ASSESSMENT OF BIOMASS ENERGY RESOURCE POTENTIAL AND OPPORTUNITY

Southend,

Peter Ballantyne Cree Nation

University of Saskatchewan

About CASES

The Community Appropriate Sustainable Energy Security (CASES) Partnership is an international research initiative involving 17 northern and Indigenous communities and public and private sector project partners from Canada, Alaska, Sweden, and Norway.

Hosted by the University of Saskatchewan, the overarching goal of the CASES initiative is to reimagine energy security in northern and Indigenous communities by co-creating and brokering the knowledge, understanding, and capacity to design, implement and manage renewable energy systems that support and enhance social and economic values.

The CASES Partnership facilitates the sharing of experience so that not all communities have to experience the same challenges or recreate solutions, thereby expediting the learning experience and accelerating renewable energy innovation.

Our unique knowledge sharing platform will enhance community capacity by providing best in-class examples and 'how to' instructions for northern and Indigenous communities to pursue community energy planning, assess and prioritize local energy needs, and ensure sustainable transition.

To learn more about CASES, visit our website:

https://renewableenergy.usask.ca/

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INTRODUCTION

To strengthen energy security and contribute to national goals to reduce greenhouse gas emissions, the Community Appropriate Sustainable Energy Security (CASES) initiative at the University of Saskatchewan has partnered with QUEST Canada and Peter Ballantyne Cree Nation (PBCN) to identify and explore opportunities and needs for accelerating community appropriate renewable energy solutions.

PBCN, a First Nations band government, occupies 51,000 km^2 of land in north-east Saskatchewan and consists of eight communities (Denare Beach, Deschambault Lake, Kinoosao, Southend, Prince Albert, Sandy Bay, Southend, and Sturgeon Landing) with a total population of approximately 11,600[1].

Saskatchewan's electricity network is comprised of two grids – a northern grid and a southern grid. The northern grid is characterized by aging infrastructure and outages caused by seasonal storm events (wind, ice), lightning strikes, and wildfire.[1] Except for Kinoosao, all PBCN communities are connected to the Saskatchewan's northern grid, which is owned and operated by SaskPower.[2]

The price of electricity in PBCN communities is the same as for all other non-urban areas of the province.[3] However, communities in northern Saskatchewan are *not* connected to the province's natural gas distribution network,[4] meaning that homes are heated by electricity and woodstoves, and some community buildings by propane. Because of high electricity use for space heating, energy costs are high compared to other parts of the province.

PBCN has expressed interest in exploring community renewable energy options for member communities to reduce power costs and to develop own-source revenue streams from renewable energy projects, with the aim of increasing energy self-reliance, providing new opportunities for the local economy, and combating climate change.

Community renewable energy is defined in this report as energy produced from local renewable resources, whereby the benefits accrue to the community who owns and produces that energy.

Bioenergy is produced in many ways, including from the combustion of 'feedstock' such as slashes, branches, cutoffs, standing and fallen trees, tree bark, and sawdust. There are different types of bioenergy facilities, including those that use feedstock to produce electricity (power), heat, or combined heat and power.

To support PBCN's efforts to strengthen energy security via renewable energy sources, and to ensure more affordable and reliable energy, this project was initiated in collaboration with PBCN to explore the local resource potential for community bioenergy development. Specifically, this report provides an estimation of bioenergy potential based on the bioenergy resources locally available near S. The report is focused on the pre-planning stages of community energy assessment; it does not address the economic feasibility of a bioenergy plant.

SOUTHEND

Southend is located between 56°20´0″N and 103°14´0″W (**Figure 1**), situated in the southern end of Reindeer Lake, with a total population of approximately 1052[5]. The community experience a sub-arctic climate characterized by long, cold winters and short, mild summers. Winter conditions in the community typically last from November to April, and temperatures often drop below freezing with average monthly temperatures ranging from -20 ˚C to -30˚C, with occasional temperatures below -40˚C.[6] Photos of Southend, SK are presented in **Figure 2**.

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[1] Leonhardt et al. (2023). Government instruments for community renewable energy in northern and Indigenous communities. *Energy Policy* https://doi.org/10.1016/j.enpol.2023.113560

[2] SaskPower is a Crown utility with the exclusive rights to supply, transmit, distribute, and sell electricity – with over 157,000 km of transmission and distribution lines.

[3] https://www.saskpower.com/Accounts/Power-Rates/Power-Supply-Rates

[4] SaskEnergy is a Crown corporation and primary distributor of natural gas, serving the central and southern regions of Saskatchewan.

[5] First Nation community profile: Peter Ballantyne Cree Nation (PBCN). https://www.peterballantyne.ca/

[6] Environment and Natural Resources Canada, Weather information, Southend, SK. https://weather.gc.ca/city/pages/sk-55_metric_e.html

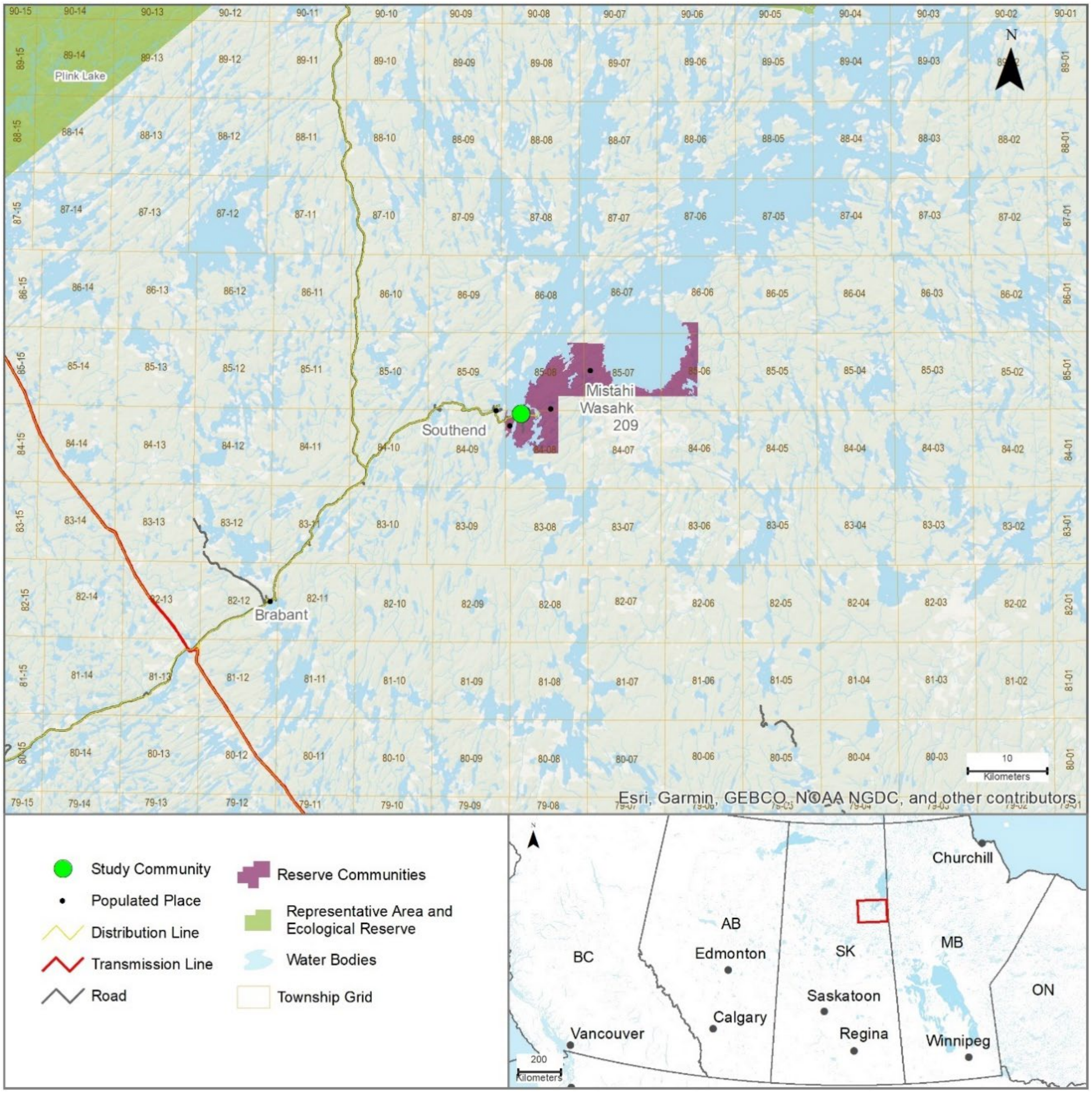

Figure 1: Southend and surrounding area of interest.

