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Use of Wood Energy for Lumber Drying and Community Heating in Southeast Alaska

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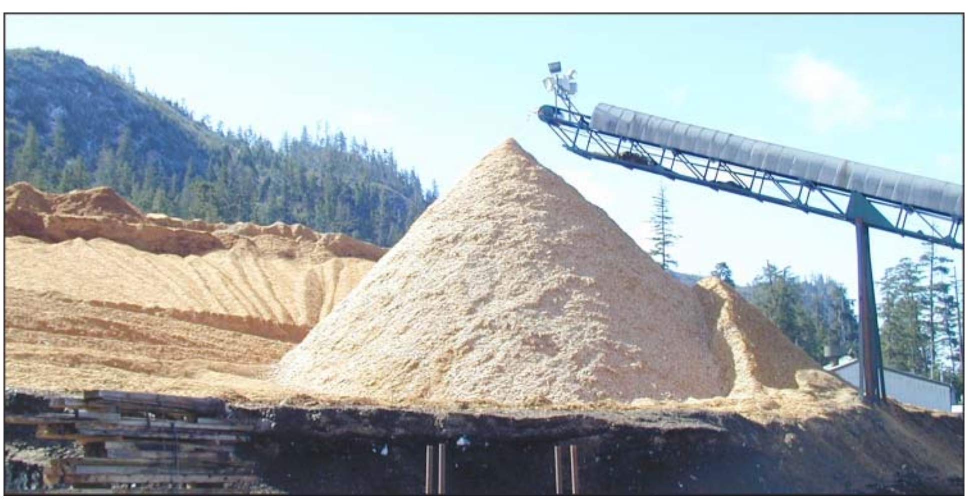

Abstract

The inadequate transportation infrastructure and undeveloped markets for sawmill residues in southeast Alaska are among the factors that limit the use of this forest resource. This study considers the potential use of sawmill residues to supply two bioenergy systems that would produce thermal energy for (1) community heating and (2) a lumber dry kiln in Hoonah, Alaska. The proposed community heating system would be a direct combustion system, burning approximately 1,450 green tons (1.315 green metric kilotons) of wood fuel per year to provide heating for seven centrally located buildings in Hoonah. Additional sawmill residues would be used in another system to provide process heat for a proposed 25,000 board foot (41.3 m^3) dry kiln. The Hoonah sawmill typically produces as much as 5 million board feet (8,255 m^3) of lumber per year, primarily from western hemlock and Sitka spruce. The processing of this amount of lumber would result in an adequate volume of residue to provide a fuel source for the heating requirements of the proposed projects. Wood residue from the sawmill is assumed to be available at no cost other than for transportation.

Use of wood fuel for community heating would save an estimated 65,000 gallons (2.47 kL) of heating oil per year. Avoided fuel costs would be approximately $91,500 per year based on No. 2 fuel oil at a market price of $1.40 per gallon ($0.37 per liter). Based on a project life of 25 years and a contingency rate of 25%, the expected after-tax internal rate of return (IRR) for the community heating portion of the project is 29.6%. Total installed costs for the 1,195,000 Btu/h (350 $kW_{thermal}$) community heating system, including distribution piping and its installation and backup oil systems, are estimated to be $631,000. For the lumber dry kiln, in the second heat-generating system, economic results were less favorable, with expected energy savings of $82,900 per year and an after-tax IRR of 24.1% (also assuming 25% contingency). Estimated installed cost of the 1,536,000 Btu/h (450 $kW_{thermal}$) dry kiln system with a backup oil system is $513,800.

Keywords: biomass, wood energy, lumber drying, wood residues, sawmill, Alaska

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Contents

Page

Introduction 1

Wood Energy Potential for Southeast Alaska 2

Lumber Drying Energy Requirements 2

The Hoonah Sawmill 4

Overview 4

Wood Residue 4

Community Energy Requirements 5

Economics and Financial Analysis 6

Conclusions 8

Literature Cited 10

Appendix A—Location and Estimated Heating Requirements for Selected Public Buildings in Hoonah, Alaska 11

Appendix B—Selected Properties of Commercially Important Softwoods in Southeast Alaska 11

Appendix C—Detailed Cost Analysis of the Hoonah Community Wood Heating System 12

Appendix D—Detailed Cost Analysis of the Hoonah Dry Kiln Wood Heating System 13

Glossary 14

Use of Wood Energy for Lumber Drying and Community Heating in Southeast Alaska

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Introduction

Although the sawmill industry in southeast Alaska has an established capacity of more than 450 million board feet (742,500 m^3)[1] per year, the actual lumber production is considerably less (Kilborn and others 2004). The facility in Hoonah, Alaska, is one of four production-oriented sawmills in southeast Alaska that has well-defined markets for lumber extending beyond local communities. Given the lack of transportation infrastructure as well as undeveloped markets for sawmill residues (including sawdust, bark, and coarse residues), most regional sawmills are challenged to find viable outlets for these materials. In a recent survey, only three sawmills within Alaska were identified as using wood residue for their primary energy needs, and an additional eight sawmills within Alaska reported using mill residues for firewood or fuel (Hill 1999).

A June 2000 report estimates that 100,000 to 120,000 bone dry tons (BDT) (90.72 to 108.9 bone dry metric kilotons) of sawmill wood residue is generated from southeast Alaska sawmills each year (TSS Consultants, unpublished report), with most of this being concentrated at five to six sawmill sites. In addition to solid wood fuel, potential products for wood residue include fuel ethanol, compost materials, and reconstituted board products. Several pilot projects and feasibility studies on the potential of these products have been conducted in recent years (E&A Environmental Consultants, Inc. 2002; TSS Consultants, unpublished report; International Resources Unlimited, Inc., unpublished report). In one southeast Alaskan community, a nine-hole golf course was constructed on a substrate of local sawmill residue.

