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Feasibility of Using Wood Wastes to Meet Local Heating Requirements of Communities in the Kenai Peninsula in Alaska

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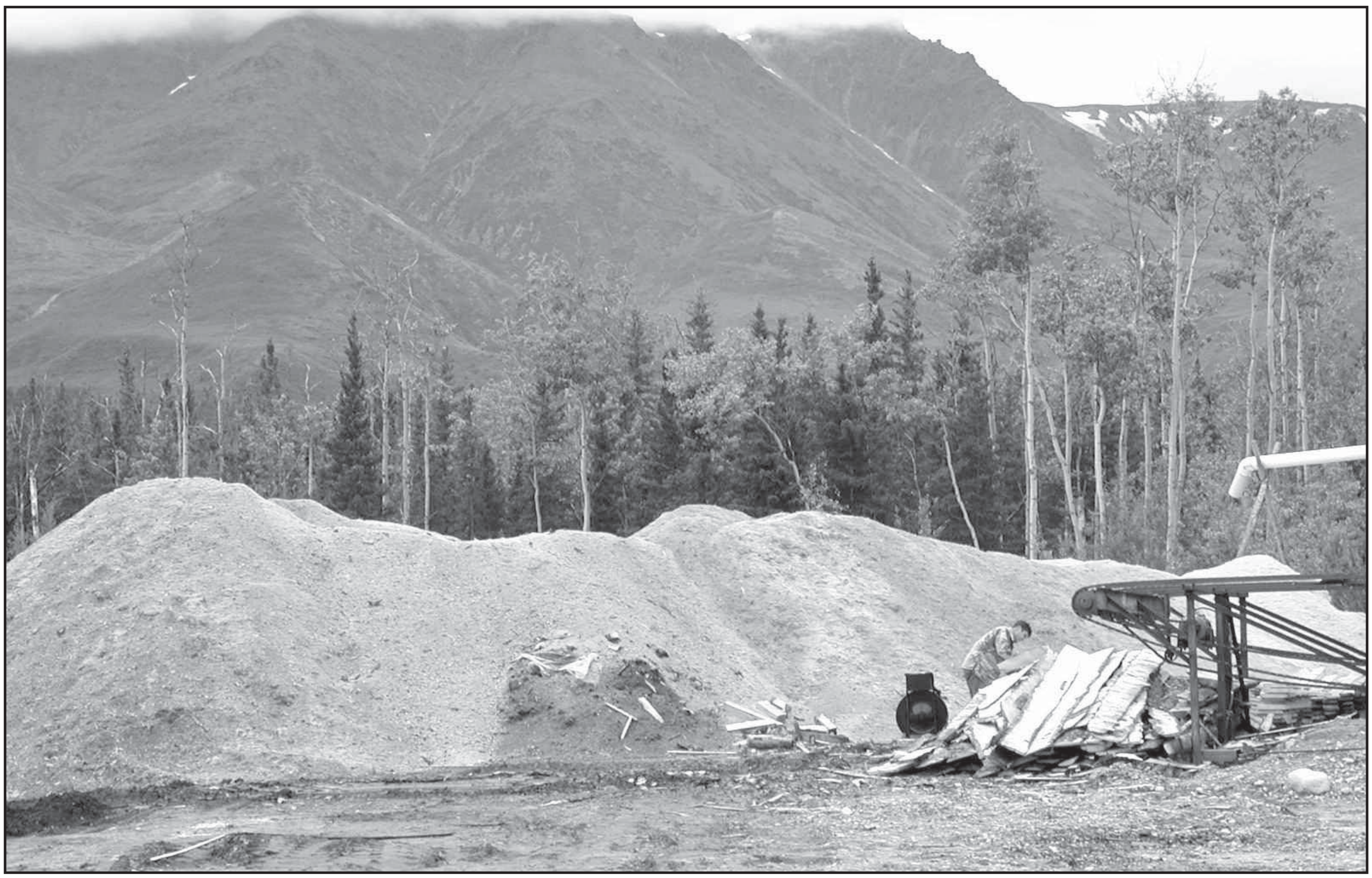

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Abstract

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Wood energy can be important in meeting the energy needs of Alaska communities that have access to abundant biomass resources. In the Kenai Peninsula, a continuing spruce bark beetle (*Dendroctonus rufipennis* (Kirby)) infestation has created large volumes of standing dead spruce trees (*Picea* spp.). For this evaluation, a site in the Kenai-Soldotna area was chosen for a small, industrial-scale (4 million British thermal units (BTUs) per hour) wood-fired hot water heating system, which could be fueled by salvaged spruce timber and also by sawmilling residues. Thirty-six different scenarios were evaluated by using wood fuel costs ranging from $10 to $50 per delivered ton, alternative fuel costs from $1 to $2 per gallon, and fuel moisture contents of either 20 percent or 50 percent (green basis). In addition, two different capital costs were considered. Internal rates of return varied from less than 0 to about 31 percent, and project payback periods varied from 4 years to greater than 20 years. Potential barriers to the long-term sustainability of a wood energy system in the Kenai Peninsula include the availability of biomass material once current spruce salvage activities subside. The estimated wood fuel requirements of about 2,000 tons per year are expected to be easily met by spruce salvage operations over the short term and by sawmill residues after salvage inventories diminish. It is expected that a wood energy system this size would not significantly reduce overall fuel loads in the area, but instead would be a good demonstration of this type of system while providing other community benefits and energy savings.

Keywords: Economics, wood energy, biomass, wood products, Alaska.

Introduction

Biomass energy can be important in meeting the heating needs of facilities that currently depend on fossil fuels. The Kenai Peninsula region of Alaska has abundant forest resources, which include a substantial amount of spruce (*Picea* spp.) wood killed by bark beetles (*Dendroctonus rufipennis* (Kirby)). This region of Alaska holds promise for the development of biomass energy projects not only because of its timber resources but also the presence of an existing timber industry (both processing and logging infrastructure). Salvaged material could be used to produce energy to heat buildings, although its long-term supply might be questionable. Many sawmill facilities in the region would be well positioned to supply wood wastes for fuel if the availability of beetle-killed wood declines. This paper evaluates the economic feasibility of using local forest and sawmill residues to supply a wood-fired hot water system that would provide space heating or process heat at a centrally located site within the Kenai Peninsula.

