Forest Sustainability and Carbon Balance of EU Importation of North American Forest Biomass for Bioenergy Production

September 2013

Report Prepared By:

AEBIOM
EUROPEAN BIOMASS ASSOCIATION

BC Bioenergy Network
PARTNERING FOR A GREENER FUTURE

USIPA
U.S. Industrial Pellet Association

WOOD PELLET ASSOCIATION OF CANADA

With the collaboration of:

Drax
GDF SUEZ / Laborelec
Essent NV
E.ON Climate & Renewables
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Executive Summary

The context

Biomass for energy plays a significant role in the EU renewable energy picture, with bioenergy expected to remain a key strategy for both the near and long term. Although biomass supplies within EU Member States are substantial, it will nonetheless be necessary to import significant volumes of fuel pellets and other forms of biomass in order to meet ambitious EU renewable energy targets.

Given that the impetus for a shift toward renewable fuels is concern over levels of atmospheric carbon, it is essential that efforts to reduce fossil fuel use in the EU lead to lower levels of atmospheric carbon and do not result in increased carbon emissions. It is also important that forest sustainability in biomass supply regions not be threatened.

A number of studies have examined the carbon implications of energy production from forest biomass. Conclusions are wide ranging, from those that claim carbon emissions stemming from energy production from trees can be worse than when burning coal, to determinations that wood-based bioenergy offers large carbon mitigation benefits. Examination of such studies reveals that outcomes are very heavily dependent upon underlying assumptions – assumptions that are sometimes unrealistic.

Objectives and focus

The objectives of this paper are to better inform stakeholders about current biomass sourcing practices, to highlight the key role of Sustainable Forest Management (SFM) in forest-based biomass energy production, to outline commercial realities of SFM decision making in the context of healthy forests used for multiple purposes, and to critically examine the carbon dynamics of forests from which biomass fuels are obtained. With regard to the latter, this paper points out the critical nature of assumptions in forest bioenergy carbon modelling, brings forth views from the bioenergy sector regarding criticisms raised in several recent reports, and examines the carbon implications of several scenarios of biomass importation for EU bioenergy production.

Although EU biomass production potential is large, in practice, projections from Member States National Renewable Energy Action Plans and from experts highlight the role of biomass imports from countries outside the EU as critical to meeting the EU renewable energy target. The US Southeast region (SE US) and British Columbia, Canada (BC) are viewed within the EU as important sources of biomass fuel needed to fulfil near and mid-term renewable energy targets. As both of these regions produce fuel pellets from woody biomass, there is concern that rising exports to the EU may inadvertently increase levels of atmospheric carbon in the near term and threaten long-term forest sustainability in North America. This report focuses on the SE US and BC as two main supply regions of forest-based fuel pellets for EU consumption.

Biomass potential and Sustainable Forest Management (SFM)

Examination of biomass availability and regulatory frameworks governing forest harvest in the two North American regions of interest shows great potential for increased extraction of woody biomass as well as long-established histories of responsible forestry and government oversight of forest management and harvest. In the SE US – a region in which private landowners control 84% of total forest land and over 93% of forest growing stock – net forest growth exceeds net removals by 35%, and standing biomass volumes are higher than at any point in over a half-century despite the fact that over the same time frame harvest volumes have doubled. These conditions in the SE US region are due in large part to strong forestry research, education, and outreach programs throughout the region coupled with a long history of investment, and commitment to forest retention and management on the part of forest landowners. For the US as a whole, the government estimates forest biomass availability at 83 to 102 million dry tons in 2030, with the vast majority of this projected volume in the SE region. In British Columbia, Canada, where most forest land is owned by the government, large volumes of mill residue that until very recently were burnt as waste are available for use, as are vast volumes of logging residues that are commonly disposed of by piling and burning annually each fall. Bioenergy production offers an immediate opportunity to stem this wasteful practice and reduce emissions to the atmosphere.

In both regions, forestry is practiced under strict guidelines that help to ensure responsible harvesting and restoration of harvested sites. Forest landowners and forest products companies must comply with multiple laws and regulations promulgated by various levels of government in conducting harvest operations and silvicultural activities. Also, these regions are involved in developing voluntary SFM certification programs. In both regions there are highly integrated and robust forest industries in which free market forces dictate a multiple product approach to raw material allocation. Forest managers consider market prices for all products, forest growth rates, and the time value of money to determine the financially optimal time to harvest. Therefore, it is the more valuable products, such as lumber and plywood, which drive the decision to harvest, not the lower value products such as biomass. Consequently, high demand for the least valuable product is unlikely to drive forest owners (public or private) to act against their own business interests while harvesting trees that will grow into more valuable products. The use of high value forestry products in the bioenergy industry is economically unlikely and there is little to no prospect of such activity becoming mainstream. Rather than being the main driver of the forest management choice and creating new commercial demand for limited forest resources, the wood energy market can lead to healthier and better managed forests, higher land values, and greater baseline carbon sequestration on the land. Indeed, this market is encouraging forest owners to use their existing resources more efficiently by allowing utilization of previously unused residues and providing revenue to support thinning of stands that will lead to more productive forests in terms of ultimate high value product potential.

Key insights regarding modelling

A review of literature and modelling of the carbon implications of biomass importation for EU bioenergy production formed much of the basis for this report. Findings reveal that assumptions and methodological choices employed in modelling forest carbon dynamics play a significant role in determining study outcomes. Methodological choices (baseline, spatial considerations and temporal consideration) and scenario assumptions (biomass origin, fossil fuel and efficiency comparators and counterfactual) are vitally important to realistic and accurate results. Findings point to fundamental flaws in key assumptions and methodology that underlie prominent studies that have found forest-based bioenergy to be associated with significant carbon deficits.

Indeed, the assumptions made for any bioenergy scenario have a very large impact on the timing of GHG emission savings of bioenergy. Studies that find very long carbon payback times are generally based on assumptions that do not match current or expected biomass production and conversion practices.

When realistic assumptions are applied, production of energy from woody biomass results in carbon payback times and foregone sequestration that are very small compared to the substantial carbon savings that are achieved over time. In fact, even studies widely reported to have determined the existence of carbon debts and long carbon payback periods acknowledge near-term carbon benefits to use of wood residues and logging wastes in energy generation.

The most important parameters for modelling are:

- *The forestry system the biomass is obtained from*. Studies finding long carbon debt repayment times generally assume that forests are managed and harvested purely for bioenergy. In addition, studies often assume that these forests are slow growing, that they were previously unmanaged, had high original carbon stocks and that they would maintain these stocks over time. This is in sharp contrast with actual wood pellet production today and anticipated production practices for the future: wood pellets are produced to a large extent from residues and low value products of existing forestry activities in forests that are already being managed for other purposes (sawtimber, pulpwood).
- *Low carbon replacement efficiencies*. Several existing studies assume very low conversion efficiencies and/or unfavourable fuel being replaced. Most industrial wood pellets however have efficient supply chains and are used to directly replace coal achieving very high carbon replacement efficiencies.
- *The assumed counterfactual* (only relevant under the Anticipated Future Baseline approach): many studies assume a ‘continued growth’ counterfactual. This is not realistic when evaluating biomass from existing production forests which have been managed for timber and pulp for years. A more appropriate counterfactual should recognise the need of forest owners (especially private owners) to continue to receive economic benefit from the forest.

These elements show that any study of the GHG benefits of bioenergy must take into account actual production practices. When applying correct methodological assumptions based on market realities and scenario choices based on today’s real life bioenergy systems, this study shows that:

a. Bioenergy using biomass from existing sustainably managed forests (e.g., growth : drain ratio equals 1 or higher, or when the Annual Allowable Cut (AAC) provides for Long-Term Sustained Yield (LTSY)) realizes absolute GHG savings from year 1 because a) forest carbon stocks are maintained or even increase over time, and b) fossil fuel burning is simultaneously avoided.

It is also possible to look at the *relative* GHG emission savings compared to an anticipated future baseline scenario without bioenergy (Anticipated Future Baseline (AFB) Approach). Modelling exercises using this methodology show that bioenergy from existing sustainably managed forests can initially lead to a small increase in emissions compared to an anticipated future baseline without harvesting for bioenergy due to a decline in the amount of carbon stored in forest litter. After this initial phase bioenergy leads to large relative GHG emission savings compared to the baseline scenario. In the SE US, time to carbon parity is short (3 years) when residues are used.

As the study shows, it is possible to demonstrate a worst case unrealistic scenario wherein long time periods to carbon parity are required. Calculations using the AFB approach show that in a scenario in which a 30 year rotation forest in the SE US were harvested entirely for bioenergy, it would take approximately 22 years before the carbon parity point were reached, but only if a completely inappropriate "no harvest" counterfactual were applied. This scenario is unrealistic since management of forests strictly for bioenergy is not expected to play a role in actual pellet production for the foreseeable future.

b. While today's biomass for pellets originate from forests that are already being managed for other purposes (sawtimber, pulpwood), some parties have expressed concerns that the increase in biomass demand for bioenergy could lead to new forest areas being taken into active management and that this could lead to significant increases in GHG emissions for substantial periods of time. However, this is unlikely to materialize as managing and harvesting new forest areas in the USA or Canada for bioenergy alone is simply uneconomic. If new forest areas were to be taken into production in the US or Canada, such an expansion would be driven by the demand for higher value products such as sawn timber and pulp. Such forests would be managed for multiple products, not only and not even primarily for bioenergy. This would lead to very large GHG emission savings due to the combined effects of bioenergy, and increased production of durable timber products that form durable carbon stocks and replace GHG intensive alternatives such as concrete or steel.

This paper shows that today's dominant bioenergy systems using wood pellets from Canada and the SE US achieve significant GHG savings, and make a meaningful contribution to climate change mitigation. Carbon debt and foregone sequestration in realistic bioenergy scenarios are very small compared to the carbon savings that are achieved over time. Further, there is a critical difference between a small and temporary carbon debt, when one might exist, and the permanent fossil carbon emissions savings achieved by use of bioenergy rather than fossil fuels.

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1. Introduction

Biomass for energy plays a significant role in the EU renewable energy picture, with bioenergy expected to remain a key strategy for both the near and long term. Although biomass supplies within EU Member States are substantial, it will nonetheless be necessary to import significant volumes of fuel pellets and other forms of biomass in order to meet ambitious EU renewable energy targets. The US Southeast region (SE US) covering the states of Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana and Texas and British Columbia, Canada (BC) are viewed as important sources of supply.

Given that the impetus for a shift toward renewable fuels is concern over levels of atmospheric carbon, it is essential that efforts to reduce fossil fuel use in the EU lead to lower levels of atmospheric carbon and do not result in increased carbon emissions. It is also important that forest sustainability in biomass supply regions not be threatened.

A number of studies have examined the carbon implications of energy production from forest biomass. Conclusions are wide ranging, from those that claim carbon emissions stemming from energy production from trees can be worse than when burning coal, to determinations that wood-based bioenergy offers large carbon mitigation benefits. Analysis of such studies reveals that outcomes are very heavily dependent upon underlying assumptions – assumptions that are sometimes unrealistic.

The objectives of this paper are to better inform stakeholders about current biomass sourcing practices, to highlight the key role of SFM in forest-based biomass energy production, to outline commercial realities of SFM decision making in the context of healthy forests used for multiple purposes, and to critically examine the carbon dynamics of forests from which biomass fuels are obtained. On this latter aspect, this report points out the critical nature of assumptions in forest bioenergy carbon modelling, brings forth views from the bioenergy sector regarding criticisms raised in several recent reports, and examines the carbon implications of several scenarios of biomass importation for EU bioenergy production.

This report focuses on the SE US and BC as the two main supply regions of forest-based fuel pellets for EU consumption. Regarding the debate on the carbon balance of biomass for energy (primarily around the time between the release of carbon when biomass is combusted and carbon uptake through subsequent forest re-growth) the report reviews methodological choices and scenario assumptions when analysing the carbon balance of bioenergy, and the impact these are having on the scenario outcomes. Insights into the carbon balance of bioenergy are provided that take into account actual industry practices.

The importance of biomass in EU climate mitigation strategy is discussed next (chapter 2), followed by examination of biomass availability and the nature of established forest products industries in potential supply regions (chapter 3). Regulatory frameworks and voluntary forest certification programs are also examined (chapter 4). Next, the issue of biomass carbon neutrality is considered in the context of forests, with extensive discussion of carbon modelling and the importance of correct selection of both methods and assumptions (chapter 5). The report concludes with a discussion of GHG savings from forest biomass for bioenergy for various scenarios (chapter 6).

2. The role of biomass for bioenergy in climate change mitigation – the European Union political context

The European Union (EU) actively promotes the use of renewable energy sources including biomass (from agriculture, forestry and waste) to meet growing energy demands and as a means of reducing fossil fuel emissions associated with climate change. Solid biomass fuel has emerged as a major renewable energy source, the development of which, according to EU projections, must be accelerated in order to tackle climate change effects. In the short to mid-term (up to 2020), biomass will play a significant role in reaching the EU legally binding 20% renewable energy target set up in the Renewable Energy Directive (RED) (EU 2009). Indeed, according to the information provided by Member States in their National Renewable Energy Action Plans[1] (AEBIOM 2013), bioenergy will contribute to approximately half of this target. In the heating and cooling and electricity sectors, biomass consumption is expected to increase from 82 Mtoe[2] today to close to 110 Mtoe final energy in 2020. As far as wood pellets are concerned, the EU consumption is projected to increase and could reach 50-60 million tonnes in 2020 (13 million tonnes in 2010). In the longer term (up to 2050), this contribution from bioenergy is expected to be maintained and even accelerated.

The RED has set out legally binding sustainability criteria for biofuels used in transport (including a Life Cycle Assessment methodology for Greenhouse Gas (GHG) emissions). In 2010, the European Commission (EC) recommended to Member States who had in place or planned to develop sustainability criteria for solid biomass used for heat and electricity production, that they follow the criteria set out for biofuels with small adaptations (European Commission 2010). The GHG calculation methodology endorsed in the RED and in the 2010 recommendations (European Commission 2010) follows the International Panel on Climate Change (IPCC) recommendations according to which biomass combustion for the production of bioenergy is carbon neutral. This methodological assumption has been challenged by certain parties and has led to a number of academic modelling studies to demonstrate that carbon neutrality is not the status quo. Other recent studies, however, support classification of biomass energy as carbon neutral. This topic is discussed further in a later section of this report.

EU 2050 energy scenarios are based on the premise that biomass will be critical to decarbonisation. The EU 2050 Energy Roadmap (European Commission 2011a) states that "*decarbonisation will require a large quantity of biomass for heat, electricity and transport*". In the scenarios established in this roadmap, biomass use is expected to significantly increase. These projections are confirmed by the 2050 low carbon economy roadmap (European Commission 2011b), which indicates that energy from biomass will be an important component of the increase in renewable energy projected over the coming decades. It is therefore critical to analyse bioenergy developments within both an immediate context as well as a long-term view.

The next section provides an overview of global biomass potential (section 3.1) and describes current and potential availability of woody biomass for pellet production in the SE US (section 3.2) and BC (section 3.3).

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[1] http://ec.europa.eu/energy/renewables/action_plan_en.htm

[2] Million tonnes of oil equivalent – National Progress Reports: http://ec.europa.eu/energy/renewables/reports/2011_en.htm

3. Biomass availability

3.1 Global biomass potential

A number of studies have assessed regional and global biomass availability in recent years. Results differ depending on the assumptions behind the studies, and a wide range of biomass availabilities have been reported from over 60 documents reviewed by Slade et al. (2011). Table 1 compiles availability ranges that are discussed in this section of the report. Overall, there appears to be sufficient volumes of biomass that can be sustainably sourced to meet increasing demand.

Table 1. Technical supply and deployment potential of bioenergy by 2050 (EJ/yr)

	1998	2012	2050: lowest estimate	2050: highest estimate
Primary bioenergy supply		50 EJ		
IEA Bioenergy Technology Roadmap target bioenergy			~150 EJ	~150 EJ
IEA Deployment potential for bioenergy			100 EJ	300 EJ
IPCC Technical potential bioenergy supply in 2050, of which:			367 EJ	1 548 EJ
Dedicated woody bioenergy crops on surplus agricultural land			~232 EJ	~1350 EJ
Technical potential from wood obtained from natural forests (Surplus forest growth)			59 EJ	103 EJ
Agricultural and forestry wastes and residues			76 EJ	96 EJ
Most likely deployment potential for bioenergy			80 EJ	190 EJ
Use of biomass for food, materials and traditional bioenergy	273 EJ	340 EJ (estimate)		
Global primary energy demand	418 EJ	507 EJ (IEA, 2011)	601 EJ	1 041 EJ
Population	5.9 billion	7 billion	8.8 billion	8.8 billion

Sources: Smeets *et al.* (2007), IPCC (2011), IEA (2012).

The International Energy Agency (IEA), in its Bioenergy for Heat and Power Technology Roadmap (IEA, 2012) projects that the potential deployment levels of biomass for energy by 2050 could be in the range of 100 to 300 EJ (2300 to 7100 Mtoe) per year, compared to 50 EJ today. The wide range of estimates results from the magnitude of uncertainty in long-term assessments related to difficulties in defining sustainability requirements which are thus far limited to certain regions and which continue to evolve. These sustainability requirements will be directly linked to local existing biomass consumption patterns for food, materials, and environmental constraints. As such, precise estimates of future biomass availability are difficult to assess (IEA, 2012).

Forest biomass already represents a large volume of bioenergy feedstock today. IPCC (2011) analysis indicates potential to sustainably extract between 59 EJ to 103 EJ (1400 to 2300 Mtoe) of wood from existing managed forests without reducing the re-growth potential. Despite large disparities between projections of potential availability, biomass assessments to date indicate that there is a substantial and sufficient quantity of sustainable biomass available for energy production and climate change mitigation beyond current levels.

Within the EU, a large share of domestic biomass used for commercial bioenergy originates from wood industry waste and by-products, agricultural biomass and other organic waste streams.

It appears that there is further potential for biomass production from logging residues in EU forests. Only a small fraction of forest residues remaining in the forest after harvest are currently utilised. In 2006, an estimated 25% of forest residues was utilised for energy, leaving about 60 million tonnes unused (Alakangas et al. 2012). EU biomass potential is confirmed by several studies which have assessed availability of EU biomass to supply EU bioenergy needs (EEA 2006, EEA 2011, Rettenmaier 2010, Böttcher et al. 2011). While, for a variety of reasons, it is important to leave a certain portion of logging residues in the forest, all recent studies have concluded that the potential for additional sustainable mobilisation of biomass within the EU is quite significant.

Although EU biomass production potential is large, in practice, projections from Member States National Renewable Energy Action Plans (Atanasiu 2010) and from experts (IEA Bioenergy Task 40) highlight the role of biomass imports from countries outside the EU as critical to meeting renewable energy targets. For various reasons, including existing woody biomass supply volumes, supply security, infrastructure, and advantages of working with large volume single suppliers, imports can in some cases deliver woody biomass at a lower cost, especially under large multiple-year biomass supply contracts.

North America (US and Canada) is today and is likely to remain in the future, the most important supply region for imported volumes of biomass, mostly wood pellets. The environmental, economic and regulatory conditions in this region make it possible to support abundant and highly productive forest cover while at the same time producing a sustainable flow of wood raw materials. Forest biomass availability in several major timber-producing regions – specifically the SE US and BC – creates economically favourable conditions for sourcing of biomass from these regions for export to locations overseas, and especially to Europe. The following sections describe the wood biomass potential in these two supply regions.

3.2 Southeastern United States (SE US) biomass potential

With 10% of global forests on 9% of global land area, and 25% of timber production for industrial products (U.S. Forest Service 2009), the US has ample timber to be a major supplier of biomass feedstock for wood pellet production. The net volume of live trees per hectare has increased in all regions of the US for more than 60 years consecutively (Alvarez 2007, Smith et al. 2009).

In the US, a number of socio-economic factors contribute to the potential for substantial, sustained harvests of forest biomass. These include the structure of land ownership, a long history of substantial wood utilization and investments in forest productivity, and the existence of diversified domestic forest-product industries. In the US, robust forest markets continue to beget more forest volumes. It is for this reason that forests have thrived and increased in both volume and area coverage even with on-going annual harvests approximating 450 million m^3 (U.S. Forest Service 2009). In all regions, the net growth-to-drain ratio (the amount of new forest growth in excess of removals) has continued to increase since at least the early 1950s, and in 2006 was estimated at 1.72 for the U.S. as a whole (Smith et al. 2009). Consequently, US forest carbon stocks also increased over the past 60+ years, and annual forest CO_2 sequestration increased 35% between 1990 and 2011 (US EPA 2012). These increased volumes of forest and carbon stocks in the US reflect strong past and current land management practices, including forest restoration and management efforts, and regulatory protections (Fernholz, et al. 2013).

Forest product markets ensure that landowners have an incentive to keep their land forested and sustainably managed, an observation underscored by a recent US Forest Service study which reported that higher demand for forest biomass in recent years has helped to counter rising pressures to convert land to other uses (U.S Forest Service 2012). In addition, the diversified forestry land ownership model in the US provides flexibility in adapting to increasing demands from forest industries and pressures for urbanization and development. About two-thirds of US forest land is classified as timberland (i.e. land declared suitable for producing timber crops and not withdrawn from timber production by statute or administrative regulation). For the US as a whole, private individuals and firms own 69% of all timberland and it is from this land that most wood used for industrial purposes is obtained (Haynes et al. 2007). When all forest land is considered, private ownership accounts for approximately 58% of total forest growing stock volume and 56% of the total forest area in the US (Smith et al. 2009). Private timberland also accounts for 73% of all net growth, including 67% of total softwood net growth and 82% of hardwood net growth, and 91% of timber harvests. A large portion of the privately-owned forest land is in the hands of families that have owned their land for generations and benefit from the revenue it generates; these land owners tend to manage their forests far less intensively than industrial owners (Arano and Munn 2006, Adams and Latta 2005). It is the non-industrial private landowners that are the largest source of wood (Haynes et al. 2007).

The SE US is well situated and equipped to be a primary source of wood pellet fuel for the EU. The US overall is home to more than 750 million acres (303 million hectares) of forestland, with more than 200 million acres (81 million hectares) in the US South region of which the SE US is a major part. In the US South region, private landowners control 84% of total forest land and over 93% of forest growing stock (U.S. Forest Service 2009). Also, this region accounts for half of the annual net growth in the US, meaning that growing stock volume is increasing at a rate of 4.6% annually (Smith et al. 2009); the net growing stock volume per hectare[3] has increased by 94% since 1953 (U.S. Forest Service 2009). This increase is due in part to a history of strong forest industry commercial activity. For instance, timber harvesting in the SE USmore than doubled between the early 1950s and 2000, raising the region's share of US national timber production from 40% in 1952 to nearly 60% by 1996. Nonetheless, the net growth to harvest ratio in the SE US was a healthy 1.12 in 1996. By 2006, this ratio had risen to 1.35, reflecting a 15% increase in net growth over the period, and a 5% decrease in removals (Smith et al. 2009). Over the long term, standing biomass stocks in the SE US region have risen steadily, from about 5 billion m^3 in 1963 to over 8.2 billion m^3 by 2010 (Adams et al. 2006, Wear and Greis 2012). The SE US would appear to be well positioned as a supply region given its growing fibre basket, history of strong forest management, and the regulatory protections provided by both US Federal and state laws and regulations.

