An Alaska case study: Biomass technology

Erin Whitney, Amanda Byrd, and Daisy Huang

Citation: Journal of Renewable and Sustainable Energy **9**, 061705 (2017);
View online: https://doi.org/10.1063/1.4986578
View Table of Contents: http://aip.scitation.org/toc/rse/9/6
Published by the American Institute of Physics

JOURNAL OF RENEWABLE AND SUSTAINABLE ENERGY **9**, 061705 (2017)

An Alaska case study: Biomass technology

Erin Whitney, Amanda Byrd, and Daisy Huang
Alaska Center for Energy and Power, University of Alaska Fairbanks, P.O. Box 755910, Fairbanks, Alaska 99775-5910, USA

(Received 6 June 2017; accepted 26 September 2017; published online 21 December 2017)

This review examines commercial biomass boilers installed around the state of Alaska for key performance and cost metrics. Capital costs and operation and maintenance costs vary with the boiler type and location around the state. Most boiler manufacturers claim system life expectancies of 20–30 years, assuming normal running conditions and adherence to maintenance schedules. System efficiencies vary with the biomass system type, installation protocol, operation and maintenance protocols, piping distance, thermal storage, and wood moisture content. Sizing biomass units to meet approximately 80% of peak required heat load ensures that the boiler will run at the maximum heat output. The boiler itself presents the highest cost for most installations. Other substantial costs include the site foundation, the boiler building, and the integration of the system into the building. Fuel storage and construction management are also large expenses although not reported in each project. Despite the large installed capacity of chip boilers in the Interior, their installation costs per installed BTUh are higher than those of other boilers. *Published by AIP Publishing.*
https://doi.org/10.1063/1.4986578

INTRODUCTION

This report summarizes the current state of biomass-fired boilers throughout Alaska today, reporting where possible their costs, pitfalls, and benefits. It also provides the details of several case studies. We hope that it can be a useful tool for communities seeking to install wood fired heating systems in Alaska. The case studies in this report can be useful for selecting the wood product and boiler type required to meet a community's heating needs.

Alaska encompasses both arctic and subarctic regions and has high heat loads; 80% of Alaska's stationary energy generation is heat. Biomass resources lend themselves well to heat generation, and wood resources are abundant in many locations in Alaska. The state's population density is sufficiently low such that forest destruction does not overwhelm the natural death and regrowth cycle of trees. Sources of woody biomass that do not involve targeted harvesting include areas of land clearing and fire remediation, wind and beetle kill, and lumber mill scrap.

Using local wood resources can keep energy costs low, provide jobs, and keep money in local communities. Southeast Alaska has developed a wood pellet industry around the use of pellet boilers installed in public buildings; exact statistics are not available. A number of rural communities have installed cordwood boilers, employing locals to harvest wood for loading them.

Many woody biomass technologies have been developed in northern latitude countries, such as Finland and Norway, and systems have been used in Europe for many years in district heating systems. The industry is now producing combined heat and power (CHP) units on scales on the order of tens to hundreds of Watts, which are suitable for small communities.

Woody biomass that can be used as an energy fuel includes cordwood (round or split logs), chips (chipped or shredded wood), pellets (densified wood product), and hog-fuel (waste wood-chips including bark). For larger-scale usage (>500 MBtuh), biomass is typically economical as an energy fuel only when it is a by-product of manufacturing or a result of forest management activities (e.g., wildfire risk reduction or forest health restoration). This is not always the case, however, as some communities such as Galena have a harvest management plan in place specifically for wood use for heat. On a smaller scale, such as for residential use, some biomass can be efficiently grown or harvested specifically for energy generation.

In private homes, woody biomass usage tends to fuel direct radiant heat, burning wood in the space to be heated. In community buildings, it is more efficient (both in terms of energy and labor) to use biomass to heat a fluid and then circulate the fluid throughout the space to be heated. Instead of controlling the heat output by controlling the air intake and/or venting, as one does with a home-scale wood stove, the heat output is modulated by controlling the fluid circulation rate. By decoupling the combustion process from heat output, the burn rate and oxygen intake may be optimized for clean, efficient burning. Typically, a boiler heats water directly, and the heat is then transferred to a water/glycol mix for circulation throughout the building. The water and glycol loops also serve as thermal storage. Only one system in which electricity and heat are produced from biomass is operational in Alaska. The system is at Tok High School, and it is customized and not highly replicable.

