FINAL REPORT

OPPORTUNITIES FOR IMPROVED UTILATION OF WASTE WOOD THROUGH A BROADER USE OF OUTDOOR WOOD FURNACES IN RESIDENTIAL HEATING APPLICATIONS

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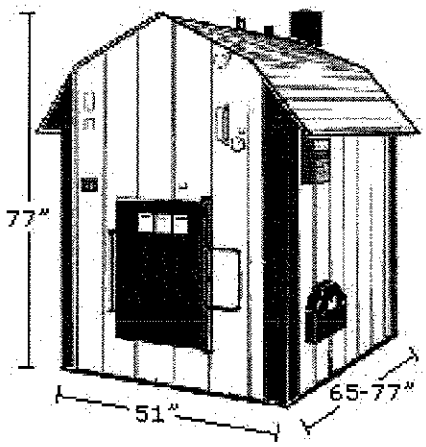

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Introduction

The following report was created in response to the community initiated proposal aimed at examining the opportunities and barriers associated with the wider spread adoption of outdoor (chunk)wood furnaces. It has been proposed that ample supply of readily available wood could be used in Southeastern Minnesota, and in doing so could produce the following benefits:

1. A reduction in residential homeowners' heating costs
2. An increase in locally spent dollars to process this wood for residential use
3. A renewable wood resource is better utilized, thus reducing waste streams and reducing dependence on fossil fuels produced out-of-area.

Our report begins with an overview and definition of outdoor wood stoves, a brief review of waste wood streams and volume in Minnesota, an analysis of residential heating costs by fuel type, and some verbatim discussions of current users of outdoor wood furnaces. From there, we proceed with a discussion of industrial suppliers' perceptions and willingness to supplier wood for residential heating purposes (primary and secondary processors). Finally, we explore the perceptions of residential homeowners in the region – gaining insight into their current heating methods, satisfaction levels, likelihood to switch heating sources, and overall perceptions of outdoor wood furnaces.

Although the results of this research suggest that substantial opportunities may exist to further promote the residential use of outdoor wood furnaces in the region, a number of obstacles must be overcome: 1) additional research is needed to support many of the efficiency claims of many outdoor wood furnace manufacturers; 2) the potential market for such furnaces must still be restricted to rural environments where emissions are no burden to neighbors or local ordinances; 3) although a number of local businesses have expressed an interest in supplying wood for this application, it does not appear that industrial sources of wood waste would provide the volume, desire, or infrastructure to distribute waste streams sufficient to support widespread use of outdoor wood furnaces.

Overview: Outdoor Wood Boilers/Stoves/Furnaces

For purposes of this paper, outdoor wood furnaces, outdoor wood boilers, and outdoor wood stoves are one in the same. Outdoor wood furnaces are becoming increasingly popular among those who live in rural areas, have a large amount of junk wood on their property or easy access to cheap wood, those who want to use renewable resources instead of or to reduce the use of fossil fuels. While this particular research focuses on the use of outdoor wood furnaces for residential use, this technology is quite often used for what woodheat.org describes as 'mini-district heating', "in which two or more buildings are hated from the same boiler. Farming operations in which outbuildings must be heated, or repair garages next to houses are good applications of the technology."

The EPA National Risk Management Research Laboratory offers the following description taken from EPS/600/DR-98/017 February 1998 entitled Emissions from Outdoor Wood Burning Residential Hot Water Furnaces:

Modern outdoor residential wood-burning hot water furnaces are freestanding units situated outside the envelope of the structure to be heated. They typically consist of a firebox and water reservoir, assembled in a horizontal configuration. Hot combustion gases flow from the firebox at one end, through channels or tubes in the water reservoir to the stack. The gases may pass through the water reservoir once to the stack at the end opposite the firebox (one pass) or an additional set of pipes may bring the gases back to the stack located above but isolated from the combustion chamber (double pass). The heated water is pumped through radiators in the dwelling or through a heat exchanger in the heating, ventilation, and air-conditioning (HVAC) duct in response to the home thermostat. A separate pipe coil in the water reservoir may be used to provide domestic hot water, year-round if desired. The furnace draft is controlled by a thermostat monitoring the temperature of the water in the reservoir.

Major Sources of Wood Residue

Most rural Minnesotans who use an outdoor boiler do not purchase cordwood to burn due to the extreme cost, plus many have access to wood on private lands or pick up wood residue from a sawmill. The following sources of wood residue are viable options for the fuel sources.[1]

1) Forest Biomass – wood left on the forest floor including growing stock tops, cull tree boles, cull tree tops, dead tree boles, and dead tree tops.
2) Primary processor residue from Primary manufacturers (sawmill, veneer mill, post and pole treaters, shaving mills, roundwood chippers, and pulpwood mills)
    a. Sawmill: (listed in order of largest volume of unused waste wood): sawdust and shavings, slabs and edging with bark, slabs and edgings without bark, bark
    b. Pulpwood: bark and fines (undersized chips or flakes and sawdust material)
3) Secondary Processor Residue from Secondary Manufacturers (companies who use lumber or other wood products produced by primary processors to manufacture products such as cabinets, windows, moldings, pallets, etc.)
    a. Lumber scraps, chips, saw and sander dust, shavings, sawdust and shavings, panel scraps, treated woods, and mixes (can include non-wood wastes such as metals and plastics)
4) Urban Wood Wastes – tree and yard wastes
5) Construction and Demolition Landfills
6) Municipal Solid Waste Landfills
7) Railroad Ties

The following table provides a summary of the general types of wood waste available in Minnesota as well as estimated volumes (by weight).

[1] This study is primarily concerned with 1-3, with an emphasis on 2 and 3.

Total Wood Waste Available for Energy and Other Uses in 1993			
	Total	**Utilized**	**Net Available**
Forest Biomass - Based on Mechanical Harvest Systems - Green Tons (50% MC)			
Growing Stock Tops	1,029,800		
Cull Tree Boles	1,304,800		
Cull Tree Tops	190,300		
Dead Tree Boles	344,600		
Dead Tree Tops	55,000		
Total Forest Biomass	**2,924,500**	**748,900**	**2,175,600**
Primary Wood Processing Industries - Green Tons (50% MC)			
Sawmills and Related Industries			
Bark	137,450	117,400	20,050
Slabs and Edgings with Bark	177,800	143,600	34,200
Slabs and Edgings without Bark	305,550	301,950	3,600
Sawdust and Shavings	244,000	197,850	46,150
Pulpwood Based Industries			
Bark	733,400	726,600	6,800
Fines	242,600	242,600	0
Total Primary Waste Wood	**1,840,800**	**1,730,000**	**110,800**
Secondary Wood Processing Industries - Dry Tons (8% MC)			
Sawdust	29,730	25,680	4,050
Shavings	5,950	4,400	1,550
Sawdust and Shavings	136,550	121,620	14,930
Chips	36,970	36,970	0
Lumber Scraps	34,260	21,980	12,280
Panel Scraps	1,980	380	1,600
Lumber and Panel Scraps	20,500	12,620	7,880
Lumber, Sawdust, and Shavings	19,790	12,010	7,780
Treated Wood	5,590	5,180	410
Mixed Waste Wood	175,550	140,070	35,480
Total Secondary Waste Wood	**466,870**	**380,910**	**85,960**
Urban Waste Wood			
Twin City Metro Area Tree Waste - Green Tons	326,000	185,900	140,100
Wood in Municipal Solid Waste - Dry Tons	245,600	0	245,600
Demolition Wood - Dry Tons	313,400	0	313,400
Railroad Ties - Dry Tons	40,000	40,000	0
Total Urban Waste Wood	**925,000**	**225,900**	**699,100**
Total Waste Wood	**6,157,170**	**3,085,710**	**3,071,460**

*Chart modified from Minnesota DNR's 1994 Wood Waste Study, "One Man's Trash is Another Man's Treasure"

Wood Fuel

Fuel sources are generally compared using the heat available measured in British Thermal Units (BTUs). One BTU is defined as the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit. MMBTU is million BTUs.

According to the Wisconsin Energy Bureau Department of Administration brochure entitled Meeting Wood Industry Energy Needs with Waste Wood, the most important characteristics of wood as a fuel source are: moisture content, ash, density, and uniformity.

Softwoods generally burn very hot and fast and are difficult to ignite due to the high resin content, all this producing more emissions and creosote. Hardwoods generally burn longer and cleaner, forming less creosote, at lower temperature but are more difficult to ignite. The dryer the wood the higher the heat content, although one pound of oven dried wood has a heating value of 8600 BTU, regardless of species. The heating values differ between species due to the wood density.

Wood Species	Total heat content/cord (MMBTU)-a,b,c
American Elm	20.0
Aspen	15.0
Basswood	13.8
Beech	24.8
Black Birch	26.2
Black Locust	29.2
Bluebeech	25.4
Butternut	15.6
Cherry	20.6
Cottonwood	15.8
Green Ash	22.9
Hard Maple	23.7
Hemlock	16.5
Honeylocust	25.6
Hophornbeam	27.9
Red Maple	21.2
Red Oak	24.6
Red Pine	17.9
Shagbark Hickory	28.3
Sycamore	20.0
Walnut	22.5
White Ash	24.2
White Oak	26.3
White Pine	14.6
Willow	15.6
Yellow Poplar	17.5

*Chart adapted from *Fuelwood and Wood Burning Stoves*, Special Circular 249, p4-5, The Pennsylvania State University, Cooperative Extension Service, University Park, Pennsylvania.
a-Weight per cubic foot at 20% MC, commonly obtained when wood is air-dried.
b-Stack of wood 4' x 4' x 8' or 128 ft^3 of wood and air, assume average cord contains 80 ft^3 of solid wood.

An important consideration is where the wood will be stored. Green mill residue has a moisture content (MC) greater than 20% and therefore can be stored outside in piles. However, burning fuel with a high moisture content (MC>20%) greatly decreases the efficiency, as the water has to be burned out of the wood first. Dry mill residue has a MC less than 10%. This should be stored inside so the moisture content does not increase.

Fuel Cost Comparison

Minnesota residents use a variety of heat sources for their home heating and hot water including: No. 2. fuel oil, No. 1 fuel oil (kerosene), propane, natural gas, electricity, coal, wind, wood, and corn as found from the homeowner survey. The Energy Efficiency and Renewable Energy Network (EREN) section of the U.S. Department of Energy recommends the following method for comparing fuel costs. They strongly advise that fuel prices should not be the sole criteria in determining a residential heating source. The method recommended determines the cost of producing one million BTU of heat. It is important to recognize that the efficiency of each heating unit affects the heat available to heat your home.

The two pieces of information needed for these comparisons are the appliance efficiency and the unit price of the fuel. In the case of wood fuel, you need to know the moisture content as well as the type of wood.

1. Convert the BTU content of the fuel to millions of BTU by dividing the fuel's BTU content by 1,000,000.
2. Energy cost ($/MMBTU) = Cost per unit of fuel / (Fuel energy content in MMBTU * Heating system efficiency in decimal form)

According to Pacific Western, an average home uses 200,000,000 BTU or 200 MMBTU for total heating, including a 25% allocation for domestic hot water heating.

Comparative Residential Fuel Comparisons

Fuel	Equivalent BTU	Efficiency*	Usable BTUs**	Units per year	Price***	Yearly Cost
Electric	1 kwH = 3413 BTU	97%	3311	60,405 kwH	$0.0611/kWh	$3691
Natural Gas	1 CCF = 1 MMBTU	80%	800,000	250 CCF	$7.62/CCF	$1905
No. 2 Fuel Oil	1 gal = 140,000 BTU	65%	91,000	2198 gal	$0.981/gal	$2156
Propane	1 gal = 91,600 BTU	80%	73,280	2729 gal	$0.885/gal	$2415
Wood (20% MC)						
Hardwood	1 cord = 24 MMBTU	50%	12,000,000	17 cords	$60-$120/cord	$1020-$2040
Pine	1 cord = 18 MMBTU	50%	9,000,000	22 cords	$60-$120/cord	$1320-$2640
Hardwood	1 cord = 24 MMBTU	30%	7,200,000	28 cords	$60-$120/cord	$1680-$3360
Pine	1 cord = 18 MMBTU	30%	5,400,000	37 cords	$60-$120/cord	$2220-$4440

*Efficiency of the heating appliance

**Usable BTUs is the amount of heat available to heat the home

***Values were averaged from data 7/2000 – 6/2001 titled Average Residential Minnesota Fuel Costs taken from p.6 of www.commerce.state.mn.us/pages/Energy/Data/PRICES.PDF

**** A standard cord 4' x 8' x 4' = 128 ft^3. Average price for bulk, seasoned firewood is $120/cord. People using an outdoor wood furnace, are most likely going to be purchasing in bulk and receiving a substantial discount per cord.

Many fuel cost comparisons do not take into account the appliance efficiencies. This is very misleading when electricity is typically 97% efficient and outdoor wood furnaces around 20-50% efficient; most manufacturers do not show this and therefore the wood cost looks quite appealing, when it really should be at least doubled. This is not to say that wood is not still a lesser cost

alternative, rather not as cheap as originally thought. Additionally, most people purchasing wood to burn in an outdoor wood furnace are not purchasing wood by the cord, rather they purchase in bulk from saw mills, pulp mills, or clear from their property and therefore pay significantly less. That is part of the allure of the outdoor wood furnace – free or very cheap fuel. Therefore one could assume that the prices of wood would be even less especially compared to the other fuel sources.

From the preceding equations it is clear that increased value is found with increased stove efficiency and decreased moisture content. Moisture in the wood decreases the number of BTUs per pound available to burn and therefore increases the amount of fuel needed thereby increasing the heating cost.

Emissions – A Potential Problem

Outdoor Wood Furnace EPA Testing

Under current EPA rules, central heating wood furnaces and boilers are not accountable for emission standards that other wood burning devices are subject to. This is why many of the outdoor wood furnace manufacturers have no testing behind their claims.

There has been little research done on the amount and types of emissions, but the EPA has completed one study in this area. The main results of the study are based on two types of outdoor wood boilers; both a single pass and double pass system. "A single-pass furnace allows the flue gases to pass once through the flue in the water tank before exiting through the chimney. As the hot flue gases pass through the flue, heat is transferred to the water in the tank. In a double-pass furnace, flue gases pass through the water tank twice before exiting through the chimney. The second pass of the stack provides more surface area and more contact time between the hot flue gases and the water in the tank."

The studies were conducted using oak cordwood and tested at two different burning levels: low – heat output of 15,000 BTU/hr and high – heat output of 30,000 BTU/hr. In general, the outdoor wood furnaces had similar emissions to traditional wood stoves and pellet burning stoves. The emissions focused on here were carbon monoxide (CO) and particulate matter. The main conclusion is not surprising considering what has long been known about wood burning; wood burning appliances have significantly more emissions than traditional fuel oil and natural gas heating appliances.

Tables 1 and 2 are taken directly from EPA National Risk Management Research Laboratory, #EPS/600/DR-98/017 February 1998, entitled Emissions from Outdoor Wood Burning Residential Hot Water Furnaces:

Table 1. Comparison Data Aggregated by Operating Mode and Furnace [Range in ()]*

	Single Pass	Double Pass	Parameter
High Heat	**19.6** (14.8-24.5)	**12.0** (10.8-13.3)	M5H Particulates (g/kg)
	0.347 (0.216-0.478)	**0.319** (0.315-0.324)	PAH (g/kg)
	45.6 (38.8-53.4)	**53.8** (50.5-57.1)	Delivered Efficiency (%)
Low Heat	**16.6** (15.9-17.3)	**9.35** (9.2-9.5)	M5H Particulates (g/kg)
	0.236 (0.228-0.245)	**0.283** (0.235-0.332)	PAH (g/kg)
	44.4 (42.4-46.4)	**55.2** (55.1-55.4)	Delivered Efficiency (%)

It is important to note that without further testing it is not appropriate to conclude that the double pass units are better than single pass. Additionally, outdoor boilers with typical chimney heights of 8 – 10 feet may tend to keep emissions closer to the home or structure being heated, whereas, traditional house chimneys which are 20-30 feet high, scatter emissions further from the home or structure being heated.

Table 2. Overall Comparison of Residential Wood, Oil, and Gas Combustion Emissions*[a]

Combustion Device	M5H Particulate mg/MJ input	PAHs mg/MJ input	Mutagenicity[b] krev/MJ input
Natural Gas Furnace			
Conventional	0.44	0.000124	0.007[c]
High Efficiency	0.43	0.000028	NC[c,d]
Oil Furnace			
Retention Head	3.2	—[e]	6
Conventional	15.1	—	20
Conventional Wood Stove	786	40	600
Certified Wood Stove			
Non-Catalytic	383	28	100
Catalytic	425	24	—
Pellet (certified)	110	0.082	—
Pellet (exempt)	176	0.014	—
Wood Furnace			
Cordwood – Swedish Lab Tests			
Intermittent firing	1862	—	—
Continuous firing	182	15.3	148[f]
Chips (dry)	45.3	<0.02	0.48[f]
US EPA lab tests			
Furnace A (single pass)[g]	*1048*	*15.6*	—
Furnace B (double pass)	*681*	*16.1*	—

*It is important to note that data for other heating apparatus have been normalized so only differences in order of magnitude are significant.