[3] Also referred to as growing stock inventory on timberland by the USDA Forest Service.

Currently, biomass sources in the SE US include processed residues such as chips, bark and sawdust; unprocessed residues such as tree tops, branches, and other forestry debris remaining after the primary biomass (tree trunk) has been processed and shipped from the forest; low-grade round wood fibre, generally of hardwood species ; and commercial thinnings of pine (Figure 1).

In the past 50 years, management of southern US pine plantations has been transformed from a relatively extensive system of planting nursery-grown seedlings from regionally collected seed and subsequent individual treatments, to a more intensive system where selective tree breeding was done to optimize stand biomass productivity and maximize economic yield (Fox 2007, Allen et al. 2005, Munsell and Fox 2010). This evolutionary process took place primarily in order to provide wood raw material to the wood industry that has been developing within this time frame (in particular lumber, plywood, and pulp and paper). Some analyses show that, for several reasons, in the near future wood from these plantations in the southern United States could provide much of the feedstock for the bioenergy industry (Munsell and Fox 2010). However, the same analyses also indicate that at current and projected prices, it is not economically viable for forest owners to establish and manage forests solely for biomass. More information regarding these economic and market aspects is provided in section 4.1.

Figure 1: Biomass Sources in the Southeastern United States

Definitions:

Mill waste and residues: Wood chips and sawdust from other types of mills, primarily sawmills. These chips and dust are created during the processing of higher value lumber and would otherwise be disposed of as waste.

Tree tops and branches: Parts of the tree that cannot be refined into lumber. Some "tops" of trees can be significant in size and are often mistaken as a "whole tree." These tops and limbs are the unusable by-products of a sawtimber harvest. Without demand, this fibre would most likely be left on the forest floor, releasing carbon through decomposition and impeding reforestation

Low grade roundwood fibre: Wood that would otherwise be rejected from lumber mills. This wood does not meet specification for higher-value uses. Characteristics which preclude processing by other mills can include: Rotten/hollow core; Bad grain/excessive knotting; Crooked stem and form; Diseased or damaged; Fire/lightning damage; Small size

Commerical thinnings: Commercial softwood plantations are generally thinned once or twice before the final harvest. This common forestry practice ensures the healthy growth of high- value timber

According to projections (U.S. Department of Energy 2011), available forest biomass from the US as a whole in 2030 could range from 83 to 102 million dry tonnes annually depending upon price (assuming prices ranging from $40 to $60 /dry ton), with the vast majority of this projected volume in the SE region. This assessment takes into consideration environmental sustainability (such as sufficient amounts of residue onsite to maintain soil productivity and prevent erosion) and identifies likely costs to access the resource at the roadside.

3.3 British Columbia (BC), Canada biomass potential

Biomass supply for pellet production in British Columbia (BC), Canada is dependent on the supply and utilisation of sawlog[4] harvesting as all forest logging is done in order to supply logs to sawmills. Therefore, without the existence of a well-established forest products industry there can be no bioenergy industry as biomass production is the result of forest management activities for this industry. The feedstock for wood pellets manufactured in BC comes from two primary sources (Wood Pellet Association of Canada 2013):

1. *Industrial residues*[5]– primarily from sawmills and timber mills (including bark, sawdust, and shavings). These were formerly burnt as waste in beehive burners. In 2009 this type of raw material represented 80-85% of pellet feedstock.
2. *Harvest residues*[6]*.* These are collected from roadsides and not from the forest floor. This category in 2009 represented 15-20% of pellet feedstock.
    a. low grade logs damaged by insects or disease, cracked, twisted or otherwise unsuitable to make lumber (90%).
    b. low value materials resulting from harvesting (e.g. branches and foliage) (10%). This category is generally avoided because such materials are difficult to handle and can cause dangerous flashing in biomass dryers.

The average annual log harvest in BC is 75 million m^3, not including bark, sourced from approximately 90% public and 10% private forests. At a ratio of 2.45 m^3 per dry tonne, this is equivalent to 30.6 million tonnes on a dry basis. As current BC annual pellet production is 1.5 million tonnes, this means that wood pellets account for only about 5% of BC's annual log harvest – entirely as waste recovery.

Using ratios provided by the BC Ministry of Forests, Range and Natural Resource Operations, Inventory Branch (Wood Pellet Association of Canada 2013), additional forest fibre is generated including 4.8 million tonnes of branches, 2.9 million tonnes of foliage, and 910,000 tonnes of bark. Moreover, the log harvest results in 4.7% waste that is left behind in the forest – an average of 1.4 million tonnes per year (BC Forest Practices Board). This totals 10 million tonnes of fibre that is left in the forest each year (Table 2).

[4] A log that meets minimum regional standards of diameter, length, and defect, intended for sawing.

[5] Called 'Process Residues' in EU RED

[6] Called 'Forestry Residues' in EU RED

Table 2. Annual fibre left over after log harvesting in BC, Canada

Branches	4,800,000 tonnes
Foliage	2,900,000 tonnes
Bark	910,000 tonnes
Waste (at 4.7% of annual log harvest)	1,400,000 tonnes
Total	10,010,000 tonnes

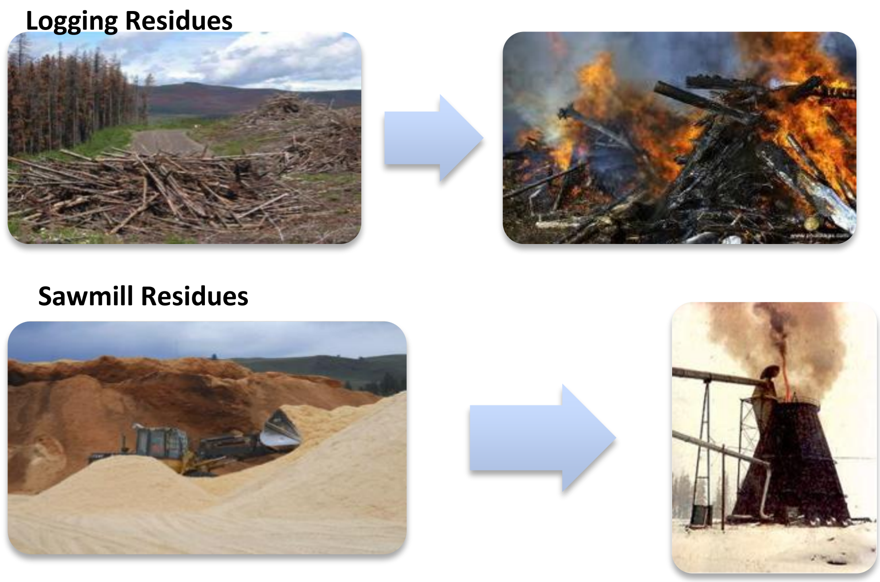
Sources: BC Ministry of Forests, Range and Natural Resource Operations – Inventory Branch 2012, Wood Pellet Association of Canada (2013), BC Forest Practices Board.

The BC wood pellet industry presently uses just 340,000 tonnes or slightly more than 3% of the fibre that is left over after log harvesting (Wood Pellet Association of Canada 2013). Perhaps another 25% is left behind as debris to provide nutrients and small mammal habitat. The remaining 72% or around 7 million tonnes is presently disposed of by burning each fall (Figure 2), resulting in waste and significant emissions to the atmosphere. As the pellet industry continues to grow, it can use this fibre and help to reduce waste.

Based on 2011 estimates, in addition to the wood harvested and actually used by the industry, 1.3 million tonnes were billed[7] to forest products manufacturers but actually left on-site as there was no economic market other than pellets for that fibre. The proportion of total cut left on site is estimated to have varied from 1.5 to 5% during the period 1990 - 2011. A study using independent data estimated 31-67 tonnes of biomass left on every hectare (Dymond et al. 2010). The numbers vary due to ecological differences in stand volume, density and forest health condition. Some of the harvest residues are left to meet the stringent silvicultural requirements of BC Forest and Range Practices Act (B.C. Ministry of Forests, Range and Natural Resource Operations 2004) in order to ensure the on-going health and biodiversity of the forest. However, the majority of the biomass left following harvest is burnt as a waste management measure, to reduce fire hazard as required by the BC Wildfire Regulation (2005), and to avoid the risk of disease and pest infestation. This burning of biomass generates a substantial health hazard and contribution to GHG emissions from BC's forests (Dymond and Spittlehouse 2009). To date, the use of this resource by the pellet sector has been limited. One of the reasons is that due to the low profit margins in the pellet industry, pellet plants can only afford to recover harvest residues from about a one-hour transportation radius around their plants. Since there are only thirteen pellet plants in BC, this means that the vast majority of harvest residues continue to be wasted. As the BC pellet industry continues to grow with ever increasing demand for feedstock, this waste (and pollution) will eventually be largely eliminated.

[7] Data is publically available through the Harvest Billing System and the Waste Billing System http://www.for.gov.bc.ca/hva/systems.htm

Figure 2. Biomass burning in BC, Canada



Photos courtesy of WPAC and FPInnovation Canada

Additional feedstock could be accessed through salvage logging of damaged stands. Standing deadwood stocks are estimated at 140 million tonnes[8] due in large part to a mountain pine beetle epidemic and fire damage that have occurred in recent years (Dymond et al. 2010). This volume will decline over time in the future as the trees are harvested or degrade.

Currently, 100% of the biomass utilised for wood fuel pellet production is wood that would otherwise be a) burnt in a beehive burner, b) be burnt at the roadside or in forest clearings each fall, or c) decay in the forest. Given current and likely future sources of biomass for fuel pellet production, there is little risk of diversion of wood from established wood products manufacturers.

As discussed in sections 3.2 and 3.3, the SE US and BC have high potential for producing biomass for energy purposes. When it comes to the mobilisation of this potential, it is essential that this take place in a framework that guarantees sustainability. The following section describes forest conditions and trends in North America and the regulatory frameworks and voluntary programs that guide the practice of forestry.

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[8] Table 4, column 5, sum of British Columbia ecozones (http://www.naturewatch.ca/eman/reports/publications/99_montane/intro/intro6.html).

4. Sustainable forest management (SFM): multiple products approach, regulatory frameworks and certification

SFM is an integral component of the management of forests in North America and for the regions that are the subject of this report (the SE US) and BC). Forests in these regions are managed for multiple commercial forest products, including solid wood products, pulpwood, panel products and bioenergy, as well as for public use, conservation and ecosystem services (section 4.1). In addition, forests in these regions are subject to sustainable forest management regulatory frameworks (sections 4.2) and are in some cases certified under voluntary schemes (section 4.3)

4.1 Multiple product approach

4.1.1 General observations

Forests in the SE US are fundamentally different from those of BC, not only because of location, geography and climate, but also due to historic land use, land ownership patterns (Canadian forests are largely publically owned whilst the majority of SE US forests are privately owned), and differences in management strategy. Over one-half of the forest land area and just under two-thirds of forest volume in the SE US and the US South in general is occupied by softwood species; hardwood stands of mixed species dominate bottomland areas and mixed oak-pine stands are common over a broad area. Twenty-two per cent of forests in the SE US are pine plantations, characterized by rapid growth rate and intensive management.

BC has 55 million hectares of forested land, an area larger than France and Germany combined. About 83% of BC forests are predominantly coniferous, 11% are mixed forests, and 6% are broadleaved. BC has 7.6 million hectares, or 14% of its forest area in protected areas. BC's entire annual timber harvest comes from less than 200,000 hectares – less than 1% of the working forest. By law all harvested areas are reforested. More than 200 million seedlings, or about three seedlings for every tree cut, are planted every year (at a rate of 6 trees per second) to supplement natural regrowth.

Following harvests, forests in the SE US are regenerated naturally or by replanting as part of an on-going sustainable forest management regime. Yet, in both BC and the SE US, forests are managed for multiple commercial products (sawlogs, pulp wood, panel board products, and bioenergy), as well as for public use, conservation and ecosystem services.

With recent growth of the fuel pellet industry in both regions, some concerns have been raised that increased demand for biomass creates a risk that forests could move toward more focused biomass production regimes, involving shorter rotations or single cut harvests. In reality, such a transition is very unlikely, owing the economic reality that current and forecast market prices for biomass are and would be inadequate to support such practices.

When forests are harvested, a number of by-products are produced that serve several markets. Generally the biggest part of the tree goes to the most valuable market, typically sawtimber[9] used in lumber or

[9] Trees or logs cut from trees meeting minimum diameter and length specifications, and with stem quality suitable for conversion to lumber.

plywood production, and/or Chip'N'Saw logs[10]. As described previously, woody fibre for energy markets which comes directly from forestry originates from the smallest parts of trees and is the least valuable by-product. With relatively low (but stable) margins, pellet producers have little demand elasticity as a function of price. This means that pellet producers will continue to use lower cost assortments of feedstock.

Forest managers and forest landowners consider market prices for all products, forest growth rates, and the time value of money to determine the financially optimal time to harvest. As trees in a particular stand approach maturity there is some flexibility in when harvests are scheduled. In a period of low prices, forest landowners and managers may elect to delay harvesting until markets improve; conversely, when prices are high, there is an incentive to harvest at that point in time. Thus, high prices for any of the products obtained at harvest can influence to some extent the timing of harvest. At all points in a forest rotation, however, it is the more valuable products, such as sawlogs, that have the greatest influence on the decision to harvest, not the lower value products such as biomass (see SE US stumpage price comparison on the following page). Consequently, high demand for the least valuable product is unlikely to drive forest owners (public or private) to act against their own business interests by harvesting trees that will grow into more valuable products. The use of high value forest products in the bioenergy industry is economically unlikely and there is little to no prospect of such activity becoming mainstream, and this is confirmed by recent analyses. Studies focused on the southern US have found, for example, that increased demand for biomass energy is unlikely to increase the price of small diameter roundwood to even 50% of typical prices for sawtimber (Abt and Abt 2013, Timber Mart South 2013).

Rather than being the main driver of the forest management choice and creating new commercial demand for limited forest resources, the wood energy market can lead to healthier and better managed forests, higher land values, and greater baseline carbon sequestration on the land. Indeed, this market is encouraging forest owners to use their existing resources more efficiently by allowing utilisation of previously unused residues and providing revenue to support thinning of stands that will lead to healthier, less fire-prone, and more productive forests in terms of ultimate high value product potential. In regions with highly integrated and robust forest industries, free market forces dictate a multiple product approach to raw material allocation. Therefore, markets for more valuable products, such as lumber and plywood, are most able to compete for raw materials; fuel pellets are at the other end of the economic scale and consequently rely on low value forms of wood as production inputs. To be clear, the pellet industry would rarely compete for sawtimber and other sawn wood assortments as these forms of wood are simply far more valuable than the value of the energy that they contain.

[10] Logs of relatively small diameter that are to be processed into lumber using a machine that converts small logs to cants, converting part of the outside of logs directly into chips without producing any sawdust. The cants produced are then sawn into lumber within the same machine. A cant is a large slab cut from a log, usually having one or more rounded edges, and destined for further processing by other saws.

4.1.2 US Southeast region (SE US)

Munsell and Fox (2010) refer to stumpage prices for various forms of southern pine, illustrating the options available to forest landowners in the SE US region:

- Biomass for energy (trees < 10 cm Diameter at breast height (dbh) plus tops, branches, and foliage): 5.40 USD/tonne
- Pulpwood (dbh 10 – 23cm) 7.25 USD/tonne
- Chip'N'Saw (dbh 23 – 30 cm) 22.67 USD/tonne
- Sawtimber (dbh > 30 cm) 34.47 USD/tonne.

The relative values as shown above confirm that the likelihood of biomass energy demand driving changes in forest management is very low. Peer reviewed literature strongly supports this view (Lowe et al. 2011; Mendell et al. 2010).

Another indicator of the extent to which highly valued products, and not biomass, are likely to drive forest management and harvest decisions is provided by Table 3.

Table 3. Yield and Value of Sawlog Components in SE US

Product	Category	Log output by volume	Value – USD per tonne (dry basis)*	Proportion of log value USD
Lumber/Trim Blocks	Main product	38.1%	$564	87.9
Chips	By-product	31.5%	$ 72	9.3
Sawdust/shavings	By-product	15.6%	$ 37	2.4
Bark	By-product	14.8%	$ 8	0.4
		100%		100.0%

*Calculated using March 2013 average lumber market value of USD 445 per thousand board feet.

At current and forecast biomass market prices, maximum returns from managing a forest for a range of products (i.e. sawtimber, pulpwood and biomass) employing traditional or integrated management yields the best economic returns. Meanwhile, a management regime for dedicated biomass production would yield less attractive or even negative financial returns. Again, the risk that forest management regimes would change in a near or distant future due to the development of bioenergy is very low, as bioenergy products are economically feasible only when carried out under a multi-products approach. When combined with sustainable forest management rules and practices, basic forestry economics will protect against over-harvesting of forests.

Markets for wood fibre and products ensure that landowners have an incentive to keep their land forested and sustainably managed. With sufficient demand for wood products, landowners are deterred from clearing for agriculture or selling their forestland for uses such as development and instead maintain their forests for sustained income (Woodworth 2012). Forests actually thrive when demand for timber is high, because trees are extracted in a sustainable manner to ensure forest owners a continuing yield of merchantable products and income.

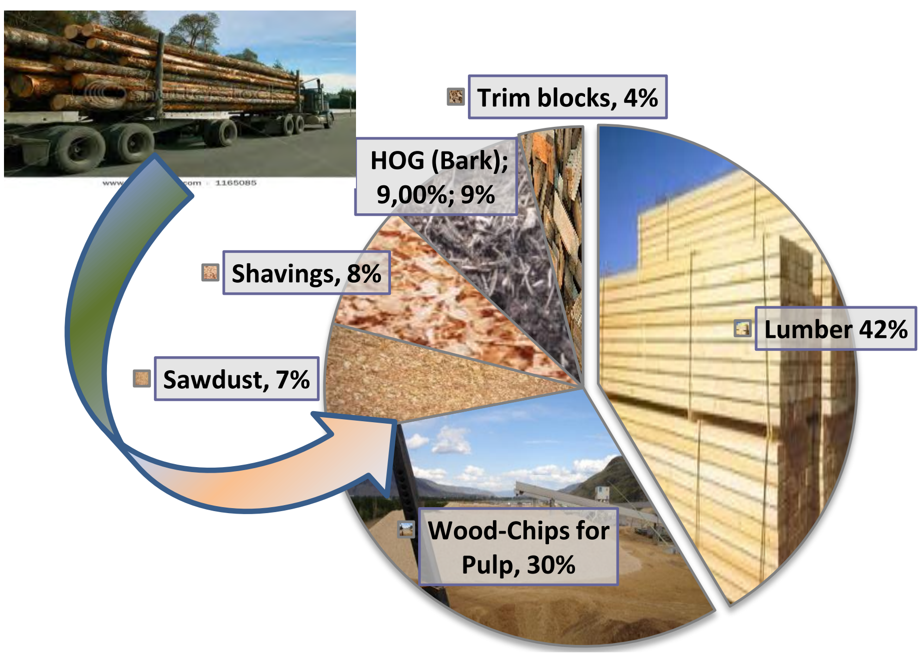
4.1.3 British Columbia (BC), Canada

In BC, pulp mills use wood chips to make pulp and sawdust/shavings and bark to feed their power boilers for making electricity and process heat. Although the pellet industry and the pulp industry both use sawdust/shavings and bark, the two industries do not currently compete for feedstock – due mainly to the abundance of feedstock, but also because many pellet mills are located far from pulp mills. The fact is that in BC, the sawmill sector, the pulp sector, and the pellet sector are co-dependent. The pellet sector relies on a healthy sawmill sector for feedstock. The pellet sector also trades feedstock i.e. bark for sawdust/shavings,with the pulp sector. The pulp sector relies on the sawmill sector for feedstock while the sawmill sector relies on the both the pellet sector and the chip sector for revenue from sales of their by-products.

In this region, 92% of the value yielded from sawlogs is from lumber (Table 4); given this situation, it is easy to see that pellets can only be produced economically by obtaining feedstock as a by-product of the sawmill industry. Pellet fibre accounts for only 2.1% of the value yielded by a typical sawlog.

An example of the relative value of each of the products yielded from logs in BC is provided by typical yield values for a sawmill in that region (Figure 3, Table 4). After logs are processed, typically they yield 46% lumber (lumber and trim blocks), 30% wood chips, 15% sawdust/shavings, and 9% bark. Chips are sent to pulp mills to make pulp and paper while sawdust/shavings and bark are used by pellet plants.

Figure 3. Typical Yield of Sawlog Components in BC, Canada



Source: Industrial Forestry Service Ltd., 2010

Table 4. Yield and Value of Sawlog Components in BC, Canada

Product	Category	Log output by volume	Value - CAD per tonne (dry basis)*	Proportion of log value CAD
Lumber/Trim Blocks	Main product	46%	$725.00	91.9%
Chips	By-product	30%	$ 70.00	6.0%
Sawdust/shavings	By-product	15%	$ 40.00	2.0%
Bark	By-product	9%	$ 5.00	0.1%
		100%		100.0%

*Calculated using March 2013 average lumber market value of CAD 450 per thousand board feet.

4.1.4 Multiple products and free markets

In any region, markets tend to be self-correcting. For example, private capital markets rigorously verify biomass supply before taking any financing decision. For a wood fibre plant, over subscription of available supply is therefore unusual. When over subscription of supply does occur, market mechanisms lead to price increases which render production of primary wood products (i.e. lumber and plywood) unprofitable, with the least efficient operations affected first. Plant capacity adjusts to the reduced supply. Therefore, investments made without properly scoping out supply availability fail as landowners do not act against their own financial interests by harvesting simply to keep a plant open. It is this very risk that creates the need for a high level of due diligence concerning raw material supply. Over a longer period of time, increased demand for fibre can stimulate investment in forest productivity.

It is counterintuitive, but nonetheless a reality that reduced demand for wood can undermine forest health and sustainability. Reduced demand for fibre, as has been occurring for over 15 years in both the SE US and BC as pulpwood demand has shifted from North American to Asia and South America (RISI 2012), is not necessarily good news for the forests of these regions. Reduced demand leads to oversupply of existing markets and a drop in fibre prices. Marginally profitable biomass is excluded from harvests. With sustained loss of markets, investments in forest productivity decline, forestry profitability drops, and other uses for the land such as for real estate development may begin to compete with forestry in areas, such as the SE US, where there is significant private ownership of forested land. In some cases reduced markets, and associated reductions in periodic harvesting activity, can allow forest stands to become over-crowded and more subject to insect infestation, disease, and/or catastrophic fire.

