Comments of the Green Power Institute on the SAB's March 9, 2012, *Deliberative Draft Report*

March 16, 2012

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Introduction

The Green Power Institute, the renewable energy program of the Pacific Institute for Studies in Development, Environment, and Security, has reviewed and analyzed the September 2011, EPA *Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources* (AF), and the March 9, 2012, SAB *Deliberative Draft report* (SAB) on the AF. We are generally supportive of the SAB, but would like to make several points that, we feel, are so far missing from, or are deficient in, the discussion concerning both the AF and the SAB:

- The intrinsic role of methane in the active carbon cycle
- Dynamic modeling and the temporal-scale issue
- System boundaries and project fuel-sheds
- Periodic major-loss events

The intrinsic role of methane in the active carbon cycle

The framework that is adopted in the AF document considers only the biogenic CO_2 emissions associated with biomass energy systems, excluding other potentially significant greenhouse gases. In explaining the rationale for excluding other greenhouse gases, the AF states, on page 9:

> All of these GHGs (CO_2, CH_4, and N_2O) are considered to be chemically long-lived in the atmosphere; unlike the other GHGs, however, CO_2 is not readily converted by chemical, photolytic, or other reaction mechanisms, allowing the carbon in CO_2 to cycle between different reservoirs in the atmosphere, ocean, land vegetation, soils, and sediments.

There are two corrections that need to be made to this sentence with regards to CH_4. First, CH_4 is not long-lived in the atmosphere in the same sense as the other greenhouse gases. In fact, based on IPCC information, CH_4 has an atmospheric residence time of approximately 12 years, compared to a residence time for CO_2 that is estimated to be in the range of 100 – 200 years, and for N_2O much longer still. Second, the carbon in CH_4, like the carbon in CO_2, does in fact cycle between different reservoirs in the atmosphere, ocean, land vegetation, soils, and sediments. Methane that is emitted to the atmosphere is cleared from the atmosphere via oxidation to CO_2, while the carbon that is in biomass can be cycled to the atmosphere in the form of either CO_2 or CH_4. In other words, CH_4 is as intrinsic a component of the active global carbon cycle as CO_2.

We agree with the AF that the focus of regulating biogenic greenhouse-gas emissions from biomass energy generators under the Tailoring Rule should be on CO_2. However, that does not mean that the active global carbon cycle, of which biogenic CO_2 emissions are a part, can be understood or analyzed without including the role of CH_4. While virtually all of the carbon emissions associated with energy production from biomass are in the form of CO_2, a significant fraction of the biogenic carbon that is recycled naturally when biomass materials are not converted into energy products is emitted in the form of CH_4, a much more potent greenhouse gas than CO_2.

Failure to include CH_4 in the carbon-cycle modeling underlying the adopted framework in the AF leads to an incomplete understanding of the AF's own adopted figure of merit, the Biogenic Accounting Factor, or BAF. The AF acknowledges that the BAF for a given application or situation can be negative, meaning that the application reduces the associated warming potential of the biomass used, as compared with the alternative.

Regarding the possibility of an application having a negative BAF, the analysis in the AF is focused on cases where the negative BAF is the result of net sequestration associated with the application. This leads to the following explanation on page 48 in Section 5.1 of the AF: "This equation results in a value [for the BAF] that can be positive or negative, with negative values meaning there is more sequestration than emissions, and positive ones meaning the converse." In fact, there are two kinds of situations that can result in a negative BAF. In addition to net sequestration, a negative BAF can result from a net shift of carbon emissions from reduced form (CH_4) to oxidized form (CO_2). This happens, for example, when wastes or residues are diverted from landfill disposal to use as a power-plant fuel.

The exclusion of the role of CH_4 in the active carbon cycle from the adopted framework results in the failure of the document to acknowledge the possibility of a negative BAF resulting from a shift in carbon emissions from CH_4 to CO_2. This leads the AF to conclude, on page 40:

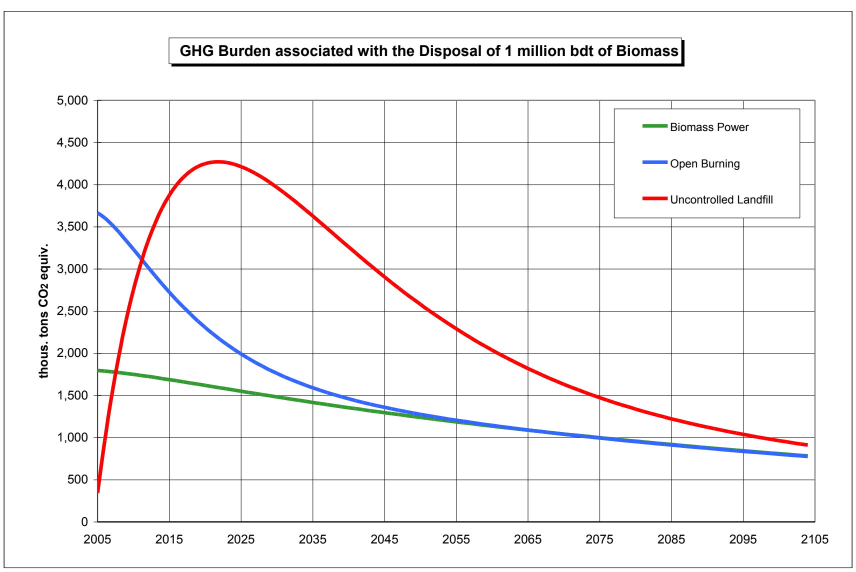
> Therefore, for this accounting framework, BAF is considered to equal 0 for biogenic CO_2 released from waste decay at waste management systems, waste combustion at waste incinerators, or combustion of captured waste-derived CH_4.

