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Engineered Wood Fuels for Southeast Alaska

Local Wood Chips for Thermal Energy Applications, and the Specific Case of Haines, Alaska

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Abstract

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The wood energy landscape is rapidly changing in southeast Alaska. One of the important decisions facing wood energy users is the best choice of wood fuel to use, with options often including wood chips, cordwood, and pellets. However, there are usually tradeoffs depending on the wood energy type selected: wood pellets must often be transported long distances, cordwood systems are relatively labor intensive, and chip-fired systems can often be very expensive. We consider the use of locally produced and engineered fuel chips as a fuel source for small thermal wood energy applications in southeast Alaska. Factors such as equipment selection, fuel moisture content, fuel transportation, wood chip dimensions, drying practices, and fuel screening and handling are evaluated. We also consider the specific case of wood energy in Haines, Alaska, where plans are underway to heat one or more community buildings with locally produced wood fuel. Locally engineered fuel chips can offer opportunities to use a flexible fuel type that could improve the reliability and efficiency of wood thermal systems. Increased use of wood energy in Haines could increase community independence and economic development, and flexible fuel types such as locally engineered chips could enhance this effort. However, site-specific factors would need to be considered more fully, including detailed financial analyses and the size of buildings to be heated. Customized engineered wood fuels have the potential for efficient operation and cost savings while providing a stable fuel type that can help guide future wood energy systems for communities in southeast Alaska.

Keywords: Pellets, wood energy, residential heating, locally engineered chips, southeast Alaska.

Contents

Introduction

Village Energy in Alaska

In rural Alaska, there are many villages with populations of fewer than about 500 residents. In some cases, villages are not connected to a road system, relying on water transport for many of their goods. Imported fossil fuels are the predominant form of energy for heat, electricity, and transportation. Thus, anything that villages can do to use local forest resources instead of importing fossil fuels will be beneficial in many respects. Rural villages often have to spend a disproportionate amount of income on energy costs. Although prices for fuel oil, diesel, and propane have moderated in recent years, they are still relatively high for remote locales. Biomass fuel prices, although typically lower than liquid fossil fuels, require more expensive processing, storage, and combustion systems. Sustainable biomass harvests from forests adjacent to communities could provide significant energy opportunities for many rural villages (Fresco and Chapin 2009). Many wood energy supply chains and technologies would require limited equipment infrastructure and could potentially create new jobs.

One type of wood energy system that has become popular in rural interior Alaska is the cordwood boiler, which operates with minimal fuel processing, low capital costs, and moderate manual labor. When greater heating needs are present, more expensive automated systems can be justified. Other systems combust wood pellets for heat, but these have often been limited by fuel costs and local supplies in Alaska where there is only one commercial producer of wood pellets. A third type of wood energy system combusts wood chips, often sourced from either local wood products manufacturers or from forest harvest residues. Regardless of system size or type of wood-burning equipment, a consistent and reliable wood fuel source is important for rural communities to achieve energy security and economic stability during the expected 20- to 30-year lifetime of the equipment.

Village energy issues have become a central part of wood energy development in Alaska over the past decade. A key benefit of wood fuel sources (vs. liquid fossil fuels) is the relatively stable price of wood fuel. However, this is just one of many community benefits derived from wood energy; others include increased employment, reduced greenhouse gas emissions, and greater energy self-reliance. Given the often adverse conditions under which wood energy systems must operate, it has been suggested that Alaska's rural communities could serve as project leaders and innovators on a global scale as more communities transition to biomass power (Fresco and Chapin 2009).

Biomass heating systems—chips vs. pellets vs. cordwood—

Biomass heating systems for community buildings are often limited to three primary types of wood fuel: wood chips, pellets, and cordwood (i.e., firewood). Regardless of the fuel type, basic operation of the heating system consists of heat being transferred from the combustion chamber to the heating destination via hot water (hydronic) systems or low-pressure steam systems. For small wood energy systems—typically less than 1 million British thermal units (BTUs) per hour—cordwood systems can be used effectively to supply hot water to thermal storage, and ultimately to the heat user. Smaller scale boilers are generally engineered for a tight range of fuel characteristics, including size, moisture content, ash content, and other parameters. Because cordwood systems cannot modulate heat output based on changing demands, they require manual labor to process and stoke firewood as needed. Larger scale systems require uniform fuel types, typically wood chips or pellets, conducive to automatic fuel handling systems. However, owing to challenges related to establishing wood pellet manufacturing systems in small remote villages, wood pellets are not generally available in rural Alaska except when imported from other regions. Therefore, many communities in forested regions could benefit from a uniform chipped fuel that could be more easily produced locally.

Wood chips can be used economically in larger systems, those consuming 800 to 1,000 tons of wood (dry basis) per year and offsetting 80,000 to 100,000 gal of heating oil per year. Examples include schools in Craig, (southeast Alaska) and Delta Junction and Tok (interior Alaska) (fig. 1). The use of chips is facilitated by abundant sawmill residues in Craig as well as affordable whole tree chips in interior Alaska. In both of these cases, wood chips are produced as a residue product, with solid wood products such as lumber or house logs being the primary product. The abundance of low-cost wood residues is often a key economic condition for using wood chips for thermal energy. Smaller villages in rural Alaska, those consuming less than about 35,000 gal per year of heating oil, would not be good candidates for the more sophisticated and expensive chip burning systems. Although smaller communities may have access to consistent supplies of wood, they often cannot afford or justify the expensive equipment designed for raw, wet, or dirty fuels. Thus, smaller heating requirements can often be better served by one or more cordwood systems.

