The Fuelwood Project

The Argument in Favour of Wood Heating

The Ontario Woodlot Association, Limestone Chapter, spearheaded an initiative they called The Fuelwood Project, intended to "implement a public awareness program linking EPA approved woodstoves, sustainable forest management and good woodburning practices to the [reduction in greenhouse gas emissions], improved forest genetics, healthier rural economy and less reliance on fossil fuels." Other partners in the Project include the Frontenac Stewardship Council, the Lennox and Addington Stewardship Council, the Upper Canada Woods Co-operative, the Ontario Woodlot Association, Quinte Chapter, and The Wood Heat Organization Inc. This article was prepared by John Gulland to form the main reference document for the Fuelwood Project. February 2007

Executive Summary

Almost 3.2 million Canadian households burn wood in fireplaces, stoves and furnaces. This number represents 26 percent of all households. In Ontario, the popularity of wood burning is well below the national average, with only 21 percent, or about 940,000 households burning wood. Still, millions of Ontarians and millions more people across Canada build wood fires for heat and enjoyment each winter. By any measure, wood is an important residential energy resource, especially in rural areas.

But judged by coverage in the mainstream media, wood heating is virtually nonexistent. Politicians don't debate its merits or plan for its strategic use. In a world of touch-screen convenience, pocket-sized computers, and automatic climate-controlled environments, wood heating is in every way rough, basic and steadfastly hands-on. People who heat with wood seem out of step with the modern world swirling around them. Have wood burners and those who labour to supply them with fuel slipped through a crack in the cozy consensus of modernity? Or are they onto something meaningful that has been missed by the mainstream?

The producers and consumers of fuelwood are engaged in an activity that reduces net greenhouse gas emissions while others merely fret about global warming. The fuelwood fraternity use a renewable energy resource, taking pressure off dwindling supplies of ever-pricier and scarce fossil fuels. Buyers of fuelwood create jobs close to home and strengthen their local communities. They know more about the cause-and-effect relationships of energy production and consumption than the economists who promote tar sands development. The story of wood heating early in the twenty-first century is about average families making decisions based on how they see their future unfolding.

Heating with wood is about a lot more than home heating. It is a tangible expression of self-reliance, of the courage to buck the trends and to resist the appeal of sedentary, push-button convenience. Heating with wood reinforces links to the land and is a willing submission to the cycle of the seasons. It provides stability and security in a turbulent world.

To its owner, the woodlot is a living community in constant evolution, while to the urban observer it may be seen as a museum in which the removal of a tree exhibit renders it diminished. The woodlot owner watches its quality improve over the years, even as it yields products and creates employment. The owner's household earns part of its income by being a fuel supplier to the neighbours. It is a gentle way to produce energy compared to open pit uranium mines and nuclear reactors.

Fuelwood is the ultimate populist energy resource, the most easily accessed and affordable of all renewable energies. The major environmental impact of wood heating is visible for all to see in the form of smoke emissions, making everyone who uses it instantly accountable for their actions. The families that heat with wood and those that supply them with fuel do so privately, without fanfare or acknowledgement. It seems they wouldn't want it any other way. Heating with wood is its own reward.

Introduction

Energy is in the news these days as policy makers, industry leaders and news commentators talk of high oil and gas prices, the need to cut greenhouse gas emissions, the security of imported oil supplies and fears of electricity shortages. They also debate the future of nuclear power and the promise of renewable energy sources like solar and wind.

The one home heating fuel that is rarely mentioned is fuelwood, yet it is the fourth most popular heating fuel in Ontario after gas, oil and electricity. Not only is it a significant contributor to the residential energy mix, wood heating is an important aspect of rural life.

The low profile of wood heating in energy policy discussions and in the media reflects the fact that policy – even rural policy – is developed in big cites, and that the large media outlets are all urban

in location and outlook. That and the fact that no large corporations are involved in wood heating and therefore no high-priced lobbyists or special interest groups prowl the halls of Toronto and Ottawa pleading the case of wood burning. So, despite the fact that more than a third of all rural residents in Ontario burn wood at home, its role as an energy source does not appear on government and media radar.

Rural people are not clamouring for government to intervene in their wood heating activities. This is a private activity in which virtually everyone involved is content to remain anonymous, quietly keeping their families warm through their own labour and ingenuity.

The one area in which wood burning does attract attention is the problem of air pollution. Although Ontario towns and cities do not tend to suffer from significant winter air pollution from wood smoke, there are places in Canada, particularly in valley communities in BC and the Yukon, where it is the primary winter air pollutant. In Ontario, the most common form of complaint about wood smoke arises when one household's plume of smoke bothers their neighbours. This nuisance wood smoke has become an increasingly serious problem with the rising popularity of large outdoor boilers designed to heat a house and one or more other buildings.

