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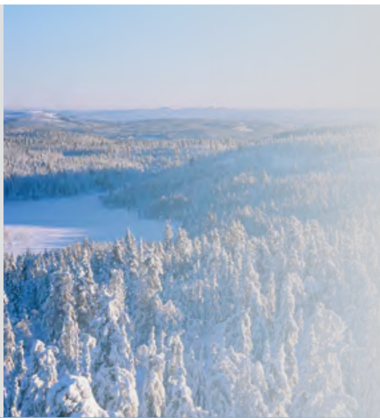


Recommendations on

Biomass Carbon Neutrality

wbcsd forest solutions

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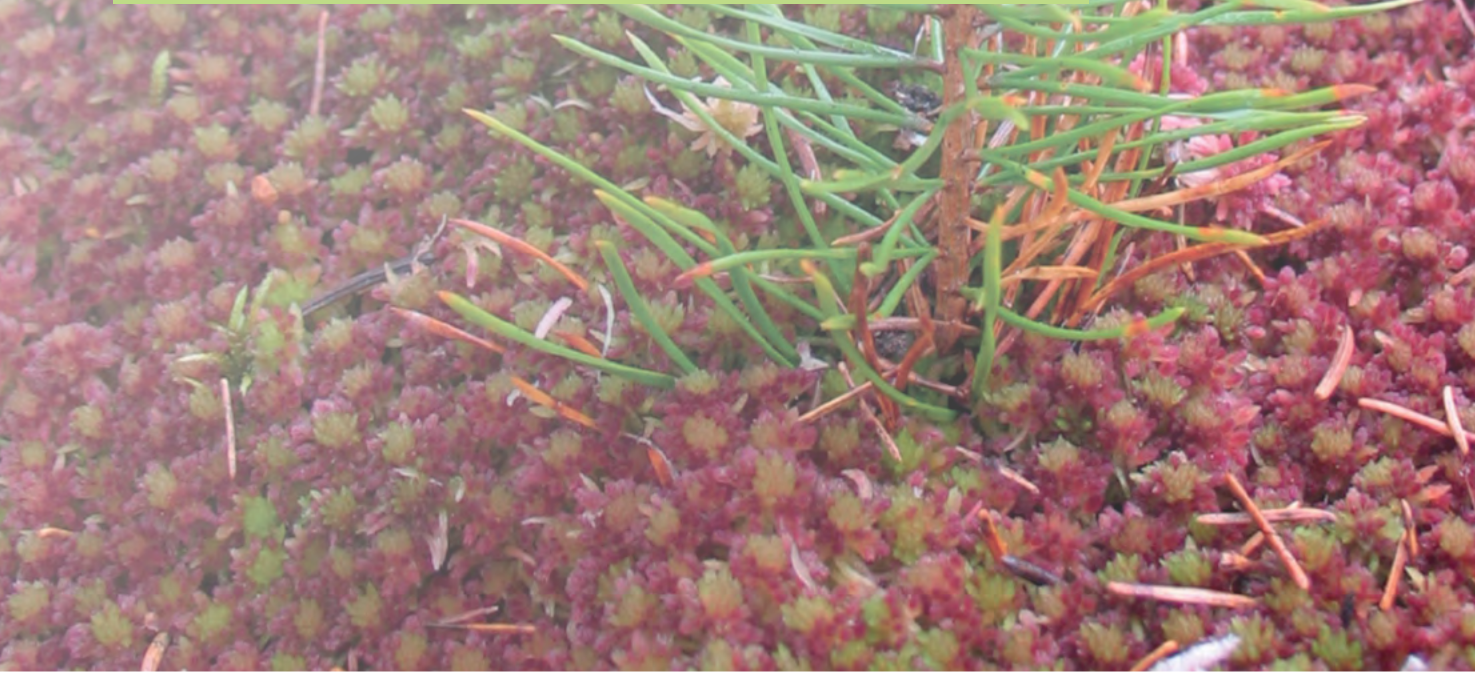


Carbon Neutrality: Forest Solutions Group's key recommendations for Policy Makers

What is carbon neutrality? – The Forest Solutions Group (FSG) defines carbon neutrality as a property of wood or other biomass harvested from forests where new growth completely offsets losses of carbon caused by harvesting. Under these conditions, as carbon is released from harvested wood back into the atmosphere, usually as biogenic CO_2, growing trees are removing CO_2 from the atmosphere at a rate that completely offsets these emissions of biogenic CO_2, resulting in net biogenic CO_2 emissions of zero or less. A forest producing carbon neutral wood will have stable or increasing stocks of forest carbon.

Why is carbon neutrality important? – Wood produced from forests with stable carbon stocks (i.e. carbon neutral wood) can be used without causing long term accumulation of carbon in the atmosphere. This is because the carbon in the wood removed from the forest, which will eventually return to the atmosphere, is offset by carbon in CO_2 removed from the atmosphere by growing trees. The use of carbon neutral wood in applications where it displaces fossil fuels, either directly or indirectly, contributes to efforts to reduce the accumulation of CO_2 in the atmosphere.

What can be carbon neutral? – Forests can be carbon neutral. Wood can be carbon neutral. The biogenic carbon in products and fuels made from carbon neutral wood and biomass is carbon neutral. Biomass residuals used for energy, such as forest products manufacturing residuals, also are considered carbon neutral because the carbon they contain would normally return to the atmosphere quickly, regardless of whether the residuals were used for energy

How can you tell if wood is carbon neutral? - If wood-producing forests have stable or increasing carbon stocks, they are producing carbon neutral wood. Assessments of forest carbon stocks should include all pools of forest carbon (e.g. above ground, below ground, litter) that are likely to be impacted by wood production. The area and time used to determine if forest carbon stocks are stable will vary and can significantly affect judgments regarding trends in forest carbon. The area used to judge the stability in forest carbon stocks should, however, include all areas providing wood for current and future use. The time used should be long enough to avoid being misled by temporary changes in forest conditions and to allow significant carbon impacts associated with past practices to be identified where they are associated with wood now being produced. Temporal and spatial scales for assessing forest carbon impacts are discussed in more detail in the Technical Background material.

Do products made from carbon neutral wood cause zero greenhouse gases? – No. Fossil fuels are used to transport wood and products and to produce forest products. In addition, small amounts of minor greenhouse gases (i.e. methane and nitrous oxide) are produced when biomass is burned and methane can be released from landfills receiving biomass products at end of life.

Does everyone accept this definition of carbon neutrality? – There are many different opinions as to the definition of carbon neutrality. Some people say that biomass is carbon neutral only if there are lower emissions of biogenic carbon as a result of using the biomass compared to a situation where it is not used. In other cases, products are called carbon neutral because the manufacturer has purchased carbon offsets equal to the life cycle emissions of the product. The Forest Solutions Group understands these concepts, which are discussed in more detail in the Technical Background Material, but has concluded, for reasons discussed in this issue brief, that the most appropriate way to define carbon neutrality is as explained above.

Uses and limitations of this definition of biomass carbon neutrality: The Forest Solutions Group definition of biomass carbon neutrality is primarily useful in understanding the actual biogenic CO_2 emissions associated with producing and using wood and other forest biomass. The actual net emissions of biogenic CO_2 attributable to carbon neutral wood are zero or less. The primary limitation of the Forest Solutions Group definition of biomass carbon neutrality is that it does not provide information on how the use of biomass might affect atmospheric greenhouse gases relative to a scenario where that biomass is not used. In addition, it must be understood that the examination of options for reducing societal emissions of greenhouse gases to meet future targets requires analyses that go far beyond the question of whether wood is carbon neutral.

Summary of the Forest Solutions Group's recommendations on biomass carbon neutrality

Introduction & purpose

Using biomass-derived fuels and materials instead of fossil fuel-intensive alternatives is one approach to mitigating increases in atmospheric CO_2. The benefits of using biomass are under question, however, with the debate often centered on whether biomass is "carbon neutral". As there is no widely accepted definition and different people understand it to have different meanings, the concept of "carbon neutrality" can be confusing.

Yet, the concept of carbon neutrality is important in public policy efforts to address climate change and potentially affects the forest-based industry, depending on how carbon neutrality is understood and applied. To the extent forest products and biomass are treated as carbon neutral, policies will tend to favor their development and use, for example as a source of bioenergy or "green" building materials. To the extent they are not treated as neutral, policies may disfavor their use or impose costs to measure, track, or control sources that limit their practical application. These policies can affect traditional as well as emerging uses of forest products and biomass.