Engineered fuel chips and microchips—

Two forms of wood chips were considered in this study: engineered fuel chips and microchips. Although there is no strict definition of “microchips,” they can be thought of as wood fuel particles sized smaller than standard chips (which are often used in the pulp and paper industry and traditional wood energy uses), but larger than wood pellets or sawdust (fig. 2). Steiner and Robinson (2011) define microchips

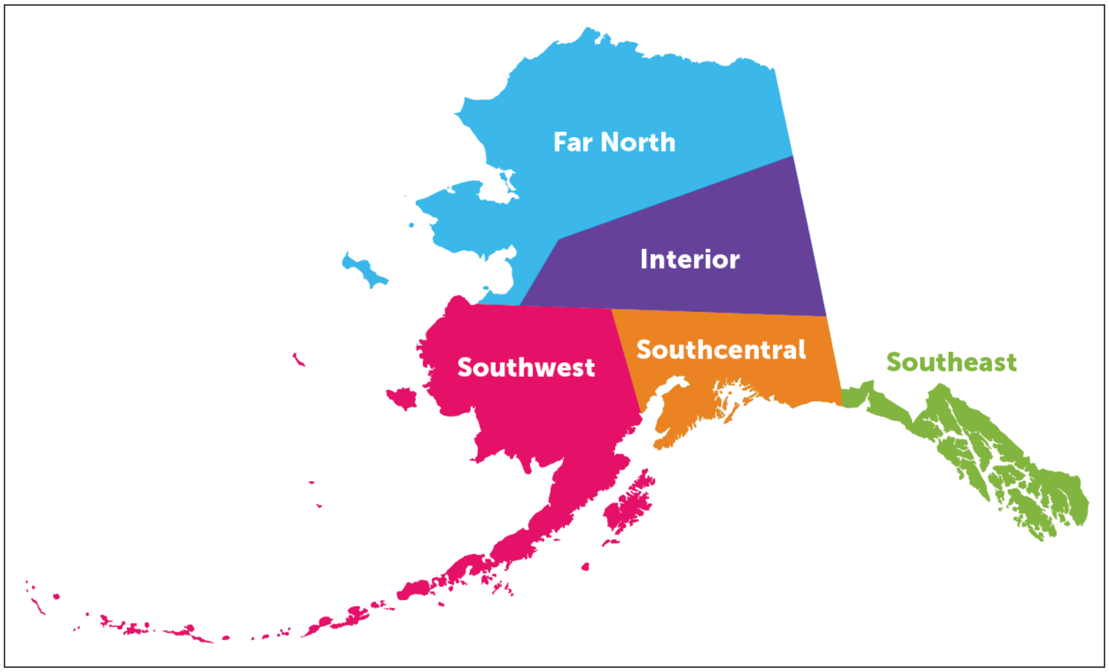

Figure 1—Regions and communities of interest in Alaska.

Portableplants.com (Smalley 2016)

Figure 2—Microchips

as "between ¼ and ⅜ inches in length," which is in contrast to traditional pulp and paper chips, which are generally 1-¼ inches long. Thus, microchips can cover a range of sizes and fuel quality, offering significant advantages for use in customized wood energy applications. When considering wood energy operations, chip size is an important variable with regard to transportation logistics, fuel handling, drying, and combustion.

A key advantage of microchips is that they do not require the processing steps necessary for wood pellets, yet they can function much like pellets while serving similar markets.

Microchips have been produced for a number of years in Europe and offer important processing efficiencies as well as more uniform drying versus conventional chips (Hein 2011). Currently, several equipment manufacturers sell microchip processing equipment, while other companies are adapting existing commercial equipment for use in microchipping operations. Microchips can be made "in-woods" on an industrial scale and sized to less than ½ inch maximum dimension. These smaller chips flow readily and can be treated as a more uniform, homogenous fuel than conventional chips from forest residues. Further, greater transportation efficiency can be realized by reducing particle size, ash content, and moisture content close to the harvest location, thereby increasing the fuel's energy density.

Recently, several wood pellet combustion systems have become established in southeast Alaska in addition to at least one pellet manufacturer. Although conventional wood pellets offer many advantages in terms of energy density, transportation logistics, and heating values, they require a relatively high amount of energy to dry the wood, grind the wood to a fine powder, and compress the wood into pellets. By contrast, microchips can be produced through a less energy-intensive process of drying and chipping only (without the final step of pellet manufacturing). Microchip production can also reduce the energy needs for regrinding wood after drying (Whitelaw 2009). Further, microchips can be produced using either drum or disc chippers (Hein 2011), offering flexibility in the choice of equipment.

Thus, a key advantage of microchips is that they do not require the processing steps necessary for wood pellets, yet they can function much like pellets while serving similar markets. A potential disadvantage of microchips versus wood pellets would be a somewhat greater storage volume for the more bulky microchip fuel as well as differing densities and heating values (table 1). Microchips would not be a "drop-in" replacement for pellets but could be used as an alternative to pellets in some cases, if sufficient storage volumes were available. In addition, microchip production rates (in tons per hour) can be 11 to 13 percent lower than for conventional chips, and greater fuel consumption is needed to create smaller particles (Thompson and Sprinkle 2013).

In practice, wood energy systems in southeast Alaska would likely operate best using chips sized larger than microchips, yet smaller than conventional pulp-sized chips. Therefore, we will use the term "locally engineered chips" for the remainder of this report to reflect the possibility of communities developing custom chip specifications—ranging in size from microchips to pulp chips—to reflect their unique local conditions (fig. 2).