In the early 1980s, Hoonah, Alaska, was the site of a detailed feasibility study for a 17,065,000 Btu/h (5 MW) electrical generating facility that required about 30,000 tons (27.216 metric kilotons) of wood fuel per year, based on 45% moisture content, green basis (81.2% moisture content, ovendry basis) (Howard J. Grey & Associates, Inc., unpublished report). At the time, community power for Hoonah was supplied by two 2,048,000 Btu/h (600 kW) and one 1,707,000 Btu/h (500 kW) diesel generators (for a total of approximately 5,802,000 Btu/h (1.7 MW) generating capacity). Although the proposed facility was never built, the study projected that local forest and harvesting residues would be readily available to supply several times the designed energy load. This was partly due to Hoonah's proximity to two large, proposed logging operations.

The transition from diesel to wood fuel was recommended in three stages, with the final stage using a downdraft wood-fired gasifier to fuel an internal combustion engine coupled to a generator to generate all the electrical energy. This type of wood gasification technology had not been commercially proven in the United States at this time. Under this plan, the power generating capacity would be added in increments of 3,413,000 Btu/h (1 MW) to match anticipated increases in local energy demand. Since the sawmill in Hoonah had not yet been established, mill residues were not a potential fuel source under consideration. Harvesting residues would have supplied the necessary fuel.

[1]Log scale basis. A nominal 2- by 4-in. surfaced dry board is actually 1.5 by 3.5 in., resulting in 0.656 actual board feet for each nominal board foot, and conversion factors will vary for different nominal sizes of lumber. An overall average for a kiln load of different sizes of lumber might be taken to be 0.700 actual board feet for each nominal board foot (Spelter 2002). In other parts of this paper, we made calculations with one million board feet = 1,650 m^3. This corresponds to about 0.700 board feet for each nominal board foot.

The current study at Hoonah differs from the previous study (conducted in the early 1980s) in several respects, including the following:

- The current study proposes a much smaller system (an equivalent of less than 3,413,000 Btu/hour (1 MW) heat-generating capacity) compared with a 17,065,000 Btu/h (5 MW) system in the previous study.
- The current study proposes the use of only sawmill residues (for example, sawdust, slabs, edgings) but no harvesting residues.
- The current study proposes only heating (steam and hot water) for lumber dry kilns and community buildings. In addition to heat, the previous study included electrical energy that could be used for a variety of end uses (residential or industrial).

Wood Energy Potential for Southeast Alaska

Although none of the major sawmills in southeast Alaska is known to have operating wood energy systems, wood energy could soon play an important role in this region as new lumber dry kiln facilities are planned. Flat, well-drained land is at a premium in southeast Alaska, and several mills are currently running out of suitable space to store mill residues. Some mills have barged wood chips to destinations in the continental United States and Canada. However, when chip markets are unfavorable, this option becomes less attractive.

As of February 2004, there were few well-defined markets for wood residues in southeast Alaska. One composting facility using wood and fish residues has recently started operation (Tkacz 2002), and several small lumber drying kilns are powered by wood energy. Wood residues could be utilized on a considerably larger scale to produce electrical energy at one or more sites in southeast Alaska. In certain parts of southeast Alaska, electricity is abundant and reasonably priced. For example, in Juneau, residential rates are $0.084/kWh (Juneau Economic Development Council 2002). In other communities, electrical rates are considerably higher. Hoonah is typical of rural communities, where fuel is either flown or barged in and local utilities generate power, often using diesel generators. Statewide, electrical rates in rural Alaskan villages average $93.70/million Btu ($0.32/kWh) and can be as much as $292.80/million Btu ($1.00/kWh) (Alaska Energy Authority 2002). As of late 2002, electrical rates in Hoonah were close to $93.70/million Btu ($0.32/kWh) (personal communication, Keith Walker, Whitestone Loggin, Inc., Hoonah, Alaska, 2002) (Table 1).

Lumber Drying Energy Requirements

Kiln drying lumber is an energy intensive process and can consume up to 60% to 70% of the total energy needed to manufacture lumber (Breiner and others 1987, Simpson 1991). Total energy consumption depends on many factors, including initial and final moisture content, lumber thickness, wood species, kiln schedule, ambient temperatures, and conditioning practices. Kiln-specific conditions, such as energy delivery system and operating efficiency, insulation levels, venting practices, and energy requirements of fans, also play an important role in overall energy demands (Simpson 1991). In addition, the actual volume of wood contained within each nominal 1,000 board feet is an important consideration. For example, a nominal 1,000 board feet of 2- by 4-in. (standard 38- by 89-mm) lumber would contain 656 actual board feet or 1.548 m^3 (656 board feet/nominal 424 board feet/m^3). However, since 2 by 4's are only one example and there is no way of taking an average of nominal sizes of lumber for actual kiln loads that may occur, an overall average for a kiln load of different sizes of lumber might be taken to 0.700 actual board feet for each nominal board foot. This means that in a kiln load of lumber (no specified size), a nominal 1,000 board feet would contain 700 actual board feet or 1.651 m^3 (700 board feet/nominal 424 board foot/m^3) (Spelter 2002).

Energy consumption can vary significantly with ways in which kilns are operated and how near to full capacity they are loaded. One study investigated these influences with alternatives of (Method 1) heat, spray, and air-circulating systems in continuous operation; (Method 2) part-time operation of heat and spray systems with full-time circulation of air; and (Method 3) part-time operation of heat, spray, and air-circulating systems (Rasmussen and Avanzado 1961). Two kiln charges were dried under each of the three procedures, and the same drying schedules were used for all runs. Method 1 required the least total energy to evaporate 1 lb (0.4536 kg) of water from the lumber (Table 2).

Table 1—Summary of feedstock–residue availability for southeast Alaska[a]

Feedstock source–residue	Estimated annual bone dry tons[b]
Timber harvest–thinning	150,000 to 170,000
Tongass timber harvest–thinning	200,000
Yards	32,500 to 37,500
Sawmills	99,625 to 120,125
Total	482,125 to 527,625

[a]TSS Consultants (unpublished report).

[b]1 ton = 0.907 metric tons.

