USDA

United States Department of Agriculture

Economic and Environmental Benefits of Community-Scale Cordwood Hydronic Heaters in Alaska—Three Case Studies

David L. Nicholls, Allen M. Brackley, and Daniel J. Parrent

Forest Service

Pacific Northwest Research Station

General Technical Report PNW-GTR-924

December 2015

Authors

David L. Nicholls is a forest products technologist and **Allen M. Brackley** is a research forester, Pacific Northwest Research Station, Alaska Wood Utilization and Development Center, 204 Siginaka Way, Sitka, AK 99835. **Daniel J. Parrent** is a program manager, Biomass Utilization and Forest Stewardship, State and Private Forestry, Alaska Region, 161 East 1st Avenue, Door 8, Anchorage, AK 99501.

Cover photos: Combustion chamber and cordwood system, by Jonathan Fitzpatrick; small-diameter cordwood in storage shed, by David Nicholls.

Abstract

Nicholls, David L.; Brackley, Allen M.; Parrent, Daniel J. 2015. Economic and environmental benefits of community-scale cordwood hydronic heaters in Alaska—three case studies. Gen. Tech. Rep. PNW-GTR-924. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

Over the past decade, the use of wood for thermal energy in Alaska has grown significantly. Since 2000, nearly 30 new thermal wood-energy installations in Alaska have been established. Cordwood units, burning primarily firewood and other forms of roundwood, have played an integral part in this success and are well suited to many rural communities in Alaska. In this case study, we evaluate cordwood installations located in three geographic regions of Alaska. Included are systems at Coffman Cove (southeast Alaska), Ionia (Kenai Peninsula, Alaska), and Gulkana (south-central Alaska).

We considered the wood-energy conversion process, system operation, economics, and carbon benefits of the three cordwood systems. We found that the simple payback period ranged from 1.1 to 14.2 years and the internal rate of return from 8 to 91 percent, and that benefits exceeded costs by a factor of from 1.6 to 17. There were also substantial carbon benefits for cordwood systems. Carbon dioxide (CO_2) emissions (relative to those from heating oil) differed by installation from 129 to 259 tons avoided per year, with total reductions of 611 tons of CO_2 per year. We also considered secondary benefits of community-scale cordwood energy systems in rural Alaska, including greenhouses for local foods, the ability to create part-time jobs for local residents, and the educational experiences for school students.

Keywords: Wood energy, cordwood, rural energy, net present value, CO_2 emissions.

Contents

Introduction

Over the past decade, the use of wood for thermal energy in Alaska has grown significantly. Confronted by high fuel costs, many rural communities have committed to the use of wood energy to displace fossil-fuel use. Since 2000, nearly 30 new wood-energy systems have been installed in Alaska at schools, government buildings, and other community facilities. Several of these are cordwood systems (table 1). Important drivers spurring this growth have included construction funding by the Alaska Energy Authority (AEA) through the State of Alaska Renewable Energy Fund program, technical assistance by numerous partners and government agencies, and more than 150 prefeasibility studies. These have been supported by the Alaska Wood Energy Development Task Group, AEA, Alaska Village Initiatives, National Renewable Energy Laboratory, and the Tanana Chiefs Conference, among others. All of the wood-energy systems so far are thermal-energy systems. All provide heat to schools and community buildings.

Since 2000, nearly 30 new wood energy systems have been installed in Alaska, including schools, government buildings, and other community facilities.

Cordwood energy systems—in contrast to wood chip or pellet systems—have played an integral role in pioneering Alaska's wood-energy growth. Cordwood systems are relatively "low tech," inexpensive systems that are robust and easy to operate, and which can provide community employment benefits for system operation and wood harvesting. They can also be used on a modular basis, with individual burners added as needed. Cordwood systems are often the most practical technology in very remote locations owing to the ready availability of wood and minimal processing requirements. In Alaska, this would include most locations south of the Brooks Range that are capable of growing trees large enough to be

Table 1—Cordwood energy systems in Alaska as of May 2015[a]

Location	Host site	Startup date	Number of burners	System type
Coffman Cove	Howard Valentine Coffman Cove School	2010	2	GARN system
Elim	Elim Water Plant	2012	1	GARNpak system
Fort Yukon	University of Alaska Fairbanks		1	Tarm system
Gulkana	Gulkana Village Council	2012	2	GARN cordwood, Tarm pellet
Galena	Galena Senior Center		3	Tarm Innova Solo system
Ionia	Ionia, Inc.	2008	2	GARN system
Kasaan	Kasaan School	2014	1	GARN system
Kokhanok	Lake and Pen Borough		1	GARN system
Tanana	Tanana washeteria	2007	3	GARN/Econoburn systems
Tetlin	Tetlin School		1	Tarm Innova Solo system
Thorne Bay	Thorne Bay School	2012	2	GARNpak cordwood system
Yakutat	Tlingit-Haida Regional Housing Authority		1	WoodMaster/Woodgun

[a] Includes systems in-operation or under construction; does not include proposed systems.

harvested for cordwood. Another important factor that varies widely throughout Alaska is precipitation. For example, in our study area, annual precipitation ranges from about 100 inches in Coffman Cove to about 11 inches in Gulkana.

In many parts of rural Alaska, cordwood energy not only makes the most economic sense, but also returns the most benefits to the community.