This review of biomass technology in Alaska is a result of Alaska Senate Bill (SB) 138. In this bill, the Alaska State Legislature created an uncodified section of law entitled: "Plan and Recommendations to the Legislature on Infrastructure Needed to Deliver Affordable Energy of the State to Areas That Do Not Have Direct Access to a (proposed) North Slope Natural Gas Pipeline." To support the Alaska Energy Authority (AEA) in its development of an Alaska Affordable Energy Strategy, the Alaska Center for Energy and Power (ACEP) contracted with AEA to document technology development needs specific to Alaska with regard to renewable and sustainable energy technologies. The intention was to determine what targeted, energy technology development solutions could be implemented in Alaska to make energy more affordable in the Alaska Affordable Energy Study area. While the focus was on technology research solutions, other factors such as logistics, labor, and training were also addressed. Drafts of technology reports were vetted by expert roundtables in late February and early March 2016. (Lists of reviewing experts may be obtained from the corresponding author.)

These reports are not meant to be exhaustive discussions of energy technologies in Alaska or proper designs for each technology, and they should not be used as guides for the choice and installation of specific systems. As such, not all possible issues with power production and each technology are addressed. Data for each technology were collected from surveys and publically available databases. Only completed projects, or projects with clearly reported data, were included in each technology analysis. These distinctions and descriptions of data sources are included in each technology report.

METHODS

This report summarizes data, shown in Table I, collected from a selection of commercial biomass boilers installed around the state of Alaska. The boilers were selected from the ones installed in institutional buildings.

Boiler models selected for analysis

The following biomass boiler models were selected for analysis in this study:

Cordwood: Garn 2000—325 MBtuh (Dectra Corporation) (Tanana, Gulkana, Koyukuk, Coffman Cove, Thorne Bay, and Kasaan)
Garn 1000—180 MBtuh (Dectra Corporation) (Installed in: Hughes, Kobuk)
Econoburn—170 MBtuh (Econoburn) (Tanana)

Small pellet boiler: MESys—109 MBtuh (Maine Energy Systems) (Haines)
Small chip boiler: EnviroChip—500 MBtuh (Portage and Maine) (Mentasta)
Large chip boiler: 750 MBtuh–5500 MBtuh (Messersmith, Chiptec) (Tok, Craig)
Large pellet boiler: 510 MBtuh–1000 MBtuh—(AKÖB/Viessman) (Juneau, Ketchikan)

TABLE I. Boiler installations around the state of Alaska.

Region	Cordwood (MBtuh)	Pellet (MBtuh)	Large pellet (MBtuh)	Small chip (MBtuh)	Large chip (MBtuh)
Interior	Tanana (8 × 325, 2 × 170); Gulkana (2 × 325)			Mentasta (1 × 500)	Tok (1 × 5500)
	Hughes (2 × 180)				
	Koyukuk (1 × 325)				
Western	Kobuk (1 × 180)				
Southeast	Coffman Cove (2 × 325) Kasaan (1 × 325)	Chilkoot Indian Association (Haines) (1 × 123)	Sealaska (1 × 750); Ketchikan Library (1 × 510)		Craig (1 × 4000)
	Thorne Bay (2 × 325 containerized)	Haines Senior Center (1 × 109)	Ketchikan GSA Building (1 × 1000)		

DISCUSSION

This section discusses what is known about performance and capital costs. Actual heat output is not known for most systems; however, other parameters such as total installed costs, installed costs per energy output, and diesel displaced are summarized.

Capital costs/MBtuh

Capital costs, which were calculated using nameplate output capacity and corrected for product efficiency for each installation, are shown in Fig. 1.

Three cordwood boilers located in the remote communities of Kobuk, Koyukuk, and Hughes and the Juneau pellet boiler in Southeast Alaska show the highest cost per installed MBtuh, partly due to the high costs of air transportation, extensive design, and construction-phase labor.