In addition to the existing regulatory and forest practices framework (see section 4.2), strong markets are clearly an important component in the sustainability of North American forests. As noted above, it is not economically feasible to manage a forest for energy purposes only and to displace the wood resource from industrial use to energy use. The best situation for forest managers is to manage their forests in an economic context with strong and robust wood fibre and products market. However, when the latter is facing economic difficulties, the energy market is in some cases a solution for forest operators to maintain investments and management of their forests. This is clear from the US pulp and paper case. Paper production was the first major market for forestry biomass (non-solid) fibre in the US. Initially, it was served by roundwood as a feedstock. As the industry grew, it began to rely on sawmill residuals and then whole tree chips as major supply components. Demand for pulpwood continued to grow until 1997. As demand grew, prices for pulpwood increased and landowners invested in forest productivity. These productivity increases more than kept pace with demand increases. Therefore, thinning and other forest stewardship practices became more feasible and common. After 1997, due to the increase of recycling and to economic considerations, paper demand began to decrease, which has continued to today and is projected to continue to decline.[11] In addition, as noted above, part of the wood supply for pulp and paper production shifted from North America to Asia and South America.

As prices for pulpwood dropped and pulp and paper mills saw increased closures in the US (Pryke 2008, Pulp and Paperworkers' Resource Council 2011), new demand for the fibre sprung up to take advantage of low prices. This was primarily demand from a growing fibreboard industry. In this context, the growing demand for biomass energy has created additional revenue sources for forest landowners while also indirectly supporting other forest related industries and the sustainable management of commercial forests (Woodworth, 2012). The energy market has not displaced the wood resource used by the pulp and paper industry but has offered an opportunity to keep managing forests and using the wood resource. Historically, a large volume of harvested wood products have gone to the market for pulp, paper or other fibre uses; however, as demand from these markets change over time there are opportunities for bioenergy to provide a market that supports the continuation of sustainable forest management.

4. 2 Regulatory frameworks governing forest operations

Both the United States and Canada have strict legal and regulatory frameworks governing forest operations – ensuring responsible harvesting and restoration of harvested sites.

4.2.1 Regulatory framework in the SE US

Private forestry operations in the US are regulated by a complex set of protective laws, regulations, and non-regulatory policies at the federal, state and local level. While the resulting framework is fairly complicated and can vary widely between jurisdictions, it has been effective in improving the environmental performance of forestry operations, and can be expected to do so in the future.

Laws governing forest practices on private land throughout the United States include the Federal Clean Water Act, Clean Air Act, Endangered Species Act, Insecticide Fungicide and Rodenticide Act, and the Coastal Zone Management Act. These laws are similar to, and in some cases more robust than comparable regulations governing forest operations within the EU. For example, the US Clean Water Act is designed to prevent negative impacts on water quality or sensitive habitats. Under this law, traditional forest management including harvesting is allowed in forested wetlands – a long standing practice – provided they do not compromise or alter the wetland habitat; this is consistent and legally compliant with sustainability criteria under Article 17 of the EU RED. US laws governing forests and forest practices are continually updated through promulgation of new regulations, court decisions, agency precedents and

[11] In recent years, the economic downturn has decreased demand for forest products (e.g. furniture, construction materials, paper products, etc.), which has had ripple effects on the entire supply chain. According to the US Forest Service, 25 per cent of all forest sector mills in the South have closed since 2005, including more than 450 sawmills. Mill closures both directly and indirectly impact employment, and the mill's supply chain, from landowners to loggers to timber supply companies.

policy decisions and violation of such regulations can result in criminal prosecution and/or steep financial fines.

Similar to other parts of the country, forestry practices in the SE US are impacted by federal, state and local laws. For example, forest management and harvest activity in North Carolina is governed by a number of state laws[12], as well as overlying federal law. North Carolina's forestry regulations include the Forest Practices Guidelines Related to Water Quality, which apply to all forestry-related harvesting. These rules require that measures be taken to protect streams and wetlands, prevent pollution, and control soil erosion and sedimentation. In addition, the NC Forestry Best Management Practices (BMP) Manual was revised in 2006 and includes many choices for implementing best practices when conducting a wide range of forestry operations, including harvesting of timber. The state also, through its Division of Forest Resources, operates a cost-sharing program focused on timber production and active forest management. Under this program, any private individual, group, association, or corporation who owns a minimum of 1 acre to a maximum of 100 acres of private forestland can receive partial reimbursement for the costs of site preparation, seedling purchases, tree planting, release of desirable seedlings and trees from competing vegetation, removal of undesirable species, prescribed burning, and forest fertilization. Moreover, forestry on private, non-industrial lands in North Carolina and other states is often eligible for other assistance programs, including the Cooperative Forestry Assistance Act of 1978 (P.G. 95-313; 16 USC. 2101-2111), as amended in 1990, which authorized the Forestry Incentives Program (FIP) and the Forest Stewardship Program, both of which are administered under the State and Private Forestry program of the US Forest Service. State and Private Forestry complements various forestry incentives initiatives operated by individual states. To participate in this program, the landowner must work with a resource development professional to develop a forest stewardship plan that identifies and describes actions to be taken to protect and manage soil, water, aesthetic qualities, recreation, timber, and fish and wildlife. Under this program, once a stewardship plan is approved, reimbursement is provided to forest landowners for a range of activities, including development of the forest stewardship plan, reforestation and afforestation, forest stand improvement, and soil and water protection. The State of North Carolina also requires that foresters be licensed, as do the states of Alabama, Georgia, Mississippi, and South Carolina.[13]

Laws and regulations similar to those above can be found for other states throughout the SE US. The federal programs outlined above operate in all of the states. Voluntary initiatives, such as master logger programs and compliance with best management practices guidelines (BMPs) also operate throughout the SE US. Master logger programs require on-going environmental and safety training beyond the typical training most loggers receive. Finally, some innovative cooperative projects between private landowners, states, and private foundations have resulted in the protection of critically important natural ecosystems and the interests of private landowners and other stakeholders.

Detailed information regarding US federal legislation, State programmes and Voluntary Cooperative Activities is provided in Appendix 1. Taken together, this robust framework leads to historically sustainable forests in the US. Evidence of this includes:

[12] http://www.ces.ncsu.edu/forestry/ordinance/laws.html#state
[13] http://forestry.about.com/cs/employment/a/forester_boards.htm

- For the past 100 years, the area of forestland in the United States has remained relatively stable, at around 304 million hectares (752 million acres), thanks to forest protection regulations, and improvements in markets for forest products coupled with aggressive reforestation efforts (Smith et al. 2009).

- Private forests account for over 171 million hectares (423 million acres), of which 115 million hectares (285 million acres) are non-industrial privately owned lands, with over 10 million private owners. Other privately-owned forest land is in the hands of corporations, investment groups, and tribal groups (Smith et al. 2009).

- The standing inventory (volume of growing stock) of hardwood and softwood tree species in US forests increased 49% between 1953 and 2006 (Smith et al. 2009).

- 20% of US forestlands are under some form of conservation program, which is almost twice the world average of 11% (Alvarez 2007).

- Net CO_2-equivalent sequestration within forests was 565 million tonnes in 1990 vs. 762 million tonnes in 2011, an increase of 35%. (USEPA 2012)

4.2.2 Regulatory framework in BC, Canada

BC is Canada's most biologically and ecologically diverse province with over 95 million hectares of land and 55 million hectares of forests representing 18% of Canada's total forested lands. Forests are managed provincially and 95% of provincial lands are publically owned and managed through a comprehensive regulatory framework for land and resource use planning, which includes direction for the establishment of protected areas and operational forest planning. Over 14.8% of lands are protected areas and an additional 14% within special management zones. Of the 55 million hectares of forests, some 22 million hectares are available for harvesting annually and the amount of harvest each year is approximately 200,000 hectares (B.C. Ministry of Forests, Lands and Natural Resource Operations 2010).

An independent Finnish academic study (Naturally Wood 2011) found that BC has some of the most stringent forest practices regulations in the world. BC's Forest and Range Practices Act (FRPA) (BC Ministry of Forests, Range and Natural Resource Operations 2004) is a leading example of forest management regulation that has long been advocated by policy experts. It requires on-the-ground results rather than process, and is built on a foundation of professional skills and accountability. Stringent forest policies and innovative forest practices continue to evolve to meet current needs and reflect the most recent scientific knowledge.

BC's results-based forest regulations ensure that public lands provide a mix of benefits such as timber, recreational opportunities, water quality, wildlife habitat, and many others identified through the public planning process. The FRPA is designed to deliver a careful balance of economic and environmental benefits across the landscape simultaneously, and not one to the exclusion of the other.

The regulatory regime specifies requirements to conserve soils, provide sustainable reforestation, and to protect riparian areas, fish and fish habitat, watersheds, biodiversity, wildlife, and cultural heritage areas, as well as specific requirements for construction, maintenance and deactivation of forest roads. The FRPA requires that licensees prepare forest stewardship plans that demonstrate how operations will be consistent with objectives set by government. The plans, which are publicly available, also indicate where forest development will be taking place (BC Ministry of Forests, Land and Natural Resource Operations, 2012). Before government approves any plan, companies must invite and consider public and First Nations[14] input

The province carefully regulates the amount of timber that may be harvested each year. BC's Chief Forester, a senior Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) civil servant, is required by law to determine how much wood can be harvested from each of the province's 70 management units (Farm Licences, Timber Supply Areas, Community Forest Agreements and Woodlot Licences). The maximum amount of timber that may be harvested per year from each management unit – referred to as the Allowable Annual Cut (AAC) – is determined by BC's Chief Forester. Although the Chief Forester is a government employee, he operates independently of government and his decisions are not subject to political oversight. In making each determination, the Chief Forester considers technical reports, analyses, and public input, as well as government's social and economic objectives. For example, in making his AAC determination, the Chief Forester considers potential timber productivity, other forest resources, short- and long-term implications of alternate rates of harvest, and impacts from fire and pests, in addition to economic and social objectives. Once he determines the AAC for a Timber Supply Area, then MFLNRO managers apportion the volume to the various forms of tenure that share rights to harvest Crown timber within the area.

The Chief Forester completes a timber supply assessment at least once every five years, the results of which inform subsequent AAC determinations. This timber supply review process is independent, and involves a detailed technical analysis, public comment and consideration of forest resource values such as wildlife and fish habitat, soils, water, and recreational opportunities. The periodic timber supply assessments ensure that harvest levels are based on the latest information, practices and government policies, both economic and environmental (British Columbia Forest Service, undated).

By law, all harvested areas in BC must be regenerated within a specified time frame, either through natural regeneration or planting to maintain species diversity. Regeneration of forests on the BC coast has a maximum period of 3-6 years. In the interior, planting is required within 4 years and for areas where natural regeneration is appropriate, up to 7 years. In practise, 80% of the harvested areas are replanted within 1.8 years, on average, after commencement of harvest (Internal calculations of BC Ministry of Forests Lands and Natural Resource Operations).

The Chief Forester has the discretion to be able to postpone a timber supply review if circumstances have not changed significantly or set a new harvest level sooner than the 5-year renewal date to deal with abnormal situations such as an insect epidemic. The timber supply review is the foundation of BC's sustainable forest management, considering ecological values while allowing stable economic benefits for communities.

[14] The First Nations are the various Aboriginal peoples in Canada. The Province of British Columbia requires that licensees engage with First Nations involved in or impacted by their operations and further develops land and resource agreements with First Nations and other parties to enhance economic opportunities, support social development, and in some cases, support the negotiation of treaties with First Nations

Along with comprehensive government regulations and best practices, well established third party forest certification programs help to ensure that sustainable forest practices are upheld throughout the supply chain.

4.3 Forest certification

Independent forest certification programs provide a framework for managing and evaluating the sustainability of a forest products company's operations, from forest to product. They also have the potential to be used as a tool for independent verification of wood biomass applications. Forest certifications were developed in the early 1990s in recognition of consumer concerns about deforestation in tropical regions and the negative environmental impacts that forestry operations can have. Certification schemes have developed over the years to address environmental and social concerns globally, and there are now more than 50 certification programs for forestry worldwide, which promote SFM through promulgation of stakeholder-developed principles, criteria and objectives (Naturally Wood 2011), and on-the-ground third-party oversight to ensure adherence.

Certification schemes have been developed with multi-product forests in mind and should be equally applicable to biomass for bioenergy, should forest owners and managers choose this route to provide assurances of their SFM practices. All major forest certification programs that exist in North America employ a chain-of-custody (CoC) mechanism that may be used to verify that products originate from a sustainably managed source. However, it must be recognized that CoC presents its own challenges. The leading global third-party certification systems for sustainable forest management in North America are: Canadian Standards Association's Sustainable Forest Management (CSA-SFM), Sustainable Forestry Initiative (SFI), and Forest Stewardship Council (FSC). The CSA-SFM and SFI standards are endorsed by the Programme for the Endorsement of Forest Certification (PEFC). In addition, within the United States, the American Tree Farm System operates a forest certification program that is PEFC endorsed. These four programs deal with such issues as forest biological diversity, use of chemicals, protection of water sources, and prompt reforestation. While the four systems have differences, they all promote the principles, criteria and objectives that are viewed as the basis of sustainable forest management around the world. None of these programs track forest carbon directly, but do, through comprehensive evaluation of forest management activity, provide a firm basis for the assessment of a range of environmental impacts, including replenishment of forest stocks and protection of forest soils. All have balanced governance, with boards representing environmental, social and economic interests, and revise their standards regularly through open public processes.

Forest certification has the potential to provide independent assurance of biomass feedstock sustainability. This is why European utilities who purchase large volumes of biomass are working together in the Initiative Wood Pellet Buyers (IWPB), supporting expansion and development of these independent third-party forest certification programs.

4.3.1 Forest certification in the United States

In the US, about 40 million hectares of forests are certified under at least one certification standard; this translates to 13% of all forest land and 19% of land classified as timberland. Most of the certified area is contained within forests regulated by individual states. For the large number of small family forest landowners, efforts are being made to promote group certification in order to reduce the cost of certification. One program specifically tailored for small, private, non-industrial landowners (family forest landowners) is the American Tree Farm System (ATFS) certification program. The Tree Farm program established a group certification program under the ATFS name in 2004, and the ATFS program was endorsed by PEFC in August of 2008.

To supplement certified fibre supplies, some companies rely on SFI Fibre Sourcing[15], PEFC Non-Controversial Sources[16], and FSC Controlled Wood[17] requirements to ensure that the raw material in the supply chain comes from legal and responsible sources, whether the forests of origin are certified or not.

One third of the certified forest area in the United States lies within the SE US region. Slightly over 94% of the certified forest area in this region is certified under PEFC endorsed programs (SFI and ATFS that account for about 8.5 and 6 million hectares, respectively), with 6% of lands certified under the FSC standard. In total, 18% of the forested land in the SE region is certified under at least one certification program (Lowe et al. 2011).

4.3.2 Forest certification in Canada

By May of 2012, the global area of certified forest was 394 million hectares.[18] Nearly three-quarters of Canada's commercial forest land is certified, a land area of about 148 million hectares that accounts for 39% of certified forests globally. The area of forest land certified under the FSC and SFI programs is about equal (54.1 and 57.6 million hectares, respectively), with certification of an additional 44.9 million hectares under the CSA program; the total of these numbers is greater than the 148 million figure indicated above due to dual certification of some forests.

In addition to rigorous forest management laws and regulations, that characterize what SFM means and what actions may take place on public forest land, BC supports third-party forest certification as a tool to demonstrate the rigor of its forest management laws, and to document its world-class sustainable forest management practices. BC supports all internationally-recognised third party forest certification programmes. Certification Canada reported that as of 2012, BC has a total of 52 million hectares under one of the three major third party forest certification programmes (24.7 million hectares (47%) certified under CSA, 25.6 million hectares (49%) under SFI, and 2.4 million hectares (4%) under FSC). This means BC has more forest area independently certified by one of three internationally recognized certification standards than any other jurisdiction in the world, with the exception of Canada as a whole.

5. Biomass carbon neutrality, carbon interactions in the forest environment, and forest carbon modelling

The following section summarizes the rationale behind the forest biomass carbon neutrality principle (section 5.1) and describes the carbon interactions in a forest environment (section 5.2). Then, various

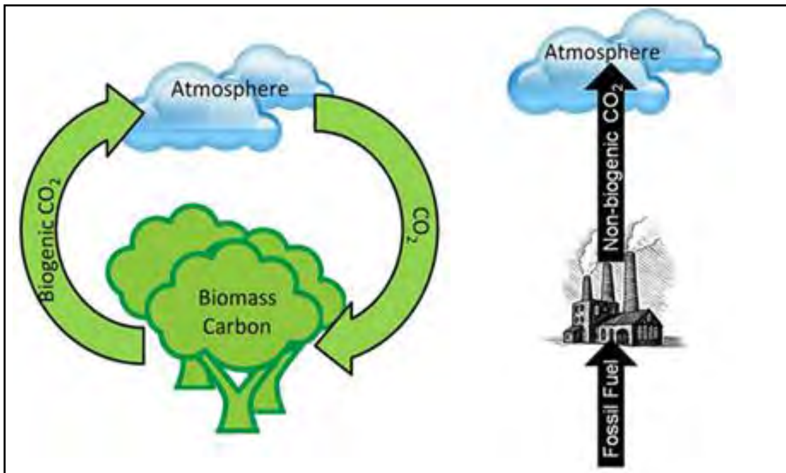
[15] http://www.sfiprogram.org/standards-and-certifications/fibre-sourcing-requirements/
[16] http://www.pefc.org/certification-services/eu-timber-regulation/the-role-of-certification
[17] https://ic.fsc.org/controlled-wood.40.htm
[18] http://www.unece.org/fileadmin/DAM/timber/publications/10.pdf

forms of biomass used for energy purposes are discussed, followed by an explanation of different parameters that must be properly considered in modelling of forest carbon dynamics (section 5.3).

5.1 Forest biomass carbon neutrality

The principle of carbon neutrality is generally understood as the biogenic carbon cycle based on photosynthesis. When wood is burnt, carbon which has been removed from the atmosphere and stored by the tree is released back into the atmosphere. This is in contrast to combustion of fossil fuels (coal, oil, and natural gas), wherein carbon is released that has been stored in the earth for millions of years, and which cannot be replenished on anything short of a geologic time scale (Figure 4).

Figure 4. The biogenic carbon cycle.



Biogenic carbon is part of a relatively rapid natural cycle that impacts atmospheric CO_2 only if the cycle is out of balance.	Fossil fuel combustion transfers geologic carbon into the atmosphere. It is a one-way process.

Source: Lucier and Miner (2010)

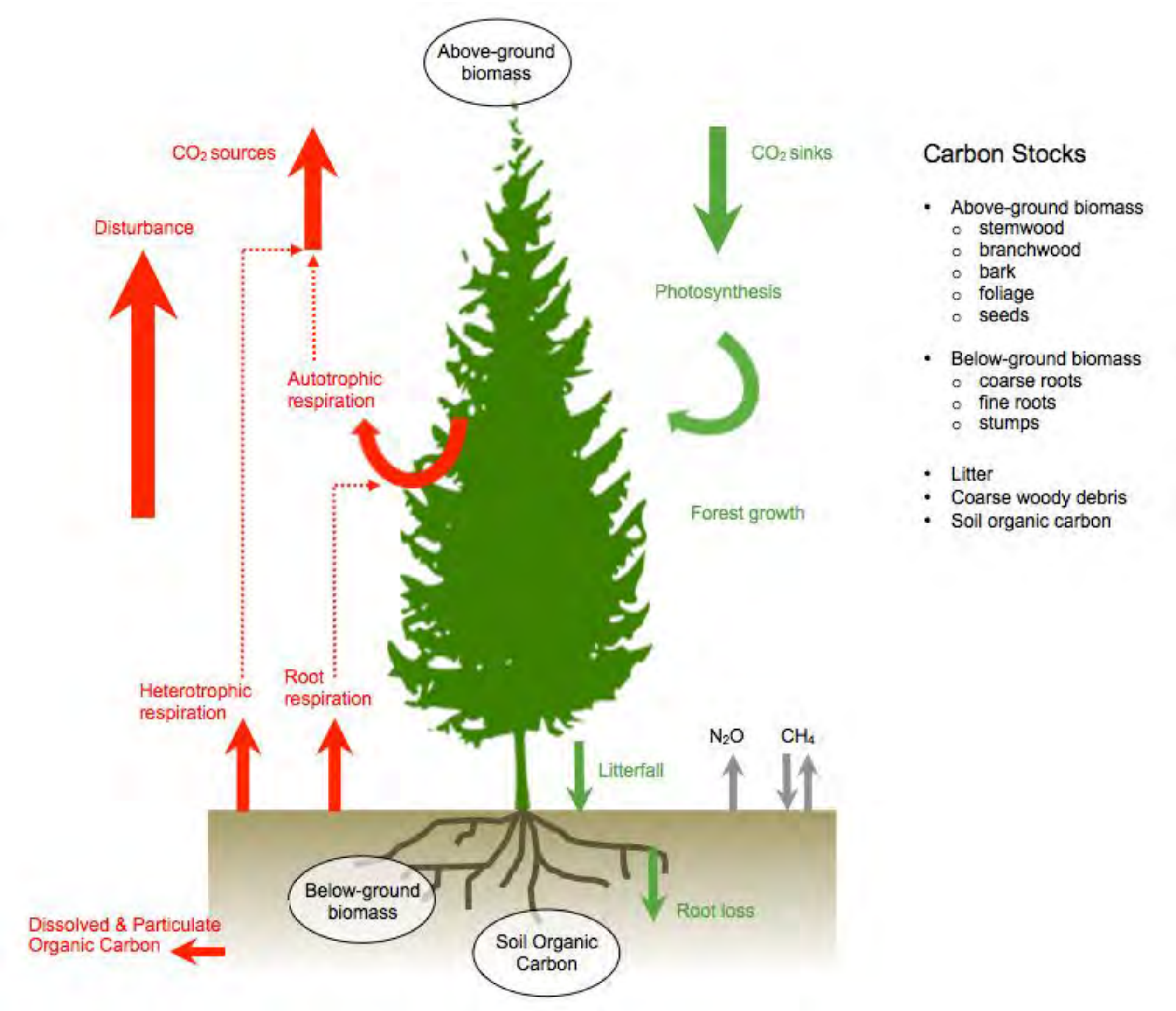
Under a sustainably managed forest regime, regeneration operations (re-planting or natural regeneration) occur soon after harvesting such that net growth across the forested landscape remains equal to or greater than total removals. Given these conditions, a quantity of carbon equal to or greater than the volume of carbon released into the atmosphere as harvested wood is combusted, is removed from the atmosphere again through the growth of new trees. Moreover, the energy generated through wood combustion displaces fossil fuels, preventing the net release of fossil carbon that would have occurred had not bioenergy been produced.

According to the IPCC, the most efficient climate mitigation option from forestry is to integrate both forest carbon stock maintenance and harvesting operations in management of forests: "*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, fibre or energy from the forest, will generate the largest sustained mitigation benefit*" (IPPC 4th Assessment Report, 2007).

5.2 Carbon interactions in the forest environment

The forest system is always dynamic and is affected by natural aging processes, climatic conditions and naturally occurring events such as forest fires, pest and disease outbreaks, storm damage (events which themselves may be exacerbated or improved by human intervention). The management of forests by human intervention also has impacts on these interactions (Figure 5).

