Can woody biomass support a pellet industry in southeastern Ontario: A case study

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ABSTRACT

The European Renewable Energy Directive introduced in 2009 mandates a 20% renewable energy share by 2020 and has driven a rising trend of wood pellet usage in EU member states that exceeds the domestic supply. This surge presents an exporting opportunity for pellet manufacturers in North America. In recent years Canada has supplied the bulk of its wood pellets to Europe; this is changing as western Canadian producers shift their focus to Asian markets. With this development and with a new dedicated pellet shipping port in Quebec, eastern Canada is well placed to increase the supply of pellets to Europe. The potential for a pellet industry in Bancroft, Ontario was evaluated by quantifying sawmill residues from twelve mills within a 200-km radius. Given recent downturns in the lumber industry, a pellet mill in Bancroft would deliver economic benefits to the local community. Using a sawmill residue model and forest biomass characterization database, these residues were evaluated to determine the potential output and quality of wood pellets. Standing trees in the region currently allocated as pulpwood were also analyzed as a potential source of biomass. The analysis of biomass resources in the Bancroft region illustrates the potential for a pellet industry meeting European pellet standards with a minimum annual production of 100 000 tonnes.

Key words: sawmills, residue, wood biomass, bioenergy, pellets, southeastern Ontario, model, database, biomass

RÉSUMÉ

La Directive de l'Union européenne en matière d'énergies renouvelables introduite en 2009 stipule que la part des énergies renouvelables devra atteindre 20 % d'ici 2020, qui a entraîné, chez les états membres de l'UE, un accroissement de l'utilisation de granules de bois dépassant la capacité de production locale. Cet accroissement de la demande constitue une occasion intéressante pour les producteurs de granules de l'Amérique du Nord. Au cours des dernières années, le Canada a exporté la majeure partie de ses granules de bois en Europe; cette situation est en voie de changer puisque les producteurs de l'Ouest canadien accordent de plus en plus d'attention aux marchés asiatiques. Avec tous ces changements et la construction d'un quai de transbordement dédié à l'expédition de granules dans le port de Québec, l'Est du Canada est en bonne position pour accroître ses expéditions de granules vers l'Europe. On a évalué la possibilité de développer un centre de production de granules à Bancroft en Ontario à partir des volumes de résidus de sciage provenant de 12 scieries situées dans un rayon de 200 km. Compte tenu du ralentissement qu'a connu l'industrie de sciage, la création d'un centre de production de granules à Bancroft apporterait des retombées économiques intéressantes pour la communauté environnante. Les résidus des scieries ont été évalués au moyen d'un modèle de production de résidus de sciage et d'une base de données sur les caractéristiques de la biomasse forestière afin de déterminer la quantité potentielle et la qualité des granules produites. On a aussi évalué le potentiel des arbres de la région destinés à la production de bois à pâte comme source potentielle de biomasse. L'analyse des sources de biomasse de la région de Bancroft démontre qu'il serait envisageable de produire annuellement 100 000 tonnes et plus de granules répondants aux exigences européennes.

Mots clés : scieries, résidus, biomasse ligneuse, bioénergie, granules, sud-est de l'Ontario, modèle, base de données, biomasse

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Introduction

North American wood pellet production has significantly increased since the 2000s, driven largely by demand in Europe which in turn is rooted in policy decisions (Arsenault 2015). Western Canada has long dominated Canadian pellet exports, but since 2013 producers in this region have begun to shift their exports to Asia (WRI 2013). Increasing overseas demand and access to Atlantic ports with access to Europe present an opportunity for eastern Canada to develop a bio-energy industry. Diversifying forest products will help to stabilize the local economy in a region that relies heavily on its forestry sector and has experienced decline in recent years (OMNR 2012).

