HEAT

Ontario's Opportunity to Rebuild the Forest Sector, Ensure Economic Resiliency, and Reduce Greenhouse Gas Emissions

Jamie Stephen, PhD

&

Malcolm Cecil-Cockwell, RPF

TorchLight Bioresources

Haliburton Forest & Wild Life Reserve Ltd

November 2018

Report Summary

Since 2000, the Ontario forest sector has lost 36,500 jobs, or approximately half of the labour force, and real employment income has declined by $1.9 billion/year. The timber harvest is also half of what it was in 2000, a volume still far below the environmentally-sustainable harvest level. Ontario needs a new wood market to address the crisis facing the sector and recreate the jobs that have been lost. Given the low greenhouse gas intensity of Ontario's electricity system and the pre-commercial state of wood-to-transportation fuel technologies, heat is the only Ontario market large enough to consume the volume of fibre available – estimated at 12 million dry tonnes per year – while providing significant near-term greenhouse gas reductions. Fortunately, there are already successful models of large-scale deployment of modern wood heating in Europe, where the energy from solid biomass heat is equal to all renewable electricity generation, including hydropower, combined. In Austria, the world's leading manufacturer of high-value cross-laminated timber, 60% of wood fibre is used for heat generation. Bioenergy represents 24% of the energy supply in Sweden and 28% in Finland, but only 5% in Ontario. At the same time, the forests in these countries have a net carbon uptake per hectare 10x that of Ontario. Economically-competitive, clean, low-emissions modern wood heating can be deployed at scales ranging from wood pellet boilers in single family detached homes to large combined heat and power plants heating entire cities. A single plant in Stockholm, connected to the city's district energy system, is 100% fuelled with sustainable wood chips and heats 200,000 apartments. Modern wood heat adoption also supports a large-scale reduction in air pollution by providing a market for forest fire-prone, low quality timber and reducing the use of inefficient and polluting conventional wood and heating oil systems. Modern wood heating is Ontario's opportunity to rebuild the province's forest sector and rural employment base while reducing U.S.-dominated natural gas imports in favour of a made-in-Ontario, job-creating, sustainable, clean, low-carbon fuel.

The Authors

Jamie Stephen, PhD

Dr. Jamie Stephen is the Managing Director of TorchLight Bioresources, a technology, strategy, and investment advisory firm based in Ottawa. He has managed bioenergy and cleantech projects for a broad variety of clients including national and provincial governments, utilities, airlines, manufacturers, investment funds, transportation fuel and power producers, First Nations, and technology developers. Projects have focused on industrial growth strategies, facility feasibility, technology deployment hurdles, and investment prioritization. Raised in Saskatchewan, Jamie holds a PhD in renewable energy & forestry economics and a Masters in chemical engineering from the University of British Columbia.

Malcolm Cockwell, RPF

Malcolm Cockwell is the Managing Director of Haliburton Forest, a private land stewardship company with 60 employees that operates a mid-sized hardwood sawmill and a diverse ecotourism business. With ownership of 100,000 acres of hardwood timberland in central Ontario, Haliburton Forest is Canada's first Forest Stewardship Council (FSC)-certified forest. Malcolm holds a B.Sc. in Forest Conservation from the University of Toronto and is a Registered Professional Forester in Ontario. Malcolm also serves as a Director of Forests Ontario, the Ontario Forest Industries Association, and Timmins Forest & Wildlife Reserve (which owns 145,000 acres of boreal timberland near Timmins).

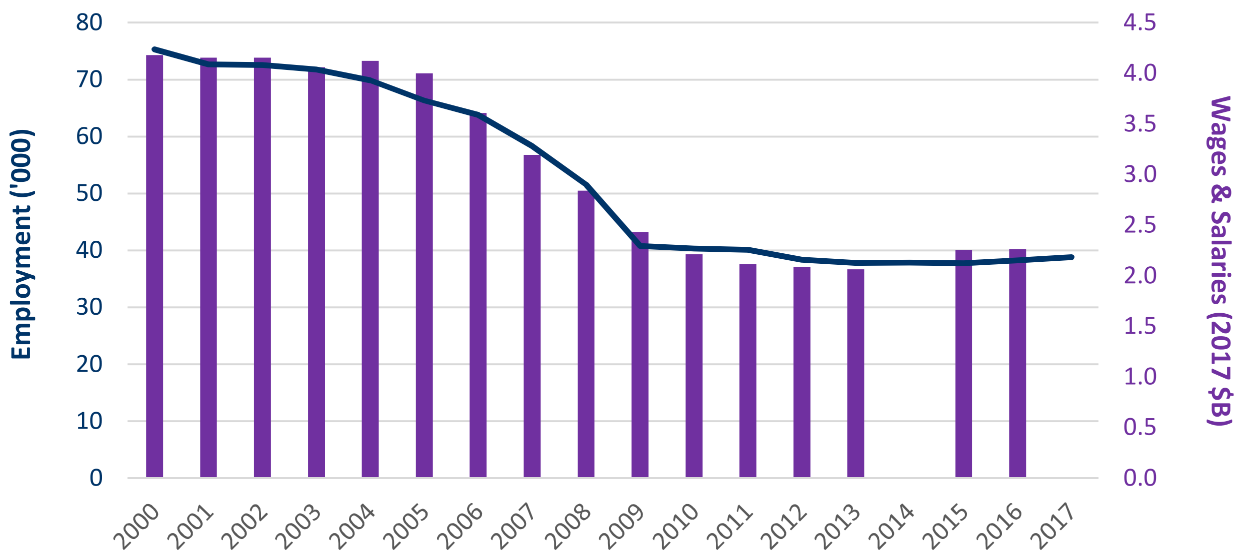
Contact the Authors: JStephen@TLBio.com & MCockwell@HaliburtonForest.com

An Economic Pillar in Trouble

Ontario's real per capita economic growth rate of 0.4% between the Great Recession of 2007/2008 and 2016 can be best described as anemic. However, the overall provincial growth rate masks dramatic regional variation in performance and prospects. While Ontario's large cities and near surrounding areas – namely the Greater Toronto Area (GTA) and Ottawa – prospered with relatively low unemployment and rapid increases in property prices, smaller centres and rural regions struggled. In many areas, particularly those in northern and eastern Ontario, real employment income is substantially lower than before the Great Recession.[1] Economic dependency – the ratio of government transfers relative to employment income – is close to 0.25 in northern and eastern Ontario, but below 0.15 in the GTA and Ottawa.[1] This situation is not unique to Ontario; a divergence in fortunes between urban-global hubs and regional-rural economies may be the defining challenge of the western world over the next several decades.