In this report, we consider the wood-energy conversion process, system operation, economics, and carbon benefits of three community-scale cordwood systems across three Alaska regions. In many parts of rural Alaska, cordwood energy not only makes the most economic sense, but also returns the most benefits to the community. Some examples of benefits include greenhouses for local foods; local employment in wood harvesting, transportation, and use; and educational benefits to students in schools, which frequently are users of wood-energy systems.

Specific objectives of this report include conducting an economic analysis of all three cordwood systems and providing the context and background needed for future wood-energy users in Alaska to make informed decisions. Finally, we hope to demonstrate how cordwood energy can successfully meet community heating needs across Alaska, even when tree species, climate, and local operating conditions differ widely.

Cordwood Use in Thermal Energy Systems—Small Industrial Scale

The terms cordwood, roundwood, and firewood are often used interchangeably. One cord of wood is defined as a stack of wood, well ranked and stowed, 4- by 4- by 8-ft, including bark and air space. Depending on wood size, straightness, soundness, and other factors, the actual amount of fuel in a cord of wood varies between 80 and 100 ft^3. A cord of softwood or hardwood grown in Alaska typically weighs between 4,300 and 5,000 lbs. green weight depending on the species (Miles and Smith 2009, Wilson et al. 2010). The use of cordwood energy in small industrial-scale systems, such as those discussed in this report, is similar to the residential use of firewood. It begins with the harvesting of roundwood, followed by splitting, drying, storage, and finally combustion. Whereas a typical home may burn 5 to 8 cords of wood per heating season, larger community heating systems in Alaska may burn more than 50 cords a year, depending on their size and heating needs. If scaling is necessary, then volume measurements using standard scaling equipment is the most efficient method. Typically, a ton of dry wood has the same energy content as about 120 gal of fuel oil (Woodpellets.com 2015).

Wood-Energy Project Development

A typical wood-energy system (whether cordwood, chips, or pellets) generally includes the following planning steps:

1. Preliminary economic feasibility study and conceptual design
2. Phased, detailed design
3. Biomass resource assessment
4. Wood fuel type
5. Financing/funding
6. Permitting (where necessary) and construction
7. Commissioning and operation
8. Project evaluation and feedback

Underlying all these steps is the need for strong community support and a "project champion." In many ways, this support is the most important element for cordwood systems (compared to chip or pellet systems), owing to the greater labor requirements for wood harvesting, processing, and transporting, and the potential to create new employment.

System Design and Operation

In this report, cordwood systems are defined as being larger than residential scale but using similar wood-fuel sources. At this scale, cordwood systems are among the simplest wood-energy systems to construct and operate, in part because of the need for manual labor during all aspects of operation. Most cordwood systems use thermal storage to make heat available several hours after combustion. Thermal storage can be in the form either of a water jacket surrounding the combustion chamber or an external tank separate from the main burner. Some designs feature large thermal storage jackets (with capacities of between 1,000 and 4,000 gal) while other designs are more compact, with considerably less water storage.

The basic process is similar for all cordwood systems. First, cordwood must be sized to fit the firebox. Typically, wood will be cut 2 to 4 inches shorter than the length of the firebox, with pieces greater than about 8 inches in diameter being split lengthwise. Then the operator "stokes" (i.e., manually loads) the firebox with wood (fig. 1). The labor needed to stoke the combustion chamber can, in some cases, be a limiting factor for cordwood use. Because manual handling of wood fuel can be a constraint for larger systems, a recommended maximum system size is 750,000 British thermal units (Btus) per hour (Biomass Energy Resource Center 2015).

As wood combusts, heat is transferred to a working fluid (often water or glycol) and then to an end use, often via a heat exchanger. Routine maintenance includes manual ash removal and cleaning the boiler firetubes. High-efficiency combustion is aided by fans (either forced air or induced draft fans), which reduce the production of smoke and particulates. In this respect, it is important to distinguish between high-efficiency cordwood burners and low-efficiency firewood units, a topic of

Jonathan Fitzpatrick

Figure 1—Many cordwood systems are designed to burn wood in an intense flame, quickly transferring heat to a water jacket surrounding the burn chamber. Note that in normal operation the door to the combustion chamber would be closed.

much attention in recent years. The distinction between high- and low-efficiency cordwood burners has been particularly important in municipalities that have air-quality problems, such as Fairbanks, Alaska.

One of the key operating decisions is whether to construct a modular system that has more than one cordwood burner, versus a single cordwood burner. An advantage of having more than one burner is the ability to heat with all units during periods of peak demand while using fewer burners during the fall and spring "shoulder" seasons. This can be important in Alaska, where shoulder seasons may still experience very cold weather. Cordwood burners may also be used to heat numerous buildings via a district heating loop, as in Gulkana, Alaska (see "Case 3" on p. 13). For single cordwood burners, scales of operation are generally limited to about 100 cords of wood per year, the equivalent of about twice the wood used at Coffman Cove (see "Case 1" below). The labor requirements to manually handle

100 cords of wood per year could also be a limiting factor in some communities. Lastly, some communities might be limited in the amount of wood that they could sustainably provide from nearby forested areas, resulting in the use of fewer than 100 cords per year.

