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A REVIEW OF BIOMASS CARBON ACCOUNTING METHODS AND IMPLICATIONS

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PRESIDENT'S NOTE

Over many years, a body of research has developed examining the greenhouse gas and carbon attributes of forests and forest products. This research has demonstrated that forest-based products, particularly building materials, and forest biomass-based energy provide long-term greenhouse gas mitigation benefits when they substitute for more greenhouse gas-intensive alternatives. Recently, however, the benefits of forests and forest products have been disputed, with the debate frequently centered on the question of whether forest biomass is "carbon neutral." In reality, this debate hinges on the methods used to characterize the carbon and greenhouse gas impacts associated with using (or not using) forest biomass.

This report explores the carbon accounting questions at the heart of the debate about the benefits of using forest-derived biomass. The discussion is complicated by differing definitions of the term, carbon neutrality, and different options that may be used to characterize carbon neutrality. There are many carbon accounting methods in use and they are useful for different purposes. The most common applications for carbon accounting are greenhouse gas inventories, product carbon footprints, company carbon footprints, and policy studies. This report makes it clear that it is important to use carbon accounting methods that are appropriate for the issue being examined. The report also examines how the choices made in applying these methods can affect the results of studies of forest carbon and forest products.

Ronald A. Yeske

July 2013

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NOTE DU PRÉSIDENT

Depuis de nombreuses années, les gaz à effet de serre et les attributs du carbone des forêts et des produits forestiers ont fait l'objet de bien des études, ce qui a donné lieu à un vaste ensemble de données de recherche. Ces études ont démontré que les produits dérivés de la forêt, notamment les matériaux de construction, et les combustibles dérivés de la biomasse forestière procurent des avantages à long terme en matière d'atténuation des gaz à effet de serre lorsqu'on les utilise pour remplacer des produits qui génèrent plus d'émissions de gaz à effet de serre. Depuis quelques temps cependant, on conteste les avantages offerts par les forêts et les produits forestiers en polarisant le débat sur la question de « carboneutralité » de la biomasse forestière. En fait, ce débat tourne autour des méthodes utilisées pour caractériser le carbone et l'impact des gaz à effet de serre associé à l'utilisation (ou non) de la biomasse forestière.

Le présent rapport traite de la question de comptabilisation du carbone qui est au cœur du débat sur les avantages de la biomasse forestière. Les différentes définitions du terme carboneutralité et les nombreuses options qui peuvent être utilisées pour caractériser cette carboneutralité viennent compliquer le débat. Il existe de nombreuses méthodes de comptabilisation du carbone et chacune sert à différentes fins. Les applications les plus courantes de la comptabilisation du carbone sont les inventaires des gaz à effet de serre, l'empreinte carbone d'un produit, l'empreinte carbone d'une entreprise et les études destinées à l'élaboration de politiques gouvernementales. Le présent rapport démontre clairement qu'il est important d'utiliser des méthodes de comptabilisation du carbone qui conviennent à la question à l'étude. Le rapport examine aussi de quelle façon les choix faits dans l'application de ces méthodes peuvent influencer les résultats des études sur le carbone forestier et les produits forestiers.

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A REVIEW OF BIOMASS CARBON ACCOUNTING METHODS AND IMPLICATIONS

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ABSTRACT

When performing greenhouse gas inventories, product carbon footprints, company carbon footprints, and policy studies, it is important to select a carbon accounting approach that is appropriate for the intended use. This report examines the available forest carbon accounting options and the factors to consider in selecting among them. It finds that the "carbon neutrality" debate involves carbon accounting questions related to system boundaries, the greenhouse gases to include, baselines, attribution, and a number of other factors. Because trees require decades to grow, it is especially important that spatial and temporal boundaries are established correctly in studies of forest carbon. Otherwise the results of the analysis may not properly reflect the renewability of forest biomass and the removals of CO_2 from the atmosphere during forest growth. Also important, especially in policy studies, is addressing market responses to increased demand for forest biomass. Studies that use accounting methods that ignore these forces produce results that understate the benefits of using forest biomass. Much of the current debate about the benefits of forest-derived materials and fuels is not about whether these benefits exist but whether the benefits are delayed (the so-called "carbon debt"). Where the benefits are delayed, the estimated delay is reduced by using accounting methods that reflect market responses. The significance of a delay in delivering greenhouse gas mitigation benefits, however, cannot be assessed by carbon accounting alone.

KEYWORDS

biogenic CO_2, biomass carbon, carbon accounting, carbon footprints, forest carbon, greenhouse gases, lifecycle assessment (LCA)

RELATED NCASI PUBLICATIONS

Technical Bulletin No. 984 (April 2011). *Greenhouse gas and non-renewable energy benefits of black liquor recovery.*

Special Report No. 08-05 (September 2008). *The greenhouse gas and carbon profile of the U.S. forest products sector.*

Special Report No. 07-09 (October 2007). *The greenhouse gas and carbon profile of the Canadian forest products industry.*

Special Report No. 07-02 (February 2007). *The greenhouse gas and carbon profile of the global forest products industry.*

Technical Bulletin No. 925 (November 2006). *Energy and greenhouse gas impacts of substituting wood products for non-wood alternatives in residential construction in the United States.*

Special Report No. 04-03 (August 2004). *An analysis of the methods used to address the carbon cycle in wood and paper product LCA studies.*

Technical Bulletin No. 872 (March 2004). *Critical review of forest products decomposition in municipal solid waste landfills.*

Technical Bulletin No. 700 (October 1995). *A preliminary investigation of releases of volatile organic compounds from wood residual storage piles*.

UNE REVUE DES MÉTHODES DE COMPTABILISATION DU CARBONE DE LA BIOMASSE ET LEURS RÉPERCUSSIONS

BULLETIN TECHNIQUE N^{O} 1015
JUILLET 2013

RÉSUMÉ

Dans la réalisation d'un inventaire de gaz à effet de serre, le calcul de l'empreinte carbone d'un produit ou d'une entreprise ou la réalisation d'une étude destinée à l'élaboration de politiques gouvernementales, il est important de choisir une méthode de comptabilisation du carbone qui convienne à l'utilisation prévue. Le présent rapport examine les méthodes existantes de comptabilisation du carbone forestier et les facteurs à considérer dans le choix d'une méthode. Le rapport constate que le débat sur la carboneutralité porte sur des questions reliées à la comptabilisation du carbone, notamment les limites du système, le type de gaz à effet de serre, les années de référence, l'attribution et un certain nombre d'autres questions. Puisque la croissance d'un arbre s'étend sur des décennies, il est particulièrement important de bien établir les limites spatiales et temporelles des études sur le carbone forestier. Sinon, les résultats de l'analyse ne représenteront peut-être pas adéquatement le caractère renouvelable de la biomasse forestière et la quantité de CO_2 retirée de l'atmosphère durant la croissance de la forêt. Il est également important, notamment dans les études destinées à l'élaboration de politiques gouvernementales, de traiter de la réaction des marchés face à la demande croissante pour la biomasse forestière. Les études qui reposent sur des méthodes de comptabilisation qui ne tiennent pas compte de ces forces donnent des résultats qui sous-estiment les avantages d'utiliser la biomasse forestière. Une bonne partie du débat sur les avantages des matériaux dérivés de la forêt n'est pas tant sur l'existence de ces avantages que sur leur report dans le temps (situation qu'on appelle « dette de carbone »). Lorsque ces avantages sont reportés dans le temps, il est possible de raccourcir la durée du délai estimé en utilisant des méthodes de comptabilisation qui tiennent compte de la réaction des marchés. Il n'est cependant pas possible d'évaluer la longueur du délai de « paiement de la dette » à l'aide de la comptabilisation du carbone seulement.

MOTS-CLÉS

analyse du cycle de vie (ACV), carbone de la biomasse, carbone forestier, CO_2 biogénique, comptabilisation du carbone, empreinte carbone, gaz à effet de serre

AUTRES PUBLICATIONS DE NCASI

Bulletin technique n^{o} 984 (avril 2011). *Avantages pour les émissions de gaz à effet de serre et la consommation d'énergie non renouvelable de la récupération de la liqueur noire* (seul le résumé est en français)

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Bulletin technique n^{o} 700 (octobre 1995). *A preliminary investigation of releases of volatile organic compounds from wood residual storage piles*.

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A REVIEW OF BIOMASS CARBON ACCOUNTING METHODS AND IMPLICATIONS

1.0 INTRODUCTION

In calculating combustion-related emissions of biogenic carbon (i.e., the carbon in, or derived from, biomass), an emission factor of zero is normally used for biogenic CO_2, reflecting guidance from the Intergovernmental Panel on Climate Change (IPCC) for the preparation of national greenhouse gas inventories (IPCC 2006). The appropriateness of this and other conventions on "carbon neutrality" is now being questioned in a range of contexts. In this report, we examine the various approaches for biomass carbon accounting, their proper application, and their connection to the debate about "carbon neutrality".

1.1 The Forest 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. 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 often referred to as "biogenic carbon" or "biomass 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 solar energy stored in biomass as chemical energy is released and the carbon is placed back into the atmosphere, completing a natural carbon cycle, depicted in Figure 1.1. As long as this cycle is in balance, the net transfers of biogenic carbon to the atmosphere are zero.