Figure 5. Carbon and Carbon Dynamics in the Forest Environment



Adapted from Matthews et al. (2012)

5.3 Modelling of carbon balance of biomass used for bioenergy

5.3.1 General Observations

In order to understand the overall GHG balance of a biomass for bioenergy supply chain, the carbon dynamics of a forest can be modelled as the change in carbon stock of the forests. As an example, a recent study (Matthews et al. 2012) supporting the UK Department of Climate Change's (DECC) Renewable Obligation (RO) consultation, has described the key components of forestry carbon accounting and modelling considerations. The elements that most impact modelling outcomes are:

1. Forestry practices and the types of forest biomass used for bioenergy: To understand the carbon outcomes of biomass use, clear and consistent definitions related to forestry and biomass types are essential;

2. Model methodological choices and scenario assumptions: Understanding the principles of modelling methodologies and assumptions assist in better understanding of carbon accounting for forestry systems and demonstrate why modelling can lead to diverse outcomes. The main model parameters are the following:

- Methodological choice: choice of the baseline, temporal consideration and spatial consideration.
- Scenario assumptions: biomass feedstock and source; supply chain and conversion efficiencies; choice of counterfactual.

In setting up a model to understand the temporal carbon outcomes of biomass use, clear definitions of the type of woody biomass are essential. For the purpose of modelling biomass, at the extreme, the feedstock used for the production of pellets can be considered as the primary product (i.e. 100% of a harvest output goes to the production of pellets for bioenergy) and in this case, all inputs and outputs of the carbon account would be attributed to biomass.

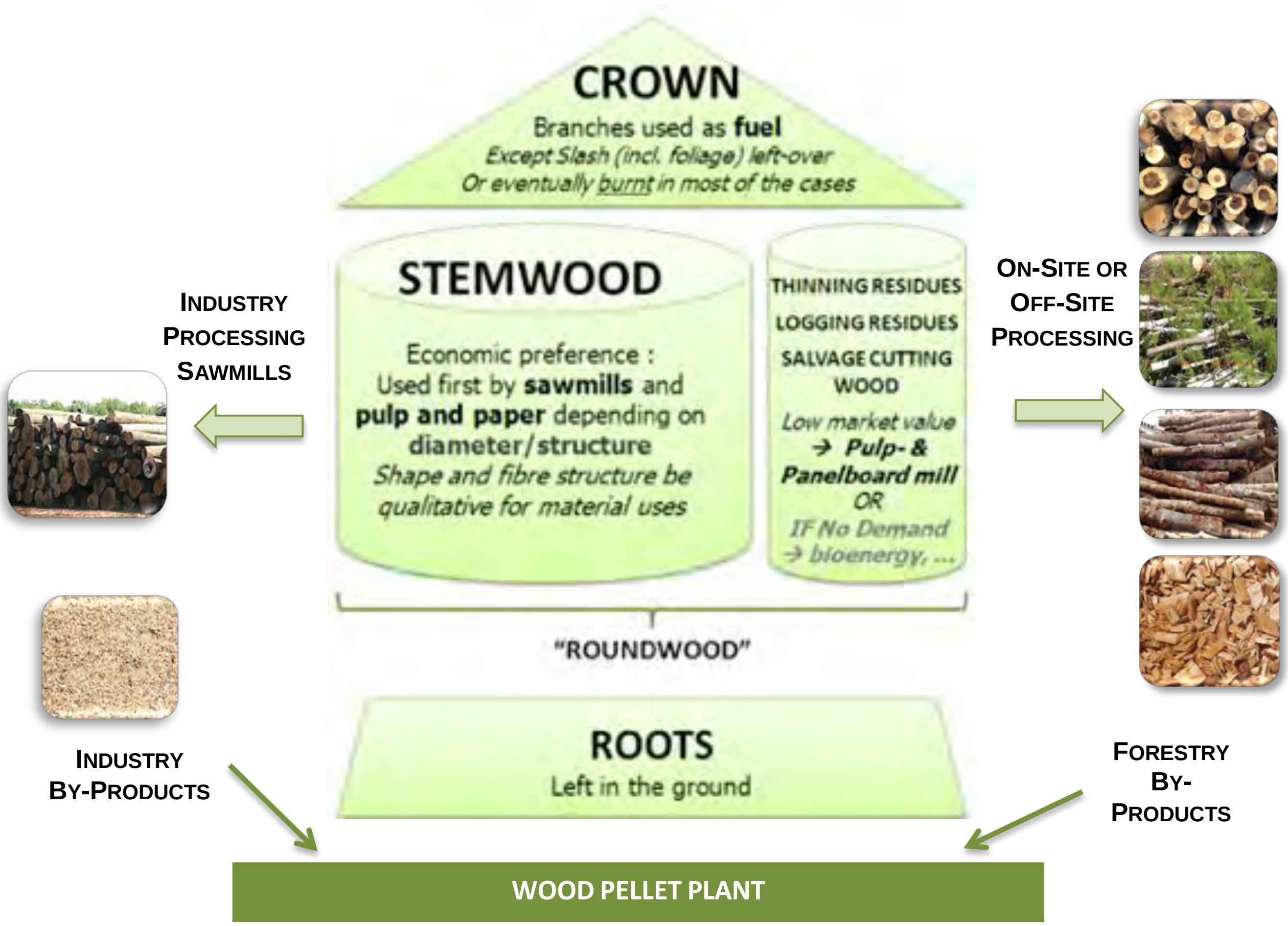
The more realistic feedstock base for bioenergy, on the basis of commercial value of forestry products (see Section 4.1), is the lower value 'secondary' products of forestry outputs. The term 'secondary product', 'by-product' or 'residue' can be applied to materials, which are not the primary product or reason for:

- a forestry management activity (forest/field/harvest residue e.g. tops and limbs, branch wood, wood from thinning that are un-merchantable for other purposes than energy (see Figure 6)).
- a forest industry process activity (process/industrial residues e.g. sawdust or shavings (see Figure 6)).

Terminologies such as 'roundwood' and 'whole tree' are often used generically and can lead to problems in the perception of modelling outcomes. Woody material which is described as 'roundwood' or 'whole tree' can also fit into residue and by-product categories. For example, thinnings are the by-product of a forest management activity to produce high quality timber. Thinnings can be seen as 'whole trees' which can also be referred to as roundwood. Roundwood can also refer to the upper portion of the tree, which does not go to the timber market as sawlogs, without being the 'whole tree'. Thus each biomass portion must be appropriately defined and considered as a component of a multi-product forestry system.

These definitional aspects are also important when considering the commercial value placed on forestry products and resulting forest management activity, and whether growing trees actually remains a viable option for land use management (section 4.1). Figure 6 shows how biomass for bioenergy is part of a sustainable forest management system with a multi-products approach.

Figure 6. Forest Management for multi-products in SE US and BC Canada



Courtesy of WPAC, FPInnovation Canada, and Enviva

5.3.2 Carbon model outcomes – highly influenced by methodological choices and assumptions

In recent years scientists have developed modelling methodologies and carried out studies to assess the temporal aspect of carbon accounting for bioenergy[19], specifically whether there is a time lag before net

[19] *A range of terminologies are used to describe the temporal aspect of carbon in biomass for bioenergy. See Appendix 3- Carbon balance terminology.*

GHG reductions are achieved and if so how long this period is. The outcome of some studies has raised questions on the merit of using biomass for bioenergy. Some environmental groups have gone so far as to claim that 'biomass can be dirtier than coal' (RSPB 2012), referring to studies (Bergsma et al. 2010, Bird et al. 2010, Manomet 2010, Zanchi 2010) which report that the use of biomass for bioenergy can lead to a 'carbon debt' of several decades to as much as hundreds of years.

From the analyses presented in this report it is concluded, however, that results as mentioned above are based on modelling assumptions which do not correspond with current and expected future industry practice and are therefore not representative. Thus, it is essential that great care be exercised in interpreting such studies.

When based on current industry practice, model results show zero or very short time periods before net GHG reductions are achieved. In fact, even studies widely reported to have determined the existence of carbon debts and long carbon payback periods acknowledge near-term carbon benefits to use of wood residues and logging wastes in energy generation (Manomet 2010, Agostini et al. 2013). This is because wood pellets for bioenergy are sourced to a large extent from forest by-products or sawmill residues, the use of which introduces no, or only small, changes in carbon stocks. When roundwood is used as the raw material for fuel pellets, as is sometimes the case in the SE US, it is pulpwood (smaller diameter) or lower quality wood which is used, the demand for which has slowed considerably in past decades in certain areas, and for which projections show substantial increases in volume and continuing slow demand growth. In view of the fact that the annual net growth in this region far exceeds total removals, carbon stocks are clearly not declining due to bioenergy.

It is possible to define a scenario wherein significant reductions of forest carbon stocks could occur that would lead to a long time lag before recovery of lost carbon. This might occur, for example, if a natural forest with high carbon stocks were harvested entirely for bioenergy. But such a scenario has no relation to reality. When modelling is based on realistic assumptions and scenarios, and results are interpreted correctly, models can give useful information for policy makers who wish to avoid ineffective policy choices. In this section of the report, modelling of the carbon balance of forest-based bioenergy is discussed in some detail. Sections 5.3.2.1 to 5.3.2.7 discuss the key methodological choices and scenario assumptions that impact the outcome of any temporal carbon analysis. Section 6 presents the modelling results of a number of scenarios that have been analysed for this report and compares the outcomes with similar scenarios published in peer reviewed literature. Finally section 7 summarizes the key insights derived from this analysis and the case studies presented herein.

5.3.2.1 Methodological choices and scenario assumptions

Carbon debt is generally described as the net reduction in total forest carbon stocks that occurs when wood is harvested, whether for timber, paper, or energy. Some studies of this issue exact a carbon "debt" on the specific area harvested and only credit regrowth in that specific area when calculating repayment of that debt. Other studies take a wider view, charging a debt only when the reduction in carbon stocks is not directly and fully compensated by associated carbon stock changes elsewhere in the forest system. In this report, the phrase **carbon debt** refers to the reduction in net carbon stocks when wood is harvested to replace fossil fuels, compensated for the emission savings achieved by the replacement of fossil fuel.

When calculating the emissions savings from avoided fossil fuels, the life cycle emissions of bioenergy (caused by fossil fuel use in harvesting, pelletizing, and transport) are also accounted for.

This debt is temporary and is repaid when the carbon savings of avoided fossil fuel use, added to the regrown carbon stocks in the forest, equal the initial debt. The time taken to achieve this position is known as the **carbon debt repayment time**. In other words, this is the point at which the net cumulative GHG savings become positive. After carbon debt repayment is completed, bioenergy achieves net emission savings. In accordance with the broad view of carbon debt, and the Reference Point Baseline modelling approach described below, any reduction in carbon stocks is quickly compensated by CO_2-emission reductions elsewhere as long as net growth as a whole exceeds net removals. In this case, there is no question of carbon debt: carbon stocks are immediately or rapidly restored.

It is also necessary to recognise that other studies utilise the term 'carbon debt' even where there is no actual reduction in carbon stocks but where use of wood for bioenergy leads to forest carbon stock increases that are smaller than they would have been in the absence of the use of wood for bioenergy. In this report, this is termed '*foregone carbon sequestration*' compared to a so-called 'counterfactual': i.e. what otherwise would have happened. The point in time where the carbon savings of avoided fossil fuel use plus the regrown carbon stocks in the forest equal the initial carbon stock reduction plus foregone sequestration is termed the '**carbon parity point'** (see Appendix 3).

As already stated, it is important to understand that the magnitude of any carbon debt and its associated repayment time are largely determined by key methodological choices and scenario assumptions. It is therefore imperative that these choices are fully explained and related to current actual, rather than to theoretical forestry practices. This section will discuss the choices and assumptions that have the largest impact on the outcomes and their relevance to realistic sustainable forest management and energy industry practices. Sections 5.3.2.2 to 5.3.2.4 explain the methodological choices and sections 5.3.2.5 to 5.3.2.7 explain the scenario assumptions that are used for modelling.

5.3.2.2 Methodological choices – "reference point" or "anticipated future" baseline

For any modelling exercise it is necessary to establish a baseline with which to compare the model scenario. Two main approaches have been identified by the US EPA for comparison of bioenergy with fossil energy sources (USEPA 2012):

Reference Point Baseline (RPB): the net change from a current reference point

The US EPA defines this as answering *the question, "Is there more or less carbon stored in the system (the stationary source and its feedstock-supply source) at the end of an assessment period than there was at the beginning?" This approach establishes as the baseline the carbon stock on a given land base (i.e., total stocks of organic and inorganic carbon stored in vegetation and soils) at a given point in time (or time interval). It is against this measureable reference point that future stocks will be measured. If stocks increase or remain constant from that level, then under this approach it would be concluded that the biogenic feedstock source region itself is not contributing to an increase in CO_2 concentrations, and therefore stationary source emissions of CO_2 from consumption of biologically based feedstocks from this region are also not contributing to an increase in CO_2 concentrations. Conversely, if stocks decline from* *that level, the feedstock production area and the stationary source(s) using biologically based feedstocks from that area are likely contributing to that decline and related net emissions.'*

Anticipated Future Baseline (AFB): the net change from a possible future**.**

The US EPA describes this approach as seeking to *answer the question, "Is more or less carbon stored after the assessment period in the system (the stationary source and its feedstock-supply source) than expected?" This approach, as used by Searchinger (2009), takes an expected rate of change in carbon stocks (for example, the rate of carbon sequestration) as the baseline. A complexity with this approach lies in how to define what would have been expected—in other words, to identify the expected rate of change in the absence of an energetic use of biomass.*

The relationship between these two approaches is outlined in Table 5. More details, definitions and examples can be found in Appendix 4.

Table 5. Comparisons between Reference Point Baseline and Anticipated Future Baseline Approaches

	Reference Point Baseline (RPB)	**Anticipated Future Baseline (AFB)**
Basis for comparison	The current situation in the given managed forest supply chain.	What would be expected to occur if the biomass were not used for bioenergy (i.e. *the counterfactual).* A realistic consideration of the purpose and function of the forest is essential when choosing the counterfactual.
Information provided	Provides information on actual (i.e. measurable) emissions and sequestration. The calculated emission savings can be theoretically verified by measurement, though in modelling, results are highly dependent upon accurate and appropriate data.	The calculated emission savings depend critically on assumptions regarding future forest growth that are input to the model. Randomized plot data, with controls, can be used as a basis for verification.
Relevant indicator	**Carbon debt repayment time**: The point in time where the initial carbon debt has been repaid by the savings of avoided fossil fuel use plus the regrowth in carbon stocks after harvesting (alternatively: the point at which the net cumulative GHG savings become positive)	**Carbon parity point:** The point at which the net cumulative GHG savings of the bioenergy scenario equal those of the Anticipated Future Baseline scenario
GHG emission reduction	**Absolute** GHG emission reduction	**Relative** GHG emission reduction

5.3.2.3 Methodological choices – spatial considerations

In setting out a carbon accounting model for forestry, three approaches have been identified (Jonker et al. 2013) for the spatial boundary or the 'level of assessment'.

Plot level approach (also referred to as stand level/single plot approach): In this case, a single plot is considered; harvested at year one, replanted and harvested again at the end of the rotation period (see Figure 7a).

Increasing plot level approach: considers the harvest (and re-planting) of 1 forest plot per year, adding annual sequential plots until the rotation period is reached (Figure 7b).

Landscape level approach: Landscape level approach considers a complete forest area. In the case of an existing managed forest, with harvested and re-planted plots interspersed in an uneven aged forest (see Figure 7c).

Figure 7. Illustration of outcomes of carbon stock models using different spatial boundaries

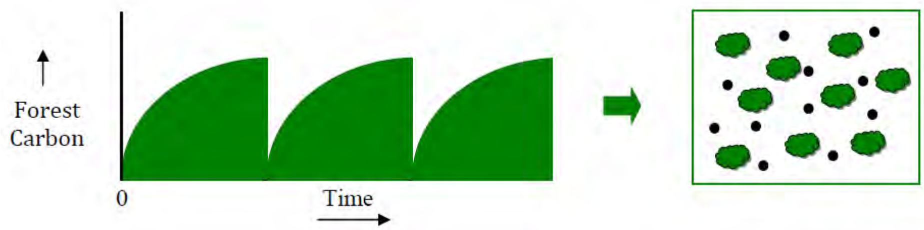


Fig 7a. Plot level taken from time of harvest

Fig 7b – Increasing plot level approach taken from time of harvest

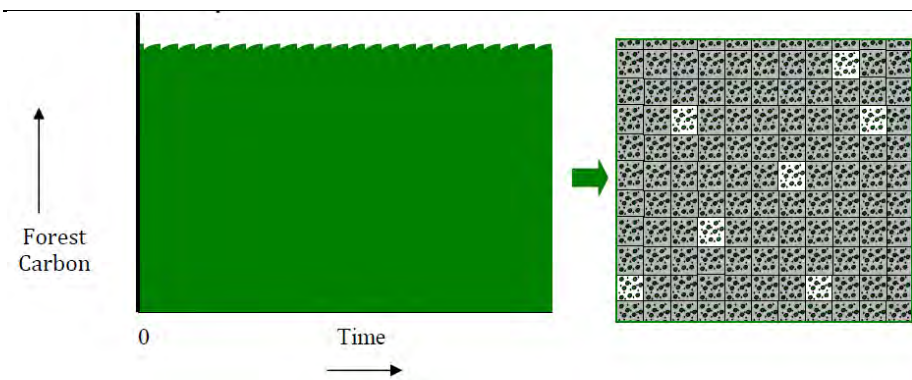


Fig 7c. Landscape level taken from time of harvest

Source: Bowyer et al (2012)

Clearly the choice of spatial scale of the model calculation is important. This will be case-specific but logically should be chosen to approximate to the catchment area serving a sawmill or pellet mill and whether the catchment area being used for bioenergy is constant ("landscape" level) or growing year by year ("increasing plot" level). The scale of the operations employed for bioenergy indicates that the "plot" level is not the most appropriate approach for a full study. Jonker et al. (2013), for instance, concluded that the landscape level carbon debt approach is appropriate for the situation in the SE US, where softwood plantations are already in existence; they note that in this case the issue of carbon payback is basically non-existent. Cowie et al. (2013) also found landscape level assessment to be most appropriate, saying that:

> *". . . in order to fully understand the climate change effects of bioenergy from existing forests, it is important to consider the entire forest landscape and the wide range of conditions within which forest bioenergy systems operate; long term as well as short term effects and climate objectives; and the interactions between human actions and forest growth. Rather than concentrating on the timing of emissions and sequestration, it is more relevant to focus on assessing the contribution that bioenergy from existing forests may make to the establishment of sustainable renewable energy systems that can provide a GHG---friendly energy supply in the future."*

5.3.2.4 Methodological choices – temporal considerations

Start of accounting period:

As an integral parameter of carbon modelling, it is important to consider when the accounting period begins. For example, as shown in Figure 7a, when considering the start time of carbon accounting (i.e. time of harvest vs. time of planting), the plot level approach is considerably influenced by the choice of carbon accounting start time. If the carbon accounting period starts at the time of planting, the carbon stock of the forest and the harvested products are effectively a carbon credit just prior to harvest, with the act of harvesting equivalent to taking the accrued interest; in this case there is no carbon debt. However, if accounting starts at the time of harvest, the carbon stock falls at harvesting creating a "carbon debt."

As shown in Figure 7, studies applying a landscape approach can also be influenced by the start time of the carbon account, but here the impact is less significant as the landscape approach describes an average carbon balance over a landscape, which is generally much more stable than carbon stocks at a single forest plot. It is also relevant to note that the start time of the account is relevant for the RPB Scenario if there have been significant changes in the carbon stock level (i.e. in the growth/drain ratio) in the recent past.

Starting the carbon account at the time of planting is an appropriate choice for newly planted forests for the production of biomass for bioenergy and perhaps also for all production forests, whatever the intended use. On the other hand, the time of harvesting is a more appropriate choice if the case concerns harvesting a (semi-) natural forest for the first time.

Relevant time horizon:

Although modelling current industry practice shows zero or short carbon debt periods when calculated with appropriate counterfactuals, it is instructive to consider what the relevant time scale is for combating climate change effectively. In order to limit global warming to 2 degrees over the preindustrial average, atmospheric CO_2 concentrations must stabilise at or below 450 ppm by 2100 (European Commission 2008) (they are currently just under 400). This requires society to limit the cumulative amount of fossil fuels burnt, as CO_2 emissions from fossil fuels affect CO_2 levels in the atmosphere for thousands of years. As the ultimate level of global warming is very insensitive to the exact timing of GHG emissions, also renewable energy options with a modest initial carbon debt can make a meaningful contribution to the 2 degree target as long as they realise significant savings by 2100. The relevant time horizon is addressed in more detail in Appendix 5.

Having discussed methodological questions, the next 3 paragraphs consider scenario assumptions.

5.3.2.5 Scenario assumptions – biomass origin

A key determinant in the extent of the GHG emission savings of biomass for bioenergy is the type of feedstock used and the forestry system it is derived from. The most important scenario assumptions leading to model results with substantial carbon debts are:

*** The assumption that bioenergy is the driver of the forest management change**. Many studies (for example Manomet, 2010) assume that a forest is harvested primarily for bioenergy and therefore attribute all impacts to bioenergy. In practice, however, wood pellets are made from forest and process residues (and in the SE US in some instances from pulpwood, where the paper industry is in decline in certain areas) from existing forest management activities, with lumber being the primary product and the main driver for harvesting. Managing and harvesting forests purely for bioenergy would simply not be economic in either the US or Canada (see section 4.1 for details).

*** High carbon stock levels in mature forest**: Removal of biomass from mature forests with high carbon stock leads to relatively long periods before net carbon reductions are achieved. Bringing such mature forest under management for the first time would, in general, reduce carbon stock levels for a considerable period as the average age of the trees (and thereby their carbon content) was reduced. It should however be realised that forest conversion purely for bioenergy does not occur in current practice (see sections 3.2, 3.3 and 4.1) and is unlikely to happen in the future.

* **Forest growth and decomposition rates:** Forests grow at very different rates in different regions, mainly as the result of climatic conditions and soil. This is reflected in the rotation time between harvests which can be 20-30 years in one region such as the SE US, and 60-100 in another, such as in BC. Many quoted model results (carbon debt repayment times of 100 years or more) are based on slow growing boreal (northern) forests. Results for the SE US show net GHG greenhouse gas reductions in a much shorter time period (Jonker et al, 2013), and no reduction in carbon stocks and thus zero payback time for softwood plantations already in existence.

Faster decomposition rates of residues left in the forest can also play a role in modelling outcomes since rapid decomposition of residue left following harvest translates to little difference in timing of carbon release through combustion or decay. Just as with growth, many often cited studies have been based on forests in which decomposition rates are low. For example, a study carried out in the northeastern US (Manomet 2010, as well as some of the scenarios presented by McKenchnie et al. 2011) find very long periods before bioenergy achieves higher GHG savings than the anticipated baseline scenario. Equivalent results for the SE US show net GHG reductions in a much shorter time period (Jonker et al, 2013) due to the faster forest growth rates and faster decomposition rates of residues left in the forest.