Note that commercial cordwood hydronic heaters are not just scaled-up wood stoves like those typically found in residential applications. Commercial systems usually have induced draft fans and large thermal storage capacity. The pairing of a "hot and fast" wood-burning period followed by several hours of thermal storage is critical for efficient cordwood use.

Case 1—Southeast Alaska (Coffman Cove)

System Overview

The Southeast Island School District (SISD), on Prince of Wales Island in southeast Alaska, oversees the operation of 10 rural schools. In 2010, the district's Howard Valentine School in Coffman Cove installed two GARN[1] units (Dectra Corporation 2015), making it the first user of a cordwood system on Prince of Wales Island. The school has recently completed its fourth heating season.

In 2012, SISD installed two prototype "GARNpak" hydronic heaters at Thorne Bay School in Thorne Bay, and in 2014 the district installed one GARN unit at Barry C. Stewart Kasaan School in Kasaan (Fitzpatrick 2015). GARN systems use a two-stage gasification process and are unpressurized. Therefore, they cannot be connected directly to a pressurized system without a heat exchanger (Ehrlich 2015). For the remainder of this case study, we focus on the Coffman Cove cordwood system.

Coffman Cove was motivated to pursue cordwood energy by several factors, including high fuel costs and an abundance of local wood wastes and forest harvesting residues.

Coffman Cove was motivated to pursue cordwood energy by several factors, including high fuel costs and an abundance of local wood wastes and forest harvesting residues. Between 2010 and 2014, wood usage in the Coffman Cove system has ranged from 30 to 55 cords per year, with recent usage of 52 cords in a single heating season (Fitzpatrick 2015). Their cordwood burner typically operates from September through June and provides heat to the school (9,480 ft^2) as well as to its domestic hot water system. In the near future, the cordwood system will also provide heat for a greenhouse (6,000 ft^2) and a teacher housing facility (4,000 ft^2). As with most cordwood systems, fuel is hand fed into the boilers daily. At the peak of the winter heating season, the boiler needs to be "stoked" up to six times a day, while on warmer days during spring and fall only two or three times per day. The system is typically not used during summer months.

[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.

The Coffman Cove wood-energy system includes two GARN WHS-2000 cordwood burners. An integrated hydronic tank stores thermal energy from a fast wood burn, which is then available over a period of several hours before the need to re-stoke the combustion chamber.

Each of Coffman Cove's two GARN boilers has a rated output of about 325,000 Btus per hour. Additional energy requirements include a 1-HP circulation pump. Their wood supply is stored in a covered building with a capacity of about 150 cords. Heat is distributed via underground piping (fig. 2) from the GARN units to the school, a distance of less than 150 ft. Coffman Cove's initial system cost was close to $424,000, which included all engineering and design work. Their ongoing maintenance (which includes parts and minor repairs) is only about $500 per year.

Jonathan Fitzpatrick

Figure 2—Cross section of insulated piping for water distribution, showing layered construction and supply and return pipes, normally buried underground.

The economic benefits to communities on Prince of Wales Island are notable. About 10 to 15 part-time jobs have been created, with individuals supplying firewood, typically one cord at a time.

Cordwood resources are accessible in most Alaskan communities and have the added benefit of increasing employment, not only through cordwood collection, but also wood splitting and stoking. Coffman Cove's system burns western hemlock (60 percent of total), Sitka spruce (30 percent of total), and Alaska yellow-cedar or red alder (10 percent of total). Firewood is procured from local individuals as well as one small business devoted to firewood production. The economic benefits to communities on Prince of Wales Island are notable. About 10 to 15 part-time jobs have been created, with individuals supplying firewood, typically one cord at a time. Other community benefits include students raising money for sports and academic travel by stacking firewood. An additional benefit is that the boiler room provides heat to community members for tanning hides and for hatching chicken eggs in incubators (fig. 3).

Jonathan Fitzpatrick

Figure 3—Construction completed for cordwood system in Coffman Cove, Alaska.

The Coffman Cove system managers are well aware of the need to dry their cordwood before burning. They have constructed a separate fuel storage building (fig. 4), where they split, stack, and dry the wood for up to 12 months, allowing it to reach 15 to 20 percent moisture content. Four-feet-in-diameter fans accelerate airflow through the covered storage building. Finally, smaller parcels of wood are placed in the boiler room for additional drying just before burning.

Jonathan Fitzpatrick

Figure 4—Covered cordwood storage in Coffman Cove, Alaska.

Cordwood Drying in Southeast Alaska

In southeast Alaska, wood drying can require careful attention whether the end use is wood energy or solid wood products such as lumber. Wood-energy applications are especially sensitive to how well the fuel has been dried, because the amount of usable British thermal units (Btus) are directly related to moisture content. For example, while oven-dry wood has a heating value of about 8,600 Btus per lb, the same quantity of wood at 20-percent moisture content green basis will provide only 7,100 Btus per lb. (Stelzer 2015). In southeast Alaska, the need for effective air drying is especially important, because the most prevalent wood here (western hemlock) has a very high green moisture content of up to 63 percent for sapwood, and an overall moisture content of close to 50 percent (USDA FS 1999). The differences in gross heating value between fresh-cut wood and properly dried wood can be substantial—in some cases close to 8 million Btus per cord (table 2).