The primary policy driver for Canadian wood pellet use in Europe is the Renewable Energy Directive, implemented by the European Commission (EC) in 2009, which sets a binding target for member states of 20% renewable energy in final energy consumption by 2020 (European Commission 2009). The Directive has been instrumental in increasing demand for wood pellets as an alternative to fossil fuel sources across the European Union (EU). In Europe, wood pellets are used in diverse applications including residential boilers and stoves, medium-sized district energy plants and large combined heat and power (CHP) plants (Flach *et al.* 2014). The Joint Wood Energy Enquiry suggests that about 4.3% of total energy consumption in 2011 was derived from wood, and that wood-based energy accounted for 42% of all renewable energy consumed in that year (JWEE 2015). Other sources suggest that wood energy consumption is higher; Eurostat reported that primary energy production from solid biofuels (including pellets) was 3476 petajoules (PJ) in 2012, which is about 10.5% of primary energy production in the 27 nations of the EU (Aguilar *et al.* 2014).

The USDA GAIN Report on EU reports on the current status of wood pellet use in Europe. Currently Europe is the biggest producer of wood pellets in the world, with production capacity increasing from 8.6 million tonnes (Mt) in 2007 to about 16.4 Mt in 2013, a near doubling in capacity; actual production has risen from 5.8 Mt in 2007 to about 11.5 Mt in 2013 (Flach *et al.* 2014). Over the same period however, EU consumption of wood pellets has increased from 6.5 Mt in 2007 to 17.5 Mt of pellets in 2013, with demand expected to reach 21 Mt in 2015 and as high as 50-80 Mt by 2020 (Flach *et al.* 2014). This means much greater reliance on imports, primarily from the United States, Canada, and Russia. In 2013, wood pellet imports to the EU were dominated by shipments from the United States (2.8 Mt) and Canada (1.9 Mt),

corresponding to 16% and 11% of EU consumption and 46% and 32% of EU imports in the year (Flach *et al.* 2014).

The United States produced about 4.1 Mt per year of wood pellets as of the end of 2012, and production continues to rise with domestic consumption of wood energy predicted to increase 47% between 2014 and 2030 (Aguilar *et al.* 2014). Significant wood pellet production capacity has been developed in recent years in the US southeast, where capacity tripled from 2012 to 2013 (WRI 2013). In 2014, US wood pellet production capacity was reported at about 10 Mt per year, with another 2.7 Mt under construction (Aguilar *et al.* 2014). While this growth is influenced by increases in the EU demand for pellets (NREL 2013), it is speculated that the recent strengthening of the US currency in relation to the UK pound and the euro will challenge profit margins and affect European purchases of US pellets (Strauss 2015).

Canada produced about 1.8 Mt per year of wood pellets as of the end of 2014 (Arsenault 2015); as in the US, wood pellet production has been rising steadily for several years. The wood pellet industry brings significant value to the domestic forest sector, and the foreign demand is driving the development of the sector: more than 90% (1.64 Mt) of Canadian production was exported in 2014 with a value of US \$ 214.5 million (NRCAN 2013, Statistics Canada 2015). In 2014, 60% of Canadian wood pellet exports were shipped to the United Kingdom, while the US received 13% of Canadian exports (Statistics Canada 2015). Canada currently has 55 operating pellet mills with a combined production capacity of 5.6 Mt/year (Wood Pellet Association of Canada 2015). The largest production volumes are split amongst three provinces: twelve mills in British Columbia produce 55%, nine Quebec mills produce 18%, and five Ontario mills contribute 12% to pellet production (Canadian Biomass 2015). It is important to note that shipments from Canada to Asia have increased from 8% of the total wood pellet exports in 2012 to 13% in 2014 (Statistics Canada 2015), with the bulk of the increase coming from British Columbia mills. A gradual shift in exports to Asian markets from western Canada could benefit the pellet industry in eastern Canada and parts of the US southeast, which are expected to continue supplying the European market (WRI 2014). Infrastructure for exporting pellets to Europe from southeastern Canada is set to improve with the construction of the first dedicated pellet export facility along the St. Lawrence Seaway at the Port of Quebec (Pulp and Paper Canada 2014).

