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Chaire K.-C.-Irving en développement durable

FOREST BIOMASS TO ENERGY ATLAS OF NEW BRUNSWICK

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The present report has been prepared by the K.C. Irving Chair in Sustainable Development of the Université de Moncton. The forest biomass to energy analysis is based on forestry data to determine the total annual potential harvest and potential power and heat capacity for each procurement area. The K.C. Irving Chair in Sustainable Development has executed the analysis such to conform to due diligence as is followed in industry. The K.C. Irving Chair in Sustainable Development ant the Université de Moncton do not assume any responsibility that might result from the usage of the results presented in this report.

EXECUTIVE SUMMARY

The K.C. Irving Chair in Sustainable Development of the Université de Moncton, in partnership with the New Brunswick Department of Energy, produced a forest biomass to energy atlas of New Brunswick. The forest biomass to energy atlas consists of a set of maps presenting the annual forest biomass resource potential and the forest biomass technical power potential for the cogeneration of heat and power in the province of New Brunswick.

Results from the development of the New Brunswick forest biomass to energy atlas show that the total annual potential harvest of forest biomass in the province of New Brunswick is 15,518,829 green metric tonnes (GMT). From this total, 8,955,290 GMT would come from softwood species and 6,563,538 GMT from hardwood species. The highest annual potential harvest is located in the Plaster Rock procurement area and is estimated at 1,646,573 GMT, while the lowest is found in the Tracadie-Sheila procurement area with a total of 240,106 GMT. The provincial average is 912,872 GMT per procurement area, with a standard deviation of 355,457 GMT. Results also indicate that 63% of the total annual potential harvest would come from merchantable wood (9,765,545 GMT), 27% would come from residual forest biomass (4,252,376 GMT), while the remaining 10% would come from the bark (1,500,907 GMT).

For its part, the province's total annual energy potential that would be available from residual forest biomass and bark is approximately 58.4 Petajoules (PJ). Of this total, residual forest biomass would provide 43.2 PJ, while bark would provide 15.2 PJ, respectively.

In terms of electric and thermal power potential, results show that if all the residual forest biomass and bark harvested annually in the province was to be used as fuel input in dedicated CHP plants, a total of 463 MW_e of electricity and 1,111 MW_{th} of thermal heat could be produced. A breakdown of the total annual potential electric and thermal energy by forest biomass type shows that the residual forest biomass could provide 343 MW_e and 823 MW_{th}, while the bark could provide 120 MW_e and 288 MW_{th}.

Finally, the New Brunswick forest biomass to energy atlas shows that the province of New Brunswick's forest biomass resource has a good potential for the cogeneration of heat and power in industrial-sized forest biomass-fired combined heat and power (CHP) plants. This New Brunswick renewable resource should be developed not only for its environmental benefits and attributes, but also for the social and economic benefits of the residents of the province.

SOMMAIRE EXECUTIF

La Chaire K.-C.-Irving en développement durable de l'Université de Moncton, en partenariat avec le Ministère de l'énergie du Nouveau-Brunswick, a développé un atlas de la ressource énergétique de la biomasse forestière au Nouveau-Brunswick. L'atlas de la ressource énergétique de la biomasse forestière est constitué d'un ensemble de cartes représentant la ressource annuelle potentielle en biomasse forestière ainsi que le potentiel de la puissance technique de la biomasse forestière pour la cogénération d'électricité et de chaleur dans des centrales industrielles de cogénération (Combined Heat and Power, CHP).

Les résultats du développement de l'atlas de la ressource énergétique de la biomasse forestière du Nouveau-Brunswick démontrent que la récolte annuelle totale potentielle de la biomasse forestière dans la province du Nouveau-Brunswick est de 15 518 829 tonnes métriques vertes (T.M.V.). De ce total, 8 955 290 T.M.V. proviennent d'espèces de bois mous, tandis que 6 563 538 T.M.V. proviennent d'espèces de bois de feuillus. La récolte annuelle potentielle la plus élevée, estimée à 1 646 573 T.M.V., se retrouve dans l'aire d'approvisionnement de Plaster Rock tandis que la récolte annuelle potentielle la plus faible, estimée à 240 106 T.M.V., se retrouve dans l'aire d'approvisionnement de Tracadie-Sheila. La moyenne provinciale est de 912 872 T.M.V. par aire d'approvisionnement avec un écart-type de 355 457 T.M.V. Les résultats indiquent que 63% de la récolte annuelle totale potentielle proviendrait du bois marchand (9 765 545 T.M.V.), 27% proviendrait de la biomasse forestière résiduelle (4 252 376 T.M.V.), tandis que 10% proviendrait de l'écorce (1 500 907 T.M.V.).

Pour sa part, le potentiel énergétique annuel qui serait disponible à partir de la biomasse forestière résiduelle et de l'écorce au niveau de la province est d'environ 58,4 pétajoules (PJ). De ce total, 43,2 PJ proviendrait de la biomasse forestière résiduelle et l'écorce contribueraient 15,2 PJ.

En termes de potentiel électrique et de potentiel thermique, les résultats montrent que si toute la biomasse forestière résiduelle et l'écorce récoltées annuellement dans la province seraient utilisées comme combustible dans des centrales de CHP, un total de 463 MW_e d'électricité et de 1 111 MW_{th} d'énergie thermique pourrait être généré à partir de ces centrales. La répartition de l'énergie électrique et thermique annuelle potentielle par type de biomasse forestière montre que la biomasse forestière résiduelle pourrait fournir 343 MW_e et 823 MW_{th}, tandis que l'écorce pourrait fournir 120 MW_e et 288 MW_{th}.

Enfin, l'atlas de la ressource énergétique de la biomasse forestière du Nouveau-Brunswick démontre que la province du Nouveau-Brunswick est dotée d'une bonne ressource renouvelable qui doit être développée non seulement pour ses bénéfices et attributs environnementaux, mais aussi pour les bénéfices sociaux et économiques des citoyens et citoyennes du Nouveau-Brunswick.

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CONTEXT

Bioenergy, a form of renewable energy, typically offers constant or controllable output and has significant greenhouse gas (GHG) mitigation potential provided that the biomass resources are developed sustainably and that efficient bioenergy systems are used [1]. For these reasons, forest biomass has been receiving increasing attention over the past decade in jurisdictions having a large forest resource.

Several technological pathways can be used to exploit forest biomass as usable energy; of these, because of its high energy efficiency, the conversion of forest biomass in cogeneration plants for the combined generation of heat and power (CHP) is currently considered to be one of the best options [2].

To this end, the K.C. Irving Chair in Sustainable Development of the Université de Moncton, in partnership with the New Brunswick Department of Energy, has developed a forest biomass to energy atlas for the province of New Brunswick using advanced mapping tools and forest inventory data. These maps form a tool to facilitate the initial site survey for possible CHP sites. Furthermore, because the maps are of public domain, the development of these maps provide a mean to inform the general public, communities, industry, and the business sector in regards to the forest biomass resource in their area.

Thus, the objective of the project is to determine the forest biomass technical power potential for the cogeneration of heat and power in New Brunswick. The forest biomass to energy atlas consists of a set of maps presenting the annual forest biomass resource potential and the forest biomass technical power potential for the cogeneration of heat and power throughout the province of New Brunswick.

This report presents the methodology, the input data, the results and the data analysis of this project.

FORESTRY IN NEW BRUNSWICK

In New Brunswick, forests cover nearly 85% of the landscape, with roughly 6.0 million hectares (14.8 million acres) being productive forests [3]. Because of this important forest resource, forestry plays an important role in the provincial economy. With more than 16,500 persons directly working in forestry related jobs, the forestry sector produces 30% of the total manufacturing output of the province, with the forest sector being the largest in New Brunswick [4].

Under the Canadian Forest Classification System, most of the forest lands in New Brunswick belongs to the Acadian forest region with red spruce (*Picea rubens Sarg*), balsam fir (*Abies balsamea* (*L.*) *Mill*), maples (*Acer L.*) and yellow birch (*Betula alleghaniensis Britton*) being the predominant tree species [5]. Small sections of the Boreal and Great Lakes-St. Lawrence forest regions can also be found in the northwestern part of the province.