Table 2—Cordwood properties of select Alaskan species, at time of harvest

Species	Average green weight	Gross heating value, green condition	Gross heating value, 20-percent moisture content
	Pounds per cubic foot	*BTUs per cord*	*BTUs per cord*
Sitka spruce	34.67	10,600,084	16,960,134
Western hemlock	39.4	12,778,120	20,444,992
Alaska yellow-cedar	39.38	14,327,853	22,924,565
Red alder	34.68	10,596,997	16,955,195
White spruce	34.67	11,633,919	18,614,271
Black spruce	35.65	11,350,678	18,161,085

Source: Simpson (1991) and Wilson et al. (2010).

In almost all cordwood energy applications, wood moisture should be reduced to about 20 percent moisture content green basis before burning. In practice, this is usually done by air drying, either outdoors or in a covered structure, or fan-aided drying in a shed. One leading manufacturer of cordwood burners recommends air-drying cordwood for a full year to reach a target of 18- to 28-percent moisture content. They also recommend splitting wood 8 to 12 inches in diameter into halves, and wood larger than 12 inches into quarters (Dectra Corporation 2013).

Simpson (1998) reported that 3 or 4 months of drying in well-ventilated and covered storage areas in southeast Alaska produce wood with 17 to 19 percent moisture content dry basis. In southeast Alaska, equilibrium moisture contents typically range between 15 and 20 percent (table 3). In other words, no amount of air drying at ambient temperatures can reduce wood moisture to less than about 15 percent, even after months of air drying at ambient temperatures. Empirical studies conducted in southeast Alaska evaluated Sitka spruce and western hemlock logs harvested in southeast Alaska. For logs that were peeled of bark and stored indoors, moisture contents between 20- and 30-percent oven-dry basis were possible after 12 months (Nicholls and Brackley 2010).

Specific cordwood drying practices to enhance air-drying include:

- Covered storage (shed, pole barn, or similar structure).
- Covered storage with fans to increase airflow through wood.
- Wood splitting prior to drying (for larger stems).
- Drying a limited amount of wood in a small hopper near the combustion unit (fig. 5).
- Drying cordwood in a fully functioning dry kiln (often used to dry lumber).
- Cutting wood to uniform lengths to fit fireboxes—split to promote drying from the longitudinal surface.
- Covered storage (shed, pole barn, or similar structure) with racks that allow spacing between the piles. Keep wood shielded from rain and snow, but do not wrap with plastic or tarps (which could impede air circulation).

Table 3—Equilibrium moisture content for Juneau, and Ketchikan, Alaska, by month of year

Month	Juneau	Ketchikan
January	16.5	22.5
February	16.0	21.0
March	15.1	20.8
April	13.9	19.7
May	13.6	17.2
June	13.9	17.6
July	15.1	18.3
August	16.5	19.8
September	18.1	22.1
October	18.0	21.9
November	17.7	18.3
December	18.1	22.0

Source: Simpson 1998 (Juneau data); https://weather-warehouse.com/ (Ketchikan data).

Jonathan Fitzpatrick

Figure 5—Fuel storage and loading area, Coffman Cove, Alaska. The final stages of wood drying take place in this room.

Coffman Cove, Alaska, Wood-Energy Economics

RETScreen® software (RETScreen International 2015) was used to evaluate the economic benefits associated with wood energy (compared to heating oil). The primary RETScreen inputs are summarized in table 4. Net present value varied from $236,895 to $647,381, depending on the assumed heating oil cost (table 5). Similarly, the internal rate of return varied from 8.1 to 13.8 percent. Simple payback (in terms of years to first positive cashflow) ranged from 8.7 to 14.2 years, and the benefits exceeded costs by a factor of from 1.56 to 2.53. The base case for heating oil costs was $4.00 per gallon. Note that for all three locations we assumed a fuel cost escalation rate of 2 percent annually, an inflation rate of 3 percent, and a discount rate of 4 percent (table 4).

Table 4—RETScreen® inputs for wood-energy economic analysis of three cordwood systems in Alaska

		Location		
Input	**Units**	**Coffman Cove**	**Ionia**	**Gulkana**
Building structure		1 building (school)	1 building (longhouse)	9 community buildings
Process water?	Yes/no	Yes	Yes	No
Cordwood burners		2 GARNs[a]	2 GARNs	2 GARNs
Heated area	Square feet	9,800	12,000	12,000
Domestic hot water demand	Percentage of total	15	15	0
Heating load	BTUs per square feet per hour	40	55	70
Base case system	Fuel type	Heating oil #6	Heating oil #6	Heating oil #6
Base case — fuel cost	Dollars per gallon	4.00	4.50	5.00
Base case — efficiency	Percent	85	85	85
Wood fuel cost	Dollars per ton	80	50	125
Wood fuel type		Waste wood/ mixed softwood	Waste wood/ mixed softwood	Waste wood/ mixed softwood
Total initial costs[b]	Dollars	424,000	115,000	898,000
Peak load system		Not required	Not required	Not required
Operation and maintenance costs	Dollars per year	600	1,200	800
Salvage value	Dollars	0	10,000	10,000
Project life	Years	25	25	25
System efficiency (wood energy)	Percent	75	75	75
Fuel cost escalation rate	Percent	2.0	2.0	2.0
Inflation rate	Percent	3.0	3.0	3.0
Discount rate	Percent	4.0	4.0	4.0

[a] Dectra Corporation (2013).
[b] Includes cost of feasibility studies, engineering, design, buildings, piping, and wood energy system.

