Greenhouse Gas Accounting:
Biogenic Carbon Emissions

A Plan B Paper

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Goal:

Advocate for revising carbon accounting of greenhouse gases to include the emissions of biogenic carbon dioxide. Doing so will better inform the development of biomass energy policies and energy policy alternatives that reduce GHG emissions, while accounting for short and long term costs and benefits of fuel sources.

Audience:

This report serves as both a comment letter to EPA regarding its current request of policy recommendations relevant to the deferral of biomass regulation under greenhouse gas frameworks (see Appendix A) and as an internal memo for MPCA leadership regarding this subject. The inclusion of scientific justification is applicable even to expert audience, but discussion is also intended to be generally accessible.

Academic Statement:

This paper relates closely to my work at the Minnesota Pollution Control Agency and my knowledge of the subject served both purposes. All content in this paper was generated solely for the purpose of this paper unless otherwise cited. The MPCA is referred to for their role in regulation and policy formation and staff did not use this paper in writing comments.

Executive Summary

The EPA has requested comment on the incorporation of biogenic CO_2 emissions into regulatory decision-making. Biogenic CO_2 emissions should be counted as greenhouse gas emissions that contribute to climate change and sequestration of carbon through regrowth should be credited. Policy, with respect to greenhouse gases, should consider that emissions, regardless of the source, contribute to climate change impacts.

There are challenges to incorporating biogenic CO_2 emissions into the same framework as other greenhouse gases, but potential methods to address these challenges exist, such as standardizing the estimate of biogenic CO_2 emissions against global warming potentials. Yet, there are uncertainties about the impact of biogenic CO_2 emissions that relates to the regrowth of biomass and relative impact as compared to fossil carbon dioxide.

The allocation of emissions to various activities and economic sectors provides information for policy development. It is important to understand how emissions over time are impacted by economic factors and policy changes, and how emissions are divided among different economic activities taking place within the state. Currently, biogenic CO_2 emissions are not included in inventories in this way. By using the approach that does include biogenic CO_2 emissions in inventories and regulatory decisions, the relationship between biomass energy policy, energy generation activity, emissions, and impacts will be retained.

The Minnesota Pollution Control Agency (MPCA) has built an emission inventory for the purposes of policy analysis and tracking progress to reducing greenhouse gas emissions. Because of the nature of many industries within Minnesota, biomass is a significant energy source, whether derived from agricultural wastes, logging slash, paper mill sludge, whole wood, municipal waste, or fuel crops. Establishing a policy that reflects the relative emissions and impacts to alternative fuels is in the best interest of the state.

Introduction

A central reason for creating inventories is to illustrate changes in emission trends over time, and, to the degree possible, evaluate policy results and forecast the effects of policy changes. Inventories that discriminate between fossil and biomass emission sources provide incomplete information, especially when the energy system adopts more biomass-based fuel sources. In this case, the supply of and demand for energy may be increasing, but the exclusion of biogenic[1] emissions would give an impression of a disproportionately decreasing greenhouse gas intensity of fuel over time as more energy is generated from biomass sources that are not counted as emissions. As a decision making tool for policy makers, inventories should present complete pictures of our choices.

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[1] Biogenic CO_2 emissions are defined as “non-fossilized and biodegradable organic material originating from plants, animals, or microorganisms (including products, by-products, residues and waste from agriculture, forestry and related industries as well as the non-fossilized and biodegradable organic fractions of industrial and municipal waste, including gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material” (EPA, 2011).

Biogenic emissions have been treated as carbon neutral, even though combustion of any organic material – coal, oil, cornhusks, or ethanol – releases carbon dioxide (CO_2) into the atmosphere (Searchinger, et al. 2009, Johnson 2009). The thought behind this treatment is that over time, the biomass fuel sources would regrow, and, in doing so, recapture the same amount of carbon previously emitted, eventually coming out as neutral. While this equilibrium is true in some extent, there is the problem of uncertainty of future regrowth and resulting challenges to quantify emissions and sequestration in the same terms as emissions of fossil fuels.

Climate change is both a wide reaching environmental threat and a threat to our health and welfare. Some of the effects of climate change on human health include poor air quality, increased temperature, changes in extreme weather event patterns, and increased allergens and spread of pathogens (EPA 2009). We will also be affected by changes in food production, agriculture, forestry, water resources, sea level, and energy supply and by environmental events such as flooding, droughts, wildfires, and extreme weather (EPA 2009). Climate change is already seen to have contributed to the increased occurrence or severity of some of these impacts, and will continue to leave the fingerprint of anthropogenic – human caused – climate change on many aspects of our lives in the years to come. We are committed to experiencing some degree of climate change from current atmospheric concentrations of greenhouse gases (GHGs), and are not showing signs of slowing our rate of emissions. This may also affect the rate of biomass regrowth under future climates.

Emissions of GHGs, which include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), threaten public health and welfare and the environment through the resulting climatic changes from increasing atmospheric concentrations of GHGs. Like many other scientific academies, international organizations, and other governments, the US Environmental Protection Agency (EPA) has found that climate change does endanger human health and welfare and the environment, and therefore has begun to regulate GHG emissions under the Clean Air Act (EPA 2009). Current regulatory efforts include reducing GHG emissions from cars, light duty trucks and heavy duty trucks through vehicle fuel efficiency requirements, establishing emission standards for refineries and power plants, and by creating permitting requirements for industrial facilities.

Business and industry will have to act within new regulations designed to reduce greenhouse gas emissions. Substituting or including biofuels can reduce fossil fuel emissions. Reducing the use of fossil fuels is a valuable goal from many perspectives, variously framed in terms of national security, energy security, self-sufficiency, or environmental conservation and protection. As part of the solution, biomass energy is a growing source of generation to meet our energy needs and is valued because it can displace fossil fuel use.

However, biogenic carbon emissions and sequestration should be subject to the same type of scrutiny as fossil fuel emissions because any emission of CO_2 to the atmosphere contributes to climate change. Replacing fossil fuels with biomass based energy generation may not provide the reductions in greenhouse gas emissions necessary to reduce the atmospheric concentration and lessen the impact of climate change. Additionally, the use of biomass may have other impacts such as displacing food or industrial inputs if supply is outpaced. Carbon dioxide emissions from biomass energy raise complex policy issues requiring careful consideration from both a scientific perspective and an energy policy perspective. The EPA is currently seeking comment on addressing biogenic emissions within the regulatory compliance framework under the Clean Air Act, which has the potential to bring biogenic emissions of CO_2 into the same regulatory framework as conventional fossil fuel GHG emissions and biogenic emissions of non-CO_2 GHGs[2].

Biogenic CO_2 emissions should be counted as greenhouse gas emissions that contribute to climate change. And sequestration of carbon through regrowth should be credited, if it does in fact occur. There are multiple models that attempt to address this issue of emission and sequestration, but the uncertainty of a future outcome and comparability of the result

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[2] CO_2 is the only biogenic greenhouse gas that is treated separately. Because biogenic N_2O and CH_4 emissions are not part of the carbon cycle that occurs with regrowth of biomass, and are only removed from the atmosphere by global processes, they are treated the same as fossil GHG emissions and are accounted for in the sector where the emission occurred and attributed to a specific activity. Other GHGs (HFCs, PFCs, and SF_6) are entirely anthropogenic and do not originate in nature.

to the existing emission estimation framework are not yet solved by the existing models. The complexity of accounting for climatic impacts from biogenic emissions in comparison to fossil fuel emissions arises through consideration of uncertainty and the short-term and long-term costs and benefits, which includes sequestration in regrowth and any contribution to increased atmospheric concentration if regrowth does not occur or fully offset emissions.

A proposal that addresses all of these concerns is needed for regulation and informed policymaking.