Table 1—Wood fuel storage systems in use in Alaska for small industrial wood energy systems, as of 2016

Type	Fuel type	Capacity	Boiler size	Location in Alaska
		Oven-dry (tons)	*MMBTUs per hour*	
Shed	Cordwood		1	Thorne Bay
Silo bin	Pellets		2.0	Juneau
Silo bin	Shavings		1	Dry Creek
Roll-off container				
Forage wagon	Chips	4	2.5	Hoonah
Scraper bin	Chips	30	4	Craig
Auger reclaim	Chips	30	8	Delta Junction, Tok
Fuel pile	Chips	300	10	Tok

MMBTUs = million British thermal units.

Study Objectives

We consider locally engineered chips as a potential substitute for wood pellets or conventional wood chips for thermal and small-scale electric energy applications in southeast Alaska. We evaluate the feasibility of locally engineered chip production, including fuel quality, fuel sizing, and fuel handling and drying.

We also provide a detailed evaluation of locally engineered chip use in Haines, Alaska, considering such factors as:

- Equipment and manufacturing practices required to produce locally engineered chips
- Fuel handling and screening
- Drying strategies

Engineered Chip Equipment Producers

Locally engineered chips have been produced in Europe for several decades and offer processing efficiencies as well as more uniform drying compared to conventional wood chips (Hein 2011). Currently, several equipment manufacturers sell chip processing equipment (Continental Biomass Industries 2014, Morbark Industries 2014, Peterson Corp 2014), while other companies are adapting existing commercial equipment for use in chipping operations (Cardinal Equipment 2014). Other manufacturers having capabilities to produce locally engineered chips include Acrowood Corporation (Acrowood Corp. 2014) and Salsco (Salsco Inc. 2014).[1]

Locally engineered chips have also been used for wood energy applications in the northeastern United States, including New Hampshire. For example, Froling Energy (2016) delivers "Precision Dry Chips" to boilers in schools and commercial buildings in the Northeast. The dried and pellet-sized chips have demonstrated more reliable operation and higher efficiency than other types of wood fuels. Research with hardwood chips has shown that unlike conventional pellets, pellet-sized chips produced with commercially available equipment can be used in ordinary pellet combustors, provided that the fuel feeding rates are increased—in contrast to conventional pellets—and the moisture content is well below 20 percent (Eriksson et. al. 2011). However, other research has shown that conventional disc chippers were somewhat ineffective in producing properly sized chips, and that production rates decreased by more than 10 percent, when compared to conventional chips (Thompson and Sprinkle 2013). In some cases, wood energy combustion equipment originally designed for pellet combustion can also be considered for locally engineered chips (Simet 2015).

Engineered Wood Fuel—Key Considerations and Fuel Types

Wood pellets—

Wood pellets can be an ideal fuel for clean, efficient combustion, having high energy density and favorable transportation properties compared to many other types of wood fuel. They are made from feedstock having low ash content, dried to less than 10 percent moisture content, and densified for automated handling (table 2). Automatic control of fuel and air during pellet combustion results in high efficiency and low emissions while providing a steady heat load. A key advantage of wood pellet systems versus chip or cordwood systems is that pellets can be stored in a compact storage area, then automatically transferred to the combustion chamber without the need for manual labor. Two pellet mills in Alaska serve nearby markets Fairbanks (interior Alaska) and Ketchikan (southeast Alaska). However, much of rural Alaska is not within an economically feasible transportation distance of either mill. A third pellet mill located in Gulkana, Alaska, recently started production (as of early 2017).

Wood pellet burners are generally not economically feasible where transportation costs are high or no pellet production facilities are nearby, as is the case for many remote villages in interior Alaska. Therefore, many of the villages have turned to other wood fuel types such as wood chips or cordwood. Wood chip systems are installed or planned in towns with infrastructure, such as Tok, Dry Creek, Delta

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Table 2—Qualities of wood fuels commonly used in Alaska

Type	Cordwood	Whole-tree chips	Chips/ microchips	Pellets
Bark included? (yes/no)	Yes	Yes	No	No
Ash content (percent)	2–5	5–8	0.5–2	1
Moisture content (percent)	20–50	50	50	8–10
Density (cubic feet per oven-dry ton)	128	200	200	60
Density (pounds per cubic foot)	16	10	10	35
Combustion efficiency (percent)	35–70	65–70	70	80
Cost ($ per ton)	200	100–125	100	400

Junction, and Craig. Haines, Alaska, has recently acquired fuel storage silos and a combustion system that could be used for pellets or other wood fuels (Ratz 2016).

Cordwood—

Over the past decade or more, cordwood systems have been very successful as small systems in rural Alaska as well as other rural locations throughout the United States, including New England and the Great Lakes States. In these systems, cordwood is harvested, collected, seasoned, and stored before being burned in high-efficiency boilers. Seasoned wood, dried to about 20 percent moisture, can be burned efficiently with low particulate emissions. Cordwood is manually loaded into boilers that burn "fast and hot," transferring heat quickly to hot water in thermal tanks surrounding the cylindrical combustion chamber.

During this burning period, a typical cordwood system can store up to 3 million BTUs, followed by a sustained heat release of about 500,000 BTUs per hour. If greater heating loads are needed, multiple burners can be installed in parallel at a single location. In southeast Alaska, winter loads may require only one 2-hour burn per day; colder interior Alaska locations may require two burns per day. Although communities, greenhouses, and large institutions have been heated with cordwood boilers, a reliable labor pool is critical to their continued operation and maintenance as cordwood boilers require considerable manual labor to collect, process, and "stoke" the wood; however, this has been shown to promote local economic development through increased employment (Ketzler 2014).

