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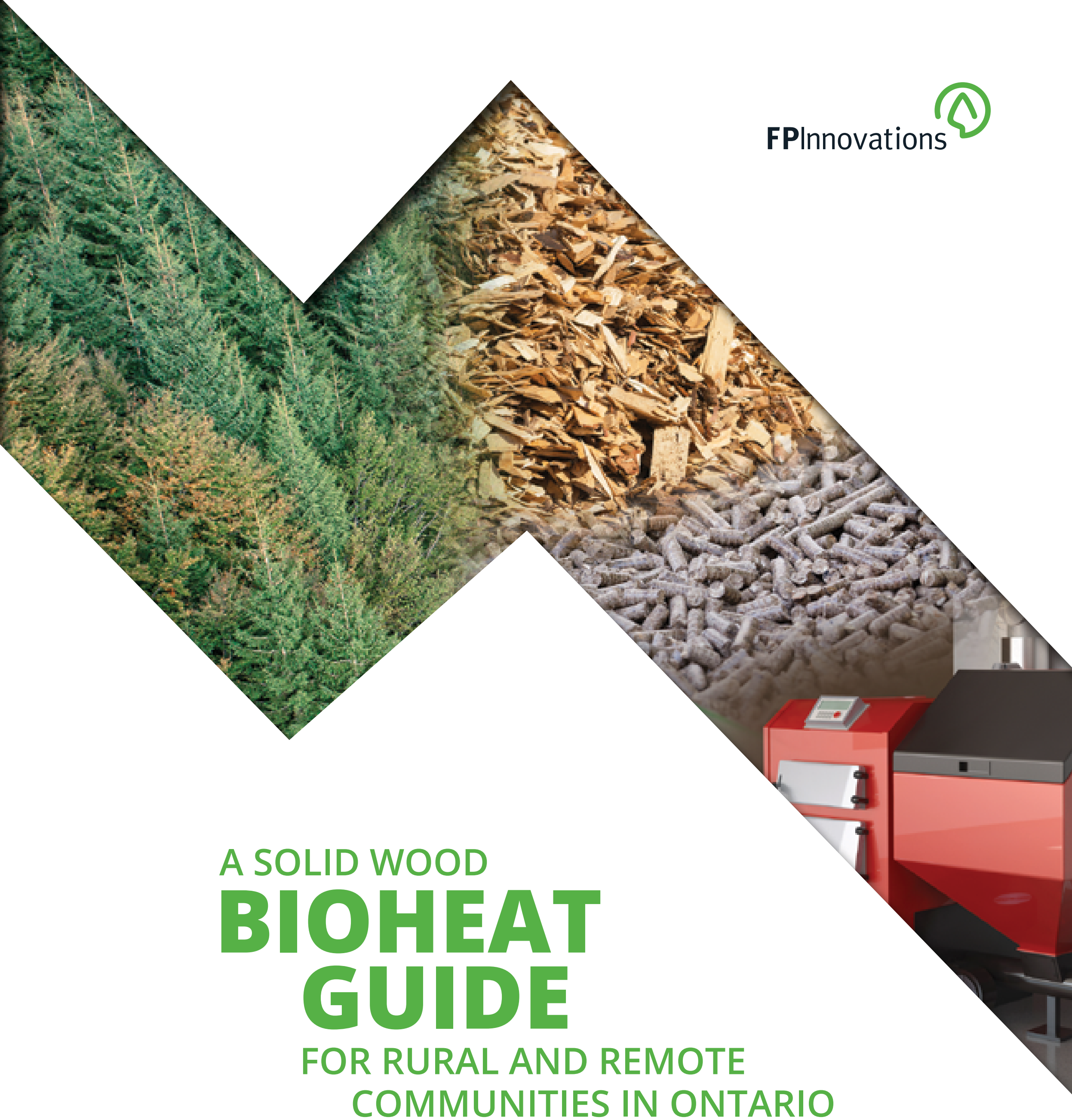

# A SOLID WOOD BIOHEAT GUIDE FOR RURAL AND REMOTE COMMUNITIES IN ONTARIO

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# A SOLID WOOD **BIOHEAT GUIDE** FOR RURAL AND REMOTE COMMUNITIES IN ONTARIO

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# EXECUTIVE SUMMARY

This guide has been developed to provide people in Ontario's remote and rural communities with the information and confidence to use wood from Ontario's sustainably managed forests to produce space heat and domestic hot water. It is aimed at community leaders such as those found in municipal governments, band councils, school boards, churches, not-for-profit organizations, and small businesses, as well as private homeowners.

Modern bioheat systems are highly engineered mechanical systems that provide space heat and domestic hot water for community buildings and businesses, as well as for private homes. This guide is applicable to systems that are less than 1 MW in size and that use solid woody biofuels to produce heat. Ontario has a large supply of woody biomass sourced from sustainably managed forests, including mill and harvest residues and unmerchantable standing timber, that could be used to produce solid woody biofuel.

Modern wood heating systems using local renewable solid woody biofuels can reduce greenhouse gas emissions, create local clean energy jobs, keep money in local communities, reduce the risk of fuel spills, and increase local energy and economic security.

This guide provides detailed information on solid woody biofuels that are available in Ontario and the combustion systems that can burn these biofuels. The four types of solid woody biofuels considered in this guide are cordwood (firewood), wood chips, wood briquettes, and wood pellets. The three types of combustion systems are stoves, furnaces, and boilers. The major considerations for sourcing and using each type of biofuel and combustion system for institutional/commercial and residential applications are outlined in this guide. The guide addresses the planning steps and funding options for bioheat systems.

# 1. INTRODUCTION

## Who will find this guide useful?

This guide has been developed to provide people in Ontario's remote and rural communities with the information and confidence to use wood from Ontario's sustainably managed forests to produce space heat and domestic hot water. It is aimed at community leaders such as those found in municipal government, band councils, school boards, churches, not-for-profit organizations, and small businesses, as well as private homeowners. This guide contains enough detail that consultants, engineers, and suppliers of woody biomass combustion systems and biofuels will also find it useful.

## What are biomass, biofuel, and bioheat?

*Biomass* includes "all organic materials of biological origin" and can originate from forestry, arboricultural, agricultural, horticultural, and aquacultural operations (CSA Group, 2015). When biomass is processed and used as fuel to produce heat and/or power, it is called *biofuel*. The heat produced when biofuel is burned is called *bioheat*.

This guide discusses only solid woody biofuel produced from forest resources. The four categories of solid woody biofuel are cordwood (firewood) (Figure 1), wood chips (Figure 2), wood briquettes (Figure 3), and wood pellets (Figure 4).

## Are bioheat systems complicated?

Bioheat systems are not complicated. The technology is well-developed and widely used in Europe, Alaska, and the northeastern United States, as well as across Canada. Bioheat systems are relatively new to Ontario, and that is why this guide has been developed. Bioheat professionals in Ontario are highly qualified and eager to help those who want to install a bioheat system. Any complexity that readers may perceive is due to the newness of bioheat systems in the province, not because the systems themselves are complex.

## What is included in this guide?

This guide is applicable to systems that are smaller than 1 MW thermal output in size and that use solid woody biofuel to produce heat. This guide does not discuss outdoor boilers, combustion systems of greater than 1 MW thermal output, combined heat and power systems of any size, or liquid biofuels made from solid wood. The guide includes the following sections:

- Section 1: Introduction
- Section 2: Benefits of choosing bioheat
- Section 3: Solid woody biofuels
- Section 4: Bioheat combustion systems
- Section 5: Important factors to consider when choosing bioheat
- Section 6: New-build bioheat installations compared to retrofit installations
- Section 7: Residential bioheat projects
- Section 8: Institutional and commercial bioheat projects
- Section 9: Other bioheat systems

Figure 1. Stacked and covered cordwood.

Figure 2. A high-quality wood chip (left) and a lower quality wood chip (right).


Figure 3. Various types of wood briquettes. (Photo: CanmetENERGY, Natural Resources Canada)

Figure 4. Wood pellets.

## 2. BENEFITS OF CHOOSING BIOHEAT

### Support for local jobs and economic development

Biofuel is usually sourced locally or regionally, which means that most of the economic benefits stay local or regional. Local labour is required to harvest, process, and deliver the biofuel. It is also required to operate and maintain combustion systems. All of this creates opportunities for individuals and businesses to develop and grow. Keeping money local and having lower energy costs provides an economic advantage to rural and remote communities. When fossil fuels or electricity are bought, much of that money leaves the community.

Solid woody biofuels are often made with poor-quality or underutilized biomass. Finding a market for this biomass reduces costs for local forestry companies, creates new local jobs, and diversifies the forest product mix.

### A sustainable and renewable fuel

Ontario has a large, sustainable supply of woody biomass that includes mill and harvest residues and standing timber that can be used to produce solid woody biofuel. Ontario's Crown Forest Sustainability Act requires that all Crown forests be sustainably managed, and Ontario uses a rigorous science-based approach for managing Crown forests. As a result, consumers of biofuel from Ontario's Crown forests can be confident that they are using a sustainable and renewable fuel. More information on sustainable forest management in Ontario can be found in Appendix A.

### Low and stable energy costs

Biofuel is often the cheapest heating fuel available. It can cost between 34% and 81% less than other heating fuels, depending on the biofuel used and the fuel it replaces. The price of biofuel also tends to be more stable than that of other fuels. Switching to bioheat reduces heating costs and insulates the community against the price fluctuations of fossil fuels. Natural gas is often cheaper than bioheat, but it cannot provide the same social and economic benefits of locally sourced solid woody biofuel.

### Reliable fuel supply

Biofuel production is well established and increasing worldwide as more people realize the benefits of switching to bioheat. Cordwood and pellets are readily available in many locations in Ontario. Wood chips are widely available, but care must be taken to ensure that local manufacturers can provide the right quality of chips. In some locations, wood chips may already be committed to other users.

### Low-carbon fuel

Many people do not realize that bioheat is a low-carbon fuel. Biofuel is a renewable resource that produces fewer greenhouse emissions than fossil fuels, as long as the forest is sustainably managed. When fossil fuels are burned, ancient carbon is released into the atmosphere, and because it cannot be returned into the original deposits, much of this carbon remains in the atmosphere and contributes to climate change. When biofuel is burned, the carbon emissions can be recaptured by the forest as new trees grow to replace the trees that were harvested to produce the biofuel. For more information on bioheat and carbon emissions, see Appendix A.

## Lower environmental risk than fossil fuels

Some people or communities believe that bioheat systems are big polluters and that fossil fuel systems are much cleaner. This is not true. All types of combustion, including that of biofuel and fossil fuel, produce emissions such as sulfur dioxide, nitrous oxides, carbon monoxide, carbon dioxide, volatile organic compounds, and particulate matter. Today's bioheat combustion systems produce far smaller amounts of emissions than residential wood stoves of the past, and are on par with their fossil fuel counterparts. The emissions from new bioheat systems are constantly being reduced. For more information on bioheat and carbon emissions, see Appendix A.

Liquid fossil fuels can pose a contamination risk if they spill. Solid woody biofuel poses no spill risk. When biofuel is spilled, it simply decomposes naturally without any harmful effects on people or the environment.

## Bioheat systems are reliable and easy to operate

Bioheat systems have all the reliability and features of any other new heating system. Bioheat systems are highly engineered mechanical systems, not unlike electric or fossil fuel systems. Most of these systems include user-friendly automatic operation and reliable performance, and all must be designed and installed by qualified professionals. However, there are important differences between bioheat systems and other heating systems that potential owners and designers need to be aware of. These differences include necessary cleaning, maintenance, and fuel management that bioheat systems require. The benefits are often worth the additional effort. With good design, the labour requirements of bioheat system operation can often be matched to the capabilities of the owner or operator.

## Stimulation of community development

Bioheat systems, especially larger, community-based systems, require partnerships with local groups. This can lead to new opportunities for community development, such as employment, training, and social interactions. The social benefits can often be the deciding factor when assessing the viability of a bioheat project. Potential social benefits include:

- Energy security
- Locally sourced renewable energy
- Local employment
- Bonding the community through a collaborative project
- Confidence in the community's future
- The opportunity to build new partnerships and collaboration within the community

## Funding for local forest stewardship activities

Biofuel production can provide a mechanism to fund forest stewardship activities, such as pre-commercial thinning of forests, forest restoration, and FireSmart initiatives. FireSmart initiatives reduce the risk of wildfire damage by removing some of the forest fire fuel (trees and deadwood) near buildings and communities.

## 3. SOLID WOODY BIOFUELS

This section describes each solid woody biofuel considered in this guide. Residential systems generally do not use wood chips, so those interested in residential systems can skip the section on wood chips. Table 1 provides a summary of the key properties of each fuel type, including approximate costs. The provided costs are broad estimates and should not be used for planning purposes. Fuel costs should be verified with local suppliers. The content of this section was adapted from Natural Resources Canada's *Solid biofuels bulletins* (Natural Resources Canada, n.d.-a,b,c,d,e,f,g). These bulletins are recommended reading for more detail on woody biofuel standards, sources, and descriptions of each type of fuel.