[a]All data except that in italics taken from: McCrillis, R.C., "Review and Analysis of Emissions Data for Residential Wood-Fired Central Furnaces," In Proceedings of the 88th Annual Meeting of the AWMA, Air & Waste Management Association, San Antonio, TX, June 1995, Paper No. 95-RP137.04.[b]Microsuspension assay, TA98+S9 unless otherwise noted.

[c]Ames plate incorporation assay, TA98+S9.

[d]ND means not detected.

[e]No data available for this parameter.

[f]Ames plate incorporation assay, TA100+S9.

[g]Only includes comparison data.

Other Smoke Related Concerns

There are many reasons for increased smoke production:

Firebox surrounded by water jacket. According to the Commonwealth of Pennsylvania Department of Environmental Protection, "one cause of the smoke is that the fireboxes of most

outdoor boilers are fully surrounded by a water jacket. While this might be a good way to transfer heat, complete combustion of the wood is almost impossible. Creosote, an oily black tar that sticks to chimneys and stovepipes, accumulates when the boiler is operated with the combustion air damper closed. When more is required and the damper opens, the creosote is burned and a large amount of smoke is produced. Fires in outdoor boilers often are allowed to smolder for hours and sometimes days, which also produces a large amount of smoke."

Poor unit design. Woodheat.org note that manufacturers who run "a series of water pipes right thorugh the firebox so the exhaust has to sweep past them to reach the chimney," increases smoke production. "The flaming combustion of wood cannot occur below about 1000°F, so those steel surfaces backed up by water at 150°F chill and quench flames well before combustion is complete."

Cyclical operating cycle. "When the boiler's water temperature falls below a set point, its combustion air damper opens and/or a small fan forces combustion air into the firebox. Once the water is heated back to the upper set point, the fan is turned off and/or the combustion air damper closes. During the off cycles, the fire smolders and much of the smoke condenses as creosote on the cold steel internal surfaces. When the thermostat again calls for heat and incoming combustion air rekindles the fire, the creosote clinging to the boiler walls and a huge belch of smoke issues from the stack for about ten minutes, before the system settles back into its normally smoky fire. Flaming chunks of creosote coming out with the smoke have ignited brush and outbuilding fires," notes woodheat.org.

Improper sized unit. Woodheat.org asserts that "The bad effects on combustion of a cold firebox and cyclical operation are made worse if the outdoor boiler is too big for the heat load…An outdoor boiler connected only to a modest-size house will spend most of its time in the off mode, particularly during a fairly mild weather, so when it does fire, it is likely to make a big smoke plume."

Outrageous performance claims. Many manufacturers state incredibly long burn times as well as high combustion efficiencies. This is not really feasible and causes people to purchase units that are improperly sized causing most energy to be in the form of smoke.

Fuel Source. Burning the wrong type of fuel (i.e. garbage, plastics, magazines, etc) or wood that is too wet (i.e. MC > 20%) causes excess smoke and emissions.

Outdoor Wood Furnace User Comments

One Southeastern Minnesota respondent to the residential survey had shared her experiences with an outdoor wood furnace, including the size, cost, problems, and fuel used:

Unit Size: 350 gal, 2x2x3 firebox cost

Research/Purchase: Compared with other manufacturers at the Minnesota State Fair

Cost: $3500 for burner only, Wirsbo tubing and all other hardware doubled the cost. We felt that the oldest most stable company would be the best, and purchased the Taylor Water Stove T-450.

Problems: The major problem is the salesman sold us too small a unit. When we returned to the fair a couple of years later and told him the problem, he agreed that we should have had a size larger. He has offered to sell us a larger one at a good price and we are now debating if we wish to do that.

Type of Wood: Because my husband still works full time in the city, he does not feel that he has the time to cut enough wood from our property to burn, therefore we purchase oak slab wood from the local saw mill only 1.5 miles from our home.

Wood drying and storage: The fall is the best time to get the wood ready. My husband takes two weeks of vacation in early September and fills the wood storage room in the shed with slab wood cut to the size it takes for the burner. The recommendation is that if the wood is somewhat green, it will burn hotter and longer. This year we used it all!

The following are some user's comments that have been posted at woodheat.org. These users discuss both advantages and disadvantages of using an outdoor wood furnace. For a technology that has little information available, it is important to note how actual performance compares to manufacturers claims. Also, while most of the comments come from Canadian users, they still have valid arguments and points.

Here we start with Rick, who lives in Eastern Ontario, Canada.

It [the outdoor wood furnace] works as described. It regularly produces enormous quantities of smoke especially in fall and spring. When used in summer, it is terrible. Our nearest neighbor is nearly 500 meters away, and the next is nearly 1km away. This is obviously a rural setting. If we were in a populated area, or near a road, there is no doubt there would be many complaints and it would be totally irresponsible to use it in the summer. Running one of these in a city or town in summer would be, at best, extremely inconsiderate.

Overall, almost all the claims made by the manufacturer were absurdly exaggerated. Long periods between burns, such as 72-96 hours? Ridiculous. As to that, in mid-winter at -30degC, we load it 3 times a day and it burns cleanly with little or no visible smoke. The claims for 96 hour burn times are absurd. This is might be true if you were not pulling any heat out of the unit, and it will indeed go 72-96 hours in July without reloading, no problem, if filled with dry seasoned oak, but this is rather pointless. The joke is that I have seen these units sold at Farm shows and it is always the same line of misrepresentation: the dealers have one set one up and are bragging about how they have only put in one armful of wood since setup three days ago

because the unit is just so efficient... Since they haven't heated anything except the furnace itself, the statement about an armload of wood is completely meaningless, even if it were true.

Efficiency? Not likely. There are numerous manufacturers of these outdoor furnaces, but I have seen no evidence that any of them has done any serious scientific engineering design of their units. There is no evidence any of them have any concept of the physics of convection, heating or cooling, nor of fluid dynamics. These are basically all just metal boxes containing a fire surrounded by a water jacket. However, as long as the source of heat energy is available and not costly or is free, then efficiency is a moot point.

Burning green wood? At this it excels. In fall and spring we burn garbage wood such as Manitoba Maple pulled from off fence lines and elsewhere on our property (all green, all unseasoned). Why not? This junk wood heats our water and when the weather is mild (anything above zero) the furnace does a fine job heating the house--there just are not enough BTUs in low quality wood to use it when it gets really cold as it goes through a load too quickly. I appreciate that some people will think it is BAD to burn green wood (bad for the environment, that is). Well, what is the alternative? Here it is: build multiple brush piles out of all your junk wood, wait for an inch or two of snow in the fall, and watch all those BTUs go up to the sky. That is just reality. So, it is very fine to talk about grams per hour from a furnace or some nice air-tight wood stove with a catalytic converter in it, but how many grams per hour of carbon are there coming out of a brush pile fire? Probably thousands or tens of thousands or more.

You mention setting fire to your fields with it or setting fire to your house. This is not surprising. The manufacturer of our unit claimed no problems at all with sparks, but we needed to add our own spark arrester because so many sparks came out. The unit as sold shoots lots of sparks unless the wood is high quality and very dry. However, with the spark arrester in place we can burn any day we like, anything we like. We do not need to worry about tending the furnace or starting brush fires.

Are there Problems? Yes.

Problem 1. These furnaces require work. Muscle power. The manufacturers ignore this detail in their exaggerated claims. You need to get out there and put the wood into it. If going from any form of automated heat to an outdoor wood furnace: THINK VERY CAREFULLY FIRST.... Wood heating can lose its romance quickly when it is a day-in-day-out operation for 6 months. The outdoor wood furnace will be one of your major winter hobbies. If going from an indoor wood-furnace to an outdoor wood-furnace (as I did) then the benefits are huge. But, lets be realistic: not very many people heat their houses with indoor wood furnaces. I would think less than 1 in a thousand even in rural areas.

Problem 2. You need a BIG wood shed. Otherwise, you are going to be burning green, or wet, or snow-covered wood. Wet and/or green wood will burn, but you will waste a lot of wood getting that wet wood up to ignition temperature. And it is very hard to get a wet-wood fire going. Most people do not have the space for the required woodshed nor space to store all the wood they will need to burn for a winter. Let alone space to store wood for the next two or three

winters. Very few people have any idea how much wood it takes to heat a house for a winter. It takes a lot.

Problem 3. A lot of wood is needed. This is because these outdoor wood furnaces are very inefficient. There is no way the efficiency of an airtight is matched even remotely. Ours produces huge amounts of heat, but we go though at least 7 bush cords (i.e., 7 piles of 8 ft logs where each pile is 4ft high and 4ft wide) of dry hard oak per year. The cost for us for to buy this much hard oak (white or red oak) or hard maple (sugar maple) and have it delivered (if we buy it as logs) is $600.

Problem 4. The units are extremely expensive. Small ones are $6K. Big ones can be $30K or more. Approximately two-three times the cost of a top-quality high-efficiency propane/oil boiler to heat the same sized space. The extra money could buy a lot of propane/oil. The economics need to be considered carefully.

Problem 5. The units are not durable. They corrode, even though anticorrosion additives are put into the water. The manufacturer of our furnace went bankrupt within one year of our purchase (so much for the 10-year warranty) when someone when after them for a faulty unit. We learned this when a faulty weld started to leak. We had to fix it ourselves, at our own cost. To do so I ripped all the casing off the front, pulled all the insulation off, drained the unit, and brought in our mobile welder at $50 per hour plus mileage etc. And at that point the real guts of the beast was sitting there before us, not just the pretty furnace, covered in decorator colour aluminum siding, that was delivered to the yard. No, in truth it is just a very poorly welded box, slapped together, apparently in a hurry. We changed the insulation before the siding went back on as the manufacturer was so sloppy in surrounding the boiler that you could see parts of it. That was just ridiculous. We had to do the same thing about 18 months later. It has sprung yes another leak, so I need to do it again. Absurd.

Problem 6. The units require daily monitoring. Also regular adjustment, regular adding of water, and that gets to be a pain. It takes very little time, but it needs to be done. No one who has one of these can just shove wood into it and forget it. For this reason alone, an outdoor wood-furnace is not for everyone. If you do not enjoy or are not good at playing with machines, then I would suggest not getting one. If you let the water level go down, and you burn out the fire box (I known one person who did this) then there goes your $6-8K investment. Scrap. Compared to the ease of the standard propane or natural gas boiler (at a third of the initial price) with the slide of a finger to do everything, the outdoor wood furnace is often one big headache (especially when it is minus 30°C outside and you would rather just stay inside and be with your wife/girlfriend but unless you get outside and feed the furnace the fire will go out, the water temperature will start to drop and the house will start to get cold).

Problem 7. Electricity is needed. The outdoor wood furnaces require electrical power to operate: power for the fan (if it has a fan), power to open and close the air vent to get it burning, power to run the circulating pump, etc. If you have a power outage, you have no heat. You probably want a secondary source of heat (i.e., indoor wood stove, or propane heater, etc.).

Problem 8. There is a risk or freeze damage and pipe bursts. If there is an extended power outage, the unit itself can probably be kept warm. Perhaps by wedging sticks into the dampers to permit airflow into the firebox, and thus a low level of combustion, during power outages if it is necessary (we did this during the Jan 1998 Ice Storm, but we were worried about the underground lines freezing). Even if the underground lines are below frost line (most installation guides appear to recommend only going down 1-2ft, well above the frost line in Ontario), the underground lines MUST come above frost line to connect to the furnace. At that point, if there is no electricity to operate the circulating pump, the lines can freeze.

Problem 9. You are a slave. Would you like to go on vacation someday in winter? Then you need an alternate way to heat the house and to heat the outdoor wood furnace. Forget about getting someone else to baby-sit the outdoor wood furnace for you while you are on vacation. No one in their right mind would do this. I would not, and I have had one for four years. They are just too unpredictable, and who would want the responsibility of keeping someone else's house from freezing after the outdoor furnace has gone out from wet-green wood too long on the smolder? If the furnace goes out in the winter, and it is not heated in some way, it will freeze unless you drain it. Draining the outdoor furnace in winter is something you probably do NOT want to do. So, you need to have things set up so that provide heat to it from the house, and this is most commonly by reverse heating from your hot-water tank. This can be a major downside.

Problem 10. Smoke. The low/no smoke claims of some manufacturers are ridiculous. There is lots of smoke unless in mid-winter when burning good dry hard maple or hard oak with frequent cycling. The units without fans smoke the worst. The talk about natural draft is hogwash as there is no stack. There is just no draft to speak of. The fan is what makes things burn well, and the fan is what allows you to burn whatever you want. The smoke usually is not a problem for us (personally) as the wind is very predominately away from our house.

Problem 11. They smoke far too much in the summer to use. It would not be much trouble to feed the machine every 2-3 days in summer just to heat hot water. However, when the only heat be drawn out of the unit is to heat a domestic hot water tank, the units sits and smolders most of the time. When the unit starts to burn after smoldering for many hours the volume of smoke is just unbelievable for about 30 minutes or more (depending on what is being burned). If we have clothes out on the line when that happens, or the windows of our house are open and the wind is toward the house, we or our clothes get fumigated! So, after that happened a few times we decided not to use it outside of heating season. It is just too much hassle and makes too much smoke. Our unit goes out in June and we fire it up again in September. The exception is burning garden weeds without having to bother tending the fire. We save oak and seasoned hardwood for winter.

Problem 12. These units need to be near the house. Claims in product brochures and manufacturer's websites that these units can be 500ft from the house are totally unbelievable. Virtually every unit I have seen is within 50ft of the house. Heat is lost underground unless the pipes are extremely well insulated. It is hard to see much heat energy being left after a run of 500ft.

Whew - sounds like Rick and Bob are not having a pleasant experience with their heat systems. My story is different. We have used an outdoor boiler for the past three winters. Prior to installing the outdoor boiler, we used a wood burning furnace installed in the basement of our farmhouse. My unscientific comparisons of fuel consumption between the indoor hot air wood burning furnace and the outdoor wood burning boiler are about equal, plus the boiler heats the domestic hot water. Smoke particles and BTUs are beyond my rural comprehension. The boiler smokes on startup, but the hot air furnace did also. I added two sections of pipe to the boiler (supplied by the manufacturer) to exhaust the smoke at a higher level. On low pressure days the smoke still drops to ground level, as did the smoke from our house chimney. I tend the boiler twice a day, summer and winter. For winter vacation, my son tends the boiler once a day, since the house temp is kept at 60 degrees while we are away. (He has to come out to feed the cattle anyway). In the summer we also burn waste paper, and wood is added about once a week. I have added water (three gallons, distilled) to the 100 gallon tank only once since it was installed. We have a modern "cutback" thermostat that drops the house temp down to 63 degrees from 10 PM to 4:30 AM. Our humidifier no longer runs constantly like it did with the indoor furnace. Our boiler is constructed of stainless steel, is well insulated and cost $4200 installed, including the "A" coil and piping/insulation. We changed from the basement furnace to the outdoor boiler because the furnace was approaching 20 years old and showing signs of fatigue. The basement furnace was a miserable machine when the outside air temp approached 40 degrees. We could not lower the temperature of the house to a comfortable level, and were forced to operate a propane fueled central furnace many days in the spring and fall. Our propane furnace has not burned since we installed the boiler. I agree that an outside wood fired boiler would be an un-neighborly choice of heat for a home in a subdivision, and might be unreasonable for someone who does not have their own woodlot, but I think our boiler serves us well in our rural setting. I recommend studying each manufacturer's boiler before making a choice. As with any product - there are some duds out there.

Paul

I read your one-sided appraisal of outdoor boilers. When I say one-sided, I have had one now for four winters and, with the exception of running it in moderate outside temperatures, it has performed very well. Yes there is smoke but this can be reduced to a minimum by controlling the fire. In fact, in Halliburton many wood furnaces leave a trail of smoke on a cold morning. Yes the smoke can bother but how about a little advice: Do not have them in a crowded situation or row housing.

Now some points that you failed to mention. I use mine for a house with no real smoke problem. I do not have a fan to force the draft but a very sensitive control that opens the draft at a small drop in house temperature. The heat in the house is constant – better than oil. There are water pipes right through the firebox and I have never had flaming chunks coming out the unit. Even if it did I question if it would ignite the snow etc.

You are right it will not go 96 hours but if filled and the temperature in the house is dropped it will go 48 hours and there will still be heat in the boiler. No there are no fire bricks in the boiler, BUT it is constructed with heavy plate that seem to hold and moderate the temperature. One problem that you missed is thin plate in the construction. A number have gone down due to the use of thin plate. Not mine.

I never try to build a big fire but fill it three times a day getting a good charcoal bed that is always hot. And unlike inside wood heaters – there is no dust.

Wood is a good source of heat and it should be promoted more as an alternative to oil and hydro (electric). An outdoor boiler can fill the bill so lets open up our vision, as there is a place for them. The builders may have some out of the world claims but maybe that is just to counteract your negative comments.

The main problem is when the temperature moderates in the fall and spring. Then we need an alternative heat such a wood stove. And is a little smoke a problem compared to a planned forest or grass burn – or an oil spill?