As of early 2015, Ontario has five operating pellet mills and four under construction, with combined production

capacity of over 1 Mt/year; these mills are located in the northern and southwestern portions of the province (Canadian Biomass 2015). At the current time, there are no industrial pellet manufacturing facilities operating in southeastern Ontario, although this region has extensive forest lands and historically has depended upon forest operations for employment and economic opportunity. The scale of forestry operations in southeastern Ontario is much smaller than in northern parts of the province with small family-owned and operated sawmills dominating the regional industry. Most of the wood that is harvested goes directly to small sawmills, which in turn have historically supplied wood residues (chips) to local pulp and composite board plants (OMNR 2004). Unfortunately, local board and pulp plants have for the most part closed, leaving few buyers for sawmill residues and challenging the economics of all forest operations (Opeongo Forestry Service 2009). The number of forestry-related jobs in Ontario is steadily declining and in 2006 and 2007 thousands of jobs were lost due to permanent and indefinite mill closures (OMNR 2012).

Developing a wood pellet industry in southeastern Ontario would serve to diversify the forest sector and make it more resilient to economic fluctuations. Current trends in wood pellet use suggest that pellets from eastern Canada will be in demand in Europe and possibly the USA; in addition, using forest biomass to generate electricity is a promising opportunity (OMNR 2012). Taken together, these factors form a strong rationale for developing such an industry. This paper explores the potential for wood pellet production from the Great Lakes-St. Lawrence forest region in southeastern Ontario, a forest that is characterized by a unique mixed tree species population (Rowe 1972). The study builds on previous work (see Levin *et al.* 2011) to quantify wood residues from sawlogs allocated to mills in Bancroft and the surrounding area. Sawlogs are suitable in size and quality for the production of lumber. The sawlog wood residue data is used to determine the scale of pellet mill that could be supported by the operations. Potentially available biomass currently designated as pulpwood is also assessed. Pulpwood is lower-quality wood traditionally used to produce paper and demand for this wood stream is declining. An examination of the residue characteristics and energy value is carried out to assess the region's ability to produce pellets that meet ENplus certification standards. ENplus certification is the recognized standard in Europe and complies with European standards for solid biomass. The operating costs of a pellet mill are discussed including consideration for additional processing equipment that may be required depending on the type of available residues.

Methods

Sawmill selection

Sawmills within a 200-km radius centered on Bancroft, Ontario were included in this study. Twelve sawmills are located within the area (Fig. 1). The relatively small size of this circle was selected to minimize transportation costs to a proposed pellet mill located in or near the town. The selected sawmills receive wood from a total of six forest management units (FMUs) in southeastern Ontario: Bancroft-Minden Forest, Nipissing Forest, Ottawa Valley Forest, Algonquin Park Forest, Mazinaw-Lanark Forest, and French-Severn For-

est. The six FMUs were determined by reviewing the forest management plans (FMPs) issued by each management unit; the FMPs are available on the Ontario Forest Management Plan website⁴.

Wood volume supply

The size of wood allocation given to various sawmills are stated in the FMPs issued by the FMUs under consideration. Data collected from the FMPs required for the residue analysis were sawmill name, wood output products (i.e., the breakdown between sawlogs and pulpwood), planned volume over a 5-year period, and species harvested.

To determine each sawmill's yearly cubic residue production, annualized harvest volumes, species, and output products were compiled into a spreadsheet. The sawlog volumes were used to determine available sawmill residue supply and the pulpwood volumes were considered potential fibre sources that could become available due to changes in the local economy.

Sawmill residue quantification

Sawmill residues and products for each mill and species were determined by processing the sawlog volumes through a sawmill residue calculation model developed previously (see Krigstin *et al.* 2012). The inputs for the model were log volume, tree species, proportion of small end diameter, and type of mill (dimension, stud, board, hardwood). To complete the residue calculations the model has a built-in database of tree characteristics for over 400 species including wood densities and bark proportion. The model outputs quantity of lumber, bark, chips, and sawdust in cubic metres and green tonnes. Green tonnes refer to freshly felled wood with a moisture content of typically 50% (Cutshall *et al.* 2012).