Context and problem definition

The EPA has been considering the treatment of biogenic CO_2 emissions in the context of regulation under the Clean Air Act for a number of years. Since greenhouse gases were defined as pollutants under the Clean Air Act, and were to be included in the regulatory programs for air pollution, the EPA has proposed rules tailoring existing regulations, such as determining if a source of emissions meets thresholds that trigger regulation (e.g., regulatory applicability determination under Prevention of Significant Deterioration (PSD) and Title V permitting) to GHGs. Tailoring the existing rules to work with GHGs is necessary because of the magnitude of greenhouse gas emissions (measured in millions of tons per year) compared to other air pollutants (measured in tons per year), otherwise very low levels of greenhouse gas emissions would be regulated. In the tailoring rule, as it is colloquially named, the EPA proposed to treat biogenic emissions of CO_2 as equal to fossil based emissions of CO_2 for purposes of determining regulatory applicability (EPA 2010). While this respects the argument that emissions from biogenic sources should be included, it overestimates the impact of biogenic emissions over time, as compared to fossil fuel emissions. Because the tailoring rule is necessary because of scale, additional tailoring should consider the nature of biogenic greenhouse gas emissions.

In response to the comments the EPA received regarding the tailoring rule as it was proposed, the EPA decided to defer including biogenic emissions in regulatory applicability determination, pending further comment and study, in order to investigate alternative approaches. The EPA has requested comment on the deferral and on considerations to take into account when developing policy that is “scientifically sound and manageable in practice” (EPA 2011). The proposal presented here is in part comment for the EPA on this matter and in part a discussion of the larger context of biogenic carbon accounting, including argument as to why biogenic CO_2 emissions should be counted and methods to estimate the contribution of biogenic CO_2 emissions to global climate change.

While fossil-based emissions and biogenic emissions of non-CO_2 GHGs are included in inventory estimates of greenhouse gas emissions, biogenic CO_2 emission sources are estimated separately from the activity that resulted in the emission or are excluded from quantification. This alone creates a problem in accounting because the full contribution of an activity, such as energy generation, to total GHG emissions is not available for policy analysis.

The discussion of biogenic carbon accounting has also recently appeared in the scientific literature (Searchinger, et al. 2009). The problem of carbon accounting has been identified as the disconnection between the actual real-world activities and constructed inventory protocols. Inventories do not account for biogenic CO_2 that is emitted from energy generation, but rather account for those emissions as originating from land use changes. This avoids double counting of emissions, but separates a significant activity factor from inclusion in the energy sector.

The separation of action and emission creates a problem for using greenhouse gas inventories for formulating and evaluating energy policy. Information about energy sources is being allocated to different sectors - energy generation and land use - and quantified through different, and possibly incompatible, methods. Though this problem has been identified, there has not been discussion in the literature of how to solve it.

In the context of the EPA request for comment, this question deserves attention because it is currently the focus of policy development. There is concern that including biogenic CO_2 emissions as equal to fossil CO_2 emissions will both overestimate emissions and will place a burden on permitting agencies by regulating many new sources. There is also concern that excluding biogenic CO_2 emissions could allow emissions that do increase the atmospheric levels of CO_2 to be ignored. Neither the all-in or all-out methods are appropriate; biogenic CO_2 emissions require a more nuanced approach.

In the context of inventories, the allocation of emissions to various activities and economic sectors provides information for policy development. Divorcing biogenic energy emissions from energy activities and the energy sector separates policy from effect and masks the impact.

Current treatment of emissions in inventories

Inventories of greenhouse gas emissions are estimated at the national, state, and local levels. Emissions of GHGs that result directly from human activities and indirectly from disturbed ecosystems are tracked, and so are, to the degree that methods allow, GHG removals from the atmosphere. CO_2 can be removed from the atmosphere photosynthetically and stored terrestrially in living and dead biomass.

Biogenic emissions occur from anthropogenic, that is, human, activities and from naturally occurring processes. Harvesting plant material, clearing land, burning biomass for energy, using biomass as an input to an industrial process, and biodegrading wastes all emit stored carbon into the atmosphere. Only the anthropogenic emissions are included in inventories, to the degree they can be identified.

While ideally, all sources of GHG emissions would be inventoried, in practice, only those sources for which there exists a well developed scientific understanding of the physical and biological processes involved in the production and emission of GHGs are included in inventory estimates. Protocols or methods must exist for source emissions to be estimated, and data must be available to support the estimation effort. Most sources of fossil-based emissions have an accepted methodology for estimation.

The convention for addressing biogenic CO_2 emissions is to leave them out of energy or other activities and include instead anthropogenic changes in carbon stocks due to land use, such as converting forested land to agricultural land, even through the emission occurred because of some other activity. The Intergovernmental Panel on Climate Change (IPCC) states: *"CO_2 emissions from biomass combustion should not be included in national CO_2 emissions from fossil fuel combustion. If energy use, or any other factor, is causing a long term decline in the total carbon embodied in standing biomass (e.g., forests), this net release of carbon should be evident in the calculation of CO_2 emissions described in the Land Use Change and Forestry Chapter"* (IPCC 1996). This design was developed to avoid double counting of emissions. However, estimates of emissions from land use change are highly uncertain, if at all quantifiable, and the use of surveys inherently includes some changes due to natural processes, such as wildfire. This method also separates the effect of energy policy from the economic sector where the fuel is utilized (e.g., collecting forest harvest slash for combustion in an industrial boiler).

Emissions of CO_2 are the only greenhouse gases that receive separate treatment for biogenic and fossil emissions. Biogenic CO_2 is different from other biogenic greenhouse gases (e.g., methane (CH_4), nitrous oxide (N_2O)) because of the additional reuptake of CO_2 through regrowth. Biogenic CO_2 has unique concerns compared to fossil CO_2 because of the time carbon has been stored in the respective reservoirs and the time it takes to re-sequester carbon in each reservoir, though the effect, quantified in terms of radiative forcing, of either type of carbon emission in the atmosphere is indistinguishable.

Within standard inventory protocols, emissions are reported in nominal and CO_2-equivalent[3] tons, which are derived from global warming potentials (e.g., 1 ton of N_2O equals 298 CO_2- equivalent tons of N_2O). Not all greenhouse gas emissions to or removals from the atmosphere can be easily expressed in CO_2-equivalent terms. The calculation of CO_2-equivalence requires prior knowledge of how long an emission will persist in the atmosphere or whether a removal remains in terrestrial storage and for how long. Because CO_2-equivalence is defined in terms of 100-years of integrated impact, this requires significant foresight.

This is particularly a problem with respect to atmospheric removals of CO_2 during

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[3] A CO_2-equivalent ton a standardized metric used to compare emissions of different greenhouse gases, and is the equivalent emission of any GHG that results in a 100-year integrated effect on the climate equal to the emission of one ton of CO_2 from fossil fuel combustion.

photosynthesis. During photosynthesis, CO_2 is removed from the atmosphere and incorporated into plant biomass. This places carbon in terrestrial storage. However, depending on how land is managed, stored carbon may remain sequestered for decades or, with more intensive use of the land, be reemitted quickly after initial sequestration. It depends on future land management decisions, and those cannot be known with any certainty in the present.

This introduces uncertainties to the quantification of emissions or removals using the IPCC CO_2-equivalence framework. Without knowing how the future will unfold, there is no way that we can know if, for any single observed removal of CO_2 from the atmosphere, those conditions will be met. However, this uncertainty does not preclude estimating the effect of emissions using global warming potential calculations. Also, even if the uncertainties remain, this method allows for the possibility to incorporate time and future actions.

Moving From a Carbon Neutral Model to Carbon Debt

Two competing theories appear in the scientific literature, policy discussions, and in comments from interest groups to the EPA in response to the request for information – carbon neutrality or carbon emissions. Given the uncertainties of specific estimates, biomass can be considered to be part of an ongoing equilibrium maintained by the natural carbon cycle in which growing forests over time would re-capture the carbon emitted by wood-burning energy facilities (Walker, et al. 2010). Many of the leading national and international governing bodies have taken this carbon neutral approach with different justifications.

- With the publication of its 1998-2002 Strategic Plan, the International Energy Agency (IEA) made its first statement on biomass carbon neutrality, and have since viewed biomass energy as carbon neutral (International Energy Agency 1995, International Energy Agency 1997).

- The IPCC treats bioenergy as carbon neutral in that is displaces fossil fuel use and net carbon stock changes are accounted for through changes in land use (IPCC 2007, IPCC 2006, IPCC 2000).

- The EPA states that burning biomass is carbon neutral when considered in the context of natural carbon cycling, because although it produces carbon dioxide, it is considered to be part of the natural carbon cycle of the earth. The plants take up carbon dioxide from the air while they are growing and then return it to the air when they are burned, thereby causing no net increase (EPA 2010).