Kenai Peninsula Wood Products Industry

In the Kenai Peninsula, there are about 10 to 15 sawmill facilities currently producing an estimated 4.5 million board feet (MMBF) of lumber per year, primarily spruce (Kilborn 2000, Parrent 2000b). During the past several decades, improved technologies in Pacific Northwest sawmills—including thinner sawkerfs, smaller green lumber target sizes, and more accurate log positioning systems—have resulted in higher lumber recovery along with corresponding reductions in residue production (Keegan et al., n.d.). Although mill technologies and lumber recovery rates in Alaska are likely not at the same level as mills in the Pacific Northwest, recent work has assessed the lumber recovery of sawmills in most regions of Alaska (Kilborn, in press). Based on the sawing efficiency and lumber recovery expected within the Kenai Peninsula from known wood products producers, an estimated 4,400[1] tons per year of manufacturing residues, including green sawdust, slabs, and edgings, are currently being generated (table 1). After considering minor uses for these residues, such as animal bedding and firewood for residential heating, it is estimated that an amount closer to 4,000 tons per year (11 tons per day, year-round basis) could potentially be available to fuel one or more hot water building heating systems.

Although most, if not all, of the active sawmills in the region are within an economically feasible commuting distance of the Kenai-Soldotna area (about 75 miles), several factors could limit the actual wood waste availability. Many of the smaller sawmills producing less than 1 MMBF of lumber per year may operate intermittently and therefore might not be steady fuel suppliers. Because transportation of small amounts of residue to a wood energy facility might not be practical for some of the smaller sawmills, alternative arrangements to collect wood wastes, perhaps through the facility owners, should be considered. Most sawmills do not have the equipment needed to reduce slabs and edgings to a size needed for automatic fuel handling systems and therefore might be limited to supplying only sawdust as a fuel source. For slabs and edgings to be used as a fuel source, it would be beneficial to have fuel-reduction equipment at a centralized location, or possibly at the biomass energy site itself. In this analysis, we assumed that equipment of this type would be purchased separately from the wood energy system and therefore was not included in the stated project cost.

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[1] Production of manufacturing residues assumes a regional lumber recovery factor of 7.5 from an estimated 12 sawmills operating in the Kenai Peninsula. Three size classes were considered to estimate the actual production from these sawmills (as indicated in table 1).

Table 1—Estimated production of wood wastes from known sawmills in the Kenai Peninsula, Alaska

Sawmills by size class	Number of sawmills	Estimated wood waste production
MBF[a] per year		*Tons per year[b]*
50-250	6	592
250-1,000	4	477
1,000-5,000	2	3,342
Total	12	4,411

[a] Thousand board feet.
[b] Assumes a regional lumber recovery factor of 7.5.

In addition to the freshly cut sawmill residues, a relatively small amount of dry manufacturing residues could be available from secondary manufacturing operations. This fuel source could include planer shavings and dry sawdust and would be primarily limited to white spruce (*Picea glauca* (Moench) Voss), although small volumes of paper birch (*Betula papyrifera* Marsh.) would potentially be available. The inclusion of minor amounts of dry residues lowers the overall fuel moisture content and therefore produces a somewhat greater heat output (British thermal units [BTUs] per pound). Small additions of dry residues would most likely not have a major effect on fuel handling properties, emissions, or other areas of system operation.

Fuel Availability from Beetle-Killed Trees

During the past few decades, a spruce bark beetle infestation has resulted in large amounts of unmerchantable timber in the Kenai Peninsula. In many cases, the timber is still standing but is losing value for lumber or other solid wood products. Since the mid-1980s, bark beetle populations have increased to epidemic levels, thereby resulting in about 400,000 affected acres by the mid-1990s (Kenai Peninsula Online 2000). In many of the timber stands, up to 95 percent of the trees have been killed. The condition of this resource differs considerably from recently killed material, which might be suitable for sawtimber, to more severely deteriorated material, which might be suitable only for wood fuel. Other estimates indicate the spruce bark beetle in the Kenai Peninsula had spread to close to 2.3 million acres by the late 1990s (Kenai Peninsula Spruce Bark Beetle Task Force 1998). Over the longer term, it is estimated that more than 2 billion board feet of timber have been lost because of spruce bark-beetle attacks over the last 25 years (Kenai Peninsula Spruce Bark Beetle Task Force 1998).

Lumber recovery of standing dead timber has been evaluated for beetle-killed spruce trees (Lowell and Willits 1998). In this study, logs were divided into four deterioration classes based on visual inspection, and log value was found to decrease through each successive deterioration class. As logs from beetle-killed trees become less valuable for lumber production because of deterioration, alternative uses for them, such as wood energy, will become more attractive. Indeed, timber sales (including salvage of beetle-killed material) reported by the Kenai Peninsula Borough have increased from about $2.2 million in 1991 to almost $26.1 million in 1998 (Kenai Peninsula Online 2000). Timber sales from Alaska state-owned lands have shown a similar trend, with projected offerings ranging from about 2 MMBF to more than 81 MMBF over the next few years within the Kenai-Kodiak region (Alaska Department of Natural Resources 2000).

Estimates differ as to the "shelf life," or length of time available, to use beetle-killed trees. Some estimates initially suggested an 8- to 10-year window for harvesting trees. Other estimates, based on practical experience, are closer to 4 to 5 years (Kenai Peninsula Online 2000). Other sources indicate any material intended for sawlogs needs to be harvested within the first 3 years after trees are killed. From the fourth to seventh year after mortality, spruce can be used for chips and, to some extent, for house logs. By the eighth year, most of the economic value of beetle-killed trees has been lost, to the extent that even reforestation costs might not be recovered (Committee on Resources, Subcommittee on Forests and Forest Health 1999). Beetle-killed trees that are not removed will eventually become woody debris, contributing to the potential for wildfire. Over the past 10 years, woody debris volumes have, in some cases, increased by a factor of 20 (resulting in up to 40 tons per acre of debris) (Rozell 1997). Based on this information, it seems that much of the beetle-killed spruce is no longer suitable for lumber production but may still have some residual value for biomass energy.

