Applied Energy xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

A financial analysis of the potential of dead trees from the boreal forest of eastern Canada to serve as feedstock for wood pellet export

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HIGHLIGHTS

- The spruce budworm outbreak will increase the amount of dead trees in Eastern Canada.
- Wood degradation did not affect the eligibility of dead trees for pellet production.
- Lumber and pulp production remains the most profitable option except in small trees.
- A drop by 20–40% in wood chip price would make pellet and pulp scenarios equivalent.

ARTICLE INFO

Article history:
Received 16 October 2016
Received in revised form 21 February 2017
Accepted 2 March 2017
Available online xxxx

Keywords:
Financial analysis
Biobased economy
Wood pellets
Dead trees
Wood degradation

ABSTRACT

Global demand for forest biomass feedstock has increased drastically in recent years, mainly due to the implementation of policies and strategies for climate change mitigation and renewable energy production in many jurisdictions. The biomass from dead trees has been recognized by the International Panel on Climate Change (IPCC) as a promising source of forest biomass for bioenergy at the global scale both because of its wide scale availability and its potential to limit global warming. In eastern Canada, dead trees are not only very abundant but are also widely perceived by lumber and pulp and paper producers as contaminants in the wood supply chain with marginal profitability. The general aim of this study was to determine the conditions of profitability of an eastern Canada independent sawmill (*i.e.*, unaffiliated with a pulp plant) to produce pellets destined for international export using either co-products or roundwood from dead trees as feedstock. We compared the yield and monetary value of dead trees at various sizes and degradation levels for the production of wood pellets, alone or in conjunction with the production of lumber, to current market conditions. Our results suggest that using dead trees for lumber and pellets is almost as profitable as using them for lumber and pulp, with a difference of about 1–12% depending on tree size. Dead trees from all classes of wood degradation could serve as an interesting feedstock for pellets because wood density was only slightly affected by wood degradation. Small dead trees (DBH < 15 cm) could serve for all scenarios, as the difference between revenues and costs remained generally minimal between them. Larger dead trees did not appear to represent a financially viable option under current market prices, unless suitable subsidies or other types of financial support are provided. The sustainability criteria applied by European consumers could therefore be a determining factor for the future importance of dead trees from eastern Canada as a source of feedstock for wood pellet production.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) [1], the International Energy Agency [2] and the International Renewable Energy Agency [3] have all identified forest biomass as an important source of energy to meet future requirements both in terms

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http://dx.doi.org/10.1016/j.apenergy.2017.03.013
0306-2619/

of future energy consumption and reduction of GHG emissions. When suitably used, forest biomass will lead over time to a net reduction in greenhouse gas (GHG) emissions when used as a substitute for fossil fuels [4–9]. In many jurisdictions, renewable energy policies and strategies have recently been implemented, leading to an increase demand for forest biomass at the global scale [10].

In Europe, the European Union (EU) member states have agreed on a 2030 Framework for climate and energy that states that by 2030, at least 27% of the total energy consumption should be supplied by renewable energy resources [11], the wood pellet demand is expected to continue to increase. Although a majority of the wood pellet demand in the EU has been supplied domestically, international trade also plays an important role, which is likely to increase in the future [12] and some EU countries such as the UK and the Netherlands have become increasingly reliant on international imports [13,14]. For the past 10 years, Canada has been a major overseas supplier of pellets to Europe [15,16] with the pellets mostly coming from British Columbia (BC). In this province, the mountain pine beetle outbreak killed large volumes of pine stands over the last number of years and has prompted a significant increase in harvest levels. This situation stimulated the development of BC's wood pellet production and export capacity by increasing feedstock availability in the form of sawmill residues, tree parts, and whole trees [17]. In 2015, BC exported 1 258 902 tonnes of wood pellets, 81% of which were sent to the UK [16]. The production of wood pellets in Canada's eastern provinces is still rather limited and mainly focused on domestic markets, despite proximity to deep-sea ports and shorter maritime routes to Europe. Wood pellet producers from Quebec exported only 138 945 tonnes of their production, which was almost entirely sent to the United States [16].

The boreal forests of eastern Canada contain an abundance of dead trees, which were either killed by natural disturbances (fire, insect outbreaks), or died through the course of stand succession. This type of biomass has been recognized by the IPCC [1] and by assessments made in various jurisdictions *e.g.* [18,19] as a promising source of feedstock for bioenergy. In European countries such as Italy [20], Finland and Sweden [21], frequent thinnings throughout the course of stand succession provide feedstock for bioenergy in the form of small or damaged/dying whole trees. Although this limits the occurrence of interspersed dead trees at the end of succession, large amounts of dead tree biomass may become available following major disturbance events such as windthrows, wildfires and insect outbreaks. Such natural disturbances are becoming more frequent at the global scale [22–24].