In recent years governments at all levels have tended to give more attention to the pollution potential of residential wood heating than to its status as a renewable energy resource, one having strategic importance. As a result, wood burning has become most often identified as a problem to be solved rather than as an opportunity to be harvested. Heating with wood is viewed by some urban environmentalists as mildly deviant behaviour. Intervention by governments is usually designed to encourage better practices that will result in less wood smoke. The one thing that no government anywhere in Canada does is encourage householders to heat with wood. Fuelwood is the only renewable energy resource that governments don't seem comfortable with.

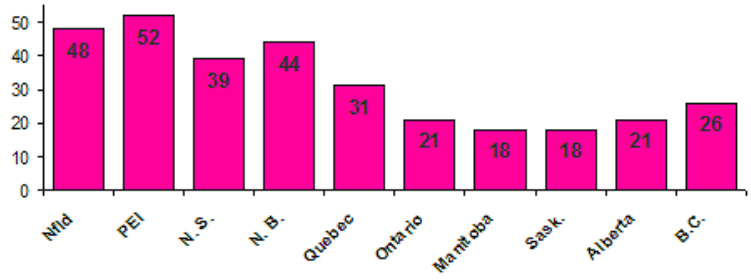
This paper explores how wood burning contributes to the prosperity of rural communities, the health and well-being of their inhabitants, and to the environmental sustainability of our society.

How Popular is Wood Burning?

A drive through small towns and down country roads confirms that fuelwood is a significant energy resource in rural Ontario. The long lines of piled firewood standing in yards serve as proof. Every winter the wood is cut from woodlots and every spring it is split and stacked to dry in the summer sun. In the fall it is moved to the house and stacked again, and in winter it keeps families cosy warm. It is a seasonal ritual that has recurred year in and year out for decades, for generations.

The popularity of wood burning is low in Ontario compared to the Atlantic Provinces and Quebec. This may be because Ontario is more urbanized than other provinces and also because it has been served by pipelines carrying inexpensive natural gas for much longer than the provinces to its east.

Table 1: Incidence of wood burning among the provinces



Graph courtesy TNS-Canadian Facts

Thirty-five percent or about 350,000 households in *rural* Ontario burn fuelwood. More than twice this many *urban* householders report burning wood. Over all, more than one million Ontario families burn wood at home.

Note: All statistical information in this report, including tables, has been adapted from an Environment Canada sponsored national survey conducted in the spring of 2006[1]. The survey, conducted by TNS Canadian Facts, was a self-administered mail-out questionnaire sent to 19,740 households on March 31, 2006. Some 9588 questionnaires were returned and processed. In the TNS-CF report, rural was defined as population centres of less than 10,000.

According to the Environment Canada/TNS-CF survey report, there has been a significant reduction in wood burning since the last such survey was conducted in 1997. Table 2 shows that nationally, the reported incidence of wood burning in *urban* areas fell by almost 18 percent in that nine year period, although there was a slight increase of 2.4 percent in *rural* areas. In Ontario, the move away from wood burning was the largest of all the provinces with a decline in *urban* areas of more than 29 percent and even in *rural* areas 12.5 percent of previous users stopped burning wood.

Table 2: Change in the Percentage of Households Reporting the Burning of Wood 1997 - 2006

Province:		1997	2006	% Change
Atlantic	<10m	51	55	+7.8
	10m+	26	24	-7.7
Newfoundland	<10m	49	56	+14.3
	10m+	28	25	-0.7
Prince Edward I.	<10m	55	62	+12.7
	10m+	17	34	+100
Nova Scotia	<10m	51	52	+20
	10m+	25	21	-16
New Brunswick	<10m	51	56	+9.8
	10m+	29	26	-10.3
Quebec	<10m	55	57	+3.6
	10m+	24	22	-8.3
Ontario	<10m	40	35	-12.5
	10m+	24	17	- 29.2
Prairies	<10m	24	23	-4.2
	10m+	21	18	-14.3
Manitoba	<10m	28	25	-10.7
	10m+	16	15	-6.2
Saskatchewan	<10m	17	14	-17.6
	10m+	20	23	+15.0
Alberta	<10m	25	28	+12.0
	10m+	23	18	-21.7
British Columbia	<10m	40	49	+22.5
	10m+	21	18	-14.3
Total Canada	<10m	42	43	+2.4
	10m+	22	19	-17.6
Total Canada		28	26	-7.1

The significant decline in the reported use of wood fuel contradicts anecdotal reports of an increase in its popularity. The use of wood was thought to have fallen during the 1990s in response to very low oil, gas and electricity prices, which bottomed out around 1998. Subsequent events such as the

ice storm of January 1998, the summer electricity blackout of 2003 and a general rise in oil and gas prices through the current decade were thought to have triggered an increase in the use of wood. Certainly, the hearth industry reported strong sales of wood stoves after the ice storm, power outage and price spikes, especially in the fall of 2005. However, this survey presents evidence of the counterintuitive opposite. There is no obvious evidence of statistical problems with the 2006 survey, although no validation study has been done on the results.

Roughly two-thirds of *rural* users burn wood for home heating in stoves, fireplace inserts and furnaces. The remainder burn in fireplaces, which may or may not produce enough heat for serious home heating. In contrast, almost 80 percent of *urban* households that burn wood use fireplaces, mainly for enjoyment rather than serious heating.