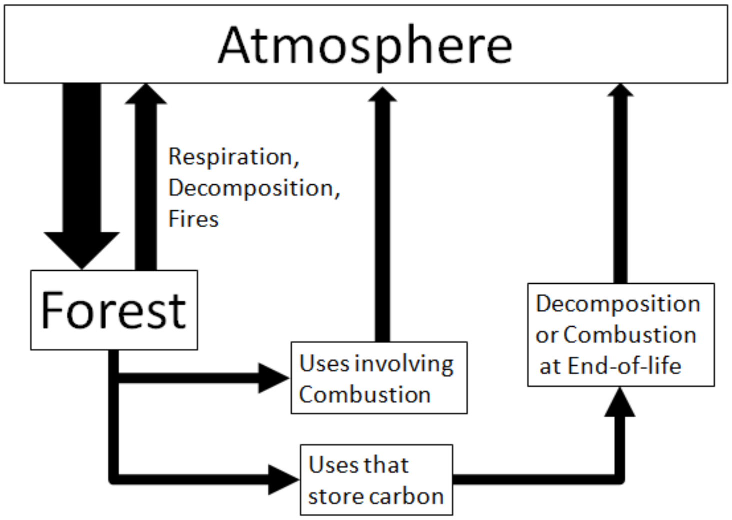


Figure 1.1 Flows of Carbon in the Forest Biomass Carbon Cycle

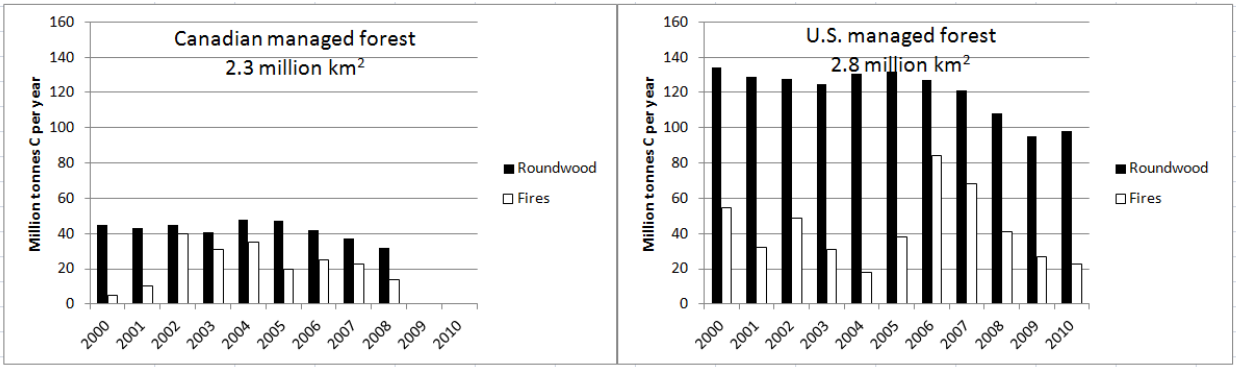
The forest biomass carbon cycle is in balance when the amounts of biogenic carbon being returned to the atmosphere via combustion and decomposition of forest biomass are equal to the amounts of carbon being removed from the atmosphere by growing forests. If the cycle is in balance, the amount of carbon stored in forests and forest products, in total, will remain constant because the overall flow of carbon from the atmosphere into these collective pools will be equal to that returning to the atmosphere. 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.

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 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 (IPCC 2007a).

1.2 Forest Carbon in the Canadian and US Context

Together, Canadian and US forests store approximately 170 billion tonnes of carbon, about 28% (or 48 billion tonnes) of which resides in live biomass (CCSP 2007). With global forests holding an estimated 283 billion tonnes of carbon in living biomass (IPCC 2007b), Canadian and U.S. forests contain about 17% of the carbon contained in forest biomass globally.

In recent years, the Canadian and US forest products industry has harvested wood containing approximately 150 million tonnes of carbon annually, with 32 to 47 million tonnes per year of this harvested in Canada and 95 to 134 million tonnes per year harvested in the US. Losses of carbon due to forest fires, shown in Figures 1.2a and 1.2b, are also significant. In 1995 and 1998, the losses of carbon due to forest fires in Canada exceeded those attributable to harvesting by a significant amount (Stinson et al. 2011; USEPA 2012b).



(a) (b)

Figure 1.2 Losses of Carbon from Forests Due to Harvesting and Fires in (a) Canada and (b) the United States

Harvesting in North America has been accomplished while forest carbon stocks have been generally stable or increasing. In the US, forests are consistently a large net sink for carbon (USEPA 2012b) with about 70% of the sink attributable to forest on public land (Heath et al. 2010). In Canada, there is large year-to-year variability in forest carbon fluxes mostly caused by fire and insect damage. As a result, Canada’s forests, which are almost entirely Crown-owned, are sometimes net sinks for carbon and sometimes net sources (not considering carbon stored in harvested wood products) (Stinson et al. 2011).

With sustainable forest management practices being widespread in Canada and the US (FAO 2010), and with only small areas affected by deforestation (Environment Canada 2012b; USEPA 2012a), it is often assumed that wood is produced in North America under circumstances that allow forest carbon stocks on wood-producing land to remain stable. This assumption is consistent, for instance, with the observation that carbon stocks on industry-owned timberland in the US, which provides approximately 30% of the wood used by the US forest products industry, have been stable in recent years (Heath et al. 2010; Haynes et al. 2007). However, given the amounts of wood from other sources in the US and Canada, where attribution of impacts is difficult to impossible, it is not possible to accurately characterize the impacts specifically attributable to the activities of the forest products industry on North American forest carbon stocks.

The area of forest managed for wood production in Canada and the US continues to increase. In the United States, much of the growth in managed forest area has involved the conversion of “natural” pine forests to planted pine forests in the southern US (Wear and Greis 2011). In Canada, the expansion in land area under tenure managed for wood production has taken place primarily on forested lands that have not previously been harvested. The carbon impacts associated with increasing the management intensity of forest previously affected primarily by natural disturbances (i.e., “natural” forest) are highly dependent on the original and converted forest types. In some cases, increases in standing forest biomass are possible (for instance, intensively managed planted pine stands in the southern US generally store more carbon than natural pine stands of comparable age (Smith et al. 2005; Fox, Jokela, and Allen 2004), while in other cases, forest carbon stocks can be decreased (e.g., see Kurz, Beukema, and Apps 1998).

Most industrial roundwood harvested in North America comes from land that is not industry-owned. In Canada most industrial wood comes from public forest, while in the US, non-industrial private forest is the largest single source of roundwood (Natural Resources Canada 2011; Haynes et al. 2007). These forests are affected by a range of disturbances besides harvesting and are often managed to accommodate a range of management objectives besides wood production. As a result, it is difficult to know how much of the change (currently an increase) in North American forest carbon stocks to attribute to management activities performed or made possible by the forest-based industry.

The carbon transferred to products remains stored in products in use and in landfills for varying lengths of time. Some of this carbon remains stored in products for periods long enough to allow the amounts of carbon stored in these sinks to grow. Indeed, in recent years, the amounts of carbon stored in products produced from wood harvested in the US have been growing by 15 to 30 million tonnes of carbon per year (USEPA 2012a). The amount of carbon stored in products made from wood harvested in Canada grew by about 8 million tonnes of carbon in 2010, a year of lower than average harvest (calculated from information in Environment Canada 2012b). The combined additions to US and Canadian stocks typically amount to a net removal of carbon from the atmosphere (transferred into stored products) of about 25 million tonnes of carbon per year.

The carbon benefits attributable to forest products extend beyond the amount of carbon they store. In some applications, most notably the use of forest products in construction, the use of forest products can avoid large amounts of fossil fuel-related emissions by substituting for more greenhouse gas intensive construction materials like concrete and steel (Sathre and O’Connor 2010).

Some of the carbon removed from the forest in industrial roundwood is released to the atmosphere by forest products manufacturing facilities, primarily in emissions generated from processes required to (a) produce energy for various manufacturing activities and (b) regenerate the pulping chemicals needed in kraft pulping. The fraction of roundwood carbon released to the atmosphere during manufacturing depends on the types of processes involved, with a smaller fraction expected for wood products manufacturing and a higher fraction likely for most types of pulp and paper production. The direct emissions of biogenic CO_2 from forest products manufacturing facilities in the US in 2004 have been estimated to total 113 million tonnes, almost twice the emissions associated with combustion of fossil fuels at these facilities (approximately 60 million tonnes CO_2) (Heath et al. 2010).

One important but often overlooked attribute of the forest products industry is the incentive it provides for keeping land in forest and even expanding forested area. The demand for wood is not causing loss of forest. In Canada, the primary contributors to forest loss are agricultural expansion, resource extraction and hydroelectric development (Environment Canada 2012b). In places where US forest area is being lost, the primary causes are urbanization and development, not demand for wood (Wear and Greis 2011; USDA 2012). Studies of the effects of increased biomass demand have found that in the face of rapid urban expansion and robust economic growth, increased demand for forest biomass reduces the loss of forested area (USDA 2012). Other studies suggest that demand for wood can result in increased forest carbon stocks and increased forested area (Daigneault, Sohngen, and Sedjo 2012). Even at the global level, patterns of deforestation suggest that "...regions with the highest levels of industrial timber harvest and forest products output are also regions with the lowest rates of deforestation" (Ince 2010, p.32). In short, research clearly shows that demand for wood results in investments in forestry that help to prevent deforestation and incentivize afforestation, both of which have carbon benefits.

In summary, the carbon removed from the forest in harvested wood represents an important element in the carbon budget of North American forests. Additions of carbon due to forest growth, however, exceed losses of carbon due to harvesting, fire, and other factors so that carbon stocks in North American forests are stable to increasing (CCSP 2007). The demand for wood provides incentive to keep land in forest and expand forested area. Wood sourcing practices in the North American forest products industry, however, are very complex and therefore it is not possible to precisely determine the industry's impact on those forests that provide wood to the industry. A fraction of the carbon in products remains out of the atmosphere, stored in products, for periods long enough to have a significant effect on the industry's carbon footprint. In many cases, the industry's products can substitute for more greenhouse gas-intensive alternatives, reducing societal greenhouse gas emissions.

2.0 THE DEBATE OVER CARBON NEUTRALITY

The substitution of biomass-derived fuels and materials for alternatives that are far more fossil fuel-intensive is one approach being used to mitigate increases in atmospheric CO_2. Biomass can be used, for instance, as a substitute for coal in producing electricity, eliminating the combustion-related emissions of fossil fuel-derived greenhouse gases from the facility producing the electricity. In recent years, however, questions have been raised about the benefits of using biomass. The debate has often centered on the question of whether biomass is "carbon neutral".

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 definition and set of calculation rules, net transfers of carbon to the atmosphere associated with using biomass are zero. Unfortunately, there is no widely accepted definition of carbon neutrality. Indeed, based on earlier work by NCASI, Malmsheimer et al. suggest that there are at least six different types of carbon neutrality, as explained in Table 2.1 (Malmsheimer et al. 2011). The different potential meanings reflect fundamentally different concerns and require fundamentally different calculation methods to assess. In some cases, the definitions are mutually exclusive while in other cases they complement each other.

Table 2.1 The Different Types of Carbon Neutrality (after Malmsheimer et al. 2011)

Type	Definition	GHGs involved	Example
Inherent carbon neutrality	Biomass carbon was only recently removed from the atmosphere; returning it to the atmosphere merely closes the cycle.	The biogenic carbon in biogenic CO_2 and biogenic methane	All biomass is "inherently carbon neutral".
Carbon cycle neutrality	If uptake of carbon (in 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.	The biogenic carbon in biogenic CO_2 and biogenic methane	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.	All GHGs	If wood products store atmospheric carbon (carbon removed from the atmosphere by the product system) in long-term and permanent storage and the amounts stored are equal (in CO_2 eq.) to the product system's life cycle GHG emissions, the products are "life cycle neutral".
Offset neutrality	If emissions of greenhouse gases are compensated for by using offsets representing removals that occur outside of a product system, that product or product system is offset neutral.	All GHGs	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 those associated with likely substitute products, that product or product system is substitution neutral.	All GHGs	Forest-based biomass energy systems with life cycle emissions equal to those associated with likely substitute systems are "substitution neutral".