Pulpwood quantification

Wood allocated as pulpwood was considered potentially available fibre. The wood volumes were processed through the sawmill residue calculation model (Krigstin *et al.* 2012) and the lumber, residue, and shrinkage volumes were combined. The model was used for this conversion to ensure the same species specific density and moisture values were applied to the fibre as in the sawmill residue determination.

Residue characteristics

Wood residue characteristics were gathered from a forest residue database containing testing results on the physical characterization of mill residue streams in 2012 (S. Krigstin, personal communication, February 25, 2015). Analysis was carried out in the Forest Biomaterial Characterization Lab at the Faculty of Forestry, University of Toronto. The quality parameters of interest for this analysis were moisture content, ash content, gross calorific value, and chlorine. Moisture content and gross calorific value are measures of net energy content; ash content and chlorine concentrations are indicators of boiler efficiency since high levels can lead to boiler fouling (Clarke and Preto 2011).

Moisture content was determined using the oven dry method by placing the samples in a 105°C oven for 24 hours. The procedure was based on ASTM E871-82 and moisture

⁴<http://www.efmp.lrc.gov.on.ca/eFMP/home.do>

Fig. 1. Sawmill location map with residue volumes

content was calculated on a wet and dry basis. Ash content of the sawmill residue samples was determined at 550 °C following the method ASTM D1102 using a muffle furnace. The gross calorific value (higher heating value, HHV) of the samples was determined using a Parr 1108 adiabatic oxygen combustion bomb calorimeter as specified in ASTM D2015-77.

Net calorific value (lower heating value, LHV) was calculated from the gross calorific value according to equation 1.

$$(1) \quad LHV = [HHV_{sample} - \lambda(MC_{od} + 9H)](1 - MC_{wet})$$

Where LHV is the lower heating value in MJ/kg, HHV is the higher heating content of dry fuel, λ is the latent heat of vaporization of water (2.31 MJ/kg at 25 °C), MC_{wet} is the moisture content of fuel on a wet basis, MC_{od} is the moisture content of fuel on a dry basis, H is the mass fraction of hydrogen in dry fuel. MC_{wet} , MC_{od} , and H are expressed as a fraction and assumed to be 0.09, 0.0989, and 0.0591 respectively.

The bark characteristics were collected from the Energy Research Centre for the Netherlands Phyllis database which contains information on the composition of biomass and waste.⁵

⁵<https://www.ecn.nl/phyllis2/>

Pellet composition

The pellet composition for ash, LHV, and chlorine was determined using moisture contents and quality parameters from the databases. The calculated wood residue dry weights for each species were applied to the quality parameters to determine the contribution from each species. The same process was done for the bark proportion. The bark and wood values were combined for each species, maintaining the residue ratios. Composition of the final pellet was determined by combining all species proportions to get the final ash, LHV, and chlorine values.

Results and discussion

Sawmill residues

The twelve sawmills in the study produced 230 340 green tonnes of residue in the form of shavings, chips, sawdust, and bark. Residue breakdown by species (Fig. 2.) indicates that sugar maple and white pine are the two most common species in the study area. Analysis of annual residues for each sawmill (Fig. 3.) suggests that four of the mills provide the bulk of the residues, with the largest generating just over 65 000 green tonnes of residue per year.

Fig. 2. Annual sawmill residues for each tree species from the 12 sawmills

Pulpwood volume

Wood allocated as pulpwood represents 173 612 m³ per year in the case study area. Processing the wood through the model has identified 168 389 green tonnes of potential biomass (Fig. 4). This wood is currently allocated but has been quantified to illustrate the biomass potential in the area.

Pellet quality

ENplus certification is a recognized pellet standard in Europe (EPC 2013). Certification complies with the European standards for solid biomass introduced in 2011. The certification system aims to ensure wood pellets for heating and CHP up to 1 MW output power in residential, commercial and public buildings are of constant quality (EPC 2013). There are currently twelve countries with national pellet associations that license ENplus pellets⁶. The Wood Pellet Association of Canada is the National Licensor for the ENplusTM wood pellet certification system in Canada. The ENplus certification covers three pellet quality classes with different demands on the raw material and wood pellet characteristics. The specifications (Table 1) are in line with the International Standard Organization (ISO) solid biofuel specifications ISO 17225.