Clearly the BAF for combustion of captured waste-derived CH_4 should be strongly negative, not just zero. Indeed, our own analysis shows that the BAF is negative for all of the biomass energy applications that we have looked at, including all biomass fuels derived from already harvested materials (wastes and residues), and residuals coming from in-forest operations (commercial harvesting residues, thinning residues). Considering the fact that virtually all of the biomass fuel used for biomass power production in the U.S. today is in these categories (wastes, residues, in-forest residuals from forestry operations), this means that this large and important segment of the country's renewable energy industry will be denied the opportunity to benefit from the biogenic greenhouse-gas emissions reduction it provides, unless CH4 is included in the analysis as part of the active carbon cycle.

Dynamic modeling and the temporal-scale issue

The SAB criticizes the AF for its deficient treatment of the issue of the long-term implications of the biogenic greenhouse-gas emissions associated with biomass energy production, but it does not provide very much guidance about how to fix the situation. In our modeling work on biogenic carbon emissions from biomass energy production,[1] we perform a dynamic analysis over a 100-year timeframe for the carbon emissions associated with biomass energy production, in order to explicitly study the long-term fate of the biogenic carbon, whether the biomass is used for energy production, or left to one of its alternative fates, like landfill disposal or open burning.

In the figure below, we illustrate the dynamic profiles for the fate of biogenic-carbon greenhouse-gas emissions from biomass energy production vs. biomass disposal via open burning, or via landfill disposal in an uncontrolled landfill. All three of the profiles in the figure are based on the disposal of one-million bdt of biomass in the year 2005. In the case of biomass energy (the green curve in the figure), virtually all of the carbon in the biomass is released immediately to the atmosphere in the form of CO_2, resulting in an atmospheric burden in 2005 of approximately 1.8 million tons. The CO_2 then slowly decays with a characteristic atmospheric residence time (120 years assumed in the example shown in the figure), falling to 0.8 million tons atmospheric burden 100 years after the biomass was converted into energy.



[1] Morris, G., *Bioenergy and Greenhouse Gases*, Report of the Pacific Institute, May 15, 2008, http://www.pacinst.org/reports/Bioenergy_and_Greenhouse_Gases/Bioenergy_and_Greenhouse_Gases.pdf

If, instead, the one-million bdt of biomass had been disposed of by open burning in 2005 (the blue curve in the figure), virtually all of the biogenic carbon in the biomass would likewise have been emitted to the atmosphere in 2005. However, with open burning combustion is inefficient, and enough of the carbon is emitted in reduced form (CH_4 and HCs) that the greenhouse-gas potency of the mixture is nearly twice as great as the potency of the power plant's CO_2 alone in the year the material is combusted (2005). Over the early years the decay curve of the gas mixture emitted during open burning is faster than the decay curve of the CO_2 emitted during energy production, with the result that by about 50 years following disposal the atmospheric greenhouse-gas burden of the two options, energy production and open burning, is indistinguishable (most of the CH_4 in the open-burning emissions, atmospheric residence time of 12 years, will have oxidized to CO_2).

The profile for biomass that is buried in a landfill (red curve in the figure) is quite different that the curves for energy production and open burning. In the landfill case there are no immediate emissions. Instead, the biomass decays slowly in the landfill, emitting an approximately 50:50 mixture of CO_2 and CH_4 over the ensuing years, with a significant fraction of the biomass carbon remaining fixed in the landfill 100 years following disposal. The atmospheric greenhouse-gas burden of the emissions of biogenic carbon resulting from the 2005 burial of the biomass rises steadily for approximately 17 – 18 years following disposal, following which it peaks and begins to decay steeply, as the rate of emissions from the landfill itself decline, and the CH_4 that has already been emitted converts to CO_2. One-hundred years following the disposal of the biomass, all three options have approximately the same lasting greenhouse-gas potency.

We believe that the best approach to understanding the time-dependent aspects of the greenhouse-gas effects of biomass energy systems requires dynamic, rather than static modeling of biogenic carbon.

System boundaries and project fuel-sheds

The SAB takes the AF to task for its treatment of spatial boundaries for use in analyzing the biogenic greenhouse gas implications of biomass power production. For example, the SAB points out that, using the framework in the AF, it would be possible to have a situation in which the same biomass generator in two different locations could be judged to have vastly different implications with respect to their greenhouse-gas implications. This is scientifically untenable. In our modeling work, we define the geographic boundaries for the analysis for a given project as encompassing the land from which the fuel for the given project is drawn, plus any additional land that is directly affected by the fuel-production operations, with respect to their effects on carbon stocking. For example, strategically located thinnings over a broad landscape can reduce the risk of fire losses over the entire landscape, not just on the treated plots themselves.[2]

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[2] USDA Forest Service Pacific Southwest Research Station, *Biomass to Energy: Forest Management for Wildfire Reduction, Energy Production, and Other Benefits*, CEC report no. CEC-500-2009-080, January 2010, http://www.energy.ca.gov/2009publications/CEC-500-2009-080/index.html

The geographic boundaries for the analysis of the greenhouse-gas implications of a biomass project should be defined as including all of the land from which fuel for the project is sourced, and any other land that is directly affected by the sourcing of the fuel for the project. Note that there are no land-based implications for biomass fuels that are derived from wastes and residues whose collection and disposal happen completely independently of how the material is used or disposed of, which are referred to as "anyway fuels" in the AF and the SAB.

Periodic major-loss events

A major deficiency in the AF document that we do not see discussed in the SAB is the lack of any discussion about periodic major-loss events, like fires, insect attacks, and disease outbreaks. Many of the forest treatments that produce forest-residue fuels in today's energy marketplace are aimed squarely at reducing the severity of these risks, among other objectives. The failure to include these events in the modeling and analysis of the carbon cycle implications of forest-fuel use ignores one of the major benefits of biomass energy production with respect to its implications for long-term stocking (sequestration) of carbon on landscapes that are candidates for treatment.