As for land ownership, the New Brunswick forest lands can be separated into four main categories: Crown Land, Private Woodlots, Industrial Freeholds and Federal Land (Figure 1). The distribution of these categories, based on their area of productive forest lands, is: 51% Crown Land, 29% Private Woodlots, 18% Industrial Freehold and 2% Federal Land. Since each category has its own distinctions and particularities in terms of how they are managed, a good understanding of these differences is essential when trying to determine the potential supply of forest biomass.

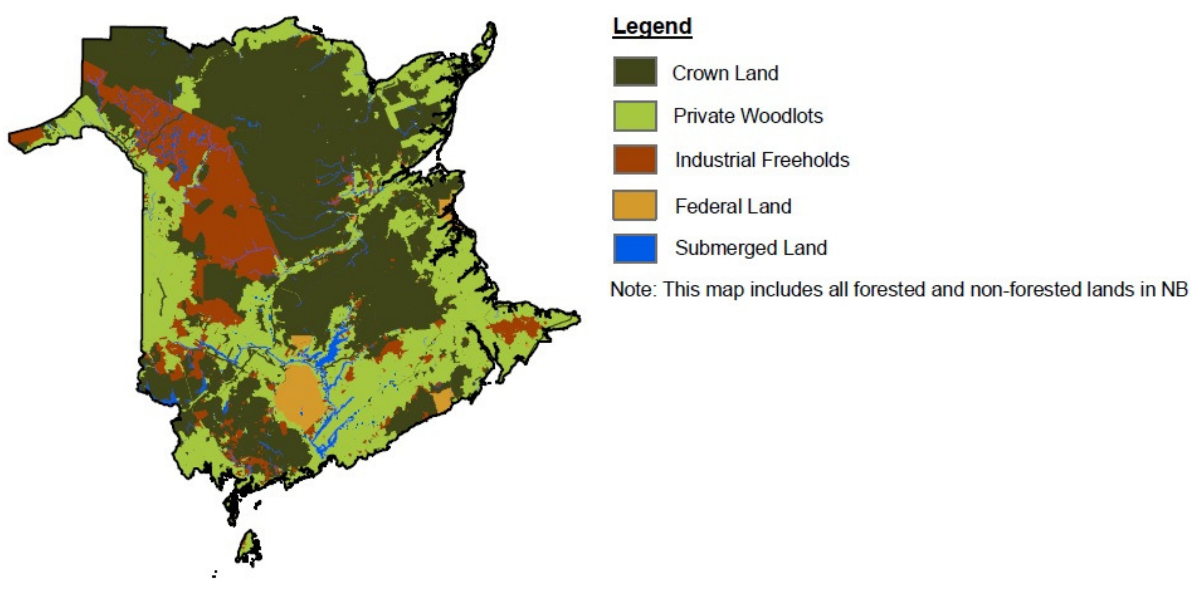

Figure 1: Major land ownership in the province of New Brunswick (forested and non-forested lands).

For its part, Crown Land represents the public forest lands owned by the citizens of the province of New Brunswick. They are administered by the Government of New Brunswick via the Department of Natural Resources. For management purposes, publicly owned forest lands are divided into six Crown Timber Licenses, managed individually and therefore each has its own Annual Allowable Cut (AAC).

For their parts, Private Woodlots are generally small privately owned forest lands that are used for a variety of purposes. These do not include large Industrial Freehold forest lands. In the province of New Brunswick, there are approximately 42,000 private woodlot owners that share almost 1.7 million hectares (4.2 million acres) of productive forest lands [6]. In order to represent their interests to the government and to the local mills who purchase their wood, the New Brunswick woodlot owners have established seven regional associations, called Forest Products Marketing Boards, covering the entire province.

In the same vein, Industrial Freeholds include forest lands generally owned by large forest-based companies. One of the main objective pursued by these companies is the production of timber through intense silviculture and forest management activities. An Industrial Freehold owner is responsible for the development of a forest management plan covering his area of ownership. Currently, there are five major Industrial Freeholds in the province of New Brunswick.

Finally, Federal Land represents the land owned by the Government of Canada, including national parks, conservation areas, military base, etc. In New Brunswick, the only forest land owned by the federal government that can be harvested for its timber on a commercial basis is located in the Canadian Forces Base Gagetown. Although production of timber is not the main objective of the military base, wood supply analyses are conducted at 10 year intervals and harvesting operations occur on an annual basis.

METHODOLOGY

The framework of this study follows three main steps. The first step consists in determining potential CHP plant locations as well as their corresponding procurement areas and transportation zones. In a second step, amounts of available forest biomass (merchantable wood, residual forest biomass and bark) are estimated for all land ownerships and these amounts are allotted to their respective procurement areas. Finally, based on the available quantities of forest biomass that can be harvested annually for each procurement area, the amount of heat and power that could be generated from this forest biomass in potential CHP plants is estimated.

Potential CHP Plant Locations, Procurement Areas and Transportation Zones

When assessing the technical power potential of forest biomass for the cogeneration of heat and power in dedicated forest biomass-fired CHP plants, location is important, mainly for two reasons: (i) to minimize the cost of transporting the forest biomass (money and carbon) and (ii) to maximize the utilisation of the residual heat. Because transportation cost is a primary concern in planning new forest biomass-fired CHP plants, many studies have been made with the objective of optimizing the location of plants [7, 8]. However, in a study performed by Schimdt *et al*. [9] to assess CHP potential, a mixed integer programming model that optimizes location of bioenergy plants not only considered the spatial distribution of forest biomass supply and costs resulting from forest biomass transportation but also took into consideration the spatial distribution of heat demands. The model was applied to assess CHP potentials in Austria and results have demonstrated that the spatial distribution of heat demands has a significant impact on CHP production. Optimal locations for plants are mainly concentrated around bigger cities because heat distribution in district heating networks is cost effective. Their study also indicated that the distance to the forest biomass supply and resulting forest biomass transportation costs are less important for the choice of the optimal location. Having a use for the residual heat is thus paramount in CHP production and will not only make the plant more efficient, it will also make it more economical.

Although no mathematical model to optimize locations is used in this study, selection of potential suitable CHP sites is based on specific criteria. First, the cities, towns and villages of the province of New Brunswick were identified because of their potential use of residual heat. Secondly, localities housing a wood products processing facility (pulp & paper mill, sawmill or other wood-based facilities) were identified. By being responsible for the harvesting, transportation and processing of the wood resource in New Brunswick, these localities have developed a skilled labor, a local know-how and have the infrastructure necessary to utilize this resource. These localities thus represent prime locations when considering the use of forest biomass for the cogeneration of heat and power in dedicated CHP plants. Further, existing facilities in the province using wood-based fuel to generate heat and/or power were indentified. For its part, the network of transmission lines was taken into consideration in order to reduce the potential costs of plant integration to the electricity grid.

As for the number of potential forest biomass-fired CHP plants, similar studies done in Portugal [10] and in the United-States [11] had procurement areas of wood-based CHP plants at around 3,800 to 5,000 km^2. Since the province of New Brunswick has a surface area of 72,908 km^2, this suggests that between 15 and 19 industrial-sized CHP plants could potentially be established within its borders. With this in mind and using the four criteria mentioned previously, 17 locations were selected for the purpose of this study.

Once the number of CHP plants and their locations have been determined, the next step is to establish their corresponding procurement areas. To this end, and since forest biomass is assumed to be transported by truck from its point of loading to the CHP plants, the road network is used to delimit the procurement areas around each CHP plant location. Furthermore, in order to reduce these transportation costs, procurement areas are delimited by the shortest transportation route possible to each corresponding plant, i.e. the shortest route possible while traveling along various connected roads.

It is also important to mention that the methodologies used to identify the location of potential CHP plants and the boundaries of procurement areas did not take into account the spatial distribution of forest biomass. Spatial distribution of forest biomass is however taken into account at the procurement area level at a later stage, i.e. when determining quantities of forest biomass available in each transportation zones.

For its part, the province of New Brunswick's road network is composed of numerous categories of roads (highways, roads, forest roads, etc.). In this study, public roads of categories Primary (P1), Secondary (P2), Tertiary (P3) and forest roads of categories Primary (F1), Secondary (F2) and Tertiary (F3), were used to establish all procurement areas. For their parts, logging roads classifieds as F4, F5 and F6 categories were not included in the analysis because they are solely built for the extraction of timber within a harvesting area. Furthermore, contrary to forest roads, they are not meant to provide long term adequate passage.