⁶<http://www.enplus-pellets.eu/production/certification-procedure/>

Sawmill residue pellet quality

The properties of wood pellets made from the sawmill residue were calculated to determine if they would meet the ENplus quality standards. By applying the moisture contents from the database there would be 152 262 dry tonnes of residue. In this case study, the pellets made out of a wood/bark blend met the requirements for A2 pellets for industrial use (Table 2). The cost of sawmill residues ranges from US \$7.8–46.8/dry tonne, therefore the annual cost to purchase the available residue would range from US \$1.2–\$7.1 million (Roser 2013).

Pulpwood pellet quality

The properties of wood pellets made from pulpwood were calculated to determine if they would pass the quality standards. By applying the moisture contents from the database there would be 112 515 dry tonnes of residue. In this case study, the pellets made out of a wood/bark blend met the requirements for A2 pellets for commercial and residential use (Table 2).

Properties of pellets made with bark

It is important to consider the impact the addition of bark would have on pellet quality since traditional pellets do not use bark. Bark generally has higher ash content and high amounts of nitrogen and sulphur which can lead to problems

Fig. 3. Annual wood residues for each sawmill

with nitrogen oxides and sulphur dioxide emissions during combustion. Bark also has a higher lignin content which contributes to a higher calorific value. A study analyzing the effect of different bark concentrations of Scots pine pellets (Filbakk *et al.* 2011) found that bark composition up to 30% would not have an effect on the quality characteristics of the pellets. In this southeastern Ontario case study, bark accounts for 20.5% of sawmill residues and 14.5% of pulpwood. Pellets made purely out of bark would have a higher ash content which would place them in a lower quality class. Blending the bark with wood residue produces a higher quality pellet compared to pellets made only with bark and utilizes the full potential of biomass in the region (Table 2).

Optimal pellet mill size

A 2009 report investigating renewable energy opportunities in southeastern Ontario forests prepared by the Opeongo Forestry Service concluded that pellet mills with an annual production rate of 60 000 to 100 000 tonnes with nearby supplies of residues were considered optimal. The report stated that a 60 000 tonne plant could be operated with a manageable group of five people per shift, and could be expanded to a maximum annual production of 100 000 tonnes. In this configuration, it is not possible to increase capital efficiency of the pellet plant by expanding beyond 100 000 tonnes, as fur-

ther expansion would require additional dryers and refining equipment which would increase capital costs.

Research has shown that with a higher plant capacity the operating costs decrease considerably more than the capital cost of the plant due to the increase in annual pellet production rate. Mani *et al.* (2006) concluded that at an annual production rate of 45 000 tonnes (6 t/hour), the pellet production cost was US \$51 per tonne, while at an annual production rate of more than 75 000 tonnes (10 t/hour) the cost decreased to roughly US \$40 per tonne. Assuming a pellet plant in the Bancroft region had an annual production of 100 000 tonnes, and operated 24 hours a day six days a week, the hourly production rate would be 13.35 tonnes (Table 3), which is well above the recommended 10 tonnes/hour required to decrease production costs.

This study has identified 183 140 green tonnes of sawmill residue in the form of chips, sawdust, and shavings. This number increases to 230 340 green tonnes when bark is included. A wood pellet mill with an annual capacity of 100 000 tonnes is estimated to require 150 750 tonnes of green sawdust with 40% moisture content (Hoque *et al.* 2006). This indicates that, including bark, there is 1.5 times as much feedstock required for a 100 000 tonne/year pellet plant in the Bancroft area.