While the challenges facing the manufacturing sectors (e.g., automobiles, steel, chemicals) in southwest Ontario have been extensively reported, there has been less attention paid to forestry, which is the critical, foundational sector in northern and eastern Ontario. **Since 2000, the Ontario forest sector has lost 36,500 jobs, or approximately half of the labour force**.[2] During this time, wages and salaries in Ontario's forest sector have been reduced by 46%. This lost employment income is equal to $1.9 billion, or $21.1 billion over the past 17 years. Over this same period, real revenue of Ontario's forest sector dropped from over $25 billion to $15.5 billion.[3]

Figure 1. Employment and Employment Income in Ontario's Forest Sector[2]



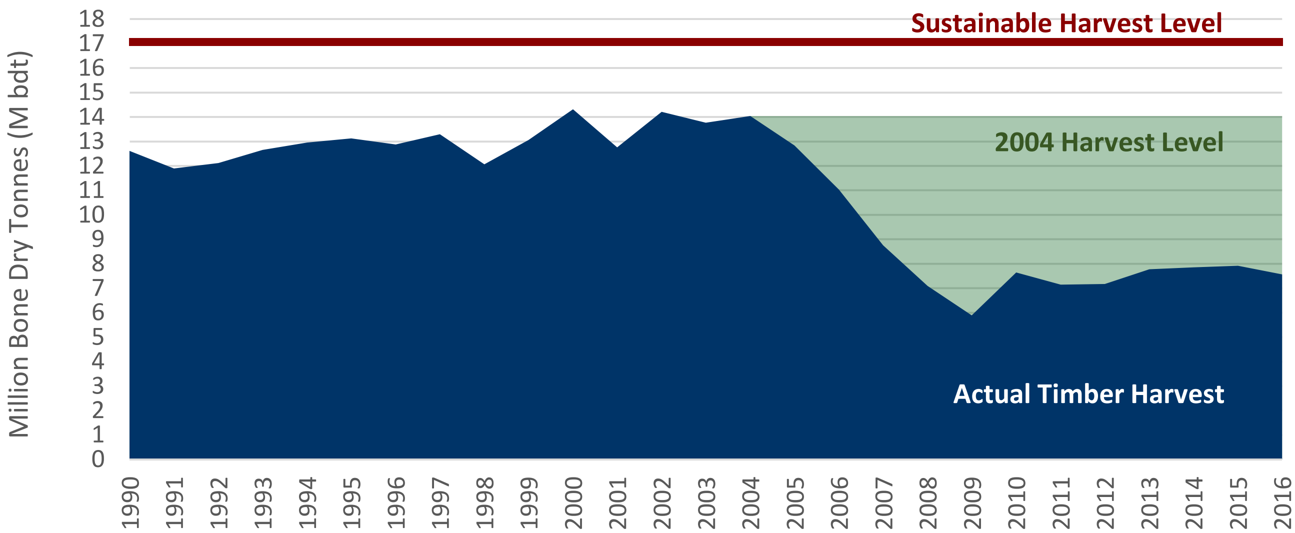
As of October 2018, northern Ontario has an unemployment rate of 10.6%, as compared to 6.1% in Toronto and 4.6% in Ottawa. With a working population of 473,200, approximately 28,400 jobs are required to bring northern Ontario's employment rate in-line with that of Ottawa. Despite healthy growth of 128,400 net new jobs in Ontario in 2017, only 1,600 net new jobs were created in northern Ontario, eastern Ontario, and southwest Ontario combined.[4] In fact, **northern and eastern Ontario employment is still below pre-recession levels** and this can largely be attributed to lack of job creation in the forest sector. Northern and eastern Ontario (including Kingston/Pembroke, Kawarthas/Muskoka) should not be discounted as minor contributors to Canada's economy; each has a population exceeding that of New Brunswick.

[1] Eisen B, Emes J, 2016. The five solitudes of Ontario: a regional analysis of labour market performance in post-recession Ontario. Fraser Institute.
[2] Statistics Canada, 2018. CANSIM tables 301-0008 and 301-0009: Principal statistics for manufacturing industries and logging industries. Income data for 2014 and 2017 unavailable.
[3] Natural Resources Canada, 2018. Forest resources statistical data. http://cfs.nrcan.gc.ca/statsprofile
[4] Financial Accountability Office of Ontario, 2018. Ontario Records Strong Labour Market Performance in 2017.

Reduced Harvest, Lost Jobs

The primary driver for the forest sector employment decline has been a dramatic reduction in timber harvest. Ontario's timber harvest dropped from a peak of 14.3 million bone dry tonnes[5] (M bdt) in 2000 to 7.5 M bdt in 2016 (blue area in Figure 2).[6] This is a decrease of 47%, which is consistent with the decline in employment and employment income. Clearly, there is **a direct linkage between harvest volume and employment**. The energy content of wood that is not being harvested on an annual basis – the 6.8 M bdt difference between 2000 and 2016 harvest levels – is 36,000 GWh (130 PJ). This amount of energy is **equal to Ontario's annual hydroelectricity generation**. It should also be noted that historical harvest levels have never reached the maximum – a conservative harvest level deemed sustainable in Ontario.

Figure 2. Actual Timber Harvest in Ontario Relative to Alternate Harvest Levels[6]



The precipitous drop in U.S. housing starts between 2005 and 2007, which was associated with the global financial crisis, was a primary contributing factor to rapid reductions in the harvest volume in Ontario. Although lumber prices have risen significantly since the depths of the crisis, the harvest volume in Ontario has not. The primary reason for this is the secular decline of the pulp and paper sector, and in particular, newsprint/groundwood demand. Canada's newsprint production dropped from 9 Mt in 2000 to just over 3 Mt in 2016.[7] This decline will not reverse course and its **continued downward direction threatens the critical lumber sector**. In many communities, the shutdown of a lumber mill would spell the end of local economic opportunities.

A successful Ontario forest sector requires strong markets for sawmill residues, which are produced during the production of lumber, and low-quality timber inappropriate for lumber production. Sawmill residues, such as wood chips, sawdust, and bark, typically represents 35-50% of a sawmill's output. Low-quality timber, also known as 'pulpwood', is usually harvested from mixed forest areas that also contain sawlog-quality timber. With poor and **declining markets for pulpwood, harvesting many areas in Ontario cannot be economically justified** – even if they contain a reasonable proportion of sawlogs. In addition, a lack of markets for sawmill residues threatens the viability of sawmills that are still operating in the province. The combined annual availability of unharvested (but sustainable) timber, harvest residues (tops/branches), and unallocated sawmill residues is estimated to be in excess of 12 M bdt/year, with an energy content of 60,000 GWh or 215 PJ. A market for this material is required if Ontario is to address the crisis facing its forest sector and to recreate the tens of thousands of jobs that have been lost.

---

[5] Assumes average density of 500 kg/m^3

[6] Canadian Council of Forest Ministers, 2018. National Forestry Database: Net merchantable harvest volume of roundwood {Ontario uses an area-based sustainable level. The implied volume is calculated by Canadian Forest Service}

[7] Food and Agriculture Organization, 2018. FAOStat database – forest products production, Canada.

Comparing Markets

High-value bioproducts, such as materials for automotive interiors and speciality biochemicals, have been touted as attractive alternatives that could take the place of pulp in Ontario's forest sector. While there is an important role for these high-margin bioproducts, the market sizes are simply too small to address the 6.8 M bdt needed to bring Ontario's forest harvest back to 2000 levels. This leaves energy markets – transportation, electricity, and heat.