Several cordwood systems have been installed in southeast Alaska that provide heat to schools and greenhouses, providing additional learning opportunities to students. Cordwood boilers could prove to be the best option for many locations in rural Alaska where a well-developed road system is present (e.g., Prince of Wales Island in southeast Alaska). Until additional infrastructure is established in Alaskan communities to harvest, chip, and transport wood, cordwood use could be the most feasible form of wood energy.

Wood chips, shavings, sawdust, and hog fuel—
When wood processing residues are available, fuel types can differ in size from chips, shavings, sawdust, and hog fuel. These fuels have been used throughout Alaska at locations such as Fairbanks, Tok, Craig, Dry Creek, Ketchikan, and Hoonah. Fuel quality can differ widely, and variables such as moisture content, ash content, presence of bark, and oversized or stringy pieces can greatly influence system performance and maintenance requirements. Although wood processing residues could be considered an easy enticement to supply fuel to wood energy users, there are several limitations to using this fuel source in Alaska:

- There are relatively few sawmills providing consistent supplies of wood residue (throughout the heating season).
- Even fewer sawmills have equipment to debark logs so that sawmill residues can produce "clean" chips.
- Because there are few dry kilns in Alaska, most wood processing residues would be in the "green" condition; high moisture content fuels can have lower heating values and combustion efficiencies.

High-moisture fuel can lead to reduced combustion efficiency, visible smoke, and inefficient use of underfire or overfire air. Oversize fuel, stringy bark, rocks, and other debris can create greater levels of ash while interrupting fuel flow on combustion grates. Flue gas recirculation can also be used to direct air to the grate, limiting agglomerations while improving combustion efficiency. Many of the operational problems just mentioned can be avoided by burning chips that are clean (i.e., free of dirt), of uniform size, and of uniform moisture content.

Wood Fuel Standards

European standards—
Wood fuel standards are specifications for some of the most important properties of wood, designed to assure consistency among different fuel suppliers and users. They are important owing to their influence on wood fuel handling, combustion, ash generation, and other elements of wood energy system operation. Most European chip burner suppliers, and some U.S. suppliers, require fuel that complies with size specifications, moisture content, energy content, and ash content (table 2). In some cases, other fuel specifications are required, such as nitrogen content, chlorine content, bulk density, and fines content.

Fuel must conform to the European Committee for Standardization specifications that designate chip size or moisture. Some European boilers (e.g., Viessmann) are designed to use chips within the G30 “Fine wood chip” standard, a green chip with a maximum dimension of 1.25 inches (R&S Biomass Equipment2016). With many chipper configurations, fuel that has been chipped to a nominal length of 1 inch is often up to 1.5 inches wide. Chips with these dimensions often have good porosity for air and combustion gas mixing, good fuel handling properties, and overall, are a consistent fuel type. Criteria for establishing standards for solid biomass fuels can include the following:

- Moisture content
- Ash content
- Bulk density
- Origin and source
- Particle dimensions

If the Haines system were to use locally engineered chips, and several suppliers were involved, fuel standards could help ensure consistency for the most important fuel properties.

Fuel standards, Haines, Alaska, context—
If the Haines system were to use locally engineered chips, and several suppliers were involved, fuel standards could help ensure consistency for the most important fuel properties. This could in turn provide more stable heating output, reduce maintenance costs, reduce ash disposal costs, and potentially improve air quality. Some of the most important properties are discussed individually below:

Fuel particle size—
Fuel particle size can have an important impact on fuel handling at the wood energy site, especially when using augers. Fuel particles that are too small can also cause problems with augers as undersized particles tend to resist the turning action of the auger. Eventually, the presence of a packed mass of undersized particles can cause augers to shut down. By contrast, oversized fuel particles can jam equipment, causing shutdowns until the wood can be manually removed.

Fines content—
The presence of fine particles can effect fuel handling in pneumatic (i.e., air-blown) systems. Fine particles combust more readily in the wood burner, often in suspension, while larger particles burn over longer periods of time on the grate. Thus, too high a fines content can cause variations in heat transfer and flame temperature that may be less than optimal. Lastly, fines can lead to increased explosion potential in enclosed spaces.

Moisture content—

Wood moisture can influence many properties important to energy generation. In northern climates, water in chips can freeze, resulting in solid masses of wood not conducive to most handling equipment. Moisture content also influences the delivered weight of wood, with fresh green wood often having close to twice the weight of oven-dry wood. Most wood fuel contracts are based on delivered weight or moisture content. Finally, most combustion systems are designed to operate most efficiently at a specified wood moisture content (or a narrow range of moisture). If fuel with higher moisture content is burned, combustion efficiency will be reduced owing to the energy needed to vaporize water. If fuel is burned at too low an optimal moisture content, excessively high combustion temperatures may result.

Presence of bark or foliage—

When compared to clean wood, bark and foliage have greater levels of alkali, silica, and other incombustible compounds that will eventually become part of the bottom ash, or possibly lead to increased slagging or fouling of metal boiler surfaces. Greater levels of ash also result in more labor needed for removal and disposal.

For fuel standards to be effective, they must be easy to use and verifiable. In the case of Haines, Alaska, any required quality tests need to ensure compliance would have minimal equipment requirements. For example, moisture content and size parameters could be tested in Haines, while more elaborate tests (e.g., ash content, alkali content, trace metals) could be sent to outside laboratories for testing. Sampling procedures would need to consider these factors as well as the variation acceptable for a given standard to remain in compliance.