Fig. 4. Annual pulpwood allocation for each tree species

Table 1. ENplus pellet quality classes

Pellet Type	A1	A2	B
Material	Stemwood, chemically untreated residues	Whole trees without roots, stemwood, logging residues, chemically untreated residues	By-products and residues from wood processing industry
Typical Applications	Private household boilers or stoves	Use in larger installations	Larger industrial heating plants
MC (wt.% wet)	–	<10	–
Ash Content (wt.% dry)	CR: ≤0.7 IU: ≤1	CR: ≤1.5 IU: ≤1.5	CR: ≤3 IU: ≤5
Net Calorific Value (MJ/kg)	CR: ≥16.5 IU: ≥16.5	CR: ≥16.3 IU: ≥16	CR: ≥16 IU: ≥15.5
Bulk Density (kg/m ³)	–	≥600	–
Chlorine (wt.% dry)	CR: ≤0.02 IU: ≤0.05	CR: ≤0.02 IU: ≤0.05	CR: ≤0.03 IU: ≤0.05

CR: Commercial and residential
IU: Industrial use

Table 2. Properties of wood pellets made from sawmill residue and pulpwood

		Sawmill Residue			Pulpwood		
		wood	bark	wood and bark	wood	bark	wood and bark
Mass	green tonnes	183 142	47 198	230 340	146 539	24 924	171 463
Mass	dry tonnes	117 129	35 134	152 262	96 093	18 403	114 496
Ash	%	0.712	3.187	1.284	0.713	3.728	1.197
Net Calorific Value	MJ/kg	17.181	18.640	17.621	16.964	18.087	17.144
Chlorine	%	0.021	0.026	0.022	0.013	0.036	0.017

Table 3. Hourly pellet production rate calculation

Daily operation	hour/day	24
Weekly operation	day/week	6
Annual operation	hours/year	7488
Annual pellet production	tonne/year	100 000
Hourly pellet production	tonne/hour	13.35

Residue pre-treatment**Milling wood chips**

Wood chips account for 60% of sawmill wood residues in this study and incorporating that material into wood pellets is one means to optimize residue use. Extra costs are associated with processing wood chips since the chips must be processed through a hammer mill equipped with a screen size of 3.2 to 6.4 mm to reduce them to a size suitable for pelleting. In addition to extra equipment and fuel costs, hammer mills can have high repair and maintenance costs due to wear and tear on the equipment that can add up to 10% of the purchase cost compared to 2% for other equipment in the pellet production plant (Mani *et al.* 2006). Two studies published by Hoque *et al.* (2006) and Mani *et al.* (2006) focused on the economics of producing pellets in North America. Each study analyzed total capital and operating costs of a pellet mill with a defined production rate. The studies show that the additional cost of a hammer mill can range between 0.96%–1.88% of total capital and operating costs of the pellet mill.

Biomass drying

Operating a dryer in the pellet plant is a necessary but costly component as green woodchips are about 50–65% moisture content. While moisture acts as a binding agent in the pellet production process, too much moisture makes the process difficult. Optimal moisture contents vary based on the pelleting temperature, but they typically range from 8–15% (Hoque *et al.* 2006). Mani *et al.* (2006) determined the cost for a drying operation to be 20% of the total capital and operating cost distribution for a pellet plant. Mani *et al.* (2006) investigated the effect of different burner fuel options on the pellet production cost and found the lowest cost option to be wet biomass compared to dry biomass, fuel pellets, and coal.

A reduction in greenhouse gas emissions is another benefit of using biomass for drying. A life cycle assessment carried out on Swedish wood pellet production found that total emis-

sions for pellet production were significantly lower if heat for drying was produced with biomass instead of oil (Hagberg *et al.* 2009).

Supply chain considerations**Truck volume and distance**

Transportation logistics can have a significant impact on the cost of transporting raw materials to the pellet mill. Aman *et al.* (2011) found that a truck with a payload of 33 green tonnes of chips saves 31% of the total delivered cost for the raw material compared to the same truck with a payload of 16 green tonnes. Haul costs are approximately US \$0.18/tonne/km (Aman *et al.* 2011). Therefore it is beneficial to locate the pellet mill close to the residue supply since transportation distance will impact the trucking costs.

