



Is Biopower Carbon Neutral?

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Summary

Congress has been increasingly interested in biopower—electricity generated from biomass. Biopower, a baseload power source, has the potential to strengthen rural economies, enhance energy security, and improve the environment, proponents say. Biopower could be produced from a large range of biomass feedstocks nationwide (e.g., urban, agricultural, and forestry wastes and residues). One challenge to biopower production is a readily available feedstock supply. At present, biopower requires tax incentives to be competitive with conventional fossil fuels.

Congressional support for biopower has aimed to promote energy security, and has generally assumed that biopower is carbon neutral. An energy production activity is typically classified as carbon neutral if it produces no net increase in greenhouse gas (GHG) emissions on a life-cycle basis. The premise that biopower is carbon neutral has come under scrutiny as its potential to help meet U.S. energy demands and reduce U.S. greenhouse gas emissions is more closely examined.

Whether biopower is carbon neutral depends on many factors, including the definition of carbon neutrality, the feedstock type, the technology used, and the time frame examined. Carbon flux (emission and sequestration) varies at each phase of the biopower pathway, given site- and operation-specific factors. A life-cycle assessment (LCA) is a common technique to calculate the environmental footprint, including the carbon flux, of a particular biopower pathway. However, past legislation has not required a standardized LCA.

Interest in the carbon classification of biopower is in part due to sustainability and air quality concerns. Where the feedstock supply for biopower originates, if it is managed in a sustainable manner, and whether the associated air quality impacts from biopower generation are tolerable are questions that are part of the biopower carbon-neutrality debate. Congress may decide whether the current carbon-neutral designation for biopower is accurate, or whether additional carbon accounting for biopower is warranted and what impact this accounting might have on renewable energy, agricultural, and environmental legislative goals.

Rulings by the U.S. Environmental Protection Agency have raised questions about the carbon neutrality of biopower. For instance, the Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule did not exempt emissions from biomass combustion. Some view EPA's decision as equating biomass emissions with fossil fuel emissions. State perspectives on the final rule are divided. Some states contend that treating biomass combustion the same as fossil fuel combustion will result in excessive permitting requirements and fees that jeopardize renewable energy development. Other states argue that not treating it the same will aggravate climate change over time. EPA recently decided to defer for three years GHG permitting requirements for carbon dioxide emissions from biomass-fired and other biogenic sources.

In addition, the June 2010 release of the Manomet Center for Conservation Sciences Biomass Sustainability and Carbon Policy Study led to a noteworthy discussion in the media and the scientific community about biomass energy and its GHG impacts. The study centered on substituting forest biomass for fossil fuels in the Massachusetts energy sector. The study found that, using conventional combustion, more GHGs are emitted per unit of energy produced from forest biomass than from fossil fuels. The study's assumptions and parameters, including the time frame necessary to pay off the carbon debt (i.e., the excess GHG emissions) and the single biomass feedstock, would need to be changed to have application to the national carbon-neutrality debate.

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Introduction

Biomass energy, or bioenergy, is receiving increased attention as an alternative to fossil fuel energy because of its potential to improve the environment, provide energy security, and promote economic development. Biomass is organic matter—woody biomass, agricultural biomass, animal wastes, aquatic biomass—that can be converted to energy (e.g., heat, electricity, or liquid transportation fuels). A substantial supply of biomass feedstocks may be required to produce bioenergy, depending on current and future renewable energy mandates. A large biomass feedstock requirement could lead to water, land use, sustainability, and economic concerns.¹ Federal support for bioenergy is available via tax incentives, loan guarantees, technical and financial assistance, and mandated use requirements.

Legislative support for bioenergy, particularly for biopower (electricity generated from biomass),² has thus far been granted under the premise that it is carbon neutral. As more public and private resources are spent—or as greater spending is debated—on biopower, more attention is being directed to the rationale for designating biopower as carbon neutral. The carbon-neutral designation is typically assigned to an energy production activity that essentially produces no net increase in greenhouse gas (GHG) emissions on a life-cycle basis (or one in which the amount of carbon dioxide emitted during the power production cycle is absorbed).³ Where biopower stands among the other renewable energy sources with respect to GHG emissions may affect the level of future legislative support granted to it. Is biopower carbon neutral? If it is not, should it receive the same type and amount of federal resources as carbon-neutral energy sources? How might the federal government account for carbon associated with biopower ventures? How Congress addresses biopower’s carbon neutrality could shape how Congress treats biopower in general.

Many views exist about whether biopower is carbon neutral. Some contend that biopower is carbon neutral because the carbon released during bioenergy production comes from a carbon-neutral feedstock—biomass. Some argue that biopower is not carbon neutral because the amount of GHG emissions released per unit of energy during simple biopower combustion may be higher for certain biomass fuels than for fossil fuels; or, if the GHG emissions from certain biomass fuels are lower than fossil fuels, they are still not zero. These perspectives are often based on differing assumptions, technologies, and time frames.

The debate concerning biopower’s designation as carbon neutral may intensify, given possible congressional and Administration decisions. Congress may consider legislation involving biopower (e.g., a renewable electricity standard, a clean energy standard, or the next farm bill). The U.S. Environmental Protection Agency (EPA) has already promulgated regulations involving biopower (e.g., the Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule) and may consider further regulatory actions. Although EPA recently announced its intention to defer for three years GHG permitting requirements for carbon dioxide emissions from biomass-fired and other biogenic sources,⁴ Congress may still decide to examine how the widely

¹ For more information, see CRS Report R41440, *Biomass Feedstocks for Biopower: Background and Selected Issues*, by Kelsi Bracmort.

² Biopower is a baseload power source offering “firm” power without the need for power storage. Combustion—the burning of biomass in a power plant—is the dominant technology used to produce biopower.

³ The life cycle of a bioenergy pathway includes all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through distribution, delivery, and use of the finished fuel by the ultimate consumer. The mass values for all greenhouse gases are adjusted to account for their relative global warming potential.

⁴ Environmental Protection Agency, “EPA to Defer GHG Permitting Requirements for Industries that Use (continued...)”

accepted premise of biopower's carbon neutrality contributes to energy, environmental, and economic development goals.