Once the road network has been established, procurement areas are determined around each CHP plant location using geographical information system (GIS) based tool, ESRI's ArcGIS Network Analyst [12]. Figure 2 shows the resulting forest biomass procurement areas for each potential CHP plant location for the province of New Brunswick.

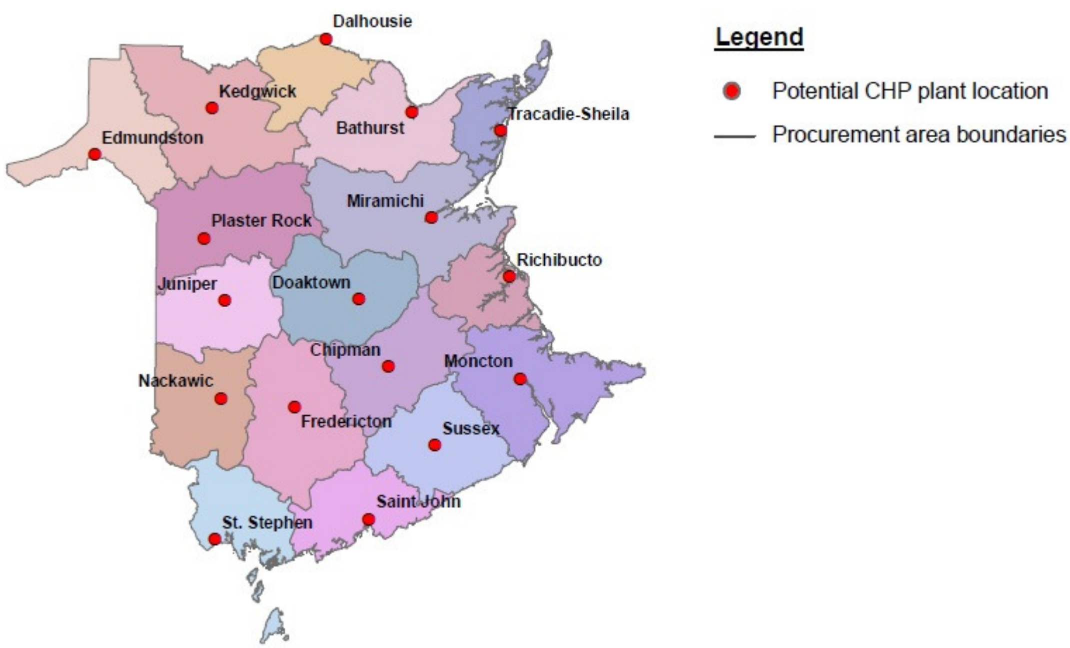

Figure 2: Potential CHP plant locations and their corresponding procurement area.

Many techniques can be used to determine an average cost for transporting forest biomass from its point of harvest to the various CHP plants of the province. One of them is to establish transportation zones within each of the procurement areas. Each procurement area will then be composed of several transportation zones representing a range of distances. The range represents the distance between the point of forest biomass collection and the corresponding CHP plant. In the instance of New Brunswick, five transportation zones were established, each having a distance range of 25 km (1 to 25 km, 26 to 50 km, 51 to 75 km, 76 to 100 km, and 101 to 125 km). By determining a transportation rate for each of these zones and knowing the amount of forest biomass available within each of them, an average cost of transportation can be determined for each procurement area. Once the number of transportation zones and the desired distance range has been determined, the spatial boundaries of these zones can be located. This is done using the same GIS-based tool, ESRI's ArcGIS Network Analyst, used in the establishment of procurement areas. By using the Service Area option of this tool, the transportation zones of the 17 procurement areas were obtained (Figure 3).

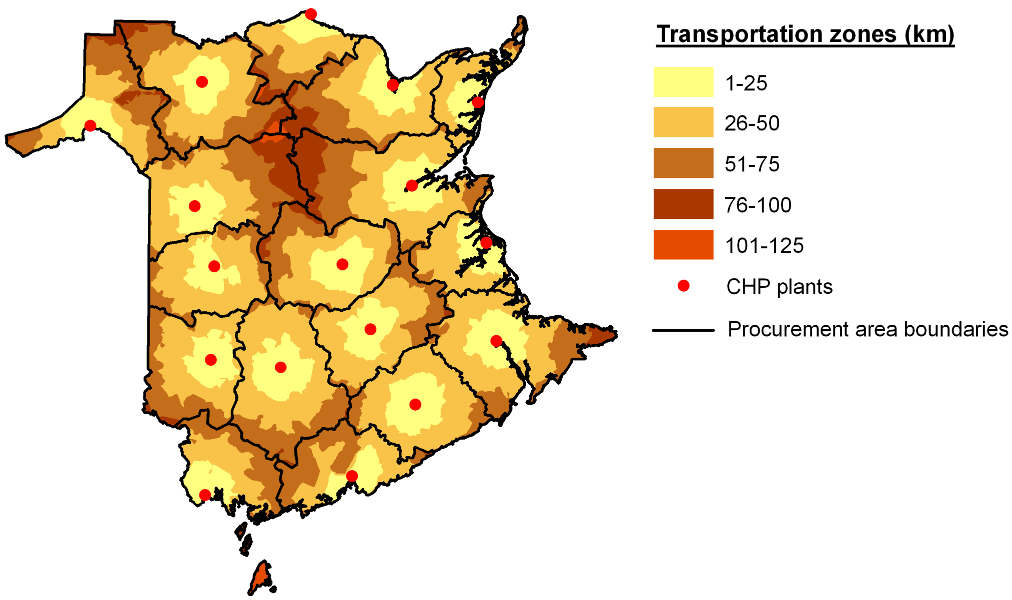

Figure 3: Transportation zones of the procurement areas.

Forest Biomass Categories and Supply

In this study, the total above ground forest biomass is separated into three distinct categories, or components: merchantable wood, residual forest biomass and bark. As can be seen from Table 1, merchantable wood represents the trunk of the tree; residual forest biomass includes branches, foliage and unmerchantable tops; while bark represents the bark of the trunk excluding the bark of the stumps and unmerchantable tops. As specified in the New Brunswick Department of Natural Resources (DNR) Forest Biomass Policy [13], stumps and root systems are not considered as harvestable forest biomass in this study.

For its part, the forest biomass procurement assessment of the merchantable wood is based on the Annual Allowable Cut (AAC) derived from management plans. In traditional forest management practices, the

AAC represents the amount of wood that can be harvested within a one year period and is used as the basis for regulating harvest levels to ensure a sustainable supply of timber [14]. With the help of forest growth models, managers are able to determine the AAC of a forested area while at the same time taking into account environmental, social and economic objectives and constraints.

For the other tree components (i.e. branches, twigs, bark, stump, foliage and unmerchantable tops), their forest biomass availabilities are estimated using data based on forest biomass allometric equations. When forest biomass data are not available, averages of stem wood to residual forest biomass or bark ratios are used. Because different types of land ownership (federal, provincial, private, industrial) have their own distinctions and particularities as how their lands are managed, as well as the type of data available, a combination of different methods are used to estimate the available supply of forest biomass. Once the forest biomass availability is assessed, the technical power potential of combined heat and power cogeneration plants can be determined.

Table 1. Categories of above ground forest biomass.

Category of forest biomass	Associated tree component(s)
Merchantable wood	Trunk of the tree (excludes stump, branches, foliage, unmerchantable top and bark)
Residual forest biomass (or logging residues)	Branches, foliage and unmerchantable top
Bark	Bark of trunk (excludes bark of stump and bark of unmerchantable top)

Furthermore, because hardwood and softwood tree species have their own physiochemical properties (e.g. density and heating value) and since they generally also have distinct physiologies (e.g. crown formation), two separate AAC, one for hardwoods and one for softwoods, are estimated for each land ownership across the province of New Brunswick.

Finally, because the goal of this study is to determine the technical power potential of the available forest biomass for the cogeneration of heat and power under the current forest management systems and practices, all forest biomass is assumed to come from traditional forestry operations. Dedicated forest biomass crops, like short-rotation willow (*Salix spp.*) and poplar (*Populus spp.*) coppice, represent an interesting option to traditional forestry; however, since these methods of producing forest biomass are still largely at an experimental stage in Canada [2], they are not considered in this study.