Table 1. Comparison of fuel properties and costs in Ontario[a]

| Fuel | Moisture content | Typical range of ash content (% dry basis) | Typical range of bulk density (kg/m³) | Typical range of higher heating value (MJ/kg) | Peak heating demand of building[b] | Nominal delivered cost ($ per unit volume) | Delivered fuel cost ($/GJ) |
|---|---|---|---|---|---|---|---|
| Cordwood (seasoned) | <25% | 1.0–3.0 | 300–500 | 14–15 | 10 kW to 150 kW | $400 per bush cord | $22 |
| Wood pellets[c] | <10% | 0.7–1.5 | 550–800 | 18–20 | 20 kW to >1 MW | $300 to $316 per tonne | $16 |
| Wood chips (air dried) | 45%[d] loosely packed | 1.0–3.0 | 300–400 | 10–11 | 150 kW to >1 MW | $90 to $110 per tonne | $10 |
| Heating oil (No. 2) | N/A | N/A | 850 | 42 | 20 kW to >1 MW | $1.14 per L | $33 |
| Propane | N/A | N/A | 1.7 | 50 | 20 kW to >1 MW | $0.8 per L | $35 |
| Natural gas | N/A | N/A | 0.7–0.9 | 43 | 20 kW to >1 MW | $0.25 per m³ | $6.70 |
| Electricity | N/A | N/A | N/A | N/A | 20 kW to >1 MW | $0.18 per kWh | $50 |

[a] Costs are rough estimates only and should not be used for detailed planning. Costs should be verified with a supplier. (Adapted from Natural Resources Canada, n.d.-a,b,c,d,e,f,g; cost estimates are based on 2018 market rates.)
[b] An upper limit of >1 MW has been used in this table to be consistent with the scope of the guide. Larger systems are available.
[c] Costs for bulk delivery in totes, vacuum truck, or pallets.
[d] Wood chips can be dried to lower than 45%. When mechanically processed, 25% is achievable.
N/A: Not applicable

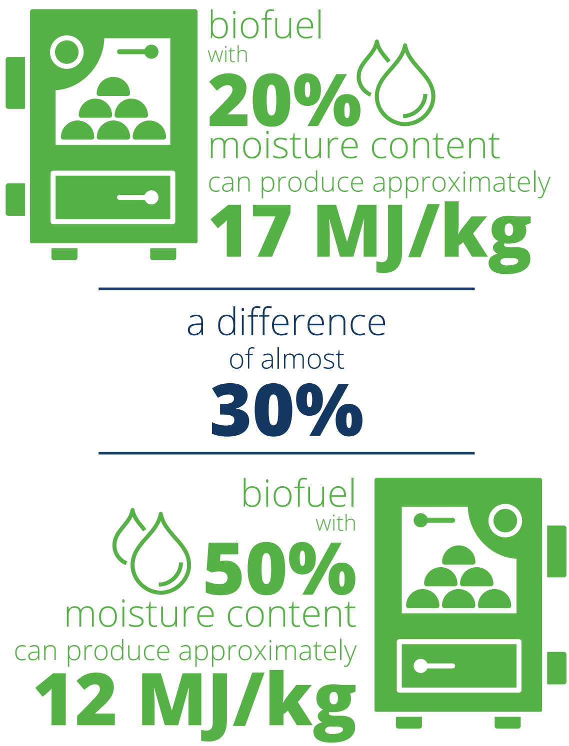
## Important properties of solid woody biofuels

The CAN/CSA-ISO 17225 Solid Biofuels Standards are voluntary fuel standards and have been adapted from the solid biofuels standards set out by the International Organization for Standardization (ISO) (Natural Resources Canada, n.d.-c; CSA Group, 2015). The standards establish grades for each type of solid woody biofuel (cordwood, wood chips, wood briquettes, and wood pellets) based on the source and properties of the biofuel. Standards are important because biofuel quality can vary greatly depending on the source and processing methods. The quality of the biofuel affects the efficiency of combustion, the life of the combustion system, and the released emissions. Canadian vendors and purchasers of solid woody biofuels can use these standards to communicate information about the needs for biofuel quality and to develop purchase agreements. Ontario uses the CAN/CSA-ISO 17225 Solid Biofuels Standards in its air quality regulations and guidelines for small wood-fired combustors (bioheat systems).

There are five fuel properties that should be considered when selecting a fuel. In order of importance, these include particle size, moisture content, ash content, bulk density, and energy content.

Particle size is a measurement of the size of the individual pieces of biofuel. Combustion systems are designed to operate using biofuel of a certain particle size. Particles that are too large or too small can cause problems for fuel-handling systems, respiratory health, and combustion emissions and efficiencies (Marinescu, 2013).

Moisture content is the amount of water that a fuel contains, expressed as a percentage of the weight of the fuel. It is measured on a percent wet basis or percent dry basis. High moisture content has several disadvantages, such as increased transportation costs per unit of energy, increased air emissions, risks of degradation through fungal and bacterial activities during storage (composting), self-heating, and off-gassing. High moisture content also lowers the amount of useful energy captured from combustion as more energy is required to evaporate water. When wet fuel is burned, a considerable amount of energy is spent evaporating water instead of providing useful heat.



For example, biofuel with 20% moisture content can produce approximately 17 MJ/kg, whereas biofuel with 50% moisture content can produce approximately 12 MJ/kg. This is a difference of almost 30%, meaning that if a system was burning biofuel with 50% moisture content, it would need to burn 30% more fuel to produce the same amount of heat as biofuel with 20% moisture content. When buying biofuels, the moisture content should be guaranteed.

Ash is the residue that remains after combustion occurs, and it must be disposed of in some way on a regular basis. Fuels with low ash content reduce handling and disposal costs. Higher bark content or contamination with dirt and rocks will increase ash content. Low ash content should be sought when sourcing biofuel (Marinescu, 2013). Clean ash can be used as a soil amendment on private lands, municipal lands, and Indian reserve lands, but not on Crown Land (except for special cases such as research trials). Care should be taken to ensure that the ash is clean and contains no heavy metals or trace elements.

Bulk density is how much the fuel weighs per unit of volume (for example, kg/m$^3$) and includes the airspace between fuel particles. The denser a solid biomass fuel is, the more energy it contains per unit volume. Solid woody biofuels with greater bulk density are more economical to transport and take up less storage space (Marinescu, 2013).

Energy content is the amount of energy per unit weight (for example, MJ/kg or MJ/m$^3$ of biofuel) the biofuel provides when burned. This value may be presented as a higher heating value (HHV) or lower heating value (LHV). The HHV assumes that all the water vapour formed during combustion will be condensed and all possible heat will be recovered. The LHV assumes that the water contained in the fuel is vaporized and is not recovered. HHV is the most commonly reported value in Canada (Marinescu, 2013). Moisture content is the most important factor affecting energy content.

## Cordwood

Cordwood (Figure 1), or firewood, is the most unprocessed and recognizable form of solid woody biofuel. It is made by cutting logs to length and then splitting as needed. It is expensive to transport and so is often sourced from local forests. Hardwood species such as maple and birch have a higher energy density (kJ/kg of wood) than softwood species such as pine and spruce. Combustion systems using hardwood will require less frequent fueling. It is best practice to process and burn cordwood locally and not move it long distances to reduce the risk of moving invasive species.

### Cordwood fuel handling and storage

Cordwood is often sold on a volume basis, such as by the cord (sometimes called a bush cord) (3.62 m$^3$, 4 ft. x 8 ft. x 4 ft., stacked), or it can be processed by the end user if they have access to a wood supply. Residential users can obtain a fuelwood licence from the Ministry of Natural Resources and Forestry to harvest cordwood on Crown land for personal heating use. A stumpage fee must be paid to the government based on the amount of wood harvested. The fee for 2018 was $4.64/m^3$, which is approximately $11.70 per bush cord of wood (accounting for 30% airspace in the pile) (Government of Ontario, 2018).

Cordwood should be dried to 20% moisture content for two seasons of drying time (spring and summer) and covered from the elements (Figure 1). Cordwood that is not covered or dried long enough will have a high moisture content and will create more emissions and burn inefficiently, requiring more wood to provide the same amount of heat.

Cordwood is the most labour-intensive fuel for the end user. Pre-processed cordwood can be purchased and delivered, but the user must often stack the cordwood themselves. If the end user decides to harvest and process the cordwood themselves, it will be more work but can result in cost savings. It is difficult to automate cordwood handling systems, so someone must be present to load the combustion system every few hours.

Figure 5. This bioheat wood chip production facility has an asphalt pad to eliminate dirt and sand contamination and keeps the chips covered to allow them to dry. It has a storage capacity of 1 000 oven-dry tonnes. (Photo: Biothermic)

Figure 6. Hog fuel (pictured here) cannot be used in the combustion systems discussed in this guide.

## Wood chips

Wood chips (Figure 2 and Figure 5) are produced by chipping or grinding wood, followed by screening the chips to make sure they are uniform in size. They are generally made of mill residues, such as slabs, bark, or shavings, and from logging residues. Biofuel wood chips, also known as energy chips, are different than pulp chips. Pulp chips often have a higher quality requirement. Chip properties can vary significantly, depending on the source and the production method. The combustion systems discussed in this guide require chips of consistent size, composition, and moisture content. Wood chips are cheaper to manufacture than wood pellets but are more expensive to transport because they have a higher moisture content and lower bulk density. Automated fuel handling systems can be used to fuel wood chip combustion systems. Lower quality wood chips, often called hog fuel (Figure 6), can be of various sizes and content (wood, bark, twigs, rocks, dirt) and are not an appropriate fuel for the combustion systems discussed in this guide.

### Wood chip fuel handling and storage

Chips are generally delivered by truck to a holding bin or room located near the combustion system. There must be space near the storage facility for delivery access. A larger storage facility means fewer deliveries, but it requires more space. The fuel storage area should be sized such that delivery vehicles can always deliver a full load and so that there is sufficient supply for two to four weeks of operation for smaller systems (<500 kW) (Community Energy Association, 2014). Ontario's Ministry of the Environment, Conservation and Parks requires 1.5 days of fuel for systems <3 MW thermal output. The storage facility needs to be connected to the combustor with an automated conveyance system (such as an auger-walking floor combination) to deliver wood chips directly to the combustion system.

Wood chips must be stored under a roof to prevent rain and snow from wetting the chips (Figure 5). Water reduces the energy content of the chips, and if it gets in between the chips and freezes, the chips turn into large blocks and become difficult to handle, clogging automated feeding systems. Chips should be stored on a concrete or similar pad to prevent soil and rock contamination. Contamination, such as rocks, sand, dirt, or soil, will foul the combustion system, increase emissions, and cause failure of the system. Chemically contaminated fuel cannot be used for combustion either. These handling requirements apply to both the processor's storage facility and the end user's facility. Chips that sit for long periods of time (longer than two weeks) and in large quantities can begin to pose safety and fuel quality risks from decomposition, off-gassing carbon monoxide, and spontaneous combustion. Most combustion systems use the chips before they begin to pose any risk. It is best to pile the logs and then chip them as needed to avoid these issues. The *Guide to Wood Chip Fuel: Characteristics, Supply, Storage and Procurement* (CSA Group, 2019) provides more detailed guidance for handling wood chips. Manufacturers of combustion systems will also provide guidance for wood chip storage.

Chips can be manufactured by the end user, but the production of biofuel is outside the scope of this guide. Special chippers and other equipment are required for chip production. Combustion system manufacturers and designers can provide guidance on this topic.

## Wood briquettes

Wood briquettes (Figure 3) are not commonly used in Ontario, but they are common in other parts of the world. They have highly consistent properties, resulting in consistent combustion system operation. They are similar to wood pellets in that they are compressed wood residues, but they are less dense than wood pellets and are made of larger particles. They often come in two sizes: large, log-sized briquettes (similar in size to cordwood) and small, puck-sized briquettes (similar in size to a soup can). Their low moisture content and consistent size make them well suited for transportation. It is not common in Canada to use additional binders in the manufacturing process to hold briquettes together.

### Wood briquette fuel handling and storage

Briquettes are sold by the bag, box, or pallet. They can be manually loaded into a combustion system, or an automatic loading system can be installed. Briquettes must be kept completely dry or they will deteriorate and disintegrate.

## Wood pellets

Wood pellets (Figure 4) are made by compressing sawdust into small, cylindrical pellets that are 6 or 8 mm in diameter and up to 40 mm long. Lignin, naturally found in wood, holds the pellets together. It is not common in Canada to use additional binders in the manufacturing process to hold pellets together. Wood pellets have highly consistent properties, resulting in consistent combustion system operation. They are cheap to handle and transport and are well suited to automated fuel handling systems.

### Wood pellet fuel handling and storage

Pellets are sold by the bag or by bulk truck delivery. Bulk delivery can be by tote (Figure 7) or pallet (Figure 8), or direct delivery by vacuum truck to a holding bin or silo, eliminating the need for end users to handle pellets themselves (Figure 9). Vacuum truck delivery is the most convenient delivery method and is currently available in some areas of Ontario (central and northwest).