Table 2—Energy balances (percentage of total energy used) on drying green 1-in.- (25.4-mm-) thick northern red oak using three drying methods on a kiln charge of 1,723 board feet (2.843 m^3)[a]

	Method 1	Method 2	Method 3
Total steam used for heating, lb[b]	16,450	17,770	20,785
Total steam used for humidification, lb	113	297	186
Total steam used per pound of water evaporated, lb	4.65	5.20	5.41
Total power used by fans, kWh	484.1	958.6	295.3
Power used per pound of water evaporated, kWh	0.136	0.276	0.076
Total energy supplied, $\times 10^6$ Btu[c]	17.923	20.851	21.567
Energy required to evaporate one pound of water, Btu (kJ/kg)[d]	5,030 (11,700)	6,000 (14,000)	5,560 (12,900)
Energy for air circulation, % of total	9.22	15.69	4.67
Energy for evaporating water, % of total	21.15	18.30	19.47
Energy for humidification, % of total	0.01	0.02	0.01
Miscellaneous losses (includes transmission, venting, leakage), % of total	69.62	65.99	75.85

[a]Rasmussen and Avanzado (1961).
[b]1 lb = 0.45 kg.
[c]1 Btu = 1.055 kJ.
[d]1 Btu/lb = 2.33 kJ/kg.

Table 3—Approximate energy uses for drying lumber[a]

Species	Initial moisture content (%, ovendry basis)	Dry moisture content (%, ovendry basis)	Range of energy use (Btu per pound of water[b])	Range of energy use (million Btu per thousand board feet of lumber[c])
Douglas-fir (*Pseudotsuga menzeisii*)	45	15	2,000 to 3,000	1.2 to 1.8
Southern yellow pine	100	12	1,600 to 2,200	3.0 to 4.0
Red oak (*Quercus rubra*)	80	6	>3,000	>6.5

[a]Comstock (1975).
[b]1 Btu/lb = 2.33 kJ/kg.
[c]1 million Btu per thousand board feet = 0.639 kJ/m^3.

Method 2 required the greatest amount of energy to evaporate water. However, method 3 required the most energy to evaporate water when all three methods were calculated based on a kiln charge of 1,723 board feet (2.843 m^3) of lumber. Although this study was conducted using red oak lumber, the energy requirements for drying softwood lumber, including western hemlock and Sitka spruce from southeast Alaska, were expected to be considerably lower (Table 3).

In a separate study, total energy consumption to kiln dry four California softwoods varied from about 4.3 to 6.9 million Btu per thousand board feet (2.7 to 4.4 kJ per m^3), including steam energy for heating, humidity control, and conditioning (Breiner and others 1987). Lumber conditioning is an energy-intensive part of kiln drying, in which steam or hot water spray is admitted into the drying chamber to provide moisture to lumber surfaces for relatively short periods, usually near the end of the drying cycle. In the California study, conditioning accounted for 6% to 14% of total energy requirements, while electrical consumption for fans represented 6.9% of the total. The demand for steam is not uniform throughout the kiln-drying process. During start-up of a kiln that is not direct fired, there is a very high demand for steam to supply heat energy. Then, during the conditioning period, toward the end of the run in a kiln that is not direct fired, there is a high demand for live steam to increase the humidity in the kiln. It is a common problem to find kilns designed with insufficient heat- and/or steam-generating capacity (Breiner and others 1987).

In southeast Alaska, where average sawing thickness variation has been estimated to be greater than 0.05 in. (0.127 cm) (Kilborn 2002), lumber thickness variations could significantly influence energy requirements for drying. In particular, sawmills in Alaska with circular resaws were found to have relatively high thickness variations (Kilborn 2002). The energy requirements for drying softwood lumber in southeast Alaska would probably be comparable to or greater than many of the studies mentioned previously. During winter, frozen lumber could require additional energy to heat and thaw. A high level of rainfall and relatively high wood moisture content would be expected to increase kiln-drying times and energy requirements compared with milder conditions found in many parts of the continental United States.

Lumber thickness is also an important variable influencing energy requirements for a dry kiln. Simpson and Tschernitz (1980) showed considerable differences in energy consumption for kiln drying 1-in.- (25.4-mm-) thick red oak lumber with only minor differences in board thickness (Table 4).

The Hoonah Sawmill

Overview

The mill in Hoonah, Alaska, typically produces in the range of 1 to 5 million board feet (1,650 to 8,250 m^3) of lumber per year and has recently purchased a 25 thousand board foot (41.25 m^3) capacity dry kiln. Their production includes 1- and 2-in. (25.4- and 50.8-mm) dimension lumber, 1-1/4- and 1-1/2-in. (31.75- and 38.1-mm) shop lumber, and larger members for timber and log home construction, primarily from western hemlock and Sitka spruce (Table 5).

The yearly mill operating season in Hoonah is typically about 40 weeks; the mill closes during mid-winter months (personal communication, Wesley Tyler, Icy Straits Lumber, Hoonah, Alaska, 2002).

The drying time for 1-in. (25.4-mm) western hemlock lumber is estimated to be 3 to 5 days (Simpson 1991); therefore, the 25 thousand board foot (41.25 m^3) kiln would be able to dry approximately 1 million board feet (1,650 m^3) annually, based on total drying time estimated at 1 week per kiln cycle and an operating season of 40 weeks per year. This drying capacity would equal about 20% of the mill's output at maximum yearly production of 5 million board feet (8,250 m^3) and be close to 100% of output under the lower production situation of 1 million board feet (1,650 m^3) per year. Alternatively, if lumber were dried throughout the year on shorter schedules, as much as about 2 million board feet (3,300 m^3) per year could be dried.

Given that the Alaskan market for kiln-dried, graded, dimensional lumber is estimated to be 65 to 70 million board feet (107,250 to 115,500 m^3) per year (McDowell Group 1998), it is expected that lumber drying volumes of 1 to 2 million board feet (1,650 to 3,300 m^3) per year, if supplied by the mill in Hoonah, could be readily absorbed into local retail markets within southeast Alaska (including nearby Juneau).

Wood Residue

A preliminary wood residue analysis was completed for a typical softwood lumber mill in southeast Alaska, and this information was used to estimate actual wood residue production at the Hoonah mill (Table 5). Lumber production estimates of 1 and 5 million board feet (1,650 and 8,250 m^3) per year were used to cover the range of expected operating conditions for the Hoonah mill and other similar mills in southeast Alaska.