For example, the AF document recognizes that a forest treatment operation (thinning) providing fuel to a biomass energy operation initially removes carbon from the forest, and adds it to the atmosphere in the form of CO_2. Subsequently, the net growth rate on the treated landscape is increased, resulting in a net-sequestration enhancement that eventually brings the stocking on the treated forestland back up to the level that it would have been had the forest not been treated. However, neither the AF nor the SAB addresses the fact that the forest is constantly subject to risks of major-loss events, which, for modeling purposes, can be handled on a probabilistic basis. If a loss event follows a treatment operation, then the extent and intensity of the loss event will be reduced compared to what it would have been had the forest treatment not been performed. In fact, in many cases the post-loss-event landscape will hold more sequestered carbon than the untreated landscape, even though immediately before the event the opposite was true, that is, the untreated forest held more carbon than the treated forest. With the analysis that is provided in both the AF and the SAB, this possibility is completely missed, even though it may be the primary motivation for performing the treatment in the first place.

The long-term greenhouse-gas implications of forest treatments or harvests of any kind that produce fuel for power generation can only be understood when periodic major-loss events are included in the modeling and analysis.

Revising the BAF, or Alternatives to the BAF

The AF introduced a new figure of merit, the BAF, that is intended to, in effect, provide a fractional comparison between the emissions of biogenic CO_2 from a biomass energy operation, and emissions of fossil CO_2. The BAF can vary from 0 to 1, where 1 means that the biogenic carbon is fully equivalent to fossil carbon in terms of its greenhouse-gas implications, and 0 means that the biogenic emissions are completely carbon neutral. Waste and residue forms of biomass whose removal from the land is completely independent of the biomass energy operation, the AF's "anyway fuels," are automatically assigned a BAF of 0 in the AF.

The SAB points out that the BAF is an unsatisfactory figure of merit, although it is not unusable. The SAB discusses options for both improving the BAF, and replacing it. The SAB appears to be particularly concerned with the challenges of performing facility-specific assessments of biogenic emissions:

> To implement the *Framework*, EPA faces daunting technical challenges, especially if a facility-specific BAF approach is retained. ... It would be desirable for EPA to ascribe all changes in greenhouse gas emission (both upstream and downstream of the stationary source) caused by the operation of the stationary facility to that source. Ideally, these emissions would need to be determined on a facility-specific basis however facility-specific calculations face some daunting practical challenges. [SAB, pg. 6 – 7.]

In our September 13, 2010, *Comments on Regulating Bioenergy Systems Under the EPA Tailoring Rule*, which were submitted in response to an EPA request for comments, we included a reference to a Carbon Footprint Report that Green Power Institute Director Gregg Morris performed for the Snowflake biomass power plant in Arizona. This report provides an example of producing a facility-specific estimation of a biomass project's greenhouse-gas implications. We are appending the report to these comments.

It is important to point out that real-world biomass power plants almost never burn only one category, or source, of fuel. Because the greenhouse-gas implications of using various categories of biomass fuels are directly related to the alternative fates for the materials, it is usually necessary to construct a matrix connecting the resource categories with their alternative fates. To illustrate, we present below Table 1, page 17, from the report referenced above in footnote 1 (the table shown provides statewide data, but the same matrix can be used for individual projects):

Table 1: Alternative Fates for Biomass Residues (CA 2005)

	Mill	Forest	Ag	Urban	Total
Annual Fuel Use (th.bdt/yr)	1,316	583	999	1,726	4,624
If No Fuel Use, % that Would Be Disposed of by					th.bdt/yr
Open Burning	0.0%	25.0%	60.0%	2.0%	780
Forest Accumulation	0.0%	70.0%	0.0%	0.0%	408
Controlled Landfill	63.0%	0.0%	2.0%	55.0%	1,798
Uncontrolled Landfill	10.0%	0.0%	18.0%	20.0%	657
Spreading	1.0%	5.0%	0.0%	10.0%	215
Composting	1.0%	0.0%	10.0%	13.0%	337
kiln boiler / firewood	25.0%	0.0%	10.0%	0.0%	429

One of the options for moving forward presented in the SAB is the development of feedstock-specific BAFs. In fact, the greenhouse-gas implications of using biomass for energy production are related more directly to the avoided alternative fate of the material than to its category. In our own work, we calculated avoided-alternative-fate-specific emissions factors, which we present below (Table 6, page 41, of the report referenced above as footnote no. 1):

Greenhouse Gas Emissions Factors for Biomass and Biogas
(all factors expressed as equivalent year-1 emissions of CO_2 equivalents)

	ton/bdt	ton/bil.btu	ton/MWh
Biomass			
Net Reduction in Biogenic C			
Open Burning	0.62	36	0.62
Forest Accumulation	1.87	110	1.87
Uncontrolled Landfill	2.28	134	2.28
Controlled Landfill	0.27	16	0.27
Spreading	0.69	41	0.69
Composting	1.00	59	1.00
Kiln Boiler / Fireplaces	0.22	13	0.22
California Biomass Mix 2005	0.81	48	0.81
Avoided Fossil Fuel Use	0.80	47	0.80
Landfill Gas (LFG)			
Net Reduction in Biogenic C			
Uncontrolled Landfill		241	2.89
Controlled Landfill		22	0.26
Avoided Fossil Fuel Use		65	0.78
Dairy Manure			
Net Reduction in Biogenic C	2.88	180	8.64
Avoided Fossil Fuel Use	0.26	16	0.78

We note that all of the types of fuels that were looked at in the 2008 study, which are the fuels that are actually used in California today, if analyzed in the context of the AF would be determined to have, by definition, BAFs of zero. Proper interpretation of the numbers in the table above suggests that legitimately, the BAFs for these fuels should be negative. Indeed, in some cases the BAFs should be strongly negative.

We are grateful for the opportunity to be able to provide these comments for the SAB's consideration. The greenhouse-gas implications of biomass energy use are complex and difficult to fully elucidate, but they are not beyond our ability to understand and act on.