This report discusses some of the most relevant factors to take into account when considering if biopower is carbon neutral. It does not discuss carbon accounting for other bioenergy pathways.⁵

Biomass Carbon Cycle

The carbon cycle encompasses the many pathways through which carbon is exchanged between the atmosphere and the land and water.⁶ Human activities (also called anthropogenic activities) contribute to the carbon cycle by emitting carbon dioxide (CO₂). The human contribution of CO₂ to the carbon cycle is relatively small compared to other contributions, but CO₂ released to the atmosphere from human activities is taken up by soils, vegetation, and the ocean at a rate that is relatively slower than the rate at which human activities are emitting CO₂. If the excess carbon is not stored in land and ocean sinks, the atmospheric concentration of CO₂ increases, potentially impacting the Earth's climate.

One significant anthropogenic source of CO₂ in the carbon cycle is energy production. The net effect of an energy activity on the carbon cycle can be classified in one of three ways. A "carbon-positive" activity releases CO₂ into the atmosphere. A "carbon-negative" activity removes more CO₂ from the atmosphere than it emits. A "carbon-neutral" activity is one where the CO₂ releases and absorption are in balance. There is no commonly accepted definition for a "carbon-neutral" activity in the biopower arena.⁷ Indeed, multiple assertions about carbon neutrality have been put forth by those involved with biomass energy, including the following:⁸

- Biomass energy is carbon neutral because biomass is naturally carbon neutral.
- Biomass energy is neutral if the activity removes as much CO₂ as was emitted into the atmosphere.
- Biomass energy is neutral only if the net life-cycle emissions are zero.⁹
- Biomass energy is neutral if it achieves lower net increases in atmospheric GHGs when compared to alternative energy activities.

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Biomass/Three-year deferral allows for further examination of scientific and technical issues associated with counting these emissions," press release, January 12, 2011, <http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/4369c709163915b485257816005971bb!OpenDocument>.

⁵ Congress addressed carbon accounting for another major bioenergy pathway—liquid transportation biofuels—with a life cycle emission analysis (a requirement within the Renewable Fuel Standard). For more information, see CRS Report R40460, *Calculation of Lifecycle Greenhouse Gas Emissions for the Renewable Fuel Standard (RFS)*, by Brent D. Yacobucci and Kelsi Bracmort.

⁶ For more information, see CRS Report RL34059, *The Carbon Cycle: Implications for Climate Change and Congress*, by Peter Folger. Carbon is an elemental building block of molecules that make up all organisms on Earth. Carbon cycling is the process by which living things absorb carbon from the atmosphere, carbonate rocks and ocean deposits, dead organic matter in the soil, or food and return it to the atmosphere or soil by respiration, combustion, or decay.

⁷ The term "carbon neutral" has been included in more than 20 bills since the 109th Congress.

⁸ R. Miner, "Biomass 'Neutrality' in the Context of Forest-based Fuels and Products," USDA Bioelectricity and GHG Workshop, Washington, DC, November 15, 2010. Some of the definitions are not mutually exclusive.

⁹ GHGs from bioenergy production can be accounted for using a life-cycle assessment (LCA). The LCA is further discussed in "Greenhouse Gas Accounting for Biopower Production," below.

There are pros and cons for each assertion. For instance, declaring that biomass energy is carbon neutral because biomass is naturally carbon neutral does not account for GHG emissions released due to management of crops grown for energy production (e.g., fertilizer). There may need to be additional plantings of certain biomass feedstocks to remove the CO₂ emitted from biomass cultivated for energy production.

The carbon cycles for a bioenergy system and a fossil fuel system differ in at least two ways: the carbon source (finite versus renewable) and the atmospheric carbon concentration (potentially stable versus additional; see **Figure 1**). Three main factors contribute to the amount of carbon emitted from biopower generation: feedstock production (cultivation and harvest), feedstock transport, and the biopower technology type. However, as noted by many sources, feedstock production also absorbs carbon during growth.