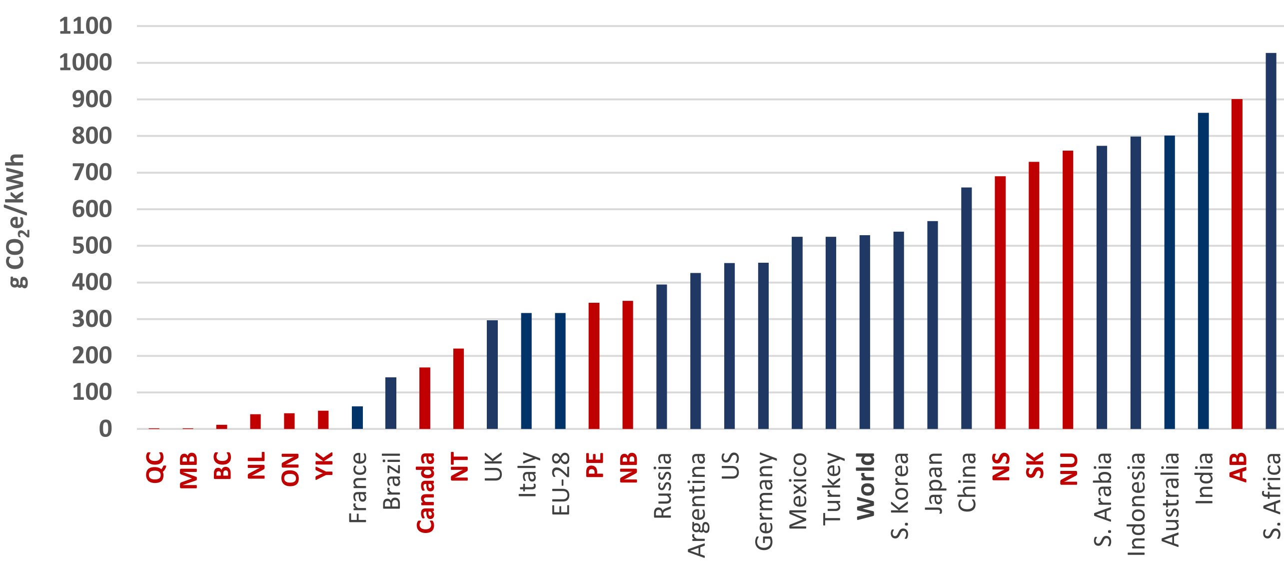
Transportation

Transportation is often the highest value energy sector, but **technologies for conversion of woody biomass into liquid transportation fuels are pre-commercial and high risk**. In addition, although wood-based liquid fuels can provide significant greenhouse gas benefits compared to diesel and gasoline, so can other, lower-cost, commercial liquid fuels such as corn ethanol and renewable diesel/biodiesel. North American ethanol supply currently outstrips demand and research has shown several countries could supply low greenhouse gas liquid biofuels to Ontario for much lower cost than they could be produced from wood in the province.[8] Unlike electricity and heat, there are **few limitations to large volumes of liquid biofuels crossing the border into Ontario**. While wood-based liquid biofuels offer significant long-term promise, they are unlikely to be produced in large volume in Ontario within the next decade.

Electricity

Electricity is already being produced from woody biomass at numerous facilities in Ontario, with most generation derived from combined heat and power plants at pulp mills. Ontario is also home to several stand-alone wood-fuelled electricity plants, including the OPG-owned 200 MW Atikokan Generating Station. Atikokan GS, which is North America's largest biomass-only plant, was converted from coal to wood pellets in 2014. However, the plant is operated at less than 10% capacity (peaker plant), which results in an extremely high per-unit cost of electricity.[9] Use of wood for generation of electricity only is inefficient (~30%) relative to the more common combined heat and power (80-90%) and uneconomical for greenfield plants. In addition, generation of electricity from wood (or wind or solar) in Ontario does not result in a notable greenhouse gas reduction. As shown in Figure 3, the **greenhouse gas intensity of electricity in Ontario is lower than all G20 countries**. The closure of Pickering GS will create opportunities for bioelectricity, but they should be pursued as efficient combined heat and power projects linked to urban heat demand.

Figure 3. Electricity Greenhouse Gas Intensity of the G20 and Canadian Provinces & Territories[10,11]

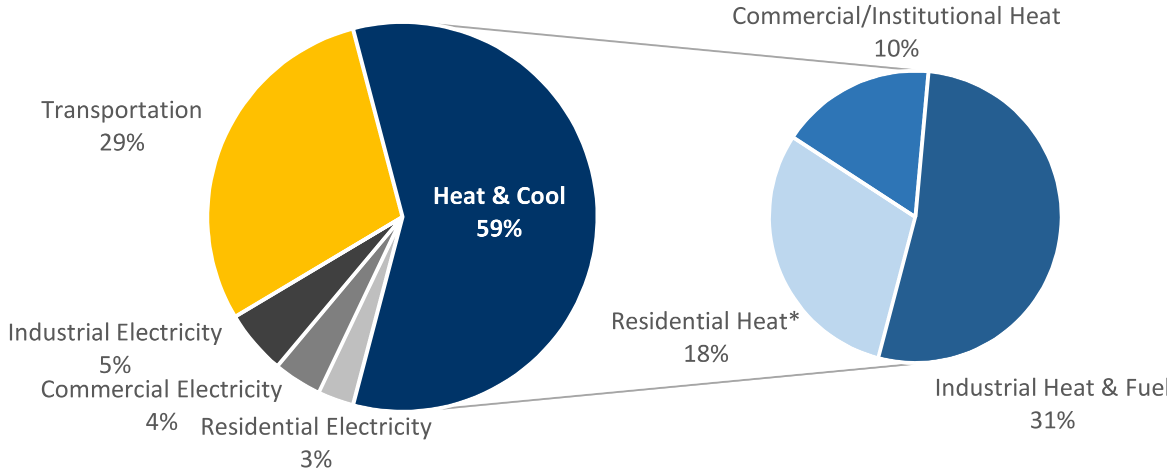


[8] Stephen JD, 2013. The viability of lignocellulosic ethanol production as a business endeavour in Canada. PhD Thesis. University of British Columbia.
[9] Auditor General of Ontario, 2015. 2015 Annual Report: Chapter 3.05 Electricity Power System Planning.
[10] International Energy Agency, 2018. Emissions Factors.
[11] Environment and Climate Change Canada, 2018. National and provincial/territorial greenhouse gas emissions tables.

Heat (Buildings and Industry)

The heating and cooling market, which includes space and hot water heating for buildings as well as industrial process heat (e.g., cement, steel production), is the largest energy market in Ontario. Of the approximately 3,000 PJ of energy consumed in Ontario, almost 60% is for heating (including modest demand for cooling) (Figure 4).[12]

Figure 4. Energy Use in Ontario (3,000 PJ Total)



*Space heating, hot water, cooling, including electric space and hot water heating

At 770 PJ, the combined energy consumption for residential and commercial/institutional (C/I) space and hot water heating (collectively, heat) in Ontario is significantly more than the entire energy consumption of Atlantic Canada or energy-intensive Saskatchewan. Natural gas is the dominant fuel, providing 74% of residential heat and 84% of C/I heat. The combined Ontario residential and C/I consumption of high-cost heating oil, propane, and electricity – which dominate in areas lacking natural gas – was 135 PJ in 2015.[12] This is the same energy content as 7.3 M bdt of wood (or 8.6 M bdt assuming 85% conversion efficiency). Despite the high penetration of natural gas in Ontario, the **province uses more than double the amount of heating oil and propane for heat as all of western Canada** (MB to BC) and almost as much as Atlantic Canada. In addition, much of the heat generated from wood in Ontario residences is done so using inefficient and pollution-intensive stoves that should be a target for replacement. Modern wood heating using boilers, furnaces, and pellet stoves can have 50% higher efficiency than traditional models, thereby reducing wood consumption and emissions.