(Continued on next page.)

Table 2.1 Continued

Type	Definition	GHGs involved	Example
Accounting neutrality	If emissions of biogenic CO_2 are assigned an emissions factor of zero at the point of combustion (regardless of whether the carbon cycle is in balance) because net emissions of biogenic carbon are determined by calculating changes in total stocks of stored carbon, the emissions factor of zero is used because of accounting neutrality.	Biogenic CO_2	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. Because biogenic CO_2 emissions from combustion are not included in emissions totals, they get an emission factor of zero (i.e., are considered "accounting neutral").

The Forest Solutions Group of the World Business Council for Sustainable Development has suggested that "carbon neutrality" is best understood as an attribute of biomass, biogenic carbon, and biogenic CO_2 and that term is best aligned with the concept of "carbon cycle neutrality", described in Table 2.1. Under this definition, biomass is carbon neutral if it is produced in a way that allows forest carbon stocks to remain stable and allows net transfers of biogenic carbon to the atmosphere to be zero. Using this definition, carbon neutrality is an attribute of biomass used to make products, not an attribute of the products themselves (WBCSD 2013).

The recommendations of the WBCSD Forest Solutions Group, however, are not universally accepted. The lack of agreement is actually a debate about (a) which concept in Table 2.1 should be attached to the term, and (b) how to calculate the impacts reflected in that concept. 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. Ultimately, the debate about carbon neutrality is a debate about the carbon accounting methods to use in characterizing the benefits of using forest biomass.

3.0 BIOMASS CARBON ACCOUNTING BASICS

The debate about the benefits of using biomass, especially in situations where doing so reduces societal consumption of fossil fuels, involves carbon accounting questions related to system boundaries, the greenhouse gases to include, baselines, attribution, and a number of other factors. These are addressed below.

3.1 System Boundaries

In calculating the net releases of GHGs associated with using biomass, or an alternative, it is necessary to specify the boundaries of the system to be characterized. This includes the physical, organizational, spatial and temporal boundaries.

3.1.1 *Physical Boundaries*

Physical boundaries (the boundaries encompassing the processes included in the analysis) are primarily relevant to biogenic carbon accounting questions that involve the assessment of products or activities over their full life cycle. This can be, for instance, the evaluation of the life cycle GHGs associated with the production of 1 kWh of electricity, the comparison of the GHG releases associated with the construction of a 200 m^2 single family house using wood or steel, or the reporting of corporate life cycle GHGs.

In these cases, the impacts on the atmosphere are calculated by examining the entire product system, consisting of all processes or operations that comprise the life cycle of a product or an activity. The physical boundaries define the processes/operations to include in the product system(s) being investigated. The assessment then focuses on greenhouse gases that enter or leave the physical boundary of the product system(s). In the case of biomass-based systems, the processes included within the physical boundaries typically include photosynthesis and sometimes, where relevant, land use change. With photosynthesis included within the physical 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 (Johnson 2011), established carbon footprint protocols include photosynthesis within system boundaries, essentially representing it as a material assembly process occurring within the system (WRI/WBCSD 2011b; ISO 2012a). If, instead of being conceived of as a raw material assembly process that produces the harvested wood, photosynthesis is only considered as it occurs during regrowth of a stand, emissions timing will be affected but the overall net emissions calculated by the study will normally be the same (unless land use change or forest conversion are involved).

In Canada and the US, wood is seldom produced under conditions that cause land use change. Therefore, there is seldom a need to include deforestation in the analysis of systems in the US or Canada. Forest conversion and planting of new forests, however, may need to be considered.

In some cases, where the objective of the analysis is to characterize both the net emissions from the biomass product system (i.e., the direct impacts), and impacts that occur outside of the product system (i.e., indirect impacts), the physical boundaries of the analysis may need to be extended to include other product systems. If, for instance, it is determined that the attributes of the wood product system include the impacts of displacing non-wood construction materials, it may be necessary to include the impacted aspects of the non-wood system with the overall boundaries because the emissions from the non-wood system will be reduced when wood-based materials are used instead. Many of the debates about biomass energy involve disagreements about whether or how to include these other processes so as to examine indirect impacts.

The boundaries for characterizing biomass-based systems are also related to whether the study is “attributional” or “consequential”. Attributional studies attempt to calculate the impacts of the system (i.e., its attributes) looking at the system as it actually exists, normally without regard to other systems or alternative courses of action. Consequential studies attempt to calculate the impacts resulting as a consequence of using the system (often compared to pursuing a “business as usual” course of action). Physical boundaries need to be established so that they include the processes required to accomplish these different objectives.

3.1.2 *Organizational Boundaries*

Organizational boundaries establish who “owns” the emissions included in an emissions inventory. Political boundaries, for instance, are important organizational boundaries in national greenhouse gas inventories. A commonly used framework for describing emissions in terms of corporate organization boundaries is contained the GHG Protocol Corporate Accounting and Reporting Standard (WRI/WBCSD, 2004). That standard defines “Scope 1” emissions as emissions released from sources owned or controlled by the company performing the inventory. “Scope 2” emissions are defined as those associated with the production of electricity, steam, and heat purchased by the company performing the inventory. “Scope 3” emissions are all other emissions in the value chain that are caused by the activities of the company performing the inventory. In the GHG Protocol Corporate Accounting and Reporting Standard, the process of classifying activities based on ownership or control is called the setting of organizational boundaries. The classification of emissions from those activities (based on Scopes) is called setting operational boundaries.

3.1.3 *Spatial Boundaries*

Spatial boundaries define the physical area over which the accounting is to be done. In inventories of forest carbon, spatial boundaries are closely related to temporal boundaries (discussed later). Spatial boundaries are slightly different from physical boundaries in that physical boundaries define the processes included in the study while spatial boundaries determine how those processes are modeled. For instance, photosynthesis is clearly a process that needs to be included in the physical boundaries of studies of forest products. Photosynthesis can be modeled, however, different spatial scales (e.g., at the spatial scale of a single plot by extending the analysis over time, or at the spatial scale of the supply area, considering all photosynthesis occurring on multiple plots across the supply area in a single year). In some cases, the spatial and temporal boundaries used to model a process can influence the results of the analysis.

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. It is also important in cases where, if instead of being conceived of as a raw material assembly process that produces the harvested wood, photosynthesis is only considered as it occurs during regrowth of a stand.

To illustrate the concepts involved, consider the fact that 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 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 users of forest biomass very different from facilities that use biomass from annual crops. The area supplying wood to a facility 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 supplied biomass to the facility in the past and will supply biomass in future years. Therefore, to accurately understand the impacts of biomass use on forest carbon stocks, the spatial boundaries of the assessment should be extended to include, at a minimum, the entire supply area. In some cases, this can be done by replicating the modeled plot over the supply area, but there are important limitations to this approach, especially regarding the ability to understand forces that are influential at larger scales, such as natural disturbances and market forces (as discussed below).

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 be offset only 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 and, in the Canadian context, is part of forest management regulatory compliance. 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.

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 overall carbon 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. Leakage can also be beneficial, as in the case of land owners reacting to increased demand for forest biomass by expanding planted forests (Daigneault, Sohngen, and Sedjo 2012). Research has demonstrated the benefits of larger spatial boundaries in reducing the potential for missing these beneficial market-related 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.

Ultimately, the considerations above suggest that 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.

3.1.4 *Temporal Boundaries*

The temporal boundary of an assessment is the period of time that is included in the assessment. In assessing the impacts of forest biomass on the atmosphere, temporal boundaries can be important in at least three ways. They can affect the perceived trends in forest carbon stocks. They can affect the processes that are included in the analysis. They can alter the conclusions about potential impacts on the atmosphere.

3.1.4.1 *Determining Trends in Forest Carbon Stocks*

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 including market dynamics and natural disturbances. 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.

3.1.4.2 *The Effect of Temporal Boundaries on the Processes Included in the Study*

The temporal boundaries determine the time period used to calculate greenhouse gas transfers into and out of a biomass-based system. Temporal boundaries are related to, but different from, physical boundaries. Temporal boundaries, like spatial boundaries, determine how processes included within physical boundaries are modeled.

Temporal boundaries vary depending on the type of study being performed, as discussed in later parts of this report. In general, for studies focusing on the attributes of specific forest products, temporal boundaries are extended back in time to include processes, including photosynthesis, that are part of the system producing the biomass (WRI/WBCSD 2011b; BSI 2011). The inclusion of photosynthesis has been questioned in cases where there has been no human intervention involved in growing the biomass (Johnson 2011) but this remains a minority view and is not reflected in widely used standards and protocols (WRI/WBCSD 2011b; BSI 2011). In addition to photosynthesis, the processes occurring earlier in time 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 total ultimate releases of greenhouse gases from product use and end of life management. In cases where there is interest in understanding the long-term, but not ultimate, impacts of a system, a fixed time horizon of 100 years or some other extended period can be selected. This may be useful in clarifying, for instance, the benefits of carbon stored in products in use.

In forest-related studies, temporal and spatial boundaries are closely related, and the combination of temporal and spatial boundaries used in a study can significantly affect the results. The dynamics of carbon flows into and out of forests are often modeled at the plot-level spatial scale by extending the temporal boundaries over several rotations. While this approach can yield important insights, it does not accurately depict the carbon flows over time attributable to a facility. 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 in the supply area, 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 together (spatial boundaries including the entire supply area) over time (temporal boundaries long enough to include effects of forces that act over time, such as shifts in age class distribution) that the actual timing of flows of carbon into and out of the system can be understood.

3.1.4.2 *The Timing of Emissions*

Until recently, most carbon footprint and life cycle studies expressed their findings as a single number reflecting the total net transfers of greenhouse gases to the atmosphere over the life cycle of the product or product system. This approach is also used in major carbon footprint and LCA standards (WRI/WBCSD 2011b; BSI 2011; ISO 2006a).The greenhouse gas transfers to and from the atmosphere associated with forest biomass-based systems, however, do not all occur at the same time. The estimated impacts on the atmosphere can vary, therefore, depending on the time horizon used to judge the impacts. The interest in the significance of emissions timing has grown in recent years, in part as a result of the concern about “carbon debts”. Many recent studies, therefore, have focused on the impacts of emissions timing.

