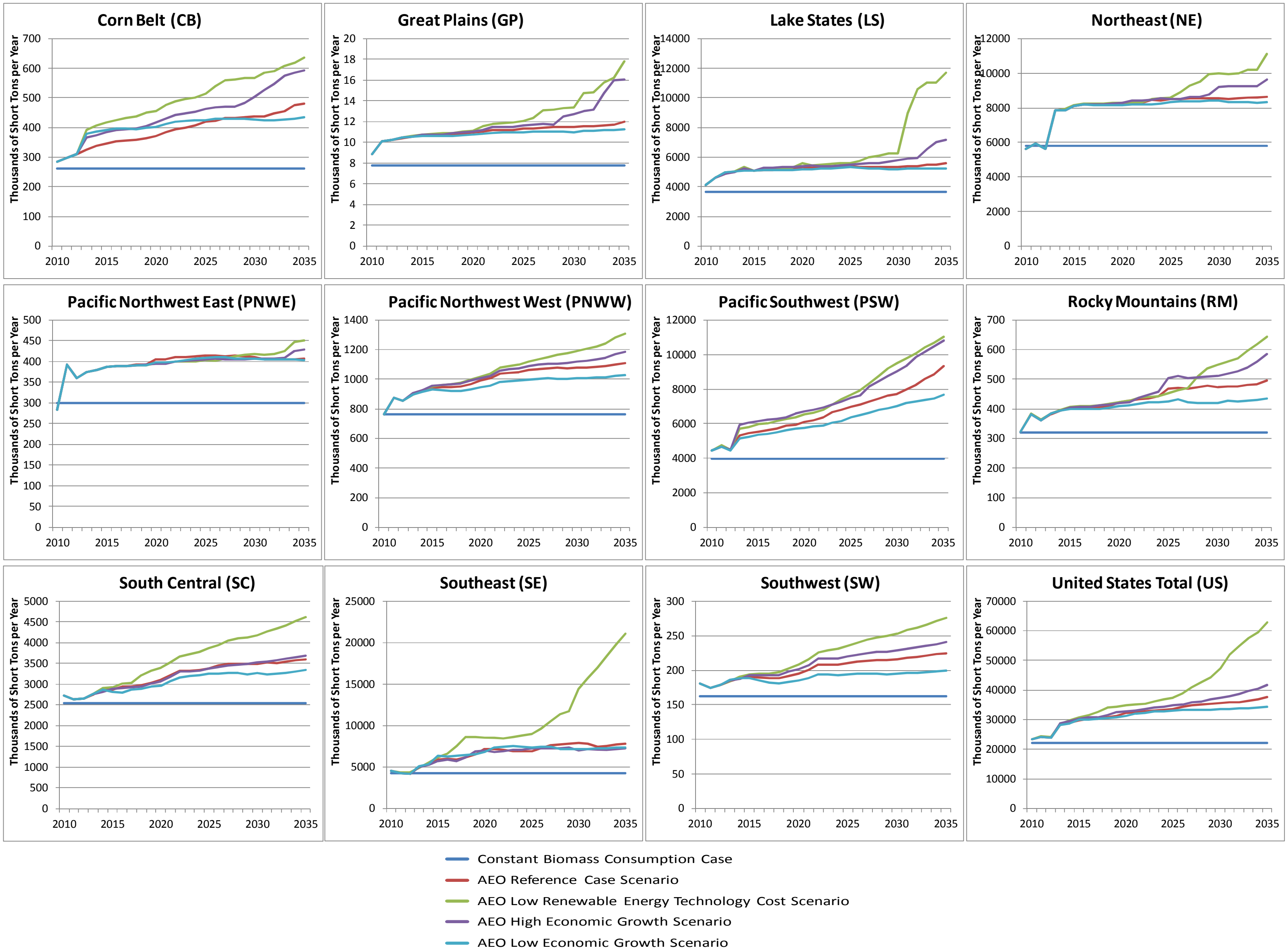

Figure K-10. Biogenic Feedstock Consumption Projections by AEO Scenario Grouped by FASOM-GHG Region.

