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POLICY BRIEF

FROM UNLOVED WOODS TO DESIRABLE RENEWABLE BIOFUELS

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POLICY BRIEF

- Increasing global demand for energy, a push by governments and industry to reduce greenhouse gases (GHG), and a desire to increase energy independence are driving the demand for renewable alternatives to fossil fuels. As a source of renewable carbon that can be used in the existing energy infrastructure, woody biomass is an attractive feedstock for the production of bioenergy (meant here to include biomass-based energy carriers in solid, gaseous and liquid forms) in the form of heat, power and liquid transportation biofuels. A key feedstock for bioenergy is woody biomass, which is defined by the United Nations Intergovernmental Panel on Climate Change (IPCC) to include surplus forest growth that could potentially be harvested over and above current harvesting rates while still remaining within the sustainable harvest rate of the forest (Chum et al. 2011). A special case of this category is low-quality, damaged, or dead trees notably trees affected by natural disturbances (e.g. forest fires, insects outbreaks, windthrow, etc.) (Dymond et al. 2010).

- Under the current forest harvest regimes in Ontario, Quebec, and Atlantic Canada, a substantial volume of dead, damaged, and low-grade trees go unutilized despite being part of the annual allowable cut (the government-dictated maximum harvest volume) or available harvest area. Forest operators leave these materials on site because they do not meet quality requirements for lumber and/or pulp production (Barrette et al. 2015). These types of low-grade trees are often too dry or too rotten, which restricts their suitability for the conventional forest industry (Barrette et al. 2012). For example, they may have been affected by fungi, cankers, cambial necrosis, trunk fissures or foliage loss.

- Although they are unfit for lumber or solid wood products, these “unloved” woods represent an attractive source of biomass for the production of renewable bioenergy (including liquid biofuels) because they do not compete with fibre supplies of other forest industries. Integration of bioenergy production within the value chain of conventional wood products not only maximizes the value of the forest resources, it is recognized as the cornerstone of a market-driven replacement of fossil fuels (Asikainen et al. 2016). The allocation of wood fibre to its best use should also ensure the greatest benefits both economically and environmentally (e.g., GHG reduction) (Egnell et al. 2016).

- Through a variety of processes, unloved woods can be converted into solid (e.g. wood pellets), liquid (e.g. ethanol, biocrude), or gaseous (e.g. renewable natural gas) biofuels. In addition to energy and fuels, they can be converted to produce bioproducts with a significantly higher value than energy. Many approaches include co-production of low-volume, high-value bioproducts and high-volume, low-value fuels and energy within a ‘biorefinery – akin to an oil refinery. The types of products and distribution of these products produced from unloved woods depends upon market opportunities but also the wood properties and volume available. It is indeed essential to explore the full spectrum of ways in which they can serve as a substitute for fossil fuels.

- Unloved woods can present significant opportunities for the development of the biofuels and bioproducts sector in Canada. They can be an important component of the Canadian renewable energy transition strategy, which aims to reduce GHG emissions and fight global climate change by using low-carbon renewable fuels. They could be central to achieving high renewable fuel blending rates, which are targeted by the Canadian government within their transportation renewable energy transition strategy. By promoting the development of new renewable forest products, they can support the forest sector’s competiveness and be part of the forest bioeconomy of Canada.