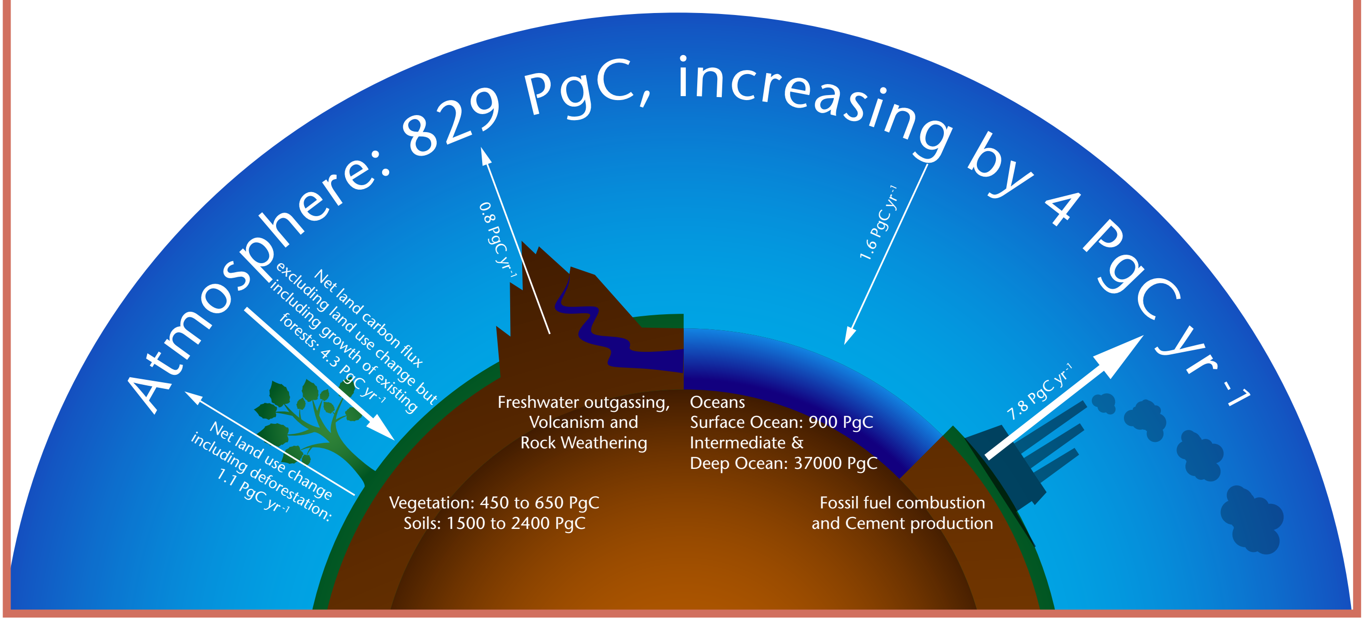
This issue brief is divided into two parts. The first describes the recommendations of the Forest Solutions Group on how to understand biomass carbon neutrality. The second part consists of Technical Background material that examines the issues related to the determination of biomass carbon neutrality and how they relate to forest carbon in particular. The aim of the Technical Background material is to help the reader understand the debate as it relates to forest-based biomass.

The biomass carbon cycle

Photosynthesis converts radiant energy from the sun and CO_2 from the air into the chemical energy stored in plant tissue, also called biomass. Biomass, therefore, can be thought of as stored solar energy. When biomass is burned, decays or is otherwise oxidized, the chemical energy is released and the CO_2 is placed back into the atmosphere, completing a natural carbon cycle. The carbon in biomass is called "biogenic carbon" and the CO_2 formed when biomass is burned is called "biogenic CO_2".

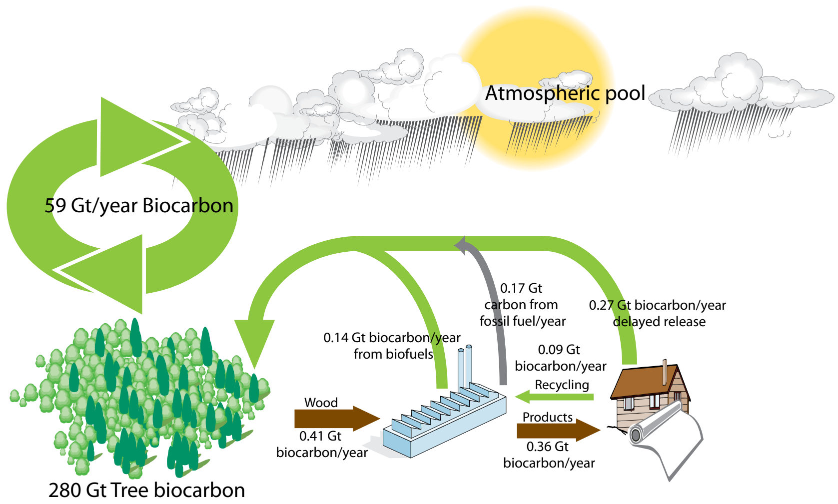
When the releases of biogenic carbon to the atmosphere are being completely offset by removals of CO_2 back into growing biomass, this carbon cycle is in balance. This is

Figure 1: Global carbon flows to and from the atmosphere (IPCC 2013)



Source: IPCC Fifth Assesment Report WGI report-Figure 6.1
Line width proportional to amount of flow

Figure 2: The forest products industry in the global carbon cycle



The carbon removed from the forests by the forest industry represents only about 0.7% of the carbon that is recycled between the forest and the atmosphere annually, and less than 0.14% of the carbon stored in trees in the world's forests.

Source: NCASI calculations based on FAO 2010a and 2011, Beer et al. 2010 and IPCC 2003 and 2007c

true whether the forest is affected by human activity or not. Under these conditions, the forest carbon "stock" is stable or increasing and the release of biogenic CO_2 resulting from the use of biomass within that cycle does not cause atmospheric CO_2 to increase. This concept is central to a large number of greenhouse gas inventory programs. The reporting guidelines of the Intergovernmental Panel on Climate Change (IPCC), for instance, calculate emissions of biogenic carbon based on the change in biogenic carbon stocks (including all above- and below-ground pools and carbon stored in harvested wood products) over a year's period. If the overall total does not change, the net emissions of biogenic carbon are zero[1]. While there are uncertainties in the estimates, there is general agreement that at the global scale, at present, the forest biomass carbon cycle is not only in balance, it is accomplishing net removals of carbon dioxide from the atmosphere (Pan et al. 2011). This net sink is due, in part, to regrowth in existing forests and to faster plant growth caused by the increases in atmospheric CO_2 (Pan et al. 2011 and IPCC 2013).

Biomass combustion and decay release CO_2 and some argue that biogenic CO_2 should be treated no differently than the CO_2 from fossil fuel: both have the same effect on the atmosphere. While CO_2 is emitted from both biomass and fossil fuel combustion, the use of biomass has a very different net effect on the atmosphere than the use of fossil fuel.

Box 1: Using sustainably produced forest biomass benefits society, the economy and the environment by:

1. Providing economic incentives to keep land forested, thus providing a sustainable source of income to forest landowners and communities living in forests
2. Protecting, through sustainable forest management practices, the ecological values of the forests (e.g. climate regulation, watershed protection, biodiversity conservation)
3. Sequestering carbon in the trees and in the soil, through the active and sustainable management of forests
4. Storing carbon in harvested wood products while in use
5. Providing substitutes for raw materials that are not renewable and more carbon intensive, such as fossil fuels
6. Generating renewable energy at the end of the product's life, and thus fully leveraging the use hierarchy of forest fiber

1 The estimated national emissions of biogenic carbon will also be influenced, however, by the imports and exports of wood by a country.

The carbon in biomass was only recently removed from the atmosphere and is destined to return to the atmosphere whether it is harvested or not. Harvesting alters the timing but as long as the forest carbon cycle is kept in balance, the return of the biomass carbon to the atmosphere does not increase overall CO_2 levels over time. This is very different from fossil fuel carbon, which has been stored in the earth for millions of years and would not return to the atmosphere - increasing CO_2 levels - if it were not extracted for use today.

To understand the biogenic carbon impacts of using wood from sustainably managed working forests, one needs to think about how wood is grown and used. When forests are managed sustainably, as wood is harvested on some plots the trees on many other plots are growing. These growing plots are critical to the long-term supply of raw material and are as much a part of a company's value chain as those harvested now. As forest science advances and markets change, companies adjust management activities such as fertilization and thinning practices across the landscape in ways that affect future forest area, growth and productivity. As a result, to understand and model the forest carbon cycle it is important to examine carbon flows across a landscape, not just a single plot.

The carbon benefits of using biomass

The products of the forest-based industry meet a wide range of societal needs, ranging from providing shelter to preserving the written word and printed image. Making products from forest biomass can be thought of as a new step in the forest carbon cycle. If this is accomplished while keeping the forest carbon cycle in balance, the world benefits from these products while keeping net releases of biogenic carbon to the atmosphere at zero.

The use of biomass carbon within a balanced cycle, however, does not fully explain the benefits of biomass for the mitigation of greenhouse gas emissions. Forest products store carbon, keeping it out of the atmosphere, sometimes for extended periods. The primary benefits occur, however, because biomass-based products can often be used in place of other materials or products that would have resulted in larger releases of fossil fuel carbon, or other greenhouse gases. This is sometimes called a "substitution effect". Some substitution effects have been studied extensively. The greenhouse gas benefits of using wood instead of other construction materials and of using biomass as a source of fuel, for instance, are the subject of a large and growing body of literature (e.g. Sathre et al. 2010). In the future, many other products, such as tree-derived chemicals and plastics, may be produced from trees and these new forest products may yield additional substitution benefits as they displace conventional products. Substitution benefits are based on the life cycle emissions of all greenhouse gases and therefore reflect much more than the net emissions of biogenic carbon. Nonetheless, the use of carbon neutral wood provides evidence that wood production is not a net source of biogenic CO_2. The use of carbon neutral wood in these applications, therefore, contributes to efforts to limit the accumulation of greenhouse gases in the atmosphere.