Moisture content

Delivering a lower moisture content raw material to the pellet plant is ideal for saving transportation costs and reducing emissions. A life cycle analysis of a Swedish pellet mill determined that approximately 30% of the total emissions come from the transport of raw materials and fuels to the plant and pellets to the consumer (Hagberg *et al.* 2009). Part of the study considered transportation of different materials and the emissions per MJ of pellets. Transportation of wet sawdust had calculated emissions ranging from 0.18–0.93 g CO_{2eq}/MJ pellets, and dry material a range of 0.03–0.86 g CO_{2eq}/MJ (Hagberg *et al.* 2009). Truck load limits are based on the weight of material and since drier materials have a higher energy content it would be optimal to ship drier materials. Freshly felled trees have a moisture content of approximately 50% wet basis, however if left to dry for at least four weeks before processing the moisture content can be reduced to 30–35% through air-drying. The extra drying decreased delivered costs on an energy basis by over 50% for materials with a moisture content decrease from 55% to 30% (Cutshall *et al.* 2012). While air-drying may not be practical for some residues, it does highlight the importance of reducing moisture content. Hoque *et al.* (2006) noted that cost per tonne of transporting chips with 45% and <10% moisture content cost US \$0.31/tonne/km and US \$0.28/tonne/km respectively.

Pulpwood harvesting

Pulpwood has been allocated by the forest management companies to mills as dictated in the FMPs. This case study is exclusively in the Great Lakes-St. Lawrence forest region which is characterized by its unique mixed tree species popu-

lations (Rowe 1972). Partial harvesting systems such as shelterwood and selection system are commonly employed in this region. Both systems bring pulpwood and saw logs to the landing concurrently where they are sorted into their respective product categories. Selection harvesting is used for shade tolerant trees and mimics individual trees dying by insect or disease and wind storms while maintaining the uneven aged composition. Shelterwood harvesting is mainly used in areas containing pines and hardwoods that tolerate partial shade and emulates small periodic ground fires resulting in trees that are mostly the same age (OMNR 2015). The lower quality pulpwood must be removed from harvested areas in order to successfully regenerate the forest and provide access to higher quality wood which sawmills depend upon.

In areas where the pulp and paper industry is no longer vying for the forest resource, forest managers often have a difficult time allocating the harvested pulp and chip wood material to an end-user. If a pellet mill existed within such an area, mill and forest managers might secure a contract for this surplus material. All forest material harvested on Crown land is subject to stumpage and forest renewal fees. For example, poplar has a stumpage fee of US \$0.46/m³ and a forest renewal fee of US \$0.38/m³ (OMNR 2015). The raw material price for pulpwood compared to sawmill residue would be affected by these fees in addition to the cost of transportation from the harvesting site to the mill.

Additional considerations

Residue competition and other sources of biomass

This study has determined that there is enough sawmill residue to support one 100 000 tonne/year pellet mill; however, if more than one pellet mill was to be constructed in the area there will be competition for resources that could drive up the price of sawmill residues.

Currently there are not any operating pellet mills within 400 km of Bancroft (Canadian Biomass 2015). Other possible competition for sawmill residue include mulch, animal bedding, pulp and paper, and panel board (Levin *et al.* 2011). A possible source of fibre competition in southeastern Ontario is Pembroke MDF, a medium-density fibreboard mill in Pembroke which reopened in 2014. Prior to its closure in 2008, the mill used over 300 000 tonnes/year of chips, sawdust, and bark from sawmill sources and remote whole log chipping operations (Opeongo Forestry Services 2009). A biomass electricity generating station would also be a source of competition for mill residues. Ontario Power Generation (OPG) currently has two biomass generating stations in Northern Ontario: Atikokan GS and Thunder Bay GS (OPG 2014). OPG's coal-fired Nanticoke Generating Station, 370 km southwest of Bancroft, ceased operation in 2013 and it was recently confirmed that the generating station would not be converted to biomass (Sonnenberg 2015); therefore, it will not compete for sawmill residues in southeastern Ontario.