Attachment A

Carbon Footprint Report for Snowflake Biomass

Carbon Footprint for Snowflake Biomass Power

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June 24, 2008

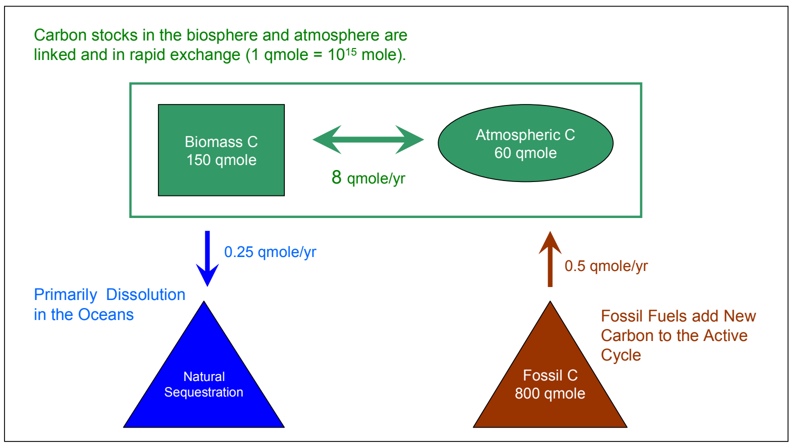
Renegy, LLC, is in the process of commissioning its 24 MW biomass power plant in Snowflake, Arizona. The generating unit will be fueled with a mixture of recycled paper-fiber residues generated at the adjacent Catalyst Paper Co. paper mill, forest residues from the recent Rodeo-Chediski fire area and from timber and stewardship contracts on National Forests in northeastern Arizona, and from urban and sawmill residue sources. All of the fuel-production activities, from forest-thinning operations to trucking, will be performed by Renegy in conjunction with the operations of the power plant. Snowflake Biomass will displace an equivalent amount of electricity generation from fossil fuels (coal), avoid a variety of alternative fates that are currently employed to dispose of the biomass fuels, and will promote the fire-safe treatment of nearby national forest land that is currently in overgrown, and in the case of Rodeo-Chediski, burnt-over, condition. Each of these activities has implications for greenhouse gas loading in the atmosphere. This report examines and characterizes the carbon footprint for the Snowflake Biomass power project, including all phases of its operation, from fuel procurement to power production.

Carbon Footprint of Biomass Power Projects

The carbon footprint for a fossil-fuel-fired power plant is essentially the result of the conversion of the carbon in the fossil fuel into atmospheric carbon dioxide (CO2). The carbon footprint for most renewable and nuclear generators is that these technologies are essentially carbon-free. The carbon footprint for biomass energy generators is far more complex. Biomass energy production uses carbon-based fuels that are secured from the world's stock of living and dead biomass. The stocks of carbon in the world's biomass and in the atmosphere are intrinsically linked. The amount of carbon that is exchanged annually between the biosphere and the atmosphere is more than ten times greater than the amount of carbon that is emitted annually from global fossil fuel use. Nevertheless, there is a fundamental difference between the use of fossil fuels and biomass fuels with regards to the implications their emissions have for atmospheric greenhouse gas concentrations.

Carbon gases in the atmosphere are in rapid exchange with carbon in the earth's biomass. Carbon is taken up by biomass through photosynthesis, and returned to the atmosphere by a combination of respiration, decomposition, and fire. Approximately 30 percent of the carbon that is in the active atmospheric-biospheric carbon cycle is in the atmosphere, and 70 percent is in the biomass (living and dead organic matter) at any given time. Figure 1 shows the global carbon cycle graphically as it relates to atmospheric carbon. The active circulation part of the global carbon cycle is enclosed by the green rectangle in the figure. The carbon circulating within the green rectangle is called biogenic carbon.

Figure 1: Global Carbon Cycle



There is far more carbon deposited inside the earth in the form of fossil fuels than there is carbon in the linked atmospheric-biospheric system. Fossil fuels are the world's principal commercial energy sources. However, the downside of fossil fuel use, from a greenhouse gas perspective, is that it entails removing carbon from geologic storage, where it is unavailable to the atmosphere, and injecting it directly into the atmosphere, adding it as new carbon to the carbon that is already in the active carbon cycle. Clearly, the amount of carbon in fossil fuels is enough to seriously unhinge the active carbon cycle (inside the green rectangle in the figure) that regulates the earth's climate, as well as life on earth.

The greenhouse gas emissions produced at biomass generating facilities comes from carbon that is already a part of the stock of the linked atmospheric – biospheric carbon cycle (biogenic carbon—see green rectangle in Figure 1). This is in stark contrast to fossil fuel combustion, which removes carbon from permanent geologic storage, and adds it as net new carbon to the carbon already in the atmospheric – biospheric system. Fossil-fuel combustion adds new carbon to the linked stocks of atmospheric and biospheric carbon. Biomass energy production makes use of biogenic carbon that is already part of the atmospheric – biospheric stock. Most people focus on this aspect of biomass energy production, and proclaim it to be "Carbon Neutral," or carbon free, the same as other renewable energy generating sources.

Carbon neutrality, while an important intrinsic characteristic of bioenergy production, is only part of the story of the greenhouse gas footprint associated with a biomass power plant. In addition to being carbon neutral, biomass energy production can affect biogenic greenhouse gas levels in the atmosphere in two important ways, as illustrated in Figure 2. First, the total amount of carbon that is sequestered in terrestrial biomass affects the total amount of carbon in the atmosphere. By contributing to forest health and fire resiliency in currently at-risk, overstocked forests, in the long term energy production from forest treatments, including both fuel-reduction treatments, and post-fire salvage operations, can increase the amount of carbon that is stored on a sustainable basis in the earth's forests, thus making a positive contribution to efforts to control atmospheric greenhouse gas levels. Second, biomass energy production can change the timing and relative mix (oxidized vs. reduced) of carbon gases emitted to the atmosphere associated with the disposal or disposition of the biomass resources. From a greenhouse-gas perspective reduced carbon (CH4) is twenty-five times more potent than oxidized carbon (CO2) on an instantaneous, per-carbon basis, so the form in which carbon is cycled from the biomass stock to the atmospheric stock is critically important from the standpoint of the resulting greenhouse forcing consequences. In the long-term CH4 has a 12-year residence time in the atmosphere, and its clearance involves conversion to atmospheric CO2, which has a 100 – 200 year atmospheric residence time.