These studies have found that in the short to intermediate term, some, but by no means all, biomass-based systems may have higher net emissions than alternative non-biomass systems, creating what some have called a “carbon debt” (Searchinger et al. 2009; Manomet Center 2010). A large body of research has demonstrated, however, that when longer time horizons are used, systems using sustainably produced forest biomass almost always provide greater greenhouse gas mitigation benefits than alternative systems. In addition, because of the renewability of forest biomass, these benefits 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, p.543). This finding has been reinforced by a more recent review of the literature which concluded that “strategies that combine increased use of forest products to offset fossil fuel use (such as use of biomass energy and substitution), in conjunction with increasing carbon storage on forested landscapes, are likely to produce the most sustainable forest carbon benefits” (Ryan et al. 2010).

3.2 Greenhouse Gases Included in the Analysis

The net impacts of a biomass-based system on atmospheric greenhouse gases extend beyond the attributes of biomass, biogenic carbon, and biogenic CO_2. 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 being studied. Most studies, therefore, address the effects of all greenhouse gases released from the system. Studies involving the forest products industry normally include, at a minimum, CO_2, CH_4, and N_2O, with a number of standards and protocols requiring attention to additional greenhouse gases.

When attempting to characterize “carbon neutrality” however, a narrower view may be appropriate. Fossil fuels are used somewhere in the life cycle of almost all products, whether they are biomass-based or not. As a result, determinations of “carbon neutrality” that extend beyond biogenic GHGs are greatly influenced by fossil fuel consumption and provide little insight into the particular role of biogenic carbon. It has been suggested, therefore, that the concept of carbon neutrality should focus on biogenic carbon, and in particular, the concept of “carbon cycle neutrality” (described in Table 2.1; WBCSD 2013). Carbon cycle neutrality occurs when the flows of biogenic carbon from the system into the atmosphere are matched by flows of atmospheric carbon into the system. Therefore, the assessment of carbon cycle neutrality is based only on flows of biogenic carbon out of the system and flows of atmospheric carbon into the system, both normally expressed as CO_2. In the context of “carbon cycle neutrality”, only the carbon in biogenic methane is considered, not its global warming potential.

In many cases, however, researchers are interested in much more than whether the biomass used in the system is carbon cycle neutral. More commonly, studies are designed to characterize the net impacts of the system on atmospheric greenhouse gases.

3.3 Baselines

In carbon accounting, a baseline is the basis against which emissions are calculated. There are two basic approaches commonly encountered in studies of biomass. 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 report, this type of baseline is called a “reference point” baseline. Reference point baselines are often used in studies attempting to characterize the actual attributes of a system (i.e., attributional studies). The second approach calculates emissions relative to a baseline consisting of an alternative scenario, usually projected business-as-usual conditions. In this report, this type of baseline is called an “anticipated future” baseline. Anticipated future baselines are often used in studies of the consequences of a new policy replacing existing policies or the consequences of replacing one type of product with another (i.e., consequential studies).

3.3.1 *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 since the beginning of the year.

Carbon footprints are also usually developed using reference point baselines. The carbon footprint for products is calculated as the actual emissions from the product system occurring over a period starting at the beginning of the life cycle, the reference point, and ending when the life cycle is complete. The carbon footprint of entities is usually defined as the net flows of greenhouse gases from the entity’s value chain occurring over one year (e.g., WRI/WBCSD 2011a, 2011b; BSI 2011). This is also the case for attributional life cycle assessment studies (Curran, Mann, and Norris 2002, p. 5)[1].

Reference point baselines have several important attributes. First, they yield results representing the actual transfers of greenhouse gases to the atmosphere over a specified period. Second, there are no assumptions involved in setting the baseline conditions. The baseline conditions are simply what they were 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 or alternative product had been chosen.

3.3.2 *Anticipated Future Baselines*

Anticipated future 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 (BAU) scenario (USEPA 2011). 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 BAU conditions.

With anticipated future 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 BAU conditions. Likewise, with anticipated future baselines, an activity can be shown to reduce atmospheric greenhouse gases even if the emissions from the system are substantial. This occurs if the activity results in lower emissions than anticipated under BAU conditions.

While studies using anticipated future baselines can provide important insights into the effects of policy options, these baselines suffer from two 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 that can have a significant impact on the results of the analysis. For instance, in a study attempting to understand the impacts of a policy promoting the use of biomass-based waste for energy generation, the analyst would need to decide whether, under business-as-usual conditions, that material would have been burned without energy generation 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. Where anticipated future baselines are embedded in regulations, these uncertainties can contribute to unintended consequences, especially when the analysis fails to account for dynamic market-related responses (e.g., Sedjo and Tian 2012).

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[1] While there is still discussion on what constitutes attributional and consequential LCAs, the International Workshop on Electricity Data for Life Cycle Inventories is considered to be the reference point for the acceptance of the attributional/consequential terminology. In this workshop, attributional LCA was described as an attempt to answer “How are things (pollutants, resources, and exchanges among processes) flowing within the chosen temporal window?” and as serving to “allocate or attribute, to each product being produced in the economy at a given point in time, portions of the total pollution (and resource consumption flows) occurring from the economy as it is at a given point in time”.

3.4 Attribution and Allocation of Impacts on Forest Carbon Stocks

Carbon footprints or claims of carbon neutrality are usually attached to a specific product or entity. It therefore becomes necessary to understand any impacts on forest carbon stocks attributable to the product or entity. 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 (e.g., food and fodder). A single forest may supply many users, further complicating the process of attributing 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 demand for wood that causes a land owner to harvest and replant with a faster-growing species, or direct, such as a company decision to convert land to 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. Options for addressing this issue are examined later in this report as they vary depending on the type of study being performed.

3.5 Availability and Quality of Data on Forest Carbon

A framework to support the development of carbon footprints or to assess carbon neutrality will not be workable if it requires data that do not exist or are too expensive to develop. Available data will vary considerably from one type of forest to another. Most commonly, data are either measurement-based or model-derived.

3.5.1 *Measurement-Based Data*

Wood volume in forests is measured based on sample plots representing only a small fraction of the forested area. The trees on these plots are measured periodically to determine their volume, and typically only the volume of the merchantable part of the tree is determined. 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, government agencies 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 for characterizing forest carbon stocks at small spatial scales except when measurements are made to schedule 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.

3.5.2 *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. To the extent that different models make different assumptions, the results will differ, introducing further uncertainty into estimates of forest carbon stocks (Malmsheimer et al. 2011).

3.6 Land Use Change and Forest Conversion

The impacts of afforestation (creating forests on previously non-forested land) and deforestation are frequently considered when assessing the impacts of using biomass. Increasingly, the impacts of forest conversion (changing forest type) are also included, for example in the carbon accounting rules for the second commitment period under the Kyoto Protocol (UNFCCC 2012). In North America, where deforestation is not occurring at large scales (Environment Canada 2012b; USEPA 2012a), very little wood is produced from deforestation. North American carbon footprint studies may, however, require analysis of afforestation and forest conversion.

While in concept there is general agreement about the need to consider the impacts of afforestation, deforestation, and forest conversion in carbon footprint studies, 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 is land use change caused by an entity's impacts on market prices for wood that cause, in turn, a different entity, perhaps in a different country, to deforest (or afforest) an area. Even in cases, however, where the impacts are direct and where it is possible to identify the specific land that has been impacted it can be difficult to accurately estimate and attribute the carbon impacts to specific entities or products. Several questions must be answered to develop these estimates. 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? Some of these questions are addressed in carbon footprint protocols and standards (e.g., WRI/WBCSD 2011b). The specific considerations involved for different types of studies are addressed later in this report.

3.7 Sustainable Forest Management

Sustainable forest management principles are essential to maintaining healthy and productive forests as well as associated wildlife. At this point, the major sustainable forest management (SFM) certification schemes do not specifically address carbon. Nonetheless, these schemes 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 2010, p. 9). 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, Criterion 5.6). Although SFM certification schemes 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 schemes 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 it is true that the carbon impacts would not be specifically addressed under current sustainable forest management certification schemes.

3.8 General Approaches for Accounting for Biogenic Carbon

The net impacts of an activity on atmospheric carbon can be characterized using two general approaches, one of which focuses on flows of carbon (usually called "atmospheric flow" or "flow" accounting) and the other of which focuses on stocks of carbon (usually called "stock change" accounting). Section 4 examines how these two general approaches, and several others derived from them, are used in national and international carbon and greenhouse gas inventories. The two concepts can also be important in carbon footprint and LCA studies.

In atmospheric flow accounting, the net transfers of biogenic carbon to the atmosphere are calculated as the simple difference between flows of carbon from the atmosphere into the system and flows of biogenic carbon out of the system to the atmosphere. In stock change accounting, the net impact on the atmosphere is calculated as the change of carbon stocks in the system. If the total quantity of carbon stocks goes up, an equal amount of carbon is assumed to have been removed from the atmosphere. If the total quantity of carbon stocks goes down, the opposite is assumed to have happened.

For systems where there are no flows of stored biogenic carbon (e.g., carbon in wood or wood products) across system boundaries, the two approaches give exactly the same results. This might be the case, for instance, in a study of a wood-to-energy system. All of the biomass carbon removed from the atmosphere by the system either returns to the atmosphere in gaseous form or remains in the system, stored in landfills as unburned carbon in ash, for instance. In cases where stored biogenic carbon enters or leaves a system, however, the two approaches yield different answers. This can be an issue in many carbon footprint and LCA studies of forest products. Significant quantities of wood fiber sometimes enter forest product systems (e.g., recovered fiber from other product systems) or leave the systems (e.g., saw mill residues that are sold to a pulp mill). Unless flow or stock change accounting is specified in a protocol or standard, there is usually no clear reason to use one rather than the other. Therefore, to provide maximum transparency in studies involving forest carbon, a good approach is to calculate and show net flows of biogenic carbon using both approaches.