Figure 7. Pellets can be delivered in 18 kg bags on a wrapped pallet (left) or in large tote bags (right). (Photo: ICS Lacroix)

Figure 8. A residential wood pellet storage set-up for storing and transporting bagged wood pellets. (Photo: Innovations Initiatives Ontario North)

Pellets will last for a long period of time if kept dry but will deteriorate and disintegrate into sawdust if exposed to even small amounts of moisture. Pellets stored in bags should be kept in a dry place, such as a basement or enclosed shed, or be covered with plastic (Figure 8). If wood pellets are delivered in bulk by truck, then an outside (Figure 9) or an inside (Figure 10) storage bin is required. Indoor storage bins can be above ground or below ground. They can be custom-made, as long as they physically contain the pellets and dust and keep pellets dry. Agricultural silos are often used as outdoor storage (Figure 9). The fuel storage area should be sized such that delivery vehicles can always deliver a full load and so that there is sufficient supply for operation for two to four weeks for smaller systems (<500 kW) and three days for larger systems (>1–2 MW) (Community Energy Association, 2014). Where space is available, systems can be designed such that delivery occurs only once per year.

Combustion system manufacturers will also provide guidance for pellet storage. As of late 2019, new standards for pellet storage were under development by CSA Group.

Figure 9. Delivery truck unloading pellets into a water-tight agricultural silo using a vacuum hose. An automatic control system tells the combustion system when to move pellets from the silo to the combustion system.
(Photo: Biothermic)

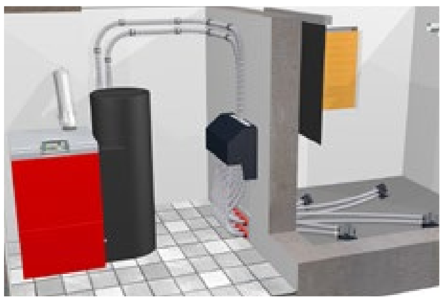


Figure 10. An indoor pneumatic pellet delivery system automatically moves pellets from the pellet storage room (right) and delivers them to the combustion system (left). (Photo: Biothermic)

## 4. BIOHEAT COMBUSTION SYSTEMS

Bioheat combustion systems are highly engineered mechanical systems with many similarities in efficiency, performance, and emissions to modern fossil fuel and electric heating systems. Bioheat combustion system technology is well established and is continuing to expand worldwide and in Ontario. These technologies are popular in Europe and the northern United States and have been widely implemented across Canada. In addition to many wood stoves, approximately 400 facilities between 50 kW and 5 MW thermal output were operating in the commercial, institutional, and agricultural (such as greenhouses) industries in Canada as of late 2017. Most of these systems were less than 1 MW thermal output capacity. Wood pellets and wood chips are the most commonly used biofuels. Approximately 10% of those installations are in Ontario. Bioheat projects have successfully been implemented in all industries, with institutional installations making up the majority (S. Madrali, personal communication, January 7, 2019).

Each combustion system considered in this guide is described in this section. Table 2 provides a summary of the typical use of each combustion system and the estimated costs. These costs are broad estimates and should not be used for planning purposes. Table 3 shows the types of fuels that can be burned in each type of combustion system.

## Table 2. Typical application for different combustors and the associated fuel types, installed cost, and approximate annual biofuel usage[a]

<table>
<tr><th></th><th colspan="3">Typical application and annual fuel consumption</th><th>Installed cost[b]</th><th>Nominal efficiency range[c]</th></tr>
<tr><td>Cordwood stove</td><td rowspan="6">Residential (2.7 to 12 tonnes per year)</td><td rowspan="2"></td><td rowspan="5"></td><td>$750 to $7 500</td><td rowspan="2">58% to 87%[d]</td></tr>
<tr><td>Pellet stove</td><td>$1 750 to $7 500</td></tr>
<tr><td>Cordwood furnace</td><td rowspan="5">Institutional (18 to 225 tonnes per year)</td><td>$3 000 to $11 000</td><td>33% to 79%</td></tr>
<tr><td>Pellet furnace</td><td>$6 500 to $13 000</td><td>48% to 89%</td></tr>
<tr><td>Cordwood boiler</td><td rowspan="3">Twice the cost of a fossil fuel system[e]</td><td>60% to 83%</td></tr>
<tr><td>Pellet boiler</td><td rowspan="2">Large institutional and district heating (>1 000 tonnes per year)</td><td>85% to 90%</td></tr>
<tr><td>Wood chip boiler</td><td></td><td>85% to 90%</td></tr>
</table>

[a] Adapted from Becker et al. (2014) and conversations with manufacturers and suppliers.
[b] Based on conversations with manufacturers and suppliers.
[c] From USEPA 2018a, 2018b, 2018c. Efficiency measurements for stoves based on Canadian Standards Association (CSA) B415.1; all others based on HHV. Boiler efficiency only considers systems with buffer tanks.
[d] Data did not allow differentiation between cordwood and pellet stoves.
[e] Boiler systems vary significantly in size and cost based on site-specific factors. Citing a dollar range is therefore not as useful.

## Table 3. Fuels burned in each type of combustion system[a]

| Combustion system | Fuels burned | Application |
|---|---|---|
| Stove | Cordwood, briquettes, pellets | Residential (10 kW to 50 kW) |
| Furnace | Cordwood, briquettes, pellets | Residential, commercial, and institutional (30 kW to 500 kW) |
| Boiler | Cordwood, briquettes, pellets, wood chips | Residential, commercial, institutional, and small district heating (15 kW to 1 MW) |

[a] Individual combustion systems are usually designed to burn only one type of fuel. For example, a stove can burn cordwood or pellets, but not both.

## Stoves

Stoves (Figure 11) are heating appliances most commonly used for heating individual rooms or single-family homes. They can be designed to burn cordwood and briquettes or pellets. Traditionally, stoves had poor efficiencies (<55%), little or no control, and high emissions, but significant improvements have been made in newer models. When stoves are the main source of heat, a backup and/or supplementary heating system is often necessary. Labour requirements are modest and include loading cordwood or briquettes into the stove for cordwood stoves or loading pellets into the stove's hopper for wood pellet stoves. In both systems, the ash tray must be emptied every week. Wood stove chimneys should be cleaned regularly to remove creosote and should be inspected for any defects. Pellet stoves require some regular cleaning that is not required for wood stoves. Stove manufacturers provide cleaning and safety recommendations for their products. Clean systems will operate safely, cleanly, and efficiently and will last longer.

Stoves offer some important advantages over other combustion systems. These include ease of operation, low initial cost to purchase and install, and the ability of users to produce their own fuel if they use cordwood and can access a private woodlot or have a fuelwood permit for harvesting Crown forest timber.

Cordwood stoves are generally (but not always) the least efficient of all wood combustion systems, but they can operate without electricity and are thus not susceptible to electricity outages. Pellet stoves generally have better control and efficiency than wood stoves, but they require electricity to operate. Battery backup systems are available for electrical power outages. Wood pellets are loaded into a hopper on the back of the stove (Figure 12) every day or two and are then are automatically fed into the stove. The user does not load the pellets directly into the combustion chamber.

Figure 11. A residential wood pellet stove. Partial bags of pellets are stored in the basket (on the left) until needed. This stove provides heat for most of the year for this typically sized home, using about 200 bags of pellets (3.6 tonnes). (Photo: Innovations Initiatives Ontario North)

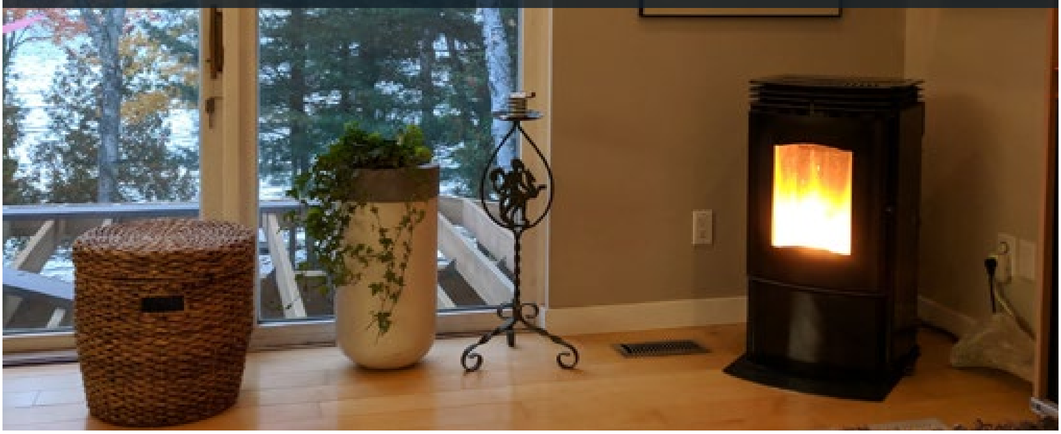


Figure 12. Pellets are loaded into the hopper of the pellet stove, as shown. A control system then automatically moves the pellets to the stove's combustion chamber as required. (Photo: Innovations Initiatives Ontario North)

## Furnaces

Furnaces (Figure 13 and Figure 14) can be used for heating small spaces, such as single-family homes or small commercial or institutional buildings. They can be designed to burn cordwood and briquettes or pellets. They look and function similar to a fossil fuel furnace and are installed in the same location, such as a utility room in the basement. Furnaces use a fan and duct system to move hot air throughout the home and are controlled using a central thermostat (Figure 15).

New models come with controls to regulate combustion, temperature, airflow, and pellet flow (for pellet furnaces). These controls can reduce emissions, improve combustion efficiency, and lower fuel consumption. A backup heating system is usually required if using a furnace; units can be bought with a built-in propane or electric backup system. Cordwood furnaces are designed to operate with electronic controls and a duct fan, but they can operate without electricity (with decreased performance) in case of an outage.

Figure 13. Wood pellet furnace with indoor pellet storage. (Photo: SBI)

Figure 14. A cordwood furnace with electric backup and indoor wood storage.

Figure 15. Modern thermostats control combustion systems. (Photo: SBI)

Labour requirements are modest and include cleaning the ash tray and loading cordwood or briquettes into the furnace. Fuel handling can be highly automated for wood pellet furnaces. Users can opt to load pellets into a hopper on the back of the furnace every few days or use a larger

Figure 16. A 30 kW cordwood boiler used to provide heat for a home or small office building. On the right is the hot water storage tank (2 250 L) used to store energy and increase system efficiency. (Photo: Biothermic)

holding bin that automatically loads the hopper (Figure 9 and Figure 13). Chimneys should be cleaned regularly to remove creosote and should be inspected for any defects. Furnace manufacturers provide cleaning and safety recommendations for their products. Clean systems will operate safely, cleanly, and efficiently and will last longer.

## Boilers

Boilers can be used to provide space heat and domestic hot water, eliminating the need for a second system to heat domestic water. For space heat, they can be easily integrated into an existing hot water heat distribution system (hydronic heating system loop) or a system that uses ducts and fans. They can be designed to burn cordwood, wood chips, briquettes, or pellets. They can be smaller systems (Figure 16), used to serve homes and small offices, or larger systems, used to serve large institutional buildings (Figure 17) or district heating systems. They have highly sophisticated controls and high efficiency. They can be installed indoors (utility room, heated shed, or boiler room) or can be bought as a packaged unit in a container (Figure 18 and Figure 19). A backup system may be required for peak heating on the coldest days or when people are not available to load the system. The backup system is often an electric hot water heater or boiler.

Figure 17. Wood chip boilers installed at Confederation College. Each boiler can provide 500 kW of baseload. These boilers provide 85% of the space heating needs of the 400 000 square foot facility. (Photo: Biothermic)


Figure 18. A containerized pellet boiler system with an agricultural silo for pellet storage used to heat a school. This type of containerized system can be used for cordwood, wood chip, and pellet boiler systems.