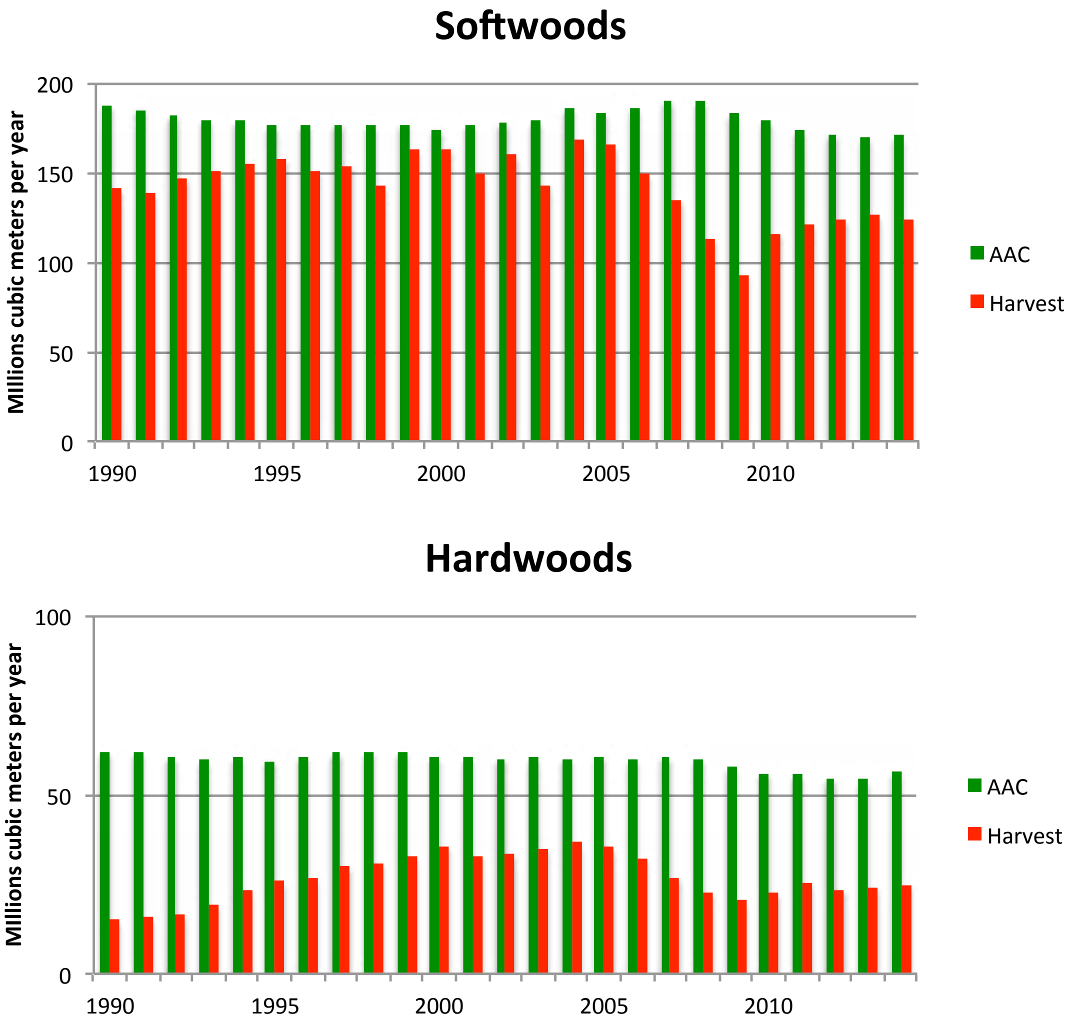
- This Policy Brief addresses four main issues related to the use of unloved woods for biofuel production within the context of the larger forest products sector: 1) What is the availability of unloved woods across the managed forest of Canada?; 2) Is the quality of the feedstock adequate for biofuel production?; 3) How do we manage environmental sustainability issues related to the increased removal of biomass?; and 4) Can conversion of unloved woods to biofuels be economically viable? Answering these questions will help establish comprehensive frameworks to ensure that environmentally responsible forestry practices underpin the use of unloved woods for biofuels production.

WHAT IS THE AVAILABILITY OF UNLOVED WOODS ACROSS THE MANAGED FOREST OF CANADA?