4.0 CARBON NEUTRALITY IN THE CONTEXT OF BIOGENIC CARBON ACCOUNTING IN NATIONAL GREENHOUSE GAS INVENTORIES

For many people, the concept of carbon neutrality emerged from accounting conventions for preparing greenhouse gas inventories submitted by nations under the United Nations Framework Convention on Climate Change (UNFCCC). The guidelines for developing these greenhouse gas inventories are issued by the Intergovernmental Panel on Climate Change (IPCC) and were most recently updated in 2006 (IPCC 2006).[2]

IPCC's guidelines separate the accounting for biogenic CO_2 from the accounting for other greenhouse gases. The net emissions (or removals) of biogenic CO_2 are reported in the category of emissions called Land Use, Land Use Change and Forestry (LULUCF), which in the most recent IPCC guidelines has been changed to Agriculture, Forestry and Other Land Use (AFOLU) (IPCC 2006). Because all types of biogenic CO_2 emissions are considered in calculating AFOLU emissions, the biogenic CO_2 emissions associated with the use of biomass for energy are not reported as energy-related emissions as this would double count this biogenic CO_2 given that it is accounted for within forest-related emissions reported under AFOLU. As a result, an emission factor of zero is used for biogenic CO_2 emitted during biomass combustion. This has been called "accounting neutrality" (Malmsheimer et al. 2011). Biogenic CO_2, therefore, is not ignored in national inventory accounting. Net flows of biogenic CO_2 are considered as emissions (or removals) of CO_2 and reported in the inventory report in the LULUCF sector.

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[2] Although the 2006 guidelines have not yet been formally adopted for use under the UNFCCC, in most important respects, they are similar to earlier versions. In the discussion here, therefore, the 2006 IPCC inventory guidelines are used, but where there are important changes from earlier versions, the differences are noted.

Under the IPCC guidelines, the calculations to estimate the net flows of biogenic CO_2 to the atmosphere are normally performed by estimating the annual change in stocks of carbon stored in forests and forest products (in use and in landfills). If these stocks, in total, increase, it means that there was a net removal of CO_2 from the atmosphere, while if they decrease, it indicates a net emission of biogenic CO_2 to the atmosphere. IPCC uses the term harvested wood products (HWP) to refer to all carbon removed from the forest so the carbon in forest products in use and in landfills are described as HWP carbon stocks.

Until recently, the default approach under IPCC guidelines assumed that stocks of biogenic carbon in HWP were not changing (i.e., losses of carbon from HWP were assumed to be exactly matched by additions). This former default approach is mathematically equivalent to (and is often explained as) assuming that the carbon removed from the forest is instantaneously oxidized. In the latest guidelines, this accounting option is no longer the default. This former default approach is not given a name in the updated guidelines but is referred to as an approach wherein the contribution of HWP to the net emissions calculation is assumed to be zero (IPCC 2006). Therefore, for purposes of this report, it is called the “zero HWP contribution” accounting approach.

It is widely accepted, however, that the amounts of carbon stored in products in use and in landfills are increasing (e.g., UNFCCC 2003). This means that the “zero HWP contribution” accounting approach overestimates biogenic CO_2 emissions, at least at the global level. The governments of the world have not been able to agree on an approach to calculating the effects of carbon stored in HWP, however, because different calculation approaches favor different countries. In specific, approaches that calculate emissions based on changes in national stocks of carbon in forests and HWP (stock change accounting) tend to favor countries that are net importers of HWP. Approaches that calculate emissions based on net flows of biogenic carbon to the atmosphere (atmospheric flow accounting) tend to favor countries that are net exporters of HWP. The relative advantages stem from how the accounting treats the carbon in exported HWP. In stock change accounting, the carbon in exported HWP represents an export of carbon storage (a benefit to the importing country). In atmospheric flow accounting, the carbon in exported HWP represents the export of delayed emissions (a benefit to the exporting country).

Stock change accounting and atmospheric flow accounting yield essentially the same result at the global level because when all stocks of carbon in forests and HWP are considered, the net overall change in these stocks must equal the net flow of biogenic carbon to or from the atmosphere[3]. Because of imports and exports of forest carbon, the two approaches do not necessarily give the same result in national inventories. To address concerns about the HWP carbon that crosses national boundaries, variations of the two basic accounting methods have been developed wherein the country producing the wood is given credit for the stock changes or emissions associated with the wood it produces, regardless of where the HWP resides. If the accounting is done using stock changes, this variation is called “production” accounting and if the accounting is done by characterizing flows of carbon to and from the atmosphere, the variation is called the “simple decay” accounting approach (IPCC 2006). These two variations generally, but not always, yield results that, for a given nation, fall between the results obtained using stock account and atmospheric flow accounting.

The various IPCC accounting approaches are summarized in Table 4.1.

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[3] Because small amounts of forest carbon are transferred to pools that are not within the system boundaries used for the accounting (e.g., deep sea sediments via dissolution, erosion, and water-borne transport), in theory the two accounting methods do not provide exactly the same result, but the differences are small enough to ignore for carbon accounting purposes.

Table 4.1 IPCC Biogenic Carbon Accounting Approaches (IPCC 2006)

Name of accounting approach	Based on changes in stocks of stored carbon or on flows of carbon to/from the atmosphere?	Which country is assigned the emissions/removals associated with stock changes or atmospheric flows in the forest?	Which country is assigned the emissions/removals associated with stock changes or atmospheric flows attributable to carbon removed from the forest (HWP)?
Zero HWP Contribution (former default approach)	Either	Country where forest is located	HWP carbon counts as an emission in the country where the wood is produced.
Stock Change	Changes in stocks	Country where forest is located	HWP stock change is assigned to country where the HWP stocks reside.
Atmospheric Flow	Flows to/from atmosphere	Country where forest is located	HWP emissions are assigned to country where the HWP emissions occur.
Production	Changes in stocks	Country where forest is located	HWP stock changes are assigned to country producing the wood.
Simple Decay	Flows to/from atmosphere	Country where forest is located	HWP emissions are assigned to country producing the wood.

The different accounting approaches can yield very different results for countries with large net imports or exports of HWP. In Canada, for instance, the 2007 emissions calculated using the atmospheric flow approach have been estimated to be 60 million tonnes CO_2 per year lower than for the stock change approach (an amount equal to 8% of Canada's national emissions) and 75 million tonnes CO_2 per year lower than the zero HWP contribution approach (FAO 2010).

Some of the controversy about "carbon neutrality", and in specific "accounting neutrality", stems from the effects of imports and exports of biomass, especially under a regulatory framework like the Kyoto Protocol that does not cover all countries. It has been pointed out that because the coverage of the Kyoto Protocol is not global, a country outside of the Protocol can export wood pellets, for instance, to a country within the protocol without the net transfers of biogenic carbon to the atmosphere being captured by the accounting (Searchinger et al. 2009). The exporting country does not report them because it is not a party to the Protocol and the importing country does not report them because under the zero HWP contribution accounting approach used for the Kyoto Protocol, the emissions occur in the country producing the wood.

5.0 BIOGENIC CARBON ACCOUNTING IN VARIOUS APPLICATIONS

Ultimately, there is no single correct way to calculate biogenic CO_2 emissions. Different methods are appropriate for different objectives. Even for a given objective, however, there can still be controversy regarding these calculations. Below, five applications for biogenic CO_2 emission accounting are identified. For each, the issues involved in deciding how to calculate emissions are explored, including the consensus on how to address these issues where consensus exists. The five applications are (a) national greenhouse gas inventories, (b) Scope 1 and 2 greenhouse gas inventories, (c) attributional carbon footprint and life cycle assessment (LCA) studies, (d) policy studies examining the greenhouse gas consequences of using forest biomass (consequential), and (e) regulatory or market-based programs.

5.1 National Greenhouse Gas Inventories

Section 4 described a number of the issues related to biogenic carbon in national greenhouse gas inventories. In this section, that information is expanded upon.

5.1.1 *Physical Boundaries*

The physical boundaries for national inventories are determined by the accounting approach selected. For stock change and flow accounting, the physical boundaries are the national boundaries. For production accounting and the simple decay approach, the physical boundaries are also the national boundaries except for harvested wood, where the boundaries (a) include harvested wood produced in the country performing the inventory, regardless of where the wood resides and (b) exclude harvested wood that originated outside of the country (IPCC, 2006).

5.1.2 *Organizational Boundaries*

The organizational boundaries for a national inventory is equivalent to political boundaries.

5.1.3 *Spatial Boundaries*

The spatial boundaries for a national greenhouse gas inventory are defined by the physical boundaries.

5.1.4 *Temporal Boundaries*

National greenhouse gas inventories cover one-year periods.

5.1.5 *Greenhouse Gases Included in the Analysis*

Under IPCC guidelines, national greenhouse gas inventories are required to include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride, nitrogen trifluoride, trifluoromethyl sulphur pentafluoride (SF_5CF_3), halogenated ethers (e.g., $C_4F_9OC_2H_5$, $CHF_2OCF_2OC_2F_4OCHF_2$, $CHF_2OCF_2OCHF_2$), and other halocarbons not covered by the Montreal Protocol including CF_3I, CH_2Br_2, $CHCl_3$, CH_3Cl, and CH_2Cl_2. Only non-biogenic CO_2 is included in the inventory results for the “Energy” category. Biogenic CO_2 is reported for information purposes in the Energy category but is included in national emissions totals as stock changes, reported in the “Land Use, Land Use Change and Forestry” category (IPCC 2006).

5.1.6 *Baselines*

National greenhouse gas inventories use reference point baselines, starting the inventory at the beginning of each year.

5.1.7 *Attribution and Allocation of Impacts on Forest Carbon Stocks*

The attribution of forest carbon stocks is determined by the accounting approach. For stock change and flow accounting, the impacts on forests carbon stocks included in the inventory are all of those that occur within national boundaries (including carbon stocks in harvested wood residing in the country). For production accounting and the simple decay approach, the impacts included are the same except that the analysis excludes carbon in wood harvested outside of the country and includes carbon in wood produced by the country but exported (IPCC 2006).

5.1.8 *Availability and Quality of Data on Forest Carbon*

The forest carbon data used by national governments in preparing national greenhouse gas inventories varies depending on the country. In Canada and the US, the national governments have extensive sampling and modeling programs in place that inform the national estimates of changes in forest carbon stocks (Environment Canada 2012b; USEPA 2012b).

5.1.9 *Land Use Change and Forest Conversion*

The impacts of land use change and forest conversion are captured in the sampling and modeling programs performed by the US and Canadian governments (USEPA 2012b; Environment Canada 2012b).

5.1.10 *Sustainable Forest Management*

While the benefits of sustainable forest management are reflected in the national inventories of the US and Canada, these are not specifically quantified.

5.1.11 *Accounting Methodologies*

Accounting methodologies for national and international greenhouse gas inventories, including biogenic carbon, are issued by the Intergovernmental Panel on Climate Change (IPCC), and adopted for use under the United Nations Framework Convention on Climate Change (UNFCCC). The most recent guidelines, issued by IPCC in 2006, are being used internationally on a trial basis (IPCC 2006).