Household electricity consumption, and thus household electricity costs, in Southend is high compared to provincial and national averages.[7] This is especially the case during the late fall to spring season. Electricity consumption reports for the community in 2020, for example, show that household electricity consumption is more than twice as high in the winter months when compared to summer. Annual household-level electricity consumption is estimated as 7,886.43 MWh, with maximum consumption reported to be 1,123.81 MWh in the month of December and the lowest at 309.86 MWh in June (Appendix I). Large public and community buildings are heated by propane-fired boilers, and many residential homes use wood stoves; yet electricity remains a primary energy source for space heating.

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[7] Huang et al. 2016. Renewable Energy Prefeasibility Assessment Results of the Peter Ballantyne Cree Nation (PBCN). https://renewableenergy.usask.ca/documents/PBCN%20SaskPower%20Prefeasibility%20Report%202016%20-%20FINAL.pdf

Figure 2: Images of Southend, Saskatchewan, November 2022.

BIOMASS ENERGY RESOURCE ASSESSMENT

Our assessment used geospatial tools and community input to identify biomass resource opportunities and potential within the non-commercial forest zone of the Peter Ballantyne Cree Nation Land Territory, for community bioenergy development at Southend.

There is no standard definition of what is considered 'local' when identifying renewable resources for community energy. Much depends on community and energy context. For example, what is *local* for solar energy development is very different than what might be considered local for harvesting biomass to supply a community bioenergy facility – which is constrained by a host of factors ranging from land tenure to supply costs. For this assessment, we adopted a 65 km boundary from the community to comprise the *local* area for biomass supply. This was tempered by township grid zones for ease of resource estimations, resulting in an assessment area that extends 65 km north, south, west and east.

Assessment focused on the estimation of biomass resources (i.e., forest residues), availability of those resources, preferability in terms of distance from the community, accessibility, and estimations of energy generation potential. The assessment was comprised of 4 core phases (**Figure 3**), and the analysis based on multiple assumptions and scenarios as presented in the report and the supporting Appendix.

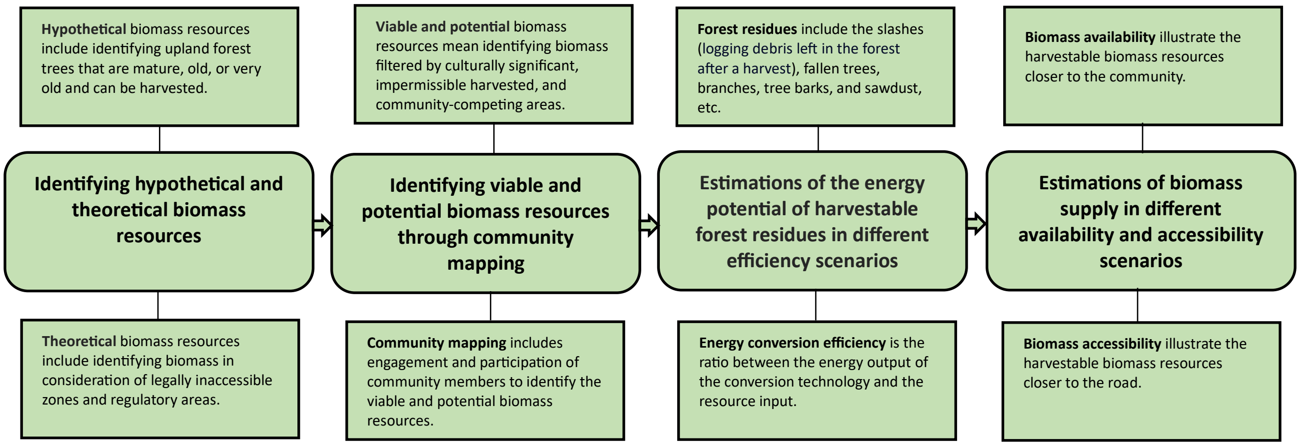

Figure 3: Core phases of biomass resource assessment and estimation of energy generation.

Hypothetical and theoretical biomass resources

The first phase of the assessment was to identify the hypothetical biomass resource (i.e., upland forests) around Southend. This is based on mapping the distribution of forest tree species, mainly white spruce, and jack pine, that are mature (75–125 years), old (126–200 years), and very old (above 200 years).[8] These mature, old, and very old species are harvested commercially by the timber supply companies operating in the boreal region (**Figure 4**).

The hypothetical biomass resource base was then assessed to identify the *theoretical* biomass resource base, which factors into consideration legally inaccessible areas, restricted and regulatory areas, and protected locations. These designated areas were mapped, including their buffers. For example, reserve communities have 200m buffers, representative areas, and ecological reserves a 50m buffer, and transmission lines a 22.5m buffer on either side (Appendix II).

Although these areas contain standing forest, availability of the resource is restricted owing to provincial and/or local regulations that pertain to the management or protection of natural habitats, to the conservation of forested areas from human-related activities to preservation for ecological or recreational purposes, or to the protection of lands around settlement areas. These legally inaccessible zones, restricted and regulatory areas, and protected locations include reserve communities, ecological and representative areas, areas around utilities (i.e., distribution and transmission lines), mining locations or regions, road networks, and permanent and seasonal water bodies (e.g., wetlands, lakes, ponds, rivers, streams).

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[8] Saskatchewan State of the Environment 2019 Technical Report: A Focus on Forest.

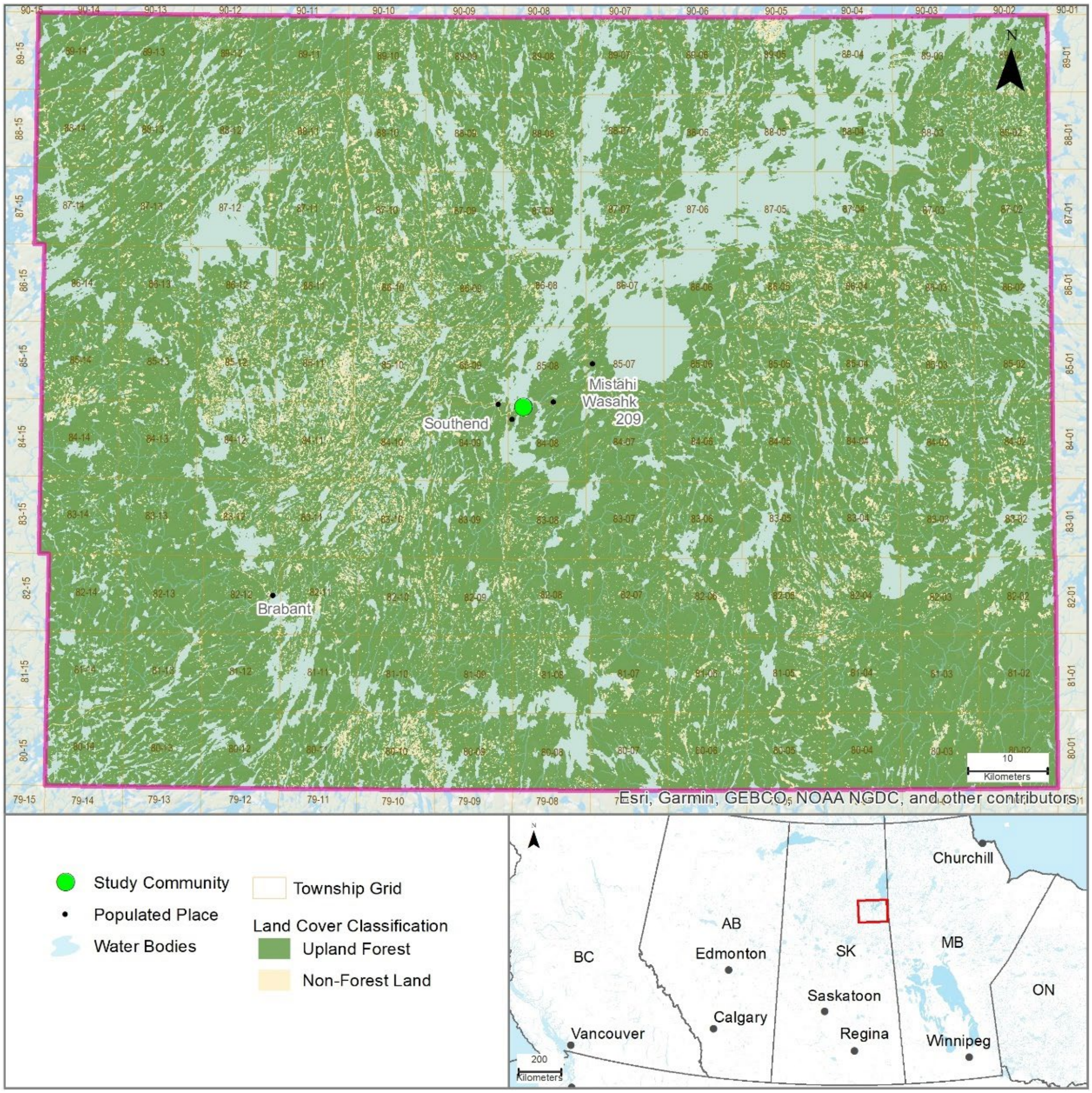

Figure 4: Hypothetical biomass resources around Southend.