Figure 5a. ON Residential Heat: 500 PJ

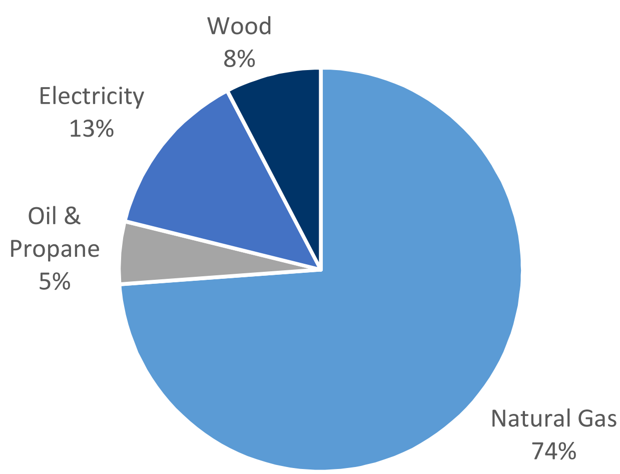
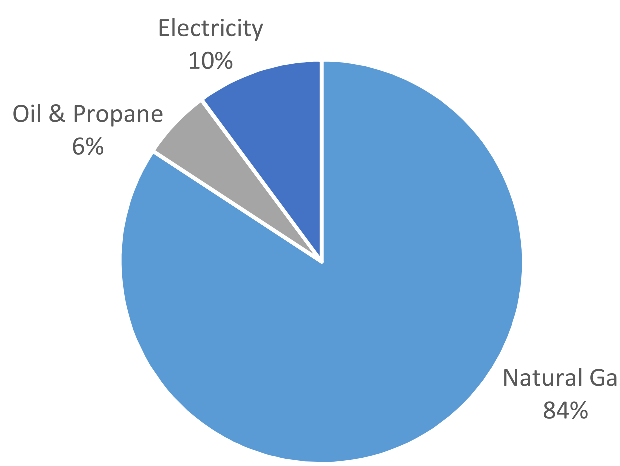


Figure 5b. ON Commercial/Institutional Heat: 270 PJ



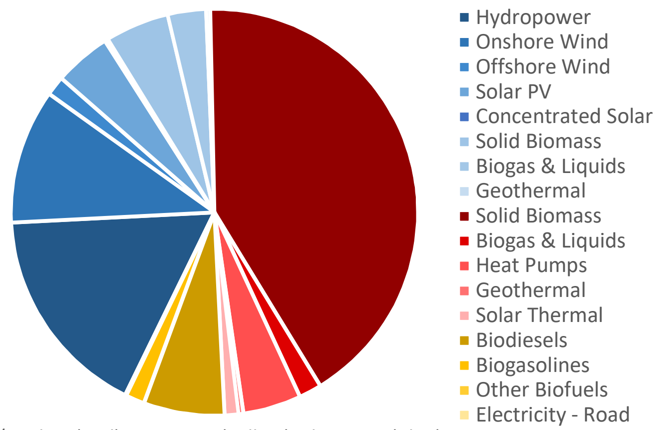
[12] Natural Resources Canada, 2018. National energy use database. Office of Energy Efficiency.

Solid Biomass Heating: The Leader in Renewables Markets

Given the low greenhouse gas intensity of Ontario's electricity, electrification of heat has been proposed as a means to reduce emissions. This is a logical approach from a greenhouse gas perspective but does not take into the account the costs to consumers or industry. Ontario has some of the highest electricity costs in North America. Electricity is used for heating extensively in jurisdictions with abundant, low-cost hydroelectricity resources such as Quebec, Manitoba, British Columbia, and Norway. However, it is rare to pursue electric heating in areas that lack a high penetration of low-cost hydroelectricity, such the United Kingdom, Sweden, Finland, Germany, or Austria. Ontario also fits this profile. However, unlike these countries, **Ontario has not, to date, actively pursued the lowest cost and greatest job creator in renewable heat: solid biomass**.

In the European Union (EU-28), the **energy from solid biomass heating is equal to all renewable electricity generation, including hydropower, combined**. Solid biomass heating, including wood heat, represents **84% of supply** in the renewable heating and cooling market, the largest renewables market in the EU-28.[13] Under the United Kingdom's C$2.6B Renewable Heat Incentive policy, 87% of the 18,900 commercial/institutional projects are solid biomass, while another 4% are other forms of bioenergy.[14] Wood heat is also responsible for the majority of energy generated by Renewable Heat Incentive residential projects.

Figure 6. EU-28 Renewable Energy Supply



*Heating/Cooling (Red), Transport (Yellow), Electricity (Blue)

For solid biomass to reach a high heat market share, key enabling infrastructure is required: district energy systems (DES). DES' utilize a central energy plant that supplies hot water or steam (or cold water, in the case of cooling) to other buildings using a network of highly-insulated underground pipes. An energy transfer substation in each building takes energy from the DES pipe and uses it for space and hot water heating (or air conditioning) within the building. A separate furnace or boiler in each building is not required. There are over 200 DES' in Canada, including systems that heat the downtowns of Toronto, Ottawa, London, and Ajax.[15] DES' are essential to solid biomass heating because delivery of solid fuel to each building in an urban centre is not feasible or efficient. However, many cities around the world have downtown energy plants operating on solid biomass. In Stockholm and Copenhagen, **over 90% of buildings are connected to the city DES and solid biomass provides over 80% of the heat for those systems**. To put the scale in perspective, the DES' in these two cities are each 4,000 MW capacity; the DES heating downtown Toronto is 350 MW capacity, despite a population several times larger. Within the EU, the countries that have the highest penetration of DES, such as Denmark, Sweden, and Latvia, also have the highest penetration of renewable energy as a whole.

Figure 7a. District Energy System Layout

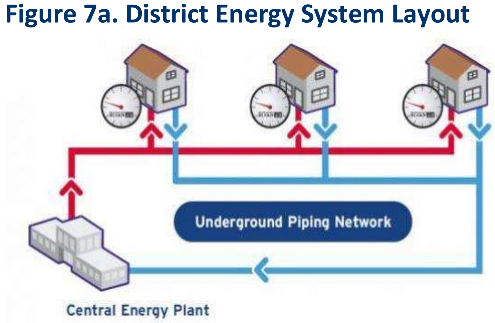
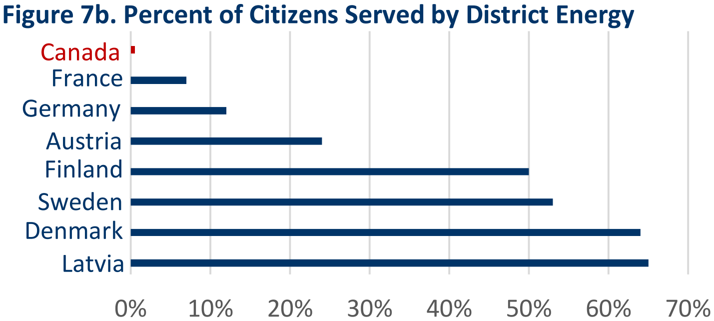


Figure 7b. Percent of Citizens Served by District Energy



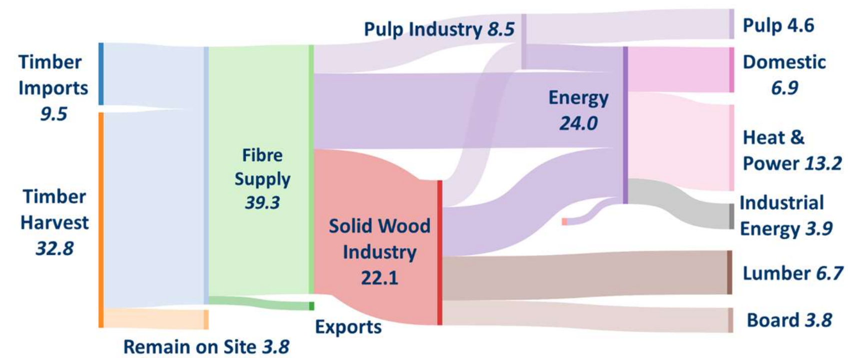
---

[13] European Environment Agency, 2017. Renewable energy in Europe – 2017 update. ISSN 1977-8449.
[14] Ofgen, 2018. Non-domestic renewable heat incentive quarterly report – October 2018.
[15] Nyboer J, Griffin B, 2016. District energy inventory for Canada, 2014.