Thorne Bay shows a relatively high capital cost ($1213/MBtuh) because the project included two containerized boilers. Two large-scale woodchip boilers in Tok and Craig represent a relatively low ($500–$1000) installed cost per MBtuh.

The lowest cost cordwood systems are installed in Tanana and Kasaan (under $500/MBtuh). The pellet systems installed in Southeast (excluding the Sealaska boiler) are all priced below $1000/MBtuh, and the installed capital costs of the boiler at the Chilkoot Indian Association are below $500/MBtuh. The installation at the Ketchikan GSA Building is $450/MBtuh, and the installation at the Ketchikan Public Library is $556/MBtuh.

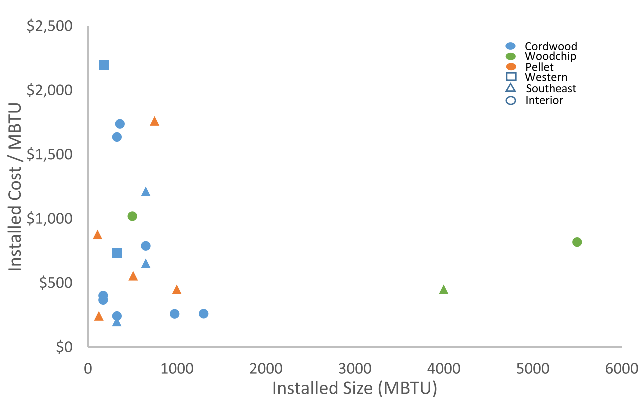

FIG. 1. Capital costs of biomass systems as a function of installed capacity ($/MBtuh), as obtained from project managers and funding agencies via survey.

Operation and maintenance costs per MBtu

Operation and maintenance (O&M) costs (Fig. 2) reported for biomass systems generally include wood handling at the boiler and boiler firing; cleaning; and monthly, annual, and other scheduled maintenance. Due to inconsistent record-keeping, it is not known whether the reported costs include the delivered (or purchased) costs of biomass feedstock.

The highest annual cost for O&M is for the boilers in Kobuk and Koyukuk and at the Chilkoot Indian Association; all of these units have a cost of around $60 per MBtuh (per thousand Btuh installed capacity per year). Kobuk and Koyukuk have created part-time boiler operator positions for their relatively small-capacity boilers, which increases the effective O&M costs.

All other O&M rates are under $30 per MBtuh. Both the Tanana Fire Hall and the Tanana Log Duplex report a zero O&M cost although this may be due to the cost unknown at the time of this report. Thorne Bay has a relatively high O&M cost of $25/MBtuh, the annual O&M costs were reported at $16 500 a year, and both Mentasta and the Ketchikan Public Library report $12/MBtuh. Gulkana has the lowest O&M rate at $3/MBtuh, which could be due in part to a stockpile of many years worth of future wood resources delivered and processed by a local wildfire prevention effort. It is not known what the drivers of these disparities are.

Expected life of unit

Most boiler manufacturers claim system life expectancies of 20–30 years. Maine Energy Systems warranties their units for 30 years (MESys). These estimates assume normal running conditions and adherence to all annual, semi-annual, and other maintenance schedules. Some units have failed much earlier due to little or no maintenance.

Overall system efficiency

System efficiency varies with the biomass system type, installation protocol, operation and maintenance protocols, piping distance, and thermal storage. System efficiency is dependent on the wood being burned, especially with regard to the moisture content.