Using forest biomass can also have important, but indirect, carbon benefits. Perhaps most important are the benefits of markets for forest biomass, which, in countries with good governance, the rule of law and public policies that value the role of working forests, provide economic incentives to keep land forested. Without these markets owners of wood-producing land would have reason to convert forest land to other non-forest uses, including agricultural crops, releasing the stored forest carbon to the atmosphere and losing the other environmental and societal benefits that forests provide. Indeed, an assessment of global patterns of deforestation found that "In general, the data show that global regions with the highest levels of industrial harvest and forest product output are also regions with the lowest rates of deforestation (Ince 2010). This phenomenon can also be seen in the trends in carbon stocks in forest biomass, which, between 2005 and 2010, increased in regions of the world representing 70% of global industrial roundwood production (data from FAO 2010b and FAOSTAT 2014).

Forest conditions vary enormously from one place to another. In many temperate forests, forest area is increasing as a result of forest returning to land that was deforested in past centuries. This land now remains in forest, in part, because of the economic value of the wood it produces. New working forests are being established every year that produce far more wood per hectare than natural forests. Where this occurs on land with low carbon stocks, the establishment of new forests results in net removals of carbon from the atmosphere. On the other hand, where new working forests replace natural forests, forest carbon stocks are often reduced, although these losses can often be offset by the reduced societal emissions of greenhouse gases attributable to the increased production of wood products that displace more greenhouse gas intensive alternatives.

Deforestation and forest degradation continue to be problems in tropical forests, but the rate of deforestation is slowing rapidly, as it did in temperate forests over previous centuries (FAO 2012) .While the proximate causes for deforestation are often expansion of crop and grazing land, the underlying causes are more complex. The United Nations Intergovernmental Forum on Forests has suggested twelve underlying causes of deforestation and forest degradation which vary among countries but include poverty, lack of good governance, undervaluation of forest products and ecosystem services and national policies that distort markets and encourage the conversion of forest land to other uses (FAO 2012).

Although research studies differ on the short-term benefits associated with using forest biomass-based products, virtually all studies agree that, in the long term, the use of forest biomass produced under conditions where forest carbon stocks remain stable results in net benefits to the atmosphere. In the words of the IPCC, *"In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fiber or energy from the forest, will generate the largest sustained mitigation benefit"* (IPCC 2007b).

The considerations involved in assessing the benefits of using forest biomass under different circumstances are addressed in more detail in the Technical Background material.

Box 2:
Demand for forest products helps keep land in forest and can increase carbon stocks

> "Rather than leading to wide-scale loss of forest lands, growing markets for tree products can provide incentives for maintaining or increasing forest stocks and land cover, and improving forest health through management" (IPCC 2014).

Carbon neutrality

The WBCSD Forest Solutions Group believes that carbon neutrality is best understood as a condition wherein the releases of biogenic carbon to the atmosphere are completely offset by forest growth. Box 3 describes a framework for understanding this concept. The framework described requires attention to many details in determining the carbon neutrality of wood. In spite of the complexities, however, there are several important generalities that can be drawn.

First, because sustainable forest management is broadly consistent with the maintenance of stable forest carbon stocks, it is also an essential element in demonstrating carbon neutrality.

Second, because forest biomass is produced from solar energy, products made from sustainably produced forest biomass will often have far lower life cycle carbon footprints than products made from alternative materials. This does not mean that these products are "carbon neutral", but it suggests that societal emissions may be reduced by substituting these products for those that are more greenhouse gas-intensive. These benefits can be revealed through carefully conducted life cycle and carbon footprint studies performed according to appropriate standards,
for example International Organization for Standardization life cycle standards and World Resources Institute/WBCSD GHG Protocol Carbon Footprint Standards for Products and Value Chains.

Box 3:
A framework for understanding carbon neutrality in the context of forests and forest products

Carbon neutrality describes a condition in which emissions of biogenic carbon to the atmosphere are completely offset by new growth, resulting in net emissions of zero. (This is described as "carbon–cycle neutrality" in Table 1 in the Technical Background Material below.) Several concepts are important to understanding this view of carbon neutrality:

- Carbon neutrality is an attribute of biogenic carbon and biogenic CO_2.
- When forest carbon stocks are stable over a landscape, it is an indication that net releases of forest carbon to the atmosphere are zero. This explains why sustainable forest management practices, which require forest regeneration adequate to provide a long term supply of wood, are important to achieving carbon neutrality, even though carbon may not be specifically tracked in sustainable forest management programs.
- The area and time used to determine if forest carbon stocks are stable will vary. The area used to judge the stability in forest carbon stocks should, however, include all areas providing wood for current and future use, including, where relevant, surrounding areas with overlapping influences that can cause "leakage". The time used should be long enough to avoid being misled by temporary changes in forest conditions and to reflect past carbon impacts attributable to the wood currently being produced
- In practice, carbon neutrality should be determined based on actual net releases of biogenic carbon to the atmosphere over a period. This period begins at a "reference point" and the calculations are done using this reference point as a baseline. Other types of baselines may be useful for other purposes, but reference point baselines are the most practical and reliable for use in policies and regulations involving the neutrality of forest carbon.

Regulatory definitions of carbon neutrality: The importance of baselines

Greenhouse gas inventories, like those developed under IPCC guidelines, use reference point baselines, meaning that they use a point in time as the starting point for the accounting. The results of the accounting represent the actual net releases of greenhouse gases to the atmosphere over a period of time.

There are other types of baselines. Policy analysts often use predicted business-as-usual conditions as a baseline (also referred to as an anticipated future baseline). Using this approach, emissions are counted only to the extent that they are more or less than those predicted under business-as-usual conditions (i.e. in the absence of the activity in question).

Business-as-usual baselines can be useful in policy analysis but, in the view of the WBCSD Forest Solutions Group, they are not appropriate for implementing regulatory or market-oriented programs. There are several important reasons.

Business-as-usual baselines require many assumptions about what would have occurred in the absence of the activity, so the results of the analysis are often highly uncertain. Of course, there are always uncertainties in estimating forest carbons stocks but the assumptions and uncertainties associated with projecting business-as-usual baselines are in addition to those that affect all estimates of forest carbon. These assumptions and uncertainties involve a range of issues, from economic conditions to technological changes.

Uncertainties in future economic conditions and wood supply and demand

The rate of change in forest carbon stocks is directly connected to harvesting rates and investments in forestry (e.g. regeneration activities, productivity improvements, afforestation) which are, in turn, a function of the condition of the economy. Errors in economic forecasting, therefore, result in errors in projected business-as-usual baselines for forest carbon stocks.

Future economic conditions are notoriously difficult to predict. The abrupt downturn that began in 2008, also known as the Great Recession, was missed by most forecasters. The OECD, for instance, predicted in December of 2007 that the GDP of OECD countries combined would grow at 2.3% in 2008 and 2.4% in 2009 (OECD 2007). Instead, as a result of the Great Recession, GDP growth was 0.2% in 2008 and -3.6% in 2009 (OECD 2014).

The uncertainties in predicting economic growth have direct implications to predictions of wood demand and net emissions from forests over time, predictions that form the basis of business-as-usual baselines. In the U.S., for instance, harvesting was 25% lower in the period 2008 through 2012 compared to the previous five years, which required revisions to recent baseline projections that had not accounted for the impact of this on future forest carbon stocks (Ince and Nepal 2012, Nepal et al. 2014) Uncertainties in future wood supply and demand are also directly related to uncertainties in future policies regarding land use, trade, subsidies, incentives and mandates that affect forest-based materials.

Box 4: Carbon neutrality and Carbon debt

Carbon debt is incurred when the use of biomass results in a temporary increase in atmospheric greenhouse gases relative to what the atmosphere would have seen if that biomass had not been used.

Some examples might include;

- The increased use of wood for energy compared to a scenario where that wood is not harvested, or
- The use of forest harvest residues for energy compared to a scenario where they are allowed to remain in the forest to decay slowly.

In either case, in the short term, the atmosphere will likely see higher emissions of carbon from the scenario that uses the biomass for energy than from the alternative scenario. This is because (a) wood generally burns less efficiently than fossil fuels, (b) in the alternative scenarios the biogenic carbon emissions are delayed and, (c) in the case of using wood for energy, additional removals of carbon from the atmosphere occur as trees continue to grow.

The concept of carbon debt, however, is not relevant to the Forest Solutions Group definition of carbon neutrality. The Forest Solutions Group definition does not involve a comparison of a biomass scenario to an alternative, non-use scenario where a non-wood material or fuel is used. Instead, the Forest Solutions Group definition of biomass carbon neutrality is concerned only with the actual net emissions of biogenic carbon from the biomass system itself.

Uncertainties in future energy prices

One of the important factors that will affect the rate of growth in using forest biomass for energy is the cost of alternative fuels. Business-as-usual scenarios, therefore, need to incorporate assumptions about future fuel prices. Predicting fuel prices, however, has proven difficult. In 2013, the Energy Information Administration of the U.S. Department of Energy examined the accuracy of its past forecasts, starting in 1993 (EIA 2013). Analysis of the EIA data indicates that when predicting prices just five years into the future, one-quarter of EIA estimates for oil prices were incorrect by more than 50% while one-third of the predicted natural gas prices were wrong by at least 50%.

Uncertainties in future technology

Business-as-usual projections of forest carbon stocks require assumptions about the changes in forest productivity over time. Because of the uncertainties in future forest productivity, it is often assumed to be constant, but history has proven that this is an extremely conservative assumption. Forests managed for wood production continue to experience increasing productivity, producing more wood per hectare, often while simultaneously allowing forest carbon stocks to remain stable (e.g. Fox et al. 2004).