Table 3: Type of wood burning equipment used by Ontario householders

	Rural <10m	Rural <10m	Urban 10m+	Urban 10m+
	Percent %	Number 000s	Percent %	Number 000s
Any Wood-burning Equipment	37	367,000	22	761,000
Any Fireplace	14	135,000	17	603,000
: Conventional	7	72,000	13	459,000
: Advanced Technology	3	31,000	3	109,000
Any Fireplace Insert	5	52,000	3	88,000
: Conventional	3	34,000	2	64,000
: Advanced Technology	2	17,000	1	23,000
Any Woodstove	20	196,000	6	196,000
: Conventional	55	108,000	31	61,000
: Advanced Technology	41	80,000	68	133,000
Any Pellet Stove	1	13,000	1	26,000
Any Wood Furnace or Boiler	7	72,000	1	26,000

Sub-categories do not add up to 100% because of 'don't know' responses.

The value of fuelwood burned in Ontario

In 2006, Ontarians burned about 1.8 million cords of wood. At today's price of around $250 per cord, this is the equivalent of about $450 million in fuelwood each year, although the actual expenditures would be considerably less than this figure because many families self-process their wood supplies. In context of the total energy-related economy of Ontario, expenditures on fuelwood are small. However, it is in the location and quality of the expenditures or avoided cost that the significance lies, as is discussed in the section on fuelwood and the local economy.

"Most official estimates understate the residential consumption of wood fuel because a large proportion is harvested and used locally and does not appear in tax records or government statistics." The Canadian Encyclopedia

The Place of Wood Heating in the Energy Mix

At a time when energy sources of all types are being scrutinized on grounds of price, availability, environmental impact and safety, fuelwood is mostly absent from the discussion. The probable cause of this oversight is the assumption that heating with wood is a marginal activity practiced by a relatively few rural folks; that if wood heating were somehow eliminated from the mix, its loss

would scarcely be noticed. The invisibility of wood fuel as an energy resource and its apparent dispensability is one good reason to raise its profile among policy makers, energy analysts, the media and the public.

The production of fuelwood and the practice of wood heating should be viewed as an important and positive part of Ontario's home energy strategy, especially in rural areas. To fully appreciate the value of residential wood energy in society, all its dimensions need to be considered, including forest management, environmental impact, rural economics and cultural significance.

Despite its considerable advantages, fuelwood is not a good choice for all households to the problems of global warming or high conventional energy prices. Fuelwood is not a suitable energy source in all locations. For example, wood is not a good fuel for heating houses in densely populated urban or suburban areas, or in less densely populated areas that suffer poor air quality. Successful heating with wood also requires a level of physical fitness and acquisition of a special set of skills.

Fuelwood and Sustainability

The Forest Carbon Cycle

Wood is considered to be a renewable fuel, which is obvious considering that new trees grow to replace those harvested. What may not be quite as obvious, however, is that use of fuelwood does not contribute to global warming/climate change the way fossil fuels do. When oil, gas and coal are burned, the carbon they contain (which was absorbed from the atmosphere by plants millions of years ago) is oxidized to carbon dioxide (CO_2), the main greenhouse gas (GHG). In effect, the combustion of fossil fuels releases ancient carbon, thereby increasing the atmospheric concentration CO_2.

Wood is about half carbon by weight but its use as a fuel is almost carbon dioxide neutral because trees absorb CO_2 as they grow. When trees mature, die and fall in the forest and decompose there, the same amount of CO_2 is emitted as would be released if they were burned for heat. In other words, decomposition (rot) is a slow form of oxidation whereas combustion in a wood stove or furnace is fast oxidation, with heat as a by-product. When considered over the normal forest regeneration period of about fifty years, heating with wood can be considered almost CO_2 neutral. In heating our houses with wood, we are simply tapping into the natural carbon cycle in which CO_2 flows from the atmosphere to the forest and back. Therefore, when wood is burned as a substitute energy source for fossil fuels, a net reduction in GHG emissions results.

Using Wood Fuel to Reduce Greenhouse Gas Emissions

The actual reduction in household CO_2 emissions by using wood instead of fossil fuels cannot easily be estimated with precision. However, a rough estimate can be made in the case of wood substituting for the use of fuel oil. The CO_2 emission factor for fuel oil is 3kg/litre[2]; i.e., for each litre of oil burned, 3 kilograms of CO_2 would be emitted. A standard 200 gallon tank holds 909 litres of fuel, so the burning of a full tank would release 2727 kg of CO_2.

The combustion of wood fuel is not completely CO_2 neutral considering that there are fossil fuel inputs to firewood production (chainsaws, splitters, trucks) and that the combustion of wood releases some methane and CO which are greenhouse gases but which are not absorbed by trees as they grow. To account for those fossil fuel inputs and other greenhouse gas emissions let us be generous and assume that wood is only about 75% CO_2 neutral. The reduction in CO_2 emissions for a household that displaced the use of one 200 gallon tank of oil through the use of wood fuel is 3 x 909 = 2727 x 75% = 2045. So, we can say that for each 200 gallon tank of fuel oil, over two fewer tonnes of CO2 would be emitted if it were displaced by wood fuel. That would mean that the

owners of a house of modest size that would have used two tanks of fuel oil each winter for heating would, if they switched 100% to wood heating, cut their GHG emissions by at least four tonnes.

