Carbon Footprint for Snowflake Biomass Power

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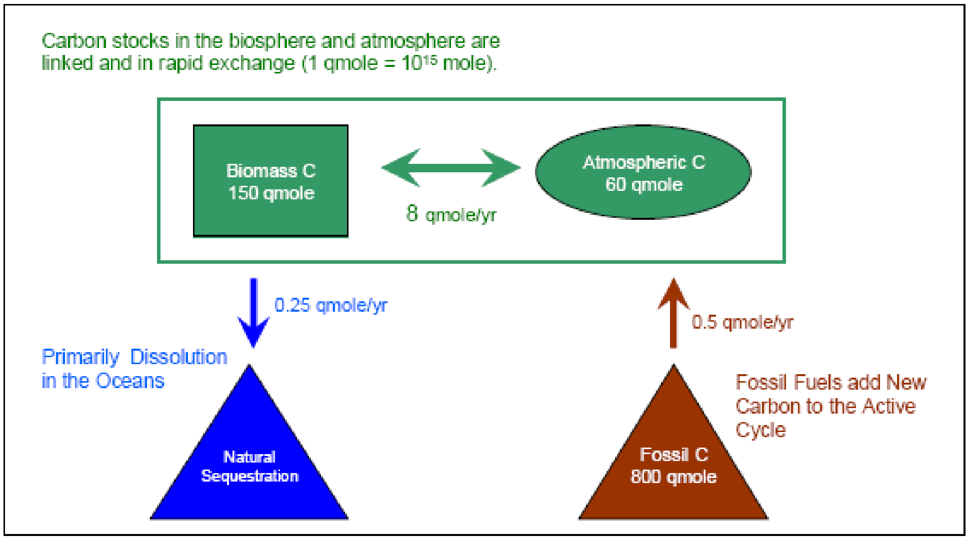
Renegy, LLC, is in the process of commissioning its 24 MW biomass power plant in Snowflake, Arizona. The generating unit will be fueled with a mixture of recycled paperfiber residues generated at the adjacent Catalyst Paper Co. paper mill, forest residues from the recent Rodeo-Chediski fire area and 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 (CH_4) is twenty-five times more potent than oxidized carbon (CO_2) 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 CH_4 has a 12-year residence time in the atmosphere, and its clearance involves conversion to atmospheric CO_2, which has a 100 – 200 year atmospheric residence time.