Local Engineered Fuel Chips—Process Overview

Within the past several decades, industrial-scale chippers with high capacities have been developed for commercial markets. One of the factors catalyzing the industrial-scale production of locally engineered chips has been the increased use of wood energy in Europe (Smalley 2016). To meet this growing demand, wood pellet mills in the southeastern United States produce chips for pellet manufacture and export. Often, locally engineered chips are produced "in-woods" (fig. 3), delivered in bulk to pellet mills, then dried and reground to less than 0.25 inch for densification.

Compared with conventionally sized wood chips, locally engineered chips are less economical to produce at smaller scales, as the initial equipment costs can be quite high. Other issues related to locally engineered chip use include potentially higher fines content, which can lead to reduced fuel flow, or "packing." Although

Figure 3—Commercial in-woods microchipping operation, supplying fiber to a wood pellet mill in Faison, North Carolina.

properly dried chips should burn easily, a drawback is that their bulk density is less than that of pellets. Therefore, in many small thermal energy applications where consistent performance is required, wood pellets can be more advantageous.

System design considerations—

A diverse type, size, and capacity of wood energy boilers are currently used in Alaska (table 3, appendix). Properly designed, locally engineered chip systems could be used by Alaskan villages to burn 500 to 1,000 tons of wood per year, heating one or more buildings. A hypothetical wood fuel system replacing a 35,000 gal-per-year heating oil system would require about 700 green tons of wood annually. There are numerous commercial chippers on the market having capacities ranging from about 700 to 2,000 tons per year. One such model is a 40-horsepower Vermeer chipper capable of processing material up to 12 inches in diameter (the log, size limit being considered by Haines). A chipper in this size class could realistically supply chips for more than one wood energy system in multiple communities.

For a typical locally engineered chip burner with a peak demand of 2 million BTUs per hour, daily wood consumption would be about 3 oven-dry tons of wood (the equivalent of about 600 ft^3, or 22 yd^3). Once chips are created, key decisions include the choice of transportation method, as well as the method of unloading fuel at the point of use. Smaller wood energy systems can allow for great flexibility in how these equipment items are configured, often limited only by available budgets.

The capacities of typical wood storage systems are highly variable and must be customized to specific conditions. Fuel storage for small systems (those smaller than 2 million BTUs per hour) at full load consumes 8 yd^3 of pellets or 28 yd^3 of

Table 3—Small boilers used for three types of wood fuel in Alaska

Fuel	Cordwood	Pellets	Chips			
Capacity (MMBTUs per hr)	0.5	1 to 2	0.1 to 0.5	2	4	8 to 10
Manufacturers	Garn	Kob, ACT, MEco	LEI	ACT, Bioen-ergy	Chiptec, KOB	Messersmith, KOB
Number of installations	17	7	1	2	1	1
Location	Statewide	Juneau, Ketchikan	Tok	Haines	Craig	Delta,Tok

[a] See supplier list in appendix. Listing does not constitute endorsement. MMBTUs = million British thermal units.

chips per 24-hour day. This is the approximate size of agricultural grade forage wagons (22- to 28-yd^{3}capacity) and roll-off drop boxes (30- to 40-yd^3 capacity). When greater fuel storage is needed, large walking floor trailers capable of storing up to 2,200 ft^3 of wood fuel, enough for about 3 days, could be used. Thus, these types of standard equipment items could be effective when just a few days supply of fuel are needed. Beyond wood thermal systems, the fuel requirements are similar for small-scale power generation equipment, including gasification with internal combustion engines. Table 4 lists several commercial systems that have been considered in Alaska for generating electricity for rural communities.

Chipping equipment—

For small-scale community applications, the choice of chipping equipment can be a critical decision. In addition to cost, some of the key operating parameters include chipping capacity (tons per hour), range of chip sizes produced, portability, allowable wood moisture content, and tolerance for bark. Often, the chipper's infeed rate (i.e., the rate in lineal feet per minute at which solid biomass is fed into the chipper) is a key operating parameter in accurately controlling chip length.

Commercial manufacturers are now producing a wider range of chipper options, driven in part by greater demand for wood energy products in Europe (Smalley 2016). One chipper in common use is the Morbark M12D Brush chipper (Morbark Industries 2016, Versalift East 2016). This chipper has been selected for two community energy projects in Alaska, including Hoonah (in southeast Alaska) and Fort Yukon (in interior Alaska). Another manufacturer, Continental Biomass Industries, has designed four different chipper configurations capable of producing 100 tons per hour. Bandit Industries has developed five models that can produce locally engineered chips and standard-sized chips (Smalley 2016). Peterson Pacific Corp. also has an extensive line of chippers, with capacities of up to 200 tons per hour (Peterson Pacific Corp. 2014), an amount that would far exceed the needs of a village-scale wood energy system in Alaska.

Table 4—Commercial small-scale electrical power generation systems suitable for community energy

Supplier	Capacity (kWe)	Capacity (kWth)
Volter	45	100
Spanner	45	100
Entrada	45	100
All power labs	20 to 150	50 to 300
Syngest/Community Power Corporation	100	200

Screening systems—

Wood particle screening is an integral part of producing chips and densified fuels, including biobricks and pellets. A primary role of the screening system is to remove oversized wood particles as well as other contaminants (such as metal or rocks that could damage equipment), while ensuring a consistent wood-fuel size. Before densification, wood particles typically require sizing to a maximum dimension of about ⅜ inch; however, undensified locally engineered chips require sizing customized to specific applications. Several types of screening systems are in commercial use, including those operating by rotary action or by vibrations.

Rotary trommel screens use a continuous tumbling action within a rotating cylinder to size and separate feed material. The rotating action helps to break down softer materials and separate different materials based on size class. As the tumbling continues, smaller pieces filter through the screen, while larger pieces continue along the length of the cylinder toward the outlet (McLanahan 2016). Although trommel screens are not currently used at Alaska's small-wood products mills, they could potentially be used for future engineered chip production where volumes are greater.