Once the procurement areas of the potential CHP plants have been established, and all forest land ownerships have been identified, the next step is to determine the AAC for each of the forest biomass categories and allot them to the appropriate procurement areas. Because each type of land ownership has its own distinctions and particularities, the methodology is different for each category of forest biomass and land ownership. Table 2 presents an overview of the methodology developed to estimate the AAC of all forest biomass categories and to allot them to the procurement areas, while details on the methodology can be found in Bouchard *et al.* [15].

Table 2. Overview of the methodology to estimate the AAC of all forest biomass categories and to allot them to the procurement areas.

Land Ownership	**Merchantable wood**		**Residual forest biomass**		**Bark**	
	AAC (SW & HW)	**Allotment of AAC to procurement areas**	**AAC (SW & HW)**	**Allotment of AAC to procurement areas**	**AAC (SW & HW)**	**Allotment of AAC to procurement areas**
Crown Land	2007-2012 Forest Management Plans (General forest) [16]	Ratio of harvest blocks volumes (2012-2032 period) [17]	Department of Natural Resources (NB) [22]	Ratio of harvest blocks residual forest biomass (2012-2032 period) [17]	Ratio between merchantable wood volumes and bark in harvest blocks (2012-2032 period)	
Private Woodlots	2012 Private Forest Task Force Report [6]	Ratio of mature stands volumes [18]	Ratio between merchantable wood volumes and residual forest biomass in mature stands		Ratio between merchantable wood volumes and bark in mature stands	
Federal Land (CFB Gagetown)	2008 CFB Gagetown Wood Supply Analysis [19]	Ratio of mature stands areas (SW, HW, MX covertypes)	Average Crown Land and Private Woodlots ratio between merchantable wood volumes and residual forest biomass in mature stands (SW, HW, MX covertypes)		Average Crown Land and Private Woodlots ratio between merchantable wood volumes and bark in mature stands (SW, HW, MX covertypes)	
Industrial Freehold (with access to inventory data and AAC)	Provided by industry					
Industrial Freehold (without access to inventory data and AAC)	Timber Utilization Survey (2000-2011) [20]	Ratio of stands areas (SW, HW, MX covertypes) [21]	Average Crown Land and Private Woodlots ratio between merchantable wood volumes and residual forest biomass in stands (SW, HW, MX covertypes)		Average Crown Land and Private Woodlots ratio between merchantable wood volumes and bark in stands (SW, HW, MX covertypes)	

Notes: AAC = Annual Allowable Cut; SW = Softwood; HW = Hardwood; MX = Mixedwood.

Conversion of Forest Biomass to Energy (Combined Heat and Power)

Once the quantities of forest biomass are determined and allocated to the appropriate procurement areas, the next step consists in finding the amount of energy that this forest biomass could produce in the form of heat and power if used as input fuel in a dedicated forest biomass combined heat and power plant. In order to achieve this, several steps are performed. In the first instance, softwood and hardwood heating values for all corresponding categories of forest biomass are determined. For this study, softwood and hardwood heating values for all forest biomass components are taken from the FPInnovations FPJoule model [23] and are presented in Table 3. These heating values are based on a wet basis moisture content of 50% and therefore take into account the amount of energy that is consumed during the vaporization of water in the forest biomass; this represents what is commonly referred to as the lower heating value (LHV). Moisture content of biomass fuels varies considerably depending on the type of biomass and biomass storage [24]. The typical wet basis moisture content of freshly-felled wood varies from 45 to 58% [25] with an average of 50% for softwood and hardwood woodchips [24]. In the context of this study, the average moisture content for all forest biomass type is established at 50%.

Table 3. Forest biomass lower heating values based on a wet basis moisture content of 50%.

Category of forest biomass	Softwood (MJ/kg)	Hardwood (MJ/kg)
Merchantable wood	10.25	9.99
Residual forest biomass	10.29	9.99
Bark	10.31	9.81

The next step is to estimate the total energy content of each forest biomass category for all procurement areas:

$$E = 1000\ m\ [\ LHV\ ] \tag{1}$$

where E is the energy content of the forest biomass (MJ), m is the quantity of forest biomass (GMT at 50% moisture content) and LHV is the lower heating value of forest biomass (MJ/kg), while the constant 1000 refers to the conversion of GMT to kilograms.

Once the amount of energy has been determined, the electrical power output of a forest biomass-fired CHP plant is calculated:

$$P_e = (\ E / t\ )\ \eta_e \tag{2}$$

where P_e is the electrical power (MW_e), E is the energy content of the forest biomass (MJ) as per Eq.1, t is the time period (seconds) and η_e is the electrical efficiency of the CHP plant.

For its part, the thermal power output of the same CHP plant is given by:

$$P_{th} = (\ E / t\ )\ \eta_{th} \tag{3}$$

where P_{th} is the thermal power (MW_{th}), E is the energy content of the forest biomass (MJ) as per Eq.1, t is the time period (seconds) and η_{th} is the thermal efficiency of the CHP plant.

Richardson *et al*. [25] describe the efficiency of a CHP plant as "the proportion of the energy contained in the fuel that can be converted to heat and electricity". The fuel properties, the type of boiler and the load factor will also play a role in the efficiency of a given plant.

The electrical efficiency (η_e) of a forest biomass-fired CHP plant can vary between 20 and 30% [24, 25]. In this study, the electrical efficiency is established at 25%. As for the thermal efficiency (η_{th}), modern CHP plants can convert between 55 and 70% of their energy input into heat [25]. For this study, the thermal efficiency is established at 60%.

Finally, the total or overall efficiency of a forest biomass-fired CHP plant is given by the following equation:

$$\eta_{tot} = \eta_e + \eta_{th} \tag{4}$$

where η_{tot} is the total efficiency, η_e is the electrical efficiency and η_{th} is the thermal efficiency. Therefore, in this study, the total efficiency of the dedicated forest biomass-fired CHP plant is established at 85%.

RESULTS

Annual Potential Harvest of Forest Biomass

The findings of the study indicate that the total annual potential harvest of forest biomass in the province of New Brunswick is 15,518,829 GMT, as shown in Table 4. From this total, 8,955,290 GMT would come from softwood species and 6,563,538 GMT from hardwood species. The highest annual potential harvest is located in the Plaster Rock procurement area and is estimated at 1,646,573 GMT, while the lowest is found in the Tracadie-Sheila procurement area with a total of 240,106 GMT (Figure 4). The provincial average is 912,872 GMT per procurement area, with a standard deviation of 355,457 GMT. Results also indicate that 63% of the total annual potential harvest would come from merchantable wood (9,765,545 GMT), 27% would come from residual forest biomass (4,252,376 GMT), while the remaining 10% would come from bark (1,500,907 GMT). For their parts, Table 5 and Figure 5 present the annual potential harvest of residual forest biomass and bark in the province of New Brunswick.

Annual Potential Electric and Thermal Energy

Currently, in New Brunswick, the merchantable wood is already utilized for other purposes, such as the production of pulp and paper, lumber and other wood products. Thus, in light of the non-availability of merchantable wood to be converted into energy in the province of New Brunswick, Tables 6 and 7 present the annual potential electric and thermal energy from residual forest biomass and bark for all procurement areas. From Tables 6 and 7, it can be seen that the province's total annual energy potential that would be available from residual forest biomass and bark is approximately 58.4 Petajoules (PJ). Of this total, residual forest biomass would provide 43.2 PJ, while the bark would provide 15.2 PJ.

In terms of electric and thermal power potential, the findings indicate that if all the residual forest biomass and bark harvested annually in the province was to be used as fuel input in dedicated CHP plants, a total of 463 MW_e of electricity and 1,111 MW_{th} of thermal heat could be produced. A breakdown of the total annual potential electric and thermal energy by forest biomass category shows that the residual forest biomass could provide 343 MW_e and 823 MW_{th}, while the bark could provide 120 MW_e and 288 MW_{th} (Table 6).

As can be seen from Table 7, a dedicated forest biomass-fired CHP plant located in the Plaster Rock procurement area would produce the highest amount of electric and thermal energy with 51 MW_e and 122 MW_{th}, respectively, while a dedicated forest biomass-fired CHP plant located in the Tracadie-Sheila procurement area would produce the lowest amount of energy with 7 MW_e and 17 MW_{th}. The provincial averages in the 17 procurement areas are 27 MW_e and 65 MW_{th}, with standard deviations of 10 MW_e and 25 MW_{th}, respectively.