Figure 2: Biomass and the Global Carbon Cycle

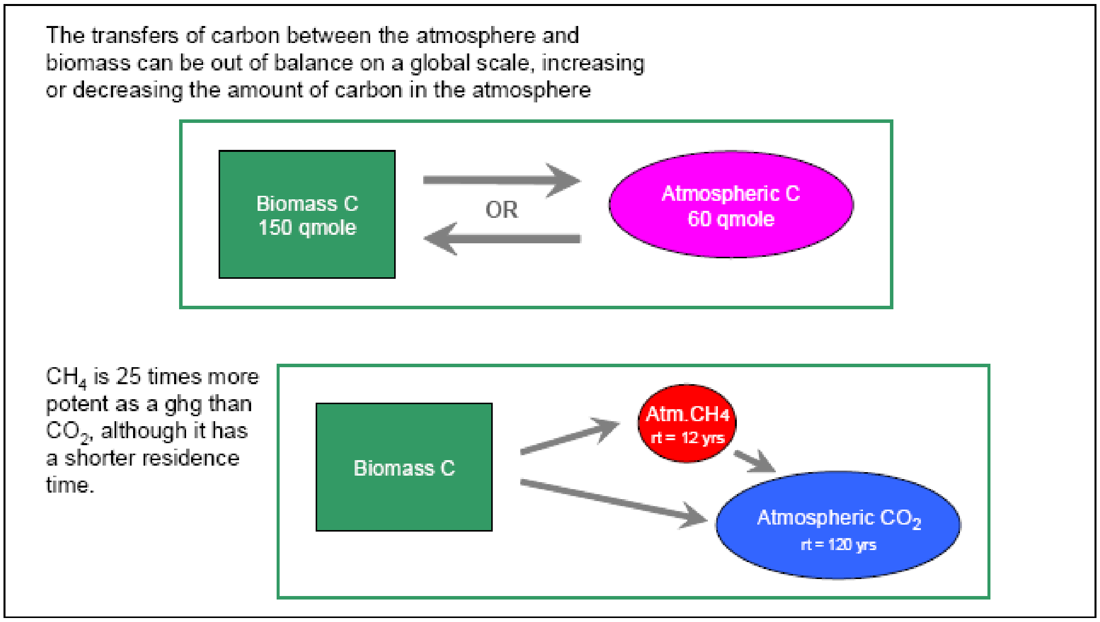
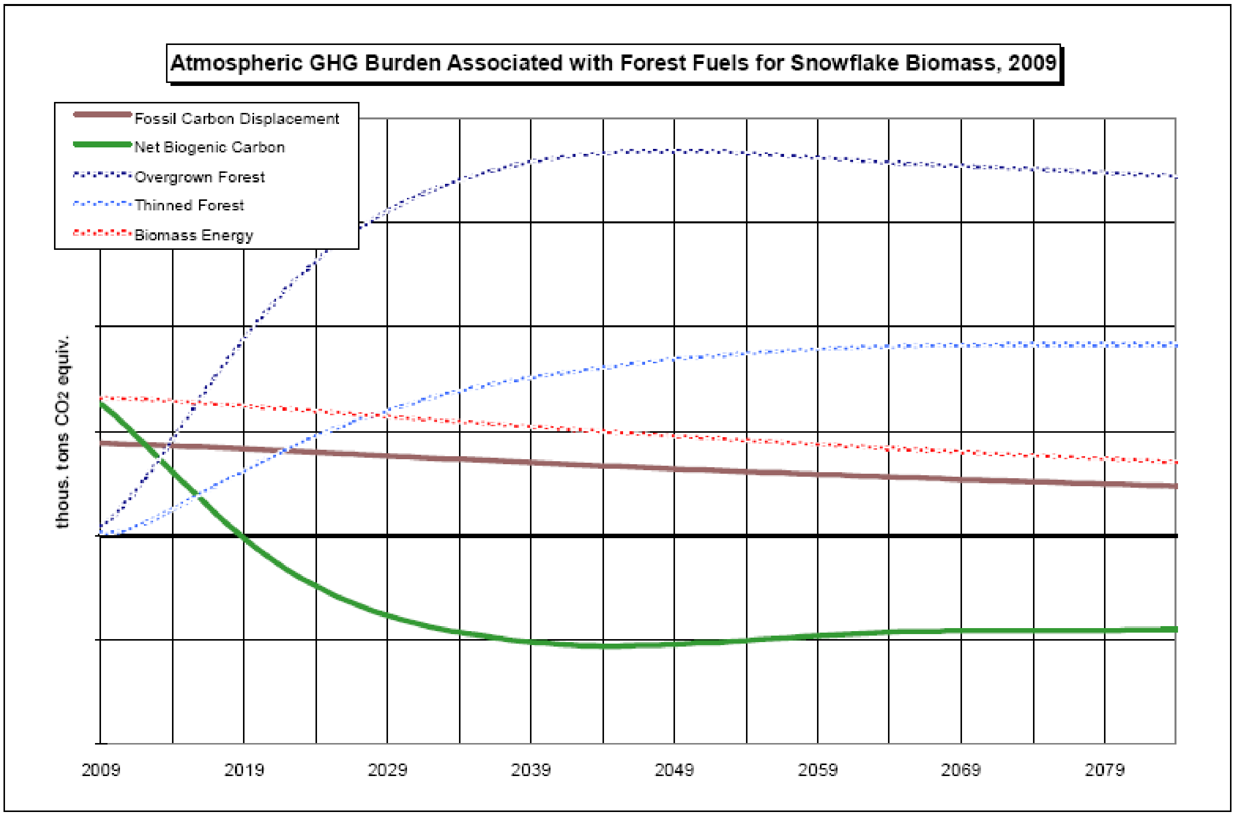