Greenhouse Gas Accounting for Biopower Production

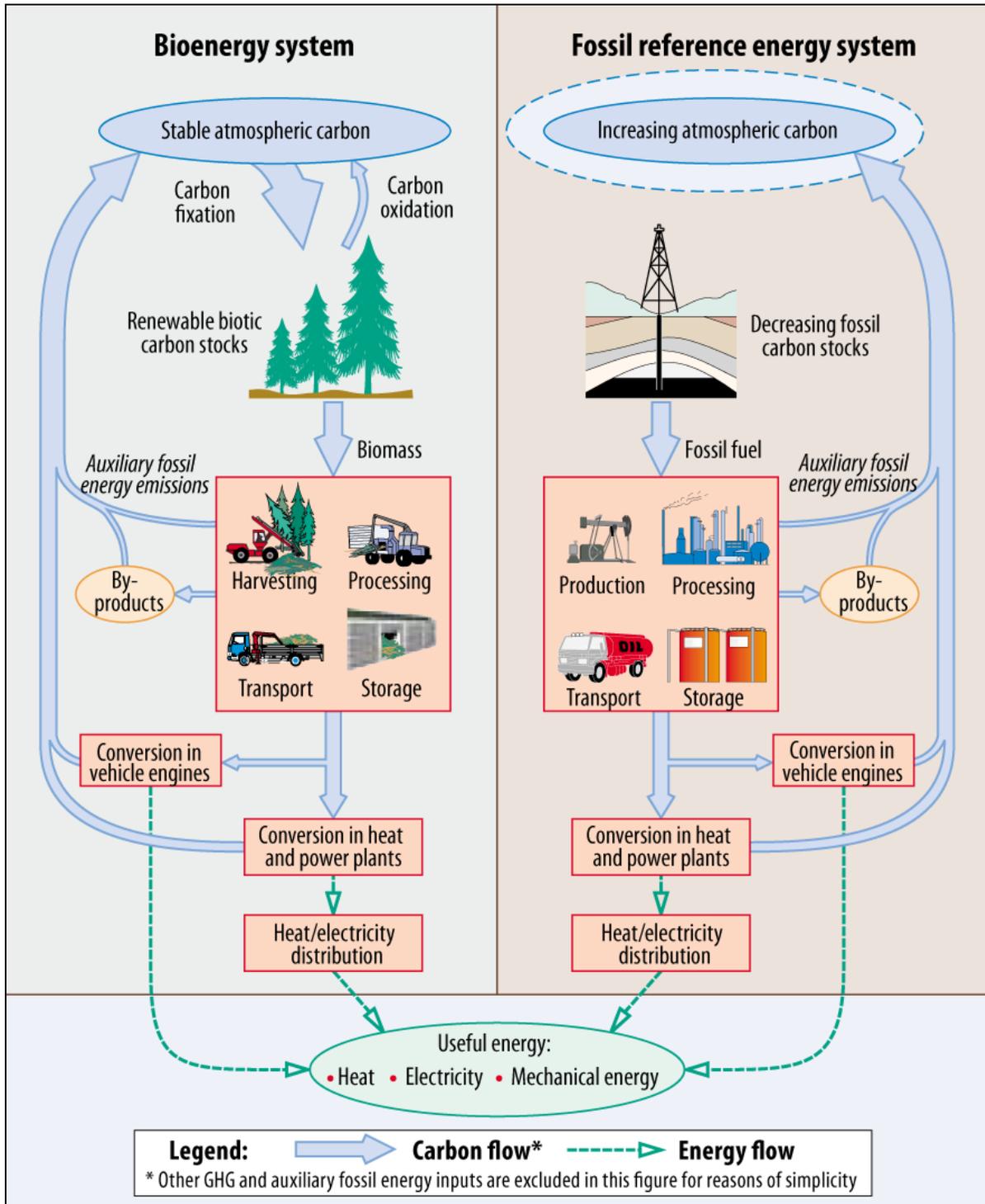
Whether and how to conduct GHG accounting for biopower is an issue at the forefront of the bioenergy movement. GHG accounting can be used to compare the environmental footprint of a biopower operation with that of conventional fossil fuel (e.g., electricity from coal). The environmental footprint is often calculated using a life-cycle assessment (LCA), an analytic method for identifying, evaluating, and comparing the environmental impacts of emissions and the resource depletion associated with a specific process.¹⁰ A LCA generally uses observed data and assumptions to model what GHGs are being released at each phase of the process. Ideally, a LCA would encompass economic and social factors for a more comprehensive assessment. Alternatively, an LCA can be one element used in assessing a preferred energy approach, along with cost and performance data. In some cases, even if LCA results favor a particular approach, an LCA alone might not be the deciding factor when choosing an energy process; financial objectives, policy goals, and other factors may influence which approach is selected.

An LCA has four major stages: goal and scope definition, inventory analysis, impact assessment, and interpretation.¹¹ While an LCA can be performed to meet various goals, the goals most applicable to the biopower arena are to support broad environmental assessments, support public policy, and provide information and direction to decision-makers. The goal and scope definition stage determines the amount of resources and time needed to conduct an LCA. The inventory analysis stage of an LCA quantifies energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes, and other releases for the entire life cycle of a product, process, or activity. The impact assessment stage evaluates the potential human health and environmental impacts of the environmental resources and releases identified during the inventory analysis stage. The interpretation stage identifies, quantifies, checks, and evaluates the results of the inventory analysis and impact assessment stages, and communicates the results.

¹⁰ National Renewable Energy Laboratory, *Energy Analysis*, October 2010, http://www.nrel.gov/analysis/tech_bio_analysis.html.

¹¹ U.S. Environmental Protection Agency, *Life Cycle Assessment: Principles and Practice*, EPA/600/R-06/060, Cincinnati, OH, May 2006, <http://www.epa.gov/nrmrl/lcaccess/pdfs/600r06060.pdf>.

Figure 1. Bioenergy CO₂ Balance vs. Fossil Fuel CO₂ Balance

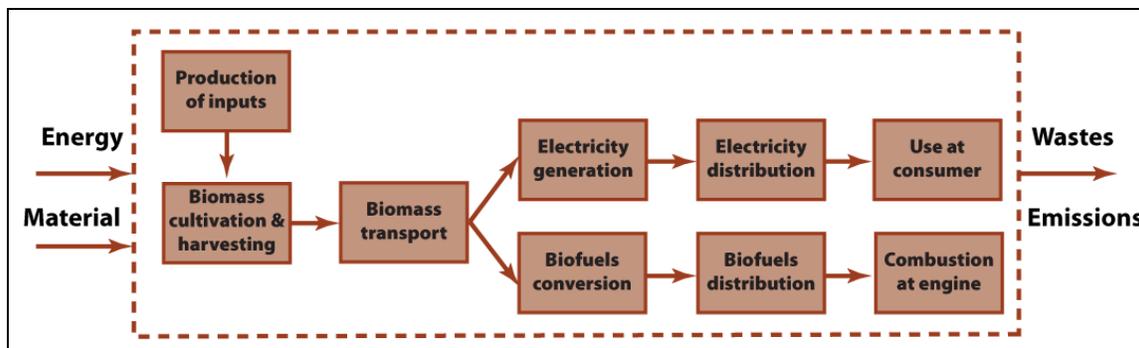


Source: International Energy Agency, IEA Bioenergy Task 38, Greenhouse Gas Balances of Bioenergy and Bioenergy Systems, 2002. Adapted by CRS.

Notes: The magnitude of the carbon flows, as indicated by the width of the arrows, is a significant part of the debate over the carbon neutrality of bioenergy.

GHG accounting with an LCA can be performed at each phase of the biopower pathway: biomass cultivation and harvest, biomass transport, electricity generation, electricity transmission and distribution, and electricity end use (**Figure 2**). The first three phases of the biopower pathway (cultivation and harvest, transport, and electricity generation) are where the bulk of GHG emissions occur. GHG flux during the first three phases is site- and operation-specific, and depends on many factors, including the biomass type, management strategies, and the biopower generation technology.

Figure 2. Biopower and Biofuel Pathways



Source: Q. Zhang, K.R. Goldstein, and J.R. Mihelcic, "A Review of Life Cycle Assessment Renewable Energy Derived from Forest Resources," in *Renewable Energy from Forest Resources in the United States*, ed. B.D. Solomon, C. A. Luzadis (New York: Routledge, 2009). Adapted by CRS.