Barney

Thanks for writing, Barney, you make some very good points.

For example, your suggestion that outdoor boilers should not be located in populated areas is a good one. We have corresponded with people whose enjoyment of their houses and property has been virtually destroyed by a close neighbor's smoky outdoor boiler. This problem is minimized if the units are located only in rural areas with lots of space between houses.

You are also careful about building a good fire. If all outdoor boiler owners did this, we wouldn't have as big a problem with them. In our experience, though, it is rare for users to build careful fires. More often they tend to fill up their boiler with unsplit, unseasoned logs so it will run as long as possible between loadings and this leads to a huge smoke plume when it fires after an off cycle. We wish more users were as conscientious as you are.

You also mention the failures due to corrosion of the boiler vessels and we have been aware of this for some time. However, our main concern about outdoor boilers is offensive smoke and low efficiency, and all wood burning product categories have had failures along their evolutionary path. We note, though, that one insurance company cites corrosion failure as the reason for refusing coverage to houses heated with outdoor boilers, so it is not, apparently, a rare problem.

We still think that outdoor boiler technology can be improved to increase efficiency and reduce emissions and will continue to criticize their manufacturers until they match the quality of their products to their advertising rhetoric.

Thanks again for your note.
John

Research into outdoor boiler pollution?

Enjoyed your article on outdoor wood furnaces. I live near one of the outdoor wood furnaces and at times it's very smoky. The problem I see is that the flue is at ground level and the smoke stays at ground level. I'm very concerned if another outdoor furnace were to be added to the subdivision that there would be a very serious health issue plus the value of my property would decrease. Do you know of any research going on to correct this serious low-level air pollution?

George

Hi George,

As you can tell from the tone of our article on the subject, the smoke pollution from outdoor boilers is a serious concern to us and your note is representative of several we have received. We don't think that the smoke production is inherent with this product category or is contributed to by their short stacks. Instead, it is our assessment that the smoke is largely the result of bad design. The boilers we have inspected all combine the primary combustion chamber with the heat exchanger; that is, the firebox is surrounded by a water jacket. From a combustion efficiency point of view this is just about the worst possible design.

In answer to your question, no, we are not aware of any research going on to correct this problem. However, the CSA committee responsible for standard B415 on emissions testing and rating of wood burning systems recently approved for publication a new edition that, if adopted into federal or provincial legislation, would require outdoor boilers to comply with an emission limit.

We think that smoke emissions from existing outdoor boilers can be reduced through the use of seasoned, properly processed wood fuel and by helping users to change their operating procedures to reduce smoldering, but the reductions achievable using these methods would have to be confirmed by field testing before they could be actively promoted.

I hope you don't mind that I have copied this correspondence to representatives of the federal and your provincial government with responsibilities in this area, as well as non-governmental colleagues with an interest. I would suggest that you contact your provincial environment ministry and ask them for help.

I should point out, though, that other correspondents who have sought help from their provincial governments received either none or an inadequate response. But, only if people like you bring the problem to government's attention will there ever be the possibility of support.

If the owner of the outdoor boiler near you is not hostile to a discussion, you could suggest they get in touch with us for some advice. Sorry that I couldn't be of more assistance. Best of luck.

John

I was surprised when I read several negative opinions of using an outdoor boiler. I installed one myself and would not hesitate to do it again! I have always supplemented my homes heating with wood but now heat exclusively (hot water, house, basement) with my outdoor boiler and the house is constantly 72 degrees and the supply of domestic hot water is constant! My electric bill is lower, heating bills are gone (no need to buy oil) and the house is the warmest it has ever been. I check my stove twice a day and fill it if needed. I NEVER get up at night to fill the stove.

I notice that some postings indicate the use of pieces of foam insulation in a 1 -2 foot trench covering their water lines (supply and return). BAD IDEA. Do it right and use insulated PVC and burry it 4 - 5 feet down. Also, I have seldom seen a unit closer than 100 -200 feet from the house.

I do agree that they produce smoke, as did my woodstove, and I would not burn wood if this was a concern do to close neighbors. In summary, I would encourage anyone that is interested in an outdoor boiler to get information on as many units as possible and don't cut corners by choosing less expensive units, or especially insulation for your water lines.

Joe

Hello,

You seem to have missed the point of the commentary, both by us and by visitors to our site on outdoor boilers. If you check all the articles on our site, you will not find much criticism of performance, except by some readers who complain about low efficiency. No one has said they won't heat a house, or that the heat is uneven or that they have to be loaded too often, although a couple of people have complained about very high fuel consumption.

We say on the site that the concept of outdoor boilers is fine. The problem is that most of the popular brands are designed so that heavy smoking is inevitable. And as much as you like your boiler, you do acknowledge that it smokes. So where is your disagreement with the comments on the site?

Thanks for your comments and advice on underground piping insulation and the purchase decision.

I am researching a project. My question is: is it recommended that outdoor boilers be used in urban areas on relatively small tracts of land even if the boilers are installed properly? I'm concerned more with environmental factors, as well as their use in residential areas. Any information about outdoor boiler use would be greatly appreciated.

Thank You.
Jeff

Jeff,

I guess it depends on who does the recommending. If you were to ask the bylaw enforcement officers of the many jurisdictions that have banned outdoor boilers because of smoke complaints, the answer would be an emphatic NO! As far as we can tell, correct installation does not resolve the smoke problems because it is the system characteristics of most outdoor boilers that causes the smoke, not specifics of the installation.

Regards,
John

I placed one of these outdoor wood burning boilers in service two weeks ago, and here is my experience to date.

The good news: The transmission loss from the boiler to the house is minimal. If the boiler is operating at 180 degrees F, the temperature delivered to the house system is 177 degrees, for a transmission efficiency of 98 percent. This is with the water lines in an uncovered trench. By the time that the 2" thick high density foam insulation arrived, the back fill was frozen solid. The trench and lines are covered with a tarp, and the only time that the snow melts over the trench is when the air temp is above freezing and the snow is starting to melt in places anyway.

The unit is actually capable of heating the whole house during the majority of the day. The house seems less drafty when heating with the outside boiler, because there is no combustion device operating inside drawing in cold outside air to replace that used in combustion.

The bad news: Where should I begin? It goes though wood in a hurry, a big hurry! It went through in a week what I thought would last for three weeks to a month. It was at that point I decided to make some measurements, and here is what I came up with. The method of measurements I'll include as a footnote, if anyone finds fault with my method of measurement, please point out my error(s) and suggest a better method.

The net delivered efficiency is horrible, much worse than claimed. Actually, the manufacturer did not give any percentage figures in their literature; they just compared their unit to others on

the market. If this one is the best, I hate to see the worst! The best I could get out of it was 22%. This was with only natural draft, I tried a temporary combustion blower, which cut the smoke down a lot, but the efficiency dropped to 19%, because the hotter fire simply went up the stack. I was really hoping for 50% efficiency, my wood supply would last twice as long if that were the case.

The manufacturer also claimed "up to 250,000 BTU/hr" for this model. Well I'd like to know how. I suspect they reported a peak-firing rate when the load was burning the hottest, with very dry red oak. The best I got was 144,000 BTU/hr ± 3% burning well-seasoned red oak. However, this is actually OK for me, since the manual J calculation for my house comes out to 150,000 BTU/hr heat loss at 10° F (the temperature used by heating contractors in our area).

I don't try to fill it chock full and let it cycle off, since it would be even more inefficient and smoky to have the fire smolder, this means that I have to reload it frequently, about every five to six hours. I do add a final maximum load just before going to bed. It does not have enough capacity to make it through the night by itself, at around 4 a.m. the oil burner kicks on to make up for the short fall, but there are still enough live coals at 8 a.m. to start a new fire.
As others have reported on this site, my outdoor boiler smokes a lot. Not nice white smoke either, which would be primarily water vapor, but nasty blue smoke. Even operating it as I do, with very little "off" time, it still smokes. That's where all the missing BTUs from my wood are going, up in smoke. As stated earlier, trying to increase the draft cut down on the smoke, but the stack temperature went way up, and my net efficiency went down.

The manufacturer claims "no wood splitting necessary because of firebox size". This might work for their largest model, but on mine, any piece larger than six inches in diameter does not completely burn. Besides, to season well, wood needs to be split anyway.

Bottom line: Fortunately I have 50 acres of wood lot, which I should be able to harvest in a sustainable manner and I'm out in the country so there's nobody around to be bothered by the smoke, and I wisely situated the machine downwind, so that my family won't be bothered by the smoke. The state of the art as currently implemented is only suitable for those with access to free wood and the time to cut, haul and split it. As it stands now, I'll only operate the boiler when it is below freezing outside, I'll revert to oil heat during spring and fall, and I'll be experimenting with improving the technology for next winter.

Bob, Pennsylvania, USA

Footnote: Method of measurement of net delivered heat efficiency and BTU/hr.

The system is known to contain 150 gallons of water. Water weighs 8 pounds per gallon, for a water weight of 1200 pounds. The BTU is defined as the amount of heat required to raise one pound of water 1 degree F. The BTU/hr rate was determined by timing how long it took to raise the water temperature by one degree, under the test conditions stated below. The boiler comes equipped with a digital thermometer with a stated accuracy of 3%
The net delivered efficiency was determined by loading the boiler with a known weight of wood, typically 40 pounds. The wood for each trial was red oak, cut from the same tree, seasoned and

stored in the same manner. Before each trial, ashes and coals from previous fires were removed from the boiler. The heat from the system was removed by allowing the house circulators to operate until the boiler temperature was down to 120°F. At this time, the house circulators were turned off and the valves to the house heating system closed. The power to the oil burner was also switched off. The circulator for the wood burner was left running, so as to prevent stratification of the water inside the wood boiler. This method also inserted the transmission loss through the piping system into the measurements, since the water circulated from the wood boiler, to the house through the inactive oil boiler and back to the wood boiler. There may have been some extra losses through the inactive oil boiler, but these are believed to be negligible, as the boiler was well insulated and the measured stack temperature of the oil boiler while inactive was the same as the ambient temperature. The wood was then ignited and allowed to burn until the boiler temperature no longer showed an increase. At that time the temperature was recorded. The embers and unburned wood, if any were weighed. The heat output was determined as detailed in the previous paragraph. The input was determined by multiplying the weight of the wood consumed by 6000 (an average value stated for seasoned red oak). Efficiency was determined by dividing the BTU output by this input value. Efficiency values for each of two trials under the same conditions were within 1 percent of each other.

Guidelines and Considerations for Furnace Replacement and Outdoor Wood Furnace Purchases

Replacing an Existing Heating Source, a home heating brochure produced by Minnesota Department of Commerce Energy Information Center offers the following guidelines to determine if repair or replacement of the furnace is necessary.

1. Does the present source operate properly? If it is more than 10 years old and cost more than $500 to fix, it should be replaced.
2. Average furnace life is 16 to 20 years, for boilers it is 30 years. Start shopping for a replacement whether it is the same source or an alternate, in advance.
3. It may be more cost effective to purchase another unit sooner depending on the design and size of the home.
4. Consider what type of fuel will be most affordable in the long run.
5. Consider the opportunities offered by different distribution systems. If you switch will you have to install new ductwork. Forced air is more economical with central air conditioning.
6. Furnace size. A larger heating system is not necessarily better. The Energy Information Center recommends that a homeowner have a heating professional do a heat loss calculation to help determine the correct size.

Outdoor Wood Furnace Purchasing Tips*

1. Stick your head in the firebox and if you don't see a lot of firebrick, there is almost no chance the unit can burn clean.
2. The harsh reality is that a good outdoor boiler will be quite a lot more expensive than the smokers, so if the one you're looking at is comparatively cheap, we suggest you look elsewhere.
3. Performance claims that seem extravagant are probably false – ask for proof.
4. If you have a modest house that needs heating, get a wood stove, heating fireplace, or small basement wood furnace. You'll burn a lot less wood, make a lot less smoke, and save yourself a lot of money in the long run.
5. If the outdoor boiler supplier claims all other forms of wood heating are hazardous, be aware that you are being misled.

*Material directly taken from woodheat.org/outboiler.htm.

Lastly woodheat.org says, "In certain situations, mainly when the heating load is big and spread out in two or more buildings, the outdoor boiler can be just the right technology. Unfortunately, the technology is all too often crudely executed by the manufacturer and miss-applied by the retailer. We look forward to the day when the industry has cleaned up its act and we can endorse the outdoor boiler as a responsible and environmentally appropriate way to heat with wood."

Outdoor Wood Furnace and Stove Characteristics and Features to Consider*

*Most information comes directly from manufacturer brochures (included at the end of the report), information found on their website, and survey respondents and is intended to give a list of both positive and negative features to be considered. This is intended as things consumers may wish to consider before purchasing an outdoor wood furnace.

Outdoor Wood Furnace Features to Consider

Fuel Source and Availability

- Junk, pallets, sawdust, braches, unsplit wood
- Wet, dry, or seasoned
- Length and size of wood
- From sawmills, newspaper ads, property

Potential Cost Reductions and Expenses

- Decrease in insurance premiums due to no open flame in the home
- Decrease in wood use
- Decrease in wood cost
- Actual unit, piping, insulation, heat exchanger
- Warranty
- Maintenance schedule and chemicals
- Cement slab for elevated insulation

Compatible Heating Options

- Forced air heating
- In-floor heating
- Unit heater
- Water heater
- Hot water baseboards
- Existing boiler heating
- Pools and hot tubs
- Clothes dryer

Time and Convenience

- Furnaces may be installed inside or outside a building
- Easy to clean flues
- Low maintenance time
- Reduced ashes due to very hot burn
- Long time between ash removals
- Large firebox and loading doors
- Controls in one location
- Auto start and stop controls
- Water temperature gauge
- Adjustable water temperature
- Low water indicator
- Fan shut off switch
- Outside light for night loading
- May need to reload fuel often (every 12 hours?)
- Backup system
- Need to gather wood and store it

- No ashes and messy wood in home

Installation

- Hookups to multiple buildings
- Pumps directly installed to furnace
- Control pre-wired and in one location
- Electrical junction box ready to hookup
- Furnace sits of ground for easy hookup

Environment

- Decreased risk of carbon monoxide poisoning
- Lower environmental impact than other fuel sources
- Pruning overgrown forests for fuel promotes regrowth of healthy trees
- Particulate emissions

Performance

- Reduced ashes
- Powered air injection and directional air flow
- Quick temperature recovery time
- Flue temperature reduction system
- Extended burn time
- Large heating capacity
- Reduced wood consumption
- Heat exchanger water baffles
- Large heat transfer area
- Even water circulation for better heat transfer
- Anti-creosote door lip
- Non-stick door gasket
- Semi-closed loop system to reduce evaporation
- Combustion efficiency

Transportation

- Delivery charges
- Fit in a truck bed
- No eaves to get dented
- Legs with tie downs
- Legs with foot plates with mounting holes
- Loaded via a roof hook or pallet forks through door
- Roof is one part of the wall, and can't blow off in high winds

Quality

- Weatherproof caulked seams
- All metal rust proofed
- Stainless steel boiler
- Round or square firebox design

- Steel floor under furnace
- Rodent proof house design
- Easily removable cladding
- Furnace materials type and thickness to minimize warpage and corrosion
- Double door design
- Ash auger system for ash removal
- Forced air draft vs. natural draft systems
- Firebrick lined firebox or heavy plate firebox construction

Safety

- No wood smoke to irritate respiratory conditions
- Distance from home and no open flame in the house
- Adjustable water temperature
- Low water indicator
- Pressurized or non-pressurized system
- Smoke bypass
- Cool door design (air or water cooled)
- Insulated and offset handles
- Design certified and tested by Wernock Hersey, CSA or UL
- Fan off caution light
- Large door lip to prevent ash fallout
- Insulated housing to protect electrical and plumbing
- Pressure relief valve
- Outer fire door lock
- Anti-flashback door safety device

Natural Draft: design provides the fire with the amount of air needed for optimal burn efficiency, less expensive, more efficient, performs best with seasoned wood.

Forced or Fan Draft: Capable of burning green wood or almost any material, no additional chimney needed to boost draft and chimney height does not matter, faster heat recovery to the water jacket, does not smolder – either burns hot or shuts down.

Major Outdoor Wood Furnace Manufacturers and Models

Central Boiler
Rt 1 Box 220
Greenbush, MN 56726
800-248-4681
218-0782-2575

Functions: Totally enclosed firebox in a water jacket. Water is maintained at a constant temperature by automatic controls on the furnace. The heated water is piped to the building to be heated through two insulated water lines that are buried 8" underground. Water is pumped through a heat exchanger mounted on the duct work of existing forced air furnace. The circulation pump circulates the water from the wood furnace continually. The thermostat calls for heat, the fan on the existing furnace starts and heats entire home through the existing duct work. Can also utilize existing hot water baseboard radiant or radiant floor heating system. A domestic water-to-water heat exchanger can be added to heat all of the hot water.