Figure 3 illustrates the way that forest treatment operations contribute to a reduction in atmospheric greenhouse gases. The immediate result of treatment with fuel removal and use is that the carbon in the biomass that is removed from the forest is converted promptly into atmospheric CO2 (red curve 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 CH4 emissions with CO2 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

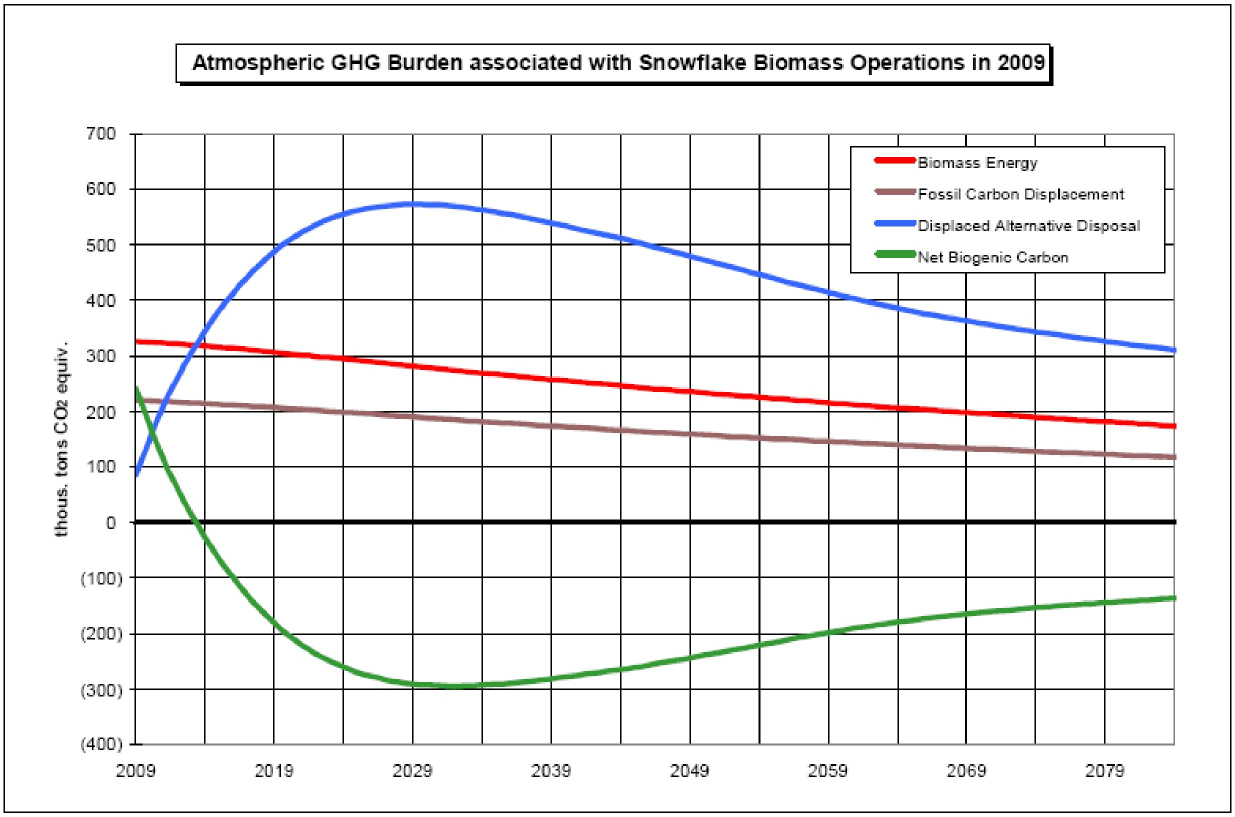
	Snowflake
Power Plant (MW_{gross})	24.0
Power Plant (MW_{net})	21.6
Electricity Prod. (MWh)	190,000
Fuel (bdt)	
Mill Residue	7,500
Forest Fuels	75,000
Urban Residues	32,500
Paper Residuals	70,000
Total Fuel	185,000
bdt/MWh net	1.08
Annual Acres Thinned	5,775