Published LCAs for biopower are limited and, as noted above, may not be applicable to specific cases.¹² The LCAs performed are often tailored to one feedstock and one biopower technology type, and LCA results vary depending on assumptions such as the time frame of the assessment. The LCAs presented in this section are based on both a long time frame (e.g., cradle to grave) and a relatively short time frame (e.g., cradle to gate).¹³ Different LCA time frames can lead to radically different, even contradictory, results.

Although biopower LCAs are scarce compared to liquid transportation biofuel LCAs, certain trends appear in existing assessments. Based on a review of more than 25 LCAs, biopower is in the top tier of bioenergy pathways that avoid the most GHG emissions and replace the largest amounts of fossil energy.¹⁴ Approximately 15 of the LCAs reviewed included electricity as an end product, of which at least 10 had an LCA time frame of cradle to gate.

The U.S. Department of Energy (DOE) has conducted some LCAs for biopower. One DOE LCA found that GHG emissions per kilowatt-hour of electricity produced are considerably more for fossil-based systems, even with CO₂ sequestration, than for the biopower generation systems

¹² Most LCAs for bioenergy have focused on GHG emissions from biomass used for liquid transportation fuels and its impact on climate.

¹³ A cradle to grave time frame generally includes all phases from feedstock production to energy end use. A cradle to gate time frame generally includes a fraction of the complete biopower pathway which may include feedstock production, feedstock cultivation, feedstock transport, and electricity generation.

¹⁴ Q. Zhang, K. R. Goldstein, and J. R. Mihelcic, "A Review of Life Cycle Assessment Renewable Energy Derived from Forest Resources," in *Renewable Energy from Forest Resources in the United States*, ed. Barry D. Solomon, Calerie A. Luzadis (New York: Routledge, 2009). Information regarding the feedstocks, conversion processes, end products, system boundaries, allocation methods, and impact metrics for each LCA is available in Table 8.1.

using 100% biomass feedstock and no CO₂ sequestration.¹⁵ GHG accounting was conducted for the feedstock procurement, transportation, electricity generation, and CO₂ sequestration phases. Furthermore, the LCA concluded that there is a substantial decrease in fossil energy consumption for the biopower systems. The DOE LCA used biomass from urban sources and incorporated avoided GHG emissions relative to landfilling or mulching the biomass. The LCA assumed that numerous small biopower plants were needed to achieve the power generation capacity. Costs associated with transporting biomass a long distance (e.g., more than 50-60 miles) to a larger plant can be uneconomical compared to using several plants within a closer proximity to the biomass feedstock. Also, the CO₂ sequestration costs can vary depending on transport and storage options (e.g., transport distance, the storage location, and depth of storage).

Biopower LCAs are usually limited to two biopower technology types: combustion and gasification. Both technologies have strengths and weaknesses.¹⁶ The technology to co-fire (or combust) biomass with coal is available at commercial scale and is in use today. A cradle-to-grave DOE LCA found that a co-firing power plant, at both the 15% and 5% biomass levels (with a 350 and 354 MW plant capacity, respectively), compared with a power plant with no co-firing, led to a reduction in GHG emissions by roughly 18% and 5%, respectively.¹⁷ Gasification technology is in the development and demonstration phase. A cradle-to-grave DOE LCA for a hypothetical 113 MW biomass plant—performed in part to identify CO₂ emissions from a biopower plant using gasification technology—concluded that more than half of all net CO₂ emissions came from feedstock production, primarily the use of fossil fuels in farming operations.¹⁸ The LCA was performed only on the biomass system and not for an immediate comparison with fossil-fueled power options.

Recent Developments Affecting Biopower Assessment

Certain actions have propelled the biomass carbon-neutrality issue to the center of the bioenergy debate. Most notable are the EPA's Prevention of Significant Deterioration (PSD) and Title V Greenhouse Gas Tailoring Rule finalized in June 2010; and the June 2010 release of the Manomet Center for Conservation Sciences Biomass Sustainability and Carbon Policy Study. Also, many scientists contributed to the discussion with the submission of two letters to Members of Congress. The first letter provided the authors' reasons for supporting legislation that differentiates GHG emissions from bioenergy based on the source of the biomass.¹⁹ The second

¹⁵ P. L. Spath and M.K. Mann, *Biomass Power and Conventional Fossil Systems with and without CO₂ Sequestration—Comparing the Energy Balance, Greenhouse Gas Emissions and Economics*, U.S. Dep. of Energy National Renewable Energy Laboratory, NREL/TP-510-32575, January 2004, <http://www.nrel.gov/docs/fy04osti/32575.pdf>.

¹⁶ D. Peterson and S. Haase, *Market Assessment of Biomass Gasification and Combustion Technology for Small- and Medium-Scale Applications*, U.S. Dep. of Energy National Renewable Energy Laboratory, NREL/TP-7A2-46190, July 2009, <http://www.nrel.gov/docs/fy09osti/46190.pdf>.

¹⁷ M. K. Mann and P. L. Spath, "A Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant," *Clean Technologies and Environmental Policy*, vol. 3, no. 2 (2001). For more information on N₂O emissions from agricultural soil management, see CRS Report R40874, *Nitrous Oxide from Agricultural Sources: Potential Role in Greenhouse Gas Emission Reduction and Ozone Recovery*, by Kelsi Bracmort.

¹⁸ M. K. Mann and P. L. Spath, *Life Cycle Assessment of Biomass Gasification Combined-Cycle System*, Department of Energy National Renewable Energy Laboratory, December 1997, <http://www.nrel.gov/docs/legosti/fy98/23076.pdf>.