Vibrating conveyor systems can be used to screen a wide variety of biomass materials, including forest residues, wood products manufacturing residuals, and urban wood waste (West Salem Machinery 2016). Perforated screens or wire mesh can be used to accurately control particle sizes. Rotary deck screens are also capable of handling a wide range of input materials and often are configured as multideck screens occupying a small footprint (BM&M 2016). Smaller wood energy systems may not be able to justify expensive mechanical screening systems. Less sophisticated screening systems could be considered, including those normally used to screen rocks. These systems are simple gravity-fed units that separate particles into two size classes based on either screens (fig. 4) or parallel bars (fig. 5).

Figures 4—Rock screen systems can be adapted for use with wood fuel (screens mounted on bars).

Figure 5—Rock screen systems with parallel bars can be adapted for use with wood fuel.

Wood fuel drying systems—

Fuel drying is important to obtain maximum value from the fuel, and most wood energy systems are designed for a specific range of moisture contents. The target moisture for "dry" fuel is often 20 percent moisture content (green basis). At this moisture content, chips should exhibit good handling properties, be free of dust, and provide good combustion behavior (including combustion efficiency). Industrial drying is often done at elevated temperatures for short periods of time, for example in rotary dryers. Other drying options could include active drum and auger dryers as well as passive stack dryers (Loria 2015). However, many small systems would not be able to justify expensive drying equipment, and therefore passive air-drying is preferred even though drying times are much longer.

Air-drying research of whole logs has been considered for several species, log diameters, and humidity conditions. Sitka spruce (*Picea sitchensis* Bong. Carriere) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) logs were dried in covered and uncovered storage in Ketchikan, Alaska (Nicholls and Brackley 2008). Logs were also found to dry more quickly when indoors (vs. outdoor conditions, exposed to rain). Perhaps the most important factor accelerating drying was the removal of bark, which led to faster drying conditions verses bark remaining. Further, western hemlock logs showed higher moisture content and greater moisture content variation (vs. Sitka spruce), and in most cases, would require more lengthy drying periods to reach a given moisture content. This study demonstrated that outdoor air drying of logs was feasible even in high-rainfall environments.

Various air-drying strategies could be adapted to southeast Alaska sites, including Haines. However, drying effectiveness would depend on a number of factors, including summertime temperatures, log diameter, whether logs are split, and initial and final moisture contents, among other variables.

Drying times can be dramatically shortened in more arid locations. For example, small-diameter ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) logs that were air dried in Hayfork, California, showed the greatest moisture loss during the first 60 days of drying (Simpson and Wang 2004). When small-diameter ponderosa pine logs were air dried during summer months, moisture content decreased from about 130 percent to about 20 percent (oven-dry basis) in only 20 days. During winter air-drying, about the same moisture loss was realized in about 4.5 months (Simpson and Wang 2004). In interior Alaska, summer-dried firewood could reach moisture contents of 20 percent in as little as 6 weeks (CCHRC 2011).

Various air-drying strategies could be adapted to southeast Alaska sites, including Haines. However, drying effectiveness would depend on a number of factors, including summertime temperatures, log diameter, whether logs are split, and initial and final moisture contents, among other variables. A log drying study is currently underway in Haines, Alaska (as of early 2017), which should provide insights for drying logs efficiently to a desired moisture content once a wood energy system is in operation there.

Chip drying—

A key advantage of locally engineered chips is that they often exhibit less moisture variation after drying than do larger conventional chips (Hein 2011). Wood chip dryers can be used to reduce moisture contents, and in southeast Alaska, this is particularly important when using high-moisture species such as western hemlock. In Craig, Alaska, a wood chip drying system has been installed at the school wood energy site to address drying high-moisture fuels (Brackley and Petersen 2016). A similar system has been installed at a Forks, Washington, (Quinalte) school, coming online in October 2010 (US DOE 2011).

Several different types of chip drying configurations are possible. Bin dryers (or batch dryers) are commonly used to dry agricultural products, and feature axial or centrifugal fans to force ambient air through the material to be dried. In another batch process, green chip piles can be dried within a custom kiln that circulates warm air until the desired wood moisture content is reached (Loria 2015). Other variations of batch drying have been adapted from agricultural grain drying. In one such system, undried material is held in a bin at the top of the unit, with hot air being forced through to provide drying. Once dried, the material is released into a chamber below, and new material added at the top of the unit for another drying cycle (AgCo 2016). Other designs feature drying continuously through a packed column (i.e., the entire cylindrical bin). Here, air is forced through from the base, creating three or more layered drying zones vertically from base to top (Hellevang 2013). Commercial batch drying systems have been developed to dry 40 tons of green chips from 50 percent down to 25 percent in about 48 hours (Froling 2016).

Continuous conveyor dryers can be used to provide a limited degree of drying quickly. For example, conveyor dryers are used as part of the BioMax15 combined heat and power system to dry wood from about 25 to 15 percent moisture content as wood is transferred from storage hopper to gasifier, using excess heat from the internal engine that is part of this system (Loria 2015).

Rotary drum dryers are capable of removing from 1,000 to 60,000 lb of water from wood each hour (Onix 2016). These dryers can single-use or multiple-pass technologies, and the heat source can be solid fuels, for example wood residues burned to dry pellet feedstocks (often referred to as closed loop drying). Belt dryers can be used to dry, cool, or roast a variety of agricultural products, including wood (Beltomatic 2016). Although most systems feature just one belt to transport material through the drying zone, a number of potential airflow configurations are possible (e.g., single pass, double pass, recycle heat, and pressurized systems). Further, individual drying modules can be staged in series or in parallel to handle special drying conditions (e.g., high, moisture, content materials).