Table 4—Total energy consumption in kiln drying red oak lumber of different thicknesses[a]

		Total energy consumption (million Btu per thousand board feet[b])					
		1-in. (25.4-mm) thickness			1-1/2-in. (38.1-mm) thickness		
Initial moisture content (%)	Final target moisture content (%)	Minimum (24/32 in.)	Target (37/32 in.)	Maximum (43/32 in.)	Minimum (51/32 in.)	Target (54/32 in.)	Maximum (57/32 in.)
80	7	6.14	6.35	6.55	7.33	7.51	7.72
50	7	4.38	4.51	4.66	5.20	5.39	5.57
30	7	2.80	2.90	3.00	3.36	3.45	3.55

[a]Simpson and Tschernitz (1980).
[b]1 million Btu per thousand board feet = 0.639 kJ/m^3.

Table 5—Conditions typical for the softwood lumber sawmill in Hoonah, Alaska

Condition	Normal operating range
Annual lumber production (range)	1 to 5 million board feet (1,650 to 8,250 m^3)
Species	Western hemlock; Sitka spruce
Lumber thickness and grade	1- and 2-in. (25.4- and 50.8-mm) dimension lumber, 1-1/4- and 1-1/2-in. (31.75- and 38.1-mm) shop grade lumber
Period of operation	40 weeks per year
Initial lumber moisture content	80% to 90% (ovendry basis) 44% to 47% (green basis)
Final lumber moisture content	15% to 19% (ovendry basis) 13% to 16% (green basis)
Average drying cycle[a]	1 week
Number of kiln cycles per year[a]	40 kiln cycles per year
Estimated kiln capacity	25 thousand board feet (41.25 m^3)

[a]Expected conditions (upon installation of a proposed dry kiln).

In a study of sawmill efficiency in Alaska, the average lumber recovery within southeast Alaska was estimated to be 6.0 board feet per cubic foot (0.5 m^3 per m^3) of logs (Kilborn 2002). If it were assumed that all wood and bark not converted into lumber would be available as residue and the wood residue had a moisture content of 80% ovendry basis (44.5% green basis), then approximately 9,250 green tons (8,392 green metric tons) per year of wood residue would be generated under the high production scenario of 5 million board feet (8,250 m^3) per year (Table 6). Wood residue generation under the lower production condition (1 million board feet (1,650 m^3) per year) would be approximately 1,850 tons (1,678 metric tons). Any increases in operating efficiency above a lumber recovery factor of 6.0 (actual recovery of 50%) would result in a corresponding decrease in wood residue production. All estimates are based on average green weights of 3,937 lb per thousand board feet (1.08 Mg per m^3) for western hemlock and 3,465 lb per thousand board feet (952 kg per m^3) for Sitka spruce, and it is assumed that these two species would be present in approximately equal volumes (Simpson 1991).

The actual wood residue production at the Hoonah mill could be considerably less than the estimated amount and could include various ratios of Sitka spruce and western hemlock. Wood residue production typically averages almost 10 green tons (9.072 green metric tons) per day under the high production condition (personal communication, Wesley Tyler, Icy Straits Lumber, Hoonah, Alaska, 2002). It is estimated that wood residue availability could be increased about 15% to 20% beyond the figures just discussed if easily transported harvesting residues were brought into the mill site rather than being left in the woods (personal communication, Keith Walker, Whitestone Loggin, Inc., Hoonah, Alaska, 2002). This material could include low grade logs, wind blown material, and the unmerchantable portions of butt logs. A disadvantage of using harvesting residues would be the need to purchase a tub grinder, log chipper, or similar equipment to reduce large wood sections to smaller particle sizes suitable for burning. Therefore, the analysis reported here focuses on mill residues only.

Community Energy Requirements

Seven community buildings in Hoonah have been identified for this study as potential sites for space heating with wood energy. A second wood energy system would be located at the mill site and would be used for lumber drying. The community buildings are all centrally located within Hoonah, and each would typically consume between 3,000 and 20,000 gallons (11.36 and 75.7 kL) of fuel oil per year, with a total estimated demand of about 65,000 gallons (246 kL) per year (Table 7, Appendix A).

In this situation, the public school complex would be the largest single energy user, requiring the equivalent of about 35,600 gallons (134.7 kL) of heating oil per year. From May through August, the monthly energy requirements of the public school would be approximately 50% less than the winter usage of September though April (personal communication, Greg Howell, Hoonah City Schools, 2002). The four other community buildings are all located between 400 and 800 ft (121.9 and 243.8 m) from the school, a distance that could easily be heated by water transported through underground pipes (Appendix A). The avoided energy cost for this system, based on market prices for No. 2 fuel oil of $1.40 per gallon ($0.37/L) is estimated to be $91,500 per year (Table 7) (personal communication, Petro Marine Services, Sitka, Alaska, 2002). Six of the seven buildings could potentially be heated only during weekday business hours, with minimal heating conditions at night and on weekends. However, the senior residential center would require continuous heating throughout the heating season and perhaps all year.

An estimated 1,450 tons (1,315 metric tons) of green wood residue per year would be needed to meet the current energy demands for these buildings. These projections are based on heating values of 138,800 Btu per gallon (3.87 MJ/m^3) of heating oil and 3,825 Btu per pound (8.89 MJ/kg) of wood for Sitka spruce and western hemlock mixtures (based on 55% moisture content, wet basis). Differences in operating efficiency and usable heat output for wood-fired systems compared with heating oil systems were not considered in this evaluation but could be an important consideration in

Table 6—Estimated wood residue generation at the sawmill in Hoonah, Alaska, under scenarios of high and low lumber production

	High production	Low production
Yearly volume of lumber produced	5 million board feet (8,250 m^3)	1 million board feet (1,650 m^3)
Average lumber recovery factor (LRF) for sawmills in southeast Alaska	6.0	6.0
Equivalent lumber volume in wood residue per year (based on LRF of 6.0)	5 million board feet (8,250 m^3)	1 million board feet (1,650 m^3)
Average weight of green lumber[a]	3,700 lb/thousand board feet (1.017 Mg/m^3)	3,700 lb/per thousand board feet (1.017 Mg/m^3)
Yearly estimated weight of green wood residue	9,250 ton (8,392 metric ton)	1,850 ton (1,678 metric ton)

[a]Assumes approximately equal volumes of western hemlock (3,937 lb/thousand board feet (1.082 Mg/m^3) at 80% moisture content, ovendry basis) and sitka spruce (3,465 lb/thousand board ft (952 kg/m^3) at 80% moisture content, ovendry basis).