"It is generally agreed by both energy and forestry scientists that, provided harvesting is conducted in a sustainable manner, the combustion of wood for energy production is essentially carbon dioxide neutral when the normal forest regeneration period is considered." Hendrickson, Gulland 1993[3]

Forest Sustainability

The Brundtland commission on environment and development, which published its report in 1987, popularized the term *sustainable development* as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The Canadian government has adopted this definition to help guide its policies and programs[4].

Forests can be used for aesthetic, recreational and industrial purposes while sustaining their essential qualities and health. Forest sustainability usually means that the integrity of the site and its soil is preserved or enhanced over time and that the diversity of native plant and animal species is maintained in perpetuity. In practical terms, sustainable woodlot management can be summarized as the selective harvesting of mature and poorer quality trees, while leaving seed trees of all present species and some standing dead trees to provide wildlife habitat.

A Model For Sustainable Woodlot Management

On the fuelwood production front, the main goal is to ensure that our forests are harvested sustainably. While Ontario has highly productive forests, a woodlot can be ruined by over harvesting or highgrading (taking the best and leaving the worst). Sustainable forest management can be simply defined as a process that maintains the long term health of forest ecosystems while providing economic, social and cultural opportunities for the benefit of present and future generations.

"Wood lot owners who forego the short-term economic rewards of clear-cutting in favour of selective logging … are helping reduce atmospheric CO_2 levels, and should be recognized for their contribution." Hendrickson, Gulland, 1993

Many Ontario woodlot owners have been maintaining their woodlots following this prescription for generations. Hendrickson and Gulland state that "the forms of wood energy use that have evolved in rural North America provide important but neglected models of sustainable development."[3]

The careful work by generations of Ontario farmers and other woodlot owners, visible in healthy woodlots throughout the province, provides the stewardship model that others can follow. Unfortunately, some farmers have maximized short term profit by clear cutting their woodlots and converting the land to cash crop production. And while many woodlot owners understand and practice sustainable forest management, others exploit the resource for short-term profit. Some companies and individuals have made a practice of buying large parcels of unused forest land, highgrading them and then reselling the depleted parcels. These profiteers do meet the definition of woodlot owners, but they do not maintain ties to the lands they buy and sell.

The selection of trees for harvesting should take into consideration all aspects of the site including the slope, soils and age range of all trees in the immediate area. To do this work correctly, a woodlot owner needs specialized training and experience. Alternatively, the owner could contract with a professional forester to evaluate the woodlot and mark trees for harvesting.

It has long been said that a healthy, well-managed woodlot can yield half a cord of wood per acre per year forever – one full cord being a pile eight feet long, four feet wide and four feet high – and that a ten acre woodlot could sustainably produce enough firewood each year to heat a house. Although that guideline is old and not very precise, it still holds true. In fact, it takes a lot less than five cords of wood, and therefore less than a ten acre woodlot, to heat a new energy-efficient house

using a modern wood stove. There is some evidence that carefully designed and built houses can be heated with as little as 1.5 cords of firewood.

The Forest as an Energy Resource

Firewood from Crown Land

The fuelwood market has two general sources of raw logs. The first is as a by-product of large-scale logging operations on crown land. The second is logs cut from private woodlots. These two sources also tend create two different business models for firewood wholesalers and retailers.

In the first case, commercial firewood producers buy low quality logs (centre-rotten or crooked) from forest products companies logging crown lands. These are typically the large-scale firewood producers with yards containing hundreds of cords of split firewood that can be seen along rural highways. Most use processors that cut the logs to firewood length and split it in one operation. These producers normally do not engage in logging, but rather receive truck loads of cull logs from harvesting operations. Firewood processing is done on site.

Commercial firewood producers require a substantial area of land where logs are stored, sorted, processed and stacked. Aside from processing the fuel, the largest aspect of the business tends to be transportation. Local fuelwood deliveries to households are made with trucks up to five tonnes, usually with dump boxes. Tractor-trailer trucks are used for longer distance deliveries to urban fuelwood retailers.

In Ontario the logging of crown land is regulated to provide fair access to timber and to ensure that harvesting is done sustainably and with as little damage to the site as possible. While the system is imperfect and there continues to be disagreement on the correct prescription for sustainable harvesting, some of the cull logs diverted to firewood production from crown land logging can be considered to have been harvested sustainably. More study of this issue is required before definitive statements on the sustainability of firewood production can be made.