The theoretical biomass resource base is comprised of 663,858 ha, within the non-commercial forest zone inside the study area (**Figure 4).** Legally inaccessible areas, restricted and regulatory areas, and protected locations comprise 255,921 ha. Non-forested land within the non-commercial forest zone comprises of 362,083 ha. **Figure 5** shows the theoretical biomass resource base, accounting for the distribution of areas of regulatory concern (legally inaccessible zones, regulatory and restricted areas, and protected locations), harvestable forest trees outside areas of regulatory concern, and non-forest lands within the non-commercial forest zone.

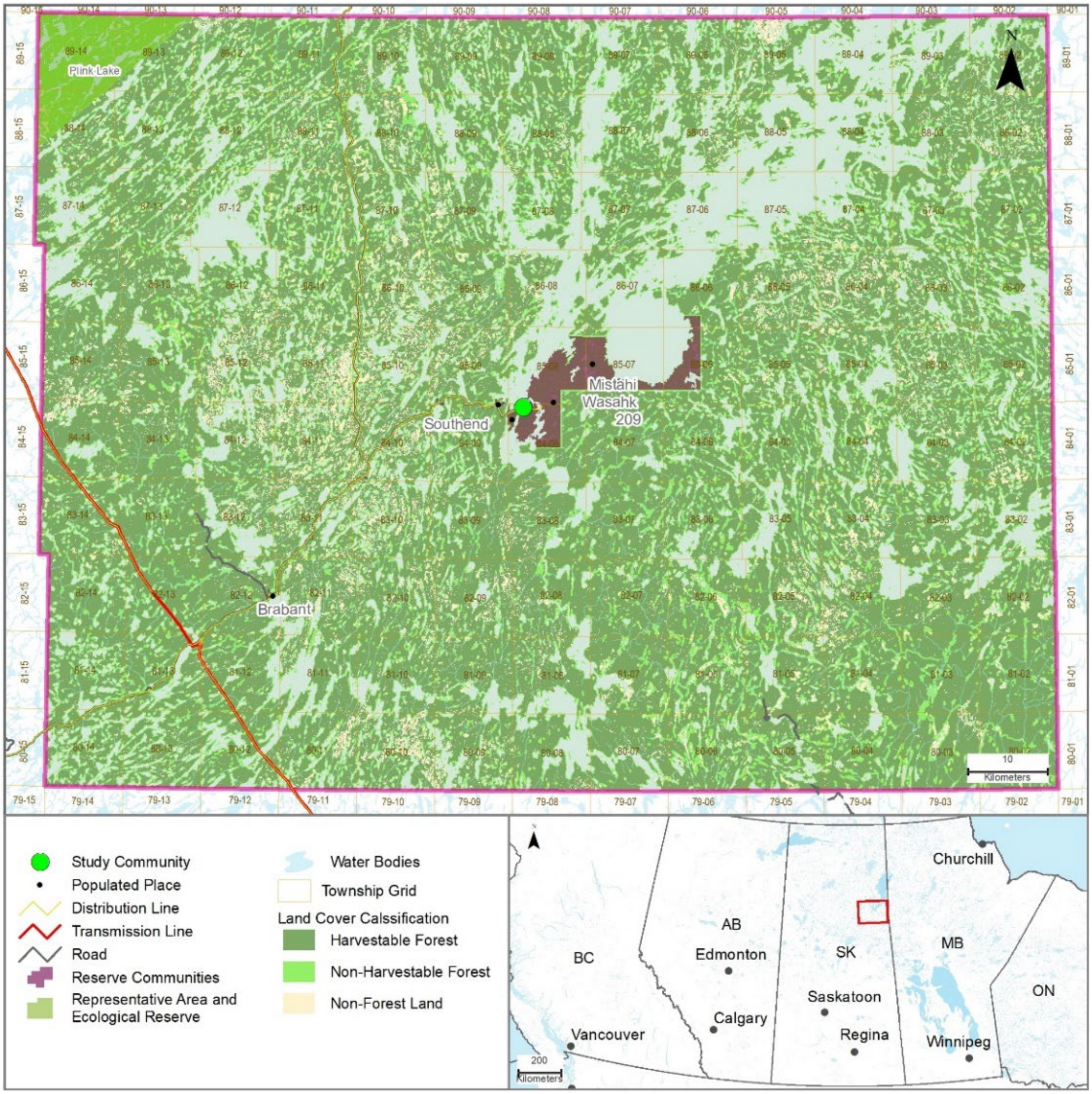

Figure 5: Theoretical biomass resource around Southend.

The theoretical biomass resource base (663,858 ha) was further assessed to estimate the availability of forest residues generated from harvestable forest, outside those areas of regulatory concern. The estimation of forest residue from harvested trees was based on a scenario informed by operations at Cold Lake First Nations, northern Alberta.[9] Estimated values of forest residue generated by the PBCN Local Timber Supplying Company (Mee-Toos) within their operational areas were not available. Data from Cold Lake First Nations was used as the basis to inform the assessment owing to the method of forest harvesting activities (clear-cutting), available annual allowable

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[9] Mansuy, N., Staley, D. and Taheriazad, L., 2020. Woody Biomass Mobilization for Bioenergy in a Constrained Landscape: A Case Study from Cold Lake First Nations in Alberta, Canada. Energies, 13(23), p.6289.

harvestable quota, comparable species within the boreal region, and available pre-feasibility studies from Cold Lake First Nation on forest residue generated from harvestable forest trees for wood-based bioenergy production.

Based on Cold Lake First Nations as a comparator, we assumed a yield per hectare of forest residue generated of 18 odt/ha. This resulted in an estimation of total and annual residue generated from harvestable trees from the theoretical resource base in the Southend study area to be 11,949,446 odt/ha and 143,393 odt/ha, respectively (Table 1). Note that 18 odt/ha is higher than the average residue estimated from managed forest areas across Canada, estimated at 14 odt/ha[10] (Appendix III).

Table 1. Estimation of forest residue in Southend study area

Forest Harvest Parameter	Value
Residue from clear-cut harvest (odt/ha)*	18
Annual harvested rate (%)*	1.2
Total residue from harvestable forest trees (odt/ha)	11,949,446
Annual residue from harvestable forest trees (odt/ha)	143,393

**odt/ha = oven dry tons per hectare. Estimated forest residue generated per hectare and annual harvested rate of forest trees are based on comparator data from Cold Lake First Nations, Alberta. The availability of forest residue was estimated from harvestable forest trees without areas of regulatory concern.*

Viable and potential biomass resources

The identification of viable and potential biomass resources in the commercial forest area for the Southend study area was carried out in two phases. First, an initial community engagement workshop was held to introduce the project to community members. Second, a community participatory mapping workshop to identify local areas of concern, cultural use areas, other restricted areas, and to suggest place-specific zones for the extraction of biomass resources around Southend for community bioenergy production. Workshops were organized with the assistance of the Local Energy Coordinator and in collaboration with QUEST Canada and Co-Mapping Solutions.

The initial community engagement workshop was held in November 2022 at the Southend community centre. During this workshop, the project was introduced, and a conversation held about bioenergy as a potential renewable energy option and community perspectives on bioenergy production. This was complemented by a conversation about the important role of community members in local energy planning, and framing opportunities to be involved in participatory mapping exercises to inform the project. A total of 20 community members attended the initial workshop (**Figure 6**).

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[10] Thiffault, E. and Brown, M., 2019. Innovative approaches for mobilization of forest biomass for bioenergy. In IEA Bioenergy Task (Vol. 43).

Figure 6: Community engagement workshop, Southend, November 2022.

The second workshop, focused on community participatory mapping, was held in June 2023 at the Southend community centre. A total of 10 community members participated in the workshop (**Figure 7**).

Figure 7: Community participatory mapping workshop, Southend, June 2023.

During the participatory mapping workshop participants discussed and mapped place-specific locations (e.g., viable, potential, conditional, locally restricted, protected, and not permissible areas for biomass harvesting), areas of competing community land use, and areas of community concern (e.g., culturally significant areas, sacred areas, local value areas) on a displayed printed map of hypothetical biomass resources within the Southend study area boundary.

Included among mapped locations where biomass harvesting would be considered inappropriate were scared areas, traditional medicinal and food (wild rice) gathering areas, local hunting areas and active trapline areas, fishing areas, rocky area, pictograph areas, wildfire zones, and campsites. Participants further identified regulatory and community-preferred buffer distances and measures to protect and conserve these culturally significant and other locations (Appendix IV). Culturally significant locations, community competing uses, and areas of concern and buffers were georeferenced, digitized and mapped (**Figure 8a, b**).