Table 7—Energy requirements to heat selected community buildings in Hoonah, Alaska

	Estimated annual energy requirements[a]		Approximate distance to building from proposed wood energy site (ft[c])
Building	Gallons of heating oil[b]	US$	
School (main building)	20,000	28,000	less than 100
School (swimming pool)	12,000	16,800	less than 100
School (auto shop)	3,600	5,040	less than 100
Church	3,600	5,040	500
Native American building	6,000	8,400	400
City hall	10,000	14,000	500
Senior housing	10,000	14,000	800
Total annual energy savings	65,200	91,500	

[a]Assumes heating oil (No. 2 fuel oil) is available at \$1.40/gallon (\$0.37/L) and no cost for wood fuel.

[b]1 gallon = 3.8 L.

[c]1 ft = 0.3048 m.

determining actual fuel requirements and would probably result in higher actual wood fuel requirements. In addition, wood fuel with higher than normal moisture content (for both spruce and hemlock) could result in less usable heat than indicated in the reference values (Appendix B).

Economics and Financial Analysis

Separate financial analyses were conducted for wood energy systems to be used for the Hoonah community heating and for the lumber dry kiln (Tables 8 and 9). For each evaluation, the wood energy system was compared with a fuel oil system, with fuel oil costing \$1.40 per gallon (\$0.37/L). In addition, a seasonal efficiency of 65% was assumed for wood energy, compared with a 70% seasonal efficiency for fuel oil systems. All evaluations were conducted using RetScreen software (Natural Resources Canada 2000) using the following financial parameters:

- discount rate: 12.0%[2]
- inflation rate: 2%
- energy cost escalation rate: 2%
- project life: 25 years
- debt: 90% equity (at 5.5% interest rate)[2]
- installed cost of district heating system: \$631,000
- installed cost of dry kiln energy system: \$513,800

[2]2003. Alaska Energy Authority Power Project Loan Fund, Anchorage, Alaska.

Table 8—Comparison of the two wood-fired heating systems considered for Hoonah, Alaska

	Community heating system	Lumber dry kiln
Size, Btu/h ($kW_{thermal}$)	1,195,000 (350)[a] 512,000 (150)[b]	1,536,000 (450)
Installed cost, US$	631,000	514,000
Feasibility study, US$	5,540	7,400
Development, US$	17,825	17,825
Engineering, US$	10,360	14,800
Wood heating system, US$	87,500	112,500
System installation, US$	35,000	45,000
Peak load heating system, US$	14,250	0
Back-up heating system, US$	33,250	67,500
Distribution network, US$	280,000	0
Balance of plant, US$	98,075	149,405
Credit for boilers not installed, US$	75,000	0
25% contingency, US$	124,200	99,570
Operating and maintenance cost, US$/year	33,860	40,200
Wood fuel requirements (55% wet basis or 122% green basis), green tons (green metric tons)	1,450 (1,315)	1,300 (1,179)
Expected energy savings, US$/year	97,900	82,900
Internal rate of return, %	29.6	24.1
Payback period, years	11	12
Expected project life, years	25	25

[a]Wood-fueled system (base load).
[b]Oil system (peak load).

Table 9—Hoonah community wood heating system costs based on initial costs and operating and maintenance costs.[a]

Contingency (%)	Annual costs ($)	Annual savings ($)	Total initial cost ($)	Payback time (years)	After-tax internal rate of return (%)	Net present value ($)
0	63,700	91,500	507,000	8.2	49.6	171,000
25	76,200	91,500	631,000	11.0	29.6	96,600
50	88,800	91,500	756,000	14.1	15.7	22,600
58	92,800	91,500	795,000	15.2	11.9	0

[a]Wood system comparison to fuel oil system with fuel at $1.40 per gallon ($0.37/L) 138,800 Btu per gallon (3.9 MJ/m^3). Wood energy system—65% seasonal efficiency (3,040 Btu per pound (7.1 MJ/kg) green wood at $5.00 per ton delivered). Fuel oil energy system—70% seasonal efficiency.
General financial parameters:
- Discount rate—12.0%
- Inflation rate—2%
- Energy cost escalation rate—2%
- Project life—25 years
- Debt—90% equity and 5.5% interest rate

The dry kiln system produced a net present value (NPV) of $53,100 and an after-tax IRR of 24.1% (Table 10 and 11); the community heating system produced a NPV of $96,600 with an after-tax IRR of 29.6% (Tables 9 and 11). When only the community heating system was considered, use of wood fuel would save an estimated 65,000 gallons (247,000 L) of heating oil per year, or $91,500 annually based on No. 2 fuel oil at $1.40 per gallon ($0.37/L). Total installed costs for the 1,195,000 Btu/h (350 $kW_{thermal}$) community heating system and for the 1,536,000 Btu/h (450 $kW_{thermal}$) dry kiln heating system were estimated to be $631,000 and $514,000, respectively (Table 8). Both energy systems had assumed project lives of 25 years and contingency costs of 25%.

The breakeven point of the Hoonah community wood heating system with a comparable fuel oil system is at 58% of projected initial and operating and maintenance costs, and the dry kiln system is 43% of these costs. Therefore, this analysis indicates that the community wood heating system is more economically favorable than the dry kiln system. The range of contingency values was different for the community heating compared with the dry kiln system (Tables 9 and 10), and these values were chosen because the wider range for the community heating better demonstrates that system's more favorable economics. The RetScreen computer evaluation assumed that no grant funding (from either State or Federal sources) would be used to finance either of the wood energy projects. If grant funding were available to offset capital costs, the resulting project economics would be more favorable than what is presented in this study.