The assumption that biomass is carbon neutral is being replaced by a theory that takes into account the complex nature of biogenic carbon release and storage. A more complete analysis examines the carbon debt and dividend cycle and considers the atmospheric effects and carbon cycle over the same 100-year timeframe as other climate policy and impacts analysis. This type of approach and concern for net greenhouse gas emissions has only recently been proposed (Searchinger, et al. 2009, Johnson 2009) (Searchinger, et al. 2009, Johnson 2009). Rather than considering biomass to be immediately carbon neutral, carbon reuptake and storage by forests follows a curve where there is first a large emission from harvest and use, followed by carbon debt, and at some point in the future enough carbon has been stored to be equal to the fossil emission with a carbon dividend produced in subsequent years until it is again harvested.

The carbon neutrality model considers the carbon cycle over a very long timeframe, and values the history of land management instead of the future management choices. The difference is in treating biomass as a recent sink that can be released without impact on the overall carbon balance, or as an emission upon its use, which is only, perhaps, replaced in the future.

Forest biomass combusted for energy generally emits more greenhouse gases than fossil fuels per equal unit of energy produced. The short term carbon debt idea is very important when trying to make policy that reduces carbon emissions. There is the potential for long term neutrality, but significant climate change impacts can occur in the near future from rising atmospheric concentrations of emissions and long term neutrality is dependent on uncertain future choices.

In a generic model, for one year of emissions, it would take 32 years for the forest to regrow and recover the carbon debt to be equal to the emissions of the same amount of coal-based energy (Walker, et al. 2010). Considering time is clearly important. In order to properly evaluate biomass energy policies, policy makers need to have accurate estimates of the emissions and net atmospheric carbon concentration impacts.

Carbon Debt Model

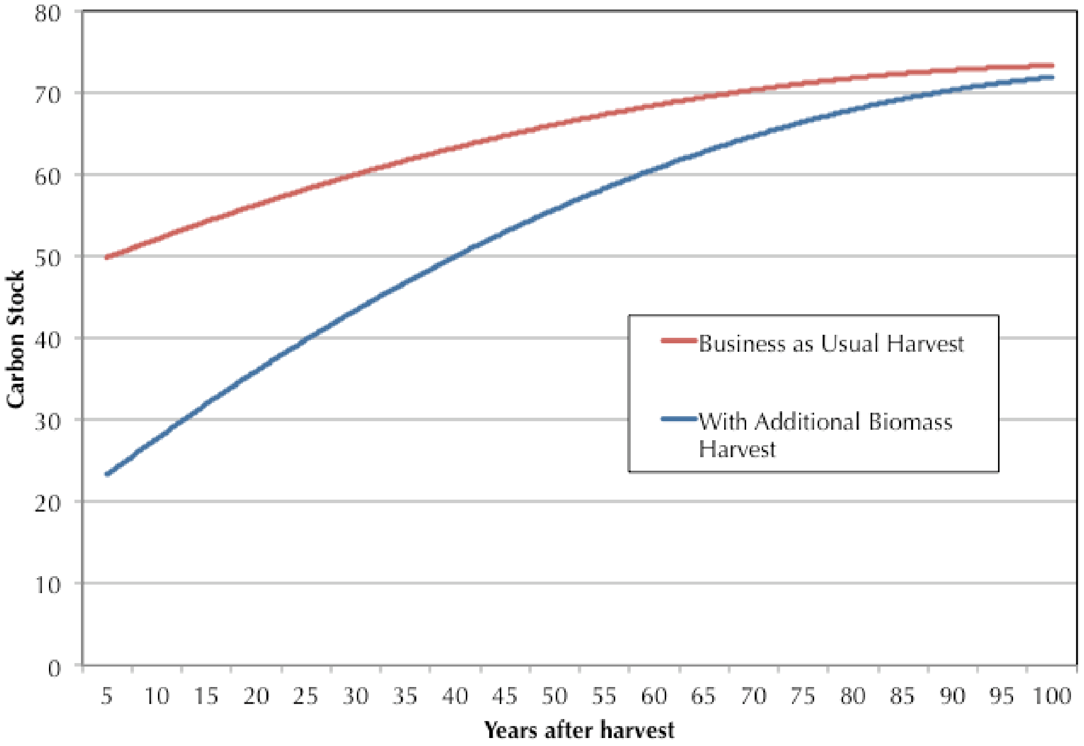
Examining carbon debt in-depth is necessary to establish justification for moving away from assumed carbon neutrality and also to demonstrate the pattern of removal of carbon from the atmosphere through regrowth. Combustion of any material for energy results in the emission of carbon dioxide, but emissions can vary depending on the energy source and efficiency of technology, which provide a way of comparing greenhouse gas intensity of energy.

The carbon debt model originated as a way to describe relative carbon dynamics (Fargione, et al., 2008) and was further developed into a forest biomass case study for Massachusetts (Walker, et al. 2010). This model included the emissions from production and transportation of feedstocks (e.g., extracting and transporting natural gas, harvesting and transporting forest products) in addition to direct combustion emissions. This type of lifecycle analysis is beyond the boundaries of emission inventories, but is often included in project proposals. Harvesting of biomass for other uses was assumed to continue under business as usual parameters in this model and biomass harvested for energy would be an additional removal. For comparison, each fossil fuel energy and biomass energy scenario produced the same amount of useable energy. In addition to carbon debt, this model introduced carbon dividends by extending the time horizon out to 100 years to capture the full potential of regrowth of the forest.

The figures below, derived from the Massachusetts carbon debt model, illustrate the carbon stock in a forest increasing along a curve after both the business-as-usual harvest and harvest of additional biomass for energy (Figure 1). The resulting additional carbon that remains in the atmosphere as emissions, given the relative differences in reuptake through growth, is compared to fossil carbon emissions in Figure 2. The total carbon stocks (Figure 1) are less important to the argument than the demonstration of the carbon reuptake curve (Figure 2), but are the basis for describing the additional carbon emission and reuptake over time.

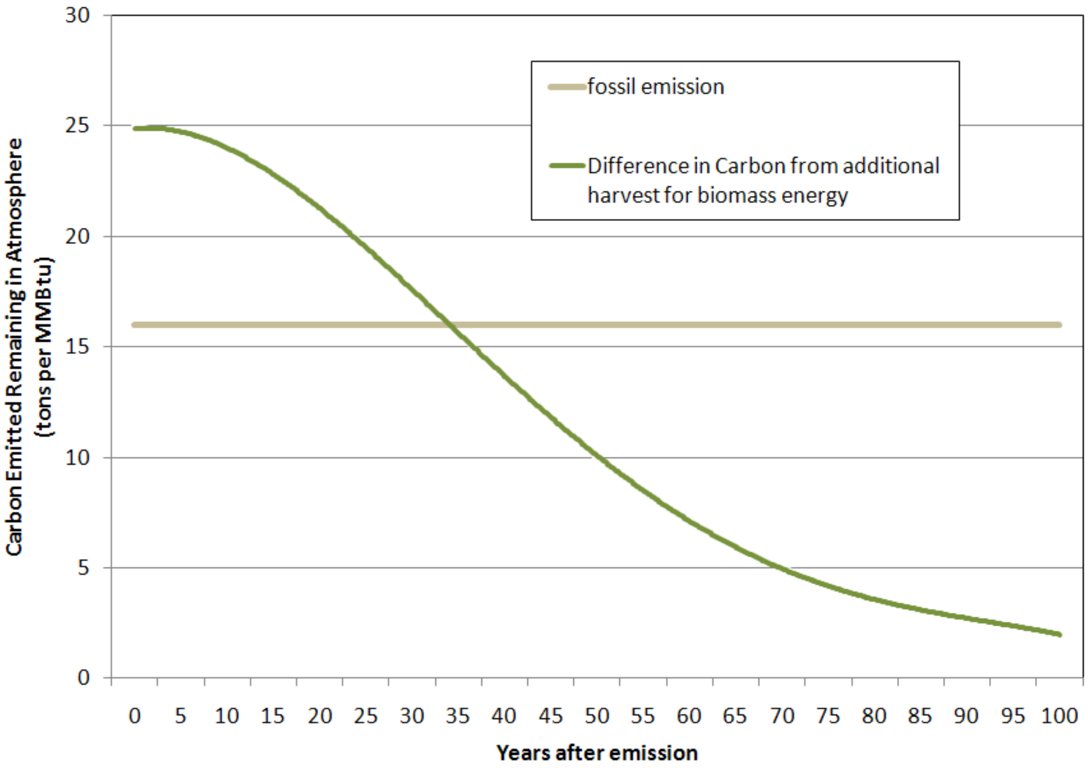
At first, there is a carbon emission that is greater than the emission from fossil fuels required to generate the same amount of energy, but because of the dynamic regrowth of the forest over time, carbon is stored in new growth and the carbon remaining in the atmosphere decreases (Figure 2). The emissions from a fossil source are constant over time because there is no reuptake of carbon emissions