Firewood from Private Woodlots

Private woodlots are the other main source of logs for fuelwood. Logging is sometimes contracted out, but is also commonly done by the land owner as part of annual or periodic work to extract income from the woodlot. For many farmers and other woodlot owners, the income from relatively small woodlots of less than 50 acres can produce significant annual income from the sustainable harvesting of saw logs, veneer, pulp and fuelwood, as well as the production of maple syrup. Case studies of several woodlots sponsored by the Huron Stewardship Council have shown that annual income from just the fuelwood component can range from as little as $25 to as more than $200 per acre.[5]

Farmers and other small scale woodlot owners have little trouble finding willing buyers for the fuelwood they produce. Most sales are to repeat customers and expansion of sales is often by word of mouth.

Firewood as an Energy Commodity

The Trade in Firewood

The firewood market is almost entirely unregulated, in the sense that there are no product quality or price controls in place. In fact, new converts to wood heating often find buying firewood an intimidating and frustrating experience. There are several reasons for this.

- Not having experience with tree species and firewood quality issues, the buyer is unable to judge the price-quality relationship and so feels vulnerable to the dealer.

- The buying experience is unlike most other retail environments, often taking place in a dusty yard with trucks and heavy equipment to dodge.
- Most new users have been warned about the problems of burning wet or green firewood and yet lack knowledge of how to judge moisture content and have no basis for trusting the word of the seller.
- The criteria for judging firewood quality and price can be learned only by experience; no amount of research or advice can create an instant expert. Some of these criteria include tree species based on wood density, piece size, moisture content, and the units the fuel is sold in; i.e. full cord, 'face cord' truck load and volume measures such as cubic feet, yards or metres.

For every household starting out to heat with wood, the fuel purchasing process is like a right of passage, with uncertainty at first and the gradual building of confidence as they gain experience.

Comparing Firewood to Conventional Heating Fuels

Fuelwood is unlike any other mainstream heating fuel in Ontario, in that users are engaged physically and mentally in its consumption, and for many, in its production as well. Users of oil, gas and electric heating are typically involved only in paying energy bills and adjusting thermostats. As a result, any cost comparisons of wood with other fuels are likely to be inaccurate, if not misleading, because they cannot account for either the labour costs or the intangible benefits of wood heating.

Householders considering a switch to wood heating would find it useful to know how much money they might save compared to the use of conventional fuels, in the same way that other major purchases are evaluated. The problem with this approach is that the cost-benefit analysis of wood heating is not easily reduced to a simple matter of money. Considering the rising prices of conventional fuels, it is probably accurate to say that households located outside major urban centres could save money using firewood on a strictly heat-energy-per-dollar basis. But how can the other less tangible costs be evaluated? These costs might include:

- the space required to store a winter's supply of firewood outside the house and space inside the house for a few day's supply
- the physical strength and stamina required to move and stack firewood
- the time consumed in managing the fuel supply, tending the fire and dealing with regular maintenance tasks like ash removal
- the impact of the inevitable 'mess' of wood chips, bark and wood ash on the time consumed by household cleaning

The intangible benefits are equally difficult to evaluate in monetary terms.

- the satisfaction one feels in having mastered home heating largely by personal labour and ingenuity
- the sense of security both in terms of energy price stability and in the ability to remain comfortable in the home during electrical power interruptions
- the beauty and ambience created by a fire burning behind clear glass doors
- the special kind of warmth given off by a wood stove located in the main living area (this may be debatable in terms of physics, but it is mentioned by most users of wood fuel as an important benefit)

Natural resources Canada offers a fuel cost comparison method in its booklet, A Guide to Residential Wood Heating. The calculation is fairly complex, taking into account of local fuel pricing, housing type, climate zone, fuel type, appliance type and efficiency.[6] The calculation is probably as valid as possible, considering the limitations of such calculations. However, a good

indication of the imprecision of this and similar calculation methods is that only whole-house heating to an even temperature throughout can be considered. This type of calculation cannot accommodate a wood stove used as a partial or complete heating replacement for a central furnace using conventional fuel. Compared to central heating, the use of a wood stove for space heating, especially if it is located in the main living area, can mean a reduction in heat energy needed by up to 25 percent, regardless of the cost of either fuel.

The table below uses the calculation method from A Guide to Residential Wood Heating to show what the price of a cord of firewood (4x4x8) would be to make it equivalent on a price-per-heat-energy basis with oil, natural gas and electricity.

	Typical Conversion Efficiency	Price of Energy Source	Equivalent Price of Hardwood at 30,600 MJ/cord and 70% efficiency
Fuel oil at 38.2 MJ/L (megajoule/litre)	80%	$0.79/L	$550.
Natural gas at 37.5 MJ/M^3	80%	$0.43/$M^3$	$300
Propane gas at 25.3 MJ/L	80%	$0.65/L	$690
Electricity at 3.6 MJ/ kWh	100%	$0.095/kWh	$595

At mid-2006 the actual retail cost of processed firewood in rural Ontario was in the range of $225 to $250 per cord, which is well below the price of natural gas, less than half the cost of fuel oil and electricity and about one-third the cost of propane. As discussed, however, price is not the only useful criteria by which to judge the suitability of wood heating for a particular household.