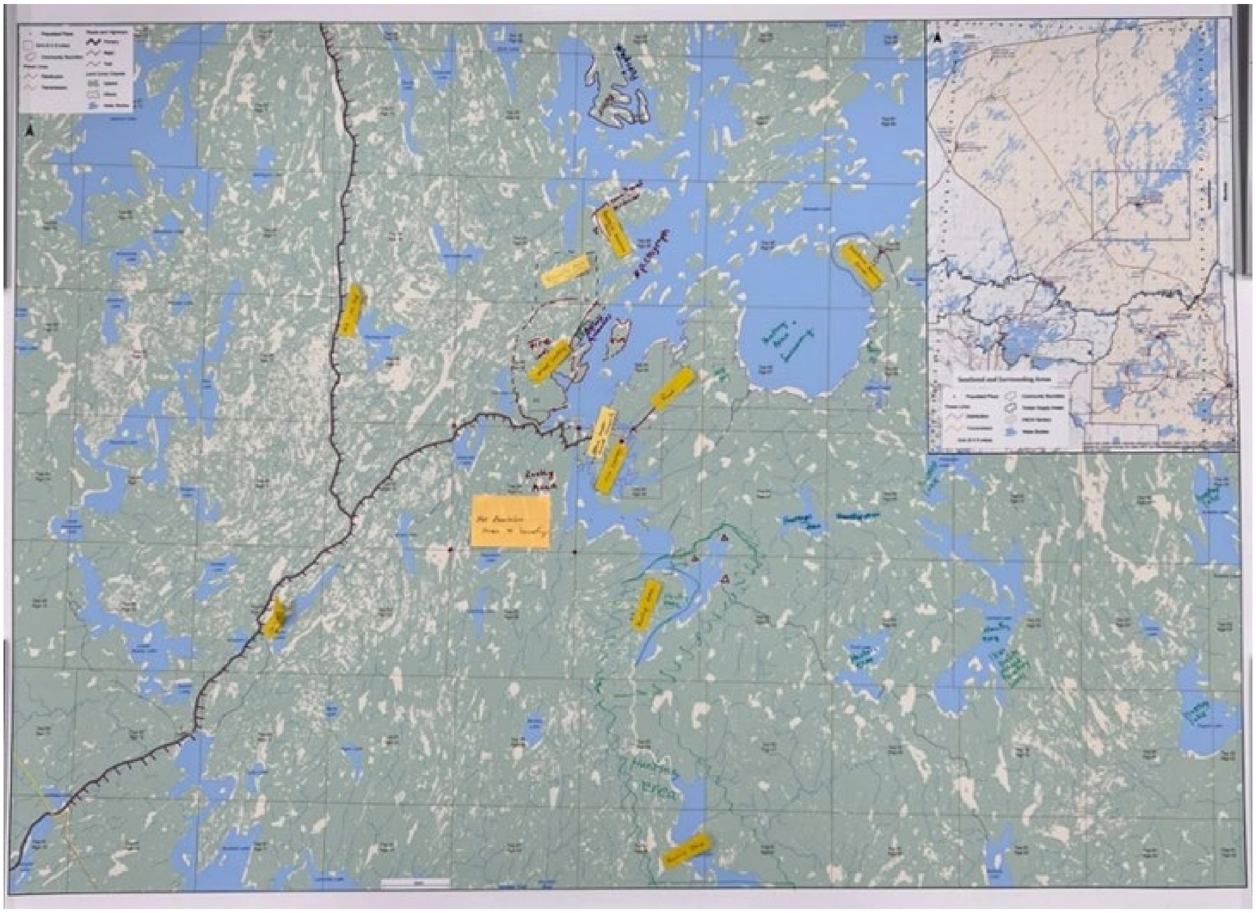

Figure 8a: Community participatory mapping workshop – sample identified features.

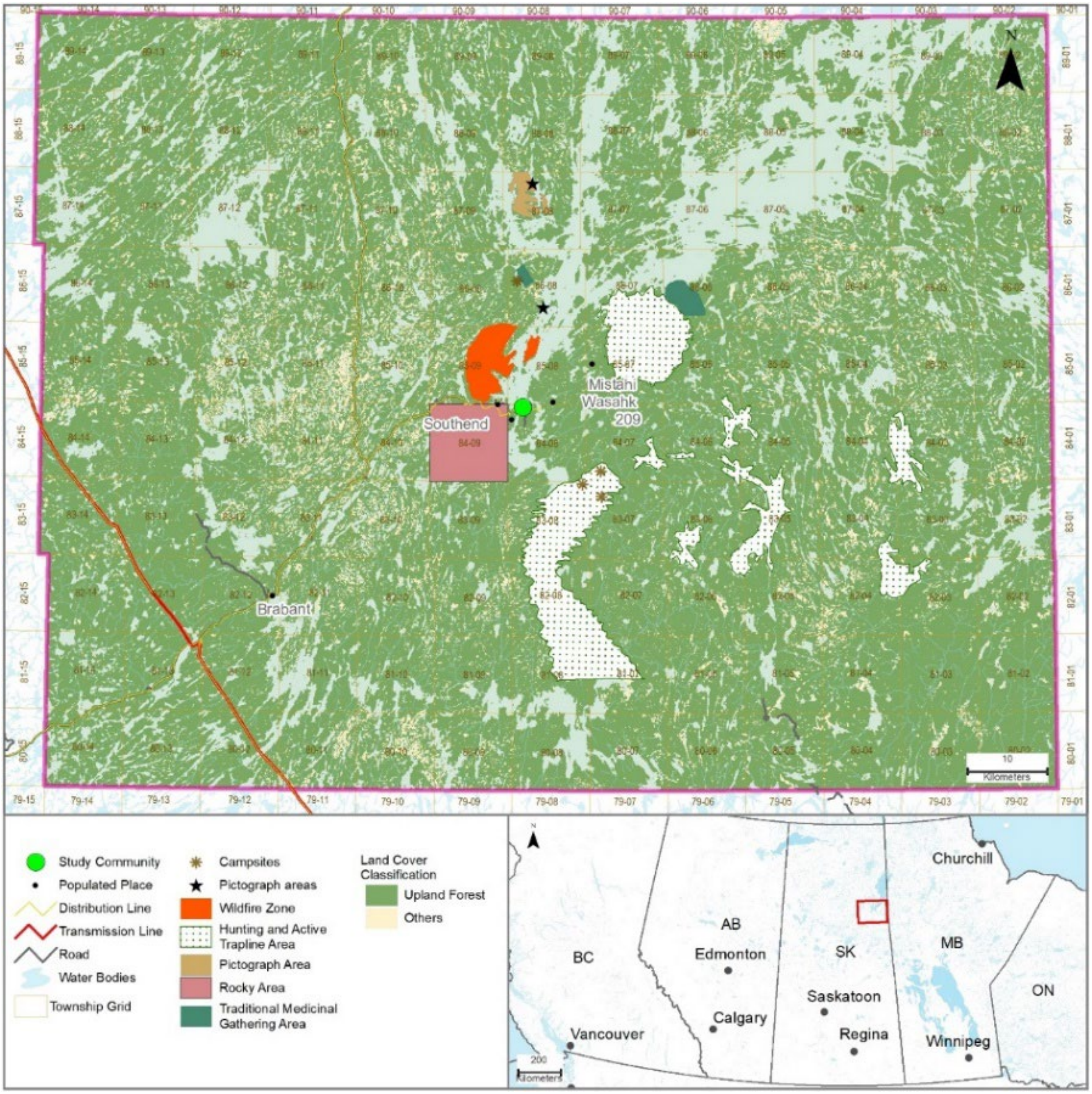

Figure 8b: Community participatory mapping workshop – sample digitized features.

Features identified and mapped by community participants were layered with previously identified regulatory, protected, and legally inaccessible areas, and their respective buffers, and extracted from the theoretical biomass resource base. The remaining resource base (**Table 2**) represents areas of viable and potentially recoverable forest residue for community bioenergy production (**Figure 9**).

Table 2: Forest area classification following identification of viable and potential biomass resource base.