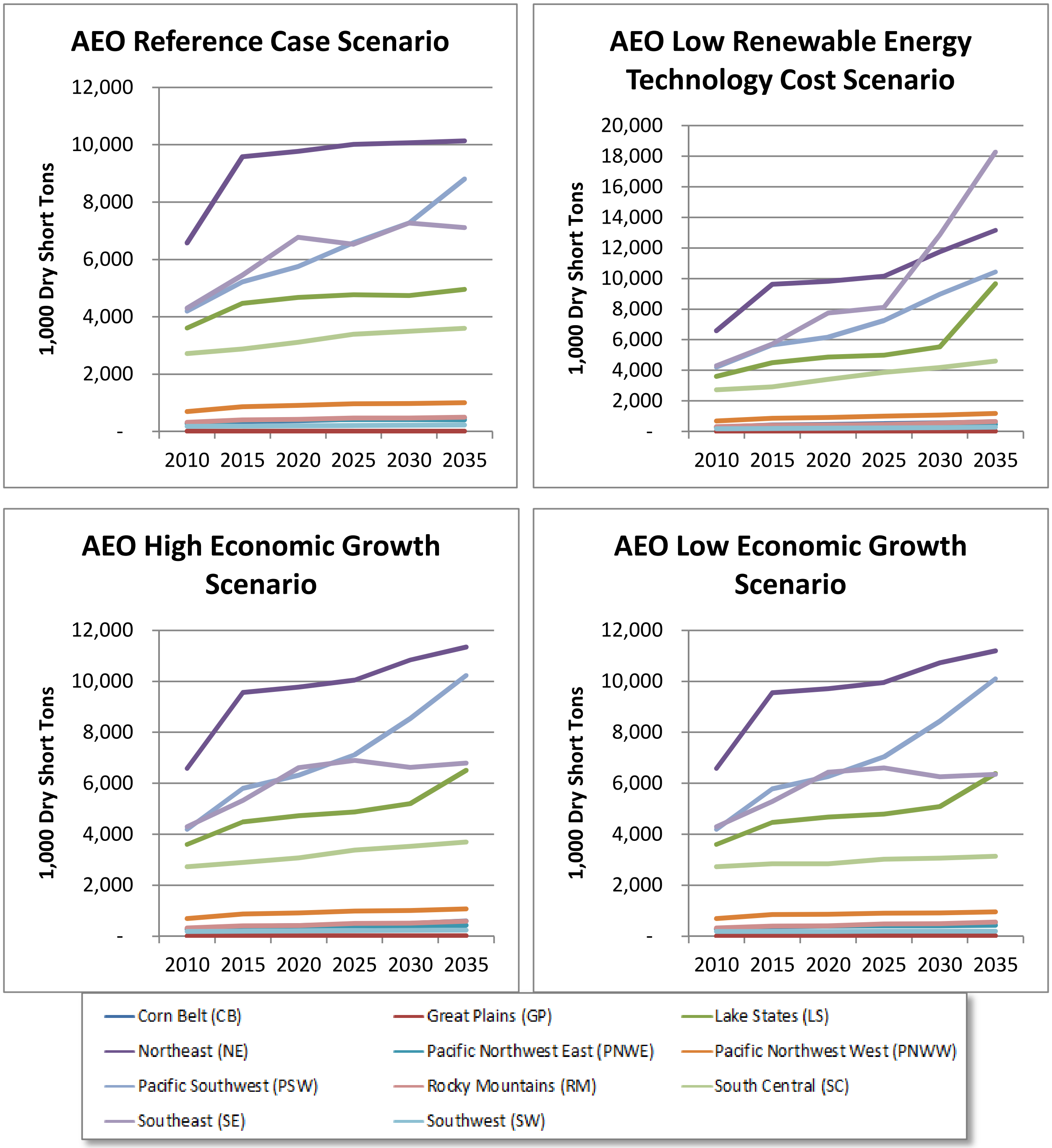

Figure K-11. Biogenic Feedstock Consumption Projections by FASOM-GHG Region Grouped by AEO Scenario.