Figure 2: Biomass and the Global Carbon Cycle

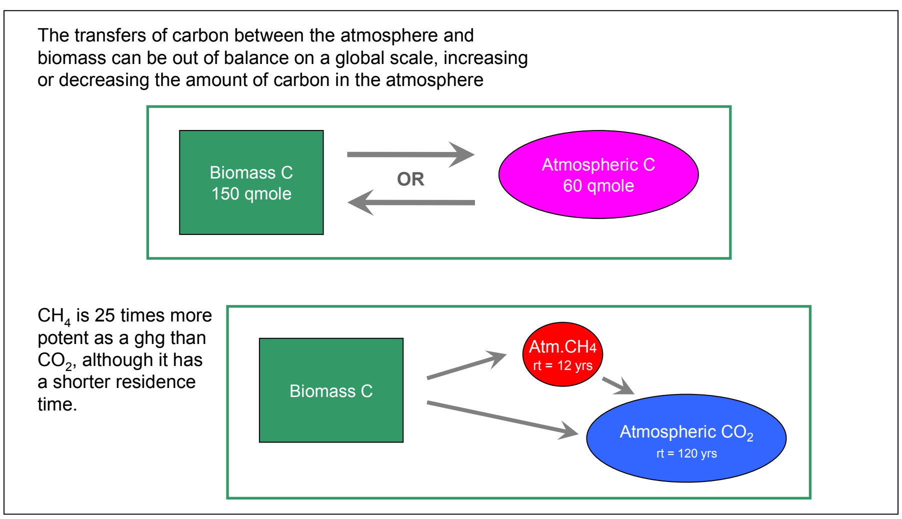
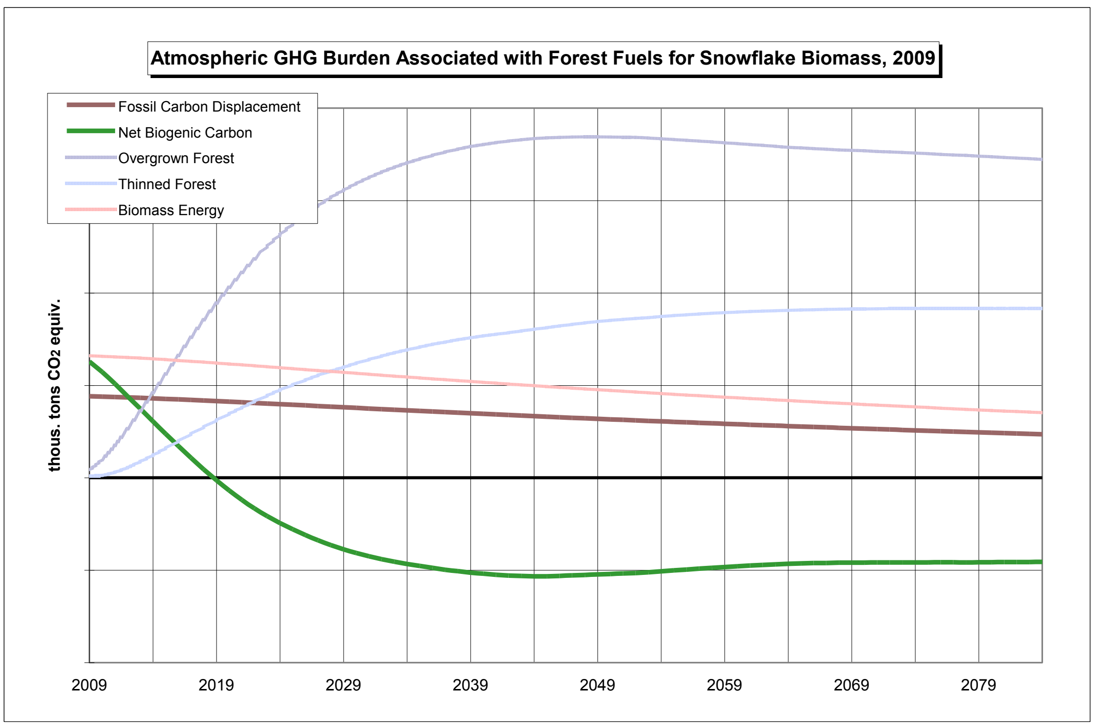


Figure 3 illustrates the way that forest treatment operations contribute to a reduction in atmospheric greenhouse gases. The immediate result of treatment with fuel removal and use is that the carbon in the biomass that is removed from the forest is converted promptly into atmospheric CO2 (red curve at the vertical axis), while simultaneously fossil carbon emissions are avoided due to the production of energy from biomass (brown curve at the vertical axis). Over time, on a statistical basis, the overgrown forests (dark blue curve) that are the source of fuel for Snowflake, if not thinned, will be a net source of biogenic greenhouse gas emissions, as fire, insect and disease losses exceed net growth in these overgrown forest stands. The thinned forest (light blue) is also a source of net greenhouse gas emissions, but at a lower level than the overgrown forest, because the thinned forest has a higher net annual growth rate, and reduced losses due to fire or disease events, compared to the overgrown stand that it was before treatment. The green curve shows the net effect over time of the 2009 treatments on biogenic greenhouse gas levels. This curve is the sum of the red curve (biomass power plant emissions) plus the light blue curve (thinned-forest impacts), less the dark blue curve (overgrown-forest impacts that are avoided). The immediate net effect of forest treatments and use of the removals as fuel is to increase biogenic greenhouse gas levels in the atmosphere (green curve, which is greater than zero at the vertical axis). However, by ten years after the treatments were performed the net effect on atmospheric biogenic greenhouse gases has dropped to zero, and for the remainder of the 75-year timeframe shown in the figure the net effect of performing the 2009 treatments is a significant reduction in biogenic greenhouse gas levels in the atmosphere associated with the treated forest land.