Forest Area Classification	Area coverage (in hectares)
Harvestable forest trees area within regulatory, legally inaccessible zones and areas of community concern	305,813
Harvestable forest trees outside regulatory, legally inaccessible zones, and areas of community concern	613,966
Non-forest lands	362,083

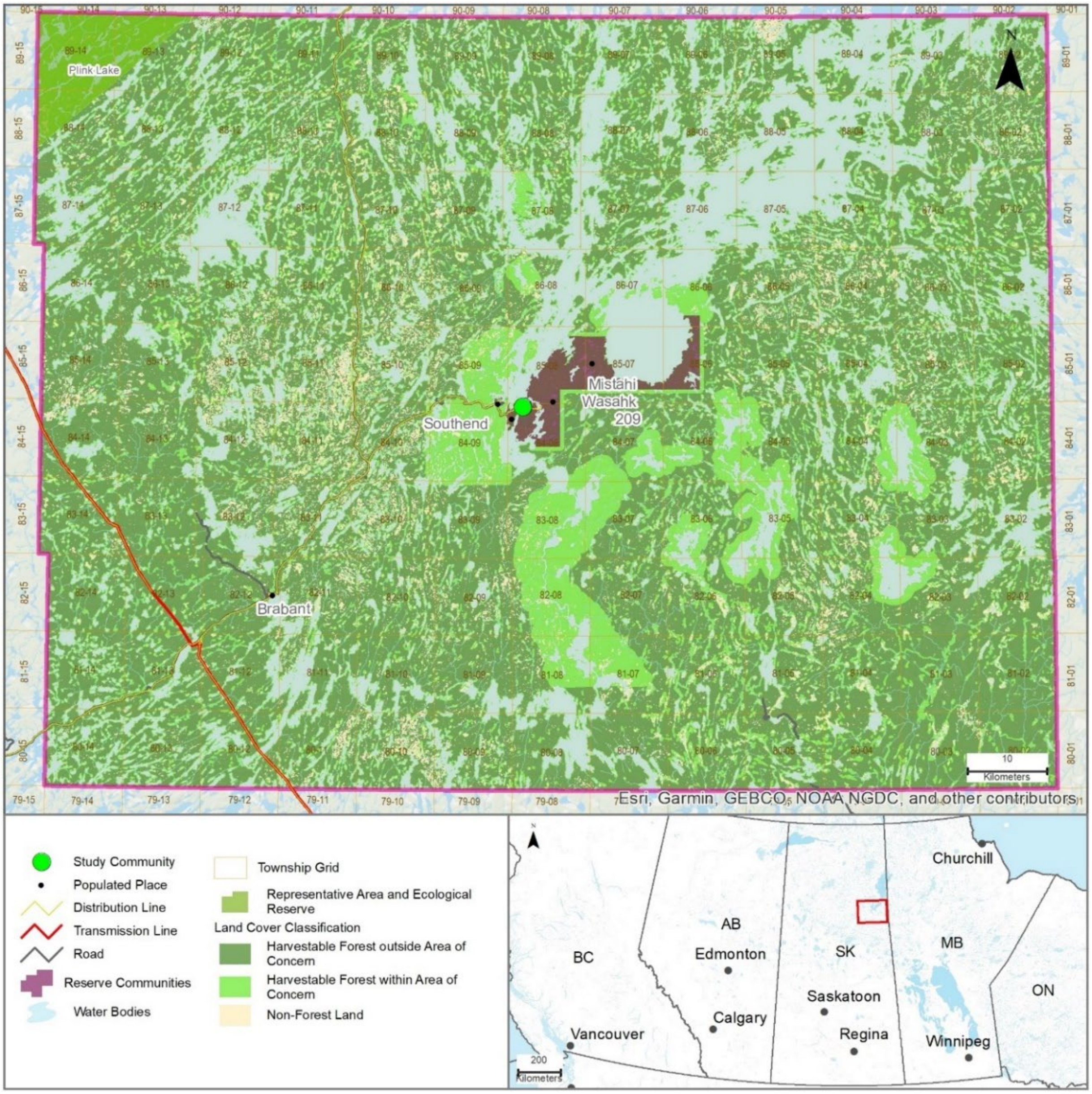

Figure 9: Viable and potentially recoverable biomass resource base.

Using the same values of forest residue generated from harvesting at Cold Lake First Nations[11] as presented previously, the availability of forest residue available in the Southend study area was estimated. This estimation factored into consideration restrictions owing to regulatory, protected, and legally inaccessible areas, and culturally significant locations, community competing uses, and area of concern as identified by community members, and respective buffer distances around these features or places (**Table 3**).

Based on the assumption that yield per hectare of forest residue generated is estimated at 18 odt/ha, the total residue and annual residue from harvestable forest trees in the Southend study area are 11,051,393 odt/ha and 132,617 odt/ha, respectively. It is estimated that the availability of forest residue in the Southend study area can be harvested approximately 83 years for community bioenergy production and assumed that harvestable forest trees can be replanted or regenerated to replace mature forest trees (75 – 125 years).

Table 3. Estimation of forest residue availability based on harvestable forest trees outside regulatory, legally inaccessible zones, and community concern areas.

Forest Harvest Parameter	Value
Residue from clear-cut harvest (odt/ha)*	18
Annual harvested rate (%)*	1.2
Total residue from harvestable forest trees (odt/ha)	11,051,393
Annual residue from harvestable forest trees (odt/ha)	132,617

**odt/ha = oven dry tons per hectare. Estimated forest residue generated per hectare and annual harvested rate of forest trees are based on comparator data from Cold Lake First Nations, Alberta.*

Estimation of energy potential based on viable and potential biomass resource base

The energy potential from harvestable biomass, based on estimated forest residue, was assessed. With various biomass conversion technologies available, a simple combustion steam turbine (high or low capacity) through thermochemical conversion and processing was assumed as the biomass conversion technology for power production (electricity)[12] to meet local community energy needs (**Table 4**).

Table 4: Estimation of energy potential based on viable and potential biomass.

Parameter	Values
Total residue from harvestable forest trees (odt/ha)*	11,051,393
Annual residue from harvestable forest trees (odt/ha)*	132,617
Energy potential (MWhr/t)(High-High)**	279,821
Energy potential (MWhr/t)(High-Low)**	221,072
Installed capacity (MW)(High-High)***	38.86
Installed capacity (MW)(High-Low)***	30.70

** Forest residue is estimated at 18 odt/ha at 1.2% annual quota.*

***Based on high-steam turbine, energy potential is estimated using the factor of 2.111 (MW/t) and 1.667 (MW/t) for high and low heating value respectively*[12]

****High-high means high conversion efficiency and high heating value (HHV) of the biomass; High-low means high conversion efficiency and low heating value (LHV) of the biomass.*

****Installed capacity is estimated per 7,884 hours respectively.*

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[11] Mansuy, N., Staley, D. and Taheriazad, L., 2020. Woody Biomass Mobilization for Bioenergy in a Constrained Landscape: A Case Study from Cold Lake First Nations in Alberta, Canada. Energies, 13(23), p.6289.

[12] Caputo, A.C., Palumbo, M., Pelagagge, P.M. and Scacchia, F., 2005. Economics of biomass energy utilization in combustion and gasification plants: effects of logistic variables. Biomass and bioenergy, 28(1), pp.35-51.

It was also assumed that a biomass facility will operate at 90% of its capacity, (i.e., 328.5 days per year or 7,884 hrs operation), allowing 10% time offline throughout the year for maintenance or other factors. To estimate the installed capacity of the bioenergy facility, 90% capacity of the plant is thus considered and assumed 38.86 MW and 30.70 MW highly efficient steam turbine biomass plant can be operated by using the available biomass resources based on high and low moisture content as well as HHV and LHV, respectively.

Based on the 2020 energy consumption report for Southend (Appendix I), total estimated household consumption was 7,886.43 MWh, which can be generated from a 1.0 MW facility at 90% capacity (i.e., operating 7,884 hrs/yr). Based on this, and considering the above assumptions, there is sufficient biomass resource available to feed a community-based biomass power plant for Southend; this would be 38 and 30 times higher than the local demand in case of high and low heating value of biomass resources respectively.

The estimations were further refined based on three additional factors or conditions:

- → Preference for harvesting resources closer to the community (i.e., distance of the harvestable resource base from community)
- → Accessibility of biomass resources for road access (i.e., distance of the harvestable resource base from existing roads)
- → Preference and accessibility (i.e. distance of the harvestable resource base from the community AND distance from existing roads)

Preference: Estimation of energy potential considering availability of biomass resource and distance from community

Estimations of energy potential were re-assessed based on an assumed preference to harvest available biomass resources closer to the community. This assessment was based on increasing distances of 10km, 20km, 30 km, and 40km from Southend, in all directions (**Figure 10**). Results indicate that sufficient biomass resources are available within 20 km of Southend to provide forest residue for power production i.e 2.46 MW and 1.94 considering high and low heating value (**Table 5**). This is compared to 1.0 MW energy consumption by households Southend in 2020 (Appendix I).

Table 5. Estimation of energy potential based on increasing distances from community.