Table 5—Economic results for Coffman Cove, Ionia, and Gulkana Village cordwood energy systems

		Fuel oil cost (heating oil #6)								
		Coffman Cove Schools			Ionia Community			Gulkana Community		
Result	Units	Low[a] ($3.20/gal)	Mid[b] ($4.00/gal)	High[c] ($4.80/gal)	Low[a] ($3.60/gal)	Mid[b] ($4.50/gal)	High[c] ($5.40/gal)	Low[a] ($4.00/gal)	Mid[b] ($5.00/gal)	High[c] ($6.00/gal)
Pre-tax internal rate of return	Percent	8.1	11.1	13.8	58.9	74.9	90.8	9.1	12.5	15.6
Simple payback period	Years	14.2	10.8	8.7	1.8	1.4	1.1	12.8	9.6	7.7
Equity payback period	Years	11.7	9.3	7.7	1.7	1.4	1.1	10.7	8.4	6.9
Net present value	Dollars	236,895	442,138	647,381	1,136,501	1,489,607	1,842,713	640,866	1,152,227	1,663,587
Annual life-cycle savings	Dollars per year	15,164	28,302	41,440	72,750	95,353	117,956	41,023	73,756	106,489
Benefit to cost ratio		1.56	2.04	2.53	10.87	13.94	17.01	1.71	2.28	2.85
Carbon dioxide emissions savings (vs. heating oil)	Tons per year	129.3	129.3	129.3	222.8	222.8	222.8	258.6	258.6	258.6

[a] Average fuel cost minus 20 percent.
[b] Average fuel cost (current April 2015).
[c] Average fuel cost plus 20 percent.

Coffman Cove, Alaska, Carbon Benefits

RETScreen software was also used to evaluate the carbon benefits associated with wood energy (versus heating oil). The Coffman Cove system had a carbon benefit of 129.3 tons of CO_2 avoided, compared to a conventional fuel oil system providing the same heating load (table 5).

Case 2—South-Central Alaska (Ionia Community)

System Overview

Ionia is a residential mental health treatment center located on the Kenai Peninsula in Kasilof, Alaska. The center installed two separate wood-fired hot water boiler systems in 2008. This wood energy system results in energy savings of about $1,000 per month in terms of propane cost avoided and about $150 per month of fuel oil savings. Projected annual energy savings are 1,500 gal of fuel oil and 8,200 gal of propane (WFLC 2008). Several buildings are connected to the wood-energy system with 120 ft of super-insulated pipe that has been buried to a depth of 10 ft.

During winter months, both cordwood units are typically in operation, with single units used during the shoulder seasons. During the 2015 heating season, about 200 lbs of wood per day typically were burned (about half a cord per week). However, on the coldest days, up to 300 lbs can be burned. Ionia can also vary its fuel use by firing the burners at either a "high dose" or "low dose." A typical firing pattern would be to start with a normal "dosage" of about 100 lbs of wood in each burner (with doses of about 100 lbs 1 to 2 hours later) (Eller 2015). An advantage of operating only one burner is that only 2,000 gal of water need to be heated (versus 4,000 gal when operating both burners).

The Ionia community practices good stewardship by planting about 1,000 trees per year (primarily lodgepole pine and western larch) for wood energy and other forest products. As of 2015, they have planted close to 5,000 trees, which are expected to be ready for cordwood burning within about 20 years.

Ionia Community Wood-Energy Economics

RETScreen software was used to evaluate the economic benefits associated with wood energy (versus heating oil). The primary RETScreen inputs are summarized in table 4. Net present value ranged from $1,136,501 to $1,842,713, depending on the assumed heating oil cost (table 5). Similarly internal rate of return ranged from 58.9 to 90.8 percent. Simple payback period (in terms of years to first positive cash flow) ranged from 1.1 to 1.8 years, and the benefits exceeded costs by a factor of from 10.87 to 17.01.

Lonia had by far the most attractive economics of any of the three cordwood facilities, primarily because of its low cost of wood (much of it harvested locally) as well as essentially free labor to load cordwood.

Ionia had by far the most attractive economics of any of the three cordwood facilities. This was primarily because of their low cost of wood (much of it being harvested locally) as well as essentially free labor to load cordwood. Their relatively low system cost ($115,000) also was instrumental in the high benefit-to-cost ratios. The base case for heating oil costs was $4.50 per gallon. Because of a bark beetle infestation in the early 2000s, Ionia has been able to benefit from a ready supply of low-cost and low-moisture-content wood.

Ionia Community Carbon Benefits

RETScreen software was used to evaluate the carbon benefits associated with wood energy (versus heating oil). The Ionia system had a carbon benefit of 223 tons of CO_2 avoided annually, compared to a conventional fuel-oil system providing the same heating load (table 5).

Case 3—South-Central Alaska (Gulkana Village)

System Overview

Gulkana Village is an Alaska Native community (population 143) located in Gulkana, Alaska, about 14 mi north of Glenallen, Alaska. In 2010, Gulkana Village received a $500,000 grant from the State of Alaska's Renewable Energy Fund to install two cordwood boilers that went into service later that year, providing heat for nine community buildings. The system has used 43 cords of wood per year (Anon. 2012). The total project cost was $898,000.