Figure 6 presents a map of the technical power potential from forest biomass (residual forest biomass and bark) in New Brunswick. It gives a visual overview of the potential power (MW_e) and heat (MW_{th}) capacity for all 17 procurement areas. From Figure 6, it can be seen that most procurement areas located in the northern half of the province have higher technical power potentials. This can be partly attributed to their larger surface area; however, their forest cover is usually higher than their southern counterpart since urban and agricultural development occupies less area in the northern part of the province.

From Figure 6, it can also be seen that procurement areas located along the edges of the province (e.g. Dalhousie, Tracadie-Sheila, Richibucto and Saint John) have smaller technical power potential than those located inland (e.g. Kedgwick, Plaster Rock, Doaktown, Moncton). Procurement areas with centralized potential CHP plants are therefore advantageous and can expect to have a greater forest biomass supply, and with it a greater technical power potential.

Spatial Distribution of Forest Biomass Across the Transportation Zones

The spatial distribution of forest biomass across transportation zones is presented in Table 8. From Table 8, it can be seen that, on a provincial scale and from a cumulative perspective, results indicate that 21.7% of all forest biomass would come from within a 25 km radius of CHP plant sites identified in this study, 72.3% within a 50 km radius, 95.4% within a 75 km radius, 99.5% within a 100 km radius and 100% within a 125 km radius. This information is needed to determine an average cost for delivering forest biomass to the CHP plants.

Validation

A Scientific Advisory Committee composed of experts from various NB Departments who have an extensive knowledge of the topography, land use and climate of New Brunswick, along with experts in the forestry and renewable energy sectors in New Brunswick, were asked to advise the research team and to participate in the validation of the results from the New Brunswick forest biomass to energy atlas. The Scientific Advisory Committee was also asked to validate the methodology and input data used in the development of the project. It was agreed upon by the Scientific Advisory Committee that the methodology and input data used in the development of the project are both sound and reliable. Finally, it was agreed by the Scientific Advisory Committee that the results from the New Brunswick forest biomass to energy atlas were in good relation with their existing knowledge of the territory and of the forestry sector in New Brunswick.

While the Scientific Advisory Committee, along with other stakeholders, were consulted in various parts of this project and in the validation of the results, it remains that the results engage only the authors.

Table 4. Total annual potential harvest of forest biomass (green metric tonnes[1] with wet basis moisture content of 50%).

Procurement area	Merchantable wood[2]			Residual forest biomass[3]			Bark[4]			Total		
	SW[5]	HW[6]	SW + HW	SW	HW	SW + HW	SW	HW	SW + HW	SW	HW	SW + HW
Dalhousie	176,726	189,393	366,119	71,170	72,464	143,634	27,434	26,814	54,248	275,329	288,671	564,001
Bathurst	382,846	221,899	604,745	158,289	91,046	249,335	57,817	32,777	90,594	598,952	345,722	944,674
Tracadie-Sheila	92,962	56,848	149,810	44,057	23,960	68,017	14,136	8,142	22,278	151,155	88,950	240,106
Miramichi	559,581	241,929	801,510	237,552	100,389	337,942	84,324	34,964	119,287	881,457	377,282	1,258,739
Richibucto	176,435	124,859	301,295	86,361	52,008	138,368	29,674	17,501	47,174	292,470	194,368	486,837
Doaktown	415,820	236,076	651,896	169,035	91,505	260,541	65,881	35,515	101,396	650,735	363,097	1,013,832
Moncton	378,857	282,983	661,840	201,352	121,620	322,973	63,322	41,222	104,544	643,531	445,825	1,089,356
Chipman	327,708	175,456	503,164	115,108	62,397	177,056	54,407	26,094	80,501	497,223	263,947	761,170
Sussex	302,602	234,440	537,041	158,336	103,656	261,992	49,333	35,276	84,609	510,271	373,371	883,642
Saint John	219,158	133,413	352,571	111,279	60,960	172,239	34,652	19,228	53,880	365,090	213,601	578,690
St. Stephen	259,671	192,773	452,443	113,954	76,035	189,989	42,050	28,222	70,273	415,675	297,030	712,705
Fredericton	314,910	259,895	574,805	150,713	110,103	260,816	51,016	37,823	88,839	516,639	407,821	924,460
Nackawic	277,586	265,372	542.958	128,326	113,542	241,868	42,748	39,705	82,453	448,660	418,619	867,279
Juniper	299,870	259,746	559,616	153,757	104,136	257,893	46,265	39,928	86,193	499,892	403,810	903,702
Plaster Rock	536,864	476,042	1,012,906	275,698	206,518	482,217	81,992	69,458	151,450	894,555	752,018	1,646,573
Edmundston	355,446	367,703	723,149	174,098	147,498	321,596	56,779	56,368	113,146	586,323	571,569	1,157,892
Kedgwick	467,592	502,084	969,676	185,608	179,843	365,451	74,133	75,909	150,043	727,333	757,837	1,485,170
Provincial	**5,544,635**	**4,220,910**	**9,765,545**	**2,534,694**	**1,717,682**	**4,252,376**	**875,961**	**624,947**	**1,500,907**	**8,955,290**	**6,563,538**	**15,518,829**
Percentage of total	**62%**	**64%**	**63%**	**28%**	**26%**	**27%**	**10%**	**10%**	**10%**	**100%**	**100%**	**100%**

[1]One metric tonne is equal to 1000 kilograms.
[2]Trunk of the tree excluding the stump, the branches, the foliage, the unmerchantable top and the bark.
[3]Includes the branches, the foliage and the unmerchantable top.
[4]Bark of the trunk excluding the bark of the stump and the bark of the unmerchantable top.
[5]Softwood (i.e. Spruce, Fir, Jack Pine, etc.).
[6]Hardwood (i.e. Maple, Birch, Poplar, etc.).

Table 5. Annual potential harvest of residual forest biomass and bark (green metric tonnes[1] with wet basis moisture content of 50%).

Procurement area	Residual forest biomass[2]			Bark[3]			Total residual forest biomass and bark		
	SW[4]	HW[5]	SW + HW	SW	HW	SW + HW	SW	HW	SW + HW
Dalhousie	71,170	72,464	143,634	27,434	26,814	54,248	98,604	99,278	197,882
Bathurst	158,289	91,046	249,335	57,817	32,777	90,594	216,106	123,823	339,929
Tracadie-Sheila	44,057	23,960	68,017	14,136	8,142	22,278	58,193	32,102	90,295
Miramichi	237,552	100,389	337,941	84,324	34,964	119,288	321,876	135,353	457,229
Richibucto	86,361	52,008	138,369	29,674	17,501	47,175	116,035	69,509	185,544
Doaktown	169,035	91,505	260,540	65,881	35,515	101,396	234,916	127,020	361,936
Moncton	201,352	121,620	322,972	63,322	41,222	104,544	264,674	162,842	427,516
Chipman	115,108	62,397	177,055	54,407	26,094	80,501	169,515	88,491	258,006
Sussex	158,336	103,656	261,992	49,333	35,276	84,609	207,669	138,932	346,601
Saint John	111,279	60,960	172,239	34,652	19,228	53,880	145,931	80,188	226,119
St. Stephen	113,954	76,035	189,989	42,050	28,222	70,272	156,004	104,257	260,261
Fredericton	150,713	110,103	260,816	51,016	37,823	88,839	201,729	147,926	349,655
Nackawic	128,326	113,542	241,868	42,748	39,705	82,453	171,074	153,247	324,321
Juniper	153,757	104,136	257,893	46,265	39,928	86,193	200,022	144,064	344,086
Plaster Rock	275,698	206,518	482,216	81,992	69,458	151,450	357,690	275,976	633,666
Edmundston	174,098	147,498	321,596	56,779	56,368	113,147	230,877	203,866	434,743
Kedgwick	185,608	179,843	365,451	74,133	75,909	150,042	259,741	255,752	515,493
Provincial	**2,534,693**	**1,717,680**	**4,252,373**	**875,963**	**624,946**	**1,500,909**	**3,410,656**	**2,342,626**	**5,753,282**
Percentage of total	**74%**	**73%**	**74%**	**26%**	**27%**	**26%**	**100%**	**100%**	**100%**

[1]One metric tonne is equal to 1000 kilograms.
[2]Includes the branches, the foliage and the unmerchantable top.
[3]Bark of the trunk excluding the bark of the stump and the bark of the unmerchantable top.
[4]Softwood (i.e. Spruce, Fir, Jack Pine, etc.).
[5]Hardwood (i.e. Maple, Birch, Poplar, etc.).