Proven at Scale to Support the Forest, Manufacturing, and Energy Sectors

Large-scale deployment of modern wood heat is proven within existing energy systems and forest industrial systems. The Ontario solid wood products sector is subject to substantial volatility. The past two decades have shown homebuilding rates in the province and the U.S. can swing widely. As heat is inherently a local, dependable market, it can provide significant stability to the forest sector of Ontario. Fuel supply contracts for heat projects are typically in excess of 5 years, with 20-year supply contracts not uncommon. While heat is invariably a lower value product than lumber, the security of heat revenue can serve as the foundation for a high-value solid wood products sector. This is the model than Austria has adopted. It is the world's leading producer of cross-laminated timber (CLT), the large timber panels used for 'wood skyscrapers'. The compound annual growth rate for CLT production in Austria is in excess of 20%. However, over **60% of wood fibre from Austria's forest sector becomes heat**, with modest amounts of co-generated electricity (Figure 8).[16] Pulp represents only 10% of output and is not an area of growth, similar to the case in Ontario. Upper Austria is also the world's leading hub for wood boiler manufacturing, with over 50,000 units produced each year (70% exported). **An equivalent approach in Ontario would create 45,000 jobs.** By establishing a wood heat market, Austria is ensuring the success of its forest products and boiler industries.

Figure 8. Forest Fibre Flows in Austria (M m^3)



Canada is the world leader in biomass availability per capita but, at 5% of energy supply (the same percentage as Ontario), it trails many other countries in penetration of biomass in energy markets (Figure 9). Given climatic, population, and land area similarities, a good comparison could be made between Ontario and Nordic countries Sweden and Finland combined. As shown in Figure 10, **Sweden and Finland have ten times greater forest harvest, more forest sector employment, and much greater bioenergy consumption – while maintaining a higher GDP per capita and dramatically lower GHG emissions**. Their forests are also a major net carbon sink.

Figure 9. Bioenergy Market Share

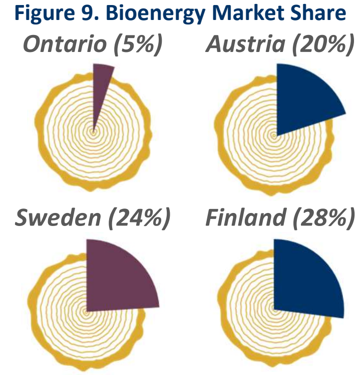


Figure 10. Comparison of Ontario and Sweden/Finland[17]

	Ontario	Sweden & Finland
Population (2017)	14,193,384	15,579,047
Area	108 M ha	79 M ha
GDP Per Capita (C$ 2017)	$58,510	$65,845
Forested Area	71 M ha	46 M ha
Forest Harvest	7.5 M bdt	75.0 M bdt
Forest Sector Direct Employment	40,000	125,000
Mean Temperature	9.4˚C (Toronto)	5.9˚C (Helsinki), 7.6˚C (Stockholm)
End-Use Energy Consumption (2015)	2,664 PJ	2,370 PJ
Natural Gas Imports (Production)	883 PJ (4 PJ)	124 PJ (0 PJ)
Bioenergy Production	**140 PJ**	**760 PJ**
GHGs per Capita (net incl. LULCF*)	12.0 t CO_2e (**11.5 t CO_2e**)	6.9 t CO_2e (**2.7 t CO_2e**)

*Land use, land use change and forestry {net emissions lower due to net forest uptake of carbon}

[16] Adapted from Lang B, Nemestothy K, 2013. Wood flows in Austria. Austrian Energy Agency and FHP Kooperations Platform.
[17] World Bank, IEA, and OECD open databases.

Wood Heat is Cleantech

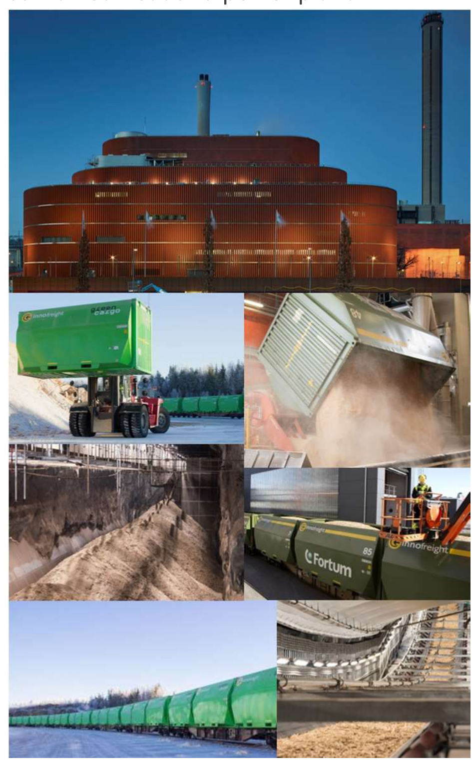
The term 'wood heating' typically elicits visions of smoky firewood stoves and open fireplaces. These are outdated, polluting technologies which should not be the basis for industry growth. In contrast, modern wood heating is automated, clean (low emissions), and efficient. Scale ranges from residential wood pellet boilers, which can serve as the primary source of heat for homes and require refuelling only 2-3 times per year, to DES-connected central energy plants heating a large number of buildings. The **world's largest wood-fuelled combined heat and power plant, in Stockholm, provides heat for over 200,000 residences**.

The difference in performance between conventional and modern wood heating is dramatic. A single traditional fireplace produces more than 1,000 times the particulate matter of a pellet boiler. Although combustion of a solid fuel does inherently produce more particulate matter than combustion of a gas, the replacement of one uncertified wood stove with a modern wood boiler more than makes up for the modestly higher emissions of 100 pellet boilers replacing propane or natural gas furnaces. For central energy plants connected to DES', the large facility scale permits the installation of flue gas cleaning equipment. In cities such as Stockholm, the air pollutant emissions from central heating plants fuelled by solid biomass are negligible compared to uncontrolled emissions sources such as vehicles and residential fuel combustion.[18] London's Heathrow Terminal 2 is heated with wood. Modern technologies can easily meet the most stringent urban air pollution emission limits, such as those of Montreal, and since wood lacks sulfur, SO_x emissions can be eliminated.

Paradoxically, generation of heat from wood in modern equipment can result in a significant net decrease in particulate matter air pollution. Despite being omitted from most pollutant inventories, 'natural' wildfires are a leading source of Ontario's particulate matter emissions that have a major impact on the health of Ontarians.[19] With a warming climate, Ontario is at **increased risk of wildfires and this risk is further elevated by the dramatic drop in timber harvest**. Wildfire risk reduction in fire-prone forests requires thinning and fuel removal. Selective stand improvement cuts – to remove damaged, diseased, or low productivity trees from mixed forest landscapes – also improves the vigour and productivity of the forest. A market for this low-grade fibre is required to economically justify operations. **Combustion of the wood in advanced equipment reduces particulate matter emissions by >99.5% relative to wildfires** or prescribed burns. A heat market also eliminates the need for slash pile burning, which is still practiced in some areas of Ontario. Finally, trucking urban wood outside a city can result in more air pollution from diesel emissions than using the wood within the city for large-scale wood heating.