Consistent with conventional power plant practices, the general project contingency was added to the total plant costs to cover project uncertainty and the cost of any additional equipment that could result from a detailed design. This project contingency is intended to cover the uncertainty in the cost estimate and represents costs that are expected to occur. A similar approach was applied to recognize process contingency, except only nonmature accounts have process contingency values. Higher than normal labor, shipping, and installation costs were assigned to Hoonah because of its remote location. In addition, operating and maintenance costs were expected to be greater than for comparable wood energy facilities in the continental United States.

A typical commercial size wood heating system costs $0.0732 per Btu/h ($250 per $kW_{thermal}$) for unit construction and $0.0293 per Btu/h ($100 per $kW_{thermal}$) for on-site installation. Annual average operating costs are a combination of fuel costs, electricity costs, operating and maintenance costs, and debt payments. Operating and maintenance costs are stable for a wide range of system sizes, and fuel and electricity costs depend greatly on unit size and local availability of fuel. For the 1,536,000 Btu/h (450 $kW_{thermal}$) dry kiln system, the annual operating costs were estimated at $40,200, as generated by the RetScreen cost analysis software (Natural Resources Canada 2000). Complete cost analyses are provided in Appendices C and D.

For the 1,195,000 Btu/h (350 $kW_{thermal}$) community heating system, the annual operating costs were estimated at $33,860. Costs for transporting the fuel between the mill site and the locations of the heating systems were based on established guidelines (Han and others 2004) and were estimated to be approximately $125 per round trip, assuming 25 ton (22.7 metric ton) per load and 10 miles (16.1 km) per round trip. The annual transportation cost of $7,000 (to transport 1,400 ton (1,270 metric ton) of fuel) represents a high estimate of actual costs, and under normal operating conditions in southeast Alaska, it might be possible to transport the fuel more economically. The range of wood fuel costs compared with internal rate of return demonstrates the highly dependent nature of fuel costs on the economic feasibility of the two heating systems (Table 11).

Conclusions

There is strong potential for using sawmill residues in Hoonah, Alaska, to fuel two wood energy systems: one for heating community buildings and one for a lumber dry kiln. For the community heating system, expected energy savings would be approximately 65,000 gallons (247,000 L) per year and avoided energy costs would be approximately $91,500. The after-tax IRR for the community heating system, designed to heat seven public buildings, is 29.6%. Three centrally located public school buildings would account for more than half the energy needs of the community heating system.

For the proposed dry kiln system, expected energy savings would be approximately $82,900 per year to heat a 25 thousand board foot (41.25 m^3) lumber dry kiln, while producing an after-tax IRR of 24.1%. Wood fuel from the sawmill is assumed to be available at no charge (other than transportation costs) for use in both energy systems. Manufacturing residues from the local sawmill should be in adequate supply to provide energy for the community heating system, estimated to require 1,450 green tons (1,315 green metric tons) per year at 55% moisture content, wet basis (122% moisture content, dry basis). However, under a lower production scenario of about 1 million board feet (1,650 m^3) per year, it is questionable whether enough wood fuel could be generated from the sawmill to heat both the community buildings and a lumber dry kiln. Special considerations might be needed when trying to burn high moisture fuel, expected to reach as high as 55% moisture content, wet basis. For example, covered storage systems could be used to minimize absorption of rainwater.

Table 10—Hoonah sawmill dry kiln costs based on initial and operating and maintenance costs[a]

Contingency (%)	Annual costs ($)	Annual savings ($)	Total initial cost ($)	Payback (years)	After-tax internal rate of return (%)	Net present value ($)
0	62,200	82,900	414,000	8.5	46.4	127,000
25	74,700	82,900	513,800	12.0	24.1	53,100
35	79,700	82,900	554,000	13.7	17.2	23,400
43	83,700	82,900	586,000	15.2	11.9	0

[a]Wood system comparison to fuel oil system with fuel at $1.40 per gallon ($0.37/L) 138,800 Btu per gallon (3.9 MJ/m^3). Wood energy system—65% seasonal efficiency (3,040 Btu per pound (7.1 MJ/kg) green wood at $5.00 per ton delivered). Fuel oil energy system—70% seasonal efficiency.

General financial parameters:

- Discount rate—12.0%
- Inflation rate—2%
- Energy cost escalation rate—2%
- Project life—25 years
- Debt—90% equity and 5.5% interest rate

Table 11—Wood fuel costs compared with internal rate of return for lumber dry kiln and community heating systems[a]

Delivered wood fuel cost ($ per ton)[b]	After-tax internal rate of return (%)	
	Dry kiln wood heating system	Community wood heating system
2.50	28.3	33.3
5.00	24.1	29.6
7.50	19.8	25.8
10.00	15.3	22.0
12.50	10.4	18.1
15.00	N/A	14.1
20.00	N/A	N/A

[a]Wood system comparison to fuel oil system with fuel at $1.40 per gallon ($0.37/L) 138,800 Btu per gallon (7.1 MJ/kg). Wood energy system—65% seasonal efficiency (3,040 Btu per pound green wood). Fuel oil energy system—70% seasonal efficiency.

General financial parameters:

- Discount rate—12.0%
- Inflation rate—2%
- Energy cost escalation rate—2%
- Project life—25 years
- Debt—90% equity and 5.5% interest rate
- Contingency on initial and operating and maintenance costs—25%

[b]1 ton = 0.91 metric ton.

Wood energy could play a role in meeting the energy requirements for Hoonah, but it is not likely to become the primary energy source. Given the current and expected availability of local sawmill residues and the generally unfavorable economics associated with using harvesting residues for fuel, it is unlikely that wood fuel could be used advantageously at scales much larger than those described in this report. However, this evaluation indicates favorable economics for both the community heating and the lumber kiln drying wood energy systems.