Wood Energy Feasibility

Problem Overview

The feasibility of installing and operating a wood-based energy system also depends on many other factors including system size, fuel costs, wood moisture content, and labor rates. Whether or not the facility will be used year-round or only during peak heating seasons is also an important consideration. In addition, daily usage requirements can differ; for example, schools, residences, and industrial facilities might all have different heating demands. In this feasibility evaluation, biomass from standing dead trees or harvesting residues would be transported to a centrally located energy facility that would include a steam or hot water heating system fueled by wood chips. Heat then would be provided to one or more facilities near the wood energy system, whereas local electrical needs would continue to be met by current systems. The cost of harvesting and transporting salvaged spruce to a centralized energy facility is expected to be one of the key factors influencing the feasibility of this project.

The economic feasibility of wood energy systems depends primarily on wood fuel being less expensive to obtain than heating oil on a long-term basis. For financially attractive systems, this energy savings would offset the higher initial investment and higher maintenance costs associated with wood-fired systems (vs. fossil fuel systems). In general, larger wood energy systems operating continuously at higher energy loads are more economical than smaller systems operating intermittently. The economic suitability of using wood fuel to provide space heat for educational and industrial facilities has been evaluated for several different system sizes (Lin 1981). If wood fuel is available for less than $20 per ton and the price of alternative fuels such as natural gas or fuel oils is about $8 per million (MM) BTU's, then conversion of systems from fossil fuel-based to wood-based is economically feasible.

Biomass energy is often used for wood products producers to generate low-pressure steam for industrial processes, such as heating lumber dry kilns. Here, systems are often run 24 hours per day under steady fuel loads and operating conditions, and steam is usually transported short distances to the point of application. By contrast, wood energy systems for many residential, institutional, and light commercial uses often run intermittently on a daily and seasonal basis. Many of these systems are designed to provide hot water rather than low-pressure steam as the heat transfer medium. Because many wood energy systems cannot be easily turned off to accommodate short-term demand fluctuations, there is often a need for supplemental heating (typically fossil fuel) as a system backup or used in conjunction with the wood energy system during normal operation. Alternatively, some systems are characterized by their ability to operate at less than rated capacity and may include automatic ignition features to turn the systems on or off under certain conditions. Systems having lower "turn-down" ratios would be better suited for situations having nonuniform energy demands. Thermal storage systems (for example, insulated hot water tanks) would be another alternative for providing heat when it is needed. Several important site-specific factors about the design of wood energy systems for space heating have been identified (USDA FS 1982):

- Annual energy demands
- Maximum heating requirements
- Supply and cost of wood fuel
- Availability and cost of labor
- Equipment layout and other site factors including the availability of auxiliary equipment
- Current or existing space heating system

Once these factors have been evaluated, system components can then be designed. These typically include fuel handling and storage systems, fuel firing system, emission control, and ash disposal systems.

Wood Energy Feasibility

Kenai Peninsula Sites

The Kenai Peninsula Borough covers about 26,000 square miles and is located south of Anchorage, Alaska (fig. 1). Along the westernmost and southern parts of the peninsula are areas of private land, several population centers, and much of the region's wood products industry. About half of the population of the Borough's 47,000 people live near several communities, including Seward, Homer, Kenai, and Soldotna (fig. 2). This population center is centrally located within the western part of the Kenai Peninsula and is bordered to the west by the Cook Inlet. The population center is within convenient commuting distances of most area sawmills, and because it is also close to large tracts of beetle-killed timber, it was chosen as the study area of a conceptual wood energy system in this evaluation.

Wood Energy Feasibility

Computer Evaluations

Computer programs such as the wood energy financial analysis model (WEFAM) can be used to obtain a preliminary analysis to evaluate the feasibility of converting to wood energy from an alternative fuel source (Michigan Department of Commerce, Public Service Commission 1988a). The program uses 10 inputs that relate to the proposed wood energy system (table 2). Results include cash flow and energy savings information over a 20-year planning horizon as well as internal rate of return and project payback period. Inputs that cannot be measured accurately can be estimated at different levels for separate computer runs. In this way, any number of scenarios can be modeled by adjusting the levels of selected inputs. In the current evaluation of the Kenai Peninsula, the three primary variables of interest were wood fuel cost (dollars per ton), cost of alternative fuel (dollars per gallon), and wood fuel moisture content (percentage, green basis). It was expected that these factors would differ with transportation distance, harvesting costs, time since infestation, and fluctuations in fuel oil prices. Several factors were held constant in the financial model, including the discount rate (7 percent) and the inflation rate (4 percent per year for years 1 to 10 and 7 percent per year for years 11 to 20).

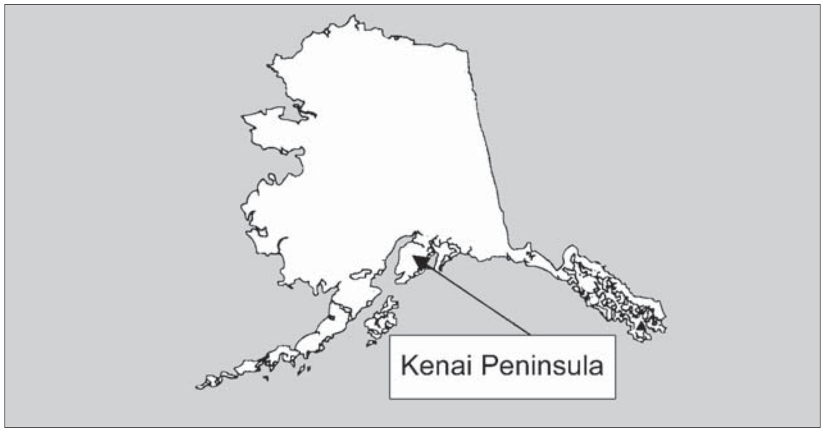
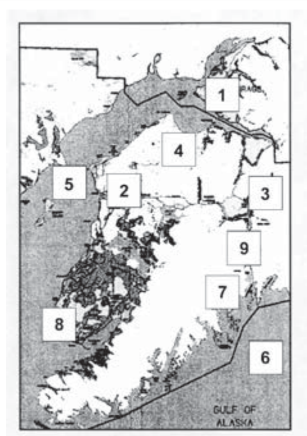


Figure 1—State of Alaska, with Kenai Peninsula indicated by the arrow.