It should be noted that we have considered only sawmill residues and allocated pulpwood in this study, as this allowed us to utilize previously developed databases of residue quantification and characterization. Several groups such as the Eastern Ontario Model Forest, Ontario's Ministry of Agriculture, Food and Rural Affairs, and the University of Guelph continue to study various sources of biomass suitable for bioe-

conomy development within this region, including biomass grown on marginal and abandoned agricultural lands. In addition, local initiatives continue to consider and move ahead with projects such as a local CHP plant.

Economic uncertainties

The value of the Canadian dollar has dropped in the past year. In July 2014 the CAD-USD exchange rate was US \$0.94; in July 2015 it was US \$0.78 (Bank of Canada 2015a). As stated by Strauss (2015), the US dollar strengthening against many of the world's currencies means that the cost per tonne of US wood pellets in Euros is increasing. The drop in Canadian currency compared to the US currency may improve the competitiveness of Canadian pellets in the European market relative to US pellets. In the winter 2014-15 Business Outlook Survey from the Bank of Canada, some businesses indicated that the recent depreciation of the dollar should help them to regain market share and boost competitiveness. Additionally, indicators of future sales growth have improved more for firms with international customers than for those selling mainly to domestic markets (Bank of Canada 2015a).

A major driver of economic uncertainty is the price of oil which has fallen 50% in the past two years from a monthly average in January 2014 of US \$ 82.17/barrel WTI to a monthly average in December 2015 of US\$ 48.67/barrel WTI⁷. According to the winter 2014-15 Business Outlook Survey, firms in Eastern and Central Canada are planning to increase their investment spending due to the drop in oil prices (Bank of Canada 2015a). In the spring 2015 Business Outlook Survey, many businesses maintained that lower oil prices, which are driving a weaker Canadian currency as noted above, actually support their business outlook, and that the combined impact of these factors is raising foreign demand for their products (Bank of Canada 2015b). It is important to note that wood pellets, while an energy product, compete primarily with coal (and to a lesser extent natural gas) as a feedstock for electricity and heat generation; these fossil fuels have not seen the same degree of price volatility as oil and furthermore, electricity markets in various EU member states are more stable than the global oil market. Thus, the impact of current economic conditions in Canada on the wood pellet market may prove to be favourable.

Conclusions

Renewable energy policies in Europe have created an opportunity in Canada for pellet production and overseas export. British Columbia has shifted exports to Asia due to increased demand, opening up the market for southeastern Canada to take advantage of Europe's rising demand for wood pellets. This study has identified a sufficient quantity of sawmill residues in the Bancroft area to support a 100 000 tonne/year mill capable of producing pellets that comply with European standards. An analysis of wood currently designated as pulpwood reveals a potential high-quality biomass resource in the area. While this residue supply may become available if the pulp market collapses, a pellet mill would need to secure a contract with forest managers to access the residue. Analyzing

⁷<http://www.nrcan.gc.ca/energy/fuel-prices/crude/4927>

the properties for each species and residue type demonstrated that bark could be blended with wood residue to form good quality pellets that utilize the full biomass potential of wood residues.

While the suitability of wood supply and quality in south-eastern Ontario have been acknowledged, further consideration is required to optimize the economics of a pellet mill operation. Competition for raw materials from other markets or pellet mills could raise the cost and limit availability of residues. However, a steady market for residues could be economically beneficial to a sawmilling industry, which highlights the importance for the pellet mill to secure an agreement with surrounding sawmills. In addition, since transportation costs impact the production costs of wood pellets, the mill should be located in an area that minimizes transportation distance for residues. One suggestion is to locate the mill close to the largest sawmill with a secured residue stream to minimize transportation cost for the raw materials.

Europe's consumption of wood pellets continues to rise above their capacity to manufacture pellets domestically, creating an opportunity for southeastern Ontario to initiate a pellet industry. The region is well-positioned to be successful in this industry given their established forestry sector, skilled workforce, and availability and quality of wood residues.

Acknowledgements

The authors thank Loni Pierce and Kaho Hayashi for their assistance. Financial assistance from the ecoEnergy Innovation Initiative, Natural Resources Canada, is gratefully acknowledged.

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