Model	CL 17SB*	CL 40SB*	CL 75**
Max BTU	250,000	500,000	-
Door	22" x 22"	22" x 30"	30" x 40"
Water Capacity	170 gal	400 gal	750 gal
Draft			
Firebox	30 x 36 x 42	26 x 48 x 54	40 x 60 x 72
Dimensions	-	-	-
Chimney	-	-	-
Steel Thickness	3/8", ¼", & 7-gauge	3/8", ¼", & 7-gauge	3/8", ¼", & 7-gauge
Heat Transfer Area	64 ft^2	114 ft^2	170 ft^2
Weight	1500 lbs	2150 lbs	3200 lbs
Warranty	6 yr warranty, cast iron door has a lifetime warranty.		
Particulate Emissions	6.0 g/hr		
Combustions Efficiency	92.5% (Warnock Hersey tested) for CL 17SB model		
Max Burn time	-	-	-
Works with	Radiant floor, baseboard, or forced air furnaces		
Special features	Night light, Cast iron firebox door, rugged skid base framework for easy insulation and no cement elevation is needed, 3/8" thick formed ash pan, electrical outlet box, enclosed area for fittings and pump, engineered rectangular firebox design with stay pins will not collapse like round firebox designs, water-cooled baffle traps heat in firebox, heavy gauge chimney outlet transition through back eliminates sealing of chimney through roof, insulated chimney, fan draft option for all models. *Urethane Foam Insulation:* 100% air tight and waterproof, 2-3X greater 'R' value than conventional fiberglass insulation, does not degrade or compress. *Ripple Top Design:* provides optimum heat transfer surfaces in the most intense heat collection area.		
Price	-	-	-
Size wood	Large pieces okay.		

*CL 17 and CL 40 are available with regular base to be installed on raised concrete foundation. Skid base frame under CL 75SB does not provide enclosed access under furnace and should be installed on a concrete foundation.
* *This is an outdoor wood furnace intended for more than residential heating.

Pro Fab – Cozeburn Inc.
PO Box 443
Aroborg, MB ROC1OAO
888-933-4440
204-364-2318
www.cozeburn.com

Functions: Non-pressurized system eliminates danger of explosion. Heats the water around the fire chamber and pumps circulate water from the furnace to the buildings and back to be reheated. Tested and approved as a natural draft system, which usually burns less wood than a forced draft system. The forced draft system would be better for burning hardwoods or greener woods.

Model	Empyre Furnace 450	Empyre Furnace 250		
Max BTU				
Door	20" x 22"			
Water Capacity	260 gal			
Draft				
Firebox	36" x 48" x 60"	30" x 37" x 42"		
Dimension	58" X 102"	54.5" x 81"		
Chimney size	8"	6"		
Steel Thickness	-	-		
Heat Transfer Area	-	-		
Weight	2500 lbs	1500 lbs		
Warranty	12 yr limited	12 yr limited		
Burn Time	48 hours	48 hours		
Works with	Radiant floor, baseboard, or forced air furnaces			
Special features	Low maintenance, remove ashes at any time while fire keeps burning, water level indicator, lift hook for loading/unloading, stainless steel water filled grate, totally enclosed bottom to avoid heat loss, pipes and fittings not exposed to cold, one piece roof, natural draft system, see through control panel cover, special breaker for solenoid. Model 250 will fit between the fenders of a pickup truck.			
Price (unit only additional for tax, shipping, pipes, etc.)	$4995.95*	$3954.50*		
Wood	1 – 4 ft decayed or seasoned wood. Dry and seasoned is recommended.			

*Heat exchanger, piping, and pumps are approximately $600.00 extra.

Wood Master
Northwest Manufacturing, Inc.
PO Box 124
Red Lake Falls, MN 56750
800-932-3629
www.woodmaster.com

Functions: The furnace warms water to its optimal heating temperature which is constantly maintained by automatic controls. The heated water is then piped to the desired location. This transfer is more efficient than forced air. A circulation pump continuously circulates the heated water to provide proper heat distribution and ensures that the desired temperature is maintained.

Model	328	434 M/S steel*	546 M/S steel*	658**
Max BTU	-	-	-	-
Door	18" x 18"	20" x 21"	24" x 24"	Dual Doors Open 44" x 30" high
Water Capacity	90 gal	150 gal	300 gal	500 gal
Draft	See price info for all models and *			
Water Jacket	3/16"	3/16" / 1/8"	3/16"	3/16"
Firebox (inches)		¼ x 34 x 44 – M 1/8 x 34 x 44 – S	¼ x 46 x 56 – M 1/8 x 46 x 56 – S	¼ x 60 x 58.5
Dimension	-	-	-	-
Chimney size	-	-	-	-
Steel Thickness	-	-	-	-
Heat Transfer Area	-	-	-	-
Heating area	2000 ft^2	5000 ft^2	10,000 ft^2	10,000 – 20,000 ft^2
Weight	1100 lbs	1500 / 1100 lbs	2300 / 1660 lbs	-
Warranty	All models have a 10 yr limited warranty			
Burn Time	-	-	-	-
Works with	Hot water, radiant baseboard, forced air, hydronic heat, existing water-to-water, and in the floor.			
Special features	*Smart Heat Baffle*: Positive direction baffle does not allow short cuts to the chimney, reduces flue temperature by 53%, and provides max heat transfer. Open position, used when fueling, allows the shortest distance to the chimney and helps eliminate smoke out the fuel door. Located at the top it will not restrict the length of wood you are using. *Oversized Air-Cooled Door:* fires WoodMaster with preheated air and allows ease of loading and cleaning. *Built In Legs:* WM does not require a slab to sit on, it freestands on four legs, allowing for year round installation. *Insulation:* Non-flammable fiberglass insulation provides an R38 value. Snow will remain on the roof while burning. *High Efficiency:* Round fire chamber and water jacket deliver a high efficiency and more durable construction with approximately 40% less welds than that of a square.			
Price (unit only)***	MF- $3195.00	MN, MF - $3895.00 SN, SF - $4695.00	MN, MF - $4895.00 SN, SF - $5895.00	$8450.00
Wood	Seasoned wood provides the best burn time and efficiency, but can burn large or green.			

***MF** – Mild Steel, Fan Draft, **MN** – Mild Steel, Natural Draft, **SF** – Stainless Steel, Fan Draft, **SN** – Stainless Steel, Natural Draft, Stainless steel = 409 stainless

** Twin Forced Air, plumbed for multi-dwellings, 4 inlets and 4 outlets

Wood Master, continued

***Example of Complete Package with Existing Forced Air	Cost
MF 434 Mild Steel Fan Draft	$3895.00
140,000 BTU Exchanger	$200.00
Circulation Pump	$79.00
Low Volt Thermostat	$30.00
Fan Center	$35.00
100' – 1" DuraPlex (Furnace 30' from house)	$99.00
30' – Advantage Foil Foam	$137.70
Forced Air Fittings Kit	$99.00
Domestic Water Tube and Fittings Kit	$157.00
TOTAL	***$4731.70***
***Does not include tax or shipping.*	

Mike's Heating Inc.
R 1 Box 217A
Mahnomen, MN 56557
800-446-4043
www.mikesheating.com/owf

Heatmor Stainless Steel Outdoor Wood Burning Furnaces

Functions:
Existing Boiler Heating: The Heatmor can be hooked directly into existing boiler. A constant flow of hot water is maintained through the use of a circulation pump. The zone valves, existing pump, and baseboard radiation transfer the heat through the house. The existing system can remain as a back up.
Forced Air Heating: You need to install a water-to-air heat exchanger in the ductwork directly above your existing furnace. How water constantly circulates through the exchanger. The blower, controlled by a thermostat, blows air though the heat exchanger coil and transfers the heat though the house. A more even heat is provided with this system. The existing system can remain as a back up.
Hot Water Baseboards: For this system, the baseboards (resembling electric baseboard heaters) are installed around the perimeter of the building. Zone valves and thermostats control individual room temperature.

Model	100CSS	200CSS	400DCSS
Max BTU	-	-	-
Door	18" x 20"	18" x 20"	18" x 20"
Water Capacity	85 gal	114 gal	155 gal
Draft	-		
Water Jacket	3/16"	3/16" / 1/8"	3/16"
Firebox (inches)	Length – 24"	Length – 36"	Length – 54"
Dimension H x W x L (in)	77 x 51 x 65	77 x 51 x 77	77 x 51 x 96
Chimney size	8"	8"	8"
Steel Thickness	-	-	-
Heat Transfer Area	-	-	-
Heating area	3000 ft^2	5000 ft^2	10,000 ft^2
Weight	1355 lbs	1620 lbs	1950 lbs
Warranty	All models have a 10 yr warranty, including corrosion warranty.		
Particulate Emissions	-	-	-
Combustions Efficiency	-	-	-
Burn Time	Up to 72 hours		
Works with	Hot water, radiant baseboard, forced air, hydronic heat, existing water-to-water, and in the floor.		

Special features	*Heavy gauge stainless steel:* used for all parts which come in contact with fire and water, protecting against corrosion and warpage . *Ash Auger chamber and cast iron gates:* provide efficient combustion that burns wood into a fine powder, providing for easy removal of ashes without a shovel. *Semi-closed loop system:* reduces evaporation of water and/or antifreeze. *Multiple hook-ups:* allow for heating of more that one building from same furnace including home, domestic hot water heater, swimming pool, hot tub, garage, workshop, greenhouse, or farm shop.		
Price (unit only)	$3795.00 sale	$4495.00 sale	$5595.00 sale
Wood	Unsplit wood up to 50"		

Mike's Heating Inc, Heatmor Stainless Steel Outdoor Wood Burning Furnaces, continued

Forced Air and Miscellaneous Parts	**Sale Price $**
100,000 BTU Triple bypass heat exchanger	175.00
140,000 BTU Triple bypass heat exchanger	220.00
Repairable Pump: 007 TACO w/Flanges	81.00
Wall Thermostat	20.00
Water Heater Kit and Mixing Valve	80.00
Kitec Water Piping ¾" I.D. (per foot)	0.85
Kitec Water Piping 1" I.D. (per foot)	1.15
4" PVC w/LOW-E Insulation (per foot)	2.50
8" INSUL-SEAL Pipe Insulation (per foot)	5.50
Valves at stove (1-set)	46.00

Mike's Heating Inc.
R 1 Box 217A
Mahnomen, MN 56557
800-446-4043
www.mikesheating.com/owf

Wood King Outdoor Wood Burning Furnaces

Function: The firebox is surrounded by water. When the water temperature drops below 160°F air is injected to the fire causing the fire to go from a dormant stage to an intense hot burn. The air temp reaches 180°F and the air turns off. The fire returns to the dormant stage burning very little wood. Meanwhile, hot water is pumped to the home 24 hours a day. The first stop in the house is the domestic hot water heater. Our systems override the heating element and takes over heating. The furnace water doesn't enter the water tank and heats by convection. The hot water now moves on to heat the home, which can be done by several methods. With hot water systems the Wood King furnace can be connected directly into the existing system using a water-to-water heat exchanger. If the building has forced air heat, a water-to air heat exchanger is used in the plenum. Other choices could be water baseboard heaters, in-floor piping or combination blower fan/exchanges. Every set-up uses a separate thermostat system to ensure constant temperature to the building. The original heating method is not disconnected but now acts as a backup system. After transferring its heat to the building, the cooled water is returned to the outdoor furnace.

Sample Installations:
Forced Air Heating – need to add water-to-air heat exchanger into your existing duct work.
In-floor Heating – After pipes are places in the floor and by using zone valves and thermostats you can individually control the heating in any part of the building. Existing system remains as a backup.
Unit Heater – a self-contained forced air water heater, can be placed at the ceiling or built into the floor or wall. Each heater is thermostatically controlled.
Hot Water Baseboards – Baseboards are simply installed around the perimeter of the building. Zone valves and thermostats control individual room temperature.
Existing Boiler Heating – the new furnace can be hooked directly into the old system (gas, oil, or electric), which remains a backup system.
Pool/Hot Tubs – Need to install a water-to-water heat exchanger.
Clothes Dryer – New furnace can heat a gas or electric dryer. Need to install a small water-to-air heat exchanger behind dryer and a fan blows hot air through the exchanger to the dryer. The existing gas or electric element is disconnected.

Model	1	2	3*
Max BTU	-	-	-
Door	21" x 20"	25" x 24`"	30" x 29"
Water Capacity	150 gal	310 gal	650 gal
Draft	Forced		
Water Jacket	-	-	-
Firebox (inches)	33 x 44	46 x 56	52 x 68
Dimension H x W x L (in)	84 x 54 x 63	97 x 69 x 75	114 x 83 x 87
Chimney size	8"	8"	8"

Steel Thickness	-	-	-
Heat Transfer Area	-	-	-
Heating area	6000 ft^2	12000 ft^2	20,000 ft^2
Weight	1600 lbs	2600 lbs	3200 lbs
Warranty	All models have a 10 yr warranty, including corrosion warranty.		
Burn Time	Up to 36 hrs	Up to 48 hrs	Up to 72 hrs
Works with	Forced air heating, in-floor heating, unit heater, hot water baseboards, existing boiler heating (gas, oil, electric), pools/hot tubs, clothes dryer, and water heater for all installations.		
Special features	*Titanium Stainless Steel Firebox* *Fast Heat Recovery via Hurricane Directional Air Injection:* The Wood King furnace uses a powered air injection fan with measured airflow. This gives a burn cycles that is extremely hot and very short. The water storage tanks are small because the reserve heat is kept in the unburned wood, not in the water from which heat will eventually escape. This means that less wood is burned, and even the wettest of woods burns easily producing instant heat. Combustion is nearly 100% and ashes are reduced. This injection air system will heat up to 50% more area than natural draft furnaces. Our directional control forces the heater air to transfer to the water at the back of the furnace. Minimal heat is lost out the flue due to the by-pass system and the measured airflow.		
Price (unit only)			
Wood	44" – 50"	56" – 60"	68" – 72"
	Wood can be any moisture content, junk wood, and pallets.		

*Available in Mild Steel only

Aqua-Therm
48301 State Hwy 55
Brooten, MN 56316
800-325-2760
www.aqua-therm.com

Functions:
To use with hot water systems: Aqua-Therm operates at the same temperature and pressure as existing boiler and hooks directly into it. An existing boiler can be used for back-up heat and can be set to come on automatically if the Aqua-Therm runs out of fuel.

To use with hot-air systems: A water-to-air exchanger is needed. Air blows through the heat exchanger taking the heat from the water and blows it into existing ducts. A separate thermostat is added. An existing boiler can be used for back-up heat and can be set to come on automatically if the Aqua-Therm runs out of fuel.

To use with domestic hot water: A water-to-water heat exchanger is used to provide hot water for household use. The boiler water circulates through the outer jacket, which has a finned inside tube. The fins assure maximum heat transfer as the hot boiler water is pumped through. Between the finned and inner tubes, there is a small air chamber which protects domestic water from contamination. The tempering valve can be set from 120 – 160°F. This valve will mix a measured amount of cold water with the hot as it leaves the water heater, giving the desired temperature at the tap. This system needs no extra pipes between the boiler and the house.

A forces air draft is used to bring in combustion air which comes in underneath grates for a more even burn.

Model	145	275*	345**
Max BTU	-	-	
Door	16" x 20"	19.5" x 25"	19.5" x 25"
Water Capacity	48 gal	59 gal	76 gal
Draft	All models are forced air		
Water Jacket	-	-	-
Firebox (inches)	Length – 42" Diameter – 25"	Length – 42" Diameter – 32.5"	Length – 55.5" Diameter – 32.5"
Dimension H x W x L (in)	46 x 30 x 58	57.5 x 38.5 x 58	57.5 x 38.5 x 73
Flue size	8"	8"	8"
Steel Thickness	1/8"	3/16"	3/16"
Heat Transfer Area	-	-	-
Heating area	1800 ft^2 or under, unless well insulated	*	**
Weight	630 lbs	900 lbs	1050 lbs
Warranty	All models have a 15 year limited warranty. The first 5 years the warranty pays 100%. Years 6 – 15 have prorated coverage. All components and controls have a one year warranty. Firebox corrosion is covered.		
Burn Time	10 – 12 hours when properly sized		
Works with	Hot water baseboards and radiators, radiant floor systems, heat exchanger placed in hot air duct systems, domestic hot water heater, pools and spas.		

Special features	*Closed system:* It is filled and then sealed, no need to add more water, this keeps air out of the system and eliminates rust and the need for additives; operates at 15 psi and 160-180°. *Less water:* Uses less water than most brands – less water being more efficient. This also makes using anti-freeze to protect the wood burner and underground lines. *Piping:* copper or high temperature polyethylene pipe may be used to conduct water. Pipe size depends on distance to house – typically a 1" I.D. pipe. Pipes are buried 12-18" deep and must be insulated, typically with standard 2" blue styro sheets (which doesn't absorb water). Preformed insulation is also available.
Price Models 145/257/345	Basic Stove Package: stove, draft fan and automatic shutter, loading switch, boiler drain, and relief valves. **$2379 / $3464 / $4173** For use with hot water boilers: stove, draft fan and automatic shutter, loading switch, boiler drain, relief valves, pressure and temperature gauge, aquastats, circulating pump, and isolation pump flanges. **$2636 / $3722 / $4431** Sheltered Models: **$3856 / $4962 / $5746** For hot water systems without an existing boiler: stove, draft fan and automatic shutter, loading switch, boiler drain, relief valves, pressure and temperature gauge, aquastats, circulating pump, isolation pump flanges, expansion tank, air scoop, and auto air vent. **$2706 / $3832 / $4541** Sheltered Models: **$3927 / $5072 / $5856** For use with forced air systems: stove, draft fan and automatic shutter, loading switch, boiler drain, relief valves, pressure and temperature gauge, aquastats, circulating pump, isolation pump flanges, relay, expansion tank, air scoop, auto air vent, and heat exchanger. **$2949 / $4074 / $4783** Sheltered Models: **$4169 / $5314 / $6098**
Wood	*, **, large size wood and green wood is okay.