Uncertainties in future economic conditions, wood demand, energy prices and technology make programs based on business-as-usual baselines prone to unintended consequences that can be environmentally and economically counterproductive.

When forest carbon stocks on wood-producing land are stable or increasing, it means that removals of biomass from the forest are being offset by growth. It also means that releases of biogenic CO_2 to the atmosphere from using biomass for energy production are being offset by removals of CO_2 from the atmosphere by growing trees, resulting in net zero releases to the atmosphere. Where wood is used to make products, the emissions of biogenic CO_2 are delayed, but as long as long-term forest carbon stocks remain stable, these emissions are also offset by removals of CO_2 by growing trees. Under these conditions, policies that attach a liability to biogenic CO_2 merely because short term emissions of biogenic carbon are higher than a business-as-usual scenario are likely to have a number of counterproductive effects on forests and on atmospheric GHGs.

First, because biomass is used for energy in producing almost all forest-based products, an emissions liability for

Box 5: Business-as-usual carbon stock baselines depend on future economic conditions, which have always been difficult to forecast

Oller and Barot (2000) examined forecasts made of GDP growth in Europe between 1970 and 2000 by 13 national institutes and the OECD and found that "… there have been three major recessions in the period studied: (1) the mid-1970s, (2) the early 1980s…and (3) the early-1990s. Did the forecasters issue correctly timed signals? The sad answer is, only in rare cases". Without accurate economic forecasts, it is not possible to accurately predict future harvesting rates and future forest carbon stocks as needed to produce reliable business-as-usual baselines.

Box 6: Demand for wood helps preserve and expand forested area

Lubowski et al. (2008) examined factors causing land use change in the United States between 1982 and 1997. They "…identified the rise in timber net returns as the most important factor driving the increase in forest areas." Net returns to forest lands could be reduced if an emissions liability was attached to biogenic CO_2.

biogenic CO_2 is likely to increase the cost of making wood and paper products, resulting in their being less competitive against non-wood alternatives. To the extent that this results in the use of more fossil-fuel intensive non-wood materials, the atmosphere will see higher levels of fossil fuel-related GHGs, and sooner or later, higher levels of total GHGs. The same is true for biomass used to produce electricity or heat outside of forest products manufacturing operations. Attaching an emissions liability to biogenic CO_2 where none now exists would have the effect of increasing the relative costs of biomass-derived electricity compared to electricity produced from fossil fuel.

Second, the loss of competitiveness of wood-based products and energy would result in a reduced demand for wood and, especially in places where wood is grown on private land, would cause landowners to consider other uses for the land, most of which would result in the loss of forest area and forest carbon.

Business-as-usual baselines do not reveal the actual net releases of carbon to the atmosphere.

When deciding on an approach to characterize emissions of biogenic CO_2, it is important to decide what the analysis is intended to accomplish. In many cases, one is interested in knowing the actual net emissions associated with a system or practice. This might be the case, for instance, in regulatory programs where there are legal consequences associated with exceeding allowed emissions. Emissions estimated using business-as-usual baselines are not actual emissions but rather emissions relative to a hypothetical business-as-usual condition. Only when emissions are determined using reference point baselines are the results equal to actual net emissions.

For these reasons, the Forest Solutions Group recommends the use of reference point baselines in regulatory and market-based programs.

There are, of course, applications where business-as-usual baselines are important. Certain types of studies require business-as-usual baselines. In particular, studies of the impacts of a policy on forest carbon stocks can only be understood when the projected stocks are compared to those that would exist at the same point in time without the policy (i.e. under business-as-usual conditions). As a part of such assessments, the sensitivity of the results to uncertainties in the business-as-usual projections can be examined and resulting insights on uncertainty can be used to interpret and apply the results. The ability to apply judgment in interpreting the significance of uncertainties is critical to properly using research studies to inform policy development. The fact that business-as-usual baselines are useful in studies used to inform policies, however, does not mean that business-as-usual baselines are needed to implement these policies.

As an example, consider rules on automobile fuel efficiency. New rules may be developed based on studies indicating that updated efficiency standards, phased in over time, would result in reduced fuel consumption across the nation's fleet of automobiles relative to what would occur given the business-as-usual rate of improvement in fuel efficiency. The rules themselves, however, are likely to contain requirements to achieve a certain absolute efficiency (e.g. kilometers per litre), rather than requirements to obtain an efficiency that is X% greater than what would be expected under business-as-usual conditions. Even though the absolute efficiency standard does not reflect the business-as-usual baseline used to estimate the benefits of the standard, it accomplishes the desired policy objective while being easier to implement and less uncertain.

Ultimately, the approaches used to regulate biogenic CO_2 in regulatory programs must be developed with a range of policy considerations in mind. While these approaches

may be informed by studies using business-as-usual baselines, there are a range of issues to consider that may suggest different types of baselines, or even different policy instruments (e.g. supply side incentives), as more effective than regulations based on a direct replication of the calculations in policy studies. Some of these issues are addressed in more detail in the Technical Background material.

Box 7: Methodologies that are consistent with the Forest Solutions Group's definition of carbon neutrality

There are a number of standards, guidelines, protocols and tools that are generally consistent with the Forest Solutions Group's definition of biomass carbon neutrality. These include:

- The IPCC's Guidelines for National Greenhouse Gas Inventories, intended for use by national governments but also applicable, in concept, to other types of entities; issued by the Intergovernmental Panel on Climate Change and available at **www.ipcc.ch**
- The GHG Protocol Product Life Cycle Accounting and Reporting Standard; issued by WRI and WBCSD and available at **www.ghgprotocol.org**
- ISO Technical Specification 14067 – Carbon Footprint of Products; issued by the International Organization for Standardization and available at **www.iso.org**
- The Forest Industry Carbon Assessment Tool (FICAT): a product of the International Finance Corporation and NCASI and available at **www.FICATmodel.org**

These methodologies address greenhouse gases besides biogenic CO_2, but nonetheless contain provisions addressing biogenic carbon. They all allow emissions of biogenic CO_2 to be offset against removals of CO_2 from the atmosphere by growing trees (although in some cases the calculations are performed based on forest carbon stocks rather than CO_2 flows). They are generally aligned with the use of reference point baselines. They require accounting for the carbon impacts of activities that cause forest carbon stocks to increase or decrease (e.g. deforestation, afforestation, and forest conversion).

Using manufacturing residuals for energy

It is generally accepted that *"…biomass should be credited for reducing emissions to the extent it results…from the use of residues or biowastes"* (Searchinger et al. 2009). The global forest products industry relies heavily on manufacturing residuals for energy. Manufacturing residuals are produced as a consequence of processing wood to make wood and paper products. The manufacturing residuals used in greatest quantities by the industry are woody mill residuals (e.g. bark and sawdust) and spent pulping liquor[2]. Woody mill residuals and pulping liquor together comprise more than 50% of the fuel used by the forest products industry globally (ICFPA 2013).

The greenhouse gas benefits associated with using these residuals for energy are easy to understand. If they were not used for energy they would be discarded, allowing the carbon to return to the atmosphere without producing energy, requiring the use of fossil fuels instead. If these residuals were disposed by incineration, the atmosphere would see essentially the same biogenic carbon releases as if the material was burned for energy. If the alternative to using for energy was disposing in a solid waste disposal site, the biogenic carbon would be released over time. While this delay might result in lower biogenic carbon releases to the atmosphere in the short term compared to using the residuals for energy, the benefits would be short-lived. This is because solid waste disposal sites convert some of the biogenic carbon into methane, which is a far more potent greenhouse gas than CO_2. As a result, when these residuals are used to displace fossil fuels, and the avoided fossil fuel emissions are also considered, the atmosphere typically sees GHG benefits in a year or less (Gaudreault and Miner 2014).

2 Spent pulping liquor is a combination of dissolved wood (primarily lignin) and spent chemicals used in the pulping process. When burned in a special furnace, the dissolved wood releases large amounts of energy, which is used by the mill, and the chemicals are regenerated for the pulping process.

Technical background

Understanding the debate over carbon neutrality

Background

Unfortunately, there is no widely accepted definition of carbon neutrality. Indeed, there are a number of different meanings implied by the term, as illustrated in the following table. In some cases, the definitions are mutually exclusive while in other cases they are mutually reinforcing. It is clear, for instance, that carbon cycle neutrality is an important element in addressing interest in substitution neutrality as it ensures that carbon impacts in the forest are not diminishing the substitution benefits observed on a lifecycle basis. Nonetheless, the different potential meanings of carbon neutrality reflect fundamentally different concerns and require fundamentally different calculation methods to assess.

This seemingly simple question about carbon neutrality is, therefore, actually a debate about (a) which concept should be attached to the term, and (b) how to calculate the impacts reflected in that concept.

The biomass carbon cycle

Photosynthesis is a process of converting radiant energy from the sun and CO_2 from the air into the chemical energy of plant tissue (Hall and Kao 1999). Through photosynthesis, energy from the sun is used to convert the carbon in atmospheric CO_2 into plant tissue, also called biomass. Biomass, therefore, can be thought of as stored solar energy. The carbon in biomass is called "biogenic carbon" and the CO_2 formed when biomass is burned is called "biogenic CO_2". When biomass is burned, decays or is otherwise oxidized, the chemical energy is released and the CO_2 is placed back into the atmosphere, completing a natural carbon cycle. As long as this cycle is in balance, it has a net zero impact on the carbon in the atmosphere.