When we compare annual harvest volume to the annual allowable cut (AAC), which refers to the amount of wood that could be harvested annually while ensuring the sustainability of forest production, it is immediately apparent that the full production capacity of Canadian forests is not used (Figure 1). The annual allowable cut available for harvest refers to an upper limit, which is determined by forest managers within each province. Differences between ACC and actual harvest volumes vary between softwoods and hardwoods and through time. Factors explaining these variations are diverse, and include a combination of forest product market pricing and broader economic performance; operational difficulties; regulatory framework and restriction; structure of the wood processing industrial network of each region; and wood properties and tree characteristics (for which occurrence of natural disturbances can be an important driver). Evaluation of the relative weight of these factors, and quantification of the proportion of unused volumes that could serve as useful feedstock for bioenergy as part of harmonised forest management activities that take into account other industrial and social stakeholders, are part of key research activities of BioFuelNet.

FIGURE 1

Annual forest allowable cut (AAC) and actual harvest volumes for softwoods and hardwoods, for Canada's managed forests between 1990 and 2015. Source: National Forest Database.



The availability of unloved woods from trees killed by natural disturbances is inherently variable because natural disturbances are episodic events and cannot be planned by forest managers. However, they tend to be cyclical and it is known that they will affect large volumes of timber over time. For example, spruce budworm outbreaks tend to occur every 30–40 years in the boreal forest and to last for 10–15 years. During a typical outbreak, the insect consumes foliage in successive years, which eventually drains the trees' resources and leads to large-scale mortality. The most recent spruce budworm epidemic started in 2006 in the eastern boreal forest of Canada. Since the beginning of its infestation, more than 7 million of hectares of forest have now been affected in the province of Quebec (MFFP, 2016) and New Brunswick has now also been significantly affected. During the last spruce budworm outbreak, which occurred in the 1970s, the insect killed 139,000,000 to 238,000,000 m^3 of balsam fir and spruce in the public forests of eastern Canada (Vezina, 1985). At a national scale, the outbreak is impacting 1.6 million of hectares per year (NRCan, 2013). A large number of trees have died since the beginning of the outbreak and it can be predicted that mortality will continue to rise. Therefore, there is an urgent need for governments to adopt strategies to utilize this large volume of dead wood, which has limited use within the conventional forest products industries (Barrette et al. 2015). This would encourage development of new business opportunities in the biofuels/bioproducts sectors, improve Canadian forest industry competitiveness, and support adaptation to natural disturbance efforts.

Wildfires are another important natural disturbance impacting forests and providing potential 'opportunity' biomass feedstocks. Fire cycles tend to vary depending on the climate of a given forest region. For example, in the boreal forest of the province of Quebec, fire cycles have been reported to vary from 140 years to 500 years (Boulanger et al. 2013). Being the main natural disturbance in the boreal forest of Canada, wildfire can generate large amounts of dead wood. For example, Dymond et al. (2010) estimated, using modelling, the average annual amount of biomass available from fire-killed stands across the Canadian commercial forests to be 19.89 M oven-dry tonnes year−1. This takes into account a 50% net-down for ecological and technical constraints. A more recent study involving BioFuelNet scientists and based on remote sensing information provides an estimate of 47 M oven-dry tonnes year−1 (not accounting for any ecological or technical net-down) (Mansuy et al. 2017).