*Model 275 – most popular unit is suited for large or poorly insulates homes and for individuals burning soft or junk wood, good for people wanting longer burn times.
**Model 345 – ideal for pole buildings, green houses, farrowing and calf barns, or anywhere a large amount of economical heat is needed. Also can be used for heating multiple buildings.

Outer jacket is 10 gauge steel, stainless steel firebox

Can put Aqua-Therm in your own building – for *comfort* – when refueling and removing ashes, *convenience* – large enough building for wood storage, *price* – cheaper than buying an already enclosed unit, *appearance* – keeps wood and ashes out of sight.
Can purchase an already plumbed, insulated, and wired to code shelter for Aqua-Therm (all models are available with or without shelter).

Shelter Dimensions:

Height to peak of roof	5'7"
Width	4'
Length – Models 145 & 275	6'
Length – Model 345	7'
Weight – Model 145	1080 lbs
Weight – Model 275	1350 lbs
Weight – Model 345	1590 lbs

Garn Smokeless Wood Heating Systems
Dectra Corporation
3425 53rd Avenue NE
St. Anthony, MN 55418
612-781-3835
www.garn.com

Funtions: Outside air is draqn through an internal air inlet tube to the air distribution collar. The door prevents air form being drqn from the room. It is insulated to prevent heat loss and consists of an air-cooled heat shield to prevent hot surfaces near the user. Combustion air from the collar flows through an upper and lower nozzle into the combustion chamber. Remaining free air is mixed with hot gases before entering the ceramic secondary combustion chamber. Within the ceramic tube, smoke, creosote, and particulates are burned at temperatures near 2000°F. The hot gases release their heat as they move through 5-pass tubular heat exchanger within the water storage. The cooled gases are then pulled into the draft inducer housing and pushed out of the exhaust pipe at temperatures approximately 130°F above the water.
Radiant Floor: Best way to distribute stored hot water. Comfortable even heat and causes no air movement. It can use lower water temperature than other distribution systems, so a smaller storage system can be installed.
Forced Hot Air: Can be a furnace, fan coil unit, or individual room heater. When thermostat calls for heat, water is pumped through a water-to-air coil and the air is heated as a blower recirculates it past the coil.
Hot Water (Hydronic): Piping can be connected directly to the cast iron radiators or hot water baseboards. Baseboard systems may require higher water temperatures than other distribution systems. This may require an increase in storage capacity or an incrase in the total length of the installed baseboard.
Domestic or Process Hot Water: A heat exchanger can be used to provide everyday domestic or process hot water.

Model	1500	2000	3200
Max BTU/hr	350,000	450,000	950,000
Door	18" x 20"	18" x 20"	18" x 20"
Water Capacity			
Draft			
Water Jacket			
Firebox LxD(in)	42 x 25	42 x 25	52 x 40
Dimension H x D x L (in)	80 x 71 x 96	80 x 71 x 120	93 x 86 x 146
Chimney size	-	-	-
Steel Thickness	-	-	-
Heat Transfer Area	-	-	-
Heating area	-	-	-
Weight	2500 lbs	3600 lbs	6500 lbs
Combustions Efficiency	84.4% avg. overall efficiency using seasoned red oak using MC of 11-23. 15 million BTU per full cord of seasoned red oak.		
Burn Time	-	-	-
Works with	Radiant floor, forced hot air, hot water (hydronic), domestic or process hot water		

Special features	Massive water storage; intermittent high temp efficient combustion; efficient 5-pass heat exchanger; sealed combustion with horizontal vent (vertical chimney is not required); insulated, cool surface, dished stainless steel door; non-pressurized energy storage; internally welded seams, epoxy coating, anode rods and water treatment corrosion protection; industrial duty, draw thru induced draft combustion air blower; optional integral off peak electric back up – does not require a separate back up furnace or boiler.		
Price (unit only)	-	-	-
Wood	24 – 32"	24 – 32"	32 – 48"
	Cord or slab wood, pallet or other scrap wood, densified wood briquettes, and air dried corn on the cob are okay. Using wet wood significantly decreases performance and increases wood use and maintenance.		

* Using GARN, approximately 97% of the wood is converted to energy and 87% of that energy is store for use, for about 84% max efficiency.

Pacific Western Inc.
Hot Water Outdoor Wood Furnaces
Box 267
Atikokan, Ontario
POT 1CD
807-929-1129
www.outdoorfurnaces.com

Waste Wood Supply for Residential Wood Heating Systems

The research presented in this report centers around two primary data collection efforts. The first phase of primary data collection involves a series of telephone interviews aimed at determining the available source and economic cost associated with waste wood supply in the region.

Sample Design

Respondents to this phase of the study where selected randomly from the Minnesota Forest Products Directory, a publication of the Minnesota Extension Service, University of Minnesota, Department of Wood and Paper Science – most recently acquired by the Minnesota DNR with an update expected later this year. This directory consists of 1700 Minnesota wood products manufacturers and sawmills. Included companies' demographics, products, production materials, and species are reported in the directory. Other information is collection, but remains strictly confidential. Twenty-two (22) completed and usable interviews are examined in this portion of the report. Of these respondents, twelve (12) participated mainly in primary processing activities, whereas ten (10) respondents participated primarily in secondary manufacturing environments.

Respondent Profile

Figure S1 provides a breakdown of respondents primary line of business, and indicates that sawmill and cabinet making operations are most heavily represented. Given the qualitative focus of this portion of the study, our goal was to obtain the perspectives of many different types of manufacturing operations to gain a fairly broad view of perceptions regarding disposal, sale, and/or use of residual wood and wood fiber streams post production.

Similar to our goal of obtaining responses from a broad range of forest products manufacturers, our interview efforts also aimed to obtain responses from both large and small producers in the region (see Table S1). Respondents represented companies with annual sales ranging from $10,000 annually to $6,000,000 annually. On average, responding companies earned just under $1 million annually. Responding companies reported employees of 1 to 36, with the average respondent employing 7.5 people.

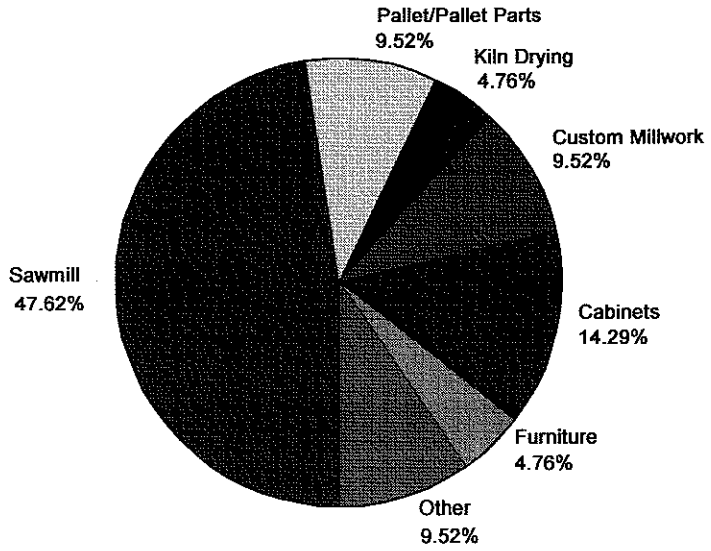


Figure S1. Respondents by primary line of business

Table S1. Respondent Size

	N	Minimum	Maximum	Mean
Number of Employees	21	1	36	7.50
2000 Sales	17	$10,000	$6,000,000	$978,235

Interview Results

The primary objective of our supply oriented interviews was to identify suppliers currently making waste wood streams available to customers, as well as identify those suppliers interested in assisting customers through additional processing (if necessary to breakdown larger pieces into ones suitable for use with outdoor wood furnaces) and/or delivery.

Table S2. Availability of Waste Wood

Current Availability of Waste Wood for Pick-up or Delivery	Percent
Respondents Making Waste Wood Available to Customers	65.0
Respondents Not Making Waste Wood Available	35.0
Total	100.0

Of those participating in our interviews, 65% indicated that they make their waste wood available to customers, either by giving it away or selling it as firewood or animal bedding. The remaining 35% use the material internally (for heat/energy), with only one respondent indicating any substantial portion of waste streams sent to the landfill.

Table S3. Interest in Delivery of Waste Wood to Consumers

	N	Min.	Max.	Mean	S.D.
Interest in Delivering Waste Wood to Residnetial Customers (assuming at least break-even)	12	1.00	5.00	1.833	1.586

Although nearly two-thirds of respondents make their waste wood available to customers, respondents were uninterested in assisting customers through delivery (even assuming that the costs of delivery could be outweighed by reductions in disposal costs or through a nominal fee).

Interviewee responses were collected qualitatively, and unfortunately, the process for collecting, packaging and removing wood wastes from the manufacturing site is loosely managed and difficult to record. Tables S4 and S5 attempt to summarize primary and secondary manufacturers comments, respectively.

The majority of primary manufacturers interviewed indicated that slabs and edging (material most suitable for outdoor wood furnace consumption, was either piled or stacked on site. Of this material flow, 60% of respondents sell some portion as wood fuel (however, few were interested in further processing these slabs and edgings to ensure lengths less than 4 feet). Approximately 80% of respondents indicated a willingness to deliver but the majority of them currently charge for this service, thus increasing the total cost to consumer.

Table S4. Summary of Primary Suppliers' Waste Stream Availability

	Collection of waste wood streems		Disposal of waste wood		Packaging of waste wood for sale[1]		Delivery Charge	
Sawdust								
	Bins	75%	Landfill	0%	N/A		N/A	
	Pile	17%	Burn	8%				
	Bag	8%	Cutomer pick-up[2]	92%				
		0%	Missing	0%				
Slabs and Edgings								
	Pile	36%	Chip and Sell	50%	Bundle	63%	Free Delivery	20%
	Stack/bundle	36%	Sell for Firewood[3]	60%	By the Ton	25%	Charge ($20-$240)	60%
	Cut	27%	Burn	20%	By the Pick-up truck	13%	Do not Deliver	20%
			Free access[4]	10%				
Bark								
	Pile	50%	Customer pick-up	100%	N/A		N/A	
	Don't Collect[5]	50%		0%				

[1] Given the outdoor wood furnace emphasis of the study, packaging and delivery of slabs and edgings were examined only.
[2] All respondents indicating customer pick-up of sawdust, sold this product for animal bedding.
[3] Although roughly 25% indicated that they either would or have in the past cut slabs and edging to small than 4 ft. demensions for customers, all respondends indicated very low levels of interest in perfoming this additional operation.
[4] Family/Friends/Employee/community pick-up.
[5] Don't collect or generate minimal amount to accurately provide a response

Similarly to primary processors, secondary manufactures – particularly the large number of relatively small operations, don't actively manage their waste streams in any formal process. This is not to say that they are wasteful in their utilization of this resource. Most respondents went out of their way to communicate that only a very small proportion of these waste streams make it to the landfill. Rather, informal arrangements have generally been made with local farmers, energy providers, and friends, family, and customers for pick-up.

Although we asked about packaging, sale, and delivery of lumber and panel scraps, most recommend against burning panel products where toxic resins or adhesives may be present. Therefore, lumber scraps are the most reasonable waste stream for an outdoor wood furnace application. Within this category, 70% of secondary manufacturers collect waste in bins or pile it. Sixty percent of respondents indicated that they make residues available to the public either through sales or giving it away. Those selling their scrap lumber (50%) sell it by the bin, packaged in 16" lengths for firewood, box it, or sell it by the truckload. Virtually all respondents indicated very little interest in current or future delivery of this material.

Table S5. Summary of Secondary Suppliers' Waste Stream Availability

	Collection of waste wood streems		Disposal of waste wood		Packaging of waste wood for sale[1]		Delivery Charge	
Lumber Scraps (n=10)	Bins	40%	Landfill	10%	Bin	10%	Free Delivery	0%
	Pile	30%	Burn	40%	16" lenghts	20%	Charge (no set price)	10%
	Cut to Burn	20%	Cutomer pick-up[2]	40%	Box	10%	Do not Deliver	90%
	Stack	10%	Fee access	20%	Don't sell scrap	50%		
	Don't collect[2]	10%	NSP (burn)	10%	Truckload	10%		
Chips and Sawdust	Pile	50%	Sell for mulch/bedding	50%	N/A		N/A	
	Bin	30%	Spread in the woods	20%				
	Don't collect	20%	NSP (burn)	10%				
			Landfill/Trash	20%				
Panel Scraps	Bin	20%	Customer pick-up	25%	Bin (free pick-up)	10%	Free Delivery	0%
	Re-use	10%	Burn	25%	Don't sell scrap	90%	Charge	0%
	Don't collect	70%	landfill	50%			Do not Deliver	100%
Treated Wood (n=0)	N/A		N/A		N/A		N/A	
Mixed Materials (n=0)	N/A		N/A		N/A		N/A	

[1] Given the outdoor wood furnace emphasis of the study, packaging and delivery of lumber and panel scaps were examined only.
[2] Don't collect or generate minimal amount to accurately provide a response

If we compare the willingness of suppliers to provide lumber/slabs/edgings scraps to the Southeastern Minnesota outdoor wood furnace market with our best-known estimates of these industrial resource streams in the area, we can begin to determine the available wood from this source. Table S6 indicates that according to DNR estimates, 8132 dry tons of lumber scraps are available in the region. This report also indicated that 4805 tones of waste wood is currently sold or given away for burning. If we assume that 80% of lumber scraps and 40% of mixed woods streams could be utilized in an outdoor wood furnace application, then we might conclude that roughly 7274 tons could be available for this purpose ([.8(8132)+.4(13934)-4805).

Table S6. Total Expanded Residue Volume (dry tons) in Southeastern Minnesota (DNR 1994)

County	Lumber scraps	Other Mixed	Total Tons	Sold/Given Fuel
Dakota	218	6193	14711	1130
Dodge	0	0	90	0
Fillmore	7	2772	2782	7
Goodhue	86	2923	4976	380
Houston	0	259	286	130
Mower	2	318	321	0
Olmsted	2238	821	4347	2417
Rice	6	206	248	49
Scott	5175	172	14771	184
Wabasha	8	270	464	116
Winona	392	0	1015	392
Totals	8132	13934	44011	4805

Assuming there are 7274 tons of wood available, there would be enough wood to support 73-160 outdoor wood furnaces per year. This was determined by the following:

7274 tons = 14,578,000 lbs
Wt = Volume*specific gravity* density of water *(1+MC/100)
14578M lbs = Volume 0.62*62.4 lb/ft^3 * 1.08
Voulme = 81372 ft^3 = 635 cords
Assuming 17-37 cords per year (see section entitled Fuel Source Comparison) this amounts to 73-160 outdoor wood furnaces per year.

To further elaborate, if we assume that nearly 1338 outdoor wood furnaces are in use in Southeastern Minnesota (.9% [6 out of 634 respondents indicated owning an outdoor wood furnace] of total households in the region of 148,612 [as indicated by 1990 US Census figures]), industrial wood waste streams would only support a 5.5-12% growth rate in the market. All other growth would need to be supported by forest biomass or urban sources of waste wood.

In the authors' opinions, this would only keep approximately $150,000 to $329,600 in the local economy ($2060 *73, $2060 *73).[2]

[2] $2060 is a weighted average of current heating expenses according to primary heating source data captured through our homeowner survey.

Residential Homeowner Analysis:

Survey Sample

A survey was developed from personal knowledge, conversations with industry and academic professionals, and a broad literature search. A draft of the survey was pretested with homeowners as well as academic and industry professionals. It was modified and sent out to 2000 rural Minnesota homeowners living in the specified zip codes in counties of Dakota, Dodge, Fillmore, Goodhue, Houston, Mower, Olmsted, Rice, Scott, Wabasha, and Winona. The zip codes from which respondents were selected are presented below. A mailing list was purchased from Best Mailing Lists, Inc., Tucson, AZ. Best Mailing Lists, Inc. had, 71,891 households. Their lists are compiled from credit card information, surveys, warranty cards, Census Information, etc. (it is a compiled list). The list was selected by taking every 35th record after the records were put in zip code order.