Stockholm Exergi Värtaverket Plant

The 4,000 MW DES heating Stockholm is owned by Stockholm Exergi, a partnership between the City of Stockholm and Fortum, a Finnish utility company. Stockholm Exergi has a goal of 100% renewable heat by 2022 and has plans to invest C$2.4 B over the next 5 years to meet this target. In 2016, the company commissioned the C$750 M 410 MW (280 MW heat, 130 MW electricity) wood chip-fuelled Värtaverket combined heat and power plant.



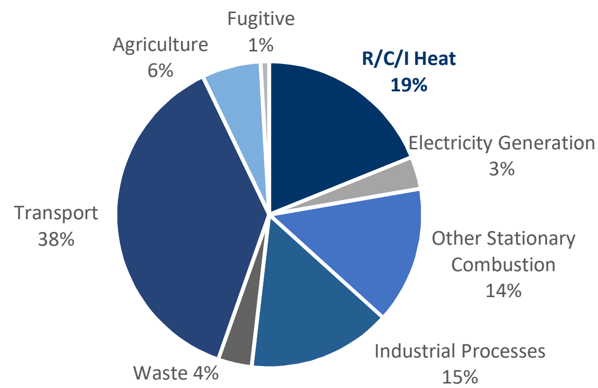
This is the largest wood chip-fuelled plant in the world (the largest biomass plant is the 2,000 MW wood pellet-fuelled Drax plant in the UK). The Värtaverket plant alone can heat 200,000 residences and has double the annual heat output of Enwave Toronto, the largest DES in Canada. It consumes up to 3,500 t/day of wood chips, which are delivered by ship and rail. The plant is located across the street from residential areas and is responsible for GHG reductions of 650,000 t CO_2e/yr.

[18] Segersson D et al., 2017. Health impact of PM10, PM2.5 and black carbon exposure due to different source sectors in Stockholm, Gothenburg and Umea, Sweden. International Journal of Environmental Research and Public Health 14: 742-763.
[19] Ontario Ministry of Environment and Climate Change, 2015. Air quality in Ontario.

The Scale of Ontario's Wood Heat Greenhouse Gas Reduction Opportunity

Greenhouse gas reductions are just one of the benefits of fuel switching from heating oil, propane, and natural gas to wood. As identified in Figure 3, Ontario has very little opportunity to reduce emissions from electricity generation. Electricity generation accounted for 5.5 Mt CO_2e, or 3%, of Ontario's 2016 greenhouse gas emissions of 160 Mt CO_2e. In contrast, residential, commercial, and institutional (R/C/I) heating accounted for over 30 Mt CO_2e, or 19%. This is not an insignificant source of emissions in Canada – it is equal to all greenhouse gas emissions from Nova Scotia and New Brunswick combined.

Figure 11. Ontario Greenhouse Gas Emissions, 2016



Greenhouse gas reduction options must be viewed through an economic efficiency lens. In general, it is higher cost to decarbonize transportation than stationary combustion.[20] Ontario does have an opportunity to expand its role as the country's largest producer of ethanol, which can be supplied for lower cost than gasoline and has been proven as the lowest cost means of transportation decarbonization.[21] However, domestic volumes will be constrained by corn production. Within stationary combustion, it is much more feasible to reduce emissions from space and hot water heating than trade-exposed manufacturing or oil refining – the two primary contributors to 'Other Stationary Combustion'. The other primary source of emissions is 'Industrial Processes', which is largely emissions from chemical reactions during steel, and to a lesser extent, cement production. These are two of the most energy intensive, trade-exposed industries and are essential to Ontario's manufacturing and construction economic base. While there are limited options for reducing chemical reaction emissions from cement production, wood-based biocoke can be used as a coal substitute at limited (<20%) volumes – albeit at much higher cost – in steel manufacturing. However, this is still at the testing stage in Ontario. Therefore, it is clear that **space and hot water heating must be a priority for greenhouse gas reductions in Ontario over the next decade**, simply due to lack of alternative cost-competitive greenhouse gas reduction options in other emission categories.

As noted in Figure 5, the energy fuel demand for R/C/I heat in Ontario is approximately 770 PJ. After adjusting for furnace and boiler efficiency,[22] actual heat demand is estimated at 713 PJ. Assuming an average modern wood boiler efficiency of 85%, the fuel required to meet this demand would be 840 PJ or approximately 50 M bdt when accounting for losses from moisture content. Clearly, the 12 M bdt of wood potentially available in Ontario can only meet a portion of heat demand. However, 2.5 M bdt of wood displacing propane or heating oil in rural R/C/I applications and 5 M bdt displacing natural gas in urban DES' would **reduce emissions by approximately 7.1 Mt CO_2e/yr. This is the equivalent of removing 1.6 million cars from the road.**

While bioheat offers significant promise for greenhouse gas reductions in Ontario, perhaps a greater opportunity – one that complements wood heat, supports rural economies, and promotes adaptation to climate change – is active forest management. As noted in Figure 10, per capita greenhouse gas emissions in Sweden and Finland drop dramatically when land use, land use change, and forestry are included in the calculation. This is because forests in these countries are actively managed to promote high productivity, which means greater carbon uptake and storage. In contrast, few forests in Ontario are actively managed. In 2016, Sweden's 23 M ha of forest land had a net carbon gain of 43 M t CO_2e (1.87 t CO_2e/ha). Although a different ecoregion, the same net rate for Ontario's 71 M ha of forests would result in an annual net carbon gain of 133 Mt CO_2e. **This is would reduce Ontario's net greenhouse gas emissions by 83%.**

[20] McKinsey & Company, 2013. Pathways to a low-carbon economy. Version 2 of the global greenhouse gas abatement cost curve.

[21] Roland Berger, 2016. Integrated fuels and vehicles roadmap to 2030+.

[22] Electricity: 98%; natural gas: 93%; propane: 90%; heating oil: 85%; conventional wood: 65%

Haliburton Forest: Ontario's Case Study on Sustainable Forest Management

Haliburton Forest & Wildlife Reserve is a multi-use private land stewardship company. It owns and manages 100,000 acres in Haliburton, ON, and oversees the management of two additional properties which are owned by the shareholders of Haliburton Forest: Limberlost Forest & Wildlife Reserve, which owns 10,000 acres in Huntsville, ON, and Timmins Forest & Wildlife Reserve, which owns 145,000 acres in Timmins, ON. All three of these properties are managed to the highest standards, participate in the provincial Managed Forest Tax Incentive Program, and are certified as sustainable by the Forest Stewardship Council.

The operations of Haliburton Forest have been diverse since the mid-1950s, when it pioneered the concept of multi-use forest management. Today, the company's revenues are nearly evenly split between its two divisions. The Tourism & Recreation division offers dogsledding, fishing, camping, hunting, hiking, and maintains the world's largest private snowmobiling operation. The Forest Products division conducts sustainable forest management, ecological research, and operates a variety of wood processing facilities including a hardwood sawmill, firewood processor, log home manufacturing, custom woodworking studio, and canoe paddle production shop. It is also developing one of the first commercial biochar production facilities in Canada and was the second company in Canada to have its biochar certified by the Canadian Food Inspection Agency as being suitable for use as a soil amendment.

The operations have been lauded on numerous occasions. Most recently, the Tourism & Recreation division was honoured with the 2018 Sustainable Tourism Award by the Ontario Tourism Industry Association at the Ontario Tourism Summit in Windsor, Ontario. The Forest Products division was honoured with the 2018 Leadership Award by the Forest Stewardship Council at the GreenBuild Expo in Chicago, Illinois.