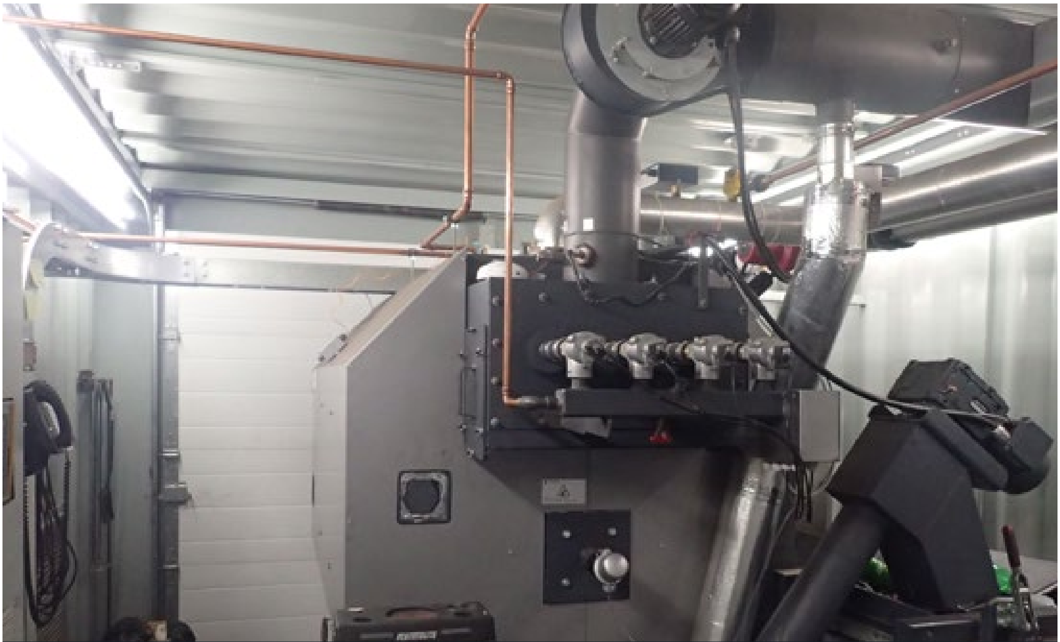


Figure 19. A pellet boiler used to heat an elementary school. Even these larger systems use hot water storage to increase efficiency and regulate heat output. Ash removal systems in larger combustion systems automatically deliver ash from the boiler to a bin. This wood pellet boiler delivers ash to a waste bin on wheels (right) for easy and clean ash removal. Operators simply wheel the ash bin away and empty it. This type of ash removal system would be typical for the systems used in larger institutional or commercial spaces.

High-performance models come with advanced controls (Figure 20) and additional hot water buffer tanks to help regulate heat output (Figure 16, Figure 19, and Figure 21). It is important to distinguish between buffer tanks and domestic hot water tanks. Buffer tanks are heat storage units and supply heat in the form of hot water to the heat distribution system (heat exchangers, air ducts, or hot water pipes). The water in the buffer tanks is distributed in pipes to deliver heat but is never consumed as potable water. Domestic hot water tanks get their heat (but not water) from the buffer tank using non-contact heat exchangers and supply hot water for consumption.


Figure 20. Combustion systems can come with sophisticated controls that manage building temperature levels and schedules and domestic hot water in addition to the combustion system itself. These control systems ensure clean and efficient combustion, monitor fuel levels, and control fuel conveyance systems. This is a control system for a pellet boiler, but it would be similar to other boilers as well.

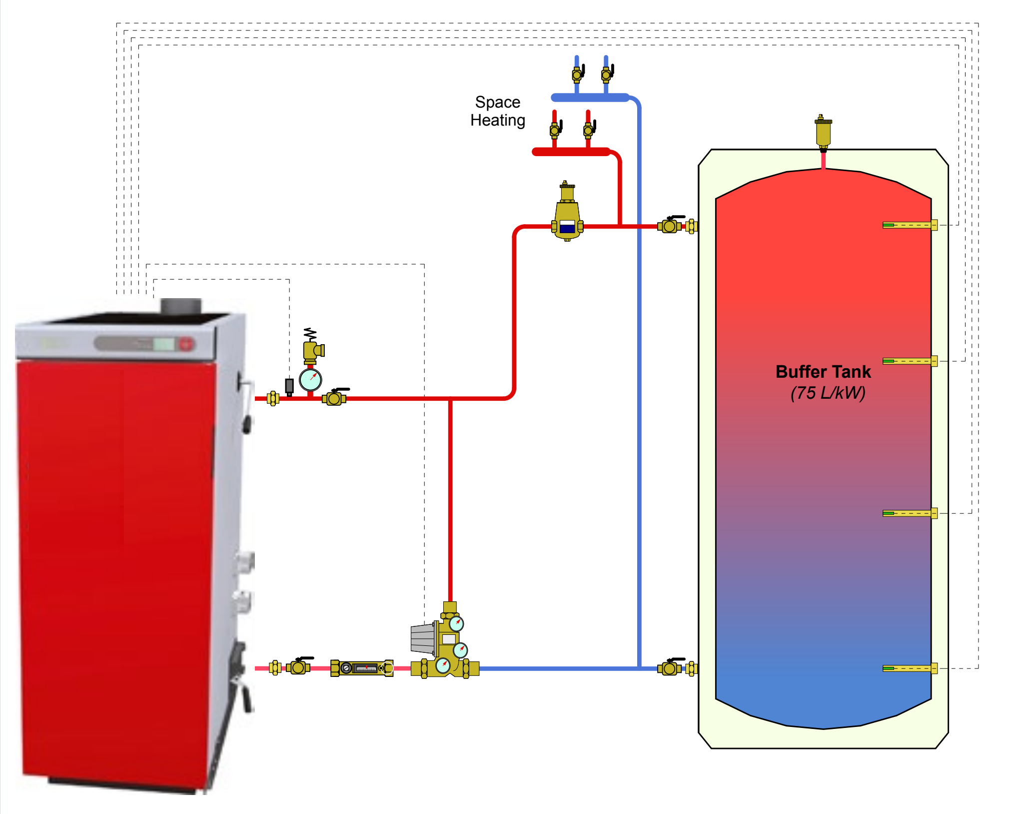



Figure 21. A general diagram showing how a boiler system is configured. The combustor (left) heats water that is stored in a tank (right). The tank then feeds hot water to the building's heating and domestic hot water system. In some larger systems, the distribution pipes can act as the storage tank. Boiler systems of all fuel types need some sort of hot water storage to ensure efficient operation. The red and blue lines indicate hot supply and cold return water, respectively. The dashed lines represent electronic signals from temperature sensors that feed information to the boiler's control system so it can manage combustion efficiently. (Photo: Biothermic)

The additional heat storage in buffer tanks can be beneficial as it allows the boiler to operate at 100% output whenever it operates, greatly increasing efficiency and reducing fuel consumption. For large systems, the hot water pipe distribution system may be able to act as the hot water storage system. Tank size and temperature depend on application and fuel burned and must be determined on a case-by-case basis. The temperature in the buffer tanks is dictated by the needs of the other heating system components (e.g., domestic hot water or space heat temperature needs).

Maintenance requirements vary depending on the type of fuel and size of system. Smaller cordwood systems (residential and small commercial/institutional) require weekly ash removal and cleaning, a task that takes five to ten minutes (Figure 22). Smaller pellet systems (residential and small commercial/institutional) can operate for one to two months without requiring cleaning and ash removal. Larger commercial or institutional systems require monthly cleaning and have automatic ash removal systems that need to be emptied only a few times per year (Figure 19). Some systems come with an alarm to alert users that the ash bin needs emptying. Chimneys should be cleaned regularly to remove creosote and should be inspected for any defects. Boiler manufacturers provide cleaning and safety recommendations for their products. Clean systems will operate safely, cleanly, and efficiently and will last longer.

Only boilers intended for indoor installation (including sheds and containerized systems) with a separate buffer tank are recommended. Outdoor boilers (often using cordwood) have poor system efficiency (20% to 30%), high emissions, and use large amounts of fuel (Burkhard & Russell, 2012). Therefore, they are not recommended.

Figure 22. Ash removal systems in combustion systems are user friendly. This cordwood boiler ash removal system uses a custom-designed scoop to easily and cleanly remove ash. This type of system would be typical for the smaller systems used in homes and smaller institutional and commercial spaces. (Photo: Biothermic)

## 5. IMPORTANT FACTORS TO CONSIDER WHEN CHOOSING BIOHEAT

There are a number of important factors to keep in mind when considering a bioheat combustion system and some important questions that need to be answered at the outset of the project (Neave, 2013). Some of these factors will not be applicable to residential bioheat systems.

**Who will be the project champion?**
A common factor in successful community bioheat projects is a strong project champion. This person or organization will see the project through from initial planning to community engagement to installation and operation. Without a champion, projects routinely fail.

**What are the goals of the project?**
Clear goals and values will help guide the project, remind the planners why the project is important, and communicate to the community why the project is being pursued. Common goals include:

- Reliable and low heating costs
- Renewable energy development
- Local employment
- Energy independence
- Community collaboration

**What are the benefits of using biofuel over other fuel sources?** In some cases, the direct cost of biofuel will be cheaper than the cost of fossil fuels or electricity. In other cases, it will be more expensive. However, there are many additional benefits bioheat can provide that fossil fuels or electricity cannot. These benefits, discussed in Section 2, should be considered when making a decision to implement a bioheat project.

**How will the benefits be communicated to the community, and how will the community be involved?**
Common misconceptions about bioheat, including environmental and health impacts, costs, and what a modern combustion system design includes, should be addressed early in the process by communicating the benefits to the community and involving the community early and often.

**Are there the local skills, resources, and labour to plan, build, and operate a bioheat system?** Bioheat systems require one or more operators to manage the fuel and operate the system. Local trades will be required for construction and periodic maintenance and repair. This may be challenging in remote areas where local skills are not available.

**Is someone prepared to undertake the day-to-day labour required to operate the system?** Depending on the type of system implemented, the labour requirements will vary, but bioheat systems generally require more work than fossil fuel systems. Wood chip and wood pellet systems can be largely automated and require relatively little labour, while cordwood systems must be loaded with wood multiple times per day. All combustion systems require periodic cleaning and ash removal to ensure efficient and safe operation.

**Who are the project partners, and what will the governance structure be?** Deciding on project partners and what the relationship will be between these partners will improve decision-making processes and project success.

**Is there a local and reliable source of biofuel, and how much does it cost?** A local and reliable biofuel source is essential to the viability of a project. Without a reliable, high-quality source of biofuel, the project will fail in the long term. Various factors affect biofuel reliability, such as local labour skills, viability of biofuel production, local forest resources, mill openings and closures, and government policies.

**How will the project be funded?** There are various methods of funding bioheat projects, including financing, government grants, and service contracts. Funding sources may affect or determine important factors of the project, such as what fuel sources are acceptable, what technologies can be used, or what governance structure works best.

**What types of government permits are required?** The Ontario Building Code should be consulted, and any permit requirements of the Ministry of the Environment, Conservation and Parks should be determined. The type of facility under consideration, the combustion system chosen, its thermal output, and the type of biofuel(s) to be used will determine the permits required.

## 6. NEW-BUILD BIOHEAT INSTALLATIONS COMPARED TO RETROFIT INSTALLATIONS

Making the decision to heat with wood early in the design stage of new buildings will help ensure success and will make certain that all mechanical systems are designed appropriately. In situations where a bioheat system is being retrofitted into an existing building, integration into the existing heat distribution system can vary from simple and relatively inexpensive to complex and expensive.

Bioheat systems can be relatively easily connected to central heating systems that heat air or water. For hot water systems, a bioheat boiler will simply replace the current boiler. For forced air, a bioheat boiler would usually be installed (rather than a furnace), and a heating coil would be installed in the duct system to heat the air. A mechanical engineer or contractor can help determine the retrofit possibilities.

If the current system is electric radiators or a fossil fuel system where there are many unit heaters spread throughout the facility and combustion occurs at the unit heaters, retrofits become much more complex and costly. In these cases, it is most likely that a bioheat boiler would be installed and then hot water pipes and radiators would be installed throughout the building. It is usually a technically viable option, but it can be costly.

In many cases, there may not be room for a new bioheat boiler in the existing boiler room, especially when the old system is being left in place for backup. In these cases, a new building could be constructed, or a containerized system (Figure 18) can be installed to house the bioheat system.

## 7. RESIDENTIAL BIOHEAT PROJECTS

In a single-family home, wood heating can provide ambient heat to one room or the entire home. The options for combustion systems are stoves, furnaces, and boilers. Residential combustion systems typically burn cordwood, briquettes, or pellets. Proponents who are interested in heating multi-unit residential buildings should refer to Section 8, "Institutional and commercial bioheat projects."

### Energy-efficient housing

A tightly sealed and well-insulated home will reduce the amount of fuel consumed in heating. Most homes, especially older homes, are poorly sealed and insulated compared to modern, energy-efficient homes. Simple retrofits can help reduce heat loads and fuel costs while improving comfort levels. Common upgrades include adding insulation to the attic and walls, replacing old windows and doors with energy-efficient ones, installing a programmable thermostat, and sealing air leaks.

For more information on ways to improve home energy efficiency, visit the Canada Mortgage and Housing Corporation's website to view their Energy Efficiency & Cost Savings fact sheets. Home energy retrofit consultants or contractors can also determine energy savings costs and estimates for home energy retrofits.

### Planning stages

The general steps required to plan and install a residential combustion system are outlined below. Those interested in greater detail on residential wood and pellet stoves should refer to *A Guide to Residential Wood Heating*, by Canada Mortgage and Housing Corporation (2002).

**Determine the type of combustion system to install: stove, forced air furnace, or boiler.** Each combustion system has different capital costs, operating costs, and labour requirements. Details about the combustion systems can be found in Section 4. Installing a combustion system in an existing home will have more constraints than installing in a new-build. Consult Section 6 for more information on installing a combustion system in a new or existing home.