The carbon in fossil fuels is different from the carbon in biomass in that fossil fuel carbon is not part of a relatively rapid natural cycle. When fossil fuel carbon is removed from the ground and added to the atmosphere via combustion, this adds carbon to the atmosphere that has not been there for millions of years. It is past and current emissions of this carbon, from geologic sources, that is responsible for about three-quarters of the radiative forcing, a measure of the effects of greenhouse gases, that has occurred in the last 250 years. The remainder is attributable to land-use change and the associated transfer of biogenic carbon into the atmosphere (IPCC 2007a).

The forest biomass carbon cycle is in balance when the amounts of biogenic carbon being returned to the atmosphere via combustion and decay are equal to the amounts of carbon being removed from the atmosphere by growing forests. In trying to determine whether the forest carbon cycle is in balance, the answer will often depend on the scales of time and space used to examine the cycle. At larger spatial scales and averaged over time, the forest carbon cycle may be in balance, even though, at small spatial scales and for short periods of time, the forest carbon cycle appears to be out of balance.

Table 1: Definitions of carbon neutrality

Type	Definition	Example
Inherent carbon neutrality	Biomass carbon was only recently removed from the atmosphere; returning it to the atmosphere merely closes the cycle	All biomass is *inherently carbon neutral*
Carbon-cycle neutrality (this refers to the framework in Box 3)	If uptake of carbon (CO_2) by plants over a given area and time is equal to emissions of biogenic carbon attributable to that area, biomass removed from that area is carbon-cycle neutral	Biomass harvested from regions where forest carbon stocks are stable is *carbon-cycle neutral*
Life-cycle neutrality	If emissions of all greenhouse gases from the life cycle of a product system are equal to transfers of CO_2 from the atmosphere into that product system, the product system is life-cycle neutral	Wood products that store atmospheric carbon in long-term and permanent storage equal to or greater than life-cycle emissions associated with products are at least *life-cycle neutral*
Offset neutrality	If emissions of greenhouse gases are compensated for using offsets representing removals that occur outside of a product system, that product or product system is offset neutral	Airline travel by passengers who purchase offset credits equal to emissions associated with their travels is *offset neutral*
Substitution neutrality	If emissions associated with the life cycle of a product are equal to (or less than) those associated with likely substitute products, that product or product system is (at least) substitution neutral	Forest-based biomass energy systems with life-cycle emissions equal to or less than those associated with likely substitute systems are at least *substitution neutral*
Accounting neutrality	If emissions of biogenic CO_2 are assigned an emissions factor of zero because net emissions of biogenic carbon are determined by calculating changes in stocks of stored carbon, that biogenic CO_2 is accounting neutral	The US government calculates transfers of biogenic carbon to the atmosphere by calculating annual changes in stocks of carbon stored in forests and forest products; emissions of CO_2 from biomass combustion are not counted as emissions from the energy sector

Malmsheimer et al. 2011

In examining the forest carbon cycle within spatial scales defined by national boundaries and temporal scales spanning multiple stages of economic development a pattern emerges. As countries develop, there is often a loss of forest as land is converted into other uses, primarily agriculture. In developed countries, most of this conversion occurred between 1600 and the mid-1950s. It is now happening in many developing countries. This loss of forested land causes the carbon cycle to be out-of-balance as carbon stored in forests is removed from the land and, for the most part, returned to the atmosphere via combustion and decay.

Then, as agriculture becomes more productive, marginal agricultural land often reverts to forest, and in some cases, new forests are established on marginal agricultural land by planting. As a result, forest area expands and the amounts of carbon stored in forests increase (e.g. see Birdsey et al. 2006). Most developed economies are now in this situation.

Of course, there are many things that affect forest carbon stocks over large spatial scales besides agriculture. Natural disturbances such as fire and insect infestations can cause large scale losses of forest carbon (e.g. see Stinson 2011). In addition, factors such as conservation policies, land tenure, and markets for forest products can influence decisions on whether and how to keep land in forest, and these decisions can impact forest carbon stocks over large areas. Carbon stocks are also being affected by the fertilizing effects of increasing levels of CO_2 and nitrogen compounds in the atmosphere (IPCC 2013).

At present, the growth and expansion of forests globally is removing more carbon from the atmosphere than is being added to the atmosphere by combustion and decay of forest biomass, including that related to deforestation (Pan et al. 2011, IPCC 2013). In other words, the global forest biomass carbon cycle is not only in balance, it is currently a net sink for carbon from the atmosphere. Annual removals of CO_2 from the atmosphere are more than 1×10^9 tonnes CO_2 greater than the amounts of biogenic CO_2 returning to the atmosphere (Pan et al. 2011). At some point, at least in theory, this will cease, but in the long term, as long as global forest carbon stocks are maintained at a stable level, the global forest carbon cycle will be approximately in balance.

If the biomass carbon cycle is in balance over relevant dimensions of space and time then the release of biogenic CO_2 resulting from the use of biomass as part of that cycle does not cause levels of CO_2 in the atmosphere to increase with time. This concept is central to a large number of greenhouse gas inventory programs. The Intergovernmental Panel on Climate Change's (IPCC) greenhouse gas reporting guidelines, for instance, consider net emissions of biogenic carbon to be zero under circumstances where the net change in total stocks of carbon stored in forests (including all above- and below-ground pools) and forest products are zero (IPCC 2006). This is equivalent to a situation where transfers of biogenic carbon to the atmosphere from biomass combustion and decay are completely offset by carbon removals from the atmosphere, in CO_2, by growing biomass.

The carbon impacts of using forest-derived biomass

When products are produced using forest biomass, it can be thought of as inserting a new step in the forest carbon cycle. If this is accomplished while keeping the forest carbon cycle in balance, the world benefits from these products while keeping net transfers of biogenic carbon to the atmosphere at zero.

Those who question the value of using biomass as a mitigation measure sometimes argue that it is wrong to differentiate one type of CO_2 from another. As far as the atmosphere is concerned, they contend, the CO_2 from biomass is the same as the CO_2 from fossil fuels. While this is true, it misses an important fact. The carbon in biomass is destined to return to the atmosphere in the relatively near term whether it is harvested or not. Harvesting alters the timing of the return of this carbon to the atmosphere, but as long as the forest carbon cycle is kept in balance, the net additions of CO_2 to the atmosphere are zero. This is very different from fossil fuel carbon. Were it not for the extraction of this carbon from geologic reserves and its subsequent combustion, this carbon would not have entered the atmosphere. This is why fossil fuels and cement production account for 75% of the increase in atmospheric CO_2 in the last 250 years, in terms of radiative forcing (IPCC 2007a).

The use of biomass carbon within a balanced cycle, however, does not fully explain the benefits of biomass in mitigating greenhouse gas emissions. The primary benefits occur because many biomass-based products can be substituted for another material or product that would have resulted in larger releases of geologic carbon (e.g. fossil fuel carbon) or other greenhouse gases. This is sometimes called a "substitution effect" because it results from substituting a biomass-based material for another material.

The calculations of substitution effects can be complex and the results can be affected by a large number of variables and assumptions. Among these are (a) the amount of each product required to perform the same function, (b) the GHG intensity of the displaced product (e.g. the GHG intensity of electricity displaced from the grid), and (c) decisions on how to allocate loads in complex systems. Nonetheless, some substitution effects have been studied extensively. The benefits of using forest biomass instead of alternative materials, for instance in building construction and as a source of fuel, are subject of a large and growing body of literature (see Sathre & O'Connor 2010; Cherubini 2009; Marland 1997; Malmsheimer et al. 2011; Schlamadinger, 1996; Miner et al. 2014).

There are also important, but indirect, carbon benefits associated with using forest biomass. Perhaps most important are the benefits of markets for products and fuels derived from sustainably produced forest biomass that provide economic incentives to keep land forested, without which some landowners would convert forest land to other non-forest uses, including agriculture and cattle ranching, releasing the stored carbon to the atmosphere and losing the other environmental and societal benefits that forests provide (e.g. see Miner et al. 2014). Of course, the impacts of demand for wood can be detrimental if wood is produced outside of the framework of sustainable forest management.

The benefits calculated for a specific use of biomass depend, in part, on the method used to perform the calculations. The debate about these methods parallels the debate about the methods used to characterize carbon neutrality.

Carbon neutrality: the concept and debate

The term "carbon neutrality" has been used as a convenient way to describe how the use of biomass is different from the use of fossil fuels in terms of net transfers of carbon to the atmosphere. The term implies that, given a specific set of calculations, net transfers of carbon to the atmosphere associated with using biomass are zero.

Unfortunately, there is no standard definition of carbon neutrality and no agreement on the calculations needed to test claims of neutrality (Malmsheimer et al. 2011, NCASI 2013). Ultimately, the debate over carbon neutrality is about the methods used to estimate the impacts of using biomass on atmospheric greenhouse gases.

To understand the controversy, the basics of biomass carbon accounting need to be understood, along with the factors that must be considered in selecting accounting options.

Biomass carbon accounting basics

Most of the debate about the benefits of using biomass, especially in situations where doing so reduces societal consumption of fossil fuels, regards questions of system boundaries, the greenhouse gases to include and baselines.