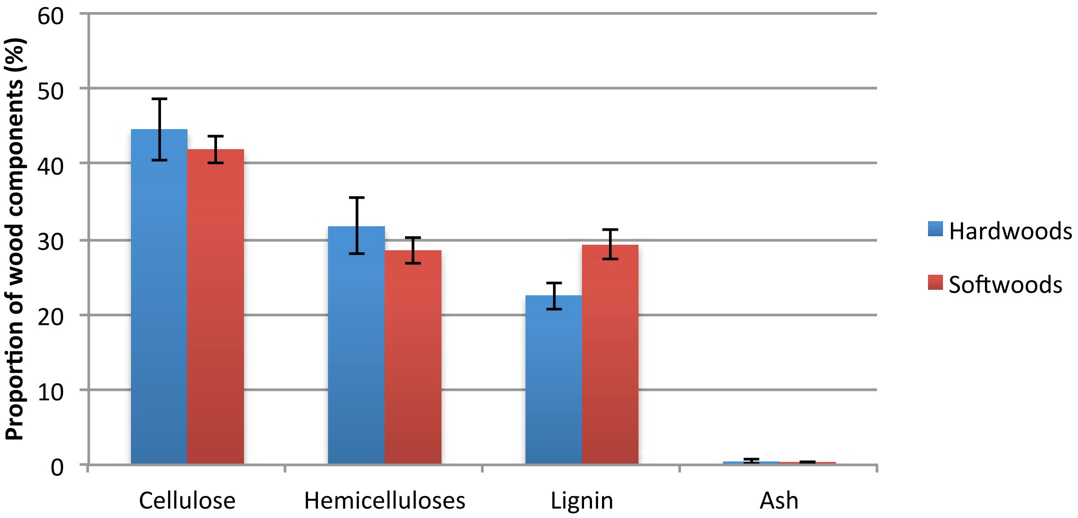
Models predict that the number, intensity, and size of fires in the boreal forest will increase markedly in the future (with large differences between regions) (Price et al. 2013). A warming climate has also been linked to greater tree mortality from insects such as Spruce Budworm and Mountain Pine Beetle. For example, with warming climates, specific insects are able to transfer to previously unattractive tree species (e.g., Spruce Budworm to Black Spruce; Mountain Pine Beetle to Jack Pine). Adapting forest management activities to the occurrence of natural disturbances is a key challenge for Canadian forestry. Therefore, utilization of fire/insect prone (proactive) and damaged (reactive) forest resources for bioenergy must be a key feature of any Canadian climate adaptation strategy. Developing tools to identify appropriate biofuel/bioenergy conversion pathways for various damaged and at-risk forest resources should be considered a priority for policy-makers and regional stakeholders.

IS THE QUALITY OF THE FEEDSTOCK ADEQUATE FOR BIOFUEL CONVERSION?

It is clear that there are significant quantities of unloved woods potentially available for conversion to biofuels that would not create undue competition for fibre with conventional wood product industries. However, is conversion feasible and efficient? Softwood trees contain a larger proportion of lignin, the ‘glue’ that holds wood fibres together, than hardwood trees (Figure 2). This makes separation of the fibres and wood sugars difficult and thermochemical conversion – using heat, chemicals, and pressure – to fuels may be preferred to biochemical conversion. Conversely, hardwood trees generally contain a higher proportion of sugars, which may provide better opportunities for sugar separation and fermentation in biochemical conversion.

FIGURE 2

Proportion of wood components for hardwoods and softwoods from Canada. The hemicelluloses refer to the pentoses and hexoses expressed as the total anhydroxylose and arabinose residues in wood. Source: Pettersen, 1984.



BioFuelNet scientists have started looking into the impact of tree death and subsequent degradation on wood biomass properties for biofuels and bioproducts production (Barrette et al. 2015). When a tree dies, it undergoes a series of changes that affects its wood fibre properties. These changes may act as a form of biomass pretreatment, increasing the quality of the feedstock for different conversion pathways. For example, wood from dead trees usually dries rapidly; this is one important advantage associated with the production of bioenergy as most thermochemical conversion processes (e.g. wood densification, combustion, pyrolysis, gasification) require feedstock with low moisture content. Also dead trees become colonized by various wood-decay fungi that degrade wood and cause it to rot; various rot fungi species also have different preferences in terms of the wood components that they primarily attack. For example, white-rot fungi, which are most often found on dead cells of hardwoods, preferentially degrade lignin over cellulose and hemicelluloses (Rayner and Boddy, 1988), which might facilitate the pre-treatment of wood for ethanol and butanol production. Conversely, brown-rot fungi, which are often (but not exclusively) found on softwoods, tend to attack mainly cellulose and hemicelluloses while leaving lignin intact (Blanchette et al. 1990). This might create interesting feedstocks for wood densification processes and increase energy potential of products, such as wood pellets, because lignin, with its high carbon content, is the most energetic component of the woody structure (Nguyen et al. 2015; Nguyen et al. 2016). Evidence (albeit anecdotal) from northern Quebec suggests wood pellets can indeed be successfully produced from dead trees, although more research is needed to confirm the suitability/profitability of this process.