In Gulkana Village, the cordwood production (a process that includes harvest, splitting, and drying) provides important employment benefits. Further, Gulkana is located within a fire-prone forest region and much of the community's wood fuel needs are provided by wildfire prevention and mitigation measures. Gulkana Village has two GARN cordwood systems (model WHS-2000 hydronic boilers) located side by side, allowing them to be coordinated for use during shoulder seasons and also during mid-winter (fig. 6). Each burner is rated at 325,000 Btus per hour, burning cordwood harvested from local lands.

Gulkana is located within a fire-prone forest region and much of the community's wood fuel is provided by wildfire prevention and mitigation measures.

David Nicholls

Figure 6—Front view of modular cordwood energy system, showing two independent units side by side (Gulkana Village Council, Gulkana, Alaska). Note that during normal operation the doors would be closed.

Figure 7—Aerial view of Gulkana Village, showing site of cordwood system and building heated (the distance between 2nd and 3rd St. is approximately 200 feet). Source: Google Maps®.

Gulkana also installed a pellet boiler to supplement the community's cordwood system. And, as of early 2014, a small pellet manufacturing system is under construction. Using locally harvested wood, the community soon expects to have the option of producing their own pellets, burning cordwood, or combinations of both. Gulkana Village uses a district heating system to heat nine community buildings that include four duplexes, a teen recreation center, a community hall with administrative offices, a fitness center, a maintenance shop, new offices, a community clinic, and a new bus garage (ACEP, n.d.) (fig. 7). The four duplexes are owned by the Copper River Housing Authority, which purchases heat from Gulkana Village.

During the system start-up in October and November 2010, the two boilers burned about 25 cords of wood, primarily white spruce (*Picea glauca*). A total of 2,963 gal of heating oil were displaced for a savings of $10,933 (ACEP, n.d.). The Gulkana wood-energy system is located in interior Alaska, where winter temperatures can sometimes reach -50 °F. Therefore, proper sizing of the combustion equipment and a reliable wood fuel supply are critical elements. Most of the cordwood

The Gulkana wood-energy system is located in interior Alaska, where winter temperatures can sometimes reach -50 °F. Therefore, proper sizing of the combustion equipment and a reliable wood fuel supply are critical elements.

is stored in a covered building, and is still in round form (fig. 8). Further, reliable pumps and circulation equipment are important (as water will quickly freeze at these temperatures).

Gulkana Village Wood-Energy Economics

RETScreen software was used to evaluate the economic benefits associated with wood energy (versus heating oil). The primary RETScreen inputs are summarized in table 4. Net present value ranged from $640,866 to $1,663,587, depending on the assumed heating oil cost (table 5). Similarly, the internal rate of return ranged from 9.1 to 15.6 percent. Simple payback period (in terms of years to first positive cash flow) ranged from 7.7 to 12.8 years, and benefits exceeded costs by a factor of from 1.71 to 2.85. The base case for heating oil costs was $5.00 per gallon.

The Gulkana project economics were comparable to that of the Coffman Cove system. Despite having a considerably higher initial cost, the Gulkana system displaces more expensive heating oil, in addition to heating a greater number of buildings. Together, these factors offset the high initial capital cost.

David Nicholls

Figure 8—Small-diameter cordwood in storage shed (Gulkana, Alaska).

Gulkana Village Carbon Benefits

RETScreen software was used to evaluate the carbon benefits associated with wood energy (versus heating oil). The Gulkana system had a carbon benefit of 259 tons of CO_2 avoided annually, compared to a conventional fuel-oil system with the same heating load (table 5).

Discussion: Cordwood Energy Systems in Alaska

Cordwood energy has proven viable for community heating in rural Alaska, with 12 systems established as of 2015, including those that were operational or under construction. There are cordwood burners in all regions of Alaska (interior, south-central, and southeast), with wood sources that include most major forest types. They are simple in design and generally appropriate for smaller facilities (i.e, facilities that use less than 10,000 gal of fuel oil annually). In many cases, more than one cordwood burner is housed at a given site because they can be installed together to meet even larger thermal energy loads. Most cordwood systems operate on the principle of storing combustion energy in a thermal water jacket that ranges in volume from a few hundred to several thousand gallons. Cordwood systems can heat multiple buildings via simple district heating loops, usually buried underground. This way, multiple uses can be accommodated—for example, heating a school, greenhouse, and teacher housing with a single system.

Cordwood burners can represent an ideal option for small remote villages, and in some aspects, they resemble residential cordwood systems. The fuelwood harvesting and delivery can be combined with residential firewood programs, offering synergies and opportunities for cooperation. Cordwood systems can be well suited to communities with no forest products infrastructure (i.e., no local sawmill), but with a well-developed network of residential users. In practice, simple procedures can aid successful operation, including splitting firewood to appropriate sizes for the burner and drying to recommended moisture levels before burning. Cordwood burners can supplement an existing residential firewood industry while creating additional employment.

New innovations are enabling use of cordwood systems in even the remotest Alaskan communities and villages. For example, the "GARNpak" design consists of modular, self-contained construction that is easily shipped to and installed in remote locations.