5.2 Scope 1 and Scope 2 Greenhouse Gas Inventories for Entities

The objective of an entity-level greenhouse gas inventory is to characterize the actual greenhouse gas emissions attributable to an entity. Often, emission inventories are limited to emissions from processes owned/controlled by the entity (Scope 1 emissions). In some cases, for instance under the WRI/WBCSD GHG Protocol Corporate Reporting Standard, emissions associated with purchased electricity or steam (Scope 2 emissions) are also included. Scope 3 emissions are all other emissions attributable to the entity that is being inventoried (WRI/WBCSD 2004). An inventory that includes Scope 1, 2, and 3 emissions is a carbon footprint, and is discussed in Section 5.3. It is important to note that the current standard and guidelines GHG Protocol Scope 1 and 2 inventories require only that biogenic CO_2 emissions be reported separately. There is no requirement to examine other forest carbon stocks or flows.

5.2.1 *Physical Boundaries*

In greenhouse gas inventories, the physical boundaries may encompass both operations owned/ controlled by the entity and those not owned/controlled. In the WRI/WBCSD GHG Protocol, these operations are defined by “organizational boundaries” and the emissions from them are categorized according to “operational boundaries”, defined by Scopes, as described above in Section 3.1.2. The physical boundaries of an inventory, therefore, include all processes described by the Scopes covered by the program of interest.

5.2.2 *Organizational Boundaries*

Under the WRI/WBSCD GHG Protocol, organizational boundaries apply to operations or processes while operational boundaries (Scopes) apply to emissions from those operations (WRI/WBCSD 2004). The boundaries of Scope 1 and 2 inventories are therefore defined based on the type of ownership or control the entity has over the sources of emissions. Organizational boundaries for a corporate entity can be limited to the processes it owns/controls (a Scope 1 emissions inventory) or the organizational boundaries may extend to the types of ownership/control associated with Scope 2 emissions.

5.2.3 *Spatial Boundaries*

The spatial boundaries for an inventory are set according to the decisions on physical and organizational boundaries that apply to the inventory. For instance, if the study is intended to characterize only the emissions from operations owned or controlled by the entity, the spatial boundaries might include only those operations and land that are owned or controlled.

5.2.4 *Temporal Boundaries*

Scope 1 and 2 inventories usually represent emissions that occur over a specific period of time. In most cases, a one-year period is used, resulting in an annual inventory (WRI/WBCSD 2004; IPCC 2006; USEPA 2009; Environment Canada 2012a).

5.2.5 *Greenhouse Gases Included in the Analysis*

The greenhouse gases covered in an inventory vary among reporting protocols and programs. Most GHG inventory programs covering Scope 1 (and sometimes Scope 2) emissions require, at a minimum, the reporting of CO_2, CH_4, N_2O, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and SF_6 (WRI/WBCSD 2004), while some extend the list to include several other fluorinated gases (USEPA 2009; Environment Canada 2012a). In all Scope 1 and Scope 2 inventory protocols known to NCASI, biogenic CO_2 emissions, where they are included in reporting requirements, are tracked separately from other emissions and are not added to emissions totals (e.g., WRI/WBCSD 2004; USEPA 2009; Environment Canada 2012a), unless, as in the case of IPCC inventory guidelines for national inventories, they are instead included within the accounting of net forest carbon emissions, which are added to overall inventory results (IPCC 2006).

5.2.6 *Baselines*

Because the objective of a Scope 1 and 2 inventory is to characterize the actual net emissions from an entity or system over time, a reference point baseline (the beginning time for the inventory) is used (WRI/WBCSD 2004; (IPCC 2006; USEPA 2009; Environment Canada 2012a).

5.2.7 *Attribution and Allocation of Impacts on Forest Carbon Stocks*

GHG Protocol Scope 1 and 2 reporting requirements, at present, do not extend back to the forest. Unless a company wants to extend the accounting beyond what is required in the GHG Protocol, therefore, attribution and allocation is not an issue for these types of inventories.

However, companies may sometimes want to address forest carbon in Scope 1 and 2 inventories. In these situations, experience has shown that attributing changes in forest carbon stocks to individual entities involves considerable uncertainty. With Scope 1 inventories, the task is simplified by the constraint that only processes owned or controlled by the entity are within the boundaries of the assessment. Even here, however, there are a number of complexities.

Emissions are often attributed, based on ownership and control, by dividing emissions into “Scopes”. The reporting of biogenic CO_2, however, is not normally done within the framework of emission Scopes. In the Corporate Accounting and Reporting Standard of the GHG Protocol, which applies to Scope 1 and 2 inventories, direct emissions of biogenic CO_2 (emissions that would otherwise be considered Scope 1 emissions) are “reported separately from the scopes” (WRI/WBCSD 2004). Nonetheless, in the GHG Protocol, and a variety of other programs, biogenic CO_2 from combustion from units owned by the entity doing the reporting must be reported, although they are not added to emissions totals (e.g., WRI/WBCSD 2011a, 2011b; IPCC 2006; USEPA 2009; Environment Canada 2012a).

5.2.8 *Availability and Quality of Data on Forest Carbon*

GHG Protocol Scope 1 and 2 reporting requirements, at present, do not extend back to the forest. Unless a company wants to extend the accounting beyond what is required in the GHG Protocol, therefore, the question of data availability does not arise for these types of inventories.

5.2.9 *Land Use Change and Forest Conversion*

GHG Protocol Scope 1 and 2 reporting requirements, at present, do not extend back to the forest. Unless a company wants to extend the accounting beyond what is required in the GHG Protocol, issues related to land use change and forest conversion are not encountered. The question does arise, however, in Scope 3 inventories and carbon footprint studies, discussed later in this document.

5.2.10 *Sustainable Forest Management*

GHG Protocol Scope 1 and 2 reporting requirements, at present, do not extend back to the forest. Unless a company wants to extend the accounting beyond what is required in the GHG Protocol, the question of the impacts of sustainable forest management does not arise for these types of inventories. The question does arise, however, in Scope 3 inventories and carbon footprint studies, discussed later in this document.

5.2.11 *Accounting Methodologies*

Accounting methodologies for Scope 1 and Scope 2 inventories are published by the GHG Protocol, an initiative of the World Resources Institute and the World Business Council for Sustainable Development (WRI/WBCSD 2004). Similar standards have been issued by the International Organization for Standardization (ISO 2006b).

5.3 Attributional Carbon Footprint Studies and LCA Studies

The discussion in this section is limited to attributional carbon footprints and LCA studies. Because a carbon footprint study is simply an LCA study which is limited to carbon and greenhouse gases, the discussion is focused on carbon footprint studies but also applies to LCA in general. Attributional studies are those intended to characterize the system as it actually exists, without consideration of how it may affect other systems.

5.3.1 *Physical Boundaries*

The objective of a carbon footprint study is to calculate the net transfers of greenhouse gases to the atmosphere attributable to an entity or a particular product. Generally, therefore, in carbon footprint and LCA studies, the physical boundaries extend to all processes that are connected to the entity or product by flows of material or energy.

5.3.2 *Organizational Boundaries*

Carbon footprint studies, by definition, extend to all processes connected to the entity or product of interest, regardless of ownership. Therefore, these studies specifically include Scope 1, Scope 2, and Scope 3 emissions. While organizational boundaries are not used to define the boundaries of the analysis, the results of carbon footprint studies, however, are often organized according to organizational boundaries and emission Scopes (i.e., operational boundaries) (WRI/WBCSD 2011a, 2011b).

5.3.3 *Spatial Boundaries*

The spatial boundaries used in carbon footprint studies are related to the physical and temporal boundaries used. The spatial boundaries need to include all processes within the physical boundaries but are different from physical boundaries in that the spatial boundaries determine how the processes are modeled. For carbon footprint studies of products, the analysis generally includes all land providing wood for the specific product of interest, wherever it is located. This area may be an area larger or smaller than the land owned by the entity making the product.

For carbon footprints of entities there is less specific guidance in current standards and protocols than provided for product-level carbon footprints. Nonetheless, it is consistent with the general objective of entity-level footprints to extend the boundaries, at a minimum, to all land owned or controlled by the entity. Because such footprints are intended to include all impacts associated with operations owned or controlled by the entity, this would normally include all owned or controlled land, whether or not the land supplies wood. Identifying spatial boundaries for land not owned or controlled by the entity may be more difficult. Conceptually, however, it is consistent with the objective of an entity-level footprint to extend the boundaries to all land supplying wood, even if that land is not owned or controlled.

In addition, when accounting for forest carbon impacts, spatial boundaries need to include whatever land area is needed to properly account for time-dependent processes in the forest that are addressed within temporal boundaries. For instance, in product-level footprints, if temporal boundaries are extended back to include photosynthesis during the growth of plots providing wood for a product of interest, spatial boundaries may only need to include plots providing the wood used in that product. In studies of entities and in policy studies, however, temporal boundaries often do not extend back in time. In these cases, great care is required in selecting spatial boundaries as they need to include time-dependent processes that are relevant to the objective of the study. In entity-level studies, for instance, to properly account for photosynthesis (a raw material assembly process), the spatial boundaries may need to extend beyond those plots supplying wood in the inventory year to include all plots growing raw material that the entity expects to use in future years. Especially in policy studies, it may be necessary to extend spatial boundaries even further to capture indirect market-related effects that occur on land that is not directly affected by the entities or activities that are the focus of the study. These indirect market-related effects are sometimes called “market leakage”. Market-related responses have been shown to be very important to policy studies of the impacts of using forest biomass suggesting the need, in some cases, to consider spatial boundaries for forest carbon accounting that extend far beyond the area supplying the facilities included in the study (e.g., Daigneault, Sohngen, and Sedjo 2012).

5.3.4 *Temporal Boundaries*

There is considerable complexity associated with the selection of temporal boundaries for carbon footprint studies of forest product companies and forest products. In general, the following general principles apply.

- In studies of products, it is common practice to extend temporal boundaries back in time to account for impacts associated with producing the wood used in the product, including photosynthesis (BSI 2011; WRI/WBCSD 2011b).
- While existing standards for carbon footprints of entities provide guidance on the general temporal boundaries for analysis, they are less specific on how to establish temporal boundaries to account for removals of CO_2 from the atmosphere associated with photosynthesis and reflected in changes in forest carbon stocks. In studies of entities, one approach is to limit analysis of changes in the forest to those that occur in the year for which the footprint is being done. It is important, however, that the analyst determine that this approach is consistent with the objectives of the study as, depending on the spatial boundaries, it may not include photosynthesis that is a key part of the entity’s supply chain. If the analyst decides to set temporal boundaries equal to one year (the year of the inventory), it

may be important to separately address legacy land use change impacts attributable to the entity. If these impacts occur outside of the temporal boundary of the inventory, they would not added to the inventory results but could be reported separately. One advantage of a one-year temporal boundary for entity-level footprints is that it results in a series of annual entity-level footprints that can be summed to obtain an accurate estimate of the cumulative impact over time. The interest in cumulative impacts over time is seldom relevant for a product-level footprint.