In the case of degraded or otherwise non-commercial or underutilized hardwood species, since hardwood-dominated forests are often located closer to urban areas (at least in Eastern Canada), it can make them very attractive to the biofuels and bioproducts sectors. Extracts from hardwood trees – for example white birch and red maple – have already been shown to be rich in bioactive molecules, which can be used in the pharmaceutics, cosmetics and nutraceuticals sectors. Some of these molecules have even been recognized for their potential anticancer and anti-HIV activities. Preliminary research by BioFuelNet scientists also suggests that boreal hardwoods, which can represent a sizeable fraction of conifer-dominated stands but have only a limited market in conventional wood product industries, contain high proportions of easily fermentable compounds and could thus be a valuable feedstock for biochemical conversion processes.

The chemical composition of the woody biomass is, without a doubt, the most critical parameter for energy and bioproducts production. Knowing the specific properties of biomass feedstocks should guide the selection of appropriate conversion pathways. Such assessments should also help promote the development of new forest products, which could ensure the Canadian forest sector's leadership and competitiveness.

HOW TO MANAGE ENVIRONMENTAL SUSTAINABILITY ISSUES RELATED TO THE INCREASED REMOVAL OF BIOMASS?

There appear to be no consistent negative impacts of forest biomass harvesting on forest ecosystems, for example soil productivity (Lamers et al. 2013; Thiffault et al. 2010; Thiffault et al. 2011). As a general rule, forest sites that are already low in nutrients tend to be more sensitive to forest biomass procurement than richer sites. Based on this, over recent years, BioFuelNet scientists, have contributed to the development of guidelines to ensure environmentally sustainable practices for forest biomass procurement. For example, planning indicators have been developed to guide decisions on forest residue removal so that poor and/or sensitive ecosystems can be properly identified and protected (Thiffault et al. 2014); those indicators can then easily be included when designing biomass supply chains (Mansuy et al. 2015).

Principles of protection of ecosystem and sustainability should generally remain the same whether forests are managed for conventional forest products only or for both conventional products and bioenergy. However, some modifications may be needed to properly identify and find mitigation strategies for sensitive conditions where field evidence suggests that the incremental removal of biomass or other forms of intensive management may not be sustainable. Moreover, landscape management regulations may need to be put in place to ensure that sufficient biodiversity-important features such as dead wood, aging stands, corridors, etc. are preserved. Special attention should then be directed to trees and stands with high biodiversity values or those important for maintaining ecosystem services (Egnell et al. 2016).

There have been several reviews of forest bioenergy system life-cycle analyses (Cherubini and Strømman 2011; Muench and Guenther 2013). Most studies commonly exclude the carbon (C) sequestration and emissions associated with forest ecological dynamics and subsequent bioenergy use (Muench and Guenther 2013). This so-called “C neutrality assumption” of bioenergy has been contested (Cherubini and Strømman 2011; Searchinger et al. 2009; Ter-Mikaelian et al. 2015). The two main points of critique are that the energy production from forest biomass feedstocks emits biomass C to the atmosphere immediately, whereas, if left in the forest, the feedstock would slowly decompose and perhaps contribute to maintain forest site productivity and capacity to sequester C. Secondly, the energy output per unit of C emitted is lower for biomass than for fossil alternatives (Berndes et al. 2003). This has led to the concept of C parity time and C payback of the forest bioenergy system, i.e. the time span needed to recover the C levels of a reference fossil fuel-based scenario before GHG mitigation benefits to the atmosphere start to be recorded (Lamers and Junginger 2013). This time difference has caused debate as to whether bioenergy is able to help achieve near-term GHG reduction targets (Cowie et al. 2013). The public and scientific developments and debates on forest bioenergy and its C parity time has brought some policymakers to consider abandoning its use entirely as a renewable energy source (Cowie et al. 2013), or to ban whole categories of feedstocks, such as roundwood (Agostini et al. 2013). However, careful prediction of the effects of forest biomass feedstock procurement on forest sites and C emissions associated with forest bioenergy systems can now be easily performed using models and tools, such as those developed by BioFuelNet scientists (Laganière et al. 2016). This can lead to the identification of optimal solutions in terms of feedstock choices, procurement strategies and conversion pathways that will provide long-term GHG reductions as compared to fossil alternatives (Dehue 2013).