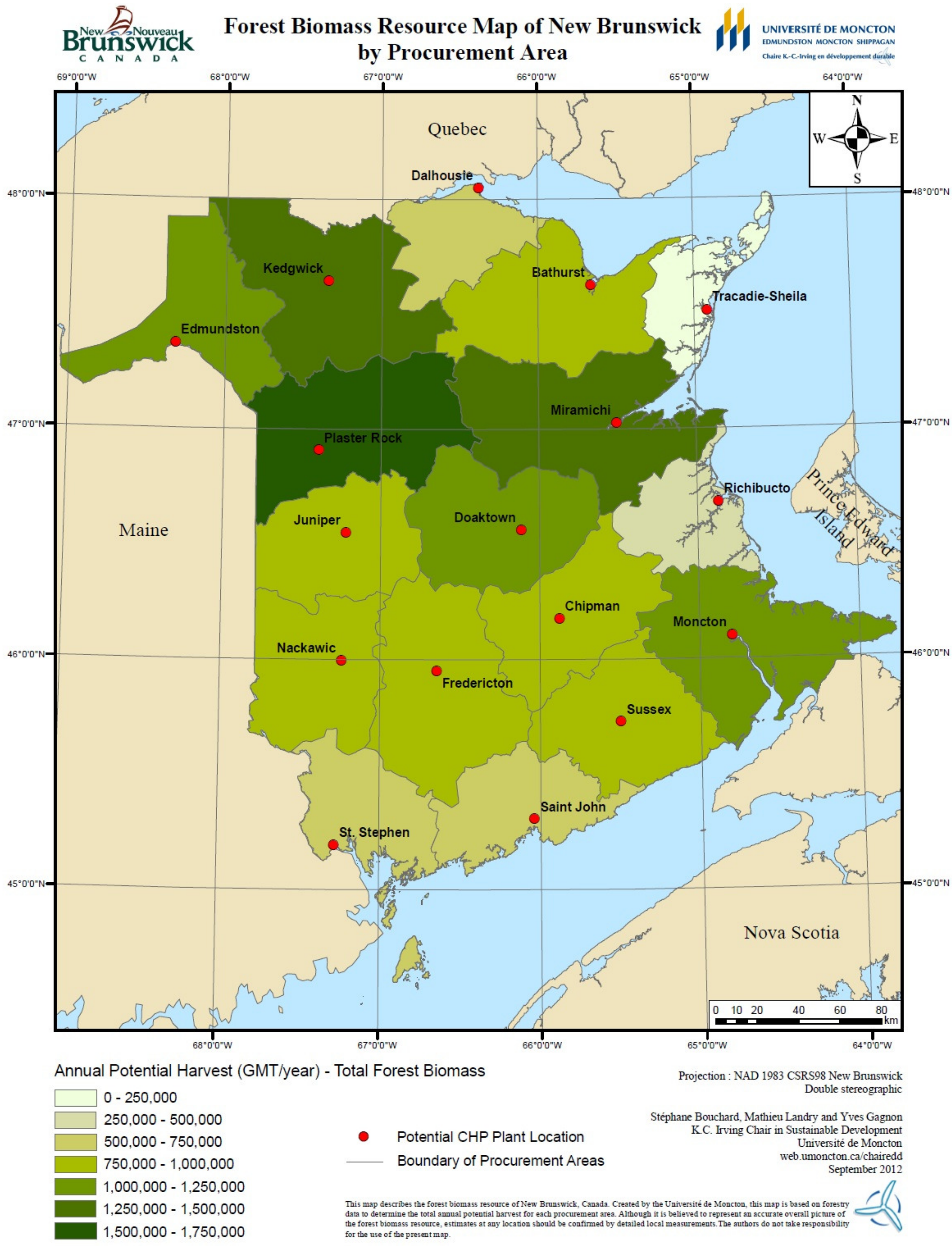

Figure 4: Map of the total annual potential harvest of forest biomass in the province of New Brunswick by procurement area.

Figure 5: Map of the annual potential harvest of forest biomass (residual forest biomass and bark) in the province of New Brunswick by procurement area.

Table 6. Detailed annual potential electric and thermal energy from residual forest biomass and bark for all procurement areas.

Procurement Area	Residual forest biomass[1]									Bark[2]									Total residual forest biomass and bark								
	SW[3]			HW[4]			SW + HW			SW			HW			SW + HW			SW			HW			SW + HW		
	Energy[5] (PJ)[8]	Power[6] (MW_e)	Heat[7] (MW_{th})	Energy (PJ)	Power (MW_e)	Heat (MW_{th})	Energy (PJ)	Power (MW_e)	Heat (MW_{th})	Energy (PJ)	Power (MW_e)	Heat (MW_{th})	Energy (PJ)	Power (MW_e)	Heat (MW_{th})	Energy (PJ)	Power (MW_e)	Heat (MW_{th})	Energy (PJ)	Power (MW_e)	Heat (MW_{th})	Energy (PJ)	Power (MW_e)	Heat (MW_{th})	Energy (PJ)	Power (MW_e)	Heat (MW_{th})
Dalhousie	0.7	6	14	0.7	6	14	1.5	12	28	0.3	2	5	0.3	2	5	0.5	4	10	1.0	8	19	1.0	8	19	2.0	16	38
Bathurst	1.6	13	31	0.9	7	17	2.5	20	48	0.6	5	11	0.3	3	6	0.9	7	17	2.2	18	42	1.2	10	23	3.4	27	65
Tracadie-Sheila	0.5	4	9	0.2	2	5	0.7	5	13	0.1	1	3	0.1	1	2	0.2	2	4	0.6	5	12	0.3	3	7	0.9	7	17
Miramichi	2.4	19	47	1.0	8	19	3.4	27	66	0.9	7	17	0.3	3	7	1.2	10	23	3.3	26	64	1.3	11	26	4.6	37	89
Richibucto	0.9	7	17	0.5	4	10	1.4	11	27	0.3	2	6	0.2	1	3	0.5	4	9	1.2	9	23	0.7	5	13	1.9	15	36
Doaktown	1.7	14	33	0.9	7	17	2.7	21	50	0.7	5	13	0.3	3	7	1.0	8	20	2.4	19	46	1.2	10	24	3.7	29	70
Moncton	2.1	16	39	1.2	10	23	3.3	26	63	0.7	5	12	0.4	3	8	1.1	8	20	2.8	21	51	1.6	13	31	4.4	34	83
Chipman	1.2	9	23	0.6	5	12	1.8	14	34	0.6	4	11	0.3	2	5	0.8	6	16	1.8	13	34	0.9	7	17	2.6	20	50
Sussex	1.6	13	31	1.0	8	20	2.7	21	51	0.5	4	10	0.3	3	7	0.9	7	16	2.1	17	41	1.3	11	27	3.6	28	67
Saint John	1.1	9	22	0.6	5	12	1.8	14	33	0.4	3	7	0.2	1	4	0.5	4	10	1.5	12	29	0.8	6	16	2.3	18	43
St. Stephen	1.2	9	22	0.8	6	14	1.9	15	37	0.4	3	8	0.3	2	5	0.7	6	14	1.6	12	30	1.1	8	19	2.6	21	51
Fredericton	1.6	12	30	1.1	9	21	2.7	21	50	0.5	4	10	0.4	3	7	0.9	7	17	2.1	16	40	1.5	12	28	3.6	28	67
Nackawic	1.3	10	25	1.1	9	22	2.5	19	47	0.4	3	8	0.4	3	7	0.8	7	16	1.7	13	33	1.5	12	29	3.3	26	63
Juniper	1.6	13	30	1.0	8	20	2.6	21	50	0.5	4	9	0.4	3	7	0.9	7	17	2.1	17	39	1.4	11	27	3.5	28	67
Plaster Rock	2.8	22	54	2.1	16	39	4.9	39	93	0.8	7	16	0.7	5	13	1.5	12	29	3.6	29	70	2.8	21	52	6.4	51	122
Edmundston	1.8	14	34	1.5	12	28	3.3	26	62	0.6	5	11	0.6	4	11	1.1	9	22	2.4	19	45	2.1	16	39	4.4	35	84
Kedgwick	1.9	15	36	18	14	34	3.7	29	71	0.8	6	15	0.7	6	14	1.5	12	29	2.7	21	51	18.7	20	48	5.2	41	100
Provincial	**26.1**	**207**	**496**	**17.2**	**136**	**326**	**43.2**	**343**	**823**	**9.0**	**72**	**172**	**6.1**	**49**	**117**	**15.2**	**120**	**288**	**35.1**	**279**	**668**	**23.3**	**185**	**443**	**58.4**	**463**	**1,111**

[1]Includes the branches, the foliage and the unmerchantable top.
[2]Bark of the trunk excluding the bark of the stump and the bark of the unmerchantable top.
[3]Softwood (i.e. Spruce, Fir, Jack Pine, etc.).
[4]Hardwood (i.e. Maple, Birch, Poplar, etc.).
[5]Energy potential using Lower Heating Values.
[6]Based on an electrical power efficiency of 25%.
[7]Based on a thermal heat efficiency of 60%.
[8]One Petajoule is equal to 10^{15} joules

Table 7. Total annual potential electric and thermal energy from residual forest biomass and bark for all procurement areas.