- In both product- and entity-level footprint studies, temporal boundaries are normally extended to include downstream processes (e.g., product use and end of life), whenever they occur. Calculations for carbon stored in products in use may consider a period of 100 years (BSI 2011) or may consider an infinite time period, thereby excluding non-permanent storage (WRI/WBCSD 2011b). Calculations for carbon stored in landfills at end of life may consider a period of 100 years (BSI 2011) or may extend to infinity, including only that carbon stored permanently (WRI/WBCSD 2011b).
- In product-level footprint studies, the results are most commonly shown as a single value representing the net life cycle emissions. In addition, however, the emissions can be shown as a time series, allowing the timing of emissions/removals to be understood.

Within these guiding principles, considerable variability may exist from one standard to another and from one study to another. The question of the timing of CO_2 removals by the forest can be particularly important to carbon footprint studies in the forest products industry. Perhaps the largest source of controversy is on the question of whether the analysis should (a) extend temporal boundaries back to include photosynthesis in the wood eventually harvested for the product or in the inventory year of interest, or (b) only consider photosynthesis in trees that are regrown after the harvest. In other words, this controversy is over whether CO_2 removals occur before or after harvest.

For carbon footprint studies, the existing protocols and standards generally include photosynthesis in the wood before harvest (BSI 2011; WRI/WBCSD 2011a, 2011b). The ISO 14044 life cycle assessment standard indicates that “ideally, the product system should be modeled in such a manner that inputs and outputs at its boundary are elementary and product flows”. “Elementary flows” are defined as “material or energy entering the system being studied that has been drawn from the environment without previous human transformation…” (ISO 2006a, p.1). Under ISO 14044, therefore, the decision on whether to include photosynthesis within the system being studied depends on whether the “elementary flow” is CO_2 from the atmosphere or wood from the forest. Helpfully, in ISO Technical Report 14047 an example is provided for examining “impacts of greenhouse gas (GHG) emissions and carbon sinks on forestry activities” and in that example, the elementary flow is CO_2 removed from the atmosphere by photosynthesis before the tree is harvested (ISO 2012a). Note that this issue does not arise when doing biogenic carbon accounting by stock change methods (see Section 3.8).

5.3.5 *Greenhouse Gases Included in the Analysis*

Carbon footprint studies typically include all significant greenhouse gases. For studies in the forest products sector, these will usually include at least CO_2, CH_4, and N_2O. Standards and protocols sometimes dictate that other gases be included (PFCs, HFCs, and SF_6 in particular).

5.3.6 *Baselines*

Attributional studies (carbon footprint and LCA) are intended to characterize the actual attributes of the system being examined, in terms of the net emissions to the atmosphere from the system (WRI/WBCSD 2011b). The reference point baseline is the beginning of the life cycle.

5.3.7 *Attribution and Allocation of Impacts on Forest Carbon Stocks*

The attribution and allocation of impacts on forest carbon are often the most difficult aspects of performing carbon footprint studies of forest products or forest product companies. These emissions/ removals are handled differently from greenhouse gas emissions associated with forest management (e.g., fossil fuel use in forest management, fertilizer use, and weed control). The following discussion does not address these other greenhouse gas emissions from forest management. The issue here is forest carbon stock-related impacts only.

5.3.7.1 *Product-Level Carbon Footprints*

Product-level carbon footprints typically include all processes that are attributable to the product being studied. In this case, it is necessary to identify all of the forest involved in growing the wood used in the product and then estimate the carbon changes on that land that are attributable to the product being studied. A method of allocating the emissions/removals, however, may still be needed. For instance, if the land produces several types of wood (e.g., thinnings and saw timber), it may be necessary to decide how to allocate emissions/removals to the various types of wood produced by the land. In cases where the forest has been managed sustainably for a considerable time (e.g., several rotations), it may be possible to justify the assumption that long-term carbon stocks are stable, meaning that there are no forest carbon impacts over time associated with wood production. In many cases, however, forest carbon stocks are affected by multiple natural and anthropogenic disturbances, making it difficult to quantify and allocate stock changes among various products.

Another important allocation decision concerns the attribution of the land use change impacts attributable to increasing the management intensity of a forest, e.g., converting an unmanaged forest to a planted forest. In such situations, it is necessary to decide how to allocate the losses (or gains) of carbon due to the forest conversion to the different products that will be produced from that forest land over the years. There is no consensus on how this should be done. Several approaches have been proposed. If the "harvest cycle" is greater than 20 years, the GHG Protocol Product Life Cycle Accounting and Reporting Standard generally allocates the entire land use change impact to the products made from the wood harvested from the original forest during the conversion, although there are exceptions. If the harvest cycle is less than 20 years, the impact is allocated to all products made from wood harvested from the land over twenty years, including those made from wood obtained from the original forest during conversion (WRI/WBCSD 2011b). Others have suggested ignoring land use change impacts because when allocated to the multiple products made from the land over the years, the allocated impact becomes negligible (Ekvall 1996).

It is normally easier to characterize the forest carbon impacts attributable to a specific product in cases where the company making the studied product owns or control the land on which the wood in the product was grown, compared to when it does not.

5.3.7.2 *Entity-Level Carbon Footprints: Company Owns the Wood-Producing Land*

Current carbon footprint standards offer relatively little guidance on how to address land use change in entity-level carbon footprint studies. Conceptually, however, in an annual entity-level carbon footprint study (i.e., a study done to calculate emissions over a one-year period), allocation is not needed for land use change (or carbon stock changes) on land that the entity owns or controls because all of the emissions/removals on land owned or controlled by the entity are included as long as they occur within the inventory year.

5.3.7.3 *Entity-Level Carbon Footprints: Company Does Not Own or Control the Wood-Producing Land*

It is common in the US for companies to obtain much of the wood they use from land that they do not own or control. In Canada, the situation is different, with most of the wood coming from Crown-owned, tenured land. While tenure rights are sometimes shared by several companies, the more common situation is for an area of land to be under tenure to only one company. Companies operating on tenured land need to determine whether tenure rights constitute "control" over the land. Guidance on making this determination is contained in the GHG Protocol Corporate Accounting and Reporting Standard, Chapter 3 (WRI/WBCSD 2004). In cases where the company does not own or control the land producing the wood of interest, it can be very difficult to characterize the carbon impacts of wood production in a carbon footprint.

As noted above, current standards offer little guidance in addressing land use change in entity-level footprints. It is consistent with the general objective of an annual entity-level footprint (one involving emissions over a one-year period), however, to identify those impacts attributable to the wood used by the company in the inventory year. When the wood-producing land is not owned or controlled by the company, this is difficult for several reasons. First, the company conducting the footprint study may not have data on the carbon stocks on the land producing the wood or information on the past use of this land. Second, it is possible that the land is providing wood to several companies, making it even more difficult to isolate the impacts attributable to the wood being used by the company performing the study. In addition, forest carbon stocks are affected by a range of other natural and anthropogenic disturbances that will be difficult to quantify and allocate among various wood users. In some cases, companies may be able to work with wood suppliers to obtain information needed either to show that long-term carbon stocks are stable or to calculate and allocate carbon impacts attributable to land use change or forest conversion. It may also be possible to use existing public data (e.g., Forest Inventory and Analysis (FIA) data in the US available at www.fia.fs.fed.us or the Canadian National Forest Inventory available at https://nfi.nfis.org/home.php) to examine trends in forest carbon stocks and perhaps show that long-term forest carbon stocks in the area providing wood are stable. The WRI/WBCSD GHG Protocol Product Life Cycle Accounting and Reporting Standard also suggests that it may be possible to make these estimates using satellite imaging data and land use modeling (WRI/WBCSD 2011b). For some purposes, a simple demonstration of the continuing use of sustainable forest management practices may be adequate proof that wood obtained is being produced under conditions unlikely to deplete long term carbon stocks. If none of these is possible, there is little that can be said about the impacts of wood production on forest carbon. In such cases, one must conclude that the carbon footprint is incomplete.

5.3.7.4 *Sources of Guidance on Allocation of Forest Carbon Emissions/Removals*

General guidance on allocation is contained in a number of places. The ISO 14044 standard on LCA, for instance, provides guidelines on allocation (ISO 2006a). In addition, the ISO/TR 14049 technical report provides guidance and examples (ISO 2012b). NCASI has reviewed the methods used for allocation in situations where co-products (e.g., thinnings and saw timber) are involved (NCASI 2012).

Guidance on identifying and allocating impacts due to land use change and forest conversion is available in only a few places, and the guidance tends to be very specific to the protocol or standard involved (WRI/WBCSD 2011b; BSI 2011). Generally, this guidance specifies a look-back or assessment period that defines the time to examine for past land use change impacts (e.g., 20 years or one rotation period, whichever is longer) and a distribution or amortization period over which the impact is distributed to the products manufactured from wood produced on the land in question (often

20 years). These standards often include generic methods for calculating land use change impacts in cases where the specific land producing the wood is not known.

The need to allocate impacts associated with land use change is primarily relevant for carbon footprints of products because in entity-level annual footprints, land use change impacts on land owned or controlled by the entity would be expected to be fully accounted for in the year they occur. The question of how to account for land use change impacts in entity-level footprints when the impacts are on land not owned or controlled by the company is a difficult one. The WRI/WBCSD GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard suggests that entities use the same approaches as used in the companion WRI/WBCSD product-level standard, but it is not clear how this would be accomplished.

In summary, it is usually difficult and often impossible to precisely identify the forest carbon emissions/removals attributable to wood used to produce a specific product. Even in entity-level footprints, there are significant challenges in estimating these emissions. Only in cases where entities own the land providing the wood in question will it normally be possible to accurately estimate impacts due to activities that change the long-term average carbon stocks on the land (e.g., forest conversion or afforestation). In other cases, it may be possible to rely on the existing data to examine regional trends in carbon stocks or to point to the adherence to sustainable forest management certification to provide evidence that wood production is unlikely to be causing a decline in long-term average stocks of forest carbon.