The U.S. Environmental Protection Agency (EPA) has reported tested efficiencies for units although these numbers are often reported using a standardized, uniform wood product (crib wood) not normally used in Alaska communities (U.S. Environmental Protection Agency, 2017). The EPA efficiencies reported are:

Cordwood: Garn 2000—74%
Pellet boiler: MESys—85%
Chip boiler: Portage and Main—73%; other chip boilers average—65%

Some companies, including Garn and Advanced Climate Technologies (ACT), have had their boiler efficiencies tested by independent third-party testing facilities. Garn boilers are

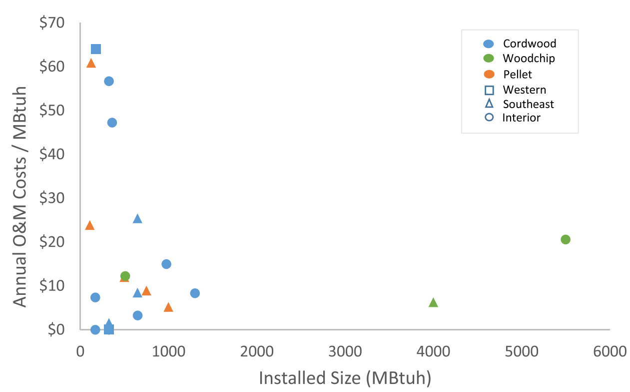

FIG. 2. Operation and maintenance costs as a function of installed capacity ($/MBtuh), as obtained from project managers and funding agencies via survey.

independently tested by Intertek, an independent test laboratory, in accordance with the Thermal Storage Appendix X1 of ASTM Document E 2618–09. Garn system efficiencies are reported as follows: Garn 2000—88.4% (Intertek, 2011a); Garn 1500—80% (Intertek, 2011b). Tested efficiencies for ACT range between 85% and 92% (ACT Bioenergy). These numbers account for the boiler only, not overall system efficiency.

Annual displaced diesel (Gallons/MBtuh)

The quantity of displaced diesel fuel, in gallons, as a function of installed-boiler capacity is shown in Fig. 3.

The Tok woodchip boiler data point of 55 000 gallons displaced annually has been omitted from the plot in Fig. 3, as the data point strongly skews the scale for the other data points, and, uniquely, the displaced or avoided diesel in Tok is used to generate electricity as well as heat.

Mentasta has the highest displaced diesel quantity (16 000 gal), followed by the Craig School boiler with 13 000 gall, and the Tanana Water Plant and the Tanana School, each at 12 000 gal. Coffman Cove was the only other system that displaced over 7000 gal.

The Tok, Mentasta, and Craig systems are automated woodchip systems that offer more constant heating output due to uniform and constant metered feedstock delivery. The Ketchikan GSA Building originally displaced only 4000 of its potential 9000 gallons due to an oversized boiler operating at a lower than ideal efficiency, at the time that data were collected. The Tanana Shop, Fire Hall, and Log Duplex recorded the lowest avoided fuel quantity which could be explained in part by the voluntary use of the biomass boilers in those buildings.

Conditions for the greatest efficiency

Biomass systems are designed to burn at their maximum capacity: hot and fast. Sizing the unit to meet approximately 80% of the required peak heat load ensures that the boiler will run at maximum heat output. Additional heating sources such as diesel fuel are often used to meet the final 20% during peak loads.

Efficiency is also greater for hydronic boilers than for direct heat radiant heat devices because the boiler is decoupled from the heat load demand by using circulating water. Thus, the wood can always be burned at its cleanest air to fuel ratio, and the delivery of heat can be controlled using the water flow instead. An added benefit is that the water serves as thermal storage. A larger thermal storage volume can reduce the number of daily firings a boiler requires to maintain a building's heat although decreasing the number of firings by too much can result in unintended consequences such as water quality issues that can affect the life of the boiler. Therefore, the water capacity must be optimized for the system. Burning wood with a moisture content of less than 25% increases a system's burn efficiency.

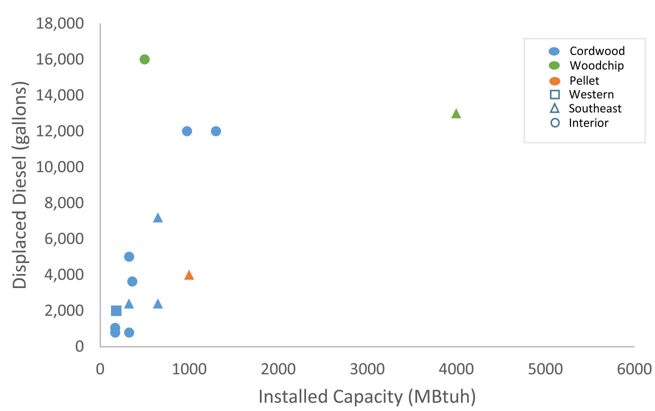

FIG. 3. Avoided diesel as a function of biomass boiler installed capacity. Avoided diesel numbers were obtained from project managers and operators and may be best estimates rather than inventory reconciliations.