With over 250,000 acres under management in Ontario between three properties, Haliburton Forest's operations are managed with two guiding principles in mind. The first is the principle of earning a social license: the ownership group and management team believe that it is the duty of private landowners to earn the trust and confidence of the public by sharing the land with others and implementing best practices. The second is the principle of upholding a land ethic: the ownership group and management team believe that operations should maintain or enhance the ecological integrity of the land for its own sake, while seeking opportunities to develop viable businesses at the same time.

To further diversify the company, create economic benefits for its community, and support the forest improvement operations that occur within its properties, Haliburton Forest has been pursuing opportunities to develop modern wood heating projects since early-2017. It formed a partnership with TorchLight Bioresources and its local government, the Municipality of Dysart et al, to develop a DES in the Village of Haliburton, which would be fuelled by wood energy chips produced by Haliburton Forest on its properties. Creating a market for low-value timber in the form of wood energy chips would allow Haliburton Forest to conduct stand improvement thinnings in marginal stands, creating wildlife habitat and improving tree species composition in the forest.

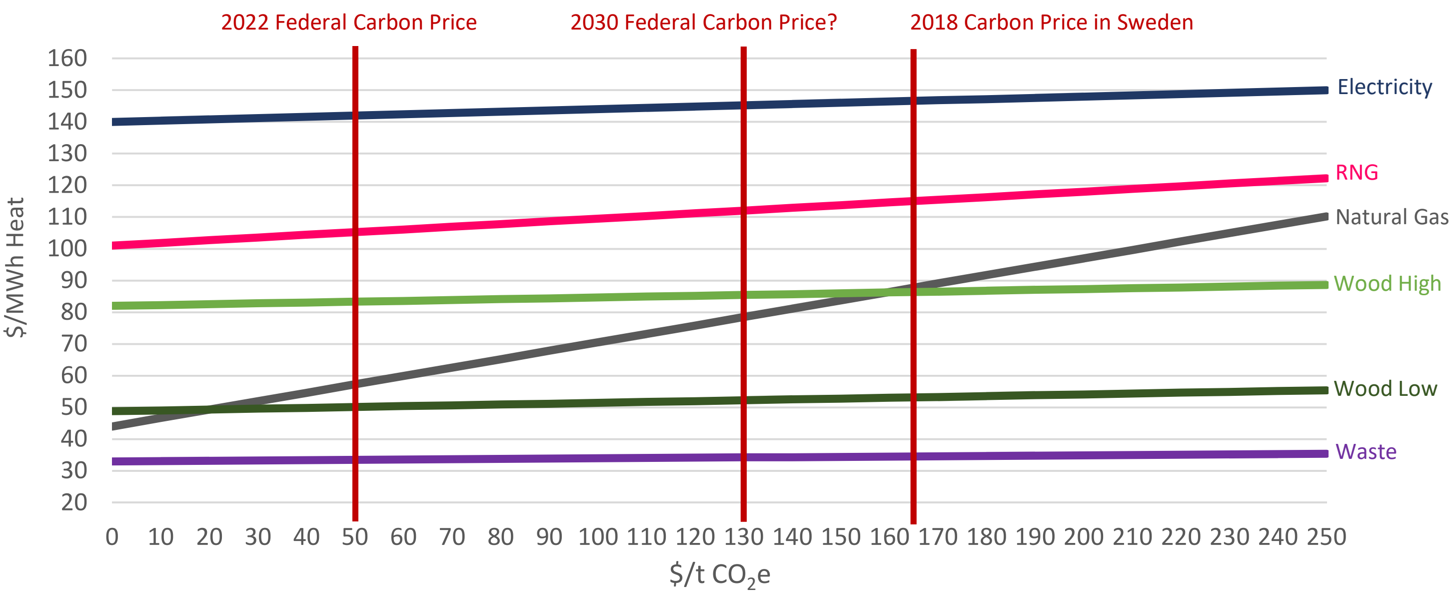
Haliburton Forest is in the process of establishing Canada's first wood energy chip production centre that adheres to Canadian standards on wood energy chips. The next stage is to develop local heating projects, made possible by long-term heat purchase contracts with building owners, which displace high cost heating oil and propane. Chief among the local opportunities are provincially-owned buildings, such as the cluster of a hospital and schools in Haliburton Village. In addition, Haliburton Forest and TorchLight Bioresources are continuing to pursue development of a DES in partnership with the local municipality. This project would be 50% owned by the municipality and generate much needed revenue for the municipality while establishing a market for energy chips.

The Economic Case for Wood Heat in Ontario

Solid biomass heat, and in particular wood heat, has been proven as the lowest-cost low-carbon heat option for commercial, institutional, and multi-unit residential buildings, as well as DES'. The dominance of wood heating under the United Kingdom's Renewable Heat Incentive policy, at 87% of the 18,900 non-residential projects, is evidence of this fact.[14] For single family detached homes, ground source heat pumps and renewable natural gas are the primary low-carbon heat alternatives to wood (electric heat is high cost). However, despite the UK Renewable Heat Incentive tariff (government payment) for heat generation by heat pumps being 2-3 times that for wood heat, the residential heat generation from wood under the policy has been greater than 4 times that of heat pumps. This indicates **wood heat is lower cost than heat pumps in all but the smallest of homes**. In addition, wood heat becomes more competitive with heat pumps as heat demand increases – due to building size or colder temperatures. Ontario is dramatically colder than the UK, while the average single family home size is 15-20% larger, making modern wood heat more relatively attractive in Ontario than the UK. Renewable natural gas has important role to play in detached homes, but analyses have shown Canada's maximum conventional renewable natural gas supply potential is ~5% of natural gas demand.[23]

Although wood heat is the lowest-cost low-carbon option in most instances, it must still be competitive with fossil fuel alternatives, such as natural gas, propane, and heating oil, to be widely adopted. Modern wood heat has a higher capital cost, but typically lower fuel cost, than propane or heating oil. Use of local wood fuels insulates building owners from the volatile pricing of globally-traded fossil fuels. In also means building owners can expect wood heat to lower costs when viewed over the lifetime of the building or equipment. However, many building owners do not plan to own their building for 20-30 years. This difference in weighting between capital and fuel when comparing wood and propane/heating oil can be managed for some buildings using heat contract policies (see page 14).

Figure 12. Comparison of DES Heat Source Options Under Carbon Pricing



	Natural Gas	Wood Chips Low (25% MC)	Wood Chips High (25% MC)	Solid Waste	Electricity	RNG
CapEx for Boiler Plant	$600/kW	$1200/kW	$1700/kW	$3100/kW	$200/kW	$600/kW
Fuel Cost (incl. transport)	$0.31/m^3 ($30/MWh)	$75/tonne ($21/MWh)	$150/tonne ($43/MWh)	-$100/tonne (-$38/MWh)	$135/MWh	$0.90/m^3 ($87/MWh)
Life Cycle GHGs (kg CO_2e/MWh heat)	265	27	27	10	40	85

*Combined Fuel and plant CapEx only; other operating costs excluded (minimal impact); 4% cost of capital; 40 yr amortization

[23] Canadian Gas Association, 2014. Renewable natural gas technology roadmap for Canada.