Figure 1: Carbon stocks (tons) on forest plots after business-as-usual harvest and with the harvest of additional biomass for energy. Additional forest biomass harvesting in a given area removes more of the carbon stock in that area. The additional carbon remaining in the atmosphere, given the rates of rebuilding the carbon stock, is compared to the emissions from fossil fuel alternatives. Over time, as the forest regrows, the carbon stocks approach similar levels, but in the near future, 30-50 years out, carbon dioxide from the combustion of biomass remains in the atmosphere. (Based on Massachusetts carbon debt model (Walker, et al. 2010))



For policy purposes, the relationship of the fossil fuel carbon emission and the curve representing the initial carbon emission and re-sequestration over time is the important consideration. In this example, 16 tons of carbon are emitted from the generation of a unit of fossil fuel energy or 25 tons of carbon are emitted from an equal unit of energy generated with biomass (Figure 2). As the forest is allowed to regrow, carbon is removed from the atmosphere and sequestered in the vegetation. At a point about 35 years after the harvest, the forest has regrown to the point where it has recovered 9 tons of carbon, so the carbon remaining in the atmosphere from biomass energy (16 tons) is equal to that from fossil fuel energy (Figure 2). Any regrowth of the forest beyond this point results in a carbon dividend, where the carbon remaining in the atmosphere is less than what would remain from fossil based energy. This demonstrates the regrowth necessary to make biomass less GHG intensive than fossil fuels.

Figure 2: Carbon emissions remaining in atmosphere. Combusting biomass initially emits more emits more carbon dioxide than fossil fuels, but over time the carbon remaining in the atmosphere decreases as the forest regrows. In this set of hypothetical alternatives, quantities of bituminous coal and wood that create 40 MMBtu of useable energy are combusted. Sixteen tons of carbon are emitted from coal and 25 tons of carbon are emitted from the wood. After 35 years, forest regrowth would make the emitted carbon remaining in the atmosphere from wood equal the carbon remaining from coal combustion. Beyond 35 years, additional regrowth yields carbon sequestration. Carbon dioxide removals by geological processes act on all emissions equally and are removed from the comparison. (Based on Massachusetts carbon debt model (Walker, et al. 2010))



The relative outcomes from the carbon debt model are sensitive to the parameters of the comparison. The type of forest harvested will change the growth curve, and there will be some regional variability. The difference between the business as usual harvest for products and additional harvest for energy feedstocks may be variable between forest types. Fast growing forest species groups like aspen will have a different shaped curve than slower growing species groups like oak (Smith, et al. 2006), and this will change the point in time where carbon debt is recovered. The fossil fuel alternative can vary depending on the fuel and technology. Depending on the type of fossil fuel project a biomass project is proposed to replace, the desirability and plausibility of the biomass project can therefore vary greatly.

The carbon debt model is most useful for comparing alternative projects because inventories do not use hypothetical comparisons for evaluation of emissions. There are technical shortcomings of this model, well. Under the carbon debt model, sequestration of carbon through other global processes, such as ocean carbonates, is not considered. Only the effect of forest regrowth, and only the regrowth that occurs in the same place as the harvest, is recognized as a mechanism for removing CO_2 from the atmosphere. The calculation of a global warming potential would inherently consider other removal mechanisms because atmospheric residence time is included in the equation. The carbon debt model does acknowledge uncertainty in the future growth. The benefits measured are only realized if the biomass is allowed to regrow. However, the carbon debt model does not propose a method to account for that uncertainty.

Multi-year version of model

The carbon debt model, as created for Massachusetts, considers a comparison between one year of operation of electric generation fueled by either fossil or biomass fuels. In reality, an electricity generating utility would operate for many years. This would require multiple annual biomass harvests and therefore would expand the model with a carbon recovery curve for each year (Figure 3) (Booth 2010).

Figure 3: Basic model replicated for multiple years (Five curves shown every five years for clarity). A utility will operate for multiple years and the carbon remaining in the atmosphere from alternative projects can be compared over the lifetime of the facility and over the 100-year carbon dioxide atmospheric residence time. In this set of hypothetical alternatives, quantities of bituminous coal and wood that create 40 MMBtu of useable energy are combusted every year. Sixteen tons of carbon are emitted from coal and 25 tons of carbon are emitted from the wood each year. Summing the area under the curves yields Figure 4. (Based on Massachusetts carbon debt model (Walker, et al. 2010) and multi-year extrapolation (Booth 2010))

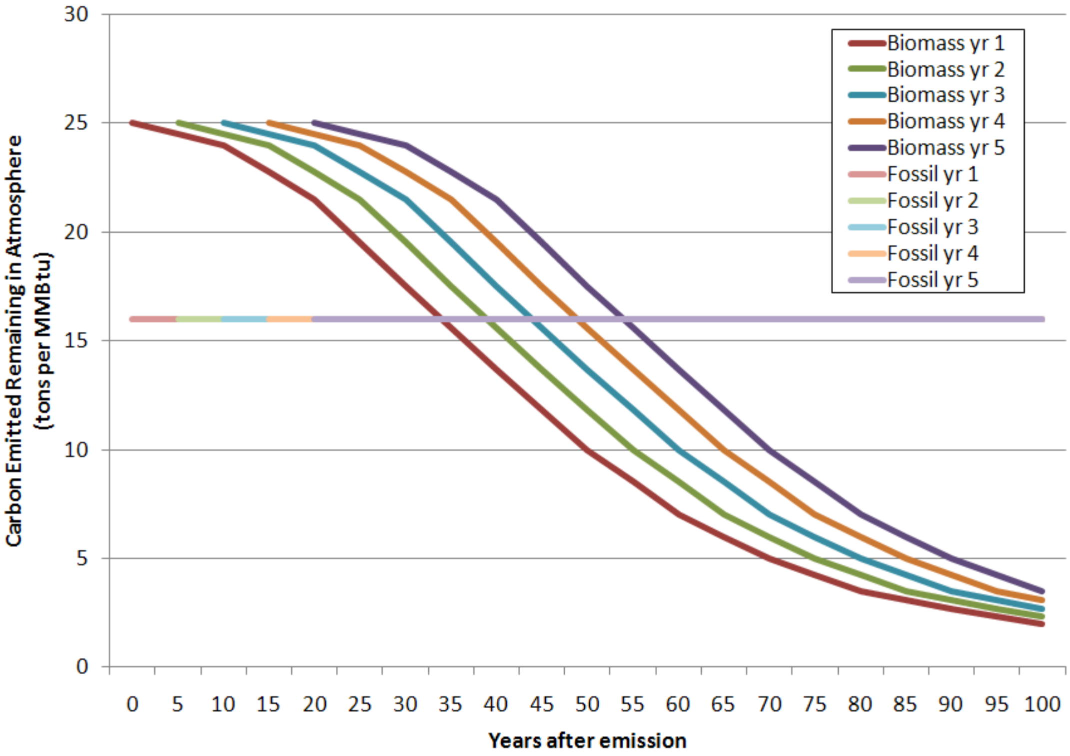
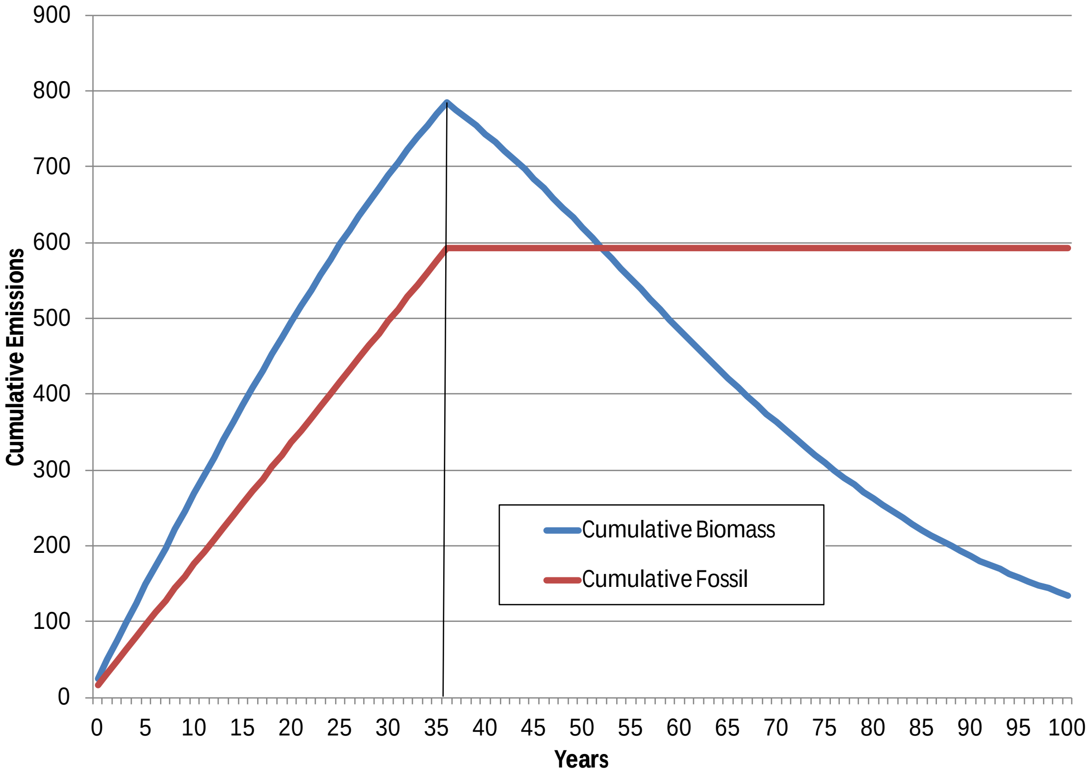