Distance from the community (km)	Total harvestable biomass (odt/ha)*	Annual harvestable biomass (odt/ha)*	Energy potential (MWhr/t)(High-High)**	Energy potential (MWhr/t)(High-Low)**	Installed capacity (MW)(High-High)***	Installed capacity (MW)(High-Low)***
10	82,269	987	2,083	1,646	0.29	0.23
20	616,270	7,395	15,604	12,328	2.17	1.71
30	1,252,104	15,025	31,703	25,047	4.40	3.48
40	1,906,946	22,883	48,284	38,147	6.71	5.30
>40	7,193,804	86,326	182,147	143,905	25.30	19.99

** Forest residue is estimated at 18 odt/ha at 1.2% annual quota.*

***Based on high-steam turbine, energy potential is estimated using the factor of 2.111 and 1.667 (MWhr/t) for high and low heating value respectively*[12]

***High-high means high conversion efficiency and high heating value (HHV) of the biomass.*

***High-low means high conversion efficiency and low heating value (LHV) of the biomass.*

****Installed capacity is estimated per 7,884 hours respectively.*

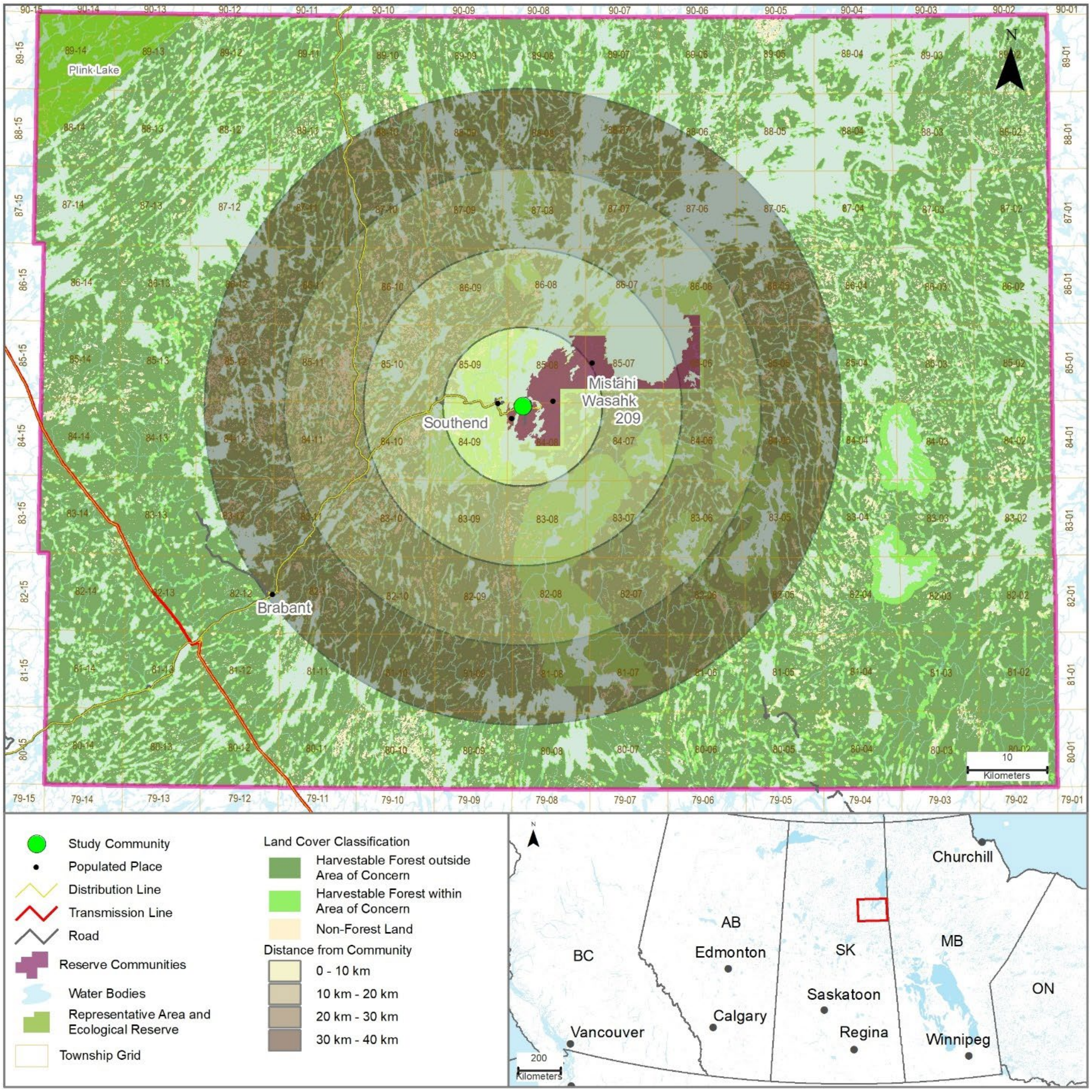

Figure 10: Harvesting zones at increasing distances from community.

Accessibility: Estimation of energy potential considering availability of biomass resource and distance from road

Estimations of energy potential were re-assessed based on an assumed preference to harvest available biomass resources closer to the road. This assessment was based on increasing distances of 0.5km, 1km, 5km, 10 km, 30 km, and 40km from the road. (**Figure 11**). Increasing distances from the road may imply higher cost of harvesting the resource.

Results suggest that the availability of biomass resources within 5 km of the road, and within the study area, would be sufficient to generate forest residue for energy power production, i.e., 2.78 MW and 2.20 MW, either considering high or low heating value of biomass resources, respectively (**Table 5**). This is compared to the 1.0 MW energy consumption by households Southend in 2020 (Appendix I).

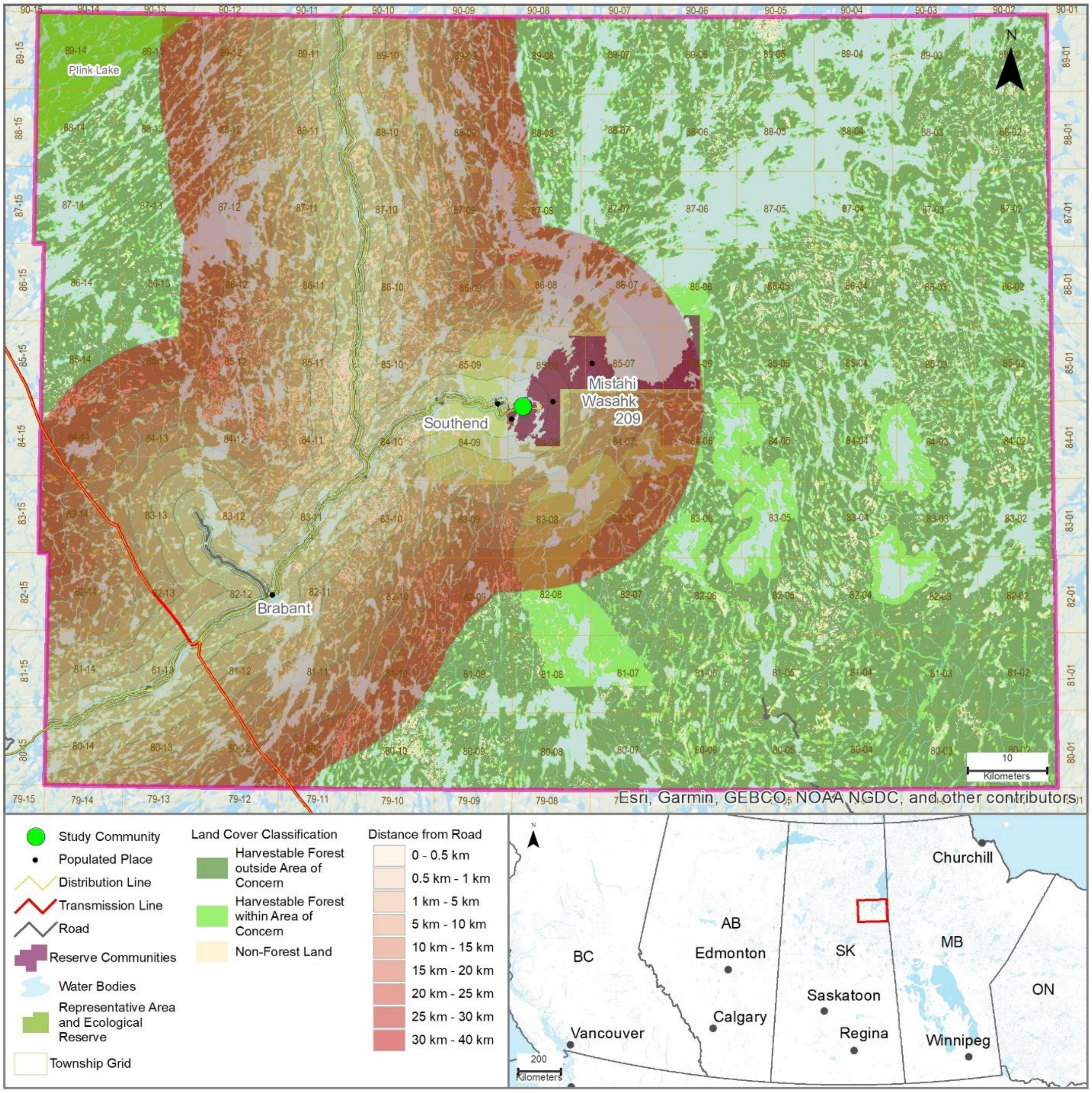

Figure 11: Availability of biomass resource at increasing distance from the road network.