**Determine the desired fuel source.** The type of combustion system will determine the fuel type. The availability of the fuel and the labour requirements of loading the fuel into the system need to be considered. For example, cordwood may be more readily available than pellets in a given community, but the labour intensity of loading a cordwood boiler is higher than loading pellet systems, which are largely automatic.

**Obtain quotes and check regulations.** Seek onsite cost estimates and installation assessments from reputable contractors or dealers. They will be able to provide information on proper installation and regulations and they can answer questions about local fuel supply and heating appliances. Request past customer references and seek their opinions on the system they chose, the fuel they used, and the quality of the contractor's service.

**Obtain the right insurance.** A bioheat system is reliable and insurable. There are insurance companies in Ontario that will insure bioheat systems, and a contractor can help identify those companies.

**Select a contractor to install the system.** Select a contractor based on the quality of their past work, reference feedback, and system costs.

## Relevant regulations

The main regulation that applies to residential users is the Ontario Building Code (O. Reg. 332/12). The building code requirements for combustion systems may differ depending on the location. Operation and installations must adhere to the building code requirements, and homeowners need to understand who is responsible for the building code in their area. A building permit may be required. Residential users can get more information on building code requirements at their local municipal building department.

A common requirement by municipalities or insurance companies is that the system is inspected by a qualified professional. The municipality or insurance company will specify the type of professional, the qualifications that the professional will require, and what the inspection must include.

Residential installations are exempt from environmental monitoring and compliance requirements in buildings or structures designed for the housing of not more than three families.

# 8. INSTITUTIONAL AND COMMERCIAL BIOHEAT PROJECTS

This section provides guidance on institutional and commercial bioheat projects. It reviews the key planning steps, community engagement, fuel supply issues, selecting a technology, and sizing a system.

## Project planning

### Facility energy audit

Before selecting and sizing a bioheat system, it is important to assess how the facility uses energy and heat. An energy-efficient building will require less energy to operate. If the facility requires less space heat and domestic hot water heat, a smaller combustion system can be installed, reducing the capital and fuel costs. These savings can be substantial. A good way to reduce energy demands is to complete an energy audit of the facility.

An energy audit is completed by an engineering consultant who specializes in energy management and can make recommendations for reducing energy consumption and costs. At a minimum, the energy audit should include a site visit by that individual, an energy bill analysis to determine current energy use and costs, and a list of recommendations, with estimated costs, benefits, and any applicable funding programs to help offset costs. Larger facilities may require temporary energy metering and modelling of building energy use. The cost of an energy audit can range from hundreds of dollars for small facilities (homes, small offices) to thousands of dollars for larger facilities.

The costs of an energy audit are usually relatively small in comparison with the identified savings, especially as the size of the building increases. The findings of the energy audit can be used to help accurately size a bioheat system and identify opportunities where systems could be converted to use bioheat that might not be obvious. The energy audit will provide a net benefit even if the bioheat project does not move forward.

## Planning stages

There are four broad planning stages discussed in this guide to assist proponents in planning a bioheat system. These steps are general in nature, and guidance from external experts and an internal champion will be required to make any bioheat project successful.

### 1. Identify a champion, engage the community, and develop goals

To implement a successful bioheat project, a project champion must be identified (Neave, 2013) and the community must be involved. The champion will guide the project, engage the community, and develop project goals. Keeping the community engaged will increase the chances of project success and increase the benefits to the community. Community engagement is discussed in more detail on page 35. Projects fail without a strong champion and community support. For bioheat systems owned by private organizations, community engagement requirements may not be applicable.

### 2. Complete a pre-feasibility study and preliminary plan

A pre-feasibility study and a preliminary plan (sometimes collectively called a feasibility study) provide the technical foundation for the project. These two documents will answer important technical questions and identify the specific processes and steps needed to take the project from concept to completion. This information is used to determine whether the project should move ahead, and if so, what that process would look like.

A pre-feasibility study is usually a desktop study to review the financial viability of a bioheat project. It would determine whether a bioheat system is theoretically feasible. It can use an online calculator, such as the Wood Energy Financial Calculator (Biomass Thermal Energy Council, 2018), FPJoule (FPInnovations, 2018), or RETScreen (Natural Resources Canada, 2018b), to determine fuel consumption and costs (see Appendix C for links to calculators). Multiple biofuel types and combustion technologies can be assessed to rank the potential options. Some background knowledge about bioheat systems and cursory research into biofuel and combustion system costs would be required for this step. An external consultant could be hired for a modest fee to complete this task. The pre-feasibility study should identify the following information:

- Basic justification for the system
- Anticipated project goals
- Potential installation location(s)
- Ranked fuel types

- Potential fuel suppliers and fuel quality (for chips and pellets)
- Approximate delivered fuel costs
- Type of combustion system, fuel storage to be used, and potential suppliers
- Approximate installed cost of systems considered
- Community engagement strategy (basic)
- Approximate costs and benefits (community, economic, environmental)
- Potential barriers
- Information gaps
- Next steps

If the project appears theoretically feasible, the pre-feasibility study can be expanded into a preliminary plan. The plan will (Neave, 2013):

- Determine biofuel availability and quality
- Estimate the system size
- Identify a location for the bioheat system
- Recommend a type of combustion system and fuel storage and handling system
- Determine how the bioheat combustion system will be integrated with the existing heating infrastructure
- Assess community capacity
- Estimate capital and operational costs and savings
- Identify funding options and amounts
- Investigate relevant regulatory requirements
- Identify the next steps

The pre-feasibility study and preliminary plan are important because they provide the basis for future decision-making. At this stage, community members can have meaningful input and assess the project against predetermined goals. The preliminary plan can be used to help secure funding and shows potential funders that the project has a solid foundation (Cold Climate Housing Research Center, 2017). An experienced engineering consultant or similar professional will be needed to help complete this plan. Establishing reliable fuel suppliers, understanding fuel qualities that are available from the suppliers, and matching combustion technology to fuel qualities are critical for the success and reliable operation of a bioheat project.

**3. Develop a business plan and assess costs in detail**

A business plan assesses the costs and benefits of the project in detail, including the impact of regulatory requirements (Neave, 2013). The business plan should include a life cycle–cost analysis for the project. Costs for design and installation, labour, fuel purchase and delivery, fuel handling, maintenance, and repair should be determined. It is important to run several scenarios or sensitivity analyses under different conditions. These scenarios could investigate different fuel prices, technology costs, funding options, and labour rates. This information will tell project planners under what conditions the project is viable or not viable and help identify any risks, such as fuel cost fluctuations (Community Energy Association, 2014). Depending on the complexity of the project and the skills available in the community, this step will likely require a professional with experience in community energy infrastructure.

The main system costs include (Biomass Energy Resource Center, 2007):

- System purchase and installation, including chimney and a connection to the existing heating system (if applicable)
- Fuel storage and handling system and installation
- Constructing a space for the boiler
- Site costs, such as a driveway for delivery
- Emissions permits and control and monitoring equipment, if applicable
- Professional fees (e.g., engineering design and feasibly studies, external project managers or consultants)
- Operation and maintenance

### 4. Develop an implementation and operations plan

An implementation plan will help communities engineer, procure, build, and begin operating the bioheat system. The implementation plan can include a timeline and a set of responsibilities delegated to various parties. It can identify any remaining gaps in the process and work to fill them before they become an issue. The operations plan will guide how the system operates day-to-day and may be as simple as identifying various duties and the parties responsible for them, and preparing a simple activity log template. For larger projects it could be more complex, containing standard operating procedures for the equipment, procedures to follow when maintenance or repairs are needed, and emergency action plans (Cold Climate Housing Research Center, 2017). The implementation plan should also include strong provisions for commissioning of the system and training the operators. A system that is working as designed and operated by knowledgeable people will last longer, be more reliable, and operate more efficiently. Several professionals may be needed for this step, specifically an engineer.

#### Community engagement

Local community support and buy-in can make or break a bioheat project (Becker, Lowell, Bihn, Anderson, & Taff, 2014). The community should be engaged early and often to make sure their ideas, concerns, and aspirations for the project are reflected in the project goals, planning process, and system operation. Assess local support for the project, taking into consideration all of the stakeholders who would have an interest. Local building officials and municipal by-laws (if applicable) should be consulted. If appropriate, plan for public meetings and information sessions throughout the process to solicit feedback and obtain buy-in (Cold Climate Housing Research Center, 2017).

The Community Energy Association (2014) suggests that project proponents think about the following issues when engaging the public:

- Air quality impacts
- Community benefits
- Risks and risk mitigation
- Municipal long-term vision

There can be misconceptions or a lack of knowledge about bioheat projects, such as air quality and environmental impacts, costs to municipalities, and benefits to the community (Community Energy Association, 2014). Many of these issues can be mitigated through clear communication and educating the public about how these issues will be addressed.

### Sourcing biofuel

The fuel supply may initially seem to be the easy part of the project, but it can be more complex and challenging than anticipated. For long-term success, it is essential to first source an affordable and reliable biofuel supply and then choose a combustion system that is designed to handle and burn the fuel that is available (Becker et al., 2014). Biofuel quality can vary greatly depending on the source and processing methods. There are high-quality fuel suppliers in Ontario, but historically there has been a poor appreciation of the quality requirements for bioheat systems. A good and consistent quality fuel is important for reliable, clean, and safe operation. Fuels with contamination or poor or inconsistent quality can damage or break bioheat system equipment. Manufacturers of combustion systems will provide a specification for the type and quality of biofuel their systems can burn. A contract with a supplier that sets acceptable fuel moisture content, particle size, durability, contamination levels, ash content, and delivery timelines will be needed. There are important questions related to biofuel supply that need to be answered before choosing a fuel, including:

- What fuels can be sourced locally, and how much do they cost?
- What type of combustion system can burn the locally available biofuels, and what are the quality requirements, such as moisture content and particle size?
- Is there a local fuel supplier who fully appreciates the importance of consistent fuel quality?
- How will the fuel be delivered?
- What are the storage requirements?
- Will any fuel be processed by the system owner or will it be delivered ready-to-burn by a supplier?
- Who will manage fuel handling at the facility, and how much time can they spare for this task?
- Will supplies be affected by local economic changes, such as mill closures or openings?

There are many potential sources of local biofuel. Cordwood is readily available from local producers. Many producers advertise online and in local classified ads.

Wood chips are generated in traditional forest operations and by businesses such as logging contractors, sawmills, urban wood/tree services, woodland management services, and waste wood recycling operations. These operations are mainly geared to serve the needs of industrial markets, such as pulp and paper mills and dimensional lumber and oriented strand board producers so the local supplies may already be spoken for. Fuel aggregators can also be used, particularly for larger installations, where the annual fuel requirements are significant.

Wood pellets can be sourced from most local hardware stores. Bulk suppliers can be found through the Wood Pellet Association of Canada.

Communities may be able to produce their own biofuel if a local supplier does not already exist. There may be other local demands for biofuel, and the community could start a small business producing biofuel for sale and for their own consumption. However, producing biofuel can be a challenge where it is not supported by harvesting of higher-value products, such as sawlogs (Neave, 2013). Another risk that should be investigated before starting a biofuel production business is whether there is competition from other lower-cost biofuel producers.

Contact your local Ministry of Natural Resources and Forestry district office (see Appendix C for listings) to learn more about accessing Crown forest resources to create biofuels.

Trained operators are needed to manage the biofuel at the facility in addition to operating the combustion system itself. Important tasks include monitoring moisture content of the biofuel and keeping it stored and dry, ensuring that automated biofuel feeding systems are working properly, and possibly processing fuel on site. Operators should inspect the fuel quality on delivery and be empowered to refuse unacceptable shipments (Community Energy Association, 2014). More details on fuel handling can be found in Section 2.

## Sizing a bioheat system

Sizing a system is a technical task that should be carried out by a qualified professional, such as a mechanical engineer. There is no simple formula to determine the size of a system, and all buildings have different requirements based on age, use, and type of construction.

Sizing a system correctly is important. An undersized combustion system will provide inadequate heat and require a supplemental heating system. Oversized systems will cycle on and off frequently, resulting in comfort control issues, premature wear, system failure, poor combustion efficiency, and increased fuel consumption. In general, wood combustion systems are best operated continuously at full load to achieve good combustion, high efficiency, and low emissions.

System designers use different strategies to determine building heat loads depending on whether the building is existing or new (or an existing building that had a recent major renovation). For new buildings, there are good energy models and design standards that engineers can use to accurately determine the building heat loads. These models can take some time to run but are needed for final design. A mechanical engineer with experience in energy systems design should be able to use rules of thumb and experience to quickly provide an approximate system size for initial planning purposes.

For existing buildings, energy bills or custom metering of the existing heating system can help determine heat loads. With some basic information, a mechanical engineer with experience in energy systems design should be able to quickly provide an approximate value for initial planning purposes.