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 CO_2 equivalents. The biomass power plant itself will emit more than 300 thousand tons of biogenic CO_2 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.

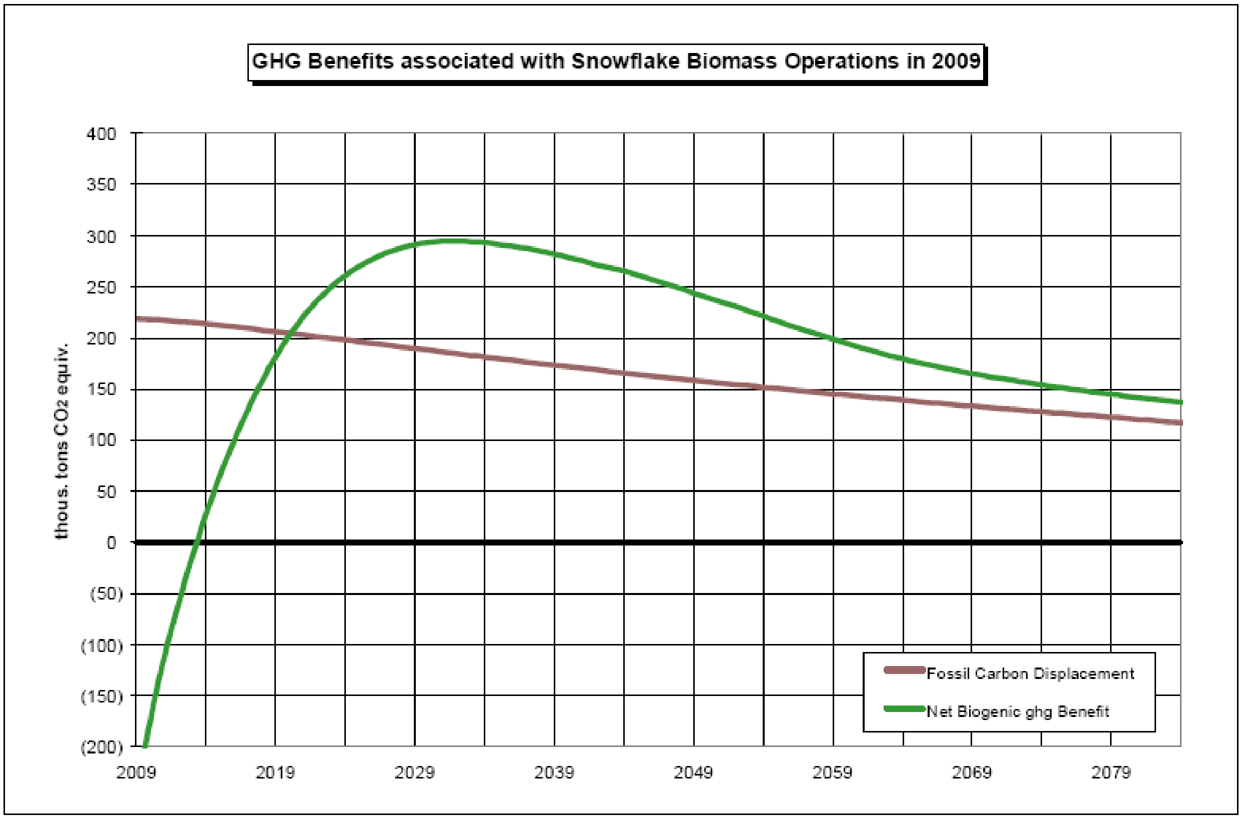
Figure 4



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).