1. Anchorage, AK
2. Kenai/Soldotna, AK (site of proposed facility)
3. Chugach National Forest
4. Kenai National Wildlife Refuge
5. Cook Inlet
6. Gulf of Alaska
7. Kenai Fjords National Park
8. Homer, AK
9. Seward, AK

Figure 2—Proposed site of the wood energy facility (Kenai, Alaska) and other points of interest.

Table 2—Wood energy system information needed for computer evaluations

Input	Units
Wood energy system size	Million BTUs[a] per hour
Current fuel used	Fuel type
Current fuel (annual usage)	Units appropriate for fuel type
Current fuel cost	Dollars per year
Wood moisture content	Percentage of total weight
Cost of wood	Dollars per ton
System operation	Hours used per day
System operation	Days used per year
Employee wage rate	Dollars per hour
Capital cost of wood energy system	Dollars

[a] BTU = British thermal unit.

Review of Key Economic Variables

Wood Fuel Properties and Availability

Wood moisture plays an important role in combustion efficiency, which in turn determines how much usable heat can be produced from the wood fuel. Fuel with more moisture is also heavier and therefore can be more difficult and costly to transport than drier fuels. Moisture content also influences fuel handling properties, and within the wood energy system, this would include conveyors, augers, and fuel storage bins. Fuel moisture may also affect chipping and other mechanical reduction processes, especially as relates to particle size distributions, which in turn can influence wood combustion properties. In this evaluation, it was assumed that all fuels would be reduced to chip-sized particles before being burned (that is, the energy system would not be able to accommodate slabs, edgings, or branches in their original sizes).

The moisture content for freshly cut Sitka spruce (*Picea sitchensis* (Bong.) Carr.) sapwood is typically greater than 50-percent moisture content, green basis (Forest Products Laboratory 1999). In the Kenai Peninsula region, beetle-killed timber and slash would be expected to be considerably drier than these values. Based on these conditions, we evaluated two moisture content classes: (1) 45-percent moisture content green basis (typical of recently killed trees) and (2) 20-percent moisture content green basis (typical of trees that have been standing dead for a while) (fig. 3). It was expected that given the length of time since the beetle infestation, this range of wood fuel moisture would encompass most of the currently available slash and harvesting residues in the Kenai region. One advantage of using fuels with low moisture content, such as partially dried beetle-killed timber, is that it produces a greater heat output per pound of fuel when compared to wetter fuels, such as freshly cut sawmill residues. Typically, net heating values[2] for green (freshly harvested) fuels with 50-percent moisture are close to 3,650 BTUs per pound, whereas net heating values for dry fuels with 10-percent moisture are about 6,100 BTUs per pound (USDA FS 1982). The heating advantages of using drier beetle-killed timber, however, need to be weighed against the possibility of wood decay and loss of wood integrity, which could negatively affect fuel values. In addition, mixing high and low moisture content fuels potentially could affect the performance of wood energy systems, including fuel handling and combustion efficiency, and would therefore require careful monitoring. Specifically, drier fuels could be more difficult to chip than green fuels, unless decay has occurred.

Although abundant wood wastes are locally available in the Kenai region, harvesting, transportation, and unloading costs need to be considered to determine the actual (delivered) fuel cost. Even when low cost fuel is available in salvage operations, the remaining costs could be significant. Given the expected fuel availability and transportation costs in the Kenai region, the sensitivity analysis we used considered wood fuel costs ranging from $10 to $50 per delivered ton (at 20- or 45-percent moisture content, green basis). The wood fuel cost per bone dry ton varied over a wide range, depending on moisture content and delivered fuel price. We assumed that sawmill residues, such as sawdust, slabs, and edgings would be available at the lower end of the price spectrum and that harvested residues and beetle-killed salvage material would be more expensive. Based on a similar evaluation for a wood-fired system in northern climates, we estimated that the system on the Kenai Peninsula would require nearly 2,000 tons per year of fuel

[2] Net heating value is the potential energy available in the wood fuel as received, taking into account the energy that will be lost in evaporating and superheating the water when the wood fuel burns (Jahn 1985).

Wood energy system	Wood fuel variables
Fuel usage:[a] • 1 million BTUs[b] per hour average load • 8,364 million BTUs per year	Wood fuel moisture content (green basis): • 25 percent • 40 percent
Annual cost of alternative fuel source: • Fuel oil no. 2 • $1.43 per gallon—$85,798 per year • $1.00 per gallon—$60,000 per year • $2.00 per gallon—$120,000 per year	Cost of wood fuel: • $10 per ton • $30 per ton • $50 per ton
Cost of wood energy system: • $500,000 • $700,000	

[a] Equivalent of 60,000 gallons per year of no. 2 fuel oil.
[b] British thermal units.

Figure 3—Wood energy and wood fuel variables used in economic feasibility evaluation of system proposed for the Kenai Peninsula.