SYSTEM BOUNDARIES

In calculating the net impacts associated with using biomass, or an alternative material, to satisfy a given function, such as producing 1 kWh of electricity, or building a single family house with 200 m^2 of living space, it is necessary to establish the boundaries of the system(s) to be characterized. In particular, it is necessary to establish physical boundaries, organizational boundaries, spatial boundaries, and temporal boundaries.

PHYSICAL BOUNDARIES

Generally, to calculate the impacts on the atmosphere, it is necessary to examine the entire product system, consisting of all processes connected by flows of material or energy – i.e. the full life cycle. The assessment then focuses on greenhouse gases that enter or leave this product system. It is important to include flows of carbon to and from the atmosphere from all carbon pools in the system including any above and below ground forest carbon pools that are likely impacted by wood production. In the case of biomass-based systems, the processes included within the system boundaries usually include photosynthesis. With photosynthesis included within system boundaries, atmospheric carbon enters the system and is converted into biomass within the system. If photosynthesis is outside of the system boundary, the system accomplishes no removal of carbon from the atmosphere, and emissions of biogenic carbon dioxide from the system are not offset by CO_2 uptake elsewhere in the system, meaning that biogenic carbon dioxide is treated exactly like fossil fuel CO_2. While this approach has been debated, especially where biomass is grown without human intervention, established carbon footprint protocols include photosynthesis within system boundaries (see WRI/WBCSD 2011a).

In some cases the objective of the analysis is to characterize both, the direct and indirect, impacts of using biomass or impacts that occur outside of the product system. In these cases, the boundaries of the analysis may need to be extended. If, for instance, the study is examining the impacts of displacing non-wood construction materials with wood-based construction materials, it may be necessary to include the non-wood system with the overall boundaries because the emissions from that system will be reduced when wood-based materials are used instead. On the other hand, if the objective is to characterize the impacts of using fossil fuels instead of forest biomass, it may be necessary to include in the system boundaries the forest biomass that would have been used for fuel had it not been displaced by fossil fuel. Many of the debates about biomass energy involve disagreements about whether or how to include these other process with system boundaries so as to examine indirect impacts. Deciding how far to extend the boundaries in these cases can be difficult and controversial.

Relevance to carbon neutrality

Most assessments of carbon neutrality include photosynthesis, and many limit the assessment to direct impacts on the atmosphere, including transfers to the atmosphere from the forest. Some people have suggested, however, that photosynthesis and the resulting removals of CO_2 from the atmosphere by the forest should be considered only if humans have been involved in the planting and nurturing of the forest. Others consider biomass carbon neutral only if the net emissions are zero when considering both the direct and indirect impacts of using biomass.

ORGANIZATIONAL BOUNDARIES

In some greenhouse gas accounting contexts, it is important to establish the organizational boundaries associated with the assessment. The factors to consider in establishing organization boundaries are addressed in detail in the Greenhouse Gas Protocol Corporate Standard (WRI/WBCSD 2004). In many cases involving questions about the use of biomass, however, the analysis extends far beyond the organization because some of the impacts of using biomass occur outside of organizational boundaries.

Relevance to carbon neutrality

Some entities claim carbon neutrality based only on greenhouse gas flows into and out of the processes they own or control. In general practice, however, assessments of carbon neutrality are understood to require analysis of the full life cycle.

SPATIAL BOUNDARIES

Spatial boundaries can be very important in calculating the impacts of using forest biomass on atmospheric greenhouse gases, but their importance depends on how the assessment is structured. In particular, the importance of spatial boundaries depends on how temporal boundaries are established and on whether it is important to understand the timing of transfers of carbon to and from the atmosphere.

The dynamics of forest carbon flows are often modeled at the plot level. The accounting usually starts either immediately before or after harvest and follows the flows of carbon over one or multiple growing cycles. While this can provide insights into the processes involved, if inappropriately interpreted, plot-level studies can yield very misleading results, especially regarding the impact of using biomass on carbon flows over time. This is because facilities using forest biomass do not use the same plot(s) every year to supply biomass. This makes them very different from facilities that use biomass from annual crops. The area supplying wood to a facility or industry consists of many different plots at many different stages of maturity. In any given year, carbon is lost from the harvested plot(s), but carbon continues to be removed from the atmosphere and added to many other plots that will supply biomass to the facility in future years. Therefore, to accurately gauge the impacts of biomass use on forest carbon stocks, the spatial boundaries of the assessment must be extended to include, at a minimum, the entire supply area.

Extending the spatial boundaries to include the entire supply area instead of looking at a single plot has sometimes been criticized as an attempt to "substitute space for time." The implication is that the net transfers of carbon to the atmosphere associated with harvesting a plot and burning the biomass can only be offset by growth on that same plot. This view, however, is inconsistent with the realities of how forest biomass is grown and used in places where sustainable forest management practices are in place. The growth occurring on plots that will supply forest biomass in the future is a critical part of the planning required to ensure a sustainable wood supply. In essence, this growth is a multi-year raw material assembly process that is just as much a part of the system as harvesting and should, therefore, be included within the system boundaries. Only by including the entire supply area can the analyst understand the impacts of changes in forest management and market forces over time.

When setting spatial boundaries, it may also be necessary to consider indirect effects. In particular, it may be necessary to look at the potential for activity within the system boundaries to impact carbon flows outside of the system boundaries, a phenomenon called "leakage". A study of the impacts of banning harvesting in a region, for instance, should extend the system boundaries to include those areas into which harvesting might shift as a result of the ban. Similarly, where increased demand for wood is expected to result in additional land being converted to forest, studies may need to extend spatial boundaries to include such "positive leakage." In

general, larger spatial boundaries are helpful in reducing the potential for missing such indirect effects (Galik and Abt 2012).

On the other hand, as spatial boundaries get larger, it can become more difficult to isolate the impacts of the particular activity being studied. If the impacts of the activity are not properly isolated, it may result in inaccurate conclusions regarding the activity's impact on forest carbon stocks. This suggests the need for special attention to the spatial scales of harvesting compared to those used to assess forest carbon.

Ultimately, the spatial boundaries of an assessment should be at least as large as the supply area and, in general, as large as possible while being consistent with the objectives of the analysis.

Relevance to carbon neutrality

The removals of CO_2 from the atmosphere accomplished by a system will vary depending on the spatial boundaries used in the calculations. Accordingly, the selection of spatial boundaries can have a large impact on the results of assessments of carbon neutrality. At a minimum, the spatial boundaries should include the entire supply area.

TEMPORAL BOUNDARIES

In assessing the impacts of biomass on the atmosphere, time can be important in several ways.

Even in regions where long-term average forest carbon stocks are stable, there are periods during which stocks may increase or decrease for a variety of reasons. The time used to judge the stability of forest carbon stocks, therefore, must be long enough so as to avoid being misled by transient conditions that may not be important in the longer term.

The temporal boundaries used to calculate greenhouse gas transfers into and out of a biomass-based system are also important. Temporal boundaries should be extended back in time to include processes that are part of the system producing the biomass. These processes include photosynthesis, and can include nursery operations, site preparation, and in some cases, land-use change impacts (e.g. changing the forest type or converting non-forested land to forest). To capture the full impacts of using biomass, the temporal boundaries should extend forward in time as long as needed to characterize the releases of greenhouse gases from product use and end-of-life management. It may be useful for

policy purposes, however, to choose a fixed future time horizon of 100 years or some other period to estimate the impacts most relevant to policy development. This may useful in clarifying, for instance, the benefits of carbon stored in product-in-use.

The dynamics of carbon flows into and out of forests are often modeled at the plot level by extending the accounting over several rotations. While this approach can yield important insights, it does not accurately depict the carbon flows over time attributable to a facility using forest biomass because a facility requires forest biomass from multiple plots spread over a supply area, only a few of which are harvested in any given year. These plots, all of which should be considered part of the biomass-production system being studied, are at different stages in the growth cycle, with many gaining carbon while a few are losing carbon due to harvesting activity. It is only by modeling all of the plots over time that the actual timing of flows of carbon into and out of the system can be understood. Modeling the entire supply area also allows the impacts of changes in management and market forces to be better understood.

The time horizon used to judge the impacts of using biomass can also be important. The greenhouse gas transfers to and from the atmosphere associated with forest biomass-based systems do not all occur at the same time. As a result, the estimated impacts on the atmosphere can vary, depending on the time horizon used to judge the impacts. In some cases, in the short to intermediate term, the use of biomass may appear to result in higher net greenhouse gas emissions. With very few exceptions, however, research has demonstrated that when longer time horizons are used, forest biomass produced under conditions

ensuring stable forest carbon stocks essentially always provides greenhouse gas mitigation benefits that, due to the renewability of biomass, increase over time. This body of research forms the foundation of IPCC's finding that: *"In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fiber or energy from the forest, will generate the largest sustained mitigation benefit"* (IPCC 2007b). The ability of forest biomass to provide long-term benefits that increase over time suggests that forest biomass can be part of a mitigation strategy intended to put the world on a trajectory to a lower carbon future.

Relevance to carbon neutrality

Temporal considerations are important to the issue of carbon neutrality for three reasons. First, the times used to judge changes in forest stocks can affect the conclusions about whether forest carbon stocks are stable and therefore influence findings of carbon neutrality. Second, limiting the temporal boundaries of the assessment in ways that eliminate important processes in the life cycle (e.g. photosynthesis, land use change and end-of-life) can significantly impact the results, altering conclusions about carbon neutrality. Third, because of the timing of flows of CO_2 into and out of biomass-based systems, the estimated impacts of these systems on atmospheric CO_2 will vary depending on the time horizon used to judge those impacts, directly affecting judgments about carbon neutrality.