Table 6: Estimation of energy potential based on increasing distances from road.

Distance from the road (km)	Total harvestable Biomass (odt/ha)	Annual harvestable biomass (odt/ha)	Energy potential (MWhr/t) (High-High) **	Energy potential (MWhr/t) (High-Low) **	Installed capacity (MW)(High-High) ***	Installed capacity (MW)(High-Low) ***
0.5	80,260	963	2,032	1,606	0.28	0.22
1	86,214	1,035	2,183	1,725	0.30	0.24
5	625,104	7,501	15,828	12,505	2.20	1.74
10	716,925	8,603	18,153	14,341	2.52	1.99
15	705,328	8,464	17,859	14,109	2.48	1.96
20	674,157	8,090	17,070	13,486	2.37	1.87
25	636,890	7,643	16,126	12,740	2.24	1.77
30	510,679	6,128	12,930	10,216	1.80	1.42
40	1,003,970	12,048	25,421	20,083	3.53	2.79
>40	6,011,867	72,142	152,220	120,261	21.14	16.70

** Forest residue is estimated at 18 odt/ha at 1.2% annual quota.*

***Based on high-steam turbine, energy potential is estimated using the factor of 2.111 and 1.667 (MWhr/t) for high and low heating value respectively*[12]

***High-high means high conversion efficiency and high heating value (HHV) of the biomass.*

***High-low means high conversion efficiency and low heating value (LHV) of the biomass.*

****Installed capacity is estimated per 7,884 hours respectively.*

Estimation of energy potential: distance from community and distance from road

Harvesting preference (i.e., closer to the community) and accessibility (i.e., distance from the road network) were combined to explore scenarios of optimization – i.e. highly optimal, medium, and low (**Figure 12**).

This section focuses on estimating energy potential that would be generated based on the scenarios of availability and accessibility of available biomass resources at specific distances to the community and from the road network. This scenario was categorized into more accessible, medium accessible and least accessible.

It is assumed that the availability of biomass resources harvestable forest within highly optimal (distance to the community) around Southend would be sufficient to generate forest residue for energy power production, i.e., 1.98 MW and 1.57 MW, either considering high or low heating value of biomass resources, respectively for Southend (**Table 7**). This is compared to the 1.0 MW energy consumption by households Southend in 2020 (as shown in Appendix I).

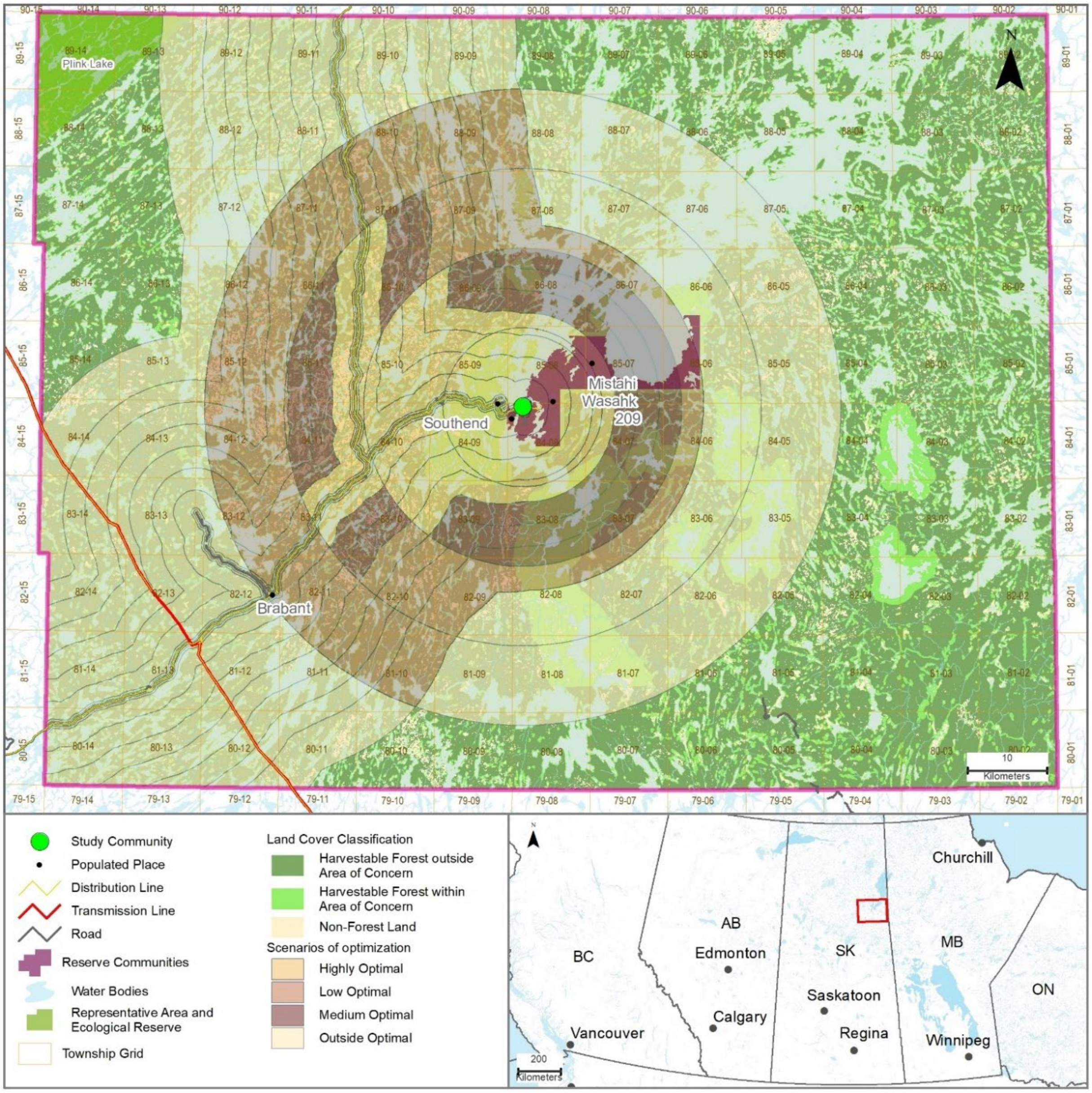

Figure 12: Availability and accessibility of biomass resource at specific distance to the community and from the road.

Table 7: Estimation of energy potential based on preference and accessibility of biomass resource at specific distance to Southend community and from the road network.

Categories of optimization	Total harvestable Biomass (odt/ha)	Annual harvestable biomass (odt/ha)	Energy potential (MWhr/t) (High-High) **	Energy potential (MWhr/t) (High-Low) **	Installed capacity (MW)(High-High) ***	Installed capacity (MW)(High-Low) ***
Highly optimal****	563,473	6,762	14,267	11,272	1.98	1.57
Medium optimal****	551,758	6,621	13,971	11,037	1.94	1.53
Low optimal****	1,334,785	16,017	33,797	26,701	4.69	3.71
Outside optimal****	3,997,084	47,965	101,206	79,958	14.06	11.11

** Forest residue is estimated at 18 odt/ha at 1.2% annual quota.*
***Based on high-steam turbine, energy potential is estimated using the factor of 2.111 and 1.667 (MWhr/t) for high and low heating value respectively*[12]
***High-high means high conversion efficiency and high heating value (HHV) of the biomass.*
***High-low means high conversion efficiency and low heating value (LHV) of the biomass.*
****Installed capacity is estimated per 7,884 hours respectively.*
*****Here:*
High optimal means harvestable forest trees that highly accessible
Medium optimal means harvestable forest trees that moderate accessible
Low optimal means harvestable forest trees that least accessible
Outside optimal means harvestable forest trees that outside community preference and distance from the road.

Conclusion

This report provided a technical assessment, informed by community participatory mapping, of biomass availability and constraints for Southend. The results are intended to support the early stages of energy planning and assessment processes. Data to support detailed feasibility assessments for Southend, at least based on spatial approaches for mapping biomass availability and access are limited. The report also makes several assumptions about technology and harvest residue from forest operations – assumptions that require more context-specific data to support more accurate assessment of local bioenergy potential.