Table 3—Current market prices for selected home heating fuels in the Kenai Peninsula, Alaska[a]

Fuel	Current market price (dollars per gallon)	Minimum purchase (gallons)	BTUs[b] per gallon	Dollars per MM BTUs[b]
No. 1 fuel oil	1.54[c]	200[b]	135,500	11.37
No. 2 fuel oil	1.43[c]	200[b]	139,400	10.26
Propane	2.06[d]	100[c]	91,500	22.51

[a] All prices include home delivery.
[b] British thermal units.
[c] Anon. 2001.
[d] Hoagland 2001.

at about 50-percent moisture content (Nicholls et al. 1992). Although precise estimates of salvage fuel inventories are not available, we expect that the relatively small volumes of residue needed (2,000 tons per year) could be easily supplied from nearby salvage activities. If the current inventory of beetle-killed material is used over the next several years, sawmilling residues such as sawdust and edgings could be used to a greater degree from that point onward, assuming that current levels of lumber production continue in the Kenai region. This illustrates, however, one of the potential liabilities of making capital investments in wood energy systems without the assurance of a long-term fuel supply.

Review of Key Economic Variables

Alternative Fuel Costs

In the Kenai Peninsula, fuel oil is a common fuel for residential heating. Current delivered price for no. 2 fuel oil in the Kenai Peninsula is about $1.43 per gallon as of March 2001 (table 3) (Anon. 2000). This value was used as the basis for alternative fuel cost comparisons in the computer economic evaluation. Two additional values ($1 and $2 per gallon) were used in the sensitivity analysis to allow for significant movements in the price of no. 2 fuel oil (fig. 3). Natural gas is also readily available as a heating fuel in the Kenai Peninsula but was not considered in this evaluation.

Review of Key Economic Variables

Wood Energy System Capital Cost

The total capital cost of installing a wood energy system is directly related to system size, which in turn can be influenced by local fuel availability. Most small industrial systems are classified according to their capacity to produce heat in MM BTUs per hour. To ensure efficient operations, it is important to match the system size to the fuel supply that is expected on a long-term basis. Typical planning horizons can be 20 years or longer, which is the timeframe that our computer evaluation used.

The capital cost levels considered in this evaluation were based on expected purchase and installation costs for all major system components for a 4-MM-BTUs-per-hour hot water system fueled by wood chips (Diskin 2000). Two system costs were evaluated—a base system that cost $500,000 and a system complete with backup energy source that cost $700,000 (fig. 3). The more expensive system included an allowance for cost overruns and unexpected expenses that were not considered with the base system. These costs are expected to be typical of stand-alone biomass energy facilities in Alaska and include delivery and installation costs to the Kenai Peninsula location (Crimp and Adamian 2000). Total project cost was for the complete system and included the thermal system, fuel storage and handling systems, emission control equipment, plumbing and wiring work, installation, and startup expenses. Site preparation and foundation costs also were included in this evaluation, but land purchase costs were not.

Review of Key Economic Variables

System Operation and Heating Season

The boiler utilization rate (BUR) is an important consideration in the use of wood-fired boilers, especially for public buildings, offices, schools, and other buildings that do not require around-the-clock heating. The BUR considers several factors including fuel consumption, fuel energy value, boiler efficiency, boiler rating, and hours of operation per year (Sarles and Rutherfoord 1982). Because most offices and workspaces are heated only 40 hours per week and do not require heat on a year-round basis, the average annual BUR might be as low as 10 to 15 percent (Sarles and Rutherfoord 1982). Industrial facilities, including dry kilns and other year-round wood products facilities, would be expected to have considerably higher BURs than offices and workspaces. For this evaluation, the BUR was an average of the BURs for office spaces and industrial facilities. We assumed energy demands for the system to be equivalent to 60,000 gallons of no. 2 fuel oil per year. This level of use would be close to operating the 4-MM-BTU-per-hour system at about 25 percent of its capacity on a year-round basis; of course seasonal demands would vary, ranging from high usage during winter to low usage (or none) during summer. Building heating loads are given as a means of comparing different types of facilities that might require space heating from biomass energy systems.

Review of Factors Remaining Constant in Evaluation

Several of the variables in the economic analysis were considered at only one level as they could be estimated fairly easily. These included the system operation at 24 hours per day, 240 days per year (based on an 8-month heating season). Note that commercial and institutional facilities such as schools would probably have daily heating requirements less than 24 hours, even during winter when energy demands would be greatest and so our evaluation might overestimate actual needs. To compensate for this, we assumed that the boiler, rated at 4 MM BTUs per hour, would operate at an average output of only about 1 MM BTUs per hour throughout the course of a heating season. The computer evaluation also required information about price increases due to inflation (since the base year of 1982), which was estimated to be a 52-percent increase (Alaska Department of Labor 2000). We also assumed that the wage rate for operators would be $20 per hour.

In addition, the computer model assumed a discount rate of 7 percent throughout the 20-year planning horizon, an inflation rate of 4 percent for years 1 to 10, and an inflation rate of 7 percent for years 11 to 20. The net heating values for wood fuel were assumed to be 5,282 BTUs per pound for 20-percent moisture content fuel and 3,275 BTUs per pound for 45-percent moisture content fuel (Michigan Department of Commerce, Public Service Commission 1988b).

Energy Alternatives—Comparison to Lumber Drying Systems

We compared the proposed energy system and an equivalent system for drying lumber. The thermal system we describe could easily be used to provide heat for one or more lumber dry kilns. Here, energy demands would be fairly constant and predictable throughout the year. The 4-MM-BTUs-per-hour energy system could provide heat to a dry kiln about 60 thousand board feet (MBF) in size, reaching maximum drying temperatures of about 140 °F. Drying conditions typical for the Kenai Peninsula wood products industry would include white spruce dimension lumber, which would be dried from initial (green) conditions of 70- to 80-percent moisture content to final kiln-dried conditions of 15- to 19-percent moisture content in about 4 to 5 days. Typical lumber thicknesses would range from 1 to 2 inches. Under these conditions, it is expected that the 4-MM-BTUs-per-hour system, if operated on about a year-round basis, could dry up to 3,000 MBF of lumber annually.