Figure 4: Integrated carbon emissions (tons) for a hypothetical biomass facility, operated for 35 years, compared to emissions from an equivalent coal-fired facility, each combusting 40 MMBtu of feedstock annually. After 55 years, 20 years after the facilities would be retired, the carbon remaining in the atmosphere is equal from each alternative; forest regrowth beyond 55 years yields carbon sequestration. (Based on Massachusetts carbon debt model (Walker, et al. 2010) and multi-year extrapolation (Booth 2010))



Expanding upon the carbon debt model, the net emissions over the lifetime of a facility, and further into the future, can be estimated. The net emissions remaining in the atmosphere from biomass can be calculated by simply adding the remaining carbon debt for each harvest curve (Figure 4). For example, assuming two facilities built to equivalent generation capacities, each with an operating lifetime of 35 years, where one is fueled by biomass and one is fueled by fossil fuels, the annual emissions cumulated over time show the different patterns for fossil and biogenic emissions. The emissions related to the biogenic source are initially higher than emissions from fossil fuels, however, after the facility is retired, the carbon remaining in the atmosphere from biogenic emissions begins to decrease because of regrowth without continued harvest. In this example, the biogenic facility is in relative carbon debt until about 50 years after the first year of operation.

This is inherently more complicated than calculating the emissions from fossil fuels. Instead of solely accounting for the emission from combustion isolated to only the year the action takes place, it is necessary to account for changing emissions remaining over time in a dynamic system. If we are interested in affecting policy change, actions and their resulting emissions are more valuable in an inventory that accounts for impacts over time and emissions are linked to causal actions.

Global Warming Potential (GWP) Model

Using the basic or expanded carbon debt models requires specific information about project parameters. It is useful for project evaluation and comparison of alternatives or for demonstrating that biogenic emissions are not immediately carbon neutral. It is not valuable for carbon accounting in the context of greenhouse gas emission inventories or permitting where the focus is actual emissions and impacts.

Global warming potentials[4] (GWP) could be used to standardize the estimate of the impact of biogenic emissions, as they are used for other greenhouse gases. The carbon debt model can be reworked to yield the sum of emissions remaining in the atmosphere. This integrated estimate can be used like a GWP, because it includes an estimate of the atmospheric lifetime of emissions, assuming regrowth. Because of the variety of biogenic sources and the variety of scenarios for management and regrowth, it is most practical to consider general classifications of sources.

The GWPs applied to GHG emissions address the 100-year integrated atmospheric effect, in terms of radiative forcing, which is generally well understood. With biogenic emissions and sequestration, the GWP must also address the aspect of sequestration, which is more uncertain and dependent on future management decisions. A GWP for biomass can be assumed to be between 0 (completely carbon neutral) and 1 (equal to fossil CO_2).

GWPs are calculated as time-integrated radiative forcing relative to CO_2 as a standard reference (Equation 1). GWPs are estimated as the comparison of the radiative effect and the atmospheric lifetime of a specific emission to those of carbon dioxide emissions from fossil fuels. Various biogenic emissions of carbon dioxide can be estimated in this equation as relative to fossil CO_2. The value in this comparison is the ability to take sequestration, or the atmospheric lifetime of biogenic emissions, into account.

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[4] A GWP is the relative effect of a GHG compared to an emission of fossil CO_2, given the radiative forcing and atmospheric lifetime, integrated over 100 years.

Equation 1:

Where (a) equals the radiative efficiency and [x(t)] is the time-dependent atmospheric concentration of the gas compared to CO_2.

Comparing two types of CO_2 emissions simplifies the equation because the infrared absorption, or radiative efficiency, term cancels out. The GWP equation then becomes the ratio of integrated net atmospheric retention of biogenic CO_2 to the integrated net atmospheric retention of fossil CO_2 (From unpublished work supporting MPCA comment to EPA). Simplifying the relative radiative forcing equations[5] to compare fossil and biogenic carbon dioxide emissions, the GWP of biomass can be presented as:

Equation 2:

Where (A) is the integrated atmospheric retention of biomass CO_2, up to the point in time where the amount of CO_2 retained in the atmosphere equals the amount of CO_2 stored in the biosphere through biomass regrowth (in ton-years), (B) is the integrated CO_2 removal from the atmosphere during plant regrowth up to the point in time where the amount of CO_2 retained in the atmosphere equals the amount of CO_2 stored in the biosphere through biomass regrowth (in ton-years), (C) is any additional biological carbon storage, such as an additional offset, and (D) is the integrated 100-year retention of CO_2 associated with 1 ton of emitted fossil CO_2 (approximately 48 ton-years). (From unpublished work supporting MPCA comment to EPA).

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[5]

This creates a GWP that includes the integrated emissions (A) and reuptake. Recovery of the carbon debt (B) and the carbon dividend (C) are integrated across the same 100-year period. The other mechanisms (e.g., absorption by oceanic biological processes) that remove carbon dioxide from the atmosphere are accounted for in the comparison of GWPs because they are inherent in the atmospheric lifetime.

Using the GWP model, different types of biomass would have different quantifiable impacts on climate change. An annual agricultural crop, like corn, would have a GWP of about 0.01, or 1% of the effect of 1 ton of fossil CO_2, and a longer (25-year) rotation crop, like aspen, would have a GWP of about 0.07, or 7% of the effect of 1 ton of fossil CO_2 (From unpublished work supporting MPCA comment to EPA, based on data from Smith, et al. 2006). The effect of the biomass GWP is shown in Appendix B as a comparison between three alternative facilities. Compared to carbon dioxide from a fossil fuel, biomass as fuel is still a strong alternative to reduce greenhouse gas emissions because the GWP discounts biogenic emissions. Again, this demonstrates that biogenic emissions shouldn’t be counted as zero, as shown by the carbon debt model, and certainly shouldn’t be counted as equal to fossil carbon if able to also re-sequester carbon through regrowth.