The most destructive insect in eastern Canada is the spruce budworm (*Choristoneura fumiferana* (Clemens)), which has outbreak cycles of 30 to 40 years. It mainly affects balsam fir (*Abies balsamea* (L) Mill.) and white spruce (*Picea glauca* (Moench) Voss) [25–28]. Because of warmer average temperatures resulting from climate change, the insect is moving further north, attacking forests and tree species that had remained relatively unaffected in the past such as black spruce (*Picea mariana* Mill. BSP)[29]. The current spruce budworm outbreak is expected to cause severe damage to the forest resource. In the province of Quebec alone, more than 7 million hectares have been affected since the beginning of the infestation in 2006 [30]. During the last spruce budworm outbreak, which occured in the 1970 s, the insect killed from 139 000 000 to 238 000 000 m^3 of balsam fir and spruce in the public forests of eastern Canada [31]. The outbreak caused severe damage to both lumber and pulp and paper industries *e.g.* [32–34].

Dead trees can also be found sporadically *(i.e.,* interspersed within stands) in undisturbed stands of eastern Canadian forests. In regions bordering the Atlantic ocean or the St.Lawrence Estuary, the maritime climate can induce mean fire return intervals of more than 300 years, which is much longer than the approximate 100-year intervals reported further inland [35]. In the absence of insect outbreaks, this implies that the period of time since the last major disturbance often exceeds the mean longevity of the trees. Isolated mortality therefore generates significant volumes of standing dead trees interspersed with live trees [36]: for example, in Quebec's North Shore region, dead wood can typically represent about 22% of the total volume in old stands [37].

In eastern Canada, harvesting of interspersed dead trees usually occur as part of normal harvesting operations. In the case of stands affected by natural disturbances, this is performed as part of emergency salvage harvesting plans. However, dead trees are widely recognized by lumber and pulp and paper producers to be of low quality and marginally profitable, and are thus often seen as "contaminants" in the wood supply chain [38]. On the other hand, the calorific value of wood from dead trees is not significantly affected by decay [39]. Dead trees could therefore be considered an interesting feedstock for the production of energy products such as wood pellets [40].

Despite the significant feedstock availability in the boreal forests of eastern Canada and recent advances in the development of solid, liquid and gaseous biofuels and bioproducts, the long-term prospects of using wood in a bio-based economy are not fully recognized by local stakeholders, which makes it difficult to mobilize support for improvement of logistics [41]. To make the most of the opportunity offered by international trade flows of biomass and global bioenergy systems, Canada's forest sector is currently considering strategies for increasing the mobilization of its forest biomass supply chains [42]. Increasing knowledge of the economics of pellet supply chains using various potential sources of feedstock, and their integration within the forest value chain along with conventional wood products, is therefore crucial to aid policy-makers and stakeholders.

In the province of Quebec, sawmills represent the main entry point of the forest value chain. Conifer roundwood of all dimensions harvested on public lands is first transported to sawmills. Sufficiently large roundwood is normally sawn for dimensional lumber, while slabs and small-size roundwood are chipped on site. Lumber processing creates co-products in the form of sawdust, shavings and wood chips, which the mill can sell as feedstock to a pulp plant or a pellet mill [43]. Revenues from such co-products are an integral part of the sawmill profitability. For some pulp plants, the low quality of co-products from dead roundwood disqualifies them for pulp production [44], which can make the production of wood pellets a preferable processing pathway. The downturn of the global paper markets may also mean that there are no takers for sawmill co-products, representing an opportunity to develop the pellet market.

Exploring various ways in which dead trees can serve as ecologically sustainable feedstock for forest value chains in Canada, including energy products such as wood pellets, would open new opportunities of value creation for the forest sector [45]and contribute to meeting the renewable energy demand at a global scale [14,46]. This could also provide a case-study example of how the forest sector in Canada and in other countries can adapt to the predicted increase in natural disturbances.

The general aim of this study was to determine the conditions of profitability for an eastern Canada independent sawmill in producing pellets destined for international export using either co-products or roundwood from dead trees as feedstock. Specifically, we estimated the yield and monetary value of dead trees of various sizes and degradation levels for the production of wood pellets, alone or in conjunction with the production of lumber. We then compared these to the reference system, *i.e.*, current market conditions where lumber and pulp are the main products from the forest sector.

Please cite this article in press as: Barrette J et al. A financial analysis of the potential of dead trees from the boreal forest of eastern Canada to serve as feedstock for wood pellet export. Appl Energy (2017), http://dx.doi.org/10.1016/j.apenergy.2017.03.013