Results

A payback period represents the time necessary for a capital investment to accumulate savings or income equivalent to the original investment. Payback periods for the most and least favorable cases ranged from 4 to greater than 20 years, respectively, and internal rates of return ranged from below 0 to about 31 percent (figs. 4 through 7). Complete results for all 36 scenarios also are provided (see app., tables 5 and 6). Wood fuel prices and wood moisture content were shown to be important economic considerations for wood energy systems (table 4). The most favorable scenarios generally were those having low wood fuel costs, low fuel moisture content, and high alternative fuel costs. By contrast, the least favorable scenarios generally were those having high fuel costs, high fuel moisture content, and low alternative fuel costs. Fuels with higher moisture content would be expected to burn less efficiently than drier fuels and result in less usable heat per delivered ton of wood. Fuel moisture content could become an important consideration as woody debris and salvaged timber are used from beetle-killed spruce trees that have been dead for several years and have experienced a certain amount of drying on site. The lower project cost was generally associated with shorter payback periods and higher rates of return, other variables being equal. This could be reasonably expected because the normal operation of the two different systems would be the same, but the more expensive system would have additional features, including a backup energy system.

Our evaluation showed that beetle-killed salvage material should have strong economic potential for use as wood energy. Regions within a convenient transportation distance of the wood energy site should be able to easily supply the approximately 2,000 tons per year fuel requirements over the short term. Any biomass shortfalls from the salvage material could be compensated for with some of the estimated 4,000 tons per year of locally available sawmilling residues.

Several additional factors could result in even greater economic potential for establishing wood energy systems. Because this analysis assumed that no. 2 fuel oil was the alternate fuel, at $1.43 per gallon, any future price increases in alternative heating fuels would result in greater favorability for wood energy systems. If a nearby sawmill were

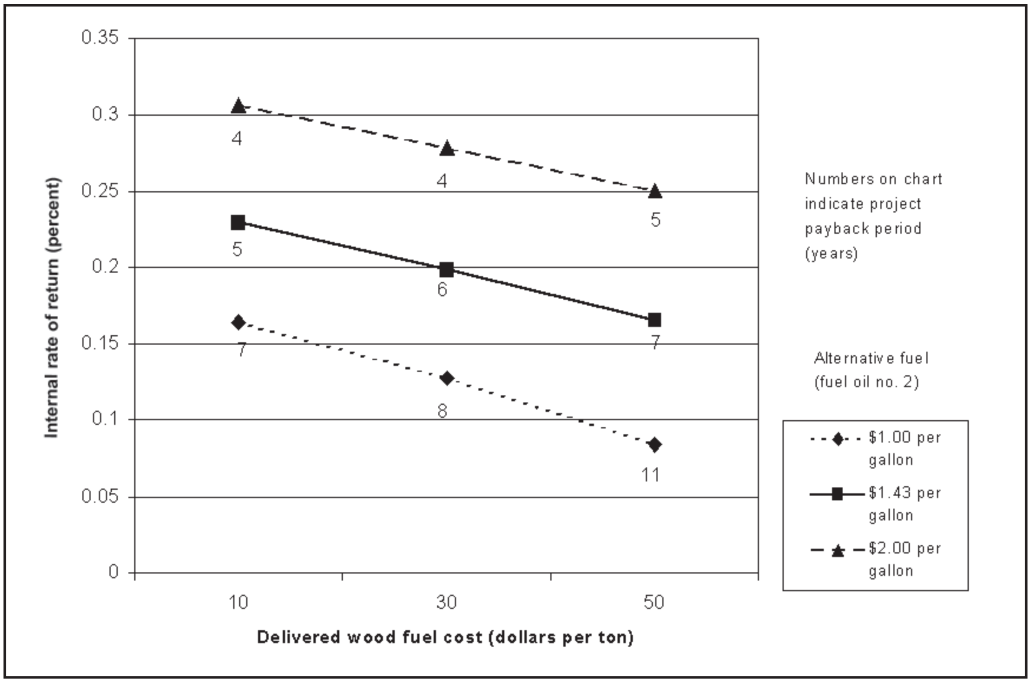


Figure 4—Internal rate of return and payback period for wood energy system utilizing Kenai Peninsula wood wastes under a scenario of 20-percent wood moisture and a system cost of $500,000.

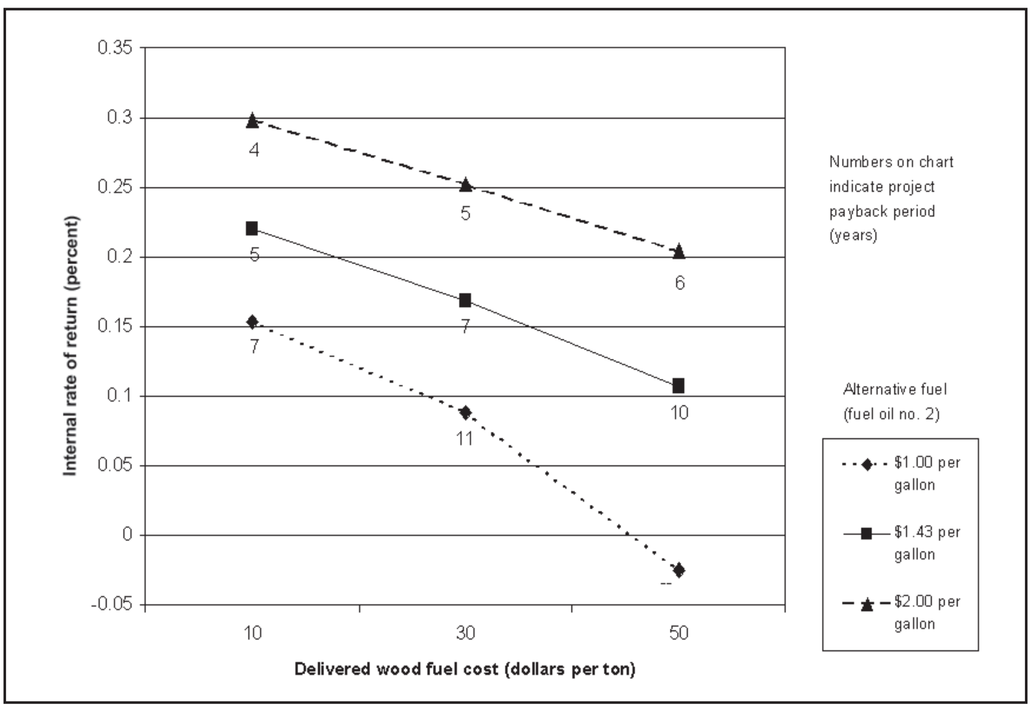


Figure 5—Internal rate of return and payback period for wood energy system utilizing Kenai Peninsula wood wastes under a scenario of 45-percent wood moisture and a system cost of $500,000.