A number of different technologies are available to dry wood fuel, varying greatly in cost, drying capacity, and moisture content control. For community energy applications in rural Alaska, an overriding factor will likely be cost. Therefore, simple drying systems (e.g., log splitting followed by air drying) could be preferred to more efficient, yet expensive, systems. Each community or village considering fuel drying will need to develop customized solutions best suited to its needs.

Local Engineered Fuel Chips—Haines, Alaska, Case Study

Wood energy system, Haines—

The community of Haines, Alaska (population 2,500), is perhaps uniquely positioned to take advantage of wood energy as a primary community heating source. Located about 60 mi north of Juneau, Haines is accessible by water (including ferry and barge service), by air, and by road from interior Alaska. Further, the city has access to extensive forest resources (including the Haines State Forest) strong community leadership and support for wood energy, and the community has been interested in wood energy issues for a number of years. The community has also acquired substantial equipment, including fuel storage and combustion system that could be used to burn pellets or other fuels such as locally engineered chips. However, as locally engineered chips would be combusted at a higher moisture content than pellets, Advanced Climate Technologies (ACT), Bioenergy burners would need to be de-rated (table 5).

One of the sites being considered is the Haines School, which could use two of the three ACT pellet boilers owned by the Haines Borough. Because the school has limited space on its property to house a wood energy installation, several neighboring sites are being considered. The Haines School occupies about 96,500 ft^2 of floor space and has used an average of 35,300 gal of fuel oil annually (Ratz 2016). The main heat demands are for domestic hot water, space heating, and for heating a swimming pool. Peak heating load is estimated to be about 3.4 million BTUs per hour. The three ACT boilers have outputs of 1.7, 1.35, and 0.5 million BTUs per hour. However, when using wood pellets at 10 percent moisture as a fuel source, each unit would be de-rated by approximately 20 percent. An estimated 22 tons of chips would be needed for one week of peak heating (Ratz 2016). Using a combination of small and large boilers would enable Haines to meet a wider range of heating needs. Further, the use of thermal storage (3,000 gal) is recommended to provide greater system availability (Ratz 2016).

As of late 2016, work has been underway to design the wood energy system in Haines, including evaluating the market price per ton of locally engineered chips, cost of heating oil versus wood fuel, and capital costs of converting to locally engineered chips (table 6). Other planning activities include designing fuel processing, handling, and storage systems as well as determining the site location.

Table 5—Rated outputs of the three boilers purchased by the borough of Haines, Alaska, for use in their wood energy system

Fuel type	Estimated moisture content	Large	Medium	Small
	Percent	*MMBTUs per hour*		
Wood pellets	8–10	1.7	1.35	0.5
Locally engineered chips	30	1.25	0.95	0.37

MMBTUs = Million British thermal unit.

Table 6—Comparison of two hypothetical scales of operation for Haines wood energy locally engineered chips utilization

	Larger scale	Smaller scale
Wood fuel volume (tons per year)	3,000	600
Fuel cost ($ per ton)	260	260
Total wood fuel cost ($ per year)	780,000	156,000
Fuel use (dry tons per hour)	2	0.4
Fuel use (cubic feet per day)	2,400	480
Bulk trailer capacity (units)	12 to 14	—
Roll off container capacity (cubic yards)	—	40
Wood dryer capacity (MMBTUs per hour)	4.5	1.0

— = Equipment not needed at this scale.
MMBTUs = Million British thermal units.

Wood fuel handling (Haines)—

For biomass energy systems, fuel handling and storage equipment are important components that must be integrated with the other equipment to ensure uninterrupted fuel flow. They must also be customized to the fuel type, fuel size, and moisture content. Three types of fuel transfer systems are being considered by Haines (Ratz 2016):

1. A rotating arm turntable can be used for either wood pellets or chips, and, in effect, sweeps wood fuel from the storage bin to an auger (which in turn feeds a metering bin). A drawback to this method is that rotating arms are effective underneath a maximum fuel depth of about 3 ft; about 2.5 tons of chips or 6 tons of pellets (Ratz 2016). So they work best with limited volumes of fuel (e.g., day storage bins) that need frequent refilling. A sweeper-turntable system would be considerably less expensive for the Haines system than either of the other two alternatives.
2. Roll-off containers are a hybrid system that could be used to unload fuel to metering bins via live bottom floors. Two or three containers could be used

at one time, ensuring that there is always at least one container at the wood energy site, while the other container(s) are being filled or in transit (Lowell et al. 2015). Roll-off bins, typically holding 10 to 15 tons of wood, are well suited for integration with chip drying systems if this additional feature were considered (Ratz 2016).

3. A large bin with travelling auger or wedge floor has been used successfully for schools in Alaska and other Western States. Here, the auger moves chips onto a conveyor belt, which then feeds the metering bin. The large storage bin provides a buffer against uncertainty in fuel delivery schedules. However the bin-auger systems can be considerably more expensive than either the turntable systems or roll-off containers. Thus, they may not be justified for smaller wood energy sites.

Wood fuel drying (Haines)—

By drying wood fuel from the green condition to about 20 percent moisture (green basis), the Haines system will realize several benefits, including greater heating values as well as more efficient and compatible operation with the wood burner system. Because conventional wood drying and predrying equipment can be very expensive, Haines is pursuing lower cost methods such as outdoor air drying of logs. The recommended procedure is to first split logs lengthwise, then stack and air dry for a period of several months before chipping to final size. Logs up to 12 inches in diameter are being considered.