In general, heating systems must be designed to provide heat on the coldest days, even though these days occur infrequently. This requirement can result in a system that is much larger and more expensive than is needed for most of the year. To address this issue, designers either size the system to meet heating needs for approximately 97% of the time and accept 3% of the year when the heat produced will be inadequate, or they rely on a backup system to manage the peak. Alternatively, to avoid the problem of operating an oversized biomass boiler at low loads or not meeting peak demand, designers may use two biomass boilers that together can handle the peak load but operate a single boiler to meet lower heat demands (refer to the case study on Confederation College in Appendix B for an example of a two-boiler system).

A backup system is often required for bioheat systems, so it can be used as a peaking system (Community Energy Association, 2014). The peaking system can be as simple and inexpensive as an electric hot water boiler, or a fossil fuel or electric furnace. Since the backup system runs infrequently, the fuel cost is not of great importance. Backup systems are a safeguard to ensure that if the bioheat system is shut down for unplanned maintenance, heat will still be available. They may even be an insurance requirement. Backup systems should be tested on a regular basis.

## Relevant regulations

Regulations and insurance requirements can affect the viability of a bioheat project. The regulations discussed in this section are for non-federal lands in Ontario. The main regulations concerning bioheat projects are the Ontario Building Code (O. Reg. 332/12), and Environmental Protection Act. Connect early with the relevant regulatory bodies (Community Energy Association, 2014), including the governmental body responsible for the building code in the local jurisdiction, the local office of the Ministry of the Environment, Conservation and Parks for emissions regulations, and an insurance provider for insurance.

Bioheat systems require a building permit, and local by-laws may affect certain aspects of a bioheat project. Local building officials, mechanical contractors, and engineers can help determine which local regulations are relevant.

Emissions regulations in Ontario are controlled by five main acts, regulations, and guidelines, including:

- Environmental Protection Act
- Ontario Regulation 524/98: Environmental Compliance Approvals
- Ontario Regulation 1/17: Activities Requiring Assessment of Air Emissions
  - Environmental Activity and Sector Registry (EASR) publication
- Guideline A-14: Guideline for the Control of Air Emissions from Small Wood-Fired Combustors (<3 MW)

- Ontario Regulation 419/05: Air Pollution - Local Air Quality

Depending on the use of the facility and the size and type of the combustion system, the facility will require one of three types of emissions permits and associated emissions monitoring. They include, from most to least complex and costly:

a. Environmental Compliance Approval (ECA), and use Guideline A-14
b. EASR, and use the EASR publication
c. No permit at all (i.e., the combustion system is exempt from Part 9 of the Environmental Protection Act)

Examples of facilities that do not require any permits or monitoring include structures designed for the housing of not more than three families; facilities with a bioheat system that has individual combustion devices, each less than 50 kW thermal output and that burns one of the untreated fuels described in this guide; and single-family homes. Most other facilities will require either an ECA or EASR. Both have certain monitoring requirements, emissions limits, and requirements for maintenance and record-keeping. These activities and associated equipment can be costly but are much cheaper under the EASR program compared to the ECA program. Boilers certified to specific standards in the EASR program require less effort for emissions monitoring. This can change the costs considerably.

Proponents should consult with the local Ministry of the Environment, Conservation and Parks office (see Appendix C) and a qualified environmental consulting firm that specializes in environmental permits. Costs of emissions monitoring equipment can vary significantly from vendor to vendor, so multiple quotes for this equipment should be sought.

The regulatory requirements of this section are not complete or definitive and are subject to change. Proponents should do their due diligence to ensure that they meet all current regulations and that they understand the associated costs before moving ahead with the bioheat project.

## Funding a bioheat project

There are agencies that may be able to help reduce project costs through grants, loans, or other types of support. The provincial and federal governments may also have programs to support bioheat projects, but these programs change over time. Proponents should contact a stable agency that will be knowledgeable about the programs currently available in their area. These organizations include:

- FedNor
- Northern Ontario Heritage Fund Corporation
- Centre for Research & Innovation in the Bio-Economy
- FPInnovations
- Federation of Canadian Municipalities
- Association of Municipalities of Ontario

Other sources of funding include:

- Municipal budgets
- Loans
- Private-sector risk capital or investment
- Energy service contracts, where the system is owned and operated by a private organization

# 9. OTHER BIOHEAT SYSTEMS

## District heating systems

District heating systems use a centralized boiler to provide heat for different buildings and can be used for space heat, domestic hot water heat, or process heat. In many cases, the owner of the centralized boiler sells heat to the other building owners or tenants. These systems are often larger than the systems described in this guide (>1 MW) and have complex administrative requirements, since the system owner effectively becomes a heat utility. Much of the content in this guide is relevant to district heating systems; however, there is much more to consider. Those interested in biofuelled district heat should consult Appendix C for additional resources.

## Combined heat and power systems

Combined heat and power (CHP) systems use combustion to generate heat and electricity. They work best in situations where there is year-round demand for heat, such as institutional (e.g., hospitals), commercial (e.g., hotels), agricultural (e.g., greenhouses), and industrial (e.g., food and beverage processing) operations. CHP systems can be used in district heating systems as well.

At the time of publication, Ontario was in the process of developing new environmental regulations for CHP systems to make the environmental permitting process easier for biofuel CHP systems. Those interested in biofuelled CHP should consult Appendix C for additional resources.

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## APPENDIX A: ENVIRONMENTAL BENEFITS AND CONSIDERATIONS

Bioheat can provide many environmental benefits. There are common misconceptions about the impacts of bioheat, which may come up in community discussions, and accurate information will be required to address any questions or concerns.

### Bioheat and the carbon cycle

The carbon element is the building block of life and is present in all living things. Carbon is found in all of Earth's environments: atmosphere, land (plants, animals, rocks), and water bodies. The carbon cycle refers to the cyclical constant movement of carbon between the land, water, atmosphere, and living organisms (Figure 23), each referred to as carbon reservoirs. Throughout the last four glacial cycles, or nearly 1.5 million years, and up to the 20th century, there was a relative balance of carbon exchanged between reservoirs (Apps, Bernier, & Bhatti, 2006; Natural Resources Canada, 2007). The amount of carbon found in the land, water, air, and living organisms remained steady.

Over the last 100 years, human-caused, or anthropogenic, carbon emissions have increased the amount of carbon in the air from 280 parts per million (ppm) to over 400 ppm. This has resulted in global climate changes (now commonly known as climate change) that are felt more strongly at mid and high latitudes, such as Ontario (Apps et al., 2006).

Forests store and release carbon through growth, decay, fire, and regeneration (regrowth) (Natural Resources Canada, 2007), which helps maintain the carbon balance, as shown in Figure 23. Younger regenerating trees generally take up carbon at a faster rate than older trees which store a larger total amount of carbon (Apps et al., 2006). As the ecosystem continues to age and approaches maturity, rates tend to level off and may even decline in some forests as emissions from decay begin to offset the carbon removed from growth (Apps et al., 2006).

Lemprière et al. (2013) reviewed relevant and recent studies regarding the Canadian boreal forest and climate change mitigation. It was found that the main potential carbon benefit bioheat provides is the displacement of fossil fuels (Lemprière et al., 2013). The combustion of fossil fuels moves ancient carbon from fossil fuel deposits to the atmosphere. However, this carbon cannot be returned into the original deposits, and much

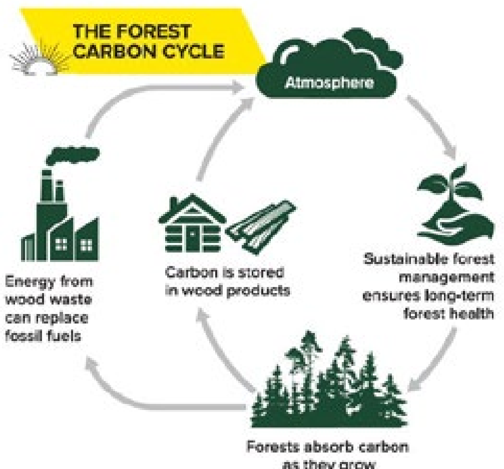


Figure 23. Forest carbon cycle (Ministry of Natural Resources and Forestry, 2016).

of it remains in the atmosphere and contributes to climate change (Apps et al., 2006). When biofuel is burned, it releases carbon that was removed from the atmosphere over the course of decades as its source forest grew. If that forest is then renewed and a new forest grows in its place, it can recapture the carbon released from the burning of bioheat (Apps et al., 2006; Lempriève et al., 2013). If the forest is converted to another use, such as agriculture or urban development, or if it is harvested before it can recapture the carbon, it will not provide carbon benefits (Lempriève et al., 2013). Not all forests are suitable for providing carbon benefits from harvesting, and some should not be used for this purpose (Apps et al., 2006; Lempriève et al., 2013).

## Emissions

All types of combustion, including that of biofuel and fossil fuel, produce emissions, including sulfur dioxide, nitrous oxides, carbon monoxide, carbon dioxide, volatile organic compounds, and particulate matter. The bioheat combustion systems available today emit far smaller amounts of these pollutants than a typical residential wood stove, and in some cases they emit even less than their fossil fuel counterparts. Biofuel boilers have slightly higher particulate matter emissions than gas and oil systems, but this is not a major concern when the system is designed to properly disperse particulate matter.

Recent tests of a new wood chip and pellet boiler at Confederation College in Thunder Bay showed that emissions from commercially available combustion systems are very low (Ontario Ministry of the Environment and Climate Change, 2016). Amounts of particulate matter (Table 4) were well below the levels deemed acceptable by the Ministry of the Environment, Conservation and Parks. Carbon monoxide was 80% to 95% below acceptable levels, and often less. Benzo[a] pyrene and acrolein, toxic chemicals of concern that are associated with combustion, were below the laboratory detection threshold limit. A case study of the Confederation College system is presented in Appendix B.

Table 4. Summary of results from particulate matter testing of a new 500 kW biofuel boiler at Confederation College (Ontario Ministry of the Environment and Climate Change, 2016)

| Fuel | Firing rate (% of full load) | Recorded level ($mg/m^3$) | Acceptable limit ($mg/m^3$) | % of limit |
|---|---|---|---|---|
| Pellets | 100 | 16.6–17.7 | 75 | 22–24 |
| Wood chips | 100 | 38.5–66.9 | 75 | 51–89 |
| Wood chips | 30 | 27.6–44.5 | 75 | 37–59 |

## Sustainable forest management in Ontario

Familiar forest-based activities such as timber harvesting for sawlogs and pulp, hunting and fishing, and camping and nature enjoyment have successfully coexisted in Ontario for many years (Ministry of Natural Resources and Forestry, 2016). The idea of using our forests as a principal source of energy is relatively new. This unfamiliarity leads to questions such as, *Will we burn through our forests?* or *Will harvesting for bioheat negatively affect the things we value about our forests?* These and other similar questions need to be addressed if a bioheat project is to be successful.

Ontario's Crown forests are sustainably managed using good forestry practices, known as sustainable forest management. Sustainable Forest Management allows Ontario's forests to provide many different values, including wildlife habitat, recreation, wood products, clean air and water, and a place to live and work (Ministry of Natural Resources and Forestry, 2016). All Crown forests across Canada are managed using sustainable forest management. Canada has a larger area of third-party certified forests than any other country in the world, using systems such as CSA Group Sustainable Forest Management System, Sustainable Forestry Initiative, and Forest Stewardship Council (Natural Resources Canada, 2018a). This means that biomass harvested on Crown forests in provinces or territories outside Ontario is also sustainable (Natural Resources Canada, 2018a).

Biomass harvesting can be an important funding tool in sustainable forest management and can contribute to forest stewardship activities. Three forest stewardship activities that biomass harvesting could benefit include thinning

Figure 24. FireSmart thinning reduces fuel loads in forests and could provide a source of fuel for bioheat systems.

over-stocked stands, FireSmart activities (Figure 24), and pre-commercial thinning. Some forests have become over-stocked (too many trees in too small an area) as a result of past fire suppression or other management activities. These forests can pose an increased fire risk and provide sub-optimal habitat and timber production. In Ontario, an average 180 000 hectares of forest are burned and 110 000 are harvested each year (Ministry of Natural Resources and Forestry, 2016). Thinning these forests can help reduce fire risk to communities, increase the growth of the trees retained, and improve wildlife habitat. In some cases, the trees harvested in these stands may not be valuable enough to harvest for sawlogs or pulp. As a result, the activities are costly and may not be performed. However, the thinned trees may be suitable for use as biomass for bioheat. This could help offset management costs and contribute to forest stewardship activities.