The Energy Return on Energy Invested

Economists focus on the money cost of energy, but the *energy* costs of energy can provide better insights into environmental costs and the underlying reasons for the money cost. For this reason, the energy return on energy invested (EROEI) should be included in any appraisal of the quality, impacts and appropriateness of various energy sources. Here is a sample EROEI analysis for fuelwood compared to other energy sources. Note that the value of labour is not included in the calculation.

Assumptions:

- hardwood fuel: 30000 megajoule (MJ)/cord
- 1 litre of gasoline: 43.2 MJ
- average round trip for fuel delivery: 50 km
- fuel consumption of pick up truck: 15 mpg = 16 L/100km
- two round trips per cord = 16L
- chainsaw fuel per cord: 2L
- log splitter fuel per cord: 4L

Total fossil fuel consumption: 22 x 43.2 = 950 MJ/cord

Calculation:
30000 ÷ 950 = 32

Energy return on energy invested: 32:1

An EROEI of 32:1 may not be worst case for fuelwood, but it is close for rural areas; some people probably produce firewood at an EROI of 30 to 40:1.

For comparison, below are the estimated EROEIs for various energy sources [7]

Oil 100:1 to 8:1[8], depending on age, type and location of oil field *
Oil Sands 2:1
Biodiesel 3:1
Coal 9:1
Natural Gas 8:1 to 10:1
Hydroelectric 10:1
Ethanol 0.8:1 to 1.8:1 *
Hydrogen 0.5:1
Nuclear 4:1
Solar PV 1:7 to 10:1 *
Wind 18:1[9]
Wood 30:1 (wood chips, bark for industrial use)[10]

* The wide ranges in EROEI for these sources reflect the relative energy intensity of facility construction, extraction, refining, transmission and maintenance.

Wood, in the form of natural firewood, compares favourably with other fuels regarding the amount of net energy realized after processing and transportation. This bodes well for a degree of price stability for fuelwood in the future. Price stability is not likely for the fossil fuels because as the easily accessible deposits are consumed the EROEI rises dramatically, as does the retail price.

Wood Heating and Air Pollution

The Problem Defined

The problem of smoke pollution from residential wood burning has been debated since the resurgence of wood as a fuel after the oil crisis of the 1970s. Because it contains toxic chemicals and known carcinogens, wood smoke is unhealthy to breathe in high concentrations and even in low concentrations can be harmful to children, the elderly and those with lung diseases or allergies. There are three aspects of wood smoke pollution that need to be considered: nuisance smoke caused by a neighbour, airshed contamination caused when many households make too much smoke in a confined area like a river valley, and indoor air pollution caused when a wood burning appliance spills smoke into the house.

The Range of Government Responses

Governments at all levels in Canada have shown varying amounts of interest in dealing with the problem of wood smoke pollution. The most aggressive regulation of wood burning pollution has been done in British Columbia, where smoke trapped in mountain valleys first attracted public attention. In 1994 the province enacted a regulation similar to the one imposed in 1988 by the U.S. Environmental Protection Agency (EPA) requiring all new wood stoves offered for sale to be certified as meeting smoke emission limits. Several communities in B.C. have enacted bylaws restricting the burning of wood during periods of poor air quality. The most restrictive bylaw of any jurisdiction in Canada is in the town of Golden, which has a new bylaw banning the installation of wood heating equipment in new or existing houses, except for the upgrading of an existing stove to a cleaner burning model. Failure to comply is punishable by a fine of up to $10,000.[11]

The Response in Ontario

In Ontario there has been less regulatory activity, mainly because the more level topography does not produce the same number or severity of winter inversions that trap smoke close to the ground. While community level smoke problems are relatively rare, nuisance smoke caused by thoughtless neighbours has been identified as a problem in dozens of Ontario towns. One technology in

particular has been the focus of many complaints. Wood-fired outdoor boilers, which look like metal garden sheds and send hot water to one or more buildings through buried pipes, have become notorious for the dense smoke they produce. Small towns have enacted bylaws restricting the installation of outdoor boilers by either banning them from residential areas or placing limits on their proximity to property lines.

A Policy Shift 1980 - 2006

Although the federal government had promoted the use of wood fuel in the late 1970s and early 1980s as one strategy to reduce dependence on expensive imported oil, a significant but unstated policy change has occurred since then. Positive statements about its status as a renewable energy source and its role in reducing net greenhouse gas emissions are less common and more qualified in government documents than previously. A typical opening statement in a government brochure is: "Many Canadians use wood to heat their homes or to simply enjoy a wood fire, but burning wood can also release pollutants into the air we breathe when poor burning techniques are used."[12] This kind of qualifying statement is usually present when the obvious appeal of wood burning to Canadians must be acknowledged in a government document that is otherwise concerned with pollution abatement.