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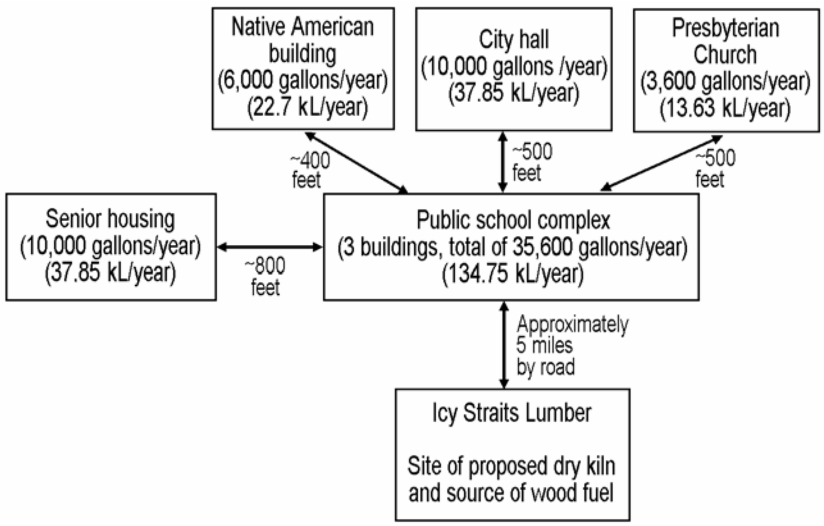
Appendix A—Location and Estimated Heating Requirements for Selected Public Buildings in Hoonah, Alaska (1 ft = 0.3048 m)



Appendix B—Selected Properties of Commercially Important Softwoods in Southeast Alaska

Selected properties of commercially important softwoods in southeast Alaska[a]

	Species	
Property	Western hemlock	Sitka spruce
Lumber drying time (green to 6% moisture content, ovendry basis), days	3 to 5	4 to 7
Heartwood moisture content (ovendry basis), %	85	41
Sapwood moisture content (ovendry basis), %	170	142
Wood specific gravity	0.42	0.37
Lumber weight per thousand board feet (80% moisture content, ovendry basis or 44% green basis), lb (kg/m^3)	3,937 (1,082)	3,465 (953)
Lumber weight per thousand board feet (15% moisture content, ovendry basis or 13% green basis), lb (kg/m^3)	2,674 (735)	2,343 (644)

[a]Simpson (1991).

Appendix C—Detailed Cost Analysis of the Hoonah Community Wood Heating System

Year	Operating and mainte-nance, US$	Fuel and electricity, US$	Debt payment, US$	Annual costs, US$	Annual savings, US$	Pre-tax, US$	Straight line depreciation, US$	Interest payments, US$	Income taxes, US$	After-tax, US$	Cumulative, US$
0	–22,200	–11,660			91,522	–63,151	—		0.00	–63,151	–63,151
1	–22,644	–11,894	–42,371	–76,909	93,352	16,444	28,705.22	(31,259.99)	(402.62)	16,846	–46,305
2	–23,097	–12,131	–42,371	–77,599	95,219	17,620	28,705.22	(30,648.88)	222.97	17,397	–28,908
3	–23,559	–12,374	–42,371	–78,304	97,124	18,820	28,705.22	(30,004.15)	868.56	17,951	–10,957
4	–24,030	–12,622	–42,371	–79,023	99,066	20,044	28,705.22	(29,323.97)	1,534.97	18,509	7,552
5	–24,511	–12,874	–42,371	–79,756	101,048	21,292	28,705.22	(28,606.38)	2,223.03	19,069	26,621
6	–25,001	–13,131	–42,371	–80,503	103,069	22,565	28,705.22	(27,849.31)	2,933.64	19,632	46,253
7	–25,501	–13,394	–42,371	–81,266	105,130	23,864	28,705.22	(27,050.61)	3,667.74	20,196	66,449
8	–26,011	–13,662	–42,371	–82,044	107,233	25,189	28,705.22	(26,207.99)	4,426.31	20,762	87,211
9	–26,531	–13,935	–42,371	–82,837	109,377	26,540	28,705.22	(25,319.01)	5,210.36	21,330	108,541
10	–27,062	–14,214	–42,371	–83,647	111,565	27,918	28,705.22	(24,381.15)	6,020.99	21,897	130,438
11	–27,603	–14,498	–42,371	–84,472	113,796	29,324	28,705.22	(23,391.70)	6,859.33	22,465	152,902
12	–28,155	–14,788	–42,371	–85,314	116,072	30,758	28,705.22	(22,347.83)	7,726.54	23,031	175,933
13	–28,718	–15,084	–42,371	–86,173	118,393	32,220	28,705.22	(21,246.55)	8,623.90	23,596	199,530
14	–29,292	–15,386	–42,371	–87,049	120,761	33,712	28,705.22	(20,084.70)	9,552.68	24,159	223,689
15	–29,878	–15,693	–42,371	–87,943	123,177	35,234	28,705.22	(18,858.94)	10,514.28	24,720	248,409
16	–30,476	–16,007	–42,371	–88,854	125,640	36,786	28,705.22	(17,565.77)	11,510.13	25,276	273,685
17	–31,085	–16,327	–42,371	–89,784	128,153	38,369	28,705.22	(16,201.48)	12,541.73	25,827	299,512
18	–31,707	–16,654	–42,371	–90,732	130,716	39,984	28,705.22	(14,762.15)	13,610.67	26,373	325,885
19	–32,341	–16,987	–42,371	–91,699	133,330	41,631	28,705.22	(13,243.65)	14,718.63	26,912	352,798
20	–32,988	–17,327	–42,371	–92,686	135,997	43,311	28,705.22	(11,641.64)	15,867.35	27,444	380,241
21	–33,648	–17,673	–42,371	–93,692	138,717	45,025	28,705.22	(9,951.52)	17,058.67	27,966	408,207
22	–34,321	–18,027	–42,371	–94,719	141,491	46,773	28,705.22	(8,168.44)	18,294.52	28,478	436,685
23	–35,007	–18,387	–42,371	–95,766	144,321	48,555		(6,287.30)	29,623.75	18,932	455,617
24	–35,707	–18,755	–42,371	–96,833	147,207	50,374		(4,302.69)	30,954.85	19,419	475,036
25	–36,421	–19,130	–42,371	–97,923	150,152	52,229		(2,208.92)	32,336.89	19,892	494,928

System parameters:

- Total initial costs $631,515
- Operating and maintenance $22,200
- Fuel and electricity $11,660
- Debt ratio 90%
- Effective income tax rate 35%
- Energy cost escalation rate 2%
- Debt payment $42,371
- Annual savings $91,522
- Depreciation amount 100%
- Debt term (yrs) 25
- Debt interest rate 5.5%
- Inflation rate 2%