GREENHOUSE GASES INCLUDED IN THE ANALYSIS

To determine the overall impact of using forest biomass on atmospheric greenhouse gases, it is necessary to examine the transfers of all greenhouse gases into and out of the system over the full life cycle. These include not only biogenic emissions but also, for instance, emissions from fossil fuel combustion during the use phase of the product. This analysis produces what is commonly called a carbon footprint. Because almost all systems involve the use of fossil fuels at some point in the life cycle, it is extremely unusual for the net emissions of greenhouse gases from a system to be zero or less, whether the system is biomass-based or not.

Relevance to carbon neutrality

Including greenhouse gases other than biogenic CO_2 in the analysis makes it very difficult to explain the particular role of biogenic carbon as part of the concept of carbon neutrality. It is more useful to base the assessment of carbon neutrality only on flows of carbon into and out of biomass, expressed as CO_2[3].

BASELINES

In carbon accounting, a baseline is the basis against which emissions are calculated. There are two basic approaches. One approach uses a point in time as the baseline. In this case, the calculated emissions represent actual emissions over a period of time. For the purposes of this brief, this type of baseline is called a "reference point" baseline. The second approach calculates emissions relative to a baseline consisting of an alternative scenario. Because the alternative scenario is usually business-as-usual conditions, in this brief, this type of baseline is called a "business-as-usual" baseline.

Reference point baselines

Reference point baselines are widely used in inventory accounting. For instance, the annual greenhouse gas inventories prepared under the United Nations Framework Convention on Climate Change (UNFCCC) use a reference point baseline where the calculated emissions are the actual emissions occurring over a one-year period.

Carbon footprints are usually developed using reference point baselines. The carbon footprint is calculated as the actual emissions from the product system occurring over a year or over a period starting at the beginning of the life cycle, the reference point, and ending when the life cycle is complete. (For examples, see WRI/WBCSD 2011a; WRI/WBCSD, 2011b.)

Reference point baselines have several important attributes. First, they yield results representing the actual transfers of greenhouse gases to the atmosphere. Second, there are no predictions involved in setting the baseline conditions. The baseline conditions are simply those that existed at the point in time selected as the reference point. This reduces the uncertainty associated with the results. A limitation of using reference point baselines is that they do not reveal whether emissions would be larger or smaller if an alternative course of action (including business-as-usual) was chosen.

3 In considering biogenic methane in this framework, it is only the carbon in biogenic methane that is considered in the assessment of carbon neutrality. The global warming potential of methane is not considered, although it clearly would be considered in calculations of the system's carbon footprint.

Business-as-usual baselines

Business-as-usual baselines are often used in policy analysis where the objective is to examine the impact of a potential policy compared to the situation that would exist without the policy, meaning under a business-as-usual scenario. In these circumstances, the study does not need to generate an estimate of the actual transfers of greenhouse gas to the atmosphere, because what is of interest is the impact of a policy relative to business-as-usual.

With business-as-usual baselines, an activity can be found to cause carbon emissions even if it actually accomplishes net removals of carbon from the atmosphere. This can occur if the actual removals are less than would have been accomplished under anticipated business-as-usual conditions.

Business-as-usual baselines are sometimes used, for instance, in developing classification schemes for biomass fuels reflecting the expected emissions when the material is burned relative to the emissions that would have occurred if that biomass had experienced its anticipated business-as-usual fate.

While studies using business-as-usual baselines can provide important insights into the effects of policy options, these baselines suffer from several disadvantages.

First, they do not reveal the actual transfers of greenhouse gases to the atmosphere associated with a system, activity or policy.

Second, they require assumptions about what will happen in the future and these assumptions can have a significant impact on the results of the analysis. For instance, a study of the emissions associated with using a biomass-based waste for energy would need to decide whether, under business-as-usual conditions, that material would have been burned without energy recovery or disposed of in a solid waste disposal site. If it would have been sent to a disposal site, it will be necessary to assume a degradation rate, the design and operating features of the disposal site, and a number of other parameters to estimate the business-as-usual fate of the carbon (and the related greenhouse gas emissions under business-as-usual conditions). The uncertainty around such estimates can be considerable. The uncertainties associated with assumptions about future market-related responses over time can be especially significant (e.g. see Daigneault et al. 2012).

Third, these uncertainties can make policies based on anticipated future baselines subject to unintended consequences that can have counterproductive environmental and economic impacts.

These uncertainties are examined in more detail in the Recommendations section at the beginning of this brief.

Relevance to carbon neutrality

The estimated impacts of using forest biomass can be very different depending on whether the calculations are done using reference point baselines, which measure actual net transfers to the atmosphere, or business-as-usual baselines, which measure net transfers relative to assumed business-as-usual conditions. The selection of baselines, therefore, is critically important to determinations of the neutrality of forest biomass. Different types of baselines are appropriate for different purposes.

ATTRIBUTION AND ALLOCATION OF IMPACTS ON FOREST CARBON STOCKS

Claims of carbon neutrality are usually attached to a specific product or entity. It therefore becomes necessary to understand how that product or entity affects forest carbon stocks. In some cases, this is straightforward. For instance, if a mill obtains all of its wood from company-owned plantations that supply only the mill, it is likely that all of the changes in forest carbon stocks in the plantations are attributable to the mill and the products it makes. In many cases, however, wood procurement practices are far more complex.

A single forest area may produce many types of biomass, for example thinnings, harvest residuals and saw timber. A forest may also produce both wood products and non-wood products. This greatly complicates efforts to attribute stock changes to one particular type of biomass or forest product. A single forest may supply many users, further complicating the process of attributing carbon stock changes. In addition, forests are affected by many factors besides harvesting and management. Natural disturbances, for instance, can have very large impacts on forest carbon stocks. Impacts may be indirect, such as a company's contribution to regional demand for wood that causes local farmers to convert pastureland to managed forests, or direct, such as a company decision to increase the management intensity of a planted forest.

Isolating the effects of one particular type of biomass in a system subject to many other anthropogenic and natural disturbances is often difficult to impossible. Decisions made on how to allocate impacts in such situations can have important effects on results and these decisions should, therefore, be communicated in a transparent manner.

Relevance to carbon neutrality

While it may be possible to construct theoretical frameworks for assessing carbon neutrality or, more broadly, assessing the impacts of using forest biomass, in practice it will often be difficult, and sometime impossible, to accurately attribute forest carbon stock changes to an entity or product. This suggests that a workable framework to assess carbon neutrality may need to allow the use of qualitative information. Sustainable forest management certification programs may have a role to play. Methods used to isolate the effects of an entity or product can significantly affect the results of carbon neutrality assessments and carbon footprint studies and these methods, therefore, should be communicated transparently.

AVAILABILITY AND QUALITY OF DATA ON FOREST CARBON

A framework to assess carbon neutrality will not be workable if it requires data that do not exist or are too expensive to develop. A workable framework must accommodate the types of data that are usually relied upon in forest management. These will vary considerably from one type of forest to another.

Measurement-based data: Forests are measured based on sample plots representing only a small fraction of the forested area. The trees on these plots are measured periodically, and typically only the merchantable part of the tree is measured. These measurements can be expensive to obtain because they are performed manually and can require travel to places that may be difficult to access. In some countries with large forest areas, national governments or other government bodies may have responsibility for taking periodic measurements of forest biomass and may make these data available to those interested in estimating forest carbon stocks. In other countries, however, measurement data may be sparse. In any event, measurement data will seldom be adequate in characterizing forest carbon stocks at small spatial scales except when measurements are made to plan harvesting activity, as these measurements need to be accurate at spatial scales relevant to harvesting. Because forest

measurement is sample-based, there is uncertainty inherent in the estimates of carbon stocks derived from these measurements, especially for carbon pools which are least likely to be sampled, such as below ground pools.

Model-derived estimates: Tree measurements are converted into estimates of forest carbon by models and there are different models that can be used. These models involve a number of assumptions about, for instance, the ratio of top and branch volume to volume of merchantable biomass, and to the extent that different models make different assumptions, the results will differ, introducing further uncertainty into estimates of forest carbon stocks[4].

Relevance to carbon neutrality

If demonstrations of carbon neutrality or methods for characterizing the impacts of using forest biomass require data that are unavailable or expensive to obtain, the methods will not be applied in practice; or, if mandated, they will increase the cost of forest biomass, increasing the incentive to use alternative materials as fuels, feedstocks and raw materials. In addition, the uncertainty inherent in estimating forest carbon stocks and changes in carbon stocks needs to be considered in interpreting claims of neutrality and the results of studies examining the impacts of using forest biomass.

LAND-USE CHANGE AND FOREST CONVERSION

Where the production of forest biomass is the cause of land-use change, the carbon implications of this change are usually addressed in determinations of carbon neutrality, and in assessments of the impacts of using forest biomass. Wood can be produced from forested land that has been converted from non-forest (afforestation), from land being converted from forest to non-forest (deforestation) or from land where the forest is degraded by wood production (forest degradation). In addition, wood can be obtained from a forest that has been modified in ways that have carbon implications, for example by changing a forest from a natural disturbance regime to a disturbance regime involving harvesting and regeneration. The impacts of afforestation, deforestation and forest degradation are frequently considered when assessing the impacts of using biomass and increasingly, the impacts of changing forest types and management regimes are also included, for example in the carbon accounting rules for the second commitment period under the Kyoto Protocol.