Cost over time

Figure 4 shows installed capital costs, corrected for boiler efficiency, of biomass boilers for the years 2007–2015. The costs shown in the figure have been corrected for inflation in the United States over time. Note that there appears to be a slight increase in capital costs per installed MBtuh over time. These data take into account all types and locations of installed systems.

The most recent cordwood boiler installations in Kobuk, Hughes, and Koyukuk have the highest capital cost; Kasaan (built during the same years) was significantly less expensive to install. Air transport was required for two of the four village systems; delivery to Koyukuk and Kasaan was by barge. In 2012, Thorne Bay had the highest capital cost of any prior installation, likely due to installation of two prototype containerized boilers. It is not known what the exact reasons are for these disparities. Larger installed systems have a lower installation cost per MBTU than smaller units of the same boiler type due to the fact that similar installation costs required are independent of the boiler size.

The installation in Juneau served as the first commercial-scale pellet boiler installation in the state; its relatively high costs might have been the result of little prior experience with these systems, this installation served as a demonstration project of exemplary installation and function, and costs were not considered a high priority.

Installed costs by major components

Different communities utilize different methods to track and report the costs of the different components. However, this section summarizes what was reported.

Figure 5 shows the installed biomass technology costs by major components. Component descriptions are as follows:

Boiler: The boiler unit
Site foundation: Preparation of the area to place the boilers
Pellet silo: Pellet fuel storage
Distribution piping: The piping required to move water heated by the boiler to the building being heated
Distribution pumps: Pumps required to move water through piping
Boiler installation: Costs for installing the boiler, including labor
Boiler building: The building housing the boiler (if it is not being housed in the heated building)
Boiler building mechanical: The mechanical requirements for the boiler in the building
Integration: The integration of the boiler into the heating system
Design and permits: The system design plans and permits required for the boiler system
Stack and install: The boiler emissions stack and the installation of the stack on the boiler unit

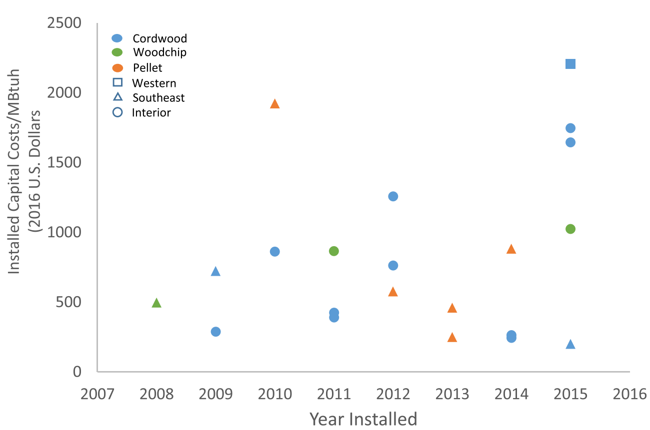

FIG. 4. Installed capital costs ($/MBtuh) of biomass boilers and year of installation. Costs were made constant to 2016 values using http://www.usinflationcalculator.com/.