¹⁹ May 17, 2010, <http://www.saveamericasforests.org/Forests%20-%20Incinerators%20-%20Biomass/Documents/> (continued...)

letter provided the authors' reasons why equating biogenic carbon emissions (or bioenergy emissions) with fossil fuel emissions in the Tailoring Rule could hinder development of bioenergy technologies and may not be scientifically valid for certain sources of biomass.²⁰

Title V Greenhouse Gas Tailoring Rule

The designation of biomass combustion as carbon neutral has come under scrutiny partly due to the Tailoring Rule finalized by EPA. The Tailoring Rule was developed by EPA to limit the number of facilities that would be required to obtain permits for greenhouse gas emissions under the Clean Air Act's Prevention of Significant Deterioration (PSD) and Title V permit programs.²¹ By statute, the PSD program requires any new or modified facility emitting more than 100 tons or 250 tons of pollutants subject to regulation to obtain a permit prior to construction or operation. Title V sets a statutory 100-ton threshold for operating permits and applies to existing as well as new facilities. These thresholds limit the applicability of the permit requirements to the largest emitters of most pollutants that have traditionally been covered by the Clean Air Act; but when applied to carbon dioxide emissions, they would not serve the same limiting function. EPA estimates that a 100-ton threshold for GHGs would ultimately require more than 6 million sources to obtain Title V permits, with administrative costs for the state and local permitting authorities in the billions of dollars annually. Faced with these "absurd results" of following the letter of the law, EPA developed the Tailoring Rule to focus first on the largest emitters of GHGs. The rule sets a 75,000 ton per year of carbon dioxide equivalent (CO₂e)²² threshold initially, allowing the agency to decide over a six-year period what to do about smaller sources.²³

The Tailoring Rule does not exempt emissions from biomass combustion.²⁴ The rule grants exemptions based not on source category (e.g., fossil fuels, biomass) but on carbon tonnage emitted from a facility. One reason EPA did not exempt the biomass industry from the Tailoring Rule requirements is lack of information demonstrating the costs and administrative burdens the biopower industry would face if subject to the permitting requirements.²⁵ EPA issued a call for information in July 2010 to request comment on possible accounting approaches for biogenic emissions under the Tailoring Rule.²⁶ EPA received over 7,000 comments in response

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Forests-Carbon%20Sequestration/90scientistsletter.pdf.

²⁰ Society of American Foresters, *Scientist/Academic Letter on Biomass Energy*, July 20, 2010, http://www.safnet.org/documents/biomass_science_letter_SENATE7-20-10.pdf.

²¹ Environmental Protection Agency, "Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule," *75 Federal Register* 31514, June 3, 2010.

²² Carbon dioxide-equivalent (CO₂ eq. or CO₂e) is the principal unit of measurement across the greenhouse gases. Different gases are converted into CO₂e by multiplying a quantity of the gas by its Global Warming Potential (GWP). GWP is an estimate of the relative greenhouse effectiveness over time relative to CO₂ which has a GWP value of 1.

²³ For more information on the history of the Tailoring Rule, see CRS Report R41103, *Federal Agency Actions Following the Supreme Court's Climate Change Decision: A Chronology*, by Robert Meltz.

²⁴ Environmental Protection Agency, "Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule," *75 Federal Register* 31590-31591, June 3, 2010. For more information on the final rule, see CRS Report R41212, *EPA Regulation of Greenhouse Gases: Congressional Responses and Options*, by James E. McCarthy and Larry Parker.

²⁵ U.S. EPA, "Prevention of Significant Deterioration," *75 Fed. Reg.* 31590, June 3, 2010.

²⁶ U.S. EPA, *Call for Information on Greenhouse Gas Emissions Associated with Bioenergy and Other Biogenic Sources*, July 9, 2010, http://www.epa.gov/climatechange/emissions/biogenic_emissions.html.

(approximately 600 were detailed responses). The two central themes for the comments reviewed by EPA included the request for certainty when it comes to biomass energy, and the recognition that all biomass is not the same.²⁷

EPA recently decided on a three-year deferment for GHG permitting requirements for CO₂ emissions from biomass-fired and other biogenic sources.²⁸ By July 2011 EPA plans to complete the rulemaking that will defer the permitting requirements. The EPA plans to seek additional “independent scientific analysis” during the three-year deferment period to determine how to treat emissions from biomass-fired and biogenic sources. The decision to defer will likely provide time to examine a complex issue, including the opportunity for affected parties to present additional data to support their position. Some are concerned that this deferment may lead to delays in biomass energy investments due to uncertainty about how EPA will address these types of facilities in three years.

Additionally, in the PSD and Title V Permitting Guidance for Greenhouse Gases issued in 2010, EPA noted that certain types of biomass could be considered a best available control technology (BACT)—a pollution control standard mandated by the Clean Air Act—after taking into account environmental, energy and economic considerations and state and federal policies that promote biomass for energy-independence and environmental reasons. EPA plans to provide further guidance in early 2011 on how to consider the unique GHG attributes of biomass as fuel in the BACT selection process. PSD permits require that facilities apply the BACT, but BACT is determined by individual states with EPA guidance on a case-by-case basis.²⁹

State perspectives on the inclusion of emissions from biomass combustion in the Tailoring Rule are divided.³⁰ Some states contend that the inclusion of biomass combustion will lead to excessive permitting requirements and fees that jeopardize renewable energy development. Other states argue that not including biomass combustion will contribute to GHG emissions over time.

Advocates of not exempting biomass combustion from the Tailoring Rule assert that not all biomass is carbon-neutral.³¹ They point out that some types of biomass, particularly biomass coming from waste streams, settle closer to the carbon-neutral and carbon-negative side of the scale. However, they assert that cutting down trees from a forest to burn in a power plant without regard to replenishing the tree stand is carbon positive. It seems, that for woody biomass under certain conditions and at certain locations, the rate at which GHGs are emitted may differ, but not necessarily the amount of GHG emitted. Moreover, these advocates argue, fossil fuels are still used to farm, harvest, and transport the biomass for biopower purposes, potentially negating carbon neutrality over the life cycle.

²⁷ D. Kruger, EPA, “Panelist, Carbon Neutrality,” oral presentation at Ag Energy Symposium, Washington, DC, November 4, 2010.

²⁸ Environmental Protection Agency, “EPA to Defer GHG Permitting Requirements for Industries that Use Biomass/Three-year deferral allows for further examination of scientific and technical issues associated with counting these emissions,” press release, January 12, 2011, <http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/4369c709163915b485257816005971bb!OpenDocument>. Biogenic includes facilities that emit CO₂ from sources originating via biological processes, such as landfills.