All of these factors – the role of bioenergy in management decisions, forest carbon stock levels, and rates of growth and decomposition – are extremely important in determining outcomes when modelling forest carbon dynamics. Studies that find a large carbon debt and long carbon debt repayment times assume dedicated harvesting for bioenergy, and tend to focus on large, older, slow-growing forests and large accumulated carbon stocks. Beyond the fact that such assumptions bias results toward large carbon debt and lengthy repayment periods, such assumptions are, as explained previously, unrealistic.

5.3.2.6 Scenario assumptions – fossil fuel replaced and energy efficiency

The efficiency of the supply chain, the efficiency of biomass conversion to energy in a power plant, and the fossil fuel that is replaced all have a considerable impact on results of modelling studies. Most industrial wood pellets are currently used to replace coal in existing coal-fired power plants. Because of the relatively high carbon intensity of coal, directly replacing coal leads to very high GHG emission savings. A study by Utrecht University indicates that US wood pellets used for co-firing in the Netherlands reduce emissions by about 85% (Jonker 2013) (i.e. coal emissions of 1081 g/kWh are replaced by biomass emissions of 162 g/kWh). This includes emissions for sourcing, processing and transporting the wood pellets.[20]

In contrast, the modelling assumptions in the Manomet Center study (Manomet 2010) included utilisation of wood pellets in installations with low conversion efficiencies, leading to carbon replacement efficiencies in the range from 33 to 69%. This carbon replacement efficiency is the amount of fossil carbon replaced by burning 1 ton of biomass carbon, including life-cycle emissions from both the bioenergy chain and the fossil alternative. These numbers used by Manomet are very low compared to the ~87% carbon replacement efficiency that follows from the results of Utrecht University – which is representative for large scale use of wood pellets in the EU[21].

For all these reasons, it is clearly important that supply chain and conversion efficiency assumptions, as well as the fossil fuel that is being replaced, correspond with the case being considered.

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[20] Life cycle analysis excluding silvicultural emissions as these are typically allocated to the main products (sawn wood and pulp and paper). Including silvicultural emission changes this result to 82%. Even when compared to the EU fossil fuel comparator a reduction of 70% is achieved.

[21] The 87% is obtained as follows from the 85% GHG emission saving number from Utrecht University: if the use of biomass delivers 85% savings compared to the use of coal, then the supply chain emissions of biomass amount to 15% of the total emissions of fossil fuel (supply chain emissions + stack emissions). The stack emissions from biomass similar to those of coal because both the conversion efficiencies of the two fuels and the emission factors are very similar in co-firing. Therefore total emissions (supply chain + stack) from biomass amount to 115% of coal emission and the carbon replacement efficiency amounts to 100/115 = 87%.

5.3.2.7 Scenario assumptions – choice of counterfactual

When using the Anticipated Future Baseline approach it is important to choose an appropriate counterfactual, the expected future scenario if the use for bioenergy does not take place.

Different counterfactuals can lead to very different assumed future GHG emissions or reductions. It is clear that detailed knowledge of a region and market trends are needed in order to choose an appropriate counterfactual which reflects the existing and future markets for the forest products, legislation, growing conditions, potential disturbance, and forest management practices.

For current sourcing in Canada, it could be argued that the most realistic counterfactual will be the situation occurring prior to the growth of bioenergy, i.e. the maintenance of a timber industry with concomitant disposal of residues either by burning or by leaving excess material on the ground in the forest.

For current sourcing in the SE US from forest residues, the previous practice of leaving logging residues on the forest floor would appear to be the most appropriate choice.

In parts of the USA the paper/pulp market has been a major user of lower grades of wood from existing managed forests and forest plantations, with thinning and other forest stewardship practices becoming feasible and common. However, as noted previously, global pulpwood markets have begun shifting toward Asia and South America, leading to the availability of pulpwood for the biomass sector. A suitable counterfactual for this situation would not be leaving the forest to grow indefinitely to old age, but would have to recognise the need of forest owners to receive economic benefit from the forest.

For a scenario involving harvesting natural forest for the first time, leaving the forest to continue growing would probably be the appropriate counterfactual. As mentioned earlier this counterfactual is often – in our view incorrectly – used for evaluating wood pellet sourcing from existing managed forests. If considered at all in evaluation, a scenario involving the harvesting of natural forest should be considered as a hypothetical worst case scenario.

The choice of counterfactual can cause large changes in calculated carbon payback times. It is therefore critical to the rational interpretation of model results. It is worth noting that the Reference Point Scenario, because it does not employ counterfactuals, does not suffer from such uncertainties.

The following section outlines various scenarios for procurement of biomass for bioenergy and examines projected GHG savings in each case. The discussion builds on the previous examination of the importance of methodological choices and assumptions.

6. GHG savings from biomass for bioenergy for various scenarios

This section presents modelling results of the temporal GHG emission savings of bioenergy scenarios for the SE US and BC, Canada. The results presented are taken from model calculations carried out by MWH Consultants using actual industry data for supply chains delivering wood pellets to Europe for use in co-firing. A key objective of this exercise was to calibrate results with those of other studies; in terms of the key methodological choices the model takes an increasing plot level approach and results are presented primarily for the AFB approach (relative savings). For each scenario the absolute savings based on the RPB approach are also considered.

The results from the MWH model are complemented by results and comparisons with other published studies. The first two scenarios presented are most representative of current actual wood pellet production, which is largely based on by-products and residues from existing managed forests in the SE US and BC.

The third scenario has been constructed entirely for the benefit of calibrating results against other studies. It is a hypothetical case which does not occur in current industry practice and is not expected to occur in the future given the economic realities of forest management and the timber, paper and energy industries. It shows results for a plantation forest in the SE US harvested entirely for the production of biomass for bioenergy.

From the point of view of Sustainable Forest Management, it is important to note that, whilst intensification of harvest for energy purposes can lead to a decline in carbon stock relative to anticipated future baseline without harvesting for bioenergy, this does not necessarily equate to an increase in absolute CO_2 emissions unless the extent of this decline is greater than the increase in carbon stock from re-growth. In the USA, this is generally modelled using a metric called the growth/drain ratio, a measure also used in conjunction with evaluation of forest trends in general; a value > 1.0 indicates that more carbon is being accumulated than is extracted. Under such a scenario, there will be zero carbon debt.

These scenarios are also useful in indicating three different aspects of the modelling process:

a. The residue example in SE US assumes a small decline in forest litter carbon stocks due to biomass extraction (scenario 1 in paragraph 6.1 below)

b. The residue example for Canada shows the use of models where no change in carbon stocks is assumed (scenario 2 in paragraph 6.2)

c. The example of the plantation forest in SE US assumes no change in absolute carbon stocks but illustrates the effect of a "no harvest" counterfactual (scenario 3 in paragraph 6.3).

In paragraph 6.4 the report shows the impacts if the demand for forest products leads to an expansion of the managed forest area. As indicated above, it is unlikely that this would ever be driven by increased demand for bioenergy.

6.1 Wood pellets from harvesting residues in the SE US

Relative savings using an Anticipated Future Baseline approach

Table 6 summarizes the assumptions and Figure 8 below shows the modelled results of the use of 100,000 tons wood pellets per year for co-firing with coal in an existing EU power plant. The pellets are assumed to be produced from harvesting residues from forestry activities in the SE US. For the AFB approach, the assumption made here is that if the biomass were not removed, it would have been left to decompose in the forest (the counterfactual).

The net relative biomass emission savings are equal to the fossil fuel savings corrected for the emissions from transport and processing and reductions in forest carbon stocks.

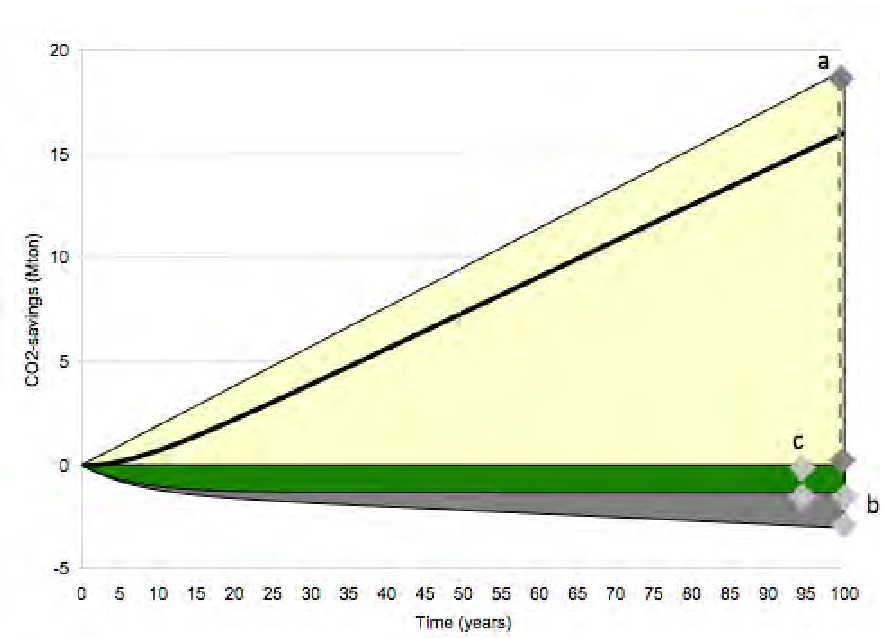
The results show that, as the result of utilizing the harvesting residues, there is a modest carbon stock decline in the forest compared to the anticipated future baseline ("c" in Figure 8). In our increasing plot level approach, this effect initially increases over time as more stands are harvested and thus more residues are utilised, until a new equilibrium is achieved. In addition, there are CO_2 emissions associated with processing biomass at the pellet mill and the transportation activities ("b" in Figure 8). The wood pellets are used to replace coal in an existing coal power plant. The emission savings from displacing coal are represented by "a" in Figure 8. The overall net GHG emission savings (relative savings) of bioenergy, taking into account the savings from replacing coal, the emissions from transport and processing, and the changes in forest carbon stocks compared to the baseline, is shown by the solid black line.

Table 6. Summary of key assumptions for a scenario for wood pellets from harvesting residues from existing forestry activities in the SE US

Feedstock type	Harvesting residues
Forest type	Managed plantation
Spatial basis for model	Increasing plot level approach based on production and consumption of 100,000 metric tons wood pellets per year
Baseline assumption	Anticipated Future Baseline (counterfactual - biomass left in forest which decomposes over time)
Region	SE US
Emissions from processing and transport	Industry data cross-referenced with literature
Wood pellet use	Co-firing in EU coal plant with 40% electrical efficiency

What can be seen from Figure 8 is that GHG emissions savings from the substitution of coal rapidly outweigh the emissions from processing and transport and the modest carbon stock reduction in the forest compared to the no-biomass-harvest baseline. Net relative savings (compared to the counterfactual) are achieved from year 3 onward. In other words, the parity point is reached after 3 years. After year 3, emission savings grow rapidly to reach 2.2 Mton CO_2 after 20 years. Note that these net relative savings are already more than 150 times larger than the initial increase in net relative emissions. For longer periods considered the emission savings increase proportionally with the amount of coal displaced.

Figure 8. Cumulative CO_2 savings modelled results for wood pellets sourced from harvesting residues in SE US



Legend

Processing and Transport emissions

Foregone forest carbon sequestration compared to counterfactual

Fossil fuel savings

NET Relative Biomass savings

Source: MWH analysis

Absolute savings using a Reference Point Baseline approach

In this scenario, the absolute emission savings under an RPB approach depend on the development of forest carbon stocks over time. As long as growth : drain ratios are 1 or more there will not be a carbon debt and bioenergy achieves net absolute savings from the start. If there are no other management changes than the introduction of harvesting of tops and branches, then there could be a modest carbon debt. In that case the results under the RPB approach would be comparable to those of the AFB approach: i.e. the repayment time point would be reached after a few years, after which the bioenergy scenario leads to significant additional savings.

6.2 Wood pellets from residues from existing forestry activities in BC, Canada

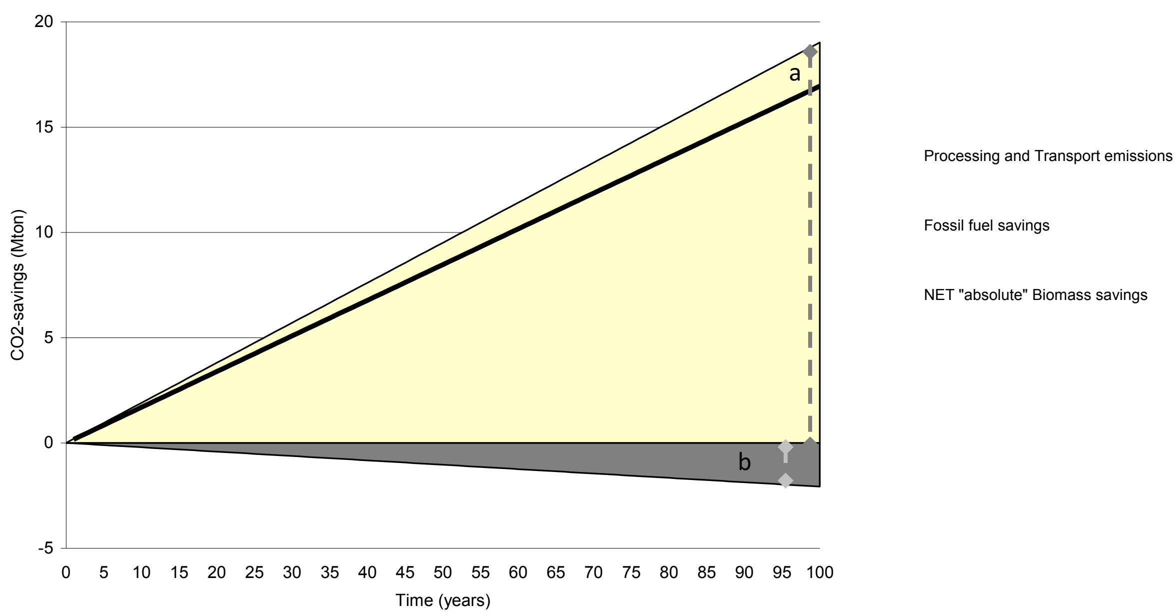
Relative savings using an AFB approach

Table 7 summarises the assumptions and Figure 9 shows GHG emission savings for the use of wood pellets, produced from residues from forestry operations in BC, for co-firing in an existing EU power plant. In this scenario pellets are produced from raw material streams typically used in Canada: principally sawmill residues with some harvest residues. The assumption made here on the counterfactual is that if the biomass was not used for the production of wood pellets the biomass would have been burnt as a means of waste disposal (Section 3.3).

Table 7. Summary of key assumptions for the following Anticipated Future Baseline scenario: Wood pellets from residues from existing forestry activities in BC, Canada

Feedstock type	Sawmill residues and Forest residues
Forest type	Managed natural forest
Spatial basis for model	Increasing plot level approach based on production and consumption of 100,000 tons wood pellets per year
Baseline assumption	Anticipated Future Baseline. (Counterfactual – burning of residuals as a means of disposal)
Region	British Colombia, Canada
Emissions from processing and transport	Industry data cross-referenced with literature
Wood pellet use	Co-firing in EU coal plant with 40% electrical efficiency

Figure 9. Cumulative CO_2 savings modelled results for wood pellets sourced from residues in BC, Canada



Legend

Processing and Transport emissions

Fossil fuel savings

NET Relative Biomass savings

Source: MWH analysis

The net relative biomass emission savings are equal to the fossil fuel savings corrected for the emissions from transport and processing. The grey area ("b" in Figure 9) represents emissions from transport and processing while the emission savings from replacing coal are shown in yellow ("a" in Figure 9).

For this scenario relative GHG emission savings are achieved by bioenergy immediately, a reality that is recognized in the JRC report entitled *Carbon Accounting of Forest Bioenergy* (Agostini 2013). In other words there is no carbon debt. This can be explained by the fact that the use of these residues does not lead to a reduction in forest carbon stocks as these residues are burnt if not used for bioenergy. After 20 years, emission savings amount to 3.3 Mton CO_2. For longer periods considered the emission savings increase proportionally with the amount of coal displaced.

Absolute savings using a RPB approach

In this scenario the absolute GHG emission savings (RPB approach) and the relative GHG emission (AFB approach) are identical. The reason is that the baseline is the same under both approaches as the pellets are made out of residual material from trees that are extracted from the forest for other purposes and that would otherwise be burnt as a means of disposal.

6.3 Wood pellets from SE US forest harvested entirely for bioenergy (hypothetical)

Relative savings using an AFB approach

As discussed in section 4.1.1, many existing studies have analysed the GHG savings of bioenergy over time for hypothetical scenarios in which whole forests are managed and harvested entirely for bioenergy. As previously explained, such practices do not resemble current actual forestry practices since managing and harvesting forests solely for bioenergy is not economic. However, as traditional forest product markets decline (as is the case for the paper/pulp industry in the SE US) increasing amounts of the material originally destined for such markets has been recently re-directed to the bioenergy sector and may continue to be so. It is therefore instructive to examine (and to calibrate results with those studies making similar assumptions) the implications of such a movement in this direction.

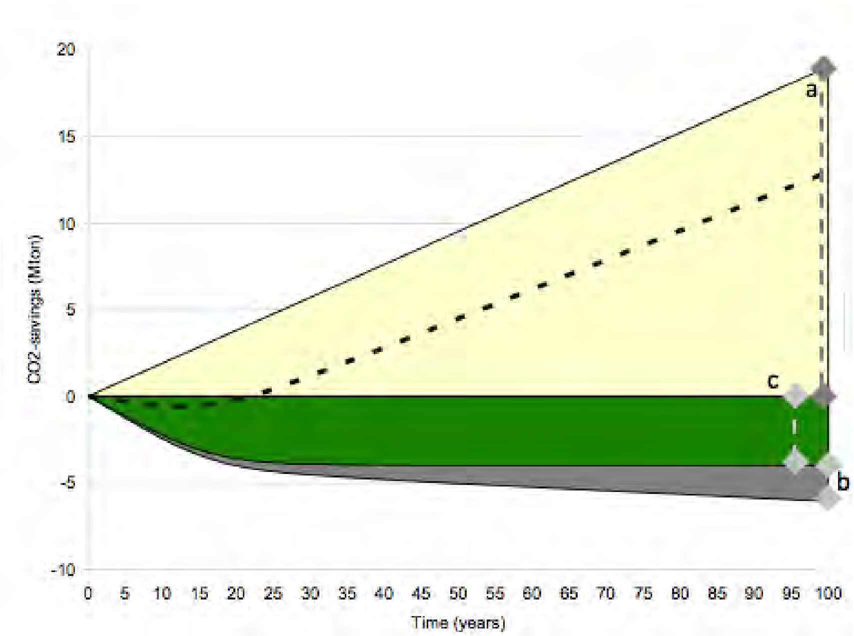
To illustrate that the model used here generates consistent results with existing studies if the same assumptions are made, Figure 10 below shows the results for a scenario in which a Loblolly pine plantation in the SE US is harvested entirely for bioenergy in a 30 year rotation. Under the AFB approach, the assumption is that in the absence of the biomass demand for bioenergy the forest area would not be harvested. Again, as noted in paragraph 5.3.2.7, this is not a realistic assumption, but used to establish consistency with other model results.

The net relative biomass emission savings are equal to the fossil fuel savings corrected for the emissions from transport and processing and the foregone carbon sequestration.

Table 8. Summary of key assumptions for the following scenario: Wood pellets from biomass sourced from forests in the SE US in which the final harvest goes entirely to bioenergy.

Feedstock type	Biomass sourced as primary product (100% harvest output)
Forest type	Managed plantation
Rotation time	30 years
Spatial basis for model	Increasing plot level approach based on production and consumption of 100,000 tons wood pellets per year
Baseline assumption	Anticipated Future Baseline (counterfactual - continued growth of forest - forest not harvested for any purpose)
Region	SE US
Emissions from processing and transport	Industry data cross-referenced with literature
Wood pellet use	Co-firing in EU coal plant with 40% energy efficiency rate

Figure 10. Cumulative CO_2 savings modelled results for a 'theoretical' scenario in which wood pellets are produced from 'dedicated' forest harvest in SE US using an AFB approach with a 'continued growth' counterfactual



Legend

(grey)	Processing and Transport emissions
(green)	Foregone forest carbon sequestration compared to counterfactual
(yellow)	Fossil fuel savings
- - - - -	NET Relative Biomass savings

Source: MWH analysis

In the bioenergy scenario, the forest area is regularly harvested at sustainable levels and forest carbon stocks for the forest area as a whole remain constant over time (growth : drain ratio = 1). In the assumed counterfactual in the AFB approach the forest is assumed not to be harvested and would therefore continue to sequester carbon until it reaches maturity (no natural disturbances, such as fires or pests, have been assumed in this counterfactual). Under these assumptions the eventual carbon stock in the forest would be higher in the counterfactual than in the bioenergy scenario. This is represented by the green area ("c" in Figure 10), the 'foregone sequestration'. This effect initially increases over time as the forest continues to sequester more carbon in the counterfactual, until it reaches maturity and stops sequestering additional carbon. Emissions from processing and transport are again shown in grey ("b" in Figure 10) and the emission savings from replacing coal in yellow ("a" in Figure 10).

In the AFB approach, the GHG emission savings attributable to use of bioenergy are viewed relative to the counterfactual (not harvesting the forest). In this case the bioenergy scenario initially leads to relative GHG emissions compared to the "no-harvest" counterfactual (indicated by the dotted black line). From year 22 onwards harvesting the forest, and using the biomass to replace coal, achieves higher GHG emission savings than leaving the forest untouched: i.e. the carbon parity point is reached after 22 years. After that, the relative emission savings reach 1.2 Mtons after 30 years and 4.5 Mtons CO_2 after 50 years. For longer periods considered the relative emission savings compared to the AFB increase linearly as more coal is displaced. Again, note that the net relative savings achieved over time are much larger than the initial increase in net relative emissions. The fact that the model shows a delay before 'carbon parity' is reached, is due to the choice of counterfactual.