Figure 3



In current carbon tracking and trading systems, which are primarily focused on fossil carbon emissions, the potential greenhouse gas benefits of biomass energy production related to the disposal of biomass resources, including healthier and more fire- and disease-resilient forests, and the substitution of natural CH_4 emissions with CO_2 emissions, are categorized as greenhouse-gas offsets. The accounting rules for greenhouse-gas offsets are in the early stage of development, and are expected to be extremely important for the future of biomass energy production and use. It is reasonable to expect that offsets for net reductions in biogenic greenhouse gases will become an important component of the carbon-constrained world of the future.

Description of Snowflake Biomass

The Snowflake biomass project will be built adjacent to Catalyst Paper Co., an existing recycled-paper mill. Snowflake will use the paper mill's residual sludge as a fuel, and procure the remainder of its fuel requirements from traditional biomass sources, such as forest residues, sawmill residues, and urban wood residues. The power plant will sell its entire gross electrical output to the grid, and will purchase its station service requirements from the local utility company. The table below shows basic project specifications for the Snowflake Biomass energy project.

Cogen Specifications

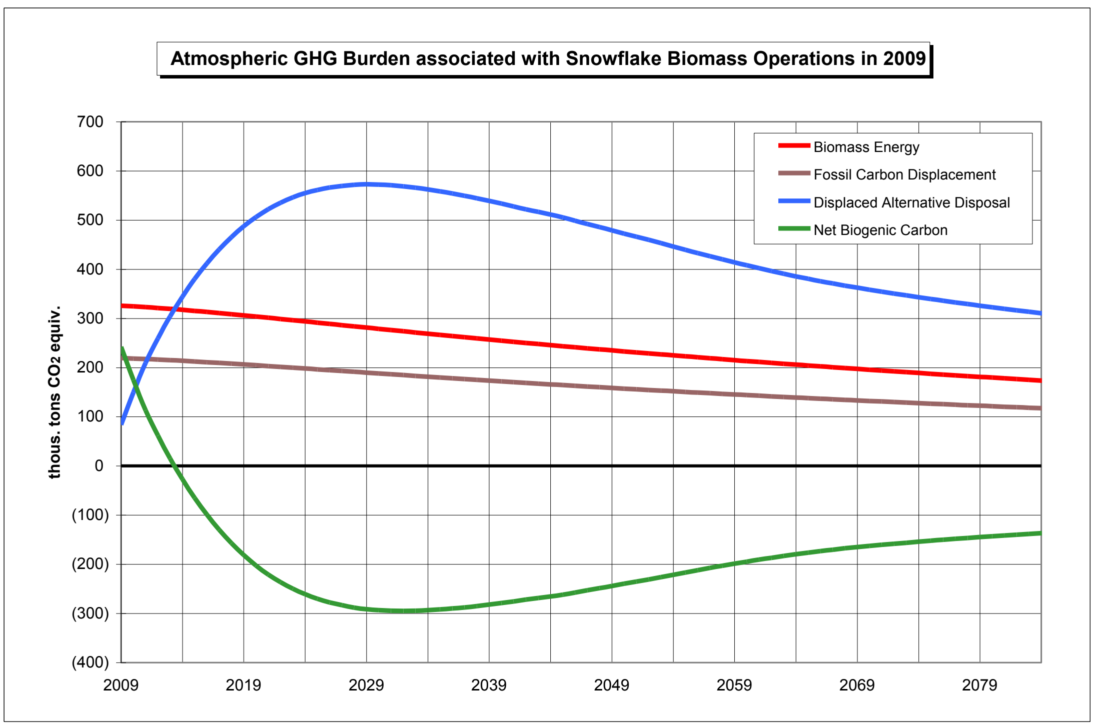
	Snowflake
Power Plant (MW_{gross})	24.0
Power Plant (MW_{net})	21.6
Electricity Prod. (MWh)	190,000
Fuel (bdt)	
Mill Residue	7,500
Forest Fuels	75,000
Urban Residues	32,500
Paper Residuals	70,000
Total Fuel	185,000
bdt/MWh net	1.08
Annual Acres Thinned	5,775

Carbon Footprint of Snowflake Biomass

The Snowflake biomass power project is a 24 MW generating facility that will use a fuel mixture of papermill sludge, and woody biomass residues from from a variety of sources, including sawmill residues, green-waste pickups, and forest treatment and wildland-urban interface (wui) residues from the surrounding forests and cities. The sawmill residues used by Snowflake Biomass probably would not be generated if not for the overall Renegy operations, which include the sawmill itself. In other words, without Snowflake Biomass and related operations, the sawmill would not be in operation, and the sawlogs would not be cut. The biomass would remain in the forest, sharing the same alternative fate as the forest fuels used for the project. The alternative fate for the forest treatment fuels is assumed to be entirely forest accumulation (no treatments performed in the absence of Renegy's Snowflake operations).