Procurement area	Total residual forest biomass and bark								
	SW[1]			HW[2]			SW + HW		
	Energy[3] (PJ)[6]	Power[4] (MW$_e$)	Heat[5] (MW$_{th}$)	Energy (PJ)	Power (MW$_e$)	Heat (MW$_{th}$)	Energy (PJ)	Power (MW$_e$)	Heat (MW$_{th}$)
Dalhousie	1.0	8	19	1.0	8	19	2.0	16	38
Bathurst	2.2	18	42	1.2	10	23	3.4	27	65
Tracadie-Sheila	0.6	5	12	0.3	3	7	0.9	7	17
Miramichi	3.3	26	64	1.3	11	26	4.6	37	89
Richibucto	1.2	9	23	0.7	5	13	1.9	15	36
Doaktown	2.4	19	46	1.2	10	24	3.7	29	70
Moncton	2.8	21	51	1.6	13	31	4.4	34	83
Chipman	1.8	13	34	0.9	7	17	2.6	20	50
Sussex	2.1	17	41	1.3	11	27	3.6	28	67
Saint John	1.5	12	29	0.8	6	16	2.3	18	43
St. Stephen	1.6	12	30	1.1	8	19	2.6	21	51
Fredericton	2.1	16	40	1.5	12	28	3.6	28	67
Nackawic	1.7	13	33	1.5	12	29	3.3	26	63
Juniper	2.1	17	39	1.4	11	27	3.5	28	67
Plaster Rock	3.6	29	70	2.8	21	52	6.4	51	122
Edmundston	2.4	19	45	2.1	16	39	4.4	35	84
Kedgwick	2.7	21	51	18.7	20	48	5.2	41	100
Provincial	**35.1**	**279**	**668**	**23.3**	**185**	**443**	**58.4**	**463**	**1,111**

[1]Softwood (i.e. Spruce, Fir, Jack Pine, etc.).
[2]Hardwood (i.e. Maple, Birch, Poplar, etc.).
[3]Energy potential using Lower Heating Values.
[4]Based on an electrical power efficiency of 25%.
[5]Based on a thermal heat efficiency of 60%.
[6]One Petajoule is equal to 10^{15} joules.

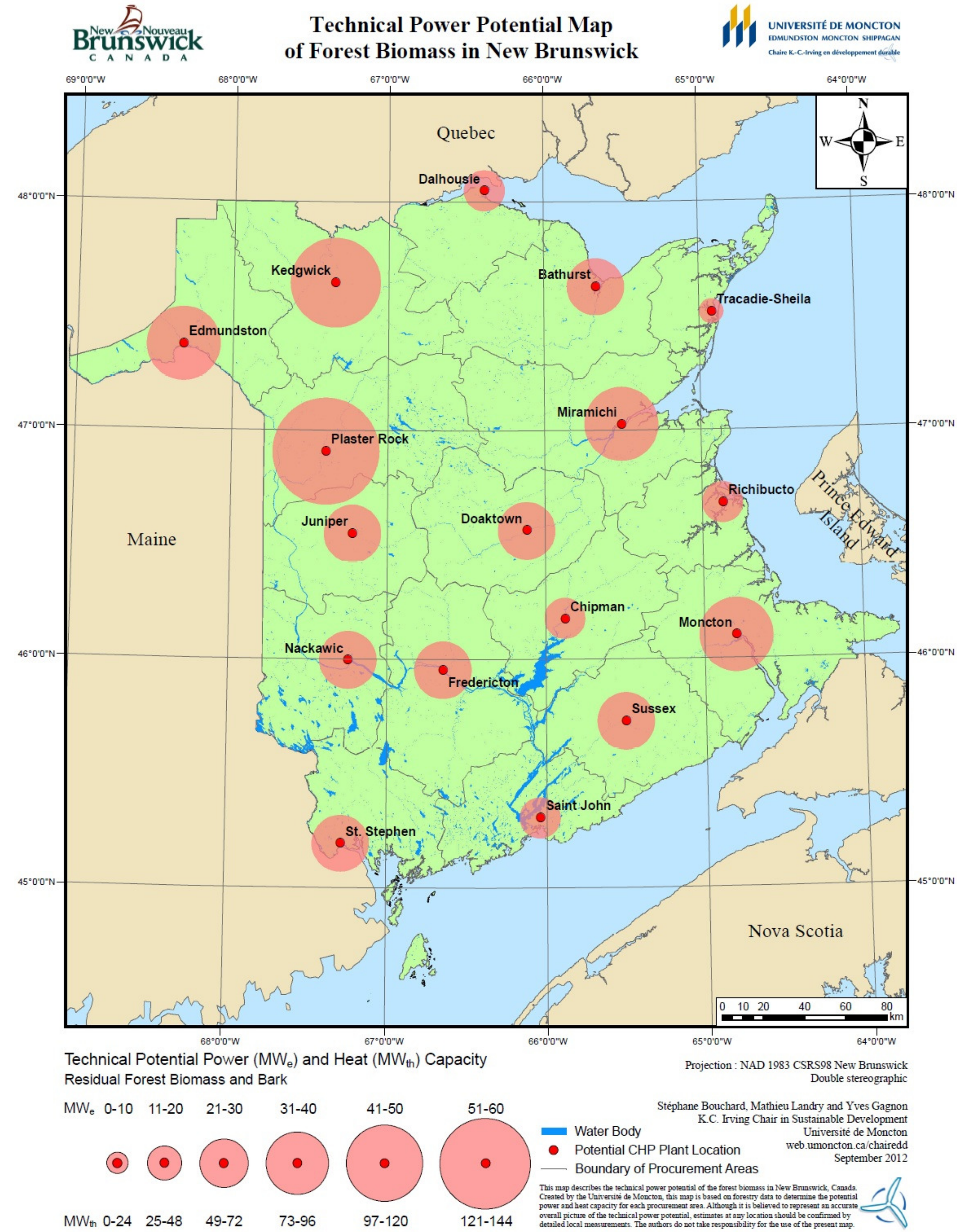

Figure 6: Map of the annual potential electric and thermal power potential from forest biomass (residual forest biomass and bark) for all procurement areas.

Table 8. Spatial distribution of the forest biomass across the transportation zones.