## APPENDIX B: CASE STUDIES

### Confederation College

**Location:** Thunder Bay, Ontario
**Combustor type:** Two wood chip hot water boilers
**Peak output:** 1 MW (500 kW per boiler)
**In-service date:** Winter 2015
**Building area served:** 400 000 square feet (provides 85% of space heat, no domestic hot water)
**Building use:** College administration offices and education space
**Estimated annual fuel use:** 1 000 oven-dry tonnes
**Average chip moisture content:** < 30%
**Chip size:** 3.15 mm to 45 mm
**Average system efficiency:** >90% (LHV)
**Backup heating system:** Natural gas

#### Project summary

Confederation College installed a wood chip hot water boiler heating system to heat a 400 000 square foot college administration and education building as a demonstration project to show the viability of bioheat systems in Ontario (Figure 25 and Figure 26). Evergreen BioHeat, a bioheat company based in B.C., supplied the equipment, provided the installation and commissioning guidance, and continues to provide technical and operational support for all aspects of the system, from the fuel feed system through to equipment maintenance. Biothermic Wood Energy Systems (Biothermic), a recently established company in Ontario, provides the wood chip fuel and ongoing operational support. The system provides space heat (no domestic hot water) for 85% of the heating load (measured over a total heating season). Heat is distributed

Figure 25. Wood chip boiler room and fuel storage facility at Confederation College. The garage door on the left leads to the on-site chip storage room. The door on the right leads to the boiler room. The system can be seen by passersby through the large windows. Wood chip boiler rooms do not need to be this large, but this boiler room was designed to accommodate tours and teaching. (Photo: Biothermic)

around the building using hot water heating piping. The existing hot water heating piping in the building was limited, so a new distribution system was installed to replace perimeter electric heat. Wood chips are sourced from the City of Thunder Bay's urban forest. Chips are delivered to the boilers from an on-site storage room through an automatic delivery system (Figure 27 and Figure 28), and ash is automatically emptied into an ash bin. Cleaning requirements are modest, with the ash bin needing to be emptied every month and a half or so, and the boilers themselves needing a thorough cleaning once a year, usually after the heating season closes. A backup natural gas system provides heat during peak periods and when the bioheat system is down.

#### Project champions

As with any demonstration or pilot project, there were issues and problems that arose that required problem-solving and perseverance to overcome.


Figure 26. Wood chip boilers installed at Confederation College. Each boiler can provide 500 kW of baseload heat. Together, the boilers provide 85% of the space heating needs of the 400 000 square foot facility. (Photo: Biothermic)

Internal champions Colin Kelly, Director of Applied Research and Chair of the School of Business, and Rick Sitarski, Director of Facilities and chair of the College Sustainability Committee, were instrumental in keeping this project on track and the systems operational.

Technology and engineering champion Evergreen BioHeat was instrumental in providing the overall management of the project, including selecting the equipment, final engineering of the feed system, and all aspects of support during the environmental approval process. A key variable was the access to European expertise, as these systems are commonplace throughout Europe.

Community partner champion Biothermic was instrumental in ensuring the development of a quality fuel supply that met system specifications. While conceptually simple in practice, it takes time and effort to develop the processes and infrastructure to supply a consistent quality of wood chips. Biothermic is a key partner in local and regional market development efforts and is a lead participant in the training and capacity building efforts at the college.

### Environmental approvals and new guidelines for Ontario

In partnership with industry and provincial and federal ministries, Confederation College completed research on air emissions in February 2015. This research was used to create new regulatory guidelines published in January 2017 (for installations <3 MW capacity) that will support the adoption of biomass technology across Ontario. Previous emissions guidelines and associated regulations were written for old technology, specifically in large-scale industrial contexts, and created a barrier for market development in the province. The new guidelines follow a much more efficient and streamlined environmental approval process, with less approval time and lower up front and operational costs.

### Wood chip sourcing and management

The wood chips used in the system at Confederation College come from trees that are removed from within the City of

Figure 27. An aerial view of the chip holding room at Confederation College, engineered by Evergreen BioHeat. The scraper floor shown moves the chips along the room's length to a series of augers. (Photo: Biothermic)

Figure 28. A series of augers automatically feed the chips to the boilers when there is a call for more chips from the boiler's control system. (Photo: Biothermic)

Figure 29.  Wood chips are chipped with conventional, hand-fed chippers and then screened with a three-deck aggregate screener to filter out fine and coarse particles, leaving only chips of the appropriate size for the bioheat system. (Photo: Biothermic)

Thunder Bay. As is typical for all Canadian cities, an urban forest yields a steady flow of wood chips from arboricultural operations like tree and shrub pruning and tree removal. Arborists' wood chips are often used for landscape mulch or compost, or are deposited in landfills. In this case, wood from the urban forest is chipped with conventional, hand-fed chippers and then screened with a three-deck aggregate screener to filter out fine and coarse particles, leaving only chips of the appropriate size for the bioheat system (Figure 29). When first chipped, the chips have a moisture content of approximately 50% but are then stored under a covered roof and are dried to 25% (Figure 30). Any loss of fuel quality from decomposition is easily compensated for with lower moisture content. Chips are stored on an asphalt pad to eliminate contamination with rocks, sand, and dirt.

The chips are delivered to the college from Biothermic's facility by a live-bottom truck typically used in forestry operations. The chips are dumped into the college's chip holding room (Figure 27). A scraper floor in the holding room moves the chips along the room's length to a series of augers that feed the chips to the boilers (Figure 28). When fuel is delivered that meets the size specification and the moisture content is below 30%, ease of storage and wood chip flow through the system are assured.

### Lessons learned

The wood chip system in Confederation College was one of the first modern wood chip systems of its size installed in Ontario. As a result, many valuable lessons were learned along the way:

- An internal project champion is required to get through the initial learning and troubleshooting stages.
- Only proven suppliers should be used who have a track record and experience with the size and type of system to be installed.

- Wood chip fuel handling systems should be designed by engineers or manufacturers with direct experience in small-scale bioheat systems. The principles applied to wood chip management in large industrial boiler systems cannot easily be scaled to smaller applications.
- The boiler supplier should also be responsible for design and installation of the fuel feed system. Initial design of the fuel feed system at the college did not incorporate expert advice from Evergreen BioHeat and resulted in costly rework. This expertise does exist, even if it must be sourced from outside the local area. The chosen boiler supplier should be a full-service company that has the capability and experience to engineer, design, install, and commission a complete system – it should essentially be a fully accountable, turnkey supplier.
- Wood chip quality is vitally important to reliable operation. Early batches of chips were of variable size and moisture content and contained non-combustible debris, resulting in jamming of the fuel conveyance system. Wood chips need to be covered to keep dry so that they burn efficiently, but also so they don’t freeze together, which can jam up conveyance systems.
- Chips must be stored on a concrete or asphalt pad at all times, or else they will become contaminated with rocks, dirt, or sand, which will damage the boilers. Early storage areas at the chip processing facility were designed with sand floors. It was anticipated that careful chip management could minimize contamination, but it proved

Figure 30. This bioheat wood chip production facility has an asphalt pad to eliminate dirt and sand contamination and keeps the chips covered to allow them to dry. It stores 1 000 oven-dry tonnes. (Photo: Biothermic)

impossible to keep the sand and rocks out of the chips. Large amounts of sand plugged the boiler ventilation areas, causing poor efficiency, overheating in certain areas, and accelerated deterioration of the boiler itself. This damage was repaired during an annual planned maintenance shutdown, and changes to the fuel preparation were implemented, including a paved and covered storage facility.

- A long-term fuel supply agreement must be in place to justify capital costs of building an appropriate fuel storage and processing facility.
- Ideally, chip processing and storage can take place on site. This will reduce costs and eliminate delivery logistics. In the event that chip processing must be located off site, the on-site storage area at the combustion facility should be able to hold at least 1.5 times as many chips as the delivery trucks can hold. This will ensure adequate flexibility around the delivery time of full truck loads. The original storage design at the college was compromised by the fact that geo-testing underestimated the amount of groundwater. Therefore, the fuel bunker could not be extended below grade, which is the preferred practice. As a result, the fuel storage volume was reduced, and the unloading area needed to be redesigned.
- Confederation College maintained a close relationship with their chip supplier, Biothermic, from the beginning. A close relationship with the supplier was essential to ensure the fuel met the system's needs and that problem-solving was handled quickly and collaboratively.
- Although the systems installed today may not have the same air emissions regulatory burden as in the past, proponents must still fully investigate and understand all regulatory requirements (environmental, American Society of Mechanical Engineers, CSA) in the pre-feasibility stage of project planning.

## Abbey Gardens

**Location:** County of Haliburton, Ontario
**Combustor type:** Pellet boiler with hot water thermal storage
**Peak output:** 32 kW
**In-service date:** 2016
**Building area served:** 6 500 square feet
**Building use:** Commercial/not-for-profit charity
**Estimated annual fuel use:** 10 to 11 tonnes
**Average pellet moisture content:** <10%
**Average system efficiency:** 87% (LHV)
**Backup heating system:** None

### Project summary

Abbey Gardens (Figure 31) is a not-for-profit charity that transformed a 300-acre spent gravel pit into a green space that provides economic and recreational opportunities for the local community. It includes local food shopping opportunities, interpretive trails, heritage breed displays, programming and event spaces, picnic areas and kiosks, gardens, and more. Abbey Gardens rents some of its space to Haliburton Solar and Wind, a renewable energy company, and Haliburton Highlands Brewing, a microbrewery. The pellet boiler system (Figure 32) supplies heat to these two businesses. The heat supplied to the businesses is metered, and Abbey Gardens then bills the tenants for the heat energy consumed. The system is operated and maintained by Abbey Gardens and was supplied by Biothermic. Members of the public are welcome to visit Abbey Gardens and look at the pellet boiler system.

Figure 31. Abbey Gardens. (Photo: Abbey Gardens)

### Community benefits and collaboration

One of the missions of Abbey Gardens is to support other local entrepreneurs who work in the area of sustainable living. This made Biothermic, also located in the County of Haliburton, a good partner. Abbey Gardens and Biothermic had been talking about the potential for a renewable bioheat system at Abbey Gardens for approximately one year before the opportunity arose to install a system. Haliburton Solar and Wind and Haliburton Highlands Brewing are both local entrepreneurs who work in the area of sustainable living and needed office and production space. These four organizations worked together to develop a bioheat project that benefits all parties. Biothermic supplied the system, and Abbey Gardens rents space to Haliburton Solar and Wind and Haliburton Highlands Brewing and sells them low-cost space heat. Biothermic takes care of the system's minimal day-to-day maintenance. This allows the other organizations to focus on their areas of expertise.

### Project champion

Abbey Gardens' board of directors fully supported the bioheat system and the collaboration between the four local organizations. Heather Reid, operations


Figure 32. The boiler and pellet hopper (left) feed hot water to the storage tank (right). Hot water is then supplied to Haliburton Solar and Wind and Haliburton Highlands Brewing and is used for space heat and domestic hot water. The energy meters used to bill the businesses can be seen on the wall beside the storage tank.

director at Abbey Gardens, was the main project champion. She continues to work closely with Biothermic to help manage the system. The boiler's electronic control system recognizes when there is a problem with the system (which happens very rarely), and an alarm is sent electronically to both Heather and Biothermic. Together they then decide how to fix the issue.

## Environmental monitoring

This system fell under the 50 kW threshold for environmental monitoring requirements. This means that Abbey Gardens did not have to install any environmental monitoring equipment or obtain any environmental permits to install or operate the system. It did have to adhere to all relevant building codes.

## Wood pellet sourcing and management

Wood pellets are delivered by pellet delivery service using a bulk pneumatic wood pellet delivery truck (Figure 9). Pellets are stored on site in an agricultural silo next to the building that houses the wood pellet boiler. Chips are automatically delivered to the boiler when there is demand (Figure 33).

Figure 33. When the boiler's pellet hopper runs low, pellets are automatically delivered from the bulk storage silo shown above via vacuum hoses to refill the hopper.

### Lessons learned

Some of the main lessons learned at Abbey Gardens were that:

- Pellet boilers are very reliable systems that require minimal maintenance, and day-to-day operation is easy and hands off.
- New pellet boilers are highly efficient, produce very little ash, and provide low-cost heat.
- New bioheat systems are advanced mechanical systems that have the same functionality as fossil fuel systems, including reliability and advanced controls that can send out alarms to users.
- Metering and billing other users is not complicated.
- Choosing the right system and fuel is important. This system is highly automated and requires very little labour, which fit the needs of Abbey Gardens very well. Other fuels such as cordwood or chips would have required more work.
- Maintenance for bioheat systems can be contracted out for a minimal cost if in-house labour is not available. The cleaning and ash removal for pellet systems takes very little time and effort.

## Residential cordwood furnace

**Combustor type:** Cordwood furnace with secondary air combustion
**Average output:** 29.3 kW wood (25 kW electric)
**In-service date:** 2018
**Location:** Mattawa, Ontario
**Building area served:** 2 200 square feet
**Building use:** Residential
**Estimated annual fuel use:** 3 to 4 bush cords (maple and birch)
**Maximum allowable cordwood moisture content:** 20%
**Average system efficiency:** 69%
**Backup heating system:** Built-in electric

### Project summary

This hybrid cordwood/electric furnace (Figure 14) was installed in a home in Mattawa, Ontario to replace an aging hybrid cordwood/electric furnace. The homeowners had economical access to firewood from a neighbour and wanted to continue using cordwood as fuel. They already had a storage system in place for cordwood and they were familiar with the fuel. Stacking firewood and chopping kindling was seen as a benefit for the exercise and enjoyment of working outdoors. The electric backup ensures that the home will always have heat even if the owners are gone for extended periods of time. The furnace is located in the basement, and the owners have found that the radiant heat from the furnace heats the basement while the forced air ducts provide heat to the upper floors.