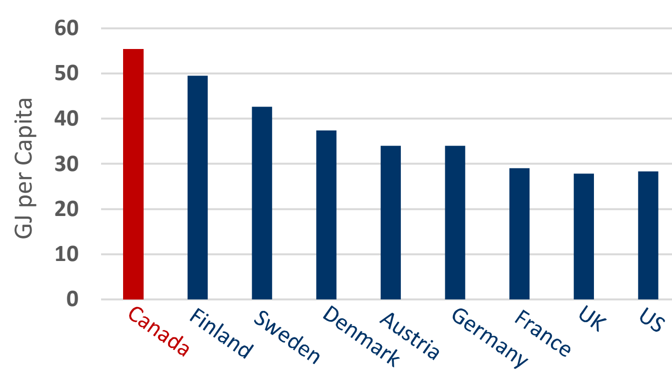
In the absence of carbon pricing, it is difficult to make a microeconomic case for modern wood heating compared to natural gas at current fuel prices. However, like Ontario, Sweden and Finland are reliant upon natural gas imports. In their case, expenditures on domestic wood fuel, as opposed to imported natural gas, have had significant macroeconomic benefits, particularly for rural regions. Natural Resources Canada estimates that **90% of the expenditures on imported fossil fuels leave the region where they are consumed**. In comparison, 75-80% of the expenditures on local wood fuels stay in the region where they are consumed. Based upon 2018 commodity, transmission, and distribution rates, it is estimated that Ontario households, business, and government spent $6 B on imported natural gas in 2017. If 25% of natural gas consumption was displaced by Ontario wood fuels at a 30% price premium ($8.50/GJ or $158/bdt), it would result in an additional $1 B staying within the province and, after accounting for the higher capital and operating cost of wood fuel, a net macroeconomic contribution of $500 M. While historically much of Ontario's natural gas came from western Canada and Ontario could benefit from transfer payments or overall Canadian economy gains, Ontario Energy Board figures indicate **74% of natural gas consumed in Ontario will come from the U.S. by 2021**.[24] At current consumption levels, this is $4 B per year leaving the province *and* the country.

The primary contributor to the higher cost of wood heat relative to natural gas is labour in the wood fuel supply chain. Ontario's forest sector has been devastated over the past 15 years and is facing continued challenges. Northern Ontario unemployment is dramatically higher than urban areas in the province, which is directly correlated to its greater reliance on government transfers and public sector employment. Wood heat can create up to 8 times the number of operating jobs as wind or solar per unit energy. Estimates from Austria place employment along the wood heat supply chain at 168 employment hours per TJ of wood fuel. Applied to the 215 PJ of potentially available wood in Ontario, this is 18,800 direct jobs. Significant demand for wood fuel also supports labour gains in the solid wood products industry and would lead to substantial indirect job creation. Using a 1.5 employment multiplier, **total job creation could reach 28,000** positions, with employment income exceeding $1.4 B per year. The development of urban DES infrastructure fuelled by Ontario wood fuel would enable urban areas with high incomes and low unemployment to economically support regions with lower incomes and higher unemployment.

Provincial Action Driving a Change in National Climate Policy Direction

The International Energy Agency predicts that "**Modern bioenergy will have the biggest growth in renewable resources** between 2018 and 2023, underscoring its critical role in building a robust renewable portfolio and ensuring a more secure and sustainable energy system."[25] **Canada has the most biomass resources per capita of any country it the world** and, with over 40% of the world's certified sustainable forests, is the undisputed world leader of sustainable forest certification. Despite these impressive resource and sustainability credentials, the country has failed to realize its potential. Apart from unique cases of Iceland and Norway, Canada is the world's largest per capita consumer of heat (Figure 13) and has double the per capita heat consumption as the U.S. and UK. However, only a small portion of Canada's heat demand is met with sustainable biomass. A near singular policy focus on electricity, and electrification of transportation and heat, has inhibited Canada's ability to capture its opportunity in bioenergy, and in particular, wood heat. Linked to this, Canada has not embraced its responsibility to implement 'Climate Smart' forest management approaches that maximize climate-positive opportunities in forest productivity, long-term carbon storage, and renewable fuel.

Figure 13. Heat Demand per Capita, 2015



[24] Ontario Energy Board, 2015. Staff report to the board on the 2015 natural gas market review.
[25] International Energy Agency, 2018. Renewables 2018 – analysis and forecasts to 2023.

Ontario Wood Heat Policy Recommendations

1. *Tender for Heat Contracts at Provincially-Owned Buildings (Schools, Hospitals)*

Heat contracting is where a building owner commits to purchase heat from a biomass plant owner/operator over a specified period of time – typically 20 years – at a predetermined, inflation-adjusted price. Government is the ideal first customer for heat project developers due to predictable, long-term energy demands and creditworthiness as a heat contract counterparty. From a government perspective, heat contracts are attractive as they place all the development, operating, fuel, investment, and technology risk on the developer, while locking in heat price for multiple decades. If a project fails, the building can revert to previous systems. PEI has embraced wood heat contracts, with 24 projects heating schools and hospitals and another 26 tendered this year.

Prince County Hospital, PEI

PEI will have 50 provincial buildings heated by wood chips within 3 years.

2. *Allocate Federal Infrastructure Funds to Municipalities for Public-Private Partnership District Energy Systems*

Under the Integrated Ontario-Canada Bilateral Agreement for the Investing in Canada Infrastructure Program, the Government of Canada has committed to provide $2.25 B for 'green' infrastructure projects in Ontario. These projects must result in climate mitigation or adaptation. DES' are critical enabling infrastructure for use of wood fuel in urban settings. As Stockholm has shown, large, centralized energy plants operating on wood chips can be connected to DES' in even the largest cities. In Stockholm, the city's DES is a public-private partnership that provides income for the city. Federal infrastructure funds allocated to municipalities for DES' (40% of project costs) would allow them to establish public-private partnership heat utilities and attract significant private sector investment. This approach of municipal ownership of heat systems could also be used for residential pellet boilers in communities where DES' are not feasible.

3. *Prioritize Comprehensive Energy Service Agreements (CESAs) at Publicly-Funded Institutions*

CESAs can be used by publicly-funded institutions, such as universities, colleges, prisons, and airports, to free up capital for investment in core operations (e.g., education) or to address deferred maintenance, pension liabilities, etc. In exchange for an upfront payment for energy infrastructure, institutions commit to long-term, fixed-price energy purchase from a private sector supplier. Transfer of non-core energy infrastructure assets can be linked to modernization and fuel switching to low-carbon biomass fuel, thus attracting additional private sector investment.

4. *Mandate DES Infrastructure for New Residential Development*

Installation of DES piping infrastructure is much lower cost at greenfield developments than retrofitting existing neighbourhoods, where natural gas lines have already been laid. There are significant benefits to installation of DES' in new developments, including elimination of furnaces and air conditioners in each residence (heat exchangers are installed instead) and the ability to develop local community heating, cooling, and electricity microgrids, thus ensuring community resiliency. Even if such community energy systems are initially fuelled by natural gas due to cost constraints, the energy distribution infrastructure enables ease of fuel switching to low-carbon, local wood fuel in the future.

5. *Incentivize Active Forest Management on Crown Timberlands*

The largest climate mitigation opportunity in Ontario is improvement of the productivity and net carbon uptake of the province's forests, which are largely Crown-owned. Under the current forest sector regime, the private forest sector is not incentivized to manage Crown forests in a manner that promotes long-term productivity or climate mitigation/adaptation performance. Countries such as Australia have pursued privatization of crown lands as a means to raise capital and attract institutional investment in 'Climate Smart' forestry practices. Many of the lands in Nova Scotia and New Brunswick are already privately owned. The current model of Crown ownership and private tenure is not maximizing value to Ontarians, nor is it resulting in forest sector success – as indicated by dramatic reductions in harvest volume, jobs, employment income, and sector revenue. It is also massively under-contributing in climate mitigation (net carbon uptake) relative to actively-managed forests in Sweden and Finland. A test program on Crown forest sales, with sale linked to long-term, enforceable commitments on active forest management that will allow Ontario to achieve its climate, biodiversity, and economic development goals, should be considered as a starting point.