Wood energy is at a critical juncture in Alaska. Over the past decade or more, nearly two dozen community-scale wood energy systems have been established.

Discussion

Wood energy is at a critical juncture in Alaska. Over the past decade or more, nearly two dozen community-scale wood energy systems have been established. The unique conditions of Alaska, including limited road systems, high fuel costs, and long transportation distances, have, in select cases, created financial incentives to use local biomass rather than import liquid fuels. However, there is limited infrastructure for harvesting, processing, and transporting biomass fuels in Alaska, meaning that bioenergy systems can also have limited economic viability. In response, the state of Alaska has provided substantial renewable energy grant funding; however, this funding source is not guaranteed for future years.

Based on these "1st generation" wood energy successes, a new "2nd generation" of installations is poised to serve even more rural Alaskan communities. However recent (2014–2016) drops in oil prices have reduced the economic incentives for wood energy. Thus new approaches are needed to overcome economic barriers, including the use of innovative wood fuel types such as engineered chips.

As the next generation of wood energy users takes hold in Alaska, a consistent theme will be the need for systems to be flexible in many aspects of operation, and customizable for local conditions.

Before locally engineered fuels can become widely adopted, important design considerations remain, including optimizing fuel handling, transportation, chip size, and moisture content. Locally engineered fuels could offer a number of significant advantages vs. other more common wood fuel types (including standard chips, cordwood, and pellets). More and more equipment manufacturers are recognizing these potential advantages, and producing custom chippers to meet these needs. For example, locally engineered chips can be used advantageously in dual fuel systems already installed in Alaska, designed for both pellets and chips. Flexible wood fuel systems can result in increased efficiency and greater use of locally produced biomass vs. systems that operate on wood fuel with more stringent size and moisture content specifications.

Several Alaska communities are well positioned to consider locally engineered chips. Numerous school energy systems are already in place, including those that heat not only school buildings, but also greenhouses for local foods production and student education. Other communities throughout Alaska have access to small-scale chippers that could be used to manufacture locally engineered chips for wood energy (even if chips are currently used for other purposes). Given the limited fuel needs of individual wood energy systems, a single chipper would likely be able to supply multiple locations, assuming that transportation logistics could be overcome to connect island communities.

As the next generation of wood energy users takes hold in Alaska, a consistent theme will be the need for systems to be flexible in many aspects of operation, and customizable for local conditions. For example, some of the key unknowns influencing all wood energy systems in Alaska include (1) the future price of oil relative to wood; (2) the volume, consistency, and form of woody biomass residues from a second growth management regime on the Tongass National Forest; (3) whether a wood pellet mill could become established in southeast Alaska, creating competitive advantages for the use of pellet fuel; and (4) future levels of state and federal funding to assist with wood energy project construction. Flexible systems capable of using a range of chip sizes, moisture content, and bark and foliage could be an asset given that rural wood supply chains often comprise one or more small operators who may not have precise control over operating conditions. Successful wood energy users in Alaska must be nimble enough to adapt to these and other future uncertainties. The result will be payoffs in the form of greater energy security, local job creation, and environmental benefits.

Metric equivalents

When you know:	Multiply by:	To get:
Inches	2.54	Centimeters
Feet (ft)	.305	Meters
Square feet (ft^2)	.0929	Square meters
Miles (mi)	1.609	Kilometers
Cubic feet (ft^3)	.0283	Cubic meters
Cubic yards (yd^3)	0.764	Cubic meters
Gallons (gal)	3.78	Liters
Tons	907	Kilograms
Pounds per cubic feet	16.02	Pascal
British thermal units (BTUs)	1,050	Joules

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Appendix

Table 7—Small industrial-scale wood energy systems in operation in Alaska (as of 2016)

Location	Fuel type	Buildings served	System type	Number of units
Craig	Chips	School and pool	Chiptec	1
Delta Junction	Chips	School	Messersmith	1
Tok	Chips	School	Messersmith	1
Tanana	Cordwood	Washeteria	Garn WHS 2000	3
Tanana	Cordwood	City buildings	Econoburn	2
Coffman Cove	Cordwood	School	Garn WHS 2000	2
Thorne Bay	Cordwood	School	GarnPak system	2
Ionia	Cordwood	Community center	Garn WHS 2000	2
Tetlin School	Cordwood	Schools	Tarm	3
Gulkana	Cordwood	Native organization	Garn WHS 2000	2
Elim	Cordwood	Water treatment plant	Garn WHS 2000	1
Fort Yukon	Cordwood	University of Alaska campus	Tarm	1
Galena	Cordwood	Interior Regional Housing Authority	Tarm Innova Solo 50	1
Kokhanok	Cordwood	Lake and Pen Borough	Garn WHS 2000	1
Ketchikan	Pellet/chip	Forest Service Discovery Center	Hurst	1
Ketchikan	Pellet	General Services Adminisration Federal Building	ACT Bioenergy	1
Ketchikan	Pellet	Public Library	ACT Bioenergy	1
Juneau	Pellet	Sealaska Corp.	KÖB	1
Gulkana	Pellet	Gulkana Village Council	Tarm	1
Haines	Pellet	Senior center	Okafen	1
Haines	Pellet	Chilkoot Indian Association	Pellergy	2
Juneau	Pellet	Tlingit-Haida Regional Housing Authority	Maine Energy Systems	1
Juneau	Pellet	Sobeloff Cultural Center	Maine Energy Systems	2
Sitka	Pellet	Forest Service-Sitka Ranger District	Froling	1

WHS = Wood Heating Systems, ACT = Advanced Climate Technologies.

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