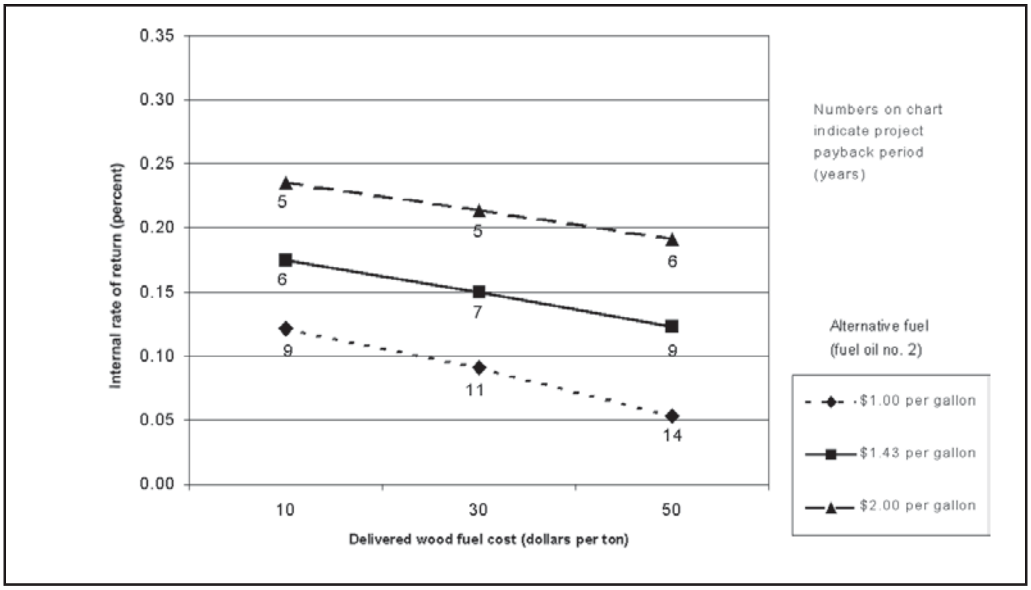


Figure 6—Internal rate of return and payback period for wood energy system utilizing Kenai Peninsula wood wastes under a scenario of 20-percent wood moisture and a system cost of $700,000.

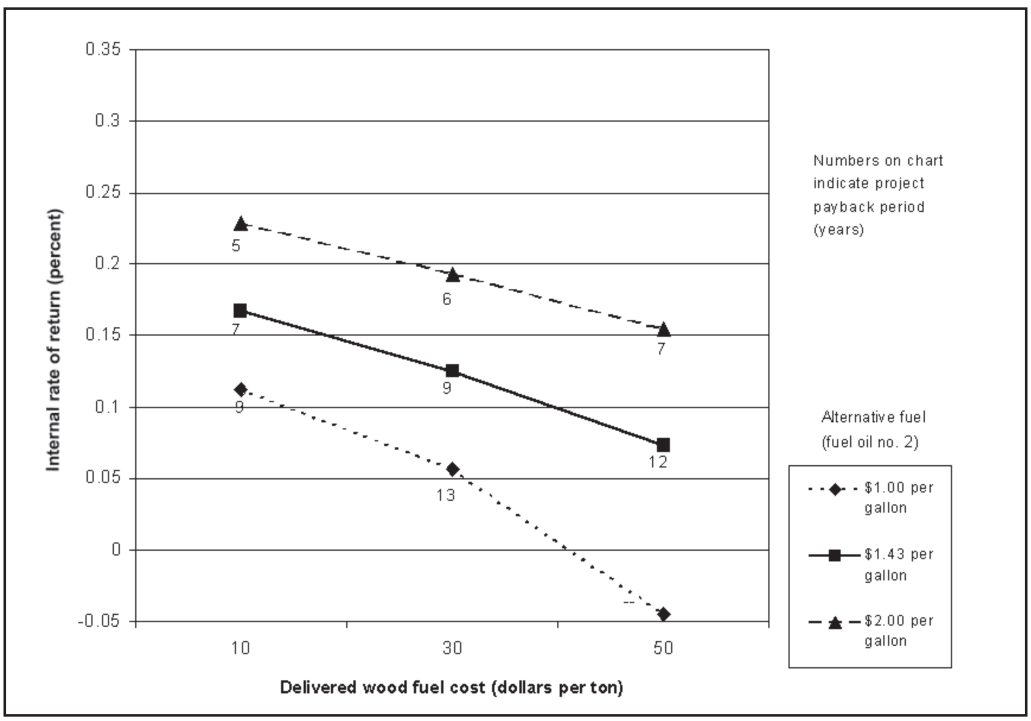


Figure 7—Internal rate of return and payback period for wood energy system utilizing Kenai Peninsula wood wastes under a scenario of 45-percent wood moisture and a system cost of $700,000.

Table 4—Most favorable and least favorable scenarios for wood energy computer evaluations for proposed system in the Kenai Peninsula, Alaska

	Most favorable scenarios			Least favorable scenarios		
Alternative fuel cost (dollars per gallon)	2.00	2.00	2.00	1.00	1.00	1.00
Wood fuel moisture content (percent)	20	45	20	45	45	20
Cost of wood fuel (dollars per ton)	10	10	30	50	50	50
System cost (dollars)	500,000	500,000	500,000	700,000	500,000	700,000
Project payback period (years)	4	4	4	20+	20+	14
Internal rate of return (percent)	30.66	29.816	27.88	-4.480	-2.518	5.33

willing to supply waste residues in the price range of $10 per ton, project economics would be favorable. Having a wood energy system near wood products manufacturers who generate large amounts of wood waste might favor low wood fuel costs. Conversely, if harvesting and transportation costs are more expensive than expected (and wood fuel was available only at $50 or more per ton), this would result in less favorable project economics than in the current evaluation. The analysis was based on operating conditions typical to public facilities such as schools, which would be operating about 240 days per year (8 months). For facilities operating year-round, shorter payback periods would be expected because there would be no change in the original capital investment, but the economic benefits would be accruing over 12 months per year rather than over a shorter heating season.