²⁹ Environmental Protection Agency, *PSD and Title V Permitting Guidance For Greenhouse Gases*, November 2010, <http://www.epa.gov/nsr/ghgdocs/epa-hq-oar-2010-0841-0001.pdf>.

³⁰ Energy Washington, *States Split on Whether Biomass Should Be Exempt from GHG Permits*, September 22, 2010.

³¹ N. Greene, *Scientists to Congress & Obama: Count the Carbon in Biomass*, Natural Resources Defense Council, May 24, 2010, http://switchboard.nrdc.org/blogs/ngreene/scientists_to_congress_obama_c.html.

Advocates of a complete biomass combustion exemption from the Tailoring Rule contend that biopower plant emissions add no new carbon to the atmosphere because biopower plants would use only residuals, byproducts, and thinnings, or waste materials that would decay.³² Furthermore, they argue that CO₂ released during biomass combustion is carbon neutral because it is re-absorbed by growing biomass. Thus, they say, measuring the emissions released during biomass combustion does not capture the entire biomass emission portfolio. The American Forest & Paper Association asserts that not exempting biomass combustion from the Tailoring Rule “jeopardizes public and private investment in biomass-based renewable energy, which is fundamental to existing and future green jobs in rural communities hit hard by the economic downturn.”³³

These competing interests may continue to be concerned with the designation of biomass combustion as carbon-neutral because of congressional discussions and proposals to expand the biomass definition in energy legislation. Expanding the biomass definition could increase the amount of land eligible for biomass removal.³⁴ The biomass definition in the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) for the Renewable Fuel Standard (RFS) excludes biomass removal from federal lands, and crops from forested lands are excluded as a biofuel feedstock.³⁵ However, the Food, Conservation, and Energy Act of 2008 (2008 farm bill, P.L. 110-246) includes biomass from federal lands as a biofuel feedstock. The RFS addresses the carbon balance issue of liquid transportation biofuels by requiring advanced biofuels to have lower life cycle emissions relative to petroleum products. EPA was responsible for determining how the LCA would be carried out. The debate about how EPA should address the LCA, especially the land use component, was controversial.³⁶ While the RFS focuses on liquid transportation fuels, legislation was introduced in the 111th Congress to create a renewable electricity standard (RES).³⁷ If the 112th Congress debates an RES that includes biomass energy, many of the same biomass and thus carbon-neutrality concerns may emerge.

Manomet Biomass Study

The Biomass Sustainability and Carbon Policy Study by the Manomet Center for Conservation Sciences examined the use of forest biomass to generate energy for Massachusetts.³⁸ It studied the GHG impact of substituting one biomass feedstock type—forest biomass—for fossil fuels in the Massachusetts energy sector. More specifically, the study addressed three concerns: atmospheric GHG implications of forest biomass, forest biomass supply to support bioenergy development,

³² Personal communication with B. Cleaves, CEO, Biomass Power Association, October 1, 2010.

³³ American Forest & Paper Association, “EPA’S Tailoring Rule Undermines Renewable Energy From Biomass, Harms Rural Communities and Puts American Jobs at Risk,” press release, May 14, 2010, <http://www.afandpa.org/pressreleases.aspx?id=1364>.

³⁴ For more information, see CRS Report R40529, *Biomass: Comparison of Definitions in Legislation Through the 111th Congress*, by Kelsi Bracmort and Ross W. Gorte.

³⁵ The Renewable Fuel Standard (RFS) is a provision established by the Energy Policy Act of 2005 requiring gasoline to contain a minimum amount of fuel produced from renewable biomass. For more information on the RFS, see CRS Report R40155, *Renewable Fuel Standard (RFS): Overview and Issues*, by Randy Schnepf and Brent D. Yacobucci.

³⁶ For more information, see CRS Report R40460, *Calculation of Lifecycle Greenhouse Gas Emissions for the Renewable Fuel Standard (RFS)*, by Brent D. Yacobucci and Kelsi Bracmort.

³⁷ For more information on the renewable electricity standard debate, see CRS Report R40565, *Biomass Resources: The Southeastern United States and the Renewable Electricity Standard Debate*, by Richard J. Campbell.

³⁸ The Manomet Center for Conservation Sciences is a non-profit research organization that works to integrate society’s social, economic, and environmental values to create sustainable systems for present and future generations.

and potential ecological impacts (including sustainability) associated with forest biomass harvests. Some of the study's conclusions for Massachusetts biomass include the following.³⁹

- For conventional technologies, more GHGs are emitted per unit of energy produced from forest biomass than from fossil fuels.
- As a result of the excess emissions, referred to in the study as biomass “carbon debt,” using forest biomass for energy initially can lead to increases in atmospheric GHG levels. However, the carbon debt is reduced as the harvested forest grows back, and at some point biomass energy yields benefits, or biomass “carbon dividends,” in the form of lower GHG levels than fossil fuels.
- The time needed to pay off the carbon debt and accrue carbon dividends (or GHG benefits) can vary by decades. This timing is a function of the characteristics of the bioenergy combustion technology, the fossil fuel technology it replaces, and the biophysical and forest management characteristics of the forests from which the biomass is harvested.
- GHG benefits can be realized relatively quickly when only waste wood—for example, logging debris that would otherwise have been left in the forest—is burned for energy. But when using biomass from harvests of live trees that would otherwise have continued to grow, GHG benefits may only be realized after many decades. Due to their efficiency, small-scale thermal and combined heat and power technologies generally yield GHG benefits sooner than utility-scale biomass electricity plants. However, where biomass replaces natural gas, the time required to achieve GHG benefits can be very long—upwards of 100 years in some cases.
- Sustainability issues are associated with forest biomass supply at the stand level (e.g., maintenance of soil productivity and biodiversity) and the landscape level (e.g., aesthetics, recreation, tourism, and long-term health of the wood-products sector).