The federal departments of environment, natural resources and health frequently include lengthy statements about the hazardous chemical contents of wood smoke in their public statements[6] that offer long lists of compounds like polycyclic aromatic hydrocarbons, dioxins and furans and acrolein. The use of intimidating technical terms without offering contextual information makes these detailed statements quite beyond the ability of the average reader to comprehend or interpret. For example, context could be provided in the form of a list of chemicals emitted by a city bus or a backyard barbecue. Government personnel insist that statements listing the chemicals found in wood smoke are simply intended to inform the public, but it might equally be said that this communications tactic reveals an underlying intention to dissuade Canadians from using wood fuel, especially considering that no other energy source receives this kind of editorial treatment in government publications. It is notable that the most recent federal publications on the subject highlight the environmental and safety problems with wood energy but play down its advantages.

A federal publication that is part of its Burn it Smart campaign concludes with the following statements: "If possible, switch to another type of heating. If you must heat with wood, upgrade to a new EPA certified wood stove."[13]

Non-governmental organizations like the Lung Association have also warned the public against the use of fuelwood. One of its publications seems to marginalize wood heating and its users by preceding its advice on wood burning with the phrase: "If you must heat with wood . . . "[14]

Other public interest groups with anti-wood burning messages lobby government to restrict its use: "Some might consider fire heating as romantic but if everybody associated their sinus and other health problems—if they were aware, really—I think they wouldn't be seeing romance in wood fires." Michelle Rivest, Pure Air Association, Quebec.[15]

It is not the intention here to minimize the environmental impacts of wood heating or attempt to deflect concerns by highlighting pollution from other energy sources. But a balanced assessment of benefits and risks is called for when any energy source is evaluated or compared to other sources, especially by government agencies. Too often, those who have concerns about the wisdom of wood heating fail to understand or communicate that all energy sources, including renewables like wind and solar, have impacts on the environment. To single out one energy source for condemnation without providing supporting evidence or contextual information is unhelpful and unlikely to sway a justifiably sceptical public.

The problem of wood smoke from residential heating is serious in some places and under some conditions, and it is important that the public understand the risks and the ways to minimize them. The three dimensions of wood smoke pollution – airshed contamination, nuisance neighbours, and

indoor air pollution – should be addressed through public information and, where necessary, regulation. To be successful in changing minds and behaviours, any government action should be developed in full recognition that people who heat with wood tend to be sceptical of experts or governments meddling with their personal wood heating practices.

Advanced Technology Wood Burning Equipment

The new wood burning technology found in EPA certified stoves goes a long way toward solving all three wood smoke problems: airshed contamination, nuisance wood smoke and indoor air pollution. These advanced stoves, inserts, fireplaces and furnaces cut wood smoke by up to ninety percent compared to older so-called 'airtight' stoves, and also tend not to spill smoke into the indoor air because fires don't tend to smoulder in them, the condition that most contributes to smoky indoor air.

Smoke (particulate) emissions from older conventional wood stoves average at least 25 grams per hour of operation, while the emissions from the notorious wood-fired outdoor boilers range from 50 g/h to well over 100 g/h. In contrast the EPA regulation limits emissions of certified wood stoves to no more than 7.5 g/h. However, since the regulation was first established in 1988, the average emissions of certified stoves has declined steadily due to advances in technology and competition among manufacturers. Today, most current wood stove models emit only 2 to 4 g/h.

The reduction in smoke emissions has been a significant technological breakthrough in wood burning, but it may not be as noticeable to users as the matching increase in efficiency. Conventional wood stoves range in efficiency from a low of about 35 percent for a cast iron box stove or furnace to a high of as much as 55 percent for a 1970s era 'airtight', while most outdoor boilers are less than 50% efficient.[16] In contrast, EPA certified wood stoves average around 70 percent and none are less than 60 percent efficient.

The difference in efficiency between conventional wood burning equipment and the advanced low-emission models is so significant that users can immediately see the difference when they upgrade and begin using a new stove. The reduction in fuelwood consumption by up to one-third is significant for each household that uses the new technology, but it also has the potential to increase the number of houses that can be heated based on the sustainable harvesting of a given area of forested land. Another significant factor that reduces a wood-heated household's impact on the forest resource is the lower heat energy requirements of modern housing. Together, the increase in wood burning appliance efficiency and improvements in housing energy conservation can roughly double the number of dwellings that can be heated by the yield from a given woodlot compared to just 25 years ago.

Home Heating With Wood

The Traditions of Fuelwood Use

It goes without saying that wood is Canada's original heating fuel. Rarely acknowledged, however, is that its dominance was only displaced relatively recently. Although coal became available to the more affluent families living close to supply routes by the mid-twentieth century, in rural Ontario wood was virtually the only practical heating fuel option until after the second world war.

Until the incentive for technological advancement was provided by the EPA regulation in the late 1980s, wood burning technology was simple and ineffective in producing complete combustion. Most wood burning devices were little more than empty steel or cast iron boxes in which to build a fire. Until the 1970s gaskets on loading doors were rare, meaning that a stove or furnace might not provide enough control to hold a fire overnight.