Appendix D—Detailed Cost Analysis of the Hoonah Dry Kiln Wood Heating System

Year	Operating and maintenance, US$	Fuel and electricity, US$	Debt payment, US$	Annual costs, US$	Annual savings, US$	Pre-tax, US$	Straight line depreciation, US$	Interest payments, US$	Income taxes, US$	After-tax, US$	Cumulative, US$
0	–30,325	–9,912			82,888	–51,384	–		0.00	–51,384	–51,384
1	–30,932	–10,110	–34,476	–75,517	84,546	9,029	23,356.53	(25,435.27)	(1,850.47)	10,879	–40,505
2	–31,550	–10,312	–34,476	–76,338	86,237	9,899	23,356.53	(24,938.02)	(1,371.90)	11,271	–29,234
3	–32,181	–10,518	–34,476	–77,175	87,962	10,786	23,356.53	(24,413.43)	(877.67)	11,664	–17,571
4	–32,825	–10,729	–34,476	–78,029	89,721	11,692	23,356.53	(23,859.99)	(367.12)	12,059	–5,512
5	–33,481	–10,943	–34,476	–78,900	91,515	12,615	23,356.53	(23,276.10)	160.41	12,454	6,943
6	–34,151	–11,162	–34,476	–79,789	93,346	13,557	23,356.53	(22,660.11)	705.64	12,851	19,794
7	–34,834	–11,385	–34,476	–80,695	95,213	14,517	23,356.53	(22,010.23)	1,269.33	13,248	33,042
8	–35,531	–11,613	–34,476	–81,620	97,117	15,497	23,356.53	(21,324.61)	1,852.25	13,645	46,687
9	–36,241	–11,845	–34,476	–82,562	99,059	16,497	23,356.53	(20,601.28)	2,455.23	14,041	60,728
10	–36,966	–12,082	–34,476	–83,524	101,040	17,516	23,356.53	(19,838.17)	3,079.13	14,437	75,165
11	–37,705	–12,324	–34,476	–84,505	103,061	18,556	23,356.53	(19,033.09)	3,724.85	14,831	89,996
12	–38,459	–12,570	–34,476	–85,506	105,122	19,617	23,356.53	(18,183.72)	4,393.35	15,223	105,220
13	–39,229	–12,822	–34,476	–86,526	107,225	20,699	23,356.53	(17,287.65)	5,085.63	15,613	120,833
14	–40,013	–13,078	–34,476	–87,567	109,369	21,802	23,356.53	(16,342.28)	5,802.73	15,999	136,832
15	–40,813	–13,340	–34,476	–88,629	111,557	22,928	23,356.53	(15,344.93)	6,545.75	16,382	153,214
16	–41,630	–13,606	–34,476	–89,712	113,788	24,076	23,356.53	(14,292.71)	7,315.85	16,760	169,973
17	–42,462	–13,879	–34,476	–90,817	116,064	25,247	23,356.53	(13,182.63)	8,114.24	17,132	187,106
18	–43,312	–14,156	–34,476	–91,944	118,385	26,441	23,356.53	(12,011.49)	8,942.20	17,499	204,605
19	–44,178	–14,439	–34,476	–93,093	120,753	27,659	23,356.53	(10,775.94)	9,801.06	17,858	222,463
20	–45,061	–14,728	–34,476	–94,265	123,168	28,902	23,356.53	(9,472.44)	10,692.24	18,210	240,673
21	–45,963	–15,023	–34,476	–95,461	125,631	30,170	23,356.53	(8,097.24)	11,617.20	18,553	259,226
22	–46,882	–15,323	–34,476	–96,681	128,144	31,463	23,356.53	(6,646.40)	12,577.51	18,885	278,111
23	–47,819	–15,630	–34,476	–97,925	130,706	32,781		(5,115.77)	21,749.59	11,032	289,143
24	–48,776	–15,942	–34,476	–99,194	133,321	34,127		(3,500.96)	22,785.58	11,341	300,484
25	–49,751	–16,261	–34,476	–100,488	135,987	35,499		(1,797.33)	23,862.07	11,637	312,120

System parameters:

- Total initial costs $513,844
- Operating and maintenance $30,325
- Fuel and electricity $9,912
- Debt ratio 90%
- Effective income tax rate 35%
- Energy cost escalation rate 2%
- Debt payment $34,476
- Annual savings $82,888
- Depreciation amount 100%
- Debt term (yrs) 25
- Debt interest rate 5.5%
- Inflation rate 2%

Glossary

Avoided energy costs. Costs, based on developing a new energy system for a utility, that are typically paid to renewable energy providers by the utility for their energy (that is, electricity).

Biomass. Organic matter available on a renewable basis. Biomass includes forest and mill residues, other wood and wood residues, agricultural crops and residues, animal residues, livestock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial residues.

Board foot. A unit of measurement of lumber represented by a board nominally 12 in. long, 12 in. wide, and 1 in. thick (30.5 cm long, 30.5 cm wide, and 2.54 cm thick).

Co-generation. The simultaneous generation of electricity or mechanical energy and low-pressure steam or other form of thermal energy for on-site use.

Kiln. A heated chamber for drying lumber, veneer, and other wood products in which temperature and relative humidity are controlled.

Lumber. The product of the saw and planing mill for which manufacturing is limited to sawing, resawing, passing length-wise through a standard planing machine, crosscutting to length, and matching.

Lumber recovery factor. A unit of measure that relates nominal volume of lumber products in board feet produced for each cubic foot of log processed.

Moisture content (dry basis). The amount of water contained in the wood, expressed as a percentage of the ovendry weight of wood.

Moisture content (wet basis). The amount of water contained in the wood, expressed as a percentage of the green weight of wood.

Nominal size. As applied to timber or lumber, the size by which it is known and sold in the market (often differing from the actual size).

Schedule, kiln drying. A prescribed series of dry- and wet-bulb temperatures and air velocities used in drying a kiln charge of lumber or other wood products.

Seasoning. Removing moisture from green wood through the process of air drying to improve its serviceability.