Dakota	Dodge	Fillmore	Goodhue	Houston	Mower	Olmsted	Rice	Scott	Wabasha	Winona
55010	55924	55922	55009	55919	55909	55901	55019	55020	55041	55910
55031	55927	55935	55018	55921	55912	55902	55053	55054	55932	55925
55085	55940	55939	55026	55931	55918	55903	55057	55352	55945	55942
	55944	22919	55027	55941	55926	55904		55372	55956	55952
	55955	55954	55066	55943	55936	55905		55378	55957	55969
	55985	55961	55089	55947	55951	55906		55378	55964	55972
		55962	55946	55974	55953	55929		56011	55968	55979
		55965	55963		55967	55934			55981	55987
		55971	55983		55970	55960			55991	
		55975	55992		55977	55976				
					55982					

Survey Administration

The first survey was mailed out on April 05, 2001 and a reminder postcard was sent on April 12, 2001 to the entire sample. On April 19, 2001 another copy of the survey was mailed to those who had not yet responded. Surveys were collected through May 28, 2001.

Response Rate

The final adjusted response rate was 33%. Surveys were sent to 2000 randomly selected homeowners within the region, of which:

- From the first survey mailing nine (9) unique surveys were returned undeliverable.
- From the postcard mailing thirteen (13) unique postcards were returned undeliverable.
- From the second mailing, fifteen (15) unique surveys were returned as undeliverable.
- Thirty-eight (38) postcards and first surveys were returned from the same unique respondent.
- Five (5) surveys were mailed back with a message that the addressee did not live at that residence.
- Six (6) surveys did not contain enough information to be usable.

Total undeliverable and unusable	86	
Adjusted number of surveys sent	1914	
First mailing response	485	
Second mailing response	149	
Total Responses	634	
Response rate		Cumulative Response Rate
From 1st mailing	0.25	0.25
From 2nd mailing	0.08	0.33

Respondent Profile

The follow section provides information regarding the demographic make-up of survey respondents, and is useful from the standpoint that it provides information related to the representative nature of this sample to the broader population in the region. It is the researcher's opinion that the sample adequately represents this population, however some highlights should be addressed.

- Substantially more men responded to the survey than women (62.5% versus 37.5%).
- Respondents tended to be of retirement, or approaching retirement, years; nearly 30% of respondents were 66 years old or older and nearly half of all respondents (47%) were older than 55.
- Given the assumed retirement status of many respondents, as well as the rural nature of the region, it is somewhat surprising that reported annual household income of respondents is higher than those previously reported statewide. Just over 40% (42.6%) of respondents indicated income levels less than $50,000; the median MN household income in 1998-1999 reported as $48,112, US Census Bureau).
- One potential explanation for the relatively high incomes may be due to high levels of education within the sample: 94% hold a high school diploma, 48% hold post-secondary degrees (13% 2-year, 35% 4-year), and 13% have earned post-graduate degrees.

This section also provides information related to the area's housing stock. Nearly 40% of respondents live in homes with between 1500 and 2500 square feet of finished living space. The current housing stock is relatively old, only 15% of these homes were built within the past 10 years. Approximately 65% of the homes identified by responds are valued at less than $150,000, with more than 30% valued at less than $100,000. Finally, respondents indicated long-time residence in these homes; 66% of respondents have lived in their homes for 10 years or more, and 35% indicated living in their homes 20 or more years.

Frequency data is provided for this information, along with additional demographic related inquiries, in the tables below. Tables are identified by the survey instrument's question number, as well as a general description of the information captured.

Q28. Respondent Sex

	Frequency	Percent
Male	377	62.5
Male	377	62.5
Female	226	37.5
Female	226	37.5
Total	603	100.0
Total	603	100.0

Q29. Age Classification

	Frequency	Percent	Cumulative Percent
Under 18	1	.2	.2
Under 18	1	.2	.2
25-30	22	3.6	3.8
25-30	22	3.6	3.8
31-35	37	6.1	9.9
31-35	37	6.1	9.9
36-40	60	9.9	19.7
36-40	60	9.9	19.7
41-45	73	12.0	31.7
41-45	73	12.0	31.7
46-55	131	21.5	53.3
46-55	131	21.5	53.3
56-65	109	17.9	71.2
56-65	109	17.9	71.2
66 and older	175	28.8	100.0
66 and older	175	28.8	100.0
Total	608	100.0	
Total	608	100.0	

Q30.People Living in Home

	Frequency	Percent	Cumulative Percent
1	88	14.5	14.5
1	88	14.5	14.5
2	273	45.0	59.5
2	273	45.0	59.5
3	82	13.5	73.0
3	82	13.5	73.0
4	100	16.5	89.5
4	100	16.5	89.5
5	49	8.1	97.5
5	49	8.1	97.5
6	9	1.5	99.0
6	9	1.5	99.0
7	5	.8	99.8
7	5	.8	99.8
8 or more	1	.2	100.0
8 or more	1	.2	100.0
Total	607	100.0	
Total	607	100.0	

Q31a.Your Upbringing

	Frequency	Percent
Rural	319	53.5

Urban	96	16.1
City	180	30.2
City	180	30.2
Not Applicable	1	.2
Not Applicable	1	.2
Total	596	100.0
Total	596	100.0

Q31b.Spouse's Upbringing

	Frequency	Percent
Rural	240	44.9
Rural	240	44.9
Urban	112	20.9
Urban	112	20.9
City	151	28.2
City	151	28.2
Don't know	4	.7
Don't know	4	.7
Not Applicable	28	5.2
Not Applicable	28	5.2
Total	535	100.0
Total	535	100.0

Q32.Years Lived in Home

	Frequency	Percent	Cumulative Percent
2 years or less	38	6.0	6.3
2 years or less	38	6.0	6.3
3-5 years	86	13.6	20.4
3-5 years	86	13.6	20.4
6-9 years	83	13.1	34.1
6-9 years	83	13.1	34.1
10-19 years	180	28.4	63.8
10-19 years	180	28.4	63.8
20 years or more	220	34.7	100.0
20 years or more	220	34.7	100.0
Total	607	95.7	
Total	607	95.7	

Q33.Home Age

	Frequency	Percent	Cumulative Percent
Less than 5 years old	38	6.2	6.2
Less than 5 years old	38	6.2	6.2
5-9 years old	53	8.7	14.9
5-9 years old	53	8.7	14.9
10-19 years old	78	12.8	27.7
10-19 years old	78	12.8	27.7
20-29 years old	96	15.7	43.4
20-29 years old	96	15.7	43.4

30-39 years old	74	12.1	55.5
40 years old or more	246	40.3	95.7
40 years old or more	246	40.3	95.7
Don't know	26	4.3	100.0
Don't know	26	4.3	100.0
Total	611	100.0	
Total	611	100.0	

Q34.Home Finished square footage

	Frequency	Percent	Cumulative Percent
Less than 500 sq. ft.	3	.5	.5
Less than 500 sq. ft.	3	.5	.5
500-1499 sq. ft.	113	18.9	19.4
500-1499 sq. ft.	113	18.9	19.4
1500-2499 sq. ft.	236	39.5	58.9
1500-2499 sq. ft.	236	39.5	58.9
2500-3499 sq. ft	113	18.9	77.8
2500-3499 sq. ft	113	18.9	77.8
3500-4499 sq. ft	33	5.5	83.3
3500-4499 sq. ft	33	5.5	83.3
4500-5499 sq. ft	7	1.2	84.4
4500-5499 sq. ft	7	1.2	84.4
5500 sq. ft. or more	4	.7	85.1
5500 sq. ft. or more	4	.7	85.1
Don't know	89	14.9	100.0
Don't know	89	14.9	100.0
Total	598	100.0	
Total	598	100.0	

Q35.Home Market Value

	Frequency	Percent	Cumulative Percent
Less than $50,000	36	6.1	6.1
Less than $50,000	36	6.1	6.1
$50,000-99,999	155	26.1	32.1
$50,000-99,999	155	26.1	32.1
$100,000-149,999	199	33.4	65.5
$100,000-149,999	199	33.4	65.5
$150,000-199,999	105	17.6	83.2
$150,000-199,999	105	17.6	83.2
$200,000-249,999	50	8.4	91.6
$200,000-249,999	50	8.4	91.6
$250,000-299,999	27	4.5	96.1
$250,000-299,999	27	4.5	96.1
$300,000-399,999	16	2.7	98.8
$300,000-399,999	16	2.7	98.8
$400,000-499,999	2	.3	99.2
$400,000-499,999	2	.3	99.2
$500,000 or more	5	.8	100.0
$500,000 or more	5	.8	100.0
Total	595	100.0	
Total	595	100.0	

Q36.Annual Household Income Before Taxes

	Frequency	Percent	Cumulative Percent
Under $15,000	35	6.4	6.4
Under $15,000	35	6.4	6.4
$5,000-29,999	72	13.2	19.7
$5,000-29,999	72	13.2	19.7
$30,000-49,999	125	23.0	42.6
$30,000-49,999	125	23.0	42.6
$50,000-74,999	145	26.7	69.3
$50,000-74,999	145	26.7	69.3
$75,000-99,999	102	18.8	88.1
$75,000-99,999	102	18.8	88.1
$100,000-149,999	44	8.1	96.1
$100,000-149,999	44	8.1	96.1
$150,000-199,999	8	1.5	97.6
$150,000-199,999	8	1.5	97.6
$200,000-299,999	10	1.8	99.4
$200,000-299,999	10	1.8	99.4
$300,000 or more	3	.6	100.0
$300,000 or more	3	.6	100.0
Total	544	100.0	
Total	544	100.0	

Q37.Education

	Frequency	Percent	Cumulative Percent
Grade School	15	2.5	2.5
Grade School	15	2.5	2.5
Some High School	22	3.7	6.2
Some High School	22	3.7	6.2
High School Graduate	150	25.0	31.2
High School Graduate	150	25.0	31.2
Some College	125	20.8	52.0
Some College	125	20.8	52.0
2-yr College Graduate	76	12.7	64.7
2-yr College Graduate	76	12.7	64.7
4-yr College Graduate	103	17.2	81.8
4-yr College Graduate	103	17.2	81.8
Some Graduate School	30	5.0	86.8
Some Graduate School	30	5.0	86.8
Graduate Degree	79	13.2	100.0
Graduate Degree	79	13.2	100.0
Total	600	100.0	
Total	600	100.0	

Primary Heating Methods in Southeastern Minnesota

In order to begin our assessment of the opportunities available for outdoor wood furnaces in Southeastern Minnesota, we must first assess the current residential heating methods being employed in the region. We examine this usage in terms of homeowners' primary heating methods and energy sources used in their homes, and then repeat this analysis focusing on secondary (either supplementary or auxiliary) heating methods and sources.

Natural gas emerged, by a large margin, as the most used energy source heating residences in Southeastern Minnesota (Questions 2 and 3 reflect these responses). Natural gas was employed more than 4 times more often than the next most reported heating source, propane (438 respondents indicated using natural gas as the primary energy source heating their home versus 108 reporting propane). The majority of respondents reporting these sources utilized them within a forced air environment – 87% of natural gas users and 83% of propane users. Only 17 respondents (2.76%) indicated using wood as their primary source of heat in their homes.

Respondents were asked to rate the attributes associated with heating their home on a seven-point importance scale, where 1 = very important and 7 = very unimportant (see Table Q4). Overall, respondents indicated that safety was the most important attribute of their heating source, followed by indoor air quality, comfort, cost per month, and cleanliness of fuel. These responses were very much representative of natural gas and propane users, however, those using wood seemed to differ substantially. Overall, wood users tended to be less discriminating about the attributes associated with heating their homes (i.e. nearly all attributes were seen as significantly less important by wood users than respondents indicating other sources). Exceptions to this general note can be found in the attributes of cost per month and comfort, the two most important attributes to wood users.

Although potentially due to the low demands wood users place on their heating source, respondents indicating wood as their primary source of heat were generally more satisfied with their primary heating system than those using other energy sources (see Table Q9a). People using propane were least satisfied, and therefore, emerging as a likely candidate for switching to an outdoor wood furnace utilizing a forced air delivery system as their primary heating unit.

Q2 and Q3) **Primary** heating method used by energy source (number of respondents)*

	Electric	Natural Gas	Propane	Heating Oil	Wood	Other	Total
Forced Air Furnace	5	381	90	28	4	1	509
Outdoor Wood Furnace/Stove	0	1	0	0	4	0	5
Indoor Wood Furnace/Stove	0	4	3	1	11	1	20
Radiant Floor Heat	1	9	6	0	2	1	19
Gas Fireplace/Insert	0	22	4	1	0	0	27
Base Board Heat	9	37	10	5	0	0	61
Other	1	18	8	1	1	0	29
Total	16	438	108	34	17	2	615

* Respondents may have selected multiple heating methods for the primary energy source used in their home.

Q4) Importance of **primary** heating source attributes

	Primary Heating Source					
Heating Attribute	Natural Gas	Propane	Heating Oil	Electric	Wood	Total
Clarity of billing statements	2.24	2.85	2.52	2.53	5.14	2.44
	(430)	(104)	(31)	(15)	(14)	
Cleanliness of fuel	1.73	1.91	1.88	2.33	3.75	1.84
	(430)	(109)	(32)	(15)	(16)	
Compatibility with air conditioning systems	2.28	1.91	2.87	2.80	4.13	2.42
	(423)	(105)	(30)	(15)	(15)	
Comfort	1.60	1.83	1.59	2.00	1.69	1.65
	(423)	(110)	(32)	(15)	(16)	
Concerns of government regulations	2.67	3.13	2.88	3.13	3.94	2.82
	(422)	(105)	(32)	(15)	(16)	
Cost per month	1.66	1.89	1.81	1.93	1.44	1.71
	(434)	(108)	(32)	(15)	(16)	
Credit terms	3.95	3.76	3.61	3.57	5.75	3.93
	(413)	(104)	(31)	(14)	(16)	
Ease of temperature control	1.97	2.10	2.03	2.07	2.94	2.02
	(427)	(107)	(31)	(15)	(16)	
Environmental impacts	2.12	2.50	2.73	2.50	3.38	2.26
	(420)	(105)	(30)	(14)	(16)	
Even distribution of heat	1.78	2.06	1.72	2.20	2.44	1.85
	(428)	(104)	(32)	(15)	(16)	
Safety	1.48	1.76	1.97	1.67	2.00	1.58
	(427)	(104)	(31)	(15)	(16)	
Social status	5.05	5.27	4.47	4.80	5.69	5.07
	(410)	(105)	(30)	(15)	(16)	
Smell	2.12	2.32	2.52	2.13	3.63	2.21
	(420)	(104)	(29)	(15)	(16)	
Physical labor - maintenance and filling fuel source	2.65	2.85	2.52	2.13	3.63	2.74
	(412)	(107)	(29)	(15)	(16)	
Maintenance/cleaning costs	2.13	2.64	2.58	2.80	4.00	2.32
	(420)	(106)	(31)	(15)	(16)	
Predictability of monthly cost	2.11	2.44	2.23	2.40	3.56	2.22
	(422)	(106)	(31)	(15)	(16)	
Indoor air quality	1.56	1.75	1.58	2.00	2.38	1.63
	(431)	(106)	(31)	(15)	(16)	

Q9a.Primary Heating Source Satisfaction

Satisfaction	Electric	Natural Gas	Heating Oil	Wood	Propane	Other	Solar	Total
1	6	179	13	7	36	1		242
2	6	156	14	8	50			234
3	2	52	3	1	9	1		68
4	1	21	1		7			30
5		9		1	1			11
6		6			2			8
7		7	1		1			9
Mean	1.87	2.00	1.91	1.82	2.03	2.00		1.99
S.D.	0.92	1.25	1.20	1.01	1.15	1.41		1.21
n	15	430	32	17	106	2		602

Secondary Heating Sources Used in Southeastern Minnesota

Because wood is used by many as a secondary heating source, we asked homeowners in the region to identify their secondary (either supplemental or auxiliary) heating sources and methods, rate attributes associated with these types of heating systems, and finally to indicate their level of satisfaction with these systems.

Not surprisingly, wood emerged, by a large margin, as the most used secondary energy source among Southeastern Minnesota residents (Questions 6 and 7 reflect these responses). Wood was employed more than 2 times more often than the next most reported heating source - natural gas, and was listed as a secondary heating source by nearly half of all respondents indicating the use of a secondary source of heat in their homes. The majority respondents using wood as a secondary heating source used it in an indoor wood stove or in a traditional fireplace. Those using natural gas as a secondary heating source did so primarily through gas converted fireplaces or inserts.

Respondents were asked to rate the attributes associated with their secondary heating source on a seven-point importance scale, where 1 = very important and 7 = very unimportant (see Table Q8). Overall, respondents indicated that safety was the most important attribute of their heating source, followed by indoor air quality, comfort, smell, and even distribution of heat. These responses were very much representative of natural gas and wood users, however, the issues of cleanliness, smell, and heat distribution seem to be driving lower levels of satisfaction among wood users. As with primary heating method ratings, wood users tended to rate attributes as less important, across the board, than those using other secondary sources of heat. But, whereas this relative apathy may have helped create higher satisfaction levels in our analysis of primary heating sources, in our analysis of secondary heating sources wood received the lowest satisfaction scores of all methods reported (see Table Q9b). These low satisfaction scores can most likely be attributed to the mess and inefficiencies associated with traditional fireplaces and wood burning stoves. An outdoor wood furnace would certainly eliminate many of these concerns, however, a more stringent burden of proof will be required to differentiate this type of product from the poor performing systems associated with it.