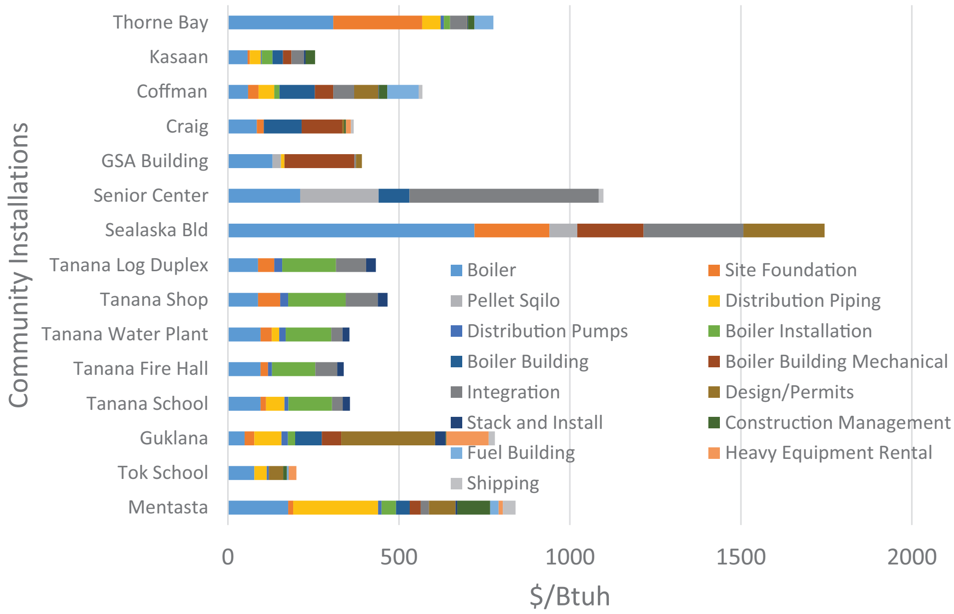

FIG. 5. Installed biomass technology costs by major components ($/MBtuh).

Construction management: Overseeing of the project's construction, including management labor
Fuel building: The building, other than a silo, required for storing biomass fuel
Heavy equipment rental: Equipment that may not have been available in the community for installation
Shipping: The costs associated with shipping the boiler and other construction materials

The boiler itself presents the highest cost for most installations. Other substantial costs include the site foundation, the boiler building, and the integration of the system into the building. Fuel storage and construction management are also large expenses although not reported in each project.

Transportation costs

Transportation costs by system type and installed capacity are shown in Fig. 6. Unfortunately, shipping costs were not reported for all projects. Of the shipping costs available, those for transporting cordwood boilers to Kobuk, Hughes, and Koyukuk were the highest. Kobuk and Hughes are located on rivers that are not accessible by barge; the shipping method was by air. Koyukuk is accessible by barge on the Yukon River.

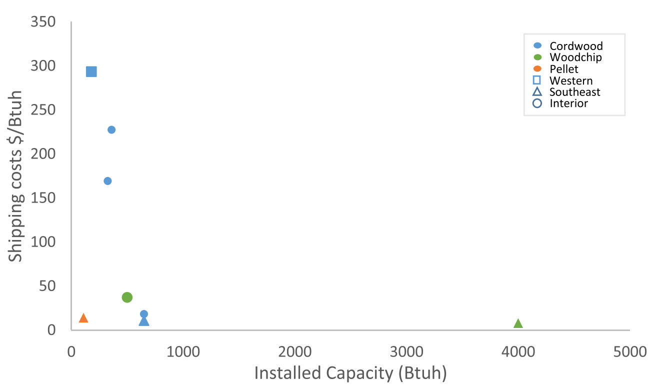

FIG. 6. Shipping costs as a function of installed capacity.

Mentasta and Gulkana are located on the road system and use shipping methods that may include rail, road, and ocean barge from Seattle.

Southeast coastal communities have lower shipping costs due to barge and ferry service from Seattle. As such, they do not incur the added costs of transporting equipment inland.

Technology trends

Cordwood biomass systems involve intensive labor. One way to reduce the O&M costs has been to move to an automated woodchip system, which, as seen in Fig. 2, costs less. In addition, the cost and the general availability of woodchips compared with cordwood and pellets make combustion technology more economical although the infrastructure required to process and deliver wood chips may be a financial limitation to some communities. Increasingly, schools and communities that are adopting biomass as a heating fuel are also installing greenhouses and incorporating biomass energy and food production into their curriculum. Compared to cordwood systems, however, chip-fed combustion requires extra processing time (and expense) to manufacture chips.

Technology-specific storage

Information here is specified by the New York State Energy Research and Development Authority (NYSERDA). Several demonstration projects, being funded by the NYSERDA, may show that thermal storage is "system dependent" rather than just a fixed ratio of gallons/Btuh.