Work undertaken by BioFuelNet suggests that forest stands in which there is a high proportion of unloved trees relative to high-value sawlogs affects the financial viability of the forest value chain and could paralyze forest management activities. Adding bioenergy to the basket of products that can be sourced from a given stand may increase the profitability of the overall forest operations and create incentives for forest management by providing an outlet for unloved trees. This will provide benefits to the whole forest sector and ensures the greatest benefits in terms of GHG savings by creating a flow of forest-based products with often high substitution and GHG mitigation benefits (Sathre and O’Connor 2010; Sikkema et al. 2014). An increase in the use of wood will also result in an increased residual stream that could be used for bioenergy. Furthermore, it may increase foresters’ belief in future markets giving them incentives to invest in measures to increase forest productivity (Bellassen and Luyssaert 2014). Analyses including the full suite of forest products do indeed show the benefits of using wood from sustainable forestry for climate change mitigation (Lundmark et al. 2014; Smyth et al. 2014).

CAN CONVERSION OF UNLOVED WOODS TO BIOFUELS BE ECONOMICALLY VIABLE?

Canadian pulp and paper production has been in decline for over a decade due to a decrease in demand for newsprint and increased competition from southern hemisphere producers. Bioenergy, biofuels and bioproducts offer the forest sector an opportunity to adapt to these changing markets and build upon current sawmill and pulp and paper mill infrastructure. Using unloved woods for biomass production can help offset fixed costs and serve to redistribute timber harvest and forest management costs amongst multiple products, including conventional solid wood products and bioenergy. In doing so, the competitiveness of the forest sector as a whole can be increased. As an example, dead or dying trees, which can inhibit site preparation and forest regeneration if left on site following harvest, can be used for biomass production. The drop in moisture content that occurs after tree death can make this ideal feedstock for thermochemical bioenergy and biofuel applications. Studies led by BioFuelNet scientists have shown how biomass recovery can serve as a site preparation method, thereby facilitating forest stand regeneration (Barrette et al. 2013; Trottier-Picard et al. 2014; Trottier-Picard et al. 2016). Therefore, funds currently allocated to site preparation could be reallocated to reduce the costs of forest biomass collection and transportation. Valuing unloved woods as a significant source of renewable carbon via carbon pricing could also provide a new revenue stream and improve the margins for biomass collection.

Understanding and communicating the economic and environmental benefits of unloved woods utilization for biofuels and bioenergy is essential to improved policy and strategy design. Research from the International Energy Agency – Bioenergy, in collaboration with BioFuelNet scientists recommends a very different approach for biomass supply chains than fossil fuels due to the distributed nature of the resources (Coote et al. 2016). Achieving economies-of-scale, which reduce production costs, will be difficult without densification and preprocessing of the material. Bioenergy companies also need strong feedstock quality management and supply chain optimization approaches to ensure competitiveness.

The best opportunities for unloved woods are likely to be found in integrated forest product chains, where conventional forest products, such as lumber, and bioenergy streams are integrated to optimize the fibre flows and values. These opportunities will only materialize if both the forest and biofuel sectors develop innovative forest management and procurement solutions, which make it possible to extract maximum value from the resource while respecting sustainability principles. Unloved woods offer the Canadian forest sector a unique opportunity to diversify its production, to innovate, to increase its competitiveness at the global scale, and to play a major role in climate change mitigation and adaptation.

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