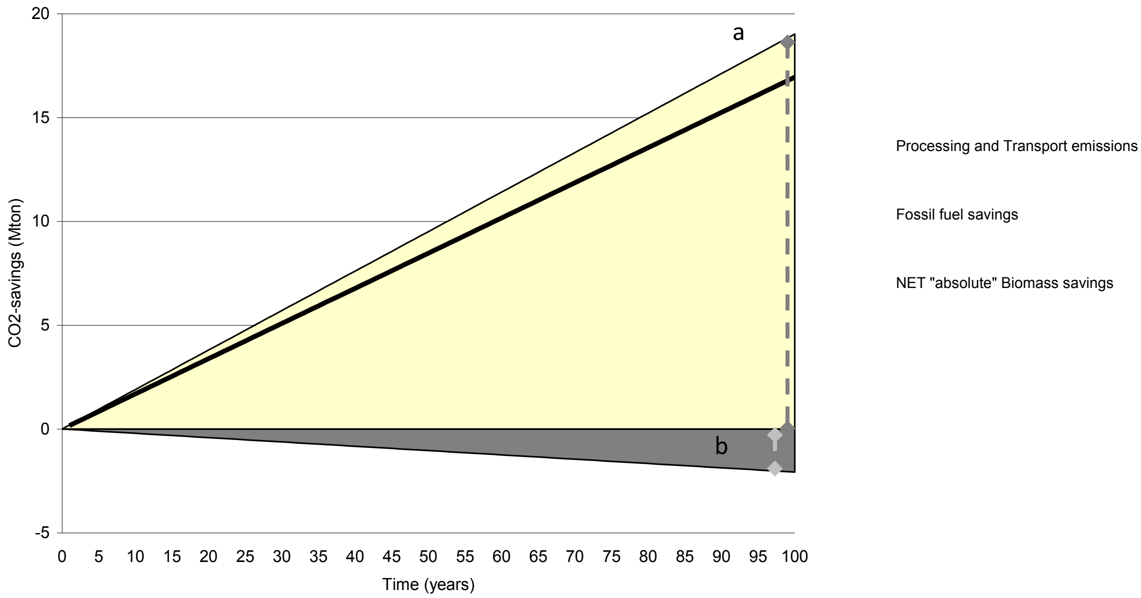
Absolute savings using a RPB approach

Figure 11 below shows the results for this scenario if the RPB approach is used to gain insight in the absolute savings of bioenergy over time. As can be seen from Figure 11, sustainable harvesting of the forest for bioenergy leads to significant absolute savings from the start (indicated by the solid line and determined by the fossil fuel savings corrected for emissions from biomass processing and transport). This can be understood by the fact that forest carbon stocks remain constant over time (the forest continues to be harvested at sustainable levels) while the use of wood pellets directly avoids the burning of coal.

The net absolute biomass emission savings are equal to the fossil fuel savings corrected for the emissions from transport and processing. The results presented here are consistent with the results found by Jonker et al. (2013) who have analysed a similar scenario.

The modelling results show that it is much more effective in the relevant timescale (see section 5.3.2.7) to use these plantations for biomass than to allow the plantations to grow undisturbed further as assumed in the counterfactual. It is also important to note that the assumed counterfactual is not realistic in this situation unless landowners were paid indefinitely not to harvest their plantations. So allowing the plantations to grow undisturbed further is not only a less effective way of reducing GHG emissions, it is also more costly.

Figure 11. Cumulative CO_2 savings for a 'theoretical' scenario in which wood pellets are produced from 'dedicated' forest harvest in SE US using an RPB approach with sustainable harvest levels - modelled results.



Legend

Processing and Transport emissions

Fossil fuel savings

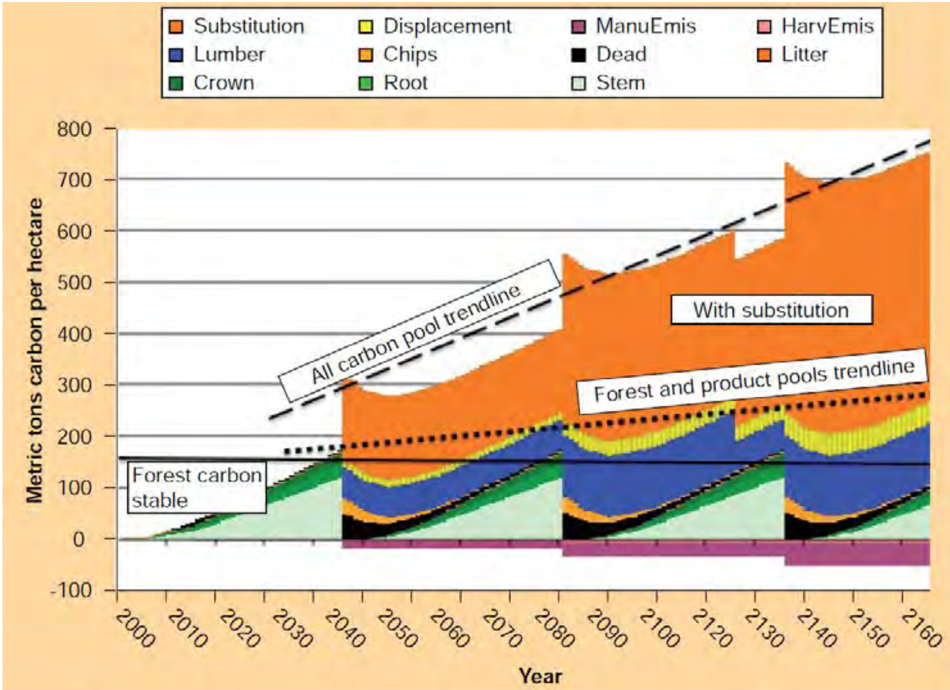
NET Absolute Biomass savings

Source: MWH analysis

6.4 Expansion of forest harvesting areas

One of the main areas of concern about growing demand for biomass for bioenergy is that the demand will lead to an expansion of harvest areas in the US or Canada. As explained in section 3.2, it will not be economic to bring new forest areas under active management just for bioenergy. Moreover, in BC, since by law, cut levels are established independently by the Chief Forester, increased demand for biomass cannot lead to increased forest harvesting. Whilst existing markets for forest products declined in many regions of North America during the period 2007-2011, concerns have also been raised about the expansion of managed forest areas, should demand for other forestry products increase again. Should increasing demand for traditional forest products lead to such an expansion of harvested areas, these areas would be managed for multiple purposes as this yields a significantly higher income than a forest harvested for bioenergy alone (see sections 3.2 and 4.1). A study by Lippke et al. (2010) has analysed the carbon balance of taking a previously unmanaged forest area into production for multiple products. The results are shown in Figure 12.

Figure 12. GHG emission savings resulting from a new forest area being taken into active management to produce a combination of products including biomass for bioenergy.



Source: Lippke et al. 2010.

What can be seen in Figure 12 is that bringing a previously unmanaged forest area under active management for the production of an economic range of products (including durable timber products, paper, and bioenergy) leads to significant GHG savings, both in absolute GHG emissions over time and in relative GHG emissions compared to the situation where the forest is left untouched (the solid line indicates the carbon stock levels if the forest were left untouched). The largest contributor to the GHG emission savings is the substitution of other GHG intensive products with wood products (e.g. building materials and fossil fuel). The exact savings from substituting other products by timber products will depend on the exact products substituted for, which will differ per case. The results in Figure 12 are based on an average carbon savings from substituting non-timber products e.g. coal, steel and concrete.

Again, it is unlikely that an increase in biomass demand for bioenergy purposes will lead to additional forest areas being taken into active management within North America (Mendell and Hamsley 2013). However, even if such an expansion of the managed forest area did occur, and assuming that such expansion occurred in North America, it would be managed for multiple products and functions under a SFM regime. Such a production regime of a combination of timber products, paper products and bioenergy will generate direct and substantial GHG emission savings compared to leaving the forest untouched.

6.5 Key insights regarding modelling

In this section we summarise the key insights from sections 5.3 and 6.1 to 6.4 with regard to:

- Methodological choices in bioenergy carbon analyses
- Scenario choices in bioenergy carbon analyses
- Model Results for realistic scenarios for US and Canadian wood pellets

6.5.1 Methodological choices in bioenergy carbon analyses

The discussion above illustrates the variances in different methodological choices. Among these choices, the discussion underscores the importance of matching the methodological choices (baseline, timescale and landscape) to the case being examined and the purpose of the study being carried out. The main choice is whether to use the RPB (Reference Point Baseline) or AFB (Anticipated Future Baseline) approach.

From the viewpoint of individual projects, forest owners or energy companies, the RPB approach has clear advantages. Applying it to a specific case is relatively simple, concrete and unambiguous.

- simple: using this approach requires only a clear understanding of what actually happens in a given bioenergy scenario (forest - supply chain - power conversion)
- concrete: it provides information on actual (i.e. in principle measurable) emissions and sequestration
- unambiguous: it does not rely on an assumed future baseline or counterfactual (choosing a relevant counterfactual can be difficult and a range of counterfactuals is time-consuming and can lead to ambiguous results).

In addition to the RPB approach, Policy makers may want to consider the AFB approach *for evaluating policy proposals*. For evaluating policy actions, it is normal practice to compare the proposed policy with what would have happened in the absence of the proposed policy (the assumed future baseline or counterfactual). In this situation, the additional complexity and possible ambiguity of comparison with more alternative futures is accepted in order to gain insight. It is concluded that both approaches are useful, and that given the specific circumstances the appropriate method can be chosen.

6.5.2. Scenario choices in bioenergy carbon analyses

The assumptions made for any bioenergy scenario have a very large impact on the timing of GHG emission savings of bioenergy. Studies that find very long carbon payback times are generally based on assumptions that do not match current or expected production and conversion practices. The most important parameters are:

- *The forestry system the biomass is obtained from*. Studies finding long carbon debt repayment times generally assume that forests are managed and harvested purely for bioenergy. In addition, it is thereby often assumed that these forests are slow growing, that they were previously unmanaged and had high original carbon stocks. As explained in sections 5.3.2.5 and 5.3.2.7, this is in sharp contrast with actual wood pellet production today and anticipated production practices for the future: wood pellets are produced from residues and low value products of existing forestry activities in forests that are already being managed for other purposes (sawtimber, pulpwood).

- *Low carbon replacement efficiencies*. Several existing studies assume very low conversion efficiencies and/or unfavourable fuel being replaced. Most industrial wood pellets however have efficient supply chains and are used to directly replace coal achieving very high carbon replacement efficiencies.
- *The assumed counterfactual* (only relevant under the AFB approach): many studies assume a 'continued growth' counterfactual. This is not realistic when evaluating biomass from existing production forests which have been managed for timber and pulp for years. A more appropriate counterfactual should recognise the need of forest owners (especially private owners) to continue to receive economic benefit from the forest.

It is concluded that studies on the GHG benefits of bioenergy must take into account actual production practices, both for the forestry operations and the energy conversion. While several studies usefully show what kind of bioenergy systems would not be beneficial from a climate change mitigation perspective, the GHG performance of such theoretical production systems holds little relevance for the GHG performance of today's real life bioenergy systems.

6.5.3. Modelling results for realistic scenarios for US and Canadian wood pellets

This study involved a temporal carbon analysis of several bioenergy scenarios (using both AFB and RPB approaches) and benefited from direct access to data on actual industry practices. Based on this analysis, the following conclusions can be drawn:

a. Bioenergy using biomass from existing sustainably managed forests (growth : drain ratio equals 1 or higher) realizes absolute GHG savings from year 1 because a) forest carbon stocks are maintained or even increase over time, and b) fossil fuel burning is simultaneously avoided.

It is also possible to look at the relative GHG emission savings compared to an anticipated future baseline scenario without bioenergy (Anticipated Future Baseline Approach). Modelling exercises using this methodology show that bioenergy from existing sustainably managed forests can initially lead to a small increase in emissions compared to an anticipated future baseline without harvesting for bioenergy due to a decline in the amount of carbon stored in forest litter. After this initial phase bioenergy leads to large relative GHG emission savings compared to the baseline scenario. In the SE US, the time to carbon parity is short (3 years) when residues are used.

As noted earlier, it is possible to craft a scenario wherein long time periods to carbon parity are required. Calculations using the AFB approach show that in a scenario in which a 30 year rotation forest in the SE US were harvested entirely for bioenergy, It would take approximately 22 years before the carbon parity point were reached , but only if a completely inappropriate "no harvest" counterfactual were applied. It should be noted that management of forests strictly for bioenergy is not expected to play a role in actual pellet production for the foreseeable future.

b. While today's biomass for pellets originate from forests that are already being managed for other purposes (saw timber, pulpwood), some parties have expressed concerns that the increase in biomass demand for bioenergy could lead to new forest areas being taken into active management and that this could lead to significant increases in GHG emissions for substantial periods of time. However, this is unlikely to materialize as managing and harvesting new forest areas in the USA or Canada for bioenergy alone, is simply uneconomic (see sections 3.2 and 4.1 for details). If new forest areas were to be taken into production in the US or Canada, such an expansion would be driven by the demand for higher value products such as saw timber and pulp. Such forests would be managed for multiple products, not only and not even primarily for bioenergy. This would lead to very large GHG emission savings due to the combined effects of bioenergy, and increased production of durable timber products that form durable carbon stocks and replace GHG intensive alternatives such as concrete or steel. Moreover, in BC, since allowable cut levels are set independently by the Chief Forester, increased demand for bioenergy cannot lead to increased harvesting.

Overall we conclude that today's dominant bioenergy systems, in which wood pellets from Canada and the SE US achieve significant GHG savings, make a meaningful contribution to climate change mitigation. Carbon debt and foregone sequestration in realistic bioenergy scenarios are very small compared to the carbon savings that are achieved over time. Last but not least it should be noted that there is a critical difference between a small and temporary "carbon debt", when one might exist, and the permanent fossil fuel carbon emissions savings achieved by use of bioenergy rather than fossil fuel.

7. Summary

The SE US and BC are viewed within the EU as important sources of biomass fuel pellets needed to fulfil near and mid-term renewable energy targets. As both of these regions produce fuel pellets from woody biomass, there is concern that rising exports to the EU may inadvertently increase levels of atmospheric carbon in the near term and threaten long-term forest sustainability in North America.

Examination of biomass availability and regulatory frameworks governing forest harvest in the two North American regions of interest shows great potential for increased extraction of woody biomass, as well as long-established histories of responsible forestry and government oversight of forest management and harvest.

In both the SE US and BC there are massive quantities of biomass available for use in bioenergy production. For the US as a whole, the government estimates forest biomass availability at 83 to 102 million dry tons in 2030, with the vast majority of this projected volume in the SE region. In BC, large volumes of mill residue that until very recently were burnt as waste are available for use, as are vast volumes of logging residues that are commonly disposed of by piling and burning annually each fall. Bioenergy production offers an immediate opportunity to stem this wasteful practice and reduce emissions to the atmosphere.

In both regions, forestry is strictly regulated by laws that ensure the responsible harvesting and restoration of harvested sites. Forest landowners and forest products companies must comply with multiple laws and regulations promulgated by various levels of government in conducting harvest operations and silvicultural activities. Also, there is a strong involvement in the development of voluntary SFM certification programs.

Both regions have highly integrated and robust forest industries in which free market forces dictate a multiple product approach to raw material allocation. Therefore, markets for more valuable products, such as lumber and plywood, are most able to compete for raw materials; fuel pellets are at the other end of the economic scale and consequently rely on low value forms of wood as production inputs. The use of high value forestry products in the bioenergy industry is economically unlikely and there is little to no prospect of such activity becoming mainstream. Rather than being the main driver of the forest management choice and creating new commercial demand for limited forest resources, the wood energy market can lead to healthier and better managed forests, higher land values, and greater baseline carbon sequestration on the land.

A review of literature and modelling of the carbon implications of biomass imports for EU bioenergy production formed much of the basis for this report. Findings reveal that assumptions and methodological choices employed in modelling forest carbon dynamics play a significant role in determining study outcomes. Methodological choices (baseline, spatial considerations and temporal consideration) and scenario assumptions (biomass origin, fossil fuel and efficiency comparators and counterfactual) are vitally important to realistic and accurate results. Findings also point to fundamental flaws in key assumptions and methodology that underlie prominent studies that have found forest-based bioenergy to be associated with carbon deficits and long carbon repayment periods. Specifically, results as mentioned above are generally based on modelling assumptions which do not correspond with current and expected production and are therefore not representative for actual bioenergy practices. These problems notwithstanding, it is important to note that several of the studies that have been widely reported to have determined the existence of carbon deficits acknowledge immediate to near-term carbon benefits to use of wood residues and logging wastes in energy generation.

A central finding of this study is that when realistic assumptions are applied, production of energy from woody biomass results in carbon debt and foregone sequestration that are very small compared to the substantial carbon savings that are achieved over time. Further, there is a critical difference between a small and temporary "carbon debt," when one might exist, and the permanent fossil carbon emissions savings achieved by use of bioenergy rather than fossil fuels.

8. References

Abt, R.C., and Abt, K.L. 2013. Potential impact of bioenergy demand on the sustainability of the southern forest resource. Journal of Sustainable Forestry 32(1-2):175-194. (http://www.srs.fs.fed.us/pubs/ja/2013/ja_2013_abt_001.pdf)

Adams, D.M., Haynes, R.W., and Daigneault, A.J. 2006. Estimated Timber Harvest by U.S. Region and Ownership, 1950-2002. U.S. Dept of Agriculture, Forest Service, Washington, D.C. General Technical Report PNW-GTR-659, pp. 11-15. (http://www.fs.fed.us/pnw/pubs/pnw_gtr659.pdf)

AEBIOM (European Biomass Association). 2013. AEBIOM and EURELECTRIC call for EU wide binding sustainability criteria for biomass now! Press release 13/03/13. (http://www.eurelectric.org/media/76410/AEBIOM%20Eurelectric%20press%20release%20FINAL.pdf)

Adams, D. and G. Latta. 2005. Timber harvest potential from private lands in the Pacific Northwest: biological, investment, and policy issues. *Understanding key issues of sustainable wood production in the Pacific Northwest*, Gen. Tech. Rep. PNW-GTR-626. Deal, R. L.; White, S. M (eds), pp 4-12. (http://www.fs.fed.us/pnw/pubs/pnw_gtr626.pdf)

Agostini, A., Giuntoli, J., and Boulamanti, L. 2013. Carbon Accounting of Forest Bioenergy – Conclusions and Recommendations from a Critical Literature Review. European Commission, Joint Research Centre (JRC) Report EUR 25354 EN. (http://iet.jrc.ec.europa.eu/bf-ca/sites/bf-ca/files/files/documents/eur25354en_online-final.pdf)

Alakangas, E., Junginger, M., Van Dam, J., Hinge, J., Keränen, J., Olsson, O., Porsö, C. Martikainen, A., Rathbauer, J., Sulzbacher, L., Vesterinen, P., and Vinterbäck, J. 2012. EUBIONET III – Solutions to biomass trade and market barriers. Renewable and Sustainable Energy Reviews 16 (6): 4277-4290. doi: 10. 1016/J.rser.2012.03.051. (http://www.sciencedirect.com/science/article/pii/S1364032112002341)

Allen, H., Fox, T., and Campbell, R. 2005. What's ahead for intensive pine plantation silviculture? Southern Journal of Applied Forestry 29:62-69.

Alvarez, M. 2007. The State of America's Forests. Bethesda, MD: Society of American Foresters. (http://www.safnet.org/publications/americanforests/StateOfAmericasForests.pdf)

Arano, K. and Munn, I. 2006. Evaluating forest management intensity: A comparison among major forest landowner types. Forest Policy and Economics, 9(3): 237-248.

Atanasiu, B. 2010. The Role of Bioenergy in the National Renewable Energy Action Plans: A First Identification of Issues and Uncertainties. Intelligent Energy Europe/Institute for European Environmental Policy.

(http://www.biomassfutures.eu/work_packages/final_deliverables/WP8/D8.4%20bioenergy_in_NREAPs.pdf)

B.C. Ministry of Forests, Lands and Natural Resource Operations. 2004. Forest and Range Practices Act. (http://www.for.gov.bc.ca/tasb/legsregs/frpa/frparegs/)

____. 2010. State of British Columbia's Forests – Third edition. (http://www.for.gov.bc.ca/hfp/sof/2010/SOF_2010_Web.pdf)

B.C. Ministry of Forests. Land and Natural Resource Operations. 2012. (http://www.for.gov.bc.ca/hth/timber-tenures/provincial-map.htm; (http://www.for.gov.bc.ca/ftp/HTH/external/!publish/web/timber-tenures/tfl-regions-tsas-districts-map-350-dpi-sep-13-2012.pdf)

B.C., Provincial Government. 2005. Wildfire Regulation. B.C. Reg. 38/2005. (http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/11_38_2005)

Bergsma G. C., Croezen H. J., Otten M. B. J. and van Valkengoed M.P.J. 2010. Biofuels: indirect land use change and climate impact. Delft, CE Delft. (http://www.birdlife.org/eu/EU_policy/Biofuels/carbon_bomb.html)

Bird N., Pena N. & Zanchi J. 2010. The upfront carbon debt of bioenergy. Graz, Joanneum Research. (http://www.birdlife.org/eu/EU_policy/Biofuels/carbon_bomb.html)

Böttcher, S., Frank, S., and Havlik, P. 2011. Biomass availability & supply analysis - Review and assessment of existing biomass potentials. BiomassFutures. [Online] December 2011. [Citaat van: 23 January 2013.] (http://www.biomassfutures.eu/public_docs/final_deliverables/WP3/D3.4%20Biomass%20availability%20&%20supply.pdf)

Bowen A. and Ranger N. 2009. Mitigating climate change through reductions in greenhouse gas emissions: The science and economics of future paths for global annual emissions. Grantham Research Institute on Climate Change and the Environment and the Centre for Climate Change Economics and Policy, Policy Brief. London. (http://www.cccep.ac.uk/Publications/Policy/Policy-docs/bowen-Ranger_MitigatingClimateChange_Dec09.pdf)

Bowyer, J., Bratkovich, S., and Fernholz, K. 2012. Utilization of Harvested Wood by the North American Forest Products Industry. Dovetail Partners, Inc. October 8. (http://dovetailinc.org/files/DovetailWoodUtilization1012.pdf)

Bowyer, J., Howe, J., Stai, S., Trusty, W., Bratkovich, S., and Fernholz, K. 2012. Carbon 101: The International Green Construction Code: Implications for Materials Selection in Commercial Construction. Dovetail Partners, Inc. May 8. (http://dovetailinc.org/files/DovetailIGCC0512.pdf)

Cowie, A., Berndes, G., Bird, N., and Smith, T. 2013. On the Timing of Greenhouse Gas Mitigation Benefits of Forest-Based Bioenergy. IEA-ExCo 71, Capetown, South Africa, 21-23 May, Doc. 14.01.

Dehue B. 2013. Implications of a 'carbon debt' on bioenergy's potential to mitigate climate change. Biofuels, Bioproducts and Biorefining 7(3): 228–234.