Snowflake Biomass will burn about 185,000 bdt of biomass fuel annually, in the process displacing the use of approximately 80,000 tons of coal, and avoiding the emissions of more than 210 thousand tons per year of fossil CO2 equivalents. The biomass power plant itself will emit more than 300 thousand tons of biogenic CO2 equivalents annually, but it will avoid the emissions of greenhouse gases that would occur with the alternative disposition of the biomass fuels. This includes avoiding both prompt and delayed emissions from each year's batch of fuel use. Figure 4 shows the atmospheric greenhouse gas burden over time of fossil and biogenic carbon gases associated with the fuel used by the Snowflake biomass project during a single (the first full) year of operations. The prompt emissions of greenhouse gases are shown on the vertical axis of the graph, including fossil carbon emissions (brown) avoided, biogenic alternative disposal emissions (blue) avoided, and biogenic greenhouse gas emissions produced by the biomass power plant (red). The net greenhouse gas burden of biogenic carbon gases (power plant emissions less avoided emissions, or red curve minus blue curve) are shown by the green curve.

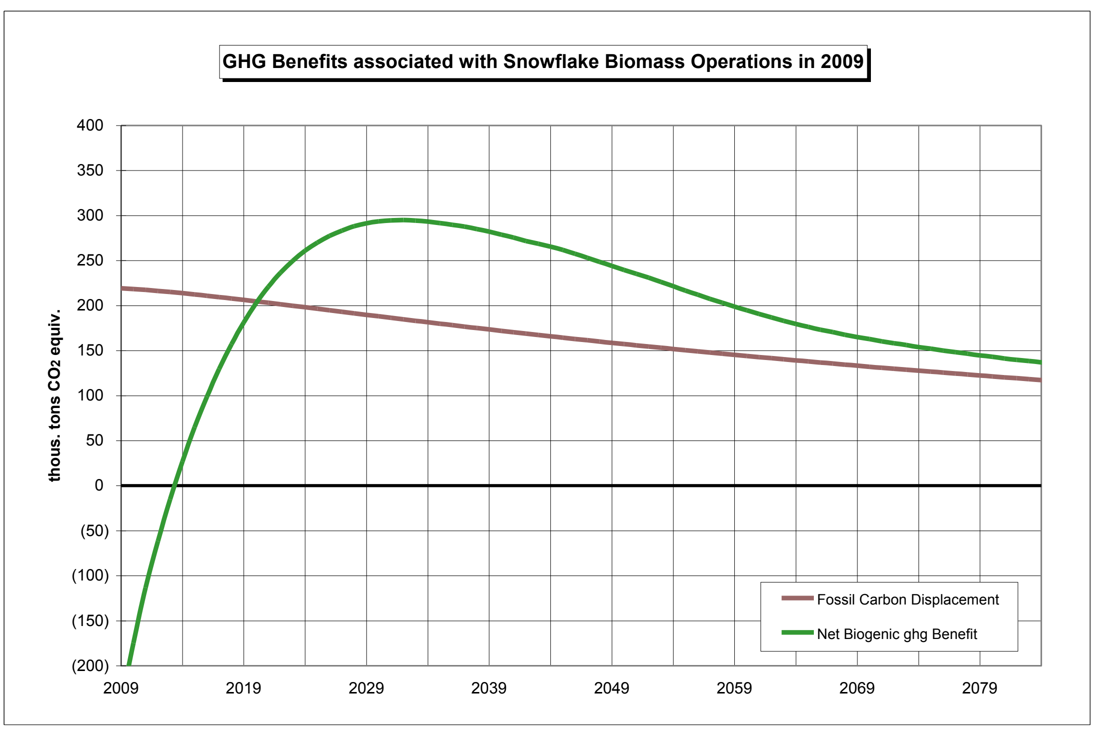
Figure 4



The figure shows the fate of the various greenhouse gas emissions associated with a single year's operation (2009) of Snowflake Biomass, over the ensuing 75-year time horizon. The emissions of biogenic greenhouse gases from the biomass power plant, and the avoided emissions of fossil carbon emissions, are both virtually entirely in the form of prompt emissions of CO2. The CO2 slowly decays out of the atmosphere with a characteristic residence time of 120 years (85-year half-life). The biogenic emissions of greenhouse gases from alternative disposal, which are avoided as a result of the operations of the biomass power plant, follow a very different trajectory. Some of the avoided emissions are prompt, but the majority of the emissions are delayed; the result, for example, of storage in forests with enhanced fire risk, or degradation of the paper fibers in the landfill. That is the reason that the avoided alternative disposal (blue) curve in the figure increases for the first twenty years after the fuel is used, before decaying away. The decay after about twenty-five years is more rapid than that for the biomass and coal power plant emissions curves, because the blue curve has a significant content of CH4, in addition to CO2, and CH4 has a much shorter residence time in the atmosphere than CO2 (12 vs. 120 years).