The study's findings received considerable press attention, but a smaller spotlight was placed on the study's assumptions. Critics could argue that at least one prominent assumption renders the study irrelevant to current and future nationwide forest energy operations: the biomass feedstock type. The analysis was limited to one type of biomass—actively managed natural forests. The study found that woody biomass generated solely from logging debris (tops and branches) will contribute minimally to commercial-scale biomass facilities in Massachusetts, which “implies that the only way to meet demand would be to increase annual forest harvest.” Critics might counter that throughout the United States, a range of biomass feedstocks are available for energy generation, many of which will have different greenhouse gas emission implications than actively managed natural forests.⁴⁰ The study stated “Our results for biomass from natural forests likely understate the benefits of biomass energy development relative to facilities that would rely primarily on these other wood feedstocks [tree care and landscaping sources, biomass from land clearing, and construction and demolition materials].” In some cases, if biomass feedstock types other than natural forest are used, such as woody matter that will decay, the GHG impact may be

³⁹ Personal communication with T. Walker, November 30, 2010.

⁴⁰ For more information on the different kinds of biomass available for power generation, see CRS Report R41440, *Biomass Feedstocks for Biopower: Background and Selected Issues*, by Kelsi Bracmort.

alleviated by removing material that would eventually decompose and release more potent greenhouse gases (e.g., methane). There are differing opinions on whether a single feedstock type will be the dominant feedstock for biopower, and which feedstock type (e.g., trees from natural forest, logging debris, dedicated energy crops) this could be. Assessment of national GHG implications of the various feedstock options is an area for further study.

Another study assumption that may not apply to the nationwide debate is the time required to pay off the carbon debt. GHG emission levels vary depending on the biopower pathway stage.⁴¹ The Manomet Biomass Study compared GHG emissions per unit of energy produced by each technology for biomass, coal, oil, and natural gas. The comparisons include both direct combustion emissions as well as indirect emissions related to feedstock production, processing and transportation. The study estimated that at the fuel combustion stage of utility-scale electricity generation, biomass emits significantly more GHGs relative to coal.⁴² However, over time, biomass combustion for electricity reaches an equal cumulative GHG flux with that of fossil fuel technology (**Table 1**). Cumulative GHG emissions from biomass for electricity then level off at a rate significantly less than that of fossil fuels (**Figure 3**). Thus biomass combustion for electricity may not be the most effective method to immediately reduce GHG emissions in the short term, but may be a viable technique for GHG emission reduction over a long period. Lastly, other aspects of the study outside the scope of this report (e.g., conversion technology, biomass feedstock source, fossil fuel to be displaced) may require further examination if the findings are to be applied more broadly.

Table 1. Years to Achieve Equal Cumulative Flux with Fossil Fuels

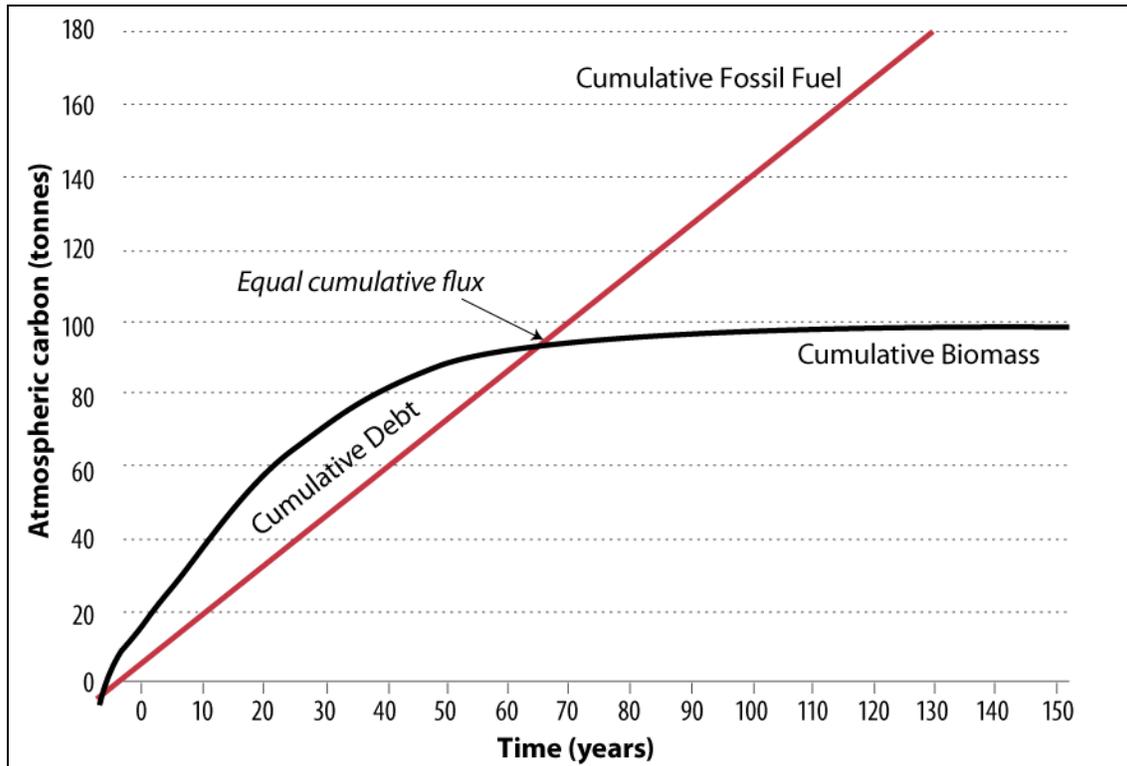
Harvest Scenario	Fossil Fuel Technology			
	Oil (#6), Thermal	Coal, Electric	Gas, Thermal	Gas, Electric
Mixed Wood	15-30	45-75	60-90	>90
Logging Residues Only	<5	10	10	30

Source: T. Walker, “USDA Bioelectricity and GHG Workshop,” Oral Presentation – “Manomet & Biomass: Moving Beyond the Soundbite,” Washington, DC, November 15, 2010.

a. Cumulative flux is a tally of the emission and sequestration that occurs during the electricity pathway.

⁴¹ The various biopower pathway stages are explained in the “Greenhouse Gas Accounting for Biopower Production” section of this report.