This model, like the others, continues to have the shortcoming of presupposing the future growth, which is uncertain. Outside of adding a term to the equation that accounts for uncertainty in regrowth, this model is the most complete method to account for the effects of biogenic carbon emissions. There is a place to include information about time, and therefore address part of the uncertainty, within the calculus. This model considers the atmospheric effects of emissions, which is the critical term for climate change policy.

Recommendations for EPA regulation and emission inventory accounting

In the EPA regulatory deferral and request for information, the EPA suggested four approaches as policy options: case-by-case analysis of impacts, categorical exclusion of all biogenic CO_2, contingent exclusion of biogenic CO_2 depending on meeting thresholds, or a generalized, feedstock-based analysis of biogenic CO_2 (EPA 2011). The EPA also identified the criteria for evaluating these policy options: the proposal must be scientifically sound, practical, predictable, and must propose a solution to the issue of the long time horizon (EPA 2011).

A case-by-case analysis would provide the most detailed and scientifically sound estimate of impact, but would be prohibitively complex. This alternative would require each project to submit complete and largely original analysis of their impact with respect to their unique situation. Categorical and contingent exclusions continue to operate under the assumption that overall biomass is carbon neutral, which ignores the issues previously presented. A categorical exclusion would exclude all biogenic carbon dioxide emissions. A contingent exclusion would also exclude all biogenic carbon dioxide emissions, as long as carbon stocks were maintained at a state or national level.

A feedstock analysis, (e.g., generic regional factors for categories of biomass feedstocks including short rotation timberland (pine, aspen), long rotation timberland (oak), and annual agricultural crops) is recommended because it balances detail with usability and represents the best current scientific understanding of climatic effects. The global warming potential model would work very well to provide generalized emission factors for various feedstocks. Using the GWP to estimate factors also takes into account the complication of regrowth over time.

One area where the EPA noted consensus among comments was regarding the level of differentiation between types of emission sources and regional variation (EPA 2011). The impact is linked to the type of biomass used (e.g., whole-tree harvest, wood waste, logging residues, biomass crops, forest type), so there is a need to create default emission factors, or global warming potentials, for general groups of feedstocks. These factors should represent the range of variation in impact between feedstock types and regions in order to provide easily accessible estimation methods.

Furthermore, the generic feedstock approach is recommended for its ability to be tailored to specific analyses. While not requiring unique analysis beyond the use of default factors, there should be flexibility to account for specific circumstances. The type of forest management practice can influence the rate of growth and therefore the carbon sequestration achieved over a given period. The variation between regional forest types and growth patterns would have to be accounted for, with flexibility to use field study data for plots that deviate from expectations. Even with regional differences in the atmospheric impact of biogenic carbon dioxide, biomass remains a favorable fuel in terms of carbon emissions when compared to fossil fuels, if regrowth does occur.

Besides recommending a straightforward protocol with a variety of default feedstock factors to make the process manageable, the rule only applies to large facilities making major modifications and new large facilities. Small facilities will not be burdened by additional regulation. Regulatory agencies will not be overburdened because covered facilities are already captured by regulation. Adding analysis of biogenic carbon dioxide would be only a marginal increase in demands on all parties.

The EPA is seeking comment to design a policy that reconciles the issues of spatial and temporal scale, practicality, predictability, and scientific soundness (EPA 2011). Establishing GWPs for types of biomass that act as default emission factors fulfills all of these criteria. As shown in the modeling, the GWP model reflects scientific understanding and addresses the problem of accounting for effects over time, and has been endorsed by Minnesota state policy makers in comments made to the EPA. The GWP model is also practical and predictable because general defaults are given, removing the necessity, though allowing for, uniquely generated estimates for each situation. The GWP model uses a local spatial scale, rather than global, which allows for actions to be attributed. The local scale also would allow for offsets, or additional carbon sequestered, to be credited.

The GWP for types of biomass also can be rolled into emission inventory protocols, such as the EPA Greenhouse Gas Emission Inventory and state inventories. In addition to the criteria the EPA established for regulatory applicability determination, this method connects emissions to actions. In an inventory context, this provides a more useful estimate of emissions associated with energy generation and other activities, which is important for informing policy.

Yet, there is still the problem of uncertainty in the future regrowth and sequestration of carbon. Under any of these models, if carbon is not sequestered, there is no recourse if the company no longer exists. An enforcement mechanism could be incorporated into permitting, but there is no precedent for holding companies accountable for future outcomes, only current actions. Additionally, each type of biomass has inherently different levels of uncertainty for regrowth (Smith, et al. 2006). An aspen timberland, because of the nature of the species, will begin to regrow immediately after harvest from roots left in the ground, whereas a pine timberland may not be replanted immediately after harvest. Management practices can also change over time, resulting in different timelines for carbon debt recovery. Biogenic CO_2 emissions from other sources, such as municipal waste combustion, also have unique uncertainties for carbon debt recovery, and each type must be evaluated individually in order to develop a method to take uncertainty into account.

Minnesota Emissions Profile

The State of Minnesota tracks greenhouse gas emissions for the purposes of informing policy and evaluating progress to meeting reduction targets. Emissions are grouped in the agricultural, commercial, electric generation, industrial, residential, transportation, and waste sectors, and into major activity groups by energy use and fuel production, agricultural process, industrial process, and waste management emissions (Ciborowski and Claflin 2011). Emissions estimated are limited to those that occur within the borders of the state, with net imported electricity to meet demand being the major exception. Emissions are largely associated with fossil sources, though CH_4 and N_2O emissions from biogenic sources (e.g., combustion of ethanol, biodiesel, biogas, and solid biomass, wastewater treatment, waste incineration, and landfilling of solid waste) are included. Removals of CO_2 from the atmosphere and long-term storage in residential structures and demolition and construction landfills are included in statewide GHG emission totals. Biogenic emissions of CO_2 are not included, but are tracked separately.

Statewide GHG emissions totaled 159.4 million CO_2-equivalent tons in 2008 (Figure 5) (Ciborowski and Claflin 2011). Depending on the year in question, between 80 and 85 percent of all GHG emission in Minnesota are associated with energy consumption or the production and transportation of finished fuels in and through Minnesota (Ciborowski and Claflin 2011).

In the GHG emission inventory, biogenic emissions of CO_2 are tracked only for combustion sources and landfills. Biogenic emissions of CO_2 totaled 10.6 million tons in 2008, and have been increasing about three percent per year since 1990 (Figure 6) (Ciborowski and Claflin 2011).

Figure 5: Greenhouse gas emissions in Minnesota, 1970-2008, organized by economic sector (million CO_2-equivalent tons). 80-85% of emissions are associated with energy consumption or production and transportation of finished fuels. Electric utilities account for approximately one third of emissions. Biogenic carbon dioxide emissions are not included in this estimate and are tracked separately. (Ciborowski and Claflin 2011)