Conclusions

This evaluation supports the economic and technical feasibility of using a small (4-MM-BTUs-per-hour) wood-fired thermal system to meet a portion of the local heating needs in the Kenai Peninsula. Project payback periods are as short as 4 years (using $10 per ton fuel at 20-percent moisture content) to as long as 20 or more years (using $50 per ton fuel at 45-percent moisture content). Fuel moisture content, which is influenced by the length of time since bark-beetle infestation, would become an important consideration for many of the technical aspects of the project including transportation, fuel storage and handling, and heat output. Moisture content has an effect on project profitability but to a smaller degree than wood fuel costs.

We expect that over the short term, beetle-killed salvage material within an economic transportation distance of Kenai can meet the approximately 2,000 tons per year fuel requirement. Over the longer term, a portion of the region’s estimated 4,000 tons per year of sawmilling residues could be used as needed. Given the large areas (estimated at up to 2 million acres) and large timber volumes (up to 2 billion board feet) affected by the spruce bark beetle, an individual wood energy project of the magnitude described in this report would probably make only modest reductions in the available fuel. The existing wood products industry, infrastructure, and location of communities within the Kenai Peninsula could enable several facilities of the size described in this paper. Larger scale projects, including electrical energy or cogeneration facilities would have the potential for utilizing larger amounts of fuel but would require careful consideration of project economics and long-term fuel supplies.

Metric Equivalents

1 mile = 1.609 kilometers
1 acre = 0.407 hectare
1 gallon = 3.785 liters
1 ton = 907.2 kilograms

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Table 5—Results of wood energy financial analysis model computer evaluations for $700,000 system cost [a b c]

Scenario	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Cost of alternative fuel (no. 2 fuel oil, dollars per gallon)	1.00	1.00	1.00	1.00	1.00	1.00	1.43	1.43	1.43	1.43	1.43	1.43	2.00	2.00	2.00	2.00	2.00	2.00
Cost of wood fuel (dollars per ton)	10	10	30	30	50	50	10	10	30	30	50	50	10	10	30	30	50	50
Wood moisture content (percent, green basis)	20	45	20	45	20	45	20	45	20	45	20	45	20	45	20	45	20	45
Payback period (years)	9	9	11	13	14	>20	6	7	7	9	9	12	5	5	5	6	6	7
Internal rate of return (percent)	12.18	11.28	9.08	5.67	5.33	-4.48	17.49	16.75	15.00	12.52	12.29	7.34	23.55	22.90	21.39	19.33	19.14	15.44

[a] All evaluations assumed the following conditions:
- Average annual output of burner is equivalent to 25 percent of its maximum rated capacity.
- Wage rate of boiler operator is $20 per hour.
- Total price increases since base year of 1982 = 52 percent.
- Assumes system operation of 24 hours per day, 240 days per year.
- Dry basis moisture contents equivalents are: 20-percent green basis = 25-percent dry basis; 45-percent green basis = 81.8-percent dry basis.

[b] Constants:
- System size: 4 MM British thermal unit (BTUs) per hour.
- Existing fuel usage: 8,364 MM BTUs per year.

[c] Alternative fuel properties:
- Alternative fuel: no. 2 fuel oil.
- Current delivered cost of alternative fuel: $1.43 per gallon.
- Sensitivity evaluation costs: $1 per gallon, $2 per gallon.
- Heat output of alternative fuel: 139,400 BTUs per gallon.
- Total amount of alternative fuel displaced by wood energy system: 60,000 gallons per year.

Table 6—Results of wood energy financial analysis model computer evaluations for $500,000 system cost [a b c]

Scenario	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Cost of alternative fuel (no. 2 fuel oil, dollars per gallon)	1.00	1.00	1.00	1.00	1.00	1.00	1.43	1.43	1.43	1.43	1.43	1.43	2.00	2.00	2.00	2.00	2.00	2.00
Cost of wood fuel (dollars per ton)	10	10	30	30	50	50	10	10	30	30	50	50	10	10	30	30	50	50
Wood moisture content (percent, green basis)	20	45	20	45	20	45	20	45	20	45	20	45	20	45	20	45	20	45
Payback period (years)	7	7	8	11	11	>20	5	5	6	7	7	10	4	4	4	5	5	6
Internal rate of return (percent)	16.43	15.36	12.76	8.81	8.42	-2.52	22.94	22.02	19.86	16.84	16.56	10.72	30.66	29.82	27.88	25.25	25.01	20.391

[a] All evaluations assumed the following conditions:
- Average annual output of burner is equivalent to 25 percent of its maximum rated capacity.
- Wage rate of boiler operator is $20 per hour.
- Total price increases since base year of 1982 = 52 percent.
- Assumes system operation of 24 hours per day, 240 days per year.
- Dry basis moisture contents equivalents: 20-percent green basis = 25-percent dry basis; 45-percent green basis = 81.8-percent dry basis.

[b] Constants:
- System size: 4 MM British thermal units (BTUs) per hour.
- Existing fuel usage: 8,364 MM BTUs per year.

[c] Alternative fuel properties:
- Alternative fuel: no. 2 fuel oil.
- Current delivered cost of alternative fuel: $1.43 per gallon.
- Sensitivity evaluation costs: $1 per gallon, $2 per gallon.
- Heat output of alternative fuel: 139,400 BTUs per gallon.
- Total amount of alternative fuel displaced by wood energy system: 60,000 gallons per year.

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