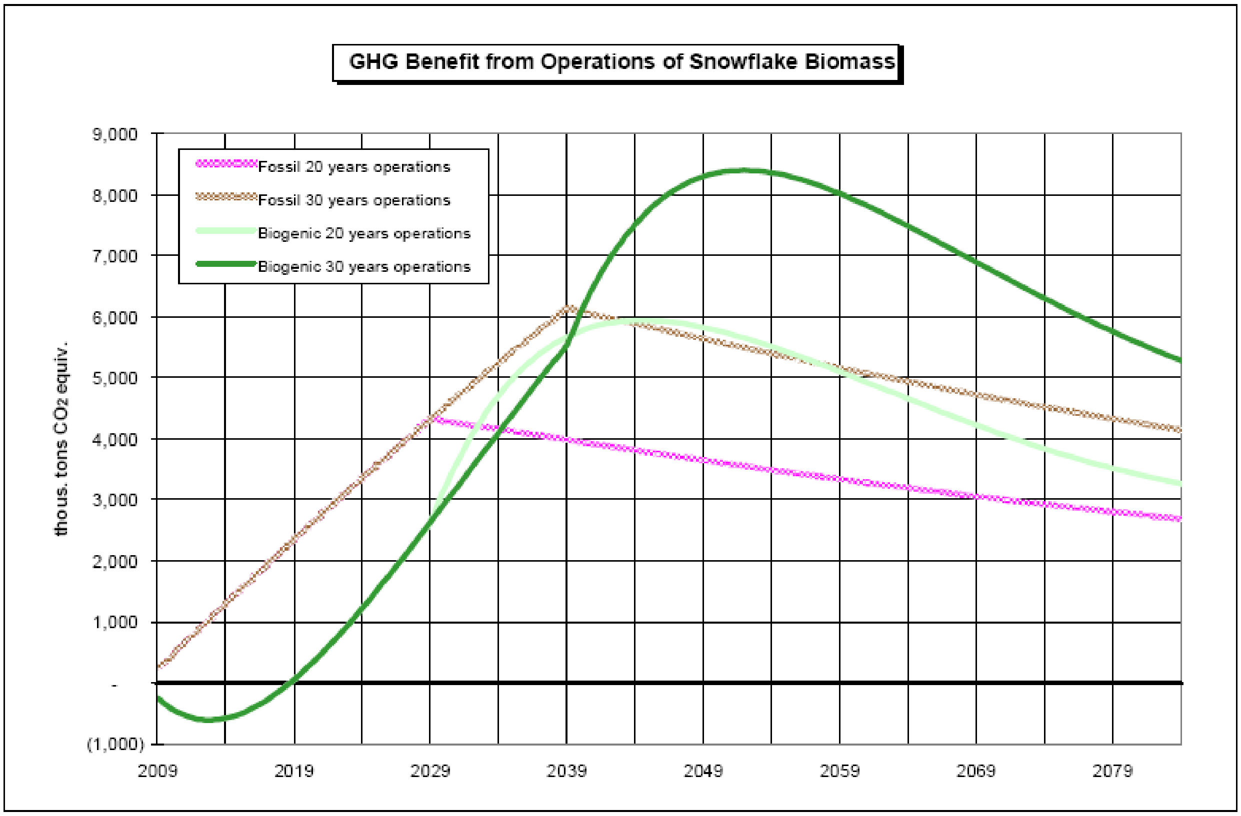
In order to compare the magnitudes of the net reduction in biogenic greenhouse gases resulting from the first-year operations of Snowflake Biomass with the avoidance of fossil carbon emissions, Figure 5 below shows the net biogenic emissions curve (green) from Figure 4 flipped, in order to show it as 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 CO2 equiv, thus reducing the atmospheric level of fossil greenhouse gases in 2030 by approximately 4.3 million tons of CO2 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.