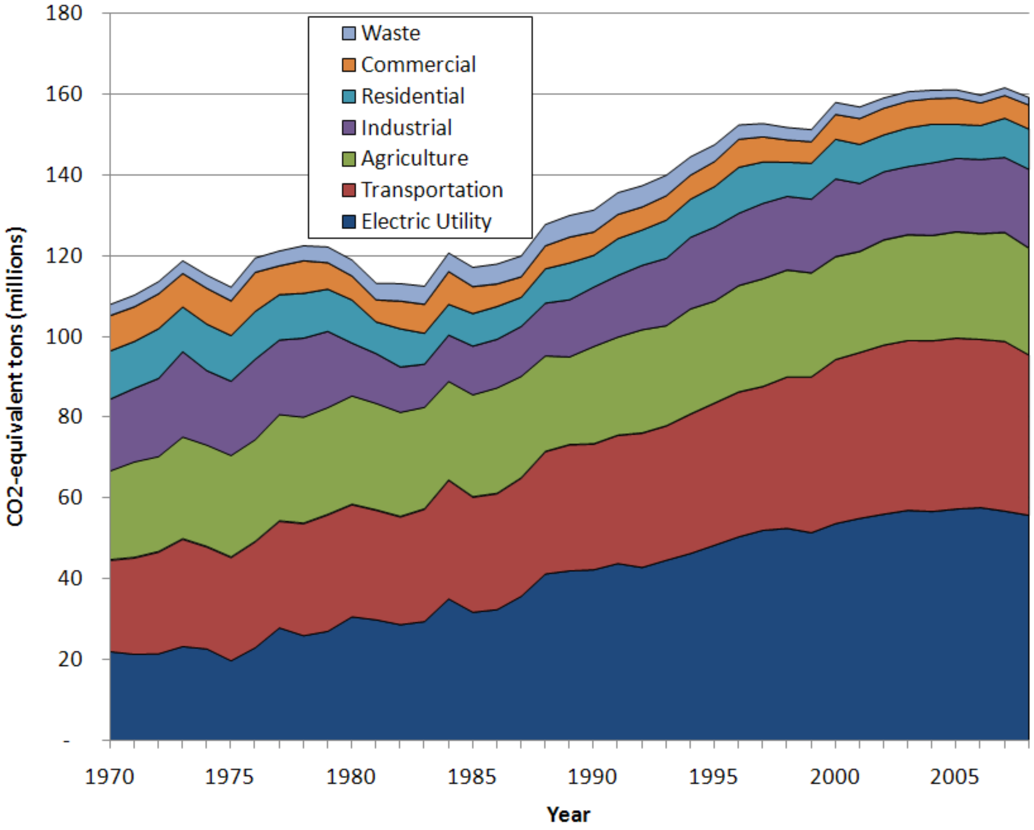
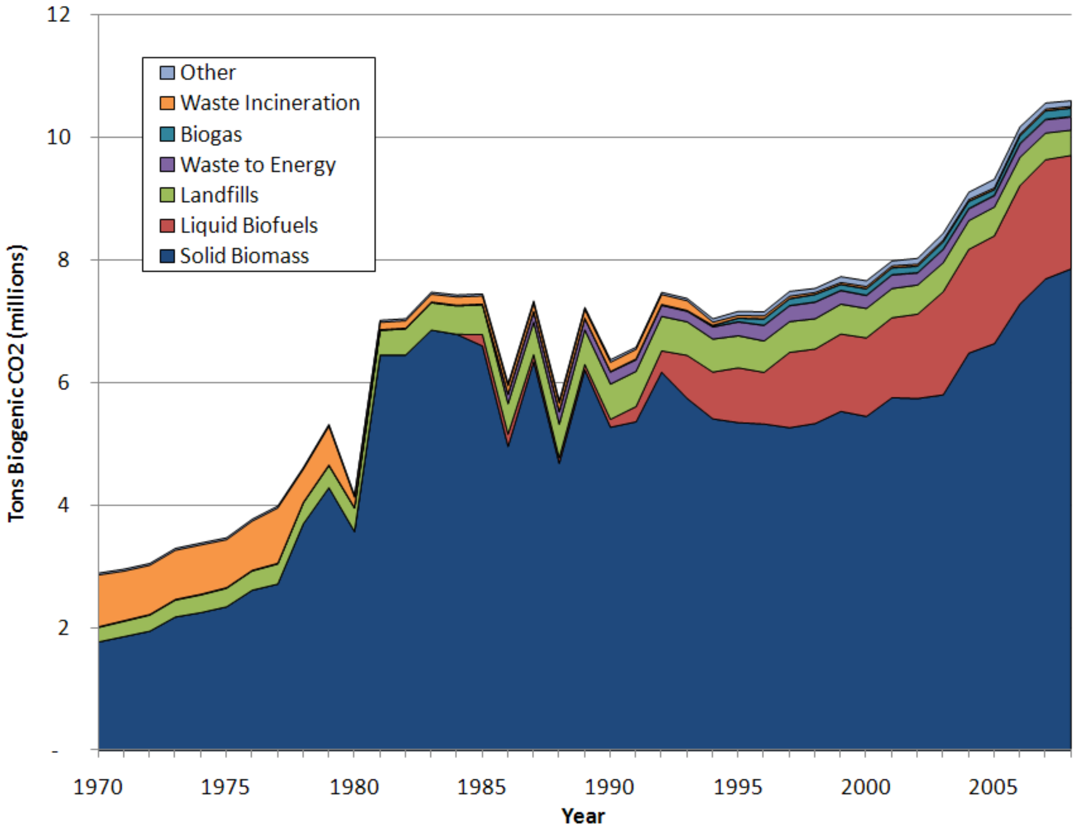


Figure 6: Biogenic emissions of CO_2, organized by type (million tons). Biogenic CO_2 emissions, if included in the state total, would make up about 6% of state emissions. Most biogenic carbon emissions result from the combustion of solid biomass for electricity generation, which includes a broad mix of materials such as forestry byproducts, followed by liquid biofuels, which include ethanol and biodiesel. (Ciborowski and Claflin 2011)



Comparatively, biogenic CO_2 emissions are a much smaller contributor to statewide greenhouse gas emissions than many sources. If these emissions were added into the state total, they would represent 6% of the emissions. Minnesota's use of biomass is higher than average, likely due to the forest industry in the state and use of wood wastes. Nationally, biogenic carbon dioxide emissions from biomass used as fuel, if added to total emissions, would account for 4% of total emissions (EPA 2010). While these are small percentages, it is not entirely insignificant. For scale, this is approximately equal to the statewide CO_2-

equivalent emissions of CH_4 or N_2O in 2008, or the total emissions from the residential sector. Biomass combustion for energy generation is also an activity increasing across all economic sectors.

However, in terms of impact, this estimate of biogenic emissions should be transformed using appropriate biogenic global warming potentials. Assuming that half of the biogenic sources are short rotation products (e.g., agricultural waste, food waste) and half are long rotation products (e.g. wood, paper), and all harvested areas are allowed to regrow, the 10.6 million tons of biogenic CO_2 emitted in 2008 has the impact of less than 0.5 million tons of fossil CO_2. This is a much smaller impact because of the regrowth that is assumed to occur, but is still an impact.

Policy Instruments

Biomass energy policies are a subset of policies that promote renewable energy sources, and are seen as a path away from a fossil fuel dependent energy economy. There are many reasons why biomass based energy would be a desirable policy goal, such as avoiding fossil carbon emissions, promoting energy security, and supporting agricultural and forest industries. Supporting a policy that counts emissions from biomass sources of energy, but counts them at a lower rate than fossil emissions, continues to promote the use of biomass and accounts for the impacts of the choice in energy.

The majority of renewable energy policies focus on renewable electricity generation and renewable transportation fuels. The development of renewable energy projects, and especially biomass projects, has been federally incentivized by creating purchase requirements through the Public Utility Regulatory Policy Act and, more recently, financial incentives, like the Renewable Electricity Production Tax Credit, Investment Tax Credit, Modified Accelerated Cost Recovery System, Biomass Crop Assistance Program, Clean Renewable Energy Bond program, Renewable Energy Credits and grants tax credits from the American Recovery and Reinvestment Act (Walker, et al. 2010). Minnesota also has programs to promote biomass electricity generation and transportation biofuels. Because of our supply of agricultural and forest biomass, promotion of these industries is an important component of supporting the state's economy.

Designation of biomass as a renewable energy source has been a point of contention, in large part due to the powerful farm lobby and energy lobby. Promoting the use of forest and agricultural products and creating a market for wastes can benefit the state and national economy. The National Alliance of Forest Owners is an interest group that has been particularly powerful and vocal. This organization filed a petition with the EPA for reconsideration of the tailoring rule as proposed, which resulted in the EPA proposing the deferral that is currently being considered (EPA 2011). Their position is that including biogenic CO_2 emissions will discourage the use of biomass for energy, which has a number of potential impacts ranging from increasing the use of fossil fuels to the loss of jobs in the forest products sector (Lippke and Oneil 2010). They, along with other groups seeking to promote biomass products, argue that biogenic emissions of CO_2 should be counted as carbon neutral. Similarly, energy utilities argue for biogenic carbon neutrality to lower their carbon footprint, at least on paper, which may benefit some facilities by not triggering regulatory thresholds. Electric utilities are interested in using the carbon neutral model because of the implications for reporting emissions, permitting new facilities, and cap and trade programs. In Minnesota, there are currently nine facilities that combust biomass for energy that are deferred from regulation because their emission of fossil-based GHGs does not exceed the threshold (Ciborowski and Claflin 2011). The permitting process for these types of facilities could add expenses for the stakeholders and also for the permitting agency.