New innovations are enabling use of cordwood systems in even the remotest Alaskan communities and villages. For example, the "GARNpak" design consists of modular, self-contained construction that is easily transported to remote locations and is easy to install. As the name suggests, this product comes as a complete package that includes primary pump, heat exchanger, piping, controls, and electrical connections (with some components being pre-piped and pre-wired) (Alaska Energy Associates 2012). After a concrete slab is ready, the "GARNpak" can be lowered in place with a lift truck, and final connections completed usually in 1 to 2 days.

Perhaps the greatest benefit to rural Alaskan communities is the employment benefits that relatively "low-tech" cordwood systems can bring. Cordwood systems seem to thrive where there is a strong village or community structure. In remote areas where forest resources are marginal or in high-latitude locations, it is important to complete a comprehensive resource analysis to ensure that cordwood supplies are sustainable.

Conclusions

Cordwood-energy systems can be an ideal way for rural communities in Alaska to realize energy independence while establishing relatively simple energy systems. Wood-energy conversion, operation, project economics, local employment, and carbon benefits are all integral aspects of cordwood systems. Cordwood systems are economically feasible in most forested regions in Alaska ranging from southeast Alaska to interior Alaska (including some locations north of the Arctic Circle). Cordwood systems work well for a variety of species; however, key practices such as splitting large sections of wood and sufficient drying are important practices sometimes overlooked. Significant carbon savings are possible when cordwood is substituted for fossil fuels such as heating oil, such as in the three systems described in this report. Broader implications can be drawn beyond these three systems because nearly a dozen cordwood systems are now in operation in Alaska. The findings from this report are even more significant when one considers that 20 wood-energy systems are now in operation in Alaska, and many of these are larger than the cordwood systems described in this report (likely having greater economic and carbon benefits). Lastly, energy self-sufficiency, local economic benefits, and educational benefits are often important byproducts of cordwood energy systems, as demonstrated by these case studies.

Tree Species Identified in This Report

Common name	Scientific name
Alaska yellow-cedar	*Callitropsis nootkatensis* (D. Don) Oerst. ex D.P. Little
Black spruce	*Picea mariana* (Mill.) Britton, Sterns & Poggenb.
Red alder	*Alnus rubra* Bong.
Sitka spruce	*Picea sitchensis* (Bong.) Carrière
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
White spruce	*Picea glauca* (Moench) Voss

Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Feet (ft)	0.3048	Meters
Miles (mi)	1.609	Kilometers
Square feet (ft^2)	0.0929	Square meters
Cubic feet (ft^3)	28.3	Liters
Pounds (lb)	.454	Kilograms
Tons (ton)	.907	Tonnes or megagrams
Gallon (gal)	.378	Liters
British thermal units (Btu)	.000948	Joules
Degrees Fahrenheit	.56 (°F) - 32	Degrees Celsius

References

Anon. 2012. Gulkana community energy plan. http://www.coppervalley.org/sites/default/files/Gulkana%20Community%20Energy%20Plan%20Draft%202.pdf. (27 April 2015).

Alaska Center for Energy and Power [ACEP]. [N.d.]. Gulkana biomass. http://energy-alaska.com/gulkana-biomass. (28 April 2015).

Alaska Energy Associates. 2012. Venetie Village Council—level two biomass feasibility study. 37 p. http://www.akenergyauthority.org/Content/Programs/AEEE/Biomass/Documents/PDF/Venetie2012.pdf. (19 August 2015).

Biomass Energy Resource Center. 2015. Heating systems—cordwood. http://www.biomasscenter.org/what-we-do/our-expertise/heating-systems-cordwood. (15 July 2015).

Bruce, D.B.; Schumacher, F.X. 1950. Forest mensuration. 3rd ed. New York: McGraw-Hill. 483 p.

Dectra Corporation. 2013. GARN®WHS 1000/1500/2000 owner's manual. http://www.garn.com/garn-whs-manuals/. (27 April 2015).

Dectra Corporation. 2015. GARN wood heating systems. http://www.garn.com/. (18 August 2015).

Ehrlich, B. 2015. GARN wood-fired hydronic heaters. http://greenspec.buildinggreen.com/product/garn-wood-fired-hydronic-heaters/dectra-corporation/9727. (27 April 2015).

Eller, T. 2015. Personal communication. Project manager, Ionia, Inc. 54932 Burdock Road, Kasilof, AK 99610.

Fitzpatrick, J. 2013. Biomass: technology update—Thorne Bay and Coffman Cove Schools GarnPac and cordwood systems. http://www.akruralenergy.org/2013/2013_REC_Thorne%20Bay%20School%20GarnPac%20and%20Cordwood%20Systems_Jonathan%20Fitzpatrick.pdf. (27 April 2015).

Fitzpatrick, J. 2015. Personal communication. Project manager, Southeast Island School District, P.O. Box 19569; 1010 Sandy Beach Rd., Thorne Bay, AK 99919.

Fonseca, M.A. 2005. The measurement of roundwood—methodologies and conversion ratios. Trowbridge, United Kingdom: CABI Publishing. 269 p.

Husch, B.; Miller, C.I.; Beers, T.W. 1982. Forest mensuration. 3rd ed. New York: John Wiley & Sons. 402 p.

Miles, P.D.; Smith, W.B. 2009. Specific gravity and other properties of wood and bark for 156 tree species found in North America. Res. Note NRS-38. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 35 p.