### Firewood management

Firewood for this system is bought from a neighbour who runs a small sawmill and a commercial firewood business. This builds community connections and keeps money in the local community, which was important for the system owners. After delivery, firewood for this system is stacked outdoors under cover to protect it from rain. The furnace is located near a walkout basement door that is close to the firewood storage. The owners have a small indoor storage space for wood that will be burned immediately. It holds approximately five to seven days' worth of wood. The furnace came with a moisture meter to measure the moisture content in the wood. This way, the owners can ensure they only burn wood with a maximum moisture content of 20% and can allow the wetter wood to dry longer.

### Maintenance and labour

Most of the labour is spent on stacking wood, cutting kindling, and bringing wood inside to the temporary storage area. When delivered, the wood is dumped in the driveway. Cleanup from firewood movement is required for the driveway and indoors where bits of wood and bark fall off the wood. There are baffles on the furnace that must be cleaned with a wire brush every five to seven days. Ash must be removed from the ash tray every five to seven days. Cleaning and ash removal takes approximately 5 to 10 minutes. The newer furnace is much more efficient than the furnace it replaced, which has cut down on labour, cleanup, and maintenance requirements.

### Alternatives considered

Many different combustion systems could have been installed other than a cordwood furnace, including a propane furnace, a pellet furnace, a cordwood boiler, a pellet boiler, or an outdoor cordwood boiler. A heating coil and fan would have been installed in the duct system to accommodate the boilers. The homeowners had a preference for a renewable fuel and eliminated propane. Outdoor cordwood boilers have system efficiencies of approximately 25% and cost just as much as pellet and cordwood furnaces, which are more efficient. The owners had a reliable and local source for cordwood, and so they did not want to use pellets. The cordwood boiler would have been more efficient but significantly more costly to install. This left the cordwood furnace as their preferred option.

## Viessmann Manufacturing Company Inc.

**Location:** Waterloo, Ontario
**Combustor Type:** Hot water pellet boiler
**Peak Output:** 390 kW
**In-Service Date:** 2017
**Building Area Served:** 60 000 square feet
**Building Use:** Viessmann Canadian Headquarters, Office and Warehouse
**Estimated Annual Fuel Use:** 120 metric tons
**Average Pellet Moisture Content:** 10%
**Average System Efficiency:** 86% (LHV)
**Backup Heating System:** Natural gas condensing hot water boiler

Figure 34. A 390 kW wood pellet boiler installed at Viessmann's Canadian Heaquarters. (Photo: Viessmann Manufacturing Company Inc.)

## Project Summary

Viessmann Manufacturing Company Inc. (Viessmann) manufactures both fossil fuel and biofuel heating systems. To promote the use of biofuel boilers and demonstrate a working example for potential customers, Viessmann installed a 390 kW thermal output wood pellet hot water boiler in their Canadian headquarters in Waterloo, Ontario (Figure 34). Pellets are stored in an external 35 metric ton silo (Figure 35) and automatically fed to the boiler. The wood pellet boiler is used to provide space heat and hot water for their warehouse and offices and replaced two natural gas hot water boilers. In addition to providing heat, the new system is used as a training centre for their staff and customers and helps reduce their GHG emissions.

## Environmental Monitoring and Compliance

In 2017, Ontario created a new regulatory pathway for permitting systems with low-risk air emissions. The new scheme is called Environmental Activity and Sector Registry (EASR) program (Regulation 1/17). Concurrently, the Province released Guideline A-14 that provided information for permitting small wood-fired combustors (SWFC) with a nominal input energy capacity of 3 MW. The goal of these new initiatives was to reduce the cost, time, and complexity of environmental permitting of low-risk air-emissions. More detail on air emissions regulations can be found in Section 8.4. The Viessmann system met the conditions required to use the new EASR and Guideline A-14 permitting processes based mainly on the size of the pellet boiler, the high-quality of the pellets used in the system, and the building use.

Figure 35. A 35 metric ton silo is used to hold wood pellets at Veissmann's Canadian Headquarters. (Photo: Viessmann Manufacturing Company Inc.)

### Lessons Learned

- High-quality equipment and system design will help ensure trouble-free operation
- Collaboration between system proponents, designers, suppliers, and regulators is critical to success
- Reliable fuel supplies must be secured at the outset of the project and should be a key component of assessing project feasibility
- Understanding regulatory requirements and processes will reduce permitting costs and time and an understanding should be developed when assessing project feasibility
- A wood chip system was not feasible because there was no local supply of wood chips of the required quality.
- Many mechanical contractors lack technical expertise and experience with bioheat systems

# APPENDIX C: ADDITIONAL RESOURCES

The following documents and websites are useful resources for those wanting more information on bioheat.


## Other bioheat guides and general resources

Appropriate Designs. (2018). *Design assistance manual for high-efficiency, low-emissions biomass boiler systems.* Albany, NY: New York State Energy Research and Development Authority. Retrieved from https://www.nyserda.ny.gov/-/media/Files/EERP/Renewables/Biomass/Design-Assistance-Biomass-Boiler.pdf

Becker, D., Lowell, E., Bihn, D., Anderson, R., & Taff, S. (2014). *Community biomass handbook. Volume I: Thermal wood energy* (Gen. Tech. Rep. PNW-GTR-899). Portland, OR: U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/treesearch/search?keywords=%22community+biomass+handbook%22

Vermont Energy Investment Corporation. (n.d.). *Biomass Energy Resource Center.* Retrieved from https://www.biomasscenter.org/

## Residential and small commercial pellet heating

Arctic Energy Alliance. (2012). *Residential wood pellet heating: A practical guide for homeowners.* Yellowknife, NT: Arctic Energy Alliance. Retrieved from http://aea.nt.ca/files/download/562

Canada Mortgage and Housing Corporation. (2002). *A guide to residential wood heating.* Ottawa, ON: Canada Mortgage and Housing Corporation and Natural Resources Canada. Retrieved from http://publications.gc.ca/collections/collection_2009/schl-cmhc/NH15-436-2008E.pdf

Northern Forest Center, Inc. (n.d.). *Feel Good Heat.* Retrieved from https://feelgoodheat.org/

## Biofuels

CSA Group. *Guide to wood chip fuel: Characteristics, supply, storage and procurement* (Report SPE-2254). https://webstore.ansi.org/standards/csa/csaspe22542019

Marinescu, M. (2013). *Critical biomass attributes of the most common bioenergy and biofuel application* (Advantage Report, Vol. 14, No. 3). FPInnovations.

Volpé, S. (2018). *Best management practices guide for access to quality forest feedstocks* (Special Publication SP-534). Pointe-Claire, QC: FPInnovations.

## Additional case studies

Bihn, D. (2016). *Community biomass handbook. Volume 3: How wood energy is revitalizing rural Alaska* (Gen. Tech. Rep. PNW-GTR-949). Portland, OR: U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/treesearch/search?keywords=%22community+biomass+handbook%22

International Energy Agency Bioenergy Task 32 Biomass Combustion and Co-Firing (n.d.) *Bioenergy for heat: the hot cases.* Retrieved from http://task32.ieabioenergy.com/publications/bioenergy-for-heat-the-hot-cases/

## District heating

Community Energy Association. (2013). *Small-scale biomass district heating guide.* Vancouver, BC: Community Energy Association. Retrieved from https://www.toolkit.bc.ca/Resource/Small-scale-Biomass-District-Heating-Guide

Community Energy Association. (2014). S*mall-scale biomass district heating handbook.* Vancouver, BC: Community Energy Association. Retrieved from http://www.toolkit.bc.ca/Resource/Small-Scale-Biomass-District-Heating-Handbook

## Combined heat and power

Neave, E. (2013). *Biomass heating and electricity production: A guidebook for rural communities in Canada.* Kemptville, ON: Canadian Model Forest Network.

Schilling, C., Marinescu, M., & Röser, D. (2017). *Small-scale combined heat and power (CHP): Part I – A primer* (Info Note No. 13). Pointe-Claire, QC: FPInnovations.

Schilling, C., Marinescu, M., & Röser, D. (2017). *Small-scale combined heat and power (CHP): Part III: Technical and economic of biomass supply chains for small-scale CHP systems under 165 kWel* (Info Note No. 15). Pointe-Claire, QC: FPInnovations.

Schilling, C., Marinescu, M., Spencer, S., & Röser, D. (2017). *Small-scale combined heat and power (CHP): Part II: Technical and economic aspects of small-scale CHP systems under 165 kWel* (Info Note No. 14). Pointe-Claire, QC: FPInnovations.

Schilling, C., Sigurdson, P., Marinescu, M., & Röser, D. (2017). *Small-scale combined heat and power (CHP): Part IV: Organic Rankine cycle CHP systems* (Info Note No. 16). Pointe-Claire, QC: FPInnovations.

## Wood heat energy calculators

Biomass Thermal Energy Council. (2018). Wood energy financial calculator [Computer software]. http://calculator.biomassthermal.org/

FPInnovations. (2018). FPJoule [Computer software].

Natural Resources Canada (2018). RETScreen clean energy management software [Computer software]. https://www.nrcan.gc.ca/energy/software-tools/7465

## Bioheat emissions

Ontario Ministry of the Environment and Climate Change. (2016). Air emissions from small wood-fired combustors. In *Background and rationale for the development of a guideline for the control of air emissions from small wood-fired combustors with a heat capacity of less than 3 MW (Guideline A-14)* (88–108). Toronto, ON: Government of Ontario. Retrieved from http://www.downloads.ene.gov.on.ca/envision/env_reg/er/documents/2016/012-7760 rationale.pdf

## Bioheat and climate change

Apps, M. J., Bernier, P. Y., & Bhatti, J. S. (2006). Forests in the global carbon cycle: Implications of climate change. In J. S. Bhatti, R. Lal, M. J. Apps, & M. A. Price (Eds.), *Climate change and managed ecosystems* (175–200). Boca Raton, FL: CRC Press and Taylor & Francis Group.

Lemprière, T. C., Kurtz, W. A., Hogg, E. H., Schmoll, C., Rampley, G. J., Yemshanov, D., Krcmar, E. (2013). Canadian boreal forests and climate change mitigation. *Environmental Reviews,* 21(4): 293–321. Retrieved from https://www.nrcresearchpress.com/doi/full/10.1139/er-2013-0039#.XIFU9GdYa3g

## Sustainable forest management in Canada and Ontario

Natural Resources Canada (2018a). *The state of Canada's forests: Annual report 2018.* Ottawa, ON: Natural Resources Canada. Retrieved from https://www.nrcan.gc.ca/forests/report/16496

Ontario Ministry of Natural Resources. (2016). *State of Ontario's natural resources: Forests 2016.* Sault Ste. Marie, ON: Queen's Printer for Ontario. Retrieved from https://www.ontario.ca/page/state-ontarios-natural-resources-forests-2016

## Ministry of Natural Resources and Forestry district offices

Visit the following web address to find a map showing all the Ministry of Natural Resources and Forestry districts

https://www.ontario.ca/page/ministry-natural-resources-and-forestry-regional-and-district-offices

| District | General inquiry |
|---|---|
| Aurora | (905) 713-7400 |
| Aylmer | (519) 773-9241 |
| Bancroft | (613) 332-3940 |
| Chapleau | (705) 864-1710 |
| Cochrane | (705) 272-4365 |
| Dryden | (807) 223-3341 |
| Fort Frances | (807) 274-5337 |
| Guelph | (519) 826-4955 |
| Hearst | (705) 362-4346 |
| Kemptville | (613) 258-8204 |
| Kenora | (807) 468-2501 |
| Kirkland Lake | (705) 568-3222 |
| Midhurst | (705) 725-7500 |
| Nipigon | (807) 887-5000 |
| North Bay | (705) 475-5550 |
| Parry Sound | (705) 746-4201 |
| Pembroke | (613) 732-3661 |
| Peterborough | (705) 755-2001 |
| Red Lake | (807) 727-2253 |
| Sault Ste. Marie | (705) 949-1231 |
| Sioux Lookout | (807) 737-1140 |
| Sudbury | (705) 564-7823 |
| Thunder Bay | (807) 475-1471 |
| Timmins | (705) 235-1300 |
| Wawa | (705) 856-2396 |

## Ministry of the Environment, Conservation and Parks regional offices

Visit the following web address to find Ministry of the Environment, Conservation and Parks district and regional office contact information:

https://www.ontario.ca/environment-and-energy/ministry-environment-district-locator

| Region | General inquiry |
| --- | --- |
| Central – Toronto | (416) 326-6700 |
| Eastern – Kingston | (613) 549-4000 |
| Northern – Thunder Bay | (807) 475-1205 |
| Southwest – London | (519) 873-5000 |
| West Central – Hamilton | (905) 521-7640 |