Q6 and Q7. Percent of **secondary** heating method used by energy source

	Electric	Natural Gas	Heating Oil	Wood	Other	Propane	Solar	Total
Forced Air Furnace	3	1	5	4	1	4	0	18
Outdoor Wood Furnace/Stove	0	0	0	0	0	0	0	0
Indoor Wood Furnace/Stove	0	0	1	68	1	0	0	70
Other	11	6	0	19*	6	0	3	45
Radiant Floor Heat	1	0	0	2	0	0	0	3
Gas Fireplace/Insert	2	32	0	2	3	6	0	45
Ceiling Cable	1	0	0	0	0	0	0	1
Solar Panels	0	0	0	0	0	0	1	1
Pellet Stove	0	0	0	1	0	0	0	1
Base Board Heat	9	3	0	0	0	0	1	13
Total	24	42	5	94	11	10	4	190

Q8. Importance of selected **secondary** heating method attributes

	Secondary Heating Source				
Heating Attribute	Wood	Natural Gas	Electric	Propane	Sig.
Clarity of billing statements	5.05	3.00	3.17	2.64	4.05
	(81)	(41)	(23)	(11)	(175)
Cleanliness of fuel	3.70	1.88	2.57	1.91	2.95
	(84)	(41)	(23)	(11)	(178)
Compatibility with air conditioning systems	5.14	4.38	4.27	3.30	4.63
	(80)	(41)	(22)	(10)	(172)
Comfort	2.29	1.98	2.17	1.55	2.16
	(85)	(41)	(23)	(11)	(179)
Concerns of government regulations	3.95	3.50	3.26	3.55	3.68
	(82)	(42)	(23)	(11)	(177)
Cost per month	3.74	2.40	2.35	1.91	3.03
	(82)	(42)	(23)	(11)	(177)
Credit terms	5.38	4.56	4.04	3.30	4.81
	(78)	(41)	(23)	(10)	(171)
Ease of temperature control	3.76	2.63	2.83	1.64	3.14
	(83)	(41)	(23)	(11)	(177)
Environmental impacts	3.40	2.43	2.77	2.70	3.02
	(84)	(42)	(22)	(10)	(177)
Even distribution of heat	3.39	2.62	2.83	1.70	2.99
	(82)	(42)	(23)	(10)	(175)
Safety	2.01	1.69	1.87	1.36	1.93
	(84)	(42)	(23)	(11)	(179)
Social status	5.53	5.31	5.22	4.82	5.31
	(83)	(42)	(23)	(11)	(177)
Smell	3.33	2.17	2.87	1.80	2.88
	(82)	(40)	(23)	(10)	(173)
Physical labor - maintenance and filling fuel source	3.73	2.98	3.17	2.82	3.38
	(83)	(41)	(23)	(11)	(177)
Maintenance/cleaning costs	3.69	2.27	2.68	2.45	3.10
	(83)	(41)	(22)	(11)	(176)
Predictability of monthly cost	5.11	2.90	2.57	1.91	3.85
	(83)	(42)	(23)	(11)	(178)
Indoor air quality	2.24	1.67	1.78	1.27	1.99
	(83)	(42)	(23)	(11)	(178)

Q9b. Secondary Heating Source Satisfaction

Satisfaction	Electric	Natural Gas	Heating Oil	Wood	Other	Propane	Solar	Total
Do Not Have	2			2	1			5
1	4	16	1	25	3	4	2	55
2	9	16	3	26	4	4	1	63
3	5	5		10	1	2		23
4	4	2	1	19	1			27
5	1	1		3	1			6
6				4			1	5
7				1	1			2
Mean	2.52	1.90	2.20	2.60	2.73	1.80	2.50	2.39
S.D.	1.28	0.98	1.10	1.53	1.98	0.79	2.38	1.42
n	23	40	5	88	11	10	4	181

Likelihood of Switching Heating Methods

A number of questions were developed in order to better understand respondents' likelihood of switching heating methods as a means of replacing ineffective/inefficient outdated units or in an effort to reduce monthly heating costs. Questions 10 through 13 are examined below.

Individuals heating their homes with propane and heating oil indicated the highest monthly heating bills this past winter, even considering the heavily publicized increases in natural gas prices (heating oil was also severely effected by these increases). Both groups of respondents reported monthly winter heating costs (November, December, January) above $300 ($383 For those using propane as there primary heating fuel and $301 For those using heating oil). In addition, the average respondent's heating bill increased by 52% in 2000-2001 from the previous year ($263 in 2000-2001 versus $173 in 1999-2000).

Prices at this level are beginning to play a significant role in switching behavior, just over 7% of respondents indicated that only a 10% additional increase would lead them to consider a switch and another 50% increase year may drive up to 50% of Southeastern Minnesotans to consider switching heating methods. Unfortunately for those promoting the use of alternative residential heating systems, natural gas and heating oil prices are expected to be considerably lower during the coming winter compared to last winter, lessoning the need to switch heating sources/fuels.

Natural gas was reported as the overwhelmingly preferred heating fuel among respondents. Even at current prices, 56% of respondents would choose natural gas to heat a new home. But, at least in times of high oil and gas prices, this preference may be slipping a bit in that 71% of respondent currently use natural gas as their primary heating fuel. Therefore, approximately 15% of current natural gas customers have indicated a preference for something other than natural gas. Picking up this slack, are many of the "alternative" heating methods. Although not a single respondent to our survey indicated using solar energy as the primary source of heat in their homes, 31 people (over 5%) indicated solar energy as the method of choice, if building today. Other net gainers were wood and electric methods (7.5% of respondents indicated a preference for wood fueled heat as the primary source in new construction).

Finally, given the sample reflects relatively long-time residents whose homes are relatively old (see Respondent Profile section above), it appears as though furnace replacement may be on the rise in recent years, and that this opportunity may be substantial for driving the use of alternative heating methods. Only one-third of respondents have indicated ever replacing their heating system. Therefore, it is thought that a significant portion of the remaining 63% of respondents' heating systems is aging and will need to be replaced in the near future. In addition, of those replacing their systems, nearly 40% changed their heating source at this time, indicating that respondents were open to new heating solutions. Although, it is the authors' opinions that outdoor wood furnaces are unlikely to win mass appeal, even in rural settings, these findings bode well for wider spread promotional efforts of these furnaces.

Q10a. Winter 2000 –2001 average heating bill

Current Heating Method	n	Mean	S.D.	95% Confidence Interval	
				Lower Bound	Upper Bound
Electric	13	237.08	131.56	157.58	316.58
Natural Gas	396	240.11	236.27	216.77	263.45
Other	2	69.00	97.58	0	945.73
Heating Oil	28	312.46	301.46	195.57	429.36
Wood	15	184.47	255.74	42.84	326.09
Propane	91	367.31	383.38	287.47	447.15
Total	545	262.83	272.20	239.93	285.74

Q10b. Winter 1999-2000 average heating bill

Current Heating Method	n	Mean	S.D.	95% Confidence Interval	
				Lower Bound	Upper Bound
Electric	12	207.67	108.56	138.69	276.65
Natural Gas	386	146.24	154.66	130.76	161.72
Other	2	47.50	67.18	-556.04	651.04
Heating Oil	28	209.71	160.93	147.31	272.11
Wood	16	140.69	213.91	26.70	254.67
Propane	90	280.33	293.71	218.81	341.84
Total	534	173.01	192.84	156.62	189.40

Q11. Most preferred primary heating method

Current Heating Method	Preferred Primary Heating Method							
	Electric	Nat. Gas	Other	Heat. Oil	Wood	Propane	Solar	Total
Electric	1	7	5		1		1	15
Natural Gas	23	300	40	5	21	2	27	418
Other			1			1		2
Heating Oil	3	6	1	16	4	1	1	32
Wood	1	2	4		10			17
Propane	8	15	17		8	52	2	102
Total	36	330	68	21	44	56	31	586

Q12. Percent Increase in Heating Costs at which Alternative Method Considered

	Frequency	Percent	Cumulative Percent
10%	39	7.2	7.2
10%	39	7.2	7.2
20%	32	5.9	13.0
20%	32	5.9	13.0
30%	51	9.4	22.4
30%	51	9.4	22.4
40%	29	5.3	27.7
40%	29	5.3	27.7
50%	101	18.5	46.2
50%	101	18.5	46.2
60%	21	3.9	50.1
60%	21	3.9	50.1
70%	18	3.3	53.4
70%	18	3.3	53.4
80%	15	2.8	56.1
80%	15	2.8	56.1
90%	7	1.3	57.4

100%	32	5.9	63.3
Never consider for this reason	149	27.3	90.6
Never consider for this reason	149	27.3	90.6
Other	51	9.4	100.0
Other	51	9.4	100.0
Total	545	100.0	
Total	545	100.0	

Q13.Ever Replaced Heating Source

	Frequency	Percent
No	372	62.7
No	372	62.7
Yes	221	37.3
Yes	221	37.3
Total	593	100.0
Total	593	100.0

Q13c.Was Heating Source Replaced with Alternate Type

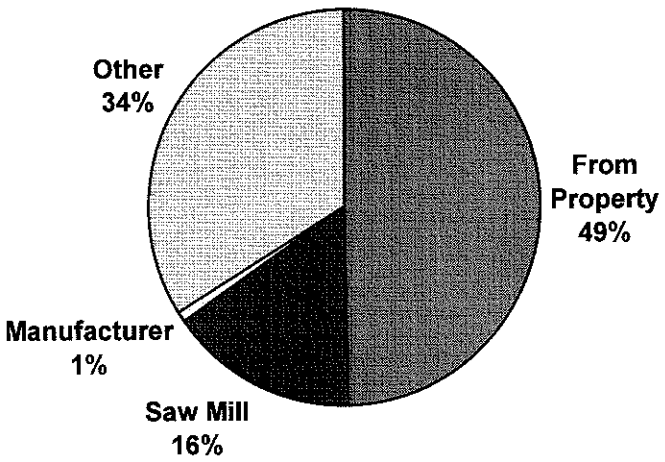
	Frequency	Percent
No	132	62.3
No	132	62.3
Yes	80	37.7
Yes	80	37.7
Total	212	100.0
Total	212	100.0

Wood Use and Outdoor Wood Furnaces

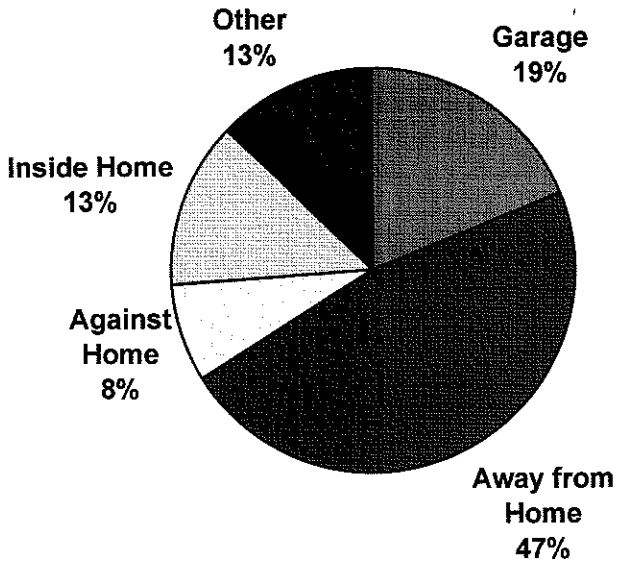
The following sections provide analysis regarding to respondents' wood sourcing and storage behavior (Q14-Q15) and perceptions toward a specifically defined outdoor wood furnace (Q16-Q22).

Wood Sourcing and Storage

Figure Q14 indicates that nearly half (49%) of the people currently using wood fuel are using wood cleared from their property, 16% get from a saw mill, 1% from a manufacturer, and 34% get their wood from another source. Those other sources include neighbor's or relative's property, classified ads, farmers, recycling site, DNR permit areas, tree removal service, logger, and trees from new construction sites. Nearly half of the people burning wood are storing the wood away from their home: 19% store in their garage, 13% store inside their home, 8% against their home, and 13% store in another location (see Figure FQ15). Other storage locations include sheds, portable wagons, barns, basements, and porches both against and away from home.



Q14. Respondent wood fuel sources



Q15. Respondent wood storage locations.

Outdoor Wood Furnace Interest

Overall, Southeastern Minnesotans were significantly uninterested in the generic outdoor wood furnace presented in question 16 of the survey document. The sample's average interest rating is 4.94 on a seven-point scale where 1 = very interested and 7 = very uninterested, and is significantly different than 4, the neutral position on the scale. Although, the average respondent was relatively uninterested in the product, nearly 30% (29.1%) indicated at least a moderate level of interest in the product, with 15% indicating fairly strong interest levels, either a 1 or 2 on the scale.

In question 17, respondents were asked to rate the importance of heating attributes as they relate to the wood furnace presented in question 16. Responses are presented in Table Q17 below based on respondents' involvement in the purchase process (no interest are those reporting interest scores of 4-7 on Q16, interested respondents are those indicating 3-1 on the same scale; consideration is based on an affirmative response to Q20a, purchase is based on affirmative response to Q20b). This data suggests that the closer one comes to purchasing on of these heating systems (i.e. those most likely to purchase), the greater convergence around the attributes of comfort and indoor air quality as most important. Possibly of greater significance is the convergence around what in NOT important (i.e. neutral in importance at best). Attributes falling into this category include: cleanliness of fuel, smell, and physical labor associated with filling and servicing the furnace – attributes of significant importance to those not interested in the outdoor wood furnace.

Q16. Interest Level in Outdoor Wood Furnace

	Frequency	Percent	Cumulative Percent
Very Interested 1	32	5.7	5.7
Very Interested 1	32	5.7	5.7
2	54	9.7	15.4
2	54	9.7	15.4
3	76	13.7	29.1
3	76	13.7	29.1
Neutral 4	67	12.0	41.1
Neutral 4	67	12.0	41.1
5	51	9.2	50.3
5	51	9.2	50.3
6	77	13.8	64.1
6	77	13.8	64.1
Very Uninterested 7	200	35.9	100.0
Very Uninterested 7	200	35.9	100.0
Total	557	100.0	
Total	557	100.0	
Mean	4.94		
Mean	4.94		
Std. Dev	2.01		

Q17. Importance of perceived heating attributes of an Outdoor Wood furnace by buying process stages

Heating Attribute	No Interest (Q16)*	Interest (Q16)	Consideration (Q20a)	Purchase (Q20b)
Clarity of billing statements	3.98	3.32	3.78	4.25
	(278)	(157)	(74)	(4)
Cleanliness of fuel	2.94	2.40	2.92	4.00
	(286)	(158)	(76)	(4)
Compatibility with air conditioning	3.30	2.75	2.89	2.00
systems	(283)	(158)	(75)	(4)
Comfort	2.74	1.76	1.92	1.50
	(287)	(158)	(75)	(4)
Concerns of government regulations	3.47	2.91	2.95	3.25
	(282)	(158)	(75)	(4)
Cost per month	2.98	2.13	2.41	2.00
	(284)	(158)	(75)	(4)
Credit terms	4.44	3.77	4.01	4.25
	(280)	(152)	(74)	(4)
Ease of temperature control	2.75	1.87	2.05	2.25
	(280)	(157)	(75)	(4)
Environmental impacts	2.97	2.48	2.80	3.25
	(280)	(159)	(75)	(4)
Even distribution of heat	2.78	3.77	2.05	2.50
	(284)	(152)	(75)	(4)
Safety	2.49	1.61	1.79	2.00
	(284)	(159)	(75)	(4)
Social status	5.26	5.10	5.41	5.00
	(282)	(157)	(74)	(4)
Smell	3.00	2.63	2.86	4.50
	(282)	(156)	(74)	(4)
Physical labor - maintenance and	2.76	2.81	3.16	4.00
filling fuel source	(286)	(159)	(75)	(4)
Maintenance/cleaning costs	2.77	2.30	2.73	3.75
	(279)	(158)	(74)	(4)

Predictability of monthly cost	3.30	2.45	2.85	2.25
	(282)	(159)	(75)	(4)
Indoor air quality	2.59	1.66	1.81	1.75
	(282)	(158)	(75)	(4)

Purchase Likelihood

Respondents were asked to indicate the degree to which adjustments in purchase/installation costs, wood fuel costs, and burning time before refilling might impact the likelihood that they would purchase an outdoor wood furnace (Q18a-c).

No variation in installation price (even a 50% reduction in cost), burn time (up to 24 hours), or wood fuel costs (to include being free) swayed the overall sample of Southeastern Minnesotans from an unlikely purchasing stance. This position changed slightly when interest levels were included in the analysis. Table Q18a-c (by Q16) presents this analysis and tests mean values against the neutral rating of four as well as tests for differences between groups – interest versus no interest. Although nothing improved purchase likelihood among those not interested, significant purchase likelihood estimates were uncovered among interested individuals.