Minnesota has various and extensive sources of biomass to feed into the energy system. Agricultural wastes or biomass crops could be used as well as woody feedstocks. Nationally there is a great deal of variation between resources available as energy feedstocks. Biomass of all types, being less energy dense, is not economical to transport long distances like coal. The dispersed locations of sources decrease the efficiency at which the material can be collected. It is only efficient to use biomass from within a close circumference of the generation plant. This can limit available options and create disparities between states. Additionally, the global warming potential or emission factor applied will vary by region and feedstock type. Annual crops would be valued as nearly carbon neutral and would have a nearly instantaneous benefit to the carbon balance. Woody biomass, would be valued as potentially carbon neutral with some uncertainty about the future carbon balance. Both are significantly less carbon intensive than fossil fuels, though these differences will create different opportunities for states to benefit from biofuels.

Under the various versions of cap and trade legislation and regional cap and trade initiatives, biomass energy is defined as renewable and carbon neutral, and generally excluded from the capped emissions, further promoting an energy policy that is not considering the sequestration of carbon that only occurs over time and is dependent on future actions. Accounting for the carbon benefits of biomass feedstocks will give credit to states where biomass is utilized, making the state energy system less carbon intensive per MWh. Additionally, being able to account for the atmospheric effects of additional carbon sequestration beyond the regenerative growth could create a tradable offset.

As biomass energy policy is developed, it is important to consider how projects will be evaluated against a fossil fuel alternative and how biogenic emissions will be accounted for in inventories. Not having complete information about the sources of generated energy and related emissions limits the analysis that is available for policy makers. The ability to evaluate energy policies for their full effect, which includes backing off fossil fuels and adopting alternative fuels, is necessary for analysis to guide policy programs.

Implication of the model for policy making

Bringing appropriate time scales for evaluation of emissions and sequestration into the debate also creates an opportunity to discuss the difference between policy-making time scales and the long-term climatic impacts resulting from policy decisions. Policymakers typically are concerned with short-term costs and benefits because of the election cycle and general shortsightedness of the evaluation of return on political investment (Kingdon 2002). Climate change requires a long-term view, but this has not necessarily been put into practice outside of climate science. The benefit of using biomass as an energy feedstock is only realized in the future, and only if certain expectations about the future are met. The impacts of greenhouse gas emissions are considered over a 100-year time horizon through the estimation of global warming potentials. The significant impacts from climate change are predicted to happen with high certainty, but only when looking 50 to 100 years into the future. These time scales are far beyond the short-term crises and immediate concerns that are the focus of most policy. Realizing benefits after a long period may not appear favorable either, regardless of shortsighted policy, because of discounting applied to future payoffs.

Energy policy is typically made with short-term goals in mind. The Next Generation Energy Act established a 10- 40- and 80-year emission reduction targets (Minn. Stat. 216H.02), but only the nearest target is considered with any seriousness (Ciborowski and Claflin 2011). Concern is much greater for the immediate reliability of energy supply and the impacts on the current consumers. The effect of decisions on the future generation has less weight than the effect on current constituents, from a political point of view focus on reelection and an economic perspective discounting future costs and benefits (Kingdon 2002). This seems to be the case regardless of the subject being considered.

Biomass energy sources require a longer view because they are so closely interlinked with time. Not only do the carbon benefits only accrue over time, but the supply of biomass is also time-dependent. There must be a sufficient supply of material, which may take many years between harvests to regenerate, and could require a very large area of land. The land management practices have to be reliably predicted far into the future, and could require long term contracts to guarantee sequestration. Many types of uncertainties about future actions make the carbon benefits from biomass energy difficult to ensure. Policy makers will have to decide if the long term costs and benefits outweigh the short term.

Conclusion

There are certainly other pieces of information to include in any debate about biomass energy policy. Creating the demand in other countries for deforestation, exploiting resources in developing countries, or shifting agriculture away from food production all have very real impacts on people and the environment. There is especially concern that policies promoting the use of biomass will cause the demand for biomass feedstocks to outpace production, and to cause rippling effects through commodities markets and environmental degradation (Fargione, et al. 2008). While we cannot account for these indirect impacts, or attribute a driving force behind them, understanding the climate impacts of biomass energy is an improvement over the current methods.

Using the feedstock approach and the global warming potential model to account for biogenic CO_2 emissions will accomplish the goal of creating meaningful information to policy makers and provide the EPA with a methodology that fulfills their criteria to roll biogenic CO_2 emissions into the regulatory framework. This option provides the most scientifically sound methodology while balancing practical ease of use. By using the approach that does include biogenic CO_2 emissions in inventories and regulatory decisions, the relationship between biomass energy policy, energy generation activity, emissions, and impacts will be retained. While there are still uncertainties to be dealt with, this method acknowledges the regrowth of biomass over time and provides a place for improvements, when the information is known.

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Appendix A: Excerpt from EPA request for comment on the deferral of the application of the Prevention of Significant Deterioration (PSD) and Title V Programs to CO_2 emissions from bioenergy and other biogenic sources.

I. General Information

A. What is the purpose of this action?

This action proposes to defer for a period of three (3) years the consideration of CO 2 emissions from bioenergy and other biogenic sources (hereinafter referred to as "biogenic CO 2 emissions") when determining whether a stationary source meets the Prevention of Significant Deterioration (PSD) and Title V applicability thresholds, including those for the application of Best Available Control Technology (BACT). Stationary sources that combust biomass and construct or modify during the deferral period will avoid the application of PSD to the biogenic CO 2 emissions resulting from those actions. This deferral applies only to CO 2 emissions and does not affect non-GHG pollutants or other greenhouse gases (GHGs) (e.g., methane (CH 4) and nitrous oxide (N 2 O)) emitted from the combustion of biomass fuel. Also, this does not affect any other EPA programs that pertain to stationary sources, such as New Source Performance Standards (NSPS) or the GHG Reporting Program.Show citation box

On January 12, 2011, EPA explained in letters to Members of Congress and to the National Alliance of Forest Owners (NAFO), the steps that the Agency intends to take to address the issues associated with biogenic CO 2 emissions from stationary sources. First, EPA granted a Petition for Reconsideration filed by the NAFO on August 3, 2010, related to the PSD and Title V Greenhouse Gas Tailoring Rule (75 FR 31514, June 3, 2010) ("Tailoring Rule"). Second, the Agency is proposing this rule to defer for three years the application of the PSD and Title V permitting requirements to biogenic CO 2 emissions from stationary sources. Third, concurrent with this rulemaking, we are providing an interim guidance document (discussed further in section III.D.3) to help permitting authorities establish a basis for concluding that BACT for biogenic CO 2 emissions at stationary sources is the combustion of biomass fuels by itself. Fourth, EPA will be conducting a detailed examination of the science associated with biogenic CO 2 emissions from stationary sources. This examination will include discussion with partners and scientists both inside and outside the Federal government, as well as engagement with an independent scientific panel, to consider technical issues that the Agency must resolve in order to account for biogenic CO 2 emissions in ways that are scientifically sound and also manageable in practice (discussed further in section II.C and II.D). Finally, EPA intends to use the feedback from the scientific and technical review to develop a rulemaking on how these emissions should be treated and accounted for in PSD and Title V permitting.

(EPA 2011)

Appendix B: Demonstration of alternatives with hypothetical alternatives

Table 1: Comparison of carbon dioxide and carbon dioxide equivalent emissions from coal and biofuels. The same generation efficiency is assumed for each fuel so that equal energy inputs are required. The carbon intensity per unit of energy is used to calculate the resulting emissions. Using estimated GWPs, the biogenic carbon dioxide emissions are discounted and expressed as CO_2-equivalent emissions. Woody biomass emits more CO_2 directly, but because regrowth and carbon re-uptake is accounted for, the atmospheric effect is approximately an order of magnitude lower than coal. Annual crops, because of the short regrowth cycle, have an even lower atmospheric effect.

	Bituminous Coal	Woody Biomass	Annual Crop Residue
Hypothetical Energy Requirement	100 MMBtu	100 MMBtu	100 MMBtu
lb CO_2/MMBtu (Ciborowski and Claflin 2011)	205.08	227.18	176.74
Tons CO_2 emitted	10.25	11.36	8.84
GWP (From unpublished work supporting MPCA comment to EPA)	1	0.07	0.01
CO_2-equivalent Tons	10.25	0.80	0.09