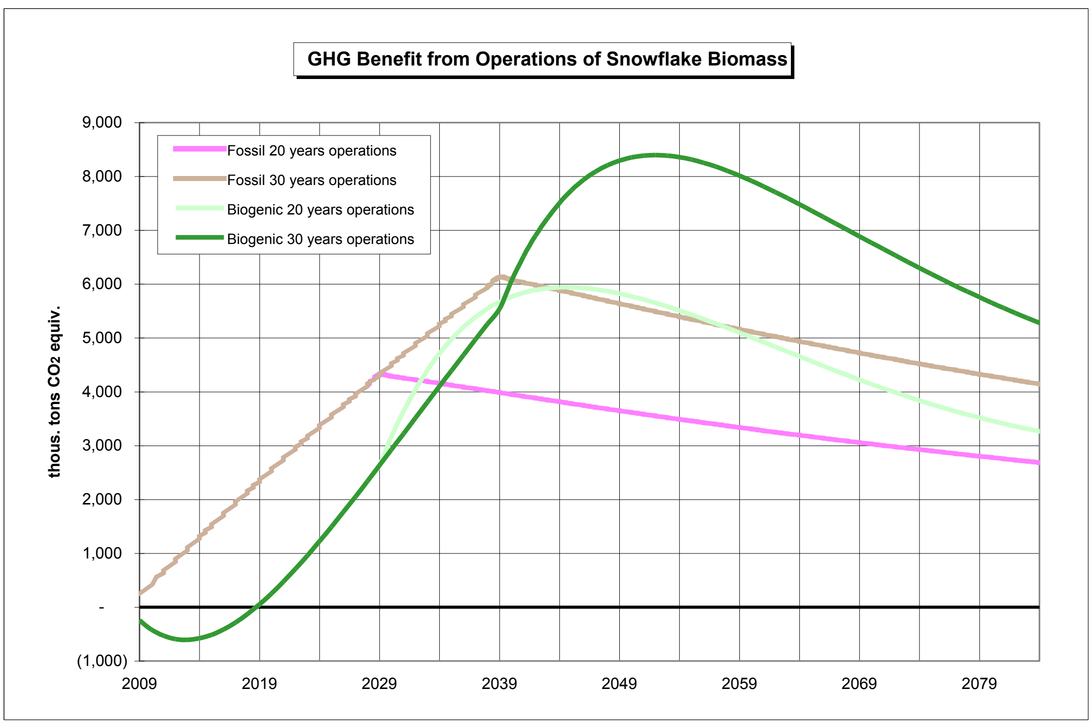
In order to compare the magnitudes of the net reduction in biogenic greenhouse gases resulting from the first-year operations of Snowflake Biomass with the avoidance of fossil carbon emissions, Figure 5 below shows the net biogenic emissions curve (green) from Figure 4 flipped, in order to show it as a benefit, superimposed on the avoided fossil emissions curve shown above. As Figure 5 shows, the warming potential of the avoided fossil fuel peaks in the year in which it is avoided (2010 in the figure), then slowly decays. The benefit of reduced warming potential associated with the reduction in biogenic greenhouse gas levels peaks 15 – 20 years following the use of the fuel, before decaying away. Twenty years following the use of the fuel (2030), the benefit provided by the power plant in terms of reduced biogenic greenhouse gases is approximately 65 percent greater, measured in terms of total warming potential (CO2 equiv.), than the benefit of fossil fuel avoidance, although it must be noted that avoiding fossil carbon emissions has the additional significant benefit of not adding new, geologically-stored carbon to the pool of carbon in the active atmospheric-biospheric carbon cycle.

Figure 5



The curves presented in Figures 4 and 5 correspond to a single year's worth (2009) of operations and fuel use for Snowflake Biomass. In fact, the project is expected to have a 20 – 30 year operating lifetime. Figure 6 shows the long-term cumulative effects of operating Snowflake Biomass over a 20 and 30 year operating lifetime, with the biogenic curve flipped like in Figure 5 to show net reductions as a benefit. As the figure shows, the atmospheric burden of avoided fossil greenhouse gases increases for the period during which the project operates, then decays with a characteristic residence time of 120 years. The net biogenic greenhouse gas consequences of operating the facility is to slightly increase atmospheric greenhouse-gas levels for the first eight years of operations, following which net biogenic greenhouse gas levels are increasingly reduced for a decade beyond the cessation of project operations, followed by a prolonged period of decay. The benefit provided by Snowflake Biomass of reducing net biogenic greenhouse gases peaks about 10 years after the project ends operations, at a level that is more than 50 percent greater than the same-year avoided fossil-fuel benefit. Integrated over the long term the benefits provided by the project of reduced net biogenic greenhouse gas levels due to operations of the project and avoidance of the alternative disposal fates for the biomass fuels are approximately 15 percent greater than the benefits of avoided fossil greenhouse gas emissions, measured in terms of total warming potential.

Figure 6



By the end of twenty years of operations, the Snowflake Biomass project will have avoided the emissions of 4.4 million tons of fossil CO_2 equiv, thus reducing the atmospheric level of fossil greenhouse gases in 2030 by approximately 4.3 million tons of CO_2 equiv. Net atmospheric levels of biogenic greenhouse gases are reduced in 2030 due to project operations by approximately 2.6 million tons of CO2 equiv., but even if the project shuts down at that time, net biogenic greenhouse gas levels associated with the project will continue to decline for an additional fifteen years. By the year 2045 the benefits of reduced biogenic greenhouse gases due to 20-years of operation of Snowflake Biomass are approximately 57 percent greater, in terms of warming potential, than the project's benefits derived from avoiding fossil greenhouse gas emissions, although it must be repeated that eliminating fossil carbon emissions has the additional significant benefit of avoiding juicing the system with new carbon released from geological storage. Integrated over the long term the biogenic benefits of Snowflake Biomass are approximately 15 percent greater than the avoided fossil carbon benefits, due to lifetime operations of the project.

The Snowflake Biomass plant avoids the use of coal for electricity production. The avoided fossil greenhouse-gas emissions from coal generation are 1.19 tons of CO2 eq. per MWh, as shown in Figure 5, where the brown curve crosses the Y axis (2009). Over the ensuing 75-year period those 1.2 tons of emissions of CO2 eq. per MWh in 2009 lead to an average atmospheric burden of 0.89 tons of CO2 eq. The reduction in the biogenic greenhouse-gas burden resulting from Snowflake Biomass operations in 2009, averaged over the same 75-year period, is 1.03 tons of CO2 eq. This is equivalent to an emissions rate of 1.37 tons of CO2 eq. per MWh for the reduction in biogenic emissions. The total greenhouse gas benefit attributable to Snowflake Biomass is the sum of the avoided emissions of fossil carbon, and the reduction in the emissions of biogenic carbon, or a total of 2.56 tons of CO2 eq. per MWh (1.19 + 1.37).

Conclusion

The Snowflake Biomass power project has a strongly positive carbon footprint that extends well beyond the operating lifetime for the project. The project has the same approximate benefits of avoiding fossil carbon emissions that would be associated with any renewable energy project with the same energy output. In addition, it provides the benefit of reducing biogenic greenhouse gases by approximately 10 – 20 percent greater magnitude of total warming potential than the avoidance of coal use that the project achieves, by providing a superior alternative, from a greenhouse gas perspective, for the disposal of the biomass residues used as fuel.