Procurement area	1 to 25 km		26 to 50 km		51 to 75 km		76 to 100 km		101 to 125 km		Total
	GMT	%	GMT	%	GMT	%	GMT	%	GMT	%	
Dalhousie	126,314	22.4	267,781	47.5	109,034	19.3	53,931	9.6	6,942	1.2	564,002
Bathurst	179,197	19.0	454,157	48.1	221,301	23.4	89,023	9.4	994	0.1	944,672
Tracadie-Sheila	59,196	24.7	174,388	72.6	6,481	2.7	42	0.0	0	0.0	240,106
Miramichi	250,819	19.9	537,638	42.7	316,513	25.1	150,476	12.0	3,296	0.3	1,258,743
Richibucto	137,103	28.2	316,149	64.9	33,590	6.9	0	0.0	0	0.0	486,842
Doaktown	246,709	24.3	445,355	43.9	275,905	27.2	45,860	4.5	0	0.0	1,013,828
Moncton	231,523	21.3	633,439	58.1	197,009	18.1	27,370	2.5	0	0.0	1,089,340
Chipman	186,784	24.5	412,812	54.2	159,113	20.9	2,453	0.3	0	0.0	761,162
Sussex	238,438	27.0	573,189	64.9	72,011	8.1	0	0.0	0	0.0	883,638
Saint John	157,603	27.2	263,810	45.6	155,974	27.0	1,307	0.2	0	0.0	578,694
St. Stephen	150,269	21.1	331,025	46.4	163,955	23.0	20,753	2.9	46,707	6.6	712,708
Fredericton	234,005	25.3	495,556	53.6	186,631	20.2	8,262	0.9	0	0.0	924,454
Nackawic	188,656	21.8	445,273	51.3	229,665	26.5	3,383	0.4	308	0.0	867,284
Juniper	173,821	19.2	527,882	58.4	200,285	22.2	1,713	0.2	0	0.0	903,700
Plaster Rock	361,055	21.9	649,232	39.4	484,423	29.4	140,773	8.5	11,093	0.7	1,646,578
Edmundston	230,812	19.9	609,181	52.6	289,439	25.0	28,455	2.5	0	0.0	1,157,886
Kedgwick	218,121	14.7	717,749	48.3	481,791	32.4	66,457	4.5	1,054	0.1	1,485,172
Total (GMT)	**3,370,425**		**7,854,616**		**3,583,118**		**640,256**		**70,395**		**15,518,810**
Percentage of total (%)	**21.7**		**50.6**		**23.1**		**4.1**		**0.5**		**100.0**
Cumulative Total (GMT)	**3,370,425**		**11,225,041**		**14,808,159**		**15,448,415**		**15,518,810**		**15,518,810**
Cumulative Percentage (%)	**21,7**		**72,3**		**95.4**		**99.5**		**100.0**		

GENERAL DISCUSSION OF RESULTS

The methodology proposed in this study is based on forest inventory data, Annual Allowable Cuts, forest biomass equations and forest biomass expansion factors (stem wood to residual forest biomass or bark ratios). The forest biomass procurement assessment of the merchantable stem-wood is based on Annual Allowable Cut while the residual forest biomass and bark categories are estimated using data based on forest biomass allometric equations. When forest biomass data are not available, averages of stem wood to residual forest biomass or bark ratios are used. Because the different types of land ownership (federal, provincial, private, and industrial) in the study area have their own distinctions and particularities as how their lands are managed, as well as the type of data available, a combination of different methods is used to estimate the available supply of forest biomass. These annual potential harvests of forest biomass are then allotted to the procurement area of each potential CHP plants. Once the forest biomass availability is assessed for each procurement area, the technical power potential of CHP plants can be determined. This methodology has been successfully applied to the province of New Brunswick, Canada.

In terms of application, it is assumed that only the residual forest biomass and bark available on an annual basis in the province of New Brunswick, Canada, would be used as input fuel for dedicated industrial-sized CHP plants distributed across the province. Indeed, since a large portion of the merchantable wood is already utilized for other purposes, such as the production of pulp and paper, lumber and other wood products in the province of New Brunswick, it is not foreseen that this forest biomass category would be made available for use as input fuel in forest biomass-fired CHP plants. However, since this merchantable wood will undergo various transformations in wood processing facilities, by-products or mill residues such as wood chips, sawdust, shavings, bark and black/red liquor could possibly become available for use as input fuel in forest biomass-fired CHP plants.

As for the availability of the residual forest biomass, its use has traditionally been limited and most of the residual forest biomass potential of the province has remained untapped. This residual forest biomass, with an estimated potential annual yield of more than 4 million GMT, is therefore viewed as having the most potential for use as input fuel in the development of new dedicated forest biomass-fired CHP plants, with electric and thermal potentials of 343 MW_e and 823 MW_{th}, respectively.

For its part, the bark forest biomass, with an estimated potential annual yield of more than 1.5 million GMT, also has potential for use as input fuel in the development of new dedicated forest biomass-fired CHP plants in the province, with electric and thermal potentials of 120 MW_e and 288 MW_{th}, respectively.

Regarding the generation of energy from forest biomass, results from this study indicate that if all the residual forest biomass and bark potentially available for harvest annually in the province was used as fuel input in dedicated forest biomass-fired CHP plants, a total of 463 MW_e of electricity could be generated. To put this in perspective, this amount of power approximately coincides to approximately one-third of the province electrical base load of nearly 1,500 MW_e [26].

In regards to heat, along with the electrical ouput, a total of nearly 1,111 MW_{th} of thermal heat could be generated by using the residual forest biomass and bark in dedicated forest biomass-fired CHP plants. Assuming an average of 140 m^2 of heating space per household and an average space heating demand of 16,725 kWh [27], this amount of heat is sufficient to supply more than 580,000 households. Since the province of New Brunswick has nearly 300,000 households [28], the amount of heat generated from CHP plants using only residual forest biomass and bark as input fuel would, theoretically, be more than enough to supply the residential space heating demand for the entire province. While this would not be feasible since all households would need to be connected to a district heating system, this data shows the extent and value of the heat that could be generated from forest biomass CHP plants. Additional to residential space heating, thermal heat generated from CHP plants could be utilized to heat industrial, commercial and institutional buildings. Industrial processes requiring large amounts of heat, such as the pulp and paper industry and the food processing industry, could also benefit from residual heat generated from CHP plants.

It is important to note that estimates of availability did not take into account the cost for harvesting and delivering the forest biomass. In reality, certain amounts of forest biomass may not be available because of economical reasons. Also, it is to be noted that because of ecological constraints, this residual forest biomass will likely never be harvested to its theoretical maximum potential.

Another aspect to take into consideration when looking at potential amounts of forest biomass for energy generation is the unknown quantities of non-commercial trees and shrubs. Tree species such as striped maples (*Acer pennsylvanicum*), mountain maples (*Acer spicatum*) and pin cherrys (*Prunus pensylvanica*), as well as shrubs species such as speckeld alders (*Alnus Rugosa*) and willows (Salix spp.), are present in the forests of New Brunswick but are not included in forest inventories. For this reason, the total amount of forest biomass estimated in this project could possibly be slightly greater if these non-commercial species were accounted for. In the same vein, tree species that are included in forest inventories but are not highly commercial, such as eastern hemlock (*Tsuga canadensis*) and larch (*Larix laricina*) would also represent additional forest biomass for energy generation since they are often not included in AAC calculations and are most of the time left standing after harvest. Future studies on forest biomass in New Brunswick would thereby benefit from taking into consideration these non-commercial and less valued tree species.

Regarding the temporal aspect of the study, it is important to note that since the method used in this project is based on Annual Allowable Cuts, the resulting quantities of forest biomass potentially available inevitably represents current conditions. Future AAC levels may fluctuate with changing management objectives, updated forest inventories, latest information from forest development surveys and new forest growth projections. The projected increase in activities occurring in managed forests comparatively to natural forests will also impact the quantities of forest biomass available as well as the distribution of the total above ground forest biomass within each of the forest biomass categories.

In short, the quantity of forest biomass can be assessed relatively precisely when one has access to comprehensive and reliable data; the quantity of this forest biomass readily available on the other hand, is much harder to predict and further detailed studies should be conducted at the procurement area level before considering the development of a new dedicated forest biomass-fired CHP plant.

This study shows that the forest biomass resource in the province of New Brunswick could provide important quantities of energy in the form of heat and electrical power if it was used as input fuel in dedicated forest biomass-fired CHP plants. Generally, in Canada, one of the main challenges in developing and operating a CHP plant is to maximize the use of its residual heat. This allows a plant to run at a higher efficiency and provides a better economic return; finding an end user for the heat is paramount. Identifying strategic locations along with potential heat users is thus important when looking at the development of new forest biomass-fired CHP plants. Future work will include the analysis of various opportunities for the utilization of the heat generated from CHP plants, with a particular emphasis on the economic impact of the various forms of utilization.

In summary, results from this study have shown that the province of New Brunswick's forest biomass resource has a good potential for energy production. Substantial amounts of electrical and thermal power could indeed be generated from this forest biomass if it was used as input fuel for industrial-sized forest biomass-fired combined heat and power (CHP) plants. Taking into account that most of the merchantable wood portion of the forest biomass is already utilized by wood processing facilities, future CHP development should pay particular attention to residual forest biomass and bark since it has remain largely untapped in the province of New Brunswick.

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