Along the price dimension, a purchase and installation decrease to $3150 (30% discount from initial example) increased purchase likelihood to a neutral rating; decreasing this price further to $2250, a 50% discount, lead to significantly positive likelihood to purchase. With respect to burn times, increases to 20 hours and above also resulted in significantly positive likelihood to purchase ratings. Positive purchase likelihood ratings were also reported among this group of interested individuals at annual wood fuel costs of $180 and below.

Finally question 20a and 20b attempt to get at past purchasing behavior through asking respondents to indicated if they have considered purchasing an outdoor wood furnace or have already purchased one. Eighty respondents (14%) indicated that they have considered purchasing a unit like this in the past, while only 6 of these (7.5% - 6/80) have purchased an outdoor wood furnace. Three of the six owners of outdoor wood furnaces provided satisfaction ratings (2 as a primary source, 1 as a secondary source). Although at best a qualitative assessment, all rated their satisfaction with the system as a 1, the highest possible rating.

Q18a-c. Sensitivities to installation costs, labor requirements, and annual wood costs

	n	Mean	S.D.
Purchase and Installation Costs			
Increase to $4950	514	2.54	2.07
Increase to $5850	500	2.34	2.06
Increase to $6750	493	2.26	2.08
Decrease to $4050	496	2.90	2.13
Decrease to $3150	496	3.17	2.23
Decrease to $2250	510	3.65	2.37
Time Between Refilling Furnace			
Increases to 20 hours	510	3.32	2.24
Increases to 24 hours	497	3.52	2.38
Decreases to 12 hours	494	2.76	2.03
Decreases to 8 hours	499	2.54	2.12
Annual Fuel (Wood) Costs			
Increases to $220	499	3.12	2.25
Increases to $260	488	3.08	2.23
Increases to $300	487	2.95	2.19
Decreases to $180	487	3.41	2.33
Decreases to $140	489	3.55	2.38
Decreases to $100	487	3.71	2.44
Is free	497	3.84	2.54

Q18a-c. Interest impact on purchase likelihood (by Q16)

Influence on likelihood of Purchase	No Interest	Interest	Sig
Purchase and Installation Costs			
Increase to $4950	2.42*	2.80*	.056
	(340)	(158)	
Increase to $5850	2.36*	2.31*	.793
	(331)	(155)	
Increase to $6750	2.32*	2.14*	.378
	(329)	(150)	
Decrease to $4050	2.56*	3.64*	.000
	(328)	(154)	
Decrease to $3150	2.70*	4.19	.000
	(328)	(154)	
Decrease to $2250	3.04*	5.03*	.000
	(341)	(155)	
Time Between Refilling Furnace			
Increases to 20 hours	2.84*	4.37*	.000
	(336)	(158)	
Increases to 24 hours	3.18*	4.74*	.000
	(328)	(156)	
Decreases to 12 hours	2.63*	3.08*	.023
	(324)	(156	
Decreases to 8 hours	2.59*	2.46*	.541
	(330)	(156)	
Annual Fuel (Wood) Costs			
Increases to $220	2.66*	4.10	.000
	(328)	(156)	
Increases to $260	2.67*	3.97	.000
	(320)	(154)	
Increases to $300	2.65*	3.60*	.000
	(319)	(154)	
Decreases to $180	2.83*	4.65*	.000
	(320)	(153)	
Decreases to $140	2.92*	4.92*	.000
	(322)	(153)	
Decreases to $100	3.05*	5.13*	.000
	(320)	(153)	
Is free	3.19*	5.38*	.000
	(331)	(154)	

*Mean significantly different than 4 (neutral value) on a 7-point scale, where 1 = very unlikely to purchase and 7=very likely to purchase.

Q20A. Considered purchasing an Outdoor Wood Furnace

	Frequency	Percent
No	494	86.1
No	494	86.1
Yes	80	13.9
Yes	80	13.9
Total	574	100.0
Total	574	100.0

Q20B. Purchased an Outdoor Wood Furnace

	Frequency	Percent
No	226	97.4
No	226	97.4

Yes	6	2.6
Total	232	100.0
Total	232	100.0

Exposure to Outdoor Wood Furnace Communications

Respondents were asked in questions 19, 21, and 22 about their exposure to communications (either promotional or otherwise) related to outdoor wood furnaces. They were also asked to rank a set of reliable sources of information by preference.

Overall, approximately one-third of respondents have seen an outdoor wood furnace in an advertisement, brochure, an informative article, or displayed in a showroom or at a trade show/fair. Although this appears to be a fairly high exposure rate, anywhere from 64% to 70% of respondents have never seen a system like this, or at least have no recollection of the exposure. Therefore, significant opportunity for increased market penetration appears to be evident.

Surprisingly, when asked about preferred mechanisms for receiving additional information about these heating systems respondents indicated the internet at the most preferred medium (36% of respondents). Consistent with expectations, the predominantly rural respondents in Southeastern Minnesota reported word-of-mouth and community forums (to include local shows and fairs) as the next most convenient way to get additional information (30% and 21% respectively).

Finally, in terms of the most reliable sources of information, respondents indicated current users of such systems, the Department of Natural Resources, and furnace manufacturers most often. Current users were considered to be the most reliable with a mean ranking of 1.36, followed by the DNR with a mean ranking of 1.68 And furnace manufacturers at 2.05.

Q19.Seen Outdoor Wood Furnace Advertising or Brochure

	Frequency	Percent
No	347	63.6
No	347	63.6
Yes	177	32.4
Yes	177	32.4
Don't Know	22	4.0
Don't Know	22	4.0
Total	546	100.0
Total	546	100.0

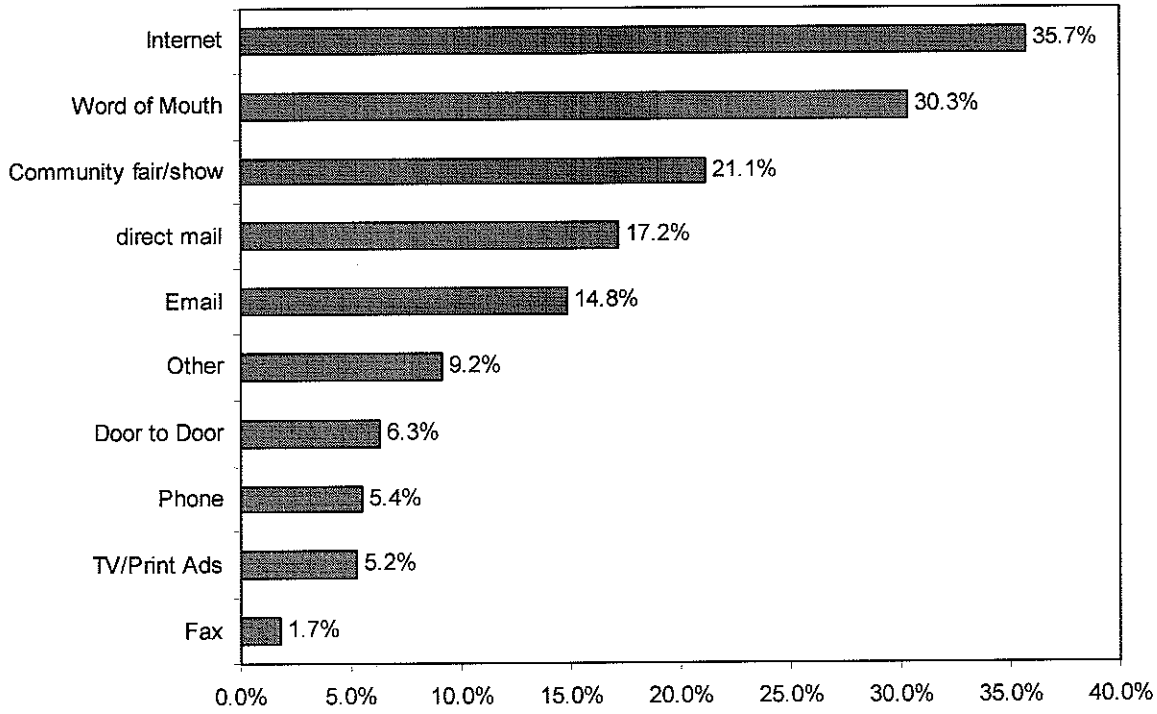
Q19. Read article about Outdoor Wood Furnace

	Frequency	Percent
No	381	70.4
No	381	70.4
Yes	141	26.1
Yes	141	26.1
Don't Know	19	3.5
Don't Know	19	3.5
Total	541	100.0
Total	541	100.0

Q19.Seen an Outdoor Wood Furnace Displayed

	Frequency	Percent
No	358	65.6
No	358	65.6
Yes	176	32.2

Don't Know	12	2.2
Total	546	100.0
Total	546	100.0



Q21. Most convenient way(s) to obtain information on outdoor wood furnaces (n=459)

Q22. Top three sources of reliable information

Sources of Information	Number of Respondents Identifying as Top-3 Source	Average Rank Score
Current Outdoor Wood Furnace User	456	1.36
Dept. of Natural Resources	338	1.68
Outdoor Wood Furnace Manufacturer	318	2.05
Internet Site	133	2.31
Other	42	1.48
Wood Producer	28	2.04

Energy Conservationism Perceptions

A number of questions were developed in order to better understand attitudes toward energy conservation and the motivation behind them. Questions address regular conservation practices as well as things that have been done at least once. Questions 24 through 27 are examined below.

Just over one forth (27%) of the respondents indicated that they have received a home energy at some time suggesting that they are concerned with energy conservation, to save on energy costs and/or conserve resources. Nearly the same percentage of respondents has had a professional home energy audit. Only 5% of respondents had received special assistance to pay their heating bill, either in grants or used budget billing (spreading the cost of high winter bills over the entire year to ensure a more even and consistent monthly payment). This is not very surprising considering the high family income data mentioned above in the demographic section.

Approximately half of respondents have caulked the interior of their home, 80% used weather stripping, 47% used shrink-wrap on windows, 65% have added insulation to their home, and 51% have insulated their water pipes. This is a very strong indicator that a strong majority of respondents is concerned with energy conservation and have taken action to prevent energy loss. Additionally 70% have had their furnace professionally cleaned.

On a more everyday basis, 55% of respondents use task lighting. This number is probably is on the low side as 18% of respondents indicated that they were unsure if they used task lighting. Task lighting would be using a lamp while reading in a chair instead of using all the overhead room lights. 56% close their fireplace damper and only 37% of the respondents close doors and registers during the day. An overwhelming number of respondents (91%) clean their outside dryer vent regularly. While 60% have a hot water heater that is at least 10 years old, 53% have a high efficiency showerhead.

As far as saving significantly on heating costs, 53% important to very important, 8% neutral, and 39% not important to very unimportant with the mean score of 4.33, leaning towards the important side of the scale. Supporting local businesses 41% important to very important, 25% neutral, and 34% not important to very unimportant, with the mean score neutral at 4.06.

Using a renewable resource as opposed to non-renewable resources is rather balanced with 38% of respondents indicating that this is important to very important, 27% neutral, and 33% checking not important to very unimportant, with the mean score neutral at 4.02. Overall we have seen attitudes in favor of energy efficient practices and conservation, so the results of this are a bit surprising. It is the opinion of the author that respondents may be influenced by all the negative press surrounding logging, such as the Sierra Club, an environmental group continually protesting logging, and not think of wood as the renewable resource that it is – perhaps this is due to a lack of education.

Frequency data is provided for this information in the tables below. Tables are identified by the survey instrument's question number, as well as a general description of the information captured.

Q24.Received Rebate

	Frequency	Valid Percent
No	427	70.8
No	427	70.8
Yes	163	27.0

Don't Know	13	2.2
Total	603	100.0
Total	603	100.0

Q24.Home Energy Audit

	Frequency	Percent
No	432	71.5
No	432	71.5
Yes	161	26.7
Yes	161	26.7
Don't Know	11	1.8
Don't Know	11	1.8
Total	604	100.0
Total	604	100.0

Q24.Special Assistance for Heating Bill

	Frequency	Percent
No	570	94.1
No	570	94.1
Yes	30	5.0
Yes	30	5.0
Don't Know	6	1.0
Don't Know	6	1.0
Total	606	100.0
Total	606	100.0

Q24.Caulked Interior of Home

	Frequency	Percent
No	298	49.6
No	298	49.6
Yes	288	47.9
Yes	288	47.9
Don't Know	15	2.5
Don't Know	15	2.5
Total	601	100.0
Total	601	100.0

Q24. Used Weather Stripping

	Frequency	Valid Percent
No	117	19.5
No	117	19.5
Yes	476	79.5
Yes	476	79.5
Don't Know	6	1.0
Don't Know	6	1.0
Total	599	100.0
Total	599	100.0

Q24. Used Shrink Wrap on Windows

	Frequency	Valid Percent

No	315	52.4
No	315	52.4
Yes	282	46.9
Yes	282	46.9
Don't Know	4	.7
Don't Know	4	.7
Total	601	100.0
Total	601	100.0

Q24. Insulated Water Pipes

	Frequency	Percent
No	282	47.2
No	282	47.2
Yes	305	51.1
Yes	305	51.1
Don't Know	10	1.7
Don't Know	10	1.7
Total	597	100.0
Total	597	100.0

Q24. Had Furnace Professionally Cleaned

	Frequency	Percent
No	174	28.7
No	174	28.7
Yes	427	70.5
Yes	427	70.5
Don't Know	5	.8
Don't Know	5	.8
Total	606	100.0
Total	606	100.0

Q24.Added Insulation to Home

	Frequency	Percent
No	210	34.9
No	210	34.9
Yes	387	64.3
Yes	387	64.3
Don't Know	5	.8
Don't Know	5	.8
Total	602	100.0
Total	602	100.0

Q25. Use Task Lighting

	Frequency	Percent
No	153	26.8
No	153	26.8
Yes	313	54.9
Yes	313	54.9
Don't Know	104	18.2

Total	570	100.0

Q25.Close Fireplace Damper

	Frequency	Percent
No	136	31.6
No	136	31.6
Yes	242	56.1
Yes	242	56.1
Don't Know	53	12.3
Don't Know	53	12.3
Total	431	100.0
Total	431	100.0

Q25.Clean Outside Dryer Vent

	Frequency	Percent
No	45	7.6
No	45	7.6
Yes	541	90.9
Yes	541	90.9
Don't Know	9	1.5
Don't Know	9	1.5
Total	595	100.0
Total	595	100.0

Q25.Close Registers and Doors During Day

	Frequency	Percent
No	378	62.9
No	378	62.9
Yes	219	36.4
Yes	219	36.4
Don't Know	4	.7
Don't Know	4	.7
Total	601	100.0
Total	601	100.0

Q25.Turn Off Lights and TV

	Frequency	Percent
No	37	6.1
No	37	6.1
Yes	571	93.8
Yes	571	93.8
Don't Know	1	.2
Don't Know	1	.2
Total	609	100.0
Total	609	100.0

Q26. 10 Years or Older Hot Water Heater

	Frequency	Percent
No	372	61.0
No	372	61.0
Yes	218	35.7
Yes	218	35.7
Don't Know	20	3.3
Don't Know	20	3.3

Total	610	100.0

Q26.High Efficiency Shower Head

	Frequency	Percent
No	264	44.3
No	264	44.3
Yes	313	52.5
Yes	313	52.5
Don't Know	19	3.2
Don't Know	19	3.2
Total	596	100.0
Total	596	100.0

Q27.Importance of Saving Significantly on Heating Costs

	Frequency	Percent	Cumulative Percent
1	121	20.0	20.0
1	121	20.0	20.0
2	69	11.4	31.4
2	69	11.4	31.4
3	46	7.6	39.0
3	46	7.6	39.0
4	47	7.8	46.8
4	47	7.8	46.8
5	44	7.3	54.0
5	44	7.3	54.0
6	132	21.8	75.9
6	132	21.8	75.9
7	146	24.1	100.0
7	146	24.1	100.0
Total	605	100.0	
Total	605	100.0	
Mean	4.33		
Mean	4.33		
Std. Dev.	2.31		

Q27.Importance of Supporting Local Business

	Frequency	Percent	Cumulative Percent
1	69	11.8	11.8
1	69	11.8	11.8
2	67	11.5	23.3
2	67	11.5	23.3
3	62	10.6	33.9
3	62	10.6	33.9
4	144	24.7	58.6
4	144	24.7	58.6
5	94	16.1	74.7
5	94	16.1	74.7
6	99	17.0	91.6
6	99	17.0	91.6

7	49	8.4	100.0
Total	584	100.0	
Total	584	100.0	
Mean	4.06		
Mean	4.06		
Std. Dev.	1.80		

Q27.Importance of Using Renewable Resources

	Frequency	Percent	Cumulative Percent
1	59	10.2	10.2
1	59	10.2	10.2
2	65	11.3	21.5
2	65	11.3	21.5
3	67	11.6	33.1
3	67	11.6	33.1
4	165	28.6	61.7
4	165	28.6	61.7
5	98	17.0	78.7
5	98	17.0	78.7
6	83	14.4	93.1
6	83	14.4	93.1
7	40	6.9	100.0
7	40	6.9	100.0
Total	577	100.0	
Total	577	100.0	
Mean	4.02		
Mean	4.02		
Std. Dev.	1.69		