Miles, T.R. 2006. Feasibility assessment for wood heating—final report. 81 p. http://www.jedc.org/forms/AWEDTG_WoodEnergyFeasibility.pdf. (27 April 2015).

Nicholls, D.L.; Brackley, A.M.; Barber, V. 2010. Wood energy for residential heating in Alaska: current conditions, attitudes, and expected use. Gen. Tech. Rep. PNW-GTR-826. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 30 p.

RETScreen International. 2015. Software suite. Ottawa, Ontario, Canada: Natural Resources Canada. http://www.retscreen.net/ang/home.php. (27 April 2015).

Simpson, W.T., ed. 1991. Dry kiln operator's manual. Agric. Handb. 188. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 274 p.

Simpson, W.T. 1998. Equilibrium moisture content of wood in outdoor locations in the United States and worldwide. Res. Note FPL-RN-0268. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 11 p.

Stelzer, H.E. 2015. Wood fuel for heating. Columbia, MO: University of Missouri Extension. 6 p. http://extension.missouri.edu/p/g5450. (27 April 2015).

U.S. Department of Agriculture, Forest Service [USDA FS]. 1999. Wood handbook—wood as an engineering material. Gen. Tech. Rep. FPL-GTR-113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 463 p.

Western Forestry Leadership Coalition [WFLC]. 2008. From wood waste to renewable energy: a summary report of wood utilization efforts in heating systems in the western United States and territories. 18 p. http://wflccenter.org/news_pdf/295_pdf.pdf. (9 September 2015).

Wilson, P.L.; Funck, J.W.; Avery, R.B. 2010. Fuelwood characteristics of northwestern conifers and hardwoods. Updated by Parrent, D.J.; Funck, J.W.; Reeb, J.; Brackley, A.M., eds. Gen. Tech. Rep. PNW-GTR-810. Portland, OR: U.S. Department of Agriculture. Forest Service, Pacific Northwest Research Station. 50 p. (First published in 1987 as Res. Bull. 60. Corvallis, OR: Oregon State University, College of Forestry, Forest Research Laboratory.)

Woodpellets.com http://www.woodpellets.com/support/fuel-savings-calculator.aspx. (19 August 2015).

Appendix: Cordwood Historical Context

Historically, firewood and pulpwood are two products that were measured by the cord. Most mensurational texts (Bruce and Shumacher 1950, Fonseca 2005, Husch et al. 1982) identify a cord as a pile of wood cut into 4-ft sticks that is 4 ft tall and 8 ft in length. What none of these authors note, however, is that there was an endless variation in how mills in the 20th century placed additional detail on how the 4- by 4- by 8-ft unit was defined. Allen M. Brackley, who previously served as a licensed wood scaler in Maine and has more than 50 years of scaling experience, notes that some mills considered the 4- by 4- by 8-ft section to be part of a continuous pile of infinite length and height. Thus, the end marks that defined the 8-ft distances in fact sliced individual 4-ft pieces into separate 4- by 4- by 8-ft units. In a similar manner, if the wood was on a truck or railcar and piled between stakes spaced 8 ft apart so that all sticks were against the stakes, scalers were instructed to adjust the width to reflect the edge effect. Height measurements were adjusted to reflect the void created by measuring heights to the top of the round stick. Thus, the boundary conditions between a cord of wood and its surroundings (whether air, the walls of a truck of railcar, or more wood) can influence the actual amount of wood within the standard volume.

In the trade of the mid 20th century, the two concepts were referred to as the "continuous cord" and the "racked cord." The racked cord, depending upon many other factors, tended to have a solid cubic content of 80 ft^3, and the continuous cord tended to have a solid cubic content in excess of 85 ft^3 per cord. The 80 and 85 ft^3 of solid wood in a cord is only a portion of the material that is available for fuel use. These cubic contents must be increased 10 percent or more to account for bark. The amount of bark is a function of many factors including species characteristics, handling, and drying methods.

In the mid to late 20th century, many factors prompted pulp mills and fuelwood vendors to convert to weight-based scaling. Many mills making this conversion assumed that wood entering the mill over a certified scale was "fresh cut" or "green." The resulting weight factors were a function of the original stick scaling methods applied to the material, the amount of drying that took place between harvest and delivery, and the species.

Miles and Smith (2009) reviewed and published sources and collected specific gravity estimates from green volume and oven-dry weight. Using this information, they evaluated oven-dry and green weight for 156 North American species. It is noted that the green weights they obtained were not necessarily from fresh-cut material.

Thus there can be considerable variation in both the cordwood resource and the measurement methods. In Alaska, consistent and repeatable cordwood measurement methods will be needed, even if they are adopted on site-specific or species-specific basis.

Pacific Northwest Research Station

Web site	http://www.fs.fed.us/pnw/
Telephone	(503) 808–2592
Publication requests	(503) 808–2138
FAX	(503) 808–2130
E-mail	pnw_pnwpubs@fs.fed.us
Mailing address	Publications Distribution Pacific Northwest Research Station P.O. Box 3890 Portland, OR 97208–3890

Federal Recycling Program
Printed on Recycled Paper

U.S. Department of Agriculture
Pacific Northwest Research Station
1220 SW 3rd Ave.
P.O. Box 3890
Portland, OR 97208–3890