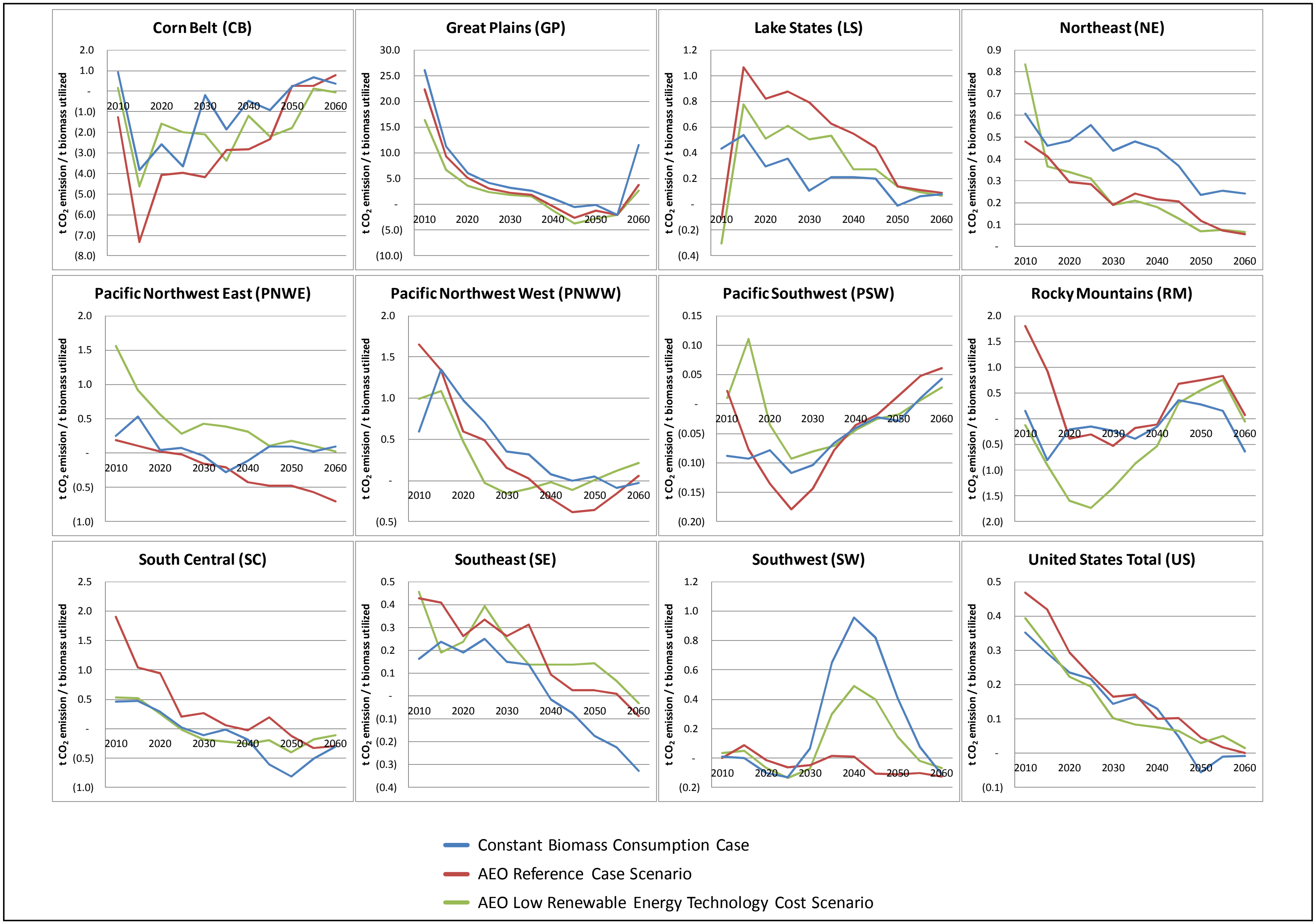

Figure K-12. Additional Emission per Ton of Biogenic Feedstock Utilized.