The Biomass Thermal Energy Council (BTEC) is forming an action group on thermal storage, and the Clean Energy State Alliance (CESA) has commissioned consultants to develop a white paper on thermal storage. John Siegenthaler, an industry specialist, says this on the topic:

My pitch on thermal storage is that it is highly system dependent. A pellet fired boiler supplying a very high mass heated concrete floor slab with only one zone could likely work fine without any water-side thermal storage. However, a low thermal mass distribution system (like fin-tube baseboard), that's divided into several zones would definitely benefit from the 2 gal per 1000 Btu/h storage requirement. Ultimately these scenarios can be simulated by high end software.

New industry standards recommended by CESA (Siegenthaler, 2016) for thermal storage volumes in biomass heating devices include:

- Pellet systems: 20 gal water/10 000 BTU/h thermal storage
- Cordwood systems: 130 gal of storage per cubic foot of combustion chamber volume minus the water volume of the boiler
- Chip boiler: No specific volume suggested

Cost of biomass fuel

Biomass fuel prices across Alaska are often tied to fuel costs for harvesting and vary both regionally and seasonally. Regionally, the available wood species is a determinant of price. Figure 7 shows the varying cordwood costs for eight regions of Alaska. Interestingly, while the price of gasoline has recently decreased, the price of wood has not. This may be due to high costs of harvest equipment and the labor needed to harvest, transport, and store roundwood biomass.

The cost of fuel oil in rural communities not connected by road systems is higher than that of communities on the Railbelt. In times of high oil prices, the residential and community demand for wood increases to offset these increased heating costs associated with oil. This can be seen, as well, when the price of fuel oil drops and a concurrent drop in biomass use may be seen. This effect has been the case in the Tanana Shop where it was deemed to be more cost effective to decrease wood use when fuel oil prices decreased.

Pellets have a higher MMBTU per ton; however, their cost per MMBTU is similar to that of cordwood in Interior Alaska (Fig. 8). Woodchips, while yielding the same MMBTU per ton as cordwood, may be delivered at a lower cost overall than cordwood although circumstances

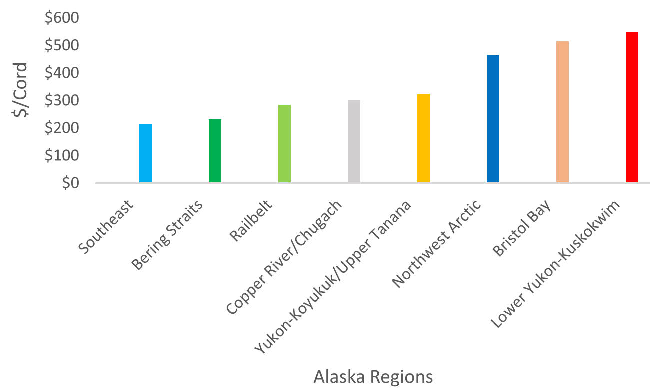

FIG. 7. Average delivered firewood costs per region in Alaska (data courtesy of WHPacific 2012 and Kerr, 2016).

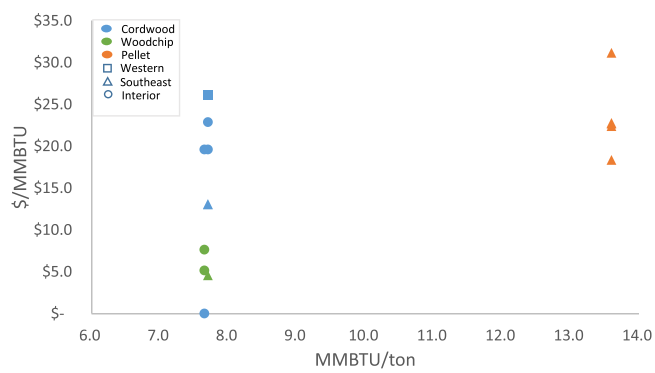

FIG. 8. Cost of delivered biomass per ton as a function of the energy content per ton, calculated with the Fuel Value Calculator (USDA, USFS, Forest Product Laboratory).

unique to individual communities may not be in accordance with the general cost patterns. For example, Gulkana reports zero cost for delivered wood, as their feedstock is provided free as part of a fire-prevention program.