While, in concept, there is general agreement about the need to consider the impacts of afforestation, deforestation, forest degradation and forest conversion in carbon neutrality assessments, the methods for doing so can involve a considerable amount of uncertainty. The uncertainty is especially large when indirect land-use change is being addressed. An example of indirect land-use change would be a case where an increase in demand for soybeans caused the expansion of soybean production into areas previously used to produce other agricultural commodities (not land-use change), but this may indirectly cause the production of these other agricultural commodities to move into areas that are forested, causing deforestation. Even in cases where it is possible to identify the specific land that has been directly impacted by biomass production, it can be difficult to accurately attribute the carbon impacts to specific entities or products. Several questions must be answered to develop these estimates, such as: How far back in time should one go to identify land-use change or forest conversion on an area being used to produce wood? If the land was affected by such changes, how does one allocate the impact to the products that are produced on the land on a continuing basis?

Relevance to carbon neutrality

Although there is general agreement that it is important to consider the carbon implications of land-use change, forest degradation and forest conversion when assessing carbon neutrality, calculating these impacts can be difficult and highly uncertain.

SUSTAINABLE FOREST MANAGEMENT

Sustainable forest management principles are essential to maintaining healthy and productive working forests. At this point, however, the major sustainable forest management certification programs

4 Model selection error arises from the need to estimate carbon stores for each live tree by selecting from thousands of analytically defensible computation pathways generated from different combinations of published biomass, volume, and density equations for whole trees, boles, branches, and bark, based on dbh (diameter at breast height) alone or dbh and height (Malmsheimer et al. 2011).

do not specifically address carbon. Nonetheless, these programs have important connections to carbon. Most important, both the Programme for the Endorsement of Forest Certification (PEFC) and Forest Stewardship Council (FSC) include the objective of achieving a long-term balance between harvesting and regrowth. PEFC operational guidelines stipulate that *"forest management practices should safeguard the quantity and quality of the forest resources in the medium and long term by balancing harvesting and growth rates"* (PEFC 2007a; PEFC 2007b). A key principle of the FSC standard is that *"the rate of harvest of forest products shall not exceed levels which can be permanently sustained"* (FSC 2002). Although certification programs are not always explicit about the connections between sustainable forest management and carbon, the practical effect of maintaining a balance between harvesting and regrowth is to achieve stable long-term carbon stocks in managed forests.

There are, however, practices that satisfy the requirements of sustainable forest management certification programs that could have carbon implications. It might be possible, for instance, to balance harvest and growth rates over a landscape by increasing the productivity of some of the land while converting parts of the land to non-forest. The carbon impacts of such changes would be small relative to those that would occur if the landscape was managed without considering future supplies of wood (i.e. ignoring sustainable forest management principles) but the carbon impacts would not necessarily be addressed under current sustainable forest management certification programs.

Relevance to carbon neutrality

Although sustainable forest management principles are consistent with the objective of maintaining stable forest carbon stocks, especially over large spatial and temporal scales, current certification programs do not specifically address carbon or guarantee against losses of forest carbon, especially at small spatial and temporal scales. Nonetheless, sustainable forest management programs can provide important evidence that forest carbon stocks are likely to remain stable over time (and hence, these programs can assist in demonstrations of carbon neutrality) even though they do not provide definitive proof.

Aspects to consider in demonstrating carbon neutrality

As noted earlier, carbon neutrality is invoked in a range of circumstances and can have many different meanings. To better understand the issues involved in demonstrating carbon neutrality, it is important to define precisely what is meant by the term. Answering the following questions will assist in selecting a calculation method appropriate for a specific purpose:

- Is the intent of the analysis to assess the net flows of all greenhouse gases or only the flows of carbon (expressed as CO_2) into and out of biomass?
- Is the intent to provide information on the actual emissions attributable to biomass, in which case reference point baselines are used, or is it to provide information about the impacts of using biomass compared to the impacts that would have occurred under business-as-usual conditions in which case business-as-usual baselines are used?
- Is the analysis intended to include greenhouse gas emissions, carbon removals or avoided emissions that are caused by the system, but occur outside of the physical system boundaries? For instance, for an entity producing biomass-based electricity as a co-product, should the calculations account for avoided emissions; that is emissions that would have occurred if that electricity had been produced by other means?
- Is the analysis intended to include only those impacts that are directly or indirectly caused by the system, or, alternatively, is it intended to allow for the use of purchased offsets that occur outside and independent of the system, thus allowing "offset neutrality" as defined in Table 1.
- Should carbon neutrality be concerned with the net impacts on the atmosphere over the short term or is it more appropriately concerned with the ability of a system to show benefits in the long term that continue to grow with time? The answer to this question will define the time horizon over which the calculations are performed. Systems relying on forest biomass produced under conditions where forest carbon stocks are stable or increasing will show benefits in the intermediate to long term and these benefits will grow with time, reflecting the renewability of forest biomass and the attributes of the forest carbon cycle.

Within the constraints established by the answers to these questions, the following considerations apply:

- **Carbon neutrality assessments,** as well as other studies intended to address the overall impacts on the atmosphere associated with using biomass **should encompass the entire life cycle, including photosynthesis and land use change** and should address gains and losses of carbon from **all forest carbon pools**.
- **The spatial boundaries for these assessments should encompass**, at a minimum, **the supply area for the facility or entity being examined in the study.** Larger spatial boundaries may be appropriate depending on the objectives of the study.
- **Great care must be exercised in creating and modeling future scenarios to use as baselines in carbon calculations.** The assumptions used in developing and modeling these scenarios can have a greater impact on the results than the attributes of the system being studied.
- To precisely document the impacts on forest carbon stocks attributable to a specific use or user of biomass is often nearly impossible. In these cases, information on the stability of regional forest carbon stocks and participation in sustainable forest management certification programs may be helpful in establishing that the use of biomass is consistent with the maintenance of stable forest carbon stocks and may, therefore, be useful in studies to demonstrate the carbon neutrality of such uses.

Is the global forest products industry carbon neutral?

At present, this question cannot be answered unconditionally. We do, however, know the following:

- **Large amounts of CO_2 are removed from the atmosphere and stored in forest products for long periods of time.** If the industry is obtaining wood in ways that allow forest carbon stocks to remain stable, this means that the forest carbon cycle for the forest used by the industry is not only in balance, or "neutral" with respect to biogenic carbon, it is a net sink for atmospheric carbon due to carbon storage in products. Unfortunately, the data needed to demonstrate the industry's impacts on global forest carbon stocks are lacking.
- **Looked at globally, carbon sequestration and storage in forest products offsets a significant fraction of the fossil-fuel related emissions attributable to the forest products value chain (FAO 2010a).** When different types of forest products are examined individually, findings show that for some types of wood products, the sequestration and storage of CO_2 in products is adequate to offset all of the greenhouse gas emissions in the value chain producing those products.
- It has been estimated that the total emissions, including end-of-life emissions, from the global forest products value chain amount to 890 million tonnes CO_2 eq. per year (FAO 2010a). **The long-term storage of atmospheric CO_2 in forest products is adequate to offset almost one-half of this** (for more information, see Table 5 in WBCSD 2012b).
- **The WBCSD Forest Solutions Group has embraced a vision of the future wherein a program of public and private afforestation raises the global forest carbon stock by 65 gigatons of carbon**, equivalent to removing 238,000 million tonnes of CO_2 from the atmosphere (WBCSD 2012a).

Essentially, regardless of how carbon neutrality is defined and calculated, the use of forest biomass produced under conditions where forest carbon stocks are stable or increasing always yields long-term mitigation benefits (IPCC 2007b).

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About the World Business Council for Sustainable Development (WBCSD)

The World Business Council for Sustainable Development is a CEO-led organization of forward-thinking companies that galvanizes the global business community to create a sustainable future for business, society and the environment. Together with its members, the Council applies its respected thought leadership and effective advocacy to generate constructive solutions and take shared action. Leveraging its strong relationships with stakeholders as the leading advocate for business, the Council helps drive debate and policy change in favor of sustainable development solutions.

The WBCSD provides a forum for its 200 member companies - who represent all business sectors, all continents and a combined revenue of more than $7 trillion - to share best practices on sustainable development issues and to develop innovative tools that change the status quo. The Council also benefits from a network of 60 national and regional business councils and partner organizations, a majority of which are based in developing countries.

About the Forest Solutions Group

Within the WBCSD, the Forest Solutions Group presents a global platform for strategic collaboration for the forest-based industry and its value chain partners to bring more of the world's forests under sustainable management and expand markets for sustainably produced & sourced forest products. The FSG provides business leadership in expanding sustainable forest-based solutions to meet societal needs by 2020 and beyond.

For more information visit: www.wbcsd.org

About NCASI

The National Council for Air and Stream Improvement (NCASI) is an independent, non-profit research institute that focuses on environmental topics of interest to the forest products industry. Established in 1943, NCASI is recognized as a leading source of technical and scientific information on environmental issues affecting this industry. Although NCASI receives most of its funding from forest products companies, it also receives funding from government agencies, associations and other organizations interested in better understanding the connections between the forest products industry and the environment.

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