Dymond, C. and Spittlehouse, D. 2009. Forests in a carbon-constrained world. B.C. Ministry of Forests, For. Sci. Prog., Extension Note 92. (http://www.for.gov.bc.ca/hfd/pubs/Docs/En/En92.htm)

Dymond, C.C., Titus, B.D., Stinson, G., and Kurz, W.A. 2010. Future quantities and spatial distribution of harvesting residue and dead wood from natural disturbances in Canada. Forest Ecology and Management 260(2): 181-192. (http://cfs.nrcan.gc.ca/publications/?id=31768)

Eby M., Z ickfeld K., Montenegro A., Archer D., Meissner, K. and Weaver A. 2009. Lifetime of Anthropogenic climate change: Millennial time scales of potential CO_2 and surface temperature perturbations. J Climate 22(10): 2501–2511. (http://journals.ametsoc.org/doi/full/10.1175/2008JCLI2554.1)

European Commission. 2008. The 2° C Target: Information Reference Document. (http://ec.europa.eu/clima/policies/international/negotiations/future/docs/brochure_2c_en.pdf)

European Commission. 2010. Report from the Commission to the Council and the European Parliament on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling. COM (2010)11 final. (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0011:FIN:EN:PDF)

European Commission. 2011a. Energy Roadmap 2050. Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions. COM(2011)885(http://ec.europa.eu/energy/energy2020/roadmap/index_en.htm)

European Commission. 2011b. A Roadmap for moving to a competitive low carbon economy in 2050. Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions. SEC (2011) 287-289 Final. (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0112:FIN:EN:PDF)

EU. 2009. EC Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=Oj:L:2009:140:0016:0062:en:PDF)

EU BioNet. 2012. Solutions for biomass fuel market barriers and raw material availability. (http://www.eubionet.org)

European Environment Agency (EEA). 2006. How much bioenergy can Europe produce without harming the environment? EEA report 7/2006. (http://www.eea.europa.eu/publications/eea_report_2006_7)

European Environment Agency (EEA). 2013. Bioenergy production must use resources more efficiently (http://www.eea.europa.eu/pressroom/newsreleases/bioenergy-production-must-use-resources)

Fernholz, K., Howe, J., Bowyer, J., Bratkovich, S., Frank, M., Zoet, A., and Stai, S. 2013. The Next 100-Years of Forests in the U.S. – Growing the Forests We Want and Need. Dovetail Partners, Inc., March 18. (http://www.dovetailinc.org/files/DovetailUSForests0313.pdf)

Fox T., Jokela E., Allen H. 2007. The development of pine plantation silviculture in the southern United States. Journal of Forestry 105 (5): 337-347. (http://rothforestry.com/Resources/Fox%20et%20al.%202007.pdf)

Hansen J., Nazarenko L., Ruedy R., Sato M., Willis J. and Genio, A.D. 2005. Earth's energy imbalance: Confirmation and implications. Science 308:1431–1435. (http://www.columbia.edu/~jeh1/mailings/2011/20110415_EnergyImbalancePaper.pdf)

Haynes, R.W., D.M. Adams, R.J. Alig, P.J. Ince, J.R. Mills, and X. Zhou. 2007. *The 2005 RPA timber assessment update*. Gen. Tech. Rep. U.S. Dept. of Agriculture, Forest Service. General Technical Report PNW-GTR-699. (http://www.fs.fed.us/pnw/publications/gtr699)

International Energy Agency. 2012. Technology Roadmap - Bioenergy for Heat and Power. (http://www.iea.org/publications/freepublications/publication/bioenergy.pdf)

IPCC. 2007. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., and Meyer, L.A. (eds). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. (http://www.ipcc.ch/publications_and_data/ar4/wg3/en/contents.html)

IPCC. 2011. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp. (http://srren.ipcc-wg3.de/report)

Jonker, J.G.G., Junginger, H.M., and Faaij, A. 2013. Carbon payback period and carbon offset parity point of wood pellet production in the South-eastern USA. GCB Bioenergy. Article first published online: 11 APR 2013, DOI: 10.1111/gcbb.12056.

Lamers, P., Junginger, H.M., Dymond, C.C., and Faaij, A. 2013. Damaged forests provide an opportunity to mitigate climate change. GCB Bioenergy, Article first published online: 3 APR 2013, DOI: 10.1111/gcbb.12055.

Lippke, B. Wilson J. Meil J. Taylor A. 2010. Characterizing the Importance of Carbon Stored in Wood Products. Wood and Fiber Science 42(CORRIM Special Issue) p. 12, Figure 6.

Lowe, L., Brogan, S., McClure, N., Nowak, J., Oates, B., Preston, D., and Tucker, W. 2011. Forest Certification Programs: Status and Recommendations in the South. Southern Group of State Foresters.
(http://www.southernforests.org/publications/SGSF%20Forest%20Certification%20Report%20r1.pdf)

Lucier, A. and Miner, R. 2010 Biomass Carbon Neutrality in the Context of Forest-Based Fuels and Products. (www.eforester.org/fp/al_lucier.ppt)

Manomet Center for Conservation Sciences. 2010. Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources. Walker, T. (Ed.). Contributors: Cardellichio, P., Colnes, A., Gunn, J., Kittler, B., Perschel, R., Recchia, C., Saah, D., and Walker, T. Natural Capital Initiative Report NCI-2010-03. Brunswick, Maine.
(http://www.manomet.org/sites/manomet.org/files/Manomet_Biomass_Report_Full_LoRez.pdf)

Matthews, R., Mortimer, N., Mackie, E., Hatto, C., Evans, A., Mwabonje, O., Randle, T., Rolls, W., Sayce, M., and Tubby, I. 2012. Carbon Impacts of Using Biomass in Bioenergy and Other Sectors: Forests. DECC Project TRN 242/08/2011, Final Report.
(https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48346/5133-carbon-impacts-of-using-biomanss-and-other-sectors.pdf)

McKenchnie, J., Colombo, S., Chen, J., Mabee, W., and Maclean, H. 2011. Forest bioenergy or forest carbon? Assessing trade-offs in greenhouse gas mitigation with woodland fuels. Environmental Science & Technology 45: 789-795.

Mendell, G. and Hamsley, A. 2013. Update and Context for U.S. Wood Bioenergy Markets. National Association of Forest Owners/Forisk Consulting. (http://nafoalliance.org/wp-content/uploads/NAFO-US_Bioenergy_Markets-FINAL-201306261.pdf)

Mendell, B., Hamsley, A., Sydor, T., and Freeman, L. 2010. Availability and Sustainability of Wood Resources for Energy Generation in the United States. American Forest and Paper Association/Forisk

Consulting.
(http://driveonwood.com/sites/default/files/pdf/Forisk_Forest_Resource_Study_July_2010.pdf)

Mitchell, S.R., Harmon, M.E., and O'Connell, K.E.B. 2012. Carbon debt and carbon sequestration parity in forest bioenergy production. GCB Bioenergy 4(6): 818–827.
(http://onlinelibrary.wiley.com/doi/10.1111/j.1757-1707.2012.01173.x/abstract)

Munsell, J. F. and Fox, T. R. 2010. An analysis of the feasibility for increasing woody biomass production from pine plantations in the southern United States. Biomass and Bioenergy 34: 1631 – 1642.

Naturally Wood. 2011. British Columbia Forest Facts.
(http://www.naturallywood.com/sites/default/files/Sustainable-Forest-Management.pdf)

Pulp and Paperworkers Resource Council. 2011. Mill Curtailments and Closures Map - 1991-2011. (http://www.pprc.info/html/millclosures.htm)

Pryke, D. 2008. Perspectives on the Pulp and Paper Industry. Alliance for Environmental Technology. (http://www.documents.dgs.ca.gov/pd/epp/PaperForum/PulpandPaper.pdf)

Rettenmaier, N., Schorb, A., Köppen, S., and others. 2010. Status of Biomass Resource Assessments, Version 3. Biomass Energy Europe (BEE). International Institute for Applied Systems Analysis (IIASA).
(http://www.eu-bee.com/default.asp?SivuID=24158)

RISI. 2012. Global Pulpwood Markets continued shift toward developing regions expected to keep prices down. PR Newswire, Oct. 12.
http://www.prnewswire.com/news-releases/global-pulpwood-markets-continued-shift-toward-developing-regions-expected-to-keep-prices-down-173895351.html

RSPB/Friends of the Earth/Greenpeace. 2012. Dirtier than Coal – Why Government Plans to Subsidise Burning trees are Bad News for the Planet. (http://www.rspb.org.uk/Images/biomass_report_tcm9-326672.pdf)

Searchinger, T.D., Hamburg, S.P., Melillo, J., Chameides, W., Havlik, P., Kammen, D.M., Likens, G.E., Lubowski, R.N., Obersteiner, M., Oppenheimer, M., Robertson, G.P., Schlesinger, W.H., and Tilman, G.D. 2009. Fixing a Critical Climate Accounting Error. Science 326 (5952): 527-528.

Slade, R., Saunders, R., Gross, R., and Bauen, A. 2011. Energy from Biomass: The Size of the Global Resource. Imperial College Centre for Energy Policy and Technology and UK Energy Research Centre, London. (http://downloads.theccc.org.uk.s3.amazonaws.com/Bioenergy/BiomassReport_FINAL.pdf)

Smeets, E.M.W., Faaij, A.P.C., Lewandowski, I.M. and Turkenburg, W.C. 2007. A bottom-up assessment and review of global bio-energy potentials to 2050. Progress in Energy and Combustion Science 33(1): 56-106. (http://www.bioenergytrade.org/reports/archive/fairbiotradeproject20012004/quickscan-global-bio-energy-potentials-to-2050.html)

Smith, W.B., Miles, P.D., Perry, C.H., and Pugh, S.A. 2009. Forest Resources of the United States, 2007. USDA-Forest Service, General Technical Report WO-78.
(http://www.fs.fed.us/nrs/pubs/gtr/gtr_wo78.pdf)

Solomona S., Plattnerb G., Knuttic R. and Friedlingsteind, P. 2009. Irreversible climate change due to carbon dioxide emissions. Proceedings National Academy of Sciences 106 (6): 1704–1709. (http://www.pnas.org/content/early/2009/01/28/0812721106.full.pdf+html)

Timber Mart-South. 2013. Southeastern timber market news and price reports. Center for Forest Business, Warnell School of Forest Resources, University of Georgia, Athens, GA. (http://www.timbermart-south.com)

U.S. Forest Service. 2009. US Forest Resource Facts and Historical Trends. U.S. Dept. of Agriculture, Forest Service, Washington, D.C. (http://www.fia.fs.fed.us/library/briefings-summaries-overviews/docs/ForestFactsMetric.pdf)

U.S. Forest Service. 2012. *Future of America's forest and rangelands*: Forest Service 2010 Resources Planning Act Assessment. Gen. Tech. Rep. WO-87. U.S. Dept. of Agriculture, Forest Service, Washington, DC. Washington, DC. 197 p. http://www.fs.fed.us/research/publications/gtr/gtr_wo87.pdf; last accessed April 17, 2013.

U.S. Department of Energy. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. (http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf)

US Environmental Protection Agency (USEPA). 2012. Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2011. Washington, DC: US Environmental Protection Agency, Section 7, Table 7.7, p.7-17. (http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html))

Wear, D.N. and Greis, J.G. 2012. The Southern Forest Futures Project: Summary Report. U.S. Dept. of Agriculture, Forest Service, Southern Research Station. General Technical Report SRS-168. (http://www.srs.fs.fed.us/pubs/gtr/gtr_srs168.pdf)

Wood Pellet Association of Canada. 2013. Potential to use forest residues to grow the wood pellet industry in British Columbia. Personal communication, May 8.

Woodworth, E. 2012. Inherent Sustainability & Carbon Benefits of the US Wood Pellet Industry. Enviva LP. (http://www.envivabiomass.com/wp-content/uploads/inherent-sustainability-carbon-benefits-20121005.pdf)

Zanchi G., Pena N., Bird N. 2010. The Upfront Carbon Debt of Bio-energy. Joanneum Research. (http://www.birdlife.org/eu/pdfs/Bioenergy_Joanneum_Research.pdf

Appendices

Appendix 1: US forestry regulatory and non-regulatory framework

The Clean Water Act

The Environmental Protection Agency. (2011). Clean Water Act. Retrieved from http://cfpub.epa.gov/npdes/cwa.cfm?program_id=45

The Clean Water Act is arguably the federal law of predominant relevance and application when it comes to environmental concerns in forestry. Since forestry operations generally involve the construction of access roads and water crossings, as well as the disturbance or removal of trees and plants that would otherwise tend to control erosion, most of the environmental concerns related to forestry operations involve the protection of water quality and aquatic habitat. Forestry operations can also involve the disturbance of plant litter and soil, the application of herbicides and fertilizers, equipment lubrication and refueling.

Under the Clean Water Act, "point sources" such as industrial facilities and wastewater treatment plants with effluents that can be directly monitored at known outfalls are regulated with a permit system based on technology-based effluent limitations. Conversely, "non-point sources" such as runoff from forests and farms cannot be so easily monitored, measured or regulated. This is particularly true with forestry, since forestry activities generally involve numerous relatively small operations occurring sporadically over large amounts of space and long periods of time, often by different landowners operating independently of one another.

Complicating the situation is the fact that different forests, even those in close proximity with one another, may have vastly different characteristics in terms of topography, tree species, soil types, wildlife habitat, geology and hydrology. Consequently, the approach to protecting the environment from forestry activities must be adapted to local conditions and circumstances. Efforts to control non-point source pollution from forest operations have been extremely successful in the US. National Water Quality Inventories conducted by the Environmental Protection Agency now contend that "the most significant source of water quality impairment to rivers and streams and lakes, ponds, and reservoirs is agriculture, and the most significant source of impairment to estuaries is municipal point sources of pollution." Other significant sources include urban runoff, storm sewer discharges, and pollutants deposited from the atmosphere.

Although forestry operations create fewer water quality impacts than agricultural operations, urban runoff and storm water, sewage plants and natural sources, major hydrologic events such as 100 year storms can nevertheless result in significant releases of sediments when sound forest management practices have not been employed. Although forest watershed protection efforts began on an ad hoc basis in the early half of the 20th Century, Section 208 of the Clean Water Act, adopted in 1972, directed states to develop watershed or regional water quality management plans to identify significant non-point sources and assess their cumulative effects, and to "set forth procedures and methods (including land use requirements) to control to the extent feasible such sources." Forest management in wetlands is regulated separately under section 404 of the Clean Water Act, which prohibits the elimination of wetlands as a result of forestry and requires specific practices and permitting for road construction through wetlands.

In 1987, the Clean Water Act was amended to include, among other provisions, Section 319, requiring states to develop control plans for any non-point source activities that were causing state waters to fall short of water quality goals. Taken together, sections 218 and 319 comprise the authority for States to control non-point source pollution, with oversight by EPA. To control non-point source pollution from forestry operations, most states have adopted Best Management Practices (BMPs) designed to take regional climate, soils, topography, biota, legal, technical and socioeconomic factors into account.

BMPs vary widely among jurisdictions, which is understandable since a BMP that is appropriate for a coastal plain pine forest in Georgia may be wholly inadequate for a mountainous temperate rainforest in Oregon. In spite of their variations, there are aspects common to most BMPs across jurisdictions. The general philosophy of BMPs is to “avoid, minimize, and mitigate.” More specifically, BMPs will generally strive to 1) minimize soil compaction and the extent of bare soils; 2) separate exposed soils from surface waters; 3) separate fertilizer and herbicide applications from surface waters; 4) inhibit hydraulic connections between bare ground and surface waters; 5) provide forested buffers to protect watercourses and wetlands; and 6) promote stable roads and watercourse crossings.

Different states manage BMPs in different ways. Some states employ mandatory BMPs administered by State Foresters under a focused state forest practices act. Other states employ non-regulatory BMPs developed or approved by state agencies, with landowner education to encourage compliance, and authority for agencies to take action against landowners who do not comply. Regardless of the approach, BMPs and the broader non-point source pollution prevention programs implemented by the states are subject to EPA oversight and approval. States whose water quality inventories fail to show continued improvement invite closer scrutiny and review by the EPA, and poor performance can result in grant funding reductions or a federal takeover of the state program. Over time, BMPs have become an accepted, well understood, widely adopted method of protecting water quality in the waters of the United States.

BMPs have become, therefore, effective tools to advance the goals of the Federal Clean Water Act. As a consequence of this success, BMPs are increasingly being used to address ancillary issues such as wildlife habitat and other issues, some of which fall under the cognizance of other federal laws.

The Endangered Species Act

The US Fish and Wildlife Service. (2012). Endangered Species Act. Retrieved from http://www.fws.gov/endangered/laws-policies/index.html.

The Endangered Species Act (ESA) applies to private forestry operations as a direct federal regulatory program which relies mainly on prohibitions against the “taking” of listed threatened or endangered plant and animal species. About 1,320 species in the United States and US waters have been listed as threatened or endangered, many of which spend at least part of their life cycle in forests or waters affected by forestry activities.

Although the ESA does not enlist the support of States or state programs in ways comparable to other federal environmental laws, States and localities have amended their laws, regulations, land use plans, policies and BMPs to help protect ESA-listed species and their habitats. In addition, some private landholders have entered into habitat conservation plans (HCPs) designed to improve habitat for listed species. Still other private landholders have been encouraged by the ESA to engage in land sales and exchanges to bring important habitat into conservation easements, non-profit ownership, or public ownership.

The Clean Air Act

The Environmental Protection Agency. (2012). Clean Air Act. Retrieved from http://www.epa.gov/air/caa/.

The Clean Air Act directs the Environmental Protection Agency to establish air quality standards protective of public health and welfare. States, in turn, develop plans and programs to achieve those standards. The direct impact of these plans and programs on forest management activities is to limit slash burning and prescribed fires. Indirect impacts include the demand for fuel wood in homes and other facilities. Finally, the motor vehicles and equipment used in forestry must be compliant with all applicable air quality standards.

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)

The Environmental Protection Agency. (2012). Federal Insecticide, Fungicide and Rodenticide Act. Retrieved from http://www.epa.gov/oecaagct/lfra.html.

The Federal Insecticide, Fungicide and Rodenticide Act, or FIFRA, establishes comprehensive programs regulating use of pesticides in forestry, agriculture and other situations. Under its provisions, pesticide compounds must be "registered" with (approved by) EPA for specific purposes and used only in accordance with EPA-approved "label" instructions designed to protect environmental resources. Pesticides which could pose environmental or health hazards if improperly handled or used by untrained people are restricted so they can be purchased and applied only by applicators trained and licensed by state agencies under EPA-approved programs.

Although FIFRA is applicable to private forest lands, the forestry market for pesticides is relatively small compared to agricultural and urban markets. Because trees grow for long periods compared to food and forage crops, forest-use pesticides usually are applied on particular lands only rarely (e.g. when establishing new plantations or responding to rare pest infestations), in contrast to agriculture, urban lawns, golf courses and other areas where the same chemicals are applied more often. It is not surprising, therefore, that environmental damage from forest-use pesticides has not been documented in the legal or scientific literature as a significant problem.

Coastal Zone Management Act

US Department of Commerce, National Oceanic and Atmospheric Administration (2012). Coastal Zone Management Act. Retrieved from http://coastalmanagement.noaa.gov/czm/czm_act.html

Unlike the Clean Water Act, Endangered Species Act, Clean Air Act, and Federal Insecticide, Fungicide and Rodenticide Act, the Coastal Zone Management Act directly addresses broader land use issues rather than narrower environmental concerns. Twenty-nine states bordering on the West, East and Gulf Coasts, Pacific Ocean or Great Lakes participate in voluntary federal- state partnerships under the CZMA, including most major private timber producing states. These CZMA programs are developed with technical assistance and funding from, and then subject to approval of, the National Oceanographic and Atmospheric Administration (NOAA) through its Office of Ocean and Coastal Resource Management (OCRM). They address a wide range of issues including coastal development, water quality, shoreline erosion, public access, natural resource protection, energy facility siting, and coastal hazards such as hurricanes and flooding. Other states also address these issues through land use planning laws, local zoning ordinances, etc.

An important component of CZMA programs is the Coastal Nonpoint Pollution Control Program under which states and territories with approved coastal zone management programs must develop and implement programs to control nonpoint source pollution from six main sources including forestry and losses of wetland and riparian areas. Understandably, there are considerable variations among the states on how forestry issues are addressed in CZMA programs, reflecting differences in state constitutions, agency roles, court decisions, political and economic factors and environmental conditions.

State forestry and land use programs

States have adopted a wide variety of regulatory and non-regulatory programs addressing forest-related environmental and land use issues. Generally these are incorporated into federally approved programs under the federal statutes listed above, but many deal with other forestry issues as well. All 50 states have a State Forester, who is responsible for administering forestry programs and coordinating regulatory and non-regulatory programs administered by his department and other agencies. Some states have forest practices acts regulating all or most forest management activities. Some require reforestation after timber harvests. Some require local government approval to convert forestlands to non-forest uses. Some provide various kinds of tax incentives to encourage forest owners to keep their lands in forests. All states provide landowner education and technical assistance delivered by State Foresters, land grant colleges and universities, and other institutions, often with federal funding through the by US Forest Service state and private forestry programs and Natural Resources Conservation Service extension service programs.

Voluntary cooperative activities

In addition to the regulatory and non-regulatory approaches listed above, some innovative cooperative projects between private landowners, states, and private foundations have resulted in the protection of critically important natural ecosystems and the interests of private landowners and other stakeholders. Here are a few recent notable examples:

• In 2007, the Nature Conservancy, the Lyme Timber Company, Conservation Forestry LLC and the State of Tennessee completed the largest conservation transaction in Tennessee since the creation of the Great Smoky Mountains National Park in the 1930s, protecting nearly 130,000 acres of hardwood forests, mountains and streams on the Cumberland Plateau, through a combination of working forest agreements, conservation easements, and land purchases.

• In 2008, Plum Creek Timber Company and King County, Washington entered into an agreement to protect the Green River Watershed by granting the county a conservation easement at no cost to the taxpayer, in exchange for Development Credits that allowed for increased development density in urban areas.

• In 2007, Forest Capital Partners signed an agreement with the Minnesota Department of Natural Resources that will restrict development on more than 51,000 acres of their privately owned forestland in Itasca and Koochiching counties in Minnesota. State and private money was used to purchase a working forest conservation easement from Forest Capital Partners, the largest single transaction for conservation in three decades in Minnesota. The terms of the conservation easement, which is in perpetuity, guarantees public access for outdoor recreation, ensures sustainable forest management, and conserves wildlife habitat.

• In 2001, the Pingree family forest ownership in Maine, in partnership with the New England Forestry Foundation, created the world's largest conservation easement (764,000 acres) designed to maintain this land in an undeveloped condition while promoting continued use of the acreage as a working forest.

These kinds of creative arrangements—employed alongside the methods already available to the federal, state and local governments to regulate, manage, or influence activities on private forests through direct regulation, regulatory and non-regulatory BMPs, land use planning, and incentive arrangements—constitute a rich set of tools that are used to ensure that US forests remain sustainable.

Appendix 2: Canadian forestry regulatory and non-regulatory framework

Canada has taken a significantly different path to forestry ownership and management than that of the US Fundamentally this difference rests in the fact that 93% of Canada's forests are publicly owned (versus only 43% in the US), with the 10 provinces and 3 territories holding jurisdiction over 77% of the forestland. This affects the development, implementation, and enforcement of public forest policies in Canada.