Appendix

Appendix I Monthly average electricity consumption (MWh) in 2020 of Southend

Months	**Electricity consumptions (MWh)**
January	1,528.71
February	1,708.11
March	1,312.41
April	1325.76
May	1,202.94
June	898.66
July	659.57
August	713.90
September	864.66
October	1,070.23
November	1,200.89
December	1,396.09

*Total annual consumption 13,881.93 MWhr

Appendix II Regulatory issues and legally inaccessible areas of biomass resources

Regulatory / Legally Inaccessible Areas	**Buffer (m)**	**Reference/Guideline**
Reserved communities	200	Forest Management Guideline for Terrestrial Buffers, Manitoba[1]
Transmission line	22.5 in either side	SaskPower[2]
Distribution lines	3 m in either side	SaskPower[2]
Road network (Two-lane highways without frontage road)	38 m from highway centerline in either side	Saskatchewan Ministry of Highways, and Infrastructure[3]
Water bodies	>60	Operational Guidelines for Forest Development Planning, BC[4]
	90	Mee-Toos (in practice) *
Representative and ecological zone	50	Ecological Buffer Guideline, ON[5]
Mining location/region	150	Buffer zone considerations for mining development in proximity to human population, NL[6]

**Mee-Toos in practice buffer value was collected by contacting them*

[1] *Forest Management Guideline for Terrestrial Buffers, 2017. Manitoba Sustainable Development Forest Practices Guidebook. Accessed from: https://www.gov.mb.ca/nrnd/forest/pubs/practices/terrestrial_final_jan2017.pdf.*

[2] *SaskPower, Trees and power line safety. Accessed from: https://www.saskpower.com/Safety/Electrical-Safety/Homeowner-Safety/Trees-and-Power-Line-Safety (on Oct. 05, 2023).*

[3] *Saskatchewan Ministry of Highways and Infrastructure, Roadside management manual. Accessed from: file:///C:/Users/lwn608/Downloads/550-10%252BSetbacks%20(1).pdf (on Oct. 05, 2023).*

[4] *Operational Guidelines for Forest Development Planning under the S'ólh Téméxw Use Plan, BC. Accessed from: https://thestsa.ca/wp-content/uploads/2021/07/FOGSTUPdoc_final.pdf (on Jan 18, 2023)*

[5] *Ecological Buffer Guideline Review, Ontario. Accessed from: https://essexregionconservation.ca/wp-content/uploads/2019/09/Ecological-Buffer-Guideline-Review.pdf (on Oct 03, 2023).*

[6] *CCSG Association, 2016. Buffer zone considerations for mining development in proximity to human population. Accessed from: https://voute.bape.gouv.qc.ca/dl/?id=00000335930 (on Oct. 04, 2023)*

Appendix III Parameters used for estimating forest harvest residues in literature.

Location/Study region	Annual harvested rate (%)	Residue from selective harvest (odt/ha)	Residue from clear cut harvest (odt/ha)	References
South-Eastern Ontario	2.2	2	16.8	Calvert and Mabee (2014)[1]
Cold Lake First Nation, Alberta	1.2	-	18	Mansuy et al. (2020)[2]
Managed forest across Canada	2.7	-	20	Dymond et al. (2010)[3]
Managed forest across Canada	-	-	26	Barrette et al. (2018)[4]
British Columbia	4.44	-	15	Barrette et al. (2018)[4]
CASCADIA Timber Supply Area (TSA), British Columbia	4.44	-	29.6	CASCADIA TSA (2021)[5]
Bulkley Timber Supply Area (TSA), British Columbia	4.44	-	25.2	Bulkley TSA (2017)[6]
Across Canada	1.2	47 (fire damaged area)	14	IEA Bioenergy (2018)[7]
Mean biomass available at managed forest across Canada	1.2	-	24	IEA Bioenergy (2018)[7]

**Oven dry tons per hectare (odt/ha)*

[1] *Calvert, K., and Mabee, W., 2014. Spatial analysis of biomass resources within a socio-ecologically heterogeneous region: identifying opportunities for a mixed feedstock stream. ISPRS Int. J. Geo-Inf., 3, 209-232. https://doi.org/10.3390/ijgi3010209.*

[2] *Mansuy, N., Staley, D., and Taheriazad, L., 2020. Woody biomass mobilization for bioenergy in a constrained landscape: a case study from Cold Lake First Nations in Alberta, Canada. Energies, 13, 6289; doi:10.3390/en13236289.*

[3] *Dymond, C.C., Titus, B.D., Stinson, G., and Kurz, W.A., 2010. Future quantities and spatial distribution of harvesting residue and dead wood from natural disturbances in Canada. Forest Ecol. Manage., 260, 181-192. https://doi.org/10.1016/j.foreco.2010.04.015.*

[4] *Barrette, J., Paré, D., Manka, F., Guindon, L., Bernier, P., and Titus, B., 2018. Forecasting the spatial distribution of logging residues across the Canadian managed forest. Canadian J. Forest Rese., 48(12), https://doi.org/10.1139/cjfr-2018-0080.*

[5] *CASCADIA TSA, 2021. CASCADIA Timber Supply Area (TSA) biomass availability estimations. Accessed from: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/supporting-innovation/cascadia_tsa_2021.pdf?bcgovtm=f58727c882-EMAIL_CAMPAIGN_2017_03_01_COPY_01.*

[6] *Bulkley TSA, 2017. Bulkley timber supply area biomass availability estimation. Accessed from: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/timber-tenures/fibre-recovery/tr2017n52.pdf.*

[7] *IEA Bioenergy, 2018. Innovative approaches for mobilization of forest biomass for bioenergy. Accessed from: https://www.ieabioenergy.com/wp-content/uploads/2019/02/TR-2018-06.pdf.*

Appendix IV Community concern issues and regulatory buffers

Aspects/community constraints	Major class	Buffer/harvest distance (min-max)	Applied buffers/Excluded (m)	Guideline/References
Traditional wild rice location/zone	Cultural heritage values	200-1000 m	1000 m	Forest Management Guide for Cultural Heritage Value, Ontario Ministry of Natural Resources[2]
Traditional medicinal plant's location	Cultural heritage values	200-1000 m	1000 m	Forest Management Guide for Cultural Heritage Value, Ontario Ministry of Natural Resources[2]
Pictograph (camera set-up for photograph) location/zone	Tourism and recreation	100 m	100 m	Forest Management Guide for Cultural Heritage Value, Ontario Ministry of Natural Resources[2]

Camp site/Cultural camp	Camp locations	50-100 m	100 m	Forest Management Guide for Cultural Heritage Value, Ontario Ministry of Natural Resources[2]
Community garden	Cultural heritage values	200-1000 m	1000 m	Forest Management Guide for Cultural Heritage Value, Ontario Ministry of Natural Resources[2]
Hunting and active trap line areas	Hunting trapping and gathering	1000 m	1000 m	Collaborative Stewardship Forum (CSF)[3]
Forest fire impacted zone	Natural catastrophic event	Not identified	-	-
Roky area	Unfertile land	Not identified	-	-
Community graveyard	Cultural heritage values	200-1000 m	1000 m	Forest Management Guide for Cultural Heritage Value, Ontario Ministry of Natural Resources[2]
Water body	Landscape aesthetics	60-1000 m	1000 m	Collaborative Stewardship Forum (CSF)[3]
Road and main roads	Traditional travel routes	30 m	30 m	Forest Management Guide for Cultural Heritage Value, Ontario Ministry of Natural Resources[2]

[1] *MiningWatch Canada, 2016. buffer zone considerations for mining development in proximity to human populations. Accessed from: https://voute.bape.gouv.qc.ca/dl/?id=00000335930.*

[2] *OMNR, 2007. Forest Management Guide for Cultural Heritage Value, Ontario Ministry of Natural Resources. Toronto, p84. Accessed from: https://dr6j45jk9xcmk.cloudfront.net/documents/2784/guide-culturalheritage-aoda.pdf.*

[3] *Collaborative Stewardship Forum (CSF), 2021. Operational Guidelines for Forest Development Planning under the S'ólh Téméxw Use Plan. Accessed from: https://thestsa.ca/wp-content/uploads/2021/07/FOGSTUPdoc_final.pdf.*

Appendix V Available biomass conversion technologies and their corresponding products

Process	**Technology**	**Feedstock**	**End products**
Thermo-chemical conversion	Combustion	Agricultural residues, woody residues, animal wastes	(a) Steam (a) Processed heat (b) Electricity
	Pyrolysis	Agricultural residues, woody residues	(a) Pyrolysis oil (b) Producer gas (c) Char
	Gasification	Agricultural residues, woody residues	(a) Producer gas (b) Liquid fuels (c) Char (d) Steam
	Liquefaction	Agricultural residues, algal biomass	(a) Fertilizer/biofuel (b) Syngas (c) Liquid fuels
Biochemical conversion	Anaerobic digestion	Animal wastes, sewage sludge	(a) Liquid fuels (b) Biogas (c) Electricity
	Fermentation	Agricultural residues, sugars, starch	(a) Liquid fuels (bioethanol)

Physico-chemical conversion	Esterification or transesterification	Vegetable oils, animal fats, waste oils	(a) Liquid fuels (b) Glycerol