⁴² T. Walker, P. Cardellicchio, and A. Colnes, et al., *Biomass Sustainability and Carbon Policy Study*, Manomet Center for Conservation Sciences, NCI-2010-03, June 2010, p. 103, http://www.manomet.org/sites/manomet.org/files/Manomet_Biomass_Report_Full_LoRez.pdf.

Figure 3. Cumulative GHG Flux for Biomass and Fossil Fuel

Source: T. Walker, “USDA Bioelectricity and GHG Workshop,” oral presentation – “Manomet & Biomass: Moving Beyond the Soundbite,” Washington, DC, November 15, 2010. Adapted by CRS.

Is Biopower Carbon Neutral? It Depends

Carbon neutrality for biopower is most accurately calculated based on the carbon flux (GHG emission or sequestration) of several parameters over a specified time period. These parameters include at least the following: (1) the feedstock type; (2) the management and procurement of the energy source (in the case of biomass, how the feedstock is managed and harvested); (3) the feedstock transportation method; (4) the energy generation technology; and (5) the timeframe to replenish the feedstock. Carbon flux attributed to the management and procurement of biomass feedstock deviates according to the type or mixture of feedstocks used. For instance, agricultural biomass entails a different nutrient management plan than woody biomass. GHG emissions may be higher for agricultural biomass due to fertilizer treatments (e.g., nitrous oxide emissions from biofuel-dedicated crops).⁴³ Carbon flux will also vary given how the biomass feedstock is harvested. For example, removal of woody biomass (e.g., thinnings) in large quantities may reduce carbon, and some methane, emissions on a CO₂ equivalent basis that would have been released if the woody biomass had been left in the forest to decompose. Biomass feedstock transport emits differing amounts of GHGs depending on how far the feedstock must be transported and if fossil fuels are used.⁴⁴ The carbon flux of the biopower generation technology

⁴³ When biomass used for biopower production is agricultural waste, some GHG emissions may be attributed to crop cultivation whereby the crop is used for other feed, fiber and fuel purposes.

⁴⁴ Some make the case that fuels (e.g., ethanol) other than fossil fuels (e.g., diesel or gasoline) may be used to transport (continued...)

will depend on the type of technology and if the emissions are captured and sequestered.⁴⁵ Last, the time frame (e.g., 40 years, 100 years) assigned for biomass feedstock replenishment will determine CO₂ sequestration rates to balance out the GHGs emitted during biomass combustion, particularly for woody biomass, as growth periods (rotation ages for the trees) are often measured in decades.⁴⁶

It could be argued that only an LCA for each biopower operation can truly determine whether biopower generation is carbon neutral. Such an LCA would measure carbon flux for each phase of the biopower pathway and incorporate biomass feedstock replenishment. A standard approach to perform a biopower LCA could ensure uniformity in GHG accounting across the biopower sector. However, multiple LCAs can be expensive and time-consuming to complete.

Biopower's carbon neutrality is a contentious aspect of the bioenergy debate. One reason the topic is so controversial is the concern about unsustainable harvests of biomass feedstocks. Some contend that if biopower proceeds with no carbon balance restrictions, large amounts of woody biomass, for example, will be removed for energy production. Another reason for controversy is concern about the air quality of areas surrounding biopower plants. These two concerns—sustainability and air quality—can be, and in some cases already are, addressed through other avenues (e.g., sustainability requirements, air quality regulations) at the federal and state level.

Legislative Implications

Biopower thus far has been included in legislation to provide energy independence and security, and under the premise that it is carbon neutral. Recent developments may prompt Congress to further analyze this premise. Carbon neutrality depends in part on the feedstock type, the technology, and the time frame for feedstock replenishment. Biopower can be created using multiple biomass feedstocks and technologies. Each feedstock and technology has its own environmental footprint. The time frame to analyze carbon neutrality is relevant because it incorporates feedstock replenishment, and thus CO₂ removal rates, and considers technology developments.

To the extent carbon neutrality continues to be a legislative concern, Congress faces a determination of whether the current carbon neutral assumption for biopower is adequate, or if additional carbon accounting for biopower is warranted and what impact this accounting might have on renewable energy, agricultural, and environmental legislative goals, especially if decisions concerning biopower made by the executive branch contradict legislative goals set by Congress (e.g., RES). A scientific assessment of whether a biopower plant is carbon positive, carbon negative, or carbon neutral may require an analysis, such as an LCA. There are time and economic constraints in conducting an LCA for each biopower operation.

(...continued)
the feedstock.

⁴⁵ There are no commercial carbon capture and sequestration (CCS) projects in operation at the moment. Therefore, CCS is not likely to impact carbon flux at the biopower generation stage in the near-term..

⁴⁶ For more information on carbon sequestration in trees, see CRS Report R40562, *U.S. Tree Planting for Carbon Sequestration*, by Ross W. Gorte.

Congress could decide to use existing legislative authorities to address carbon accounting for biopower. Federal environmental regulatory controls exist for the three chief environmental concerns associated with a biopower plant—air quality, land use, and water discharges. GHG emissions may be accounted for with federal regulations regarding air quality. In addition, a biopower plant also has to meet state regulatory standards, which in some cases may be stricter than the federal regulatory controls.

A full carbon accounting for biopower may result in slowing the achievement of multiple renewable energy, agricultural and environmental goals. Alternatively, the carbon neutrality debate for biopower may lead to requests for carbon accounting of some or all energy ventures—renewable and conventional. Lastly, an ill-defined carbon accounting assessment for biopower may limit public and private investment, feedstock production, and more. Scientists, investors, biomass producers, and others may hesitate to expend time and money on expanding biopower efforts if they are not provided certainty about the future contribution of biopower to U.S. energy and environmental goals.

If the 112th Congress chooses to address energy security and GHG emission increases, some have argued that these goals could be met through the creation of a national RES or a clean electricity standard (CES). The mandate of a potential national RES or CES may require substantial quantities of baseload power which some see as achieved by using biopower. If biopower is a part of an RES or CES, its carbon neutrality designation may need to be reconsidered in response to environmental and sustainability concerns.

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