Canada oversees its forest management through three basic activities:

- Laws & regulations
- Management plans (through tenure arrangements)
- Monitoring and enforcement

Laws & regulations

In 1992 Canada adopted five international agreements that affect federal policies in regard to forestry[22]:

- Rio Declaration on Environment and Development is a global partnership designed to foster cooperation among states and protect the integrity of the global environment and "development system."
- Agenda 21 is a plan adopted at the United Nations Conference on Environment and Development in 1992. It primarily addresses conservation of forest biodiversity. It calls for combating deforestation by ensuring that the multiple roles and functions of all types of forests, forest lands and woodlands are sustained
- Convention on Biological Diversity has three main goals: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits from the use of genetic resources
- The United Nations Framework Convention on Climate Change (UNFCCC) has as its main objective "to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system." Links between Earth's climate and the fundamental role biodiversity plays in the carbon cycle make the UNFCCC an important tool for conserving forest biodiversity
- One UNFCCC implementation mechanism is the framework for Reducing Emissions from Deforestation and Forest Degradation (REDD)[23] in Developing Countries. REDD provides incentives to reduce emissions from deforestation and forest degradation and enhance forest carbon stocks
- Forests Principles is a non-legally binding agreement on the management, conservation and sustainable development of all types of forests.[24]

[22] http://cfs.nrcan.gc.ca/pages/118
[23] http://www.un-redd.org
[24] http://www.un.org/documents/ga/conf151/aconf15126-3annex3.htm

There are also a number of very broad federal laws that underpin forest management, including:

Constitution Act (Canada), 1867 to 1982 and subsequent amendments : *Delivery Agent: Department of Justice, Canada*[25]

Among other things it directs authority over who can buy and sell public land – since 93% of Canada's forest is publicly owned… this is important. Also appears to direct funding to some degree (directly or indirectly).

Canadian Environmental Protection Act Consolidated Statutes of Canada, Chapter C.15 : *Delivery Agent: Environment Canada*[26]

Regulates: Pollution (air, water, soil), toxic substances, biotechnology, waste management, environmental emergencies, government operation on federal and aboriginal land.

Fisheries Act (Canada), Revised Statutes 1985, Chapter F.14 and Ontario Fisheries Regulations :[27] *Delivery Agent: Department of Fisheries and Oceans (DFO) and Ontario Ministry of Natural Resources Individual Conservation Authorities*

Regulates: Fish habitat and pollution prevention (affects watersheds – and thus forests).

Forestry Act (Canada), Consolidated Statutes of Canada, Chapter F-30 : *Delivery Agent: Natural Resources Canada – Canadian Forest Service*[28]

Regulates:

- Research &Development
- Identification and implementation of experimental forest areas
- Cutting or harvest of forest areas
- Permitting
- Enforcement (officers)
- Details of harvest methodology

Department of Natural Resources Act 1994, c.41: *Delivery Agent Natural Resources Canada.* Establishes department to govern natural resources including forests.

The Canadian federal government is also responsible for several national forest-related laws[22]:

- The *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act* prohibits commercial trade in rare and endangered species and prevents the introduction of undesirable species to Canadian ecosystems.
- The *Migratory Birds Convention Act* (MBCA) protects migratory birds, their eggs and their nests.

[25] http://laws-lois.justice.gc.ca/eng/const/page-18.html#f45
[26] http://laws-lois.justice.gc.ca/eng/acts/C-15.31/page-1.html#docCont
[27] http://laws-lois.justice.gc.ca/eng/acts/F-14/index.html
[28] http://laws-lois.justice.gc.ca/eng/regulations/SOR-94-118/page-1.html#docCont

- The *Species at Risk Act* provides for the legal protection of wildlife species and the conservation of biological diversity. The Act applies to all federal lands in Canada and to all at-risk wildlife species and their critical habitats. Most provinces and territories also have their own species-at-risk legislation.

Canada has also entered into a number of forest-related agreements:

Softwood Lumber Agreement (SLA): The US and Canada have been embroiled in one of the longest trade disputes in modern history over claims by US forest products companies that Canada unfairly subsidizes stumpage prices on Canada's publicly owned land. The current (2006 SLA) negotiated settlement imposes quotas and other export measures in lieu of the previously imposed 10.8 percent countervailing and antidumping duty on softwood lumber imported into the US from Canada. The matter is still under dispute.[29]

Provinces and territories manage their own natural resources, including forests, except on federal lands, such as First Nations lands and national parks. Each province and territory sets the policies, legislation and other regulatory matters for its own resources. Many provincial acts are similar between provinces due to the needs of meeting national guidelines. Examples include:

British Columbia's Forest and Range Practices Act (FRPA, 2004) is an example of provincial forest management regulation. The FRPA establishes requirements for planning, road construction, logging, reforestation, and grazing. The act is designed to be outcome based in combination with rigorous enforcement.[30]

Crown Forest Sustainability Act, 1994 (Ontario) c. 25: Purpose is to provide for the sustainability of Crown (Ontario's) forests and manage said forests to meet social, economic, and environmental needs of present and future generations.[31]

Provincial Parks and Conservation Reserves Act, 2006 (Ontario) c. 12: Purpose is to permanently protect a representative system of Ontario's natural regions, provincially significant natural and cultural heritage, as well as to maintain diversity while providing for compatible and sustainable (ecologically) recreation.[32]

Management plans

The forest mandate of the federal government includes:

- Managing the forests on its own lands
- Managing international trade and relations, enforcing environmental regulation (e.g., *Species at Risk Act*)
- Coordinating responsibility for healthy forests
- Increasing Aboriginal participation
- Reporting under national and international obligations

[29] http://en.wikipedia.org/wiki/Canada–United_States_softwood_lumber_dispute
[30] http://www.for.gov.bc.ca/code/
[31] http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_94c25_e.htm
[32] http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_06p12_e.htm

To meet the management requirements of the mandate, the Canadian council of forest ministers (CCFM)[33] produces a five-year forest sector strategy paper that guides management activities within the various government programs (current version at “http://www.ccfm.org/pdf/CCFMCanForStratBklt.pdf”).

Enforcement

The primary enforcement tools Canadian governments can apply to great affect are through the management of permits and “tenure” rights. Through tenure or lease agreements the federal and provincial governments have both the carrot (lease opportunities) and the stick (loss of tenure rights) to ensure existence of and compliance with long-term forest management plans.

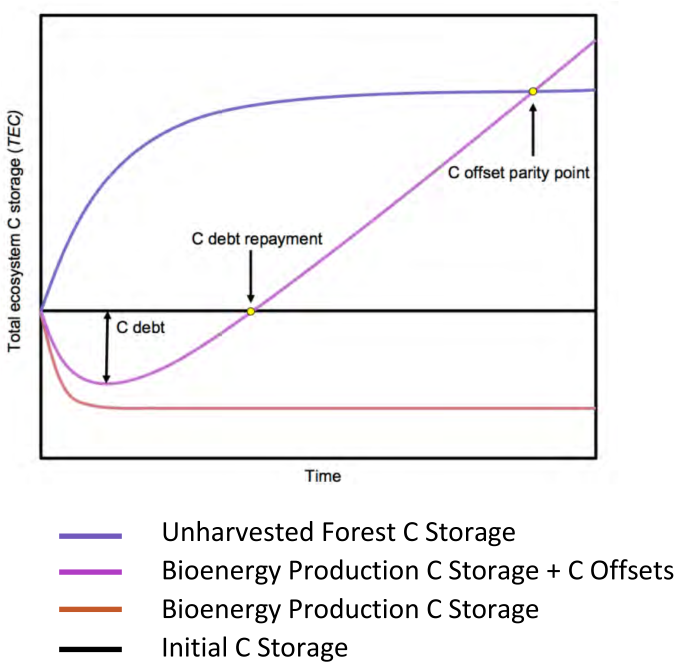
[33] http://www.ccfm.org/english/coreproducts-nscf.asp

Appendix 3 Carbon balance terminology

Various terms are used to describe the temporal carbon balance of bioenergy. In line with the definitions introduced by Mitchell and associates (Mitchell et al. 2012) this paper uses the following terminology:

- **Carbon debt:** the reduction in forest carbon stocks that occurs when wood is harvested, compensated for the emission savings achieved by the replacement of fossil fuel. It is re-paid when the carbon savings of avoided fossil fuel use from using the wood to generate energy plus the regrown carbon stocks in the forest equal the initial debt
- **Carbon debt repayment time:** the point in time where the initial carbon debt has been repaid by the savings of avoided fossil fuel use plus the regrowth in carbon stocks after harvesting. In other words the point at which the net cumulative GHG savings become positive. Thereby the concept of the carbon debt repayment is consistent with the Reference Point Baseline explained in section 5.3.2.2. After the carbon debt repayment time has been reached, bioenergy achieves *absolute* emission savings.
- **Carbon parity point:** the point in time at which the net cumulative GHG savings of the bioenergy scenario equal those of the Anticipated Future Baseline scenario. Thereby, the concept of the carbon parity point is consistent with the Anticipated Future Baseline approach explained in section 5.3.2.2. After the carbon parity point is reached, bioenergy achieves positive GHG emission savings *relative* to the Anticipated Future Baseline.

Figure A.3.1. Illustration of Various Terms Related to Carbon Debt Concept



Adapted from: Mitchell (2012)

Appendix 4: Differences between the reference point baseline and anticipated future baseline approaches

This Appendix illustrates the difference between the Reference Point Baseline approach (absolute emissions) and the Anticipated Future Baseline approach (relative emissions). This is done using two hypothetical examples.

Example 1: The actual forest carbon stock is different from the carbon stock in the anticipated baseline scenario

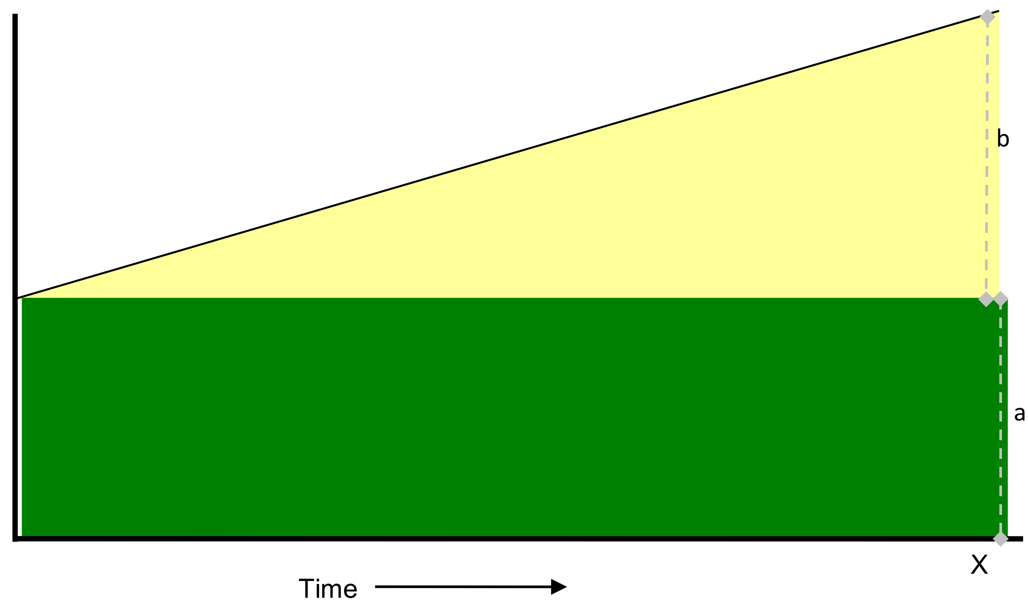
Example 2: The actual forest carbon stocks is similar to the forest carbon stock in the anticipated future baseline

Example 1 using a Reference Point Baseline approach

The Reference Point Baseline approach yields information on the 'absolute' GHG emissions and savings which is the sum of all carbon inputs associated with the forest operation (including the forest carbon stock assessment). It is modelled using the indicator "carbon debt repayment time".

Figure A.4.1 depicts a simplified example of the absolute GHG emission savings of the use of biomass for bioenergy over time, following the RPB approach. In this case, biomass is harvested from an existing sustainably managed forest. The harvest level equals the mean annual increment (i.e. harvest = re-growth) and as a result, carbon stocks in the forest remain constant over time ("a" in Figure A.4.1). Therefore, there is no 'carbon debt' observed. In this case, the harvested biomass is used to produce pellets, which replace coal in power stations. The yellow area on the graph represents the GHG emission savings from replacing coal. The GHG emission savings achieved by the use of bioenergy from time=0 to time=X amount to "b" in Figure A.4.1. These are absolute GHG savings to the atmosphere, achieved by the use of biomass for bioenergy by time X.

Figure A.4.1. Carbon flows for a simplified hypothetical scenario in which biomass is harvested from an existing sustainably managed forest using the RPB approach.

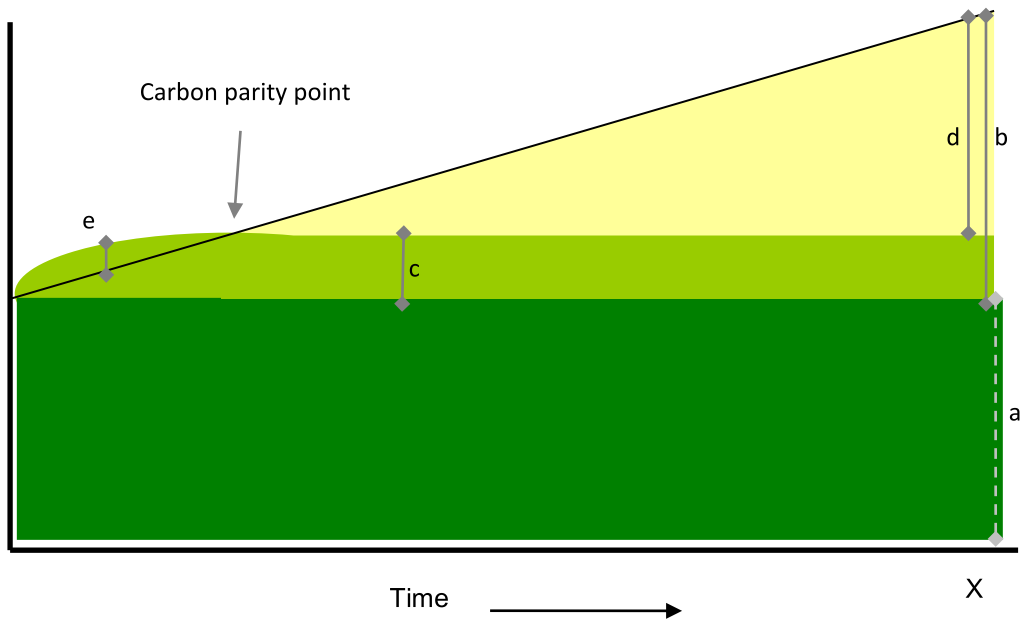


Example 1 using an Anticipated Future Baseline approach

The same scenario can be viewed with an AFB approach. The AFB approach to the same scenario is shown in the Figure A.4.2 below. The anticipated counterfactual in this theoretical example is that the forest would otherwise not be harvested. (Note that this is not a realistic assumption as explained in sections 4.1., 5.3.2.7 and 6.3. This example is merely included here to demonstrate the difference in methodological approaches.) In this counterfactual, the forest would continue to sequester carbon until it reaches a new equilibrium. This 'foregone sequestration' is shown in light green ('c' in Figure A.4.2). In the AFB approach then the absolute GHG savings achieved by the use of biomass for bioenergy ('b' in Figure A.4.2) are reduced by the foregone sequestration ('c' in A.4.2), to obtain the relative savings of bioenergy ('d' in A.4.2). Thereby the relative savings (d) are smaller than the absolute savings (b) because the removal of biomass for bioenergy leads to a lower forest carbon stock compared to the anticipated future baseline.

In this theoretical example there is an initial period of time when the bioenergy scenario has higher emissions than the AFB scenario (in which no harvesting for bioenergy occurs) – small debt 'e' in Figure A.4.2. The point at which net cumulative GHG savings as the result of bioenergy catch up with the counterfactual is the 'carbon parity point'. After this point we see that the net cumulative CO_2-emission reduction from bio-energy steadily increases and becomes much larger than the foregone CO_2 sequestration.

Figure A.4.2 Carbon flows for a simplified hypothetical scenario in which biomass is harvested from an existing sustainably managed forest using the AFB approach with a 'continued growth' counterfactual.



In an AFB model, the counterfactual scenarios must be realistic and this can only be achieved by thorough understanding of the existing systems of SFM and by understanding current markets and market dynamics. The position is complicated by the local market dynamics – certainly in the SE US, forests have been planted and managed without necessarily identifying the end-use, whether timber, paper or energy, so that projections of future use are uncertain.

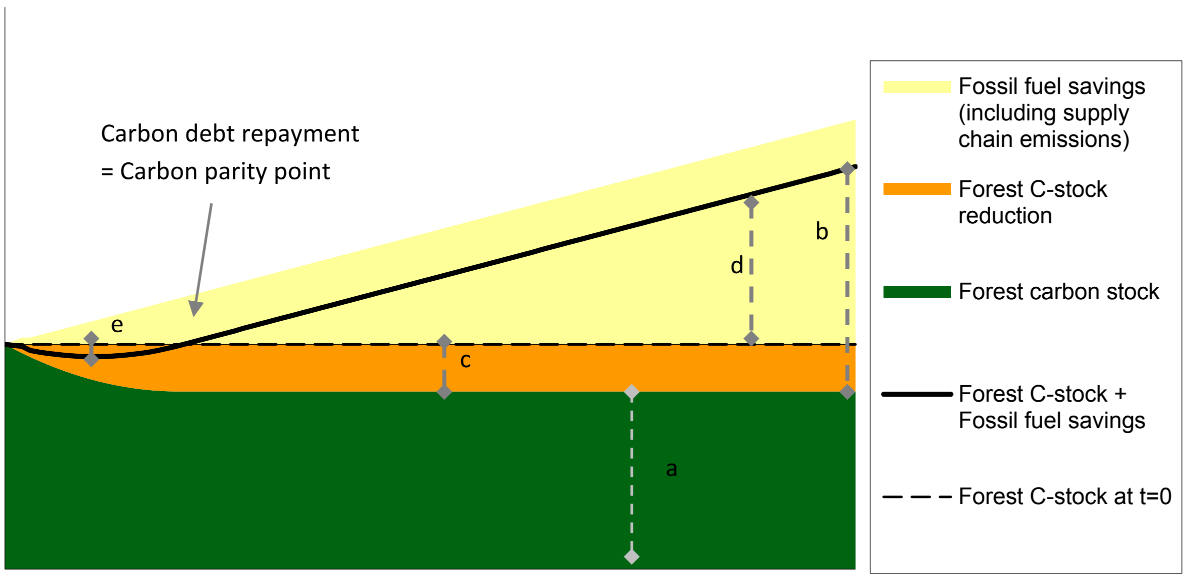
Example 2 using a Reference Point Baseline approach

Example 1 illustrates that the RPB and the AFB can lead to different results. The cause of this difference is that the two approaches compare the bioenergy scenario to a difference reference point. The RFB approach compares the bioenergy scenario to the current situation (in terms of forest carbon stocks and fossil fuel consumption for energy generation). The AFB approach compares the bioenergy scenario to an anticipated future baseline. Therefore, if the assumed forest carbon stocks in the anticipated future baseline are very different from the current forest carbon stocks, the two approaches find a different result. However, if the assumed forest carbon stock in the anticipated future baseline is similar to the current forest carbon stocks, then the two approaches actually find similar results. This is illustrated in Figure A.4.3.

In this example, an existing sustainably managed forest is considered again. However, in this example the forest is managed and harvested primarily for non-energy products, such as sawn timber and pulp. The biomass that is used for bioenergy consists purely of harvesting residues (tops and branches) that would have been left in the field to decompose if there were no demand for bioenergy. Under the RPB approach the forest carbon stocks start out at a certain level, indicated by the dotted black line. Due to the d

introduction of harvesting of tops and branches for bioenergy, forest carbon stocks ('a' in Figure A.4.3) decrease slightly by a total amount of 'c'. When the net cumulative savings (changes in forest C-stock + Fossil fuel savings, shown by the solid black line) become positive, the carbon debt 'e' is said to be repaid. Before this point, there is a short period during which the bioenergy scenario leads to slightly higher emissions. However, after this point the bioenergy scenario leads to much larger emission savings that increase linearly over time as more bioenergy is produced without any further reductions in forest carbon stocks. The reference and the outcomes are similar under both the RPB and the AFB approach, as explained in the main text.

Figure A.4.3. Carbon flows for a simplified hypothetical bioenergy system based on harvesting residues.



Example 2 using an Anticipated Future Baseline approach

Example 2 gives the same outcome under an AFB approach. In this case the anticipated future baseline (the counterfactual) is that the forest continues to be harvested for other products, but without harvesting of tops and branches for bioenergy. The forest carbon stocks in this counterfactual would remain constant over time (dotted black line in Figure A.4.3). The point at which the net cumulative savings of the bioenergy scenario are higher than the savings in this counterfactual is called the carbon parity point. As can be seen from Figure A.4.3, the carbon parity point in this example is the same as the carbon repayment point. This can be explained by the fact that the reference scenario in this example is the same for both the AFB approach and the RPB approach.

Appendix 5: Timing of bioenergy's GHG emission savings in perspective with EU climate change mitigation target

The EU is committed to the target of limiting global warming to two degrees. Therefore, the discussion on the GHG emission savings of bioenergy should be seen in light of this two degrees target. This section explains the time scales at which such global warming would occur and what implications this has for the timing of the GHG emission savings of bioenergy for it to make a meaningful contribution to this two degrees target.

It is known from climate change science that it does not matter much for global warming when GHG emissions, or GHG emission savings, are realized. What ultimately affects the level of global warming is the cumulative amount of fossil fuels burnt without carbon capture and storage (UNEP 2010, Eby 2009, Bowen and Ranger 2009). The relative insensitivity of our climate to the timing of GHG emission (savings) is caused by the following two principles:

• Fossil CO_2emissions have an essentially permanent effect on the Earth's climate. Even if humanity were to stop emitting CO_2 from fossil fuels tomorrow, atmospheric CO_2 concentrations would not come down for many millennia (Eby et al. 2009, Solomona et al. 2009).

• It takes time for the Earth to warm up. So an increase in atmospheric CO_2 concentrations will not directly lead to higher temperatures (Hansen et al. 2005, Bowen and Ranger 2009). The ultimate level of man-made global warming is therefore not influenced much by short term fluctuation in atmospheric CO_2 concentrations but is determined by the long term equilibrium in atmospheric CO_2¬ concentrations, which is again determined by the amount of fossil fuels burnt.

It follows from the above that bioenergy systems with a temporary delay in achieving their GHG-emission savings can make a meaningful contribution to climate change mitigation. Due to the delay in the actual warming of the planet, global temperatures will not reach their maximum before ~2100, even if society manages to stay within two degrees of global warming (Bowen and Ranger2009). The level of global warming is therefore primarily influenced by the atmospheric CO_2 concentrations by 2100 and beyond. For bioenergy to make a meaningful contribution to society's climate change mitigation ambitions, significant GHG savings must therefore be achieved by 2100. (See Dehue 2013 for more details.) The typical industry practices for wood pellet production, as explained in the previous sections of this report, will certainly meet this requirement, and can thus play an important role in mitigation climate change.

With respect to climate change mitigation it should furthermore be born in mind that productive land is a limited natural resource and humanity has to decide how best to use it for the short, but especially the long term. Using land to accumulate carbon in un-harvested forests may accrue short-term benefits, but it also leads to a lock-in situation: the more carbon is sequestered in forest over the years, the more the land becomes "off limits" for other uses: for energy, but also for the production of food and materials. Because climate change will affect humanity well beyond this century, it is questionable whether such a scarce resource should be locked-in for short term benefits while it could achieve much more significant long term benefits if used wisely.