In Tanana, while biomass feedstock costs are around $20/MMBTU, the community recently received approximately 6 years' worth of feedstock from a road construction project. The wood still needs to be processed and brought to the boilers, however, and current calculated cost for processing and delivering the wood is around $50 per cord. These numbers have not been fully reflected in this study, as they have not been confirmed. In addition, it is unlikely that zero-cost feedstock will be available over the economic life of the biomass system.

CONCLUSIONS

This review examines commercial biomass boilers installed around the state of Alaska for key performance and cost metrics. Capital costs and operation and maintenance costs vary widely with the boiler type, capacity, and location around the state. The installed cost per MBtuh ranges from $500 to over $2000. Annual O&M costs per MBtuh also range an order of magnitude, from under $10 to almost $70. Accessibility seems to correlate somewhat with costs, with costs being lower along the highway system or the ferry system. However, it appears that it is still too early in the introduction of biomass heat to public Alaskan buildings to definitely state what, if any, trends or patterns exist. At this point in time, each installation, in conjunction with the unique community situations surrounding it, is *sui generis* and not representative of any larger pattern.

However, the stories from each community reveal some qualitative patterns. First, sizing biomass units to meet 80% of peak required heat load ensures that the boiler will run at the maximum heat output. Second, the communities need to offer both financial and human resource stabilities to maintain a successful biomass project. For example, the most highly efficient communities all have personnel dedicated to operation and maintenance of the boiler. Third, community members need to have vested interest in the continuous operation of the boilers, i.e., the biomass boilers must provide some tangible benefit in terms of job creation and/or retention of wealth within the community.

ACKNOWLEDGMENTS

The authors wish to thank the Alaska Energy Authority for its funding to support this project. The following communities and individuals provided costs and numbers via survey.

Coffman Cove, Kasaan, and Thorne Bay—Jonathan Fitzpatrick, Craig—Jon Bolling, Gulkana—Sandra Tsinnie, Haines Chilkoot Indian Association—Harriette Brouillette, Haines Senior Center—Ed Bryant, Hughes, Kobuk, and Koyukuk—Eric Hanssen, Juneau Sealaska Building—Shawn Blumenshine, Ketchikan GSA—NREL Report, Ketchikan Public Library—Linda Lyshol, Kokhanok—Nathan Hill, Mentasta—Rex Goolsby, Tanana—Jeff Weltzin, and Tok—Scott MacManus.

ACT Bioenergy, http://www.actbioenergy.com/faq.html for information on tested efficiencies.

Intertek, http://www.garn.com///wp-content/uploads/2011/07/G100248857MID-006R-REVISED-06232011-signed.pdf for Test Report: Model WHS1500V Solid Fuel Hydronic Furnace; accessed June 23, 2011a.

Intertek, http://www.garn.com///wp-content/uploads/2011/07/G100463637MID-005R2-WHS2000-EPA-report-Revised-signed.pdf for Test Report: Model WHS2000 Solid Fuel Hydronic Furnace; accessed November 14, 2011b.

Kerr, C., Northern Economics, personal communication (2016).

Maine Energy Systems (MESys), http://www.maineenergysystems.com/wood-pellet-boiler/ for MESys AutoPellet - Fully Automated Wood Pellet Boiler.

Siegenthaler, J., P.E. Principal, Appropriate Designs, Holland Patent, NY, personal communication (2016).

U.S. Department of Agriculture, U.S. Forest Service, Forest Products Laboratory, https://www.fpl.fs.fed.us/documnts/techline/fuel-value-calculator.pdf for Fuel Value Calculator, 2004.

U.S. Environmental Protection Agency, https://www.epa.gov/compliance/list-epa-certified-hydronic-heaters for List of EPA Certified Hydronic Heaters, 2017.

WHPacific, *Alaska Energy Authority End Use Study: 2012* (WHPacific, 2012).