5.3.8 *Sustainable Forest Management*

Often, carbon footprint protocols have different forest carbon calculations for wood from sustainably managed forests, specifically those where it can be assumed that forest carbon stocks are stable over the long term, vs. wood from land where the removal of the wood has caused a change in long-term carbon stocks (e.g., land affected by land use change such as forest conversion or afforestation) (e.g., WRI/WBCSD 2011b). It is usually necessary, therefore, when developing the framework for analysis, that wood supplying areas be divided into these two types.

5.3.9 *Accounting Methodology*

Biogenic carbon accounting methodologies for carbon footprint studies and LCA studies are described in various standards, guidelines and protocols (WRI/WBCSD 2011a, 2011b; BSI 2011; ISO 2006b, 2012a).

5.4 Policy Studies of the GHG Impacts of Using Forest Biomass

Studies of the potential impacts of government policies on atmospheric greenhouse gases are fundamentally different than Scope 1 and 2 greenhouse gas inventories as well as carbon footprint and attributional LCA studies. Studies of the impacts of policies are done to understand the consequences of a proposed change in policy, and the type of analysis involved is therefore sometimes called “consequential”. Consequential analyses are fundamentally different from inventories, carbon footprints, and other attributional studies (i.e., studies intended to characterize a system’s existing attributes). In short, attributional studies are intended to describe the system as it exists, while consequential studies are usually intended to describe the consequences of choosing one course of action rather than continuing with business as usual (BAU). In studies of potential policy outcomes, the question is almost always “What will the consequence of the proposed policy be relative to a BAU scenario?”

5.4.1 *Physical Boundaries*

Because policy studies are normally interested in the differences between the outcomes under a new policy scenario compared to a BAU scenario, the analysis can often be limited to only those processes that will be different under the two scenarios. One must be careful, however, to consider how the policy might cause changes outside of the boundaries of the specific systems that could either increase or decrease the total benefits of the policy (i.e., indirect effects, such as those due to leakage). An example of such changes that can be important in studies involving forest biomass is the response of land owners to market forces. Land owners have shown themselves to be adept at expanding forested acreage and increasing forest productivity in anticipation of new demand. In the southern US, for instance, the amount of softwood harvested from private land for the forest products industry more than doubled between the early 1950s and the late 1990s (Adams, Haynes, and Daigneault 2006). Over the same period, carbon stocks on private softwood forest land remained essentially constant (Mickler, Smith, and Heath 2004), while the acreage of planted pine increased from less than 5 million acres in the early 1950s to almost 30 million (Wear and Greis 2011). Without these market-driven investments, carbon stocks would likely have declined in the face of a doubling of harvesting. Policy studies that ignore such market-related responses are likely to understate the benefits of using forest biomass (Daigneault, Sohngen, and Sedjo 2012). The boundaries of policy studies, therefore, must extend as far as needed to capture important indirect effects.

5.4.2 *Organizational Boundaries*

Organizational boundaries are usually not considered in policy studies, as the intent is to understand the total consequences of policy selection. In cases where political boundaries are important to the outcome, however, they may need to be specifically addressed in the analysis.

5.4.3 *Spatial Boundaries*

The spatial boundaries used in policy studies are largely defined by the scope of the policies of interest. There are, however, important trade-offs to consider. Larger spatial boundaries will help reduce many sources of leakage. For instance, some policies may have the effect of shifting forest-related activity. By extending the spatial boundaries to include potentially affected areas, this type of leakage can be reduced. To address market-related leakage, an attempt should be made to extend boundaries to include areas likely to respond to changes in supply and demand associated with the policy being studied. The larger the spatial boundaries, however, the more complex the analysis is likely to become.

Policy studies addressing forest carbon are sometimes performed at the scale of a single stand and then extrapolated to larger spatial scales. While this may be appropriate for some purposes, it should be done with care as this approach can miss important factors that operate at larger scales. The importance of scale in policy studies has been examined by Galik and Abt who found that small-scale analysis is likely to understate the benefits of using forest biomass, suggesting that, in general, policy studies should be performed at large spatial scales (Galik and Abt 2012).

5.4.4 *Temporal Boundaries*

The issues involved in selecting temporal boundaries for policy studies are generally similar to those involved in carbon footprint studies of products, discussed in Section 5.3.4 above. An additional important consideration, however, is the time over which policy outcomes are compared. In some policy studies, it may be found that the net emissions from biomass-based systems exceed those from alternative systems for a period but, due to the renewability of biomass, this is almost always reversed in the intermediate to long term. It is important in policy studies, therefore, that the period of analysis extend far enough into the future to reveal the long-term attributes of systems relying on forest biomass. The decision on whether short-, intermediate- or long-term impacts are the most important is a policy decision, but if policy makers are going to understand the impacts of emissions timing the analysis needs to be performed in a way that reveals all three.

5.4.5 *Greenhouse Gases Included in the Analysis*

The greenhouse gases included in policy studies will be determined by the goal of the studies. In general, however, these studies should include all greenhouse gases that are potentially important to the differences between policies being examined. For policy studies involving biomass-based systems, this will normally include at least CO_2, CH_4, and N_2O.

5.4.6 *Baselines*

In most policy studies, the objective of the study is to understand the consequences of changing a policy from what is now in place (i.e., business as usual or BAU) to a new policy. In other words, policy studies are almost always “consequential” rather than “attributional”. This requires what has been called an “anticipated future baseline” (USEPA 2011).

When using an anticipated future baseline, two scenarios are projected into the future. The first represents the anticipated future under BAU policies while the second represents the anticipated future under the new policy. The estimated consequence of the policy is the difference between these two projections.

Anticipated future baselines are inherently more uncertain than reference point baselines where the impact is simply determined as the difference in GHG emissions from a system at the end of an accounting period compared to those at the beginning of the accounting period. This is because of all of the assumptions that go into predicting the future and the many factors not considered in the analysis that can cause predictions to be incorrect. An interesting example of the inherent certainty in forecasting the effects of policies on forest carbon can be found in comparing the findings of two recent and credible studies of future US forest carbon stocks. One of these studies predicts peaking carbon stocks followed by a gradual decline of carbon stocks, while the other predicts considerable and continuing growth in carbon stocks over the same period (USDA 2012; Ince and Nepal 2012).

Because of the inherent uncertainties involved in policy studies, especially those involving alternative future baselines, it is important to perform sensitivity analyses around policy scenarios so that the robustness of the findings to various assumptions and uncertainties can be understood.

5.4.7 *Attribution and Allocation of Impacts on Forest Carbon Stocks*

In studies of the impacts of proposed policies, the impacts of interest are those attributable to the policy change.

5.4.8 *Land Use Change and Forest Conversion*

These effects can be addressed in studies looking at the impacts of policies by expanding the spatial and temporal boundaries to include areas that could be directly or indirectly affected by the change in policy. These include areas that could be impacted by land owner responses to changes in supply and demand for forest biomass. It must be understood, however, that projections on land use change or forest conversion impacts are uncertain and become more so as boundaries are expanded.

5.4.9 *Accounting Methodology*

Policy studies are usually performed using consequential carbon footprint or LCA methodologies. These typically rely on anticipated future baselines combined with standard LCA and carbon footprint methods, described elsewhere in this report.

5.5 Forest Carbon Regulations or Market-Related Programs

The accounting frameworks used in regulatory or market-related programs will, by necessity, be constrained by the laws and regulations under which they are developed. As a general matter, however, it is important to understand that while these programs may be informed by the results of policy studies, they need not rely on the same carbon accounting approach as used in policy studies. In many cases, policy makers have the flexibility to implement regulatory or market-oriented programs using any carbon accounting framework that leads to the desired outcomes identified in the associated policy studies. In considering the options, policy makers may have to weigh a number of factors including (a) the robustness of the accounting framework to the uncertainties revealed in sensitivity analyses performed in policy studies and (b) a range of implementation issues (cost, simplicity, etc.).

6.0 SUMMARY AND CONCLUSIONS

Various methods can account for biogenic carbon and biogenic CO_2. The current debate about “carbon neutrality” is essentially a debate about how the term should be defined and the carbon accounting methods that should be used. Ultimately, the methods used for biogenic carbon accounting need to be matched to the objectives of the study.

In Scope 1 and Scope 2 inventories, emissions from an entity are normally characterized over a one-year period. Biogenic CO_2 is reported separately from other inventory results and not included in emissions totals.

In national greenhouse gas inventories, emissions of combustion-related biogenic CO_2 are not included in emissions totals for combustion sources, but net flows of biogenic CO_2 are included as emissions (or removals) in the section of the inventory dealing with land use, land use change, and forestry (called agriculture, forestry, and land use in the most recent IPCC guidelines). The net emissions (or removals) are also included in the inventory totals for the nation. These inventories capture impacts on carbon in forests and forest products (or net flows of biogenic carbon to the atmosphere) that occur within the inventory year.

Carbon footprint and LCA studies involve many more considerations. First, these studies involve the complete value chain instead of just those processes responsible for Scope 1 and 2 emissions. Second, the methods used are generally different when looking at products compared to looking at entities. Third, careful attention is required to the physical, spatial, and temporal boundaries of the analysis so that the attributes of the systems are properly characterized. In product-level footprints, the analysis typically extends from the cradle to the grave, encompassing the entire value chain. Existing protocols and standards indicate that in product-level footprints, the boundaries of the analysis should include photosynthesis occurring before harvest. In entity-level footprints, the guidance is less specific. In both cases, the temporal boundaries extend through end of life. One of the most significant challenges for carbon footprints is identifying, attributing, and allocating changes in forest carbon stocks to specific products or entities, especially where land use change or forest conversion is involved. Sustainable forest management certification schemes can help reinforce claims that wood is being produced in ways that are not depleting long term forest carbon stocks, although these initiatives do not, at present, include metrics related specifically to carbon.

Studies of the impacts of forest carbon policies usually use anticipated future baselines so that a proposed new policy can be compared to anticipated future conditions under business as usual conditions. Such analyses involve considerable uncertainty. The results of these studies can be influenced by a number of factors, including the extent to which they address important indirect impacts, such as those related to market responses and land owner responses to changes in supply and demand. Addressing these considerations will normally dictate that the spatial scale of the assessment be as large as possible. Given the uncertainties in policy studies attempting to examine alternative futures, sensitivity analysis can be important tool for understanding the robustness of different policies to uncertain future conditions.

While many regulatory programs are informed by policy studies, these programs do not need to rely on the same methods for biogenic carbon accounting as used in policy studies. Ultimately, when implementing regulatory or market programs, policy makers need to consider a range of factors, including the alignment of the accounting framework with the policy objectives, the robustness of the accounting in the face of uncertainties about the future, and the ease of implementation.

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