Before the advent of small chain saws, trees were felled and logs were bucked up with hand saws, and splitting was done with axes. The amount of labour involved in producing enough fuel for a large, leaky old farmhouse was enormous. A typical farmhouse had a furnace or one or more

heating stoves, as well as a cook stove, all burning wood and none of which would have exceeded 50 percent efficiency. Each household would have had to produce ten or more cords of firewood.

The old cast iron stoves and furnaces burned inefficiently, sending smoky exhaust through long flue pipe assemblies to masonry chimneys that were frequently supported by wood structures. Frequent cleaning of flue pipes and chimneys was needed if chimney fires were to be avoided. But chimney fires are inevitable when simple technology is matched with user practices that produced long smouldering fires. This sense that wood heating is inherently hazardous remains with many people even today. A small-town fire chief speaking at a public meeting some years ago said: "It is not a question of *if* you will have a chimney fire, it is a question of *when*."

The use of wood fuel gave rural people a degree of security and independence, even though staying warm in winter entailed some risk and a large amount of household labour.

The Appeal of Wood Heating Falls and Rises Again – Twice

After the second world war the use of fuelwood for home heating declined rapidly as fuel oil became a convenient and popular rural heating source. For many people wood heating was viewed as passé and associated with rural poverty and hardship. During the period of the 1950s through the 1970s, decorative wood burning fireplaces were installed in a large proportion of new single family dwellings, especially in urban Ontario. In the minds of most Ontarians, wood had slipped from consciousness as a heating fuel to become a fuel for ambiance and recreational use. This transition may partly explain why wood tends not to be viewed by city dwellers as a significant part of the home energy landscape, but rather as a marginal option.

The energy crisis of the 1970s was a watershed event for wood heating in Canada. Not only did the price of oil spike upwards with unprecedented suddenness, but the resulting high interest rates and recession of the early 1980s put additional pressure on household budgets. For many families, switching to wood heating became the single response to a number of related problems: the high cost of heating, insecurity about energy supply, and a defiant response to the economic pain that the OPEC oil cartel had inflicted on North Americans. The wood stove became a symbol of the resourcefulness and ingenuity in tens of thousands of households.

The rush back to wood heating after decades of decline led to problems. Having lost the family and cultural memory of the risk of house fires and the way to prevent them, and there being virtually no recognized safety rules, much less enforced regulations, thousands of new users lost their houses to fire caused by hazardous installations. In just a few years, wood heating became one of the leading causes of residential structural fires. Governments at all levels, the insurance industry and the wood heating industry worked together throughout the 1980s to develop safety standards and professional training programs.

By the mid-1980s the price of oil and other energy commodities had settled back to manageable levels and the economy recovered. Gradually wood heating lost its appeal for a portion of the households that had adopted it. By the early 1990s oil and gas were again cheap relative to other consumer goods and the gas fireplace had been improved to the extent than tens of thousands of them were sold to replace the trusty wood stove that had been installed fifteen years earlier. With the economy booming and people working longer hours, convenience trumped energy self-reliance for many.

The year 1998 was notable for two events. First was the infamous ice storm of January, which once again elevated the wood stove (along with the portable electric generator) to technological hero status. Wood stove dealers reported a flood of new customers in the fall of '98, people who vowed they would never again be vulnerable to the frailties of the electrical grid.

The second notable event of 1998 was the bottoming out of oil prices at around $10 for a barrel of crude, along with the publishing of The End of Cheap Oil,[17] an article appearing in Scientific American magazine. Authors Colin Campbell and Jean Laherrère predicted that the peak of oil production was not too many years away and that thereafter the price of oil would rise steadily,

never to fall again. Even though most experts do not believe the peak has arrived yet, the price of a barrel of crude oil has nevertheless risen inexorably in the years since the low price and first widely-read prediction of the bleak future for world oil production.

And once again, as the prices of energy commodities rise along with fears about security of supply, homeowners turn in increasing numbers to fuelwood.

Fuelwood Use in the Twenty-first Century

Compared to wood burning in the first half of the last century – the backbreaking work to produce fuel, the crude stoves and furnaces and dangerous chimneys – heating with wood today is different and better in every way. The efficiency of the average wood stove has roughly doubled to around seventy percent. Chimney technology and safety have improved. Recognized standards for virtually every appliance type and component have been developed and adopted into building code legislation. A national training and certification program for wood heating salespeople, installers, chimney sweeps and municipal and insurance inspectors was established and has been maturing since 1988. Today, the Wood Energy Technical Training program (WETT)[18] trains and issues certificates of qualification to wood heat professionals across Canada. The public and insurance companies now rely on WETT for the selection of qualified professional services. There are now clear (if complicated) safety rules and trained professionals to help householders comply with them. There are more and better public information materials available, most of it produced by the federal government.

Aside from improved safety and performance, modern wood stoves, which are by far the most popular type of wood burning device, used by about 70 percent of wood heated households[1], have become more aesthetically pleasing. Stoves are now available in enamel colours and both traditional and modern designs. No longer dusty black boxes, the new stoves can look at home in a well-appointed living or family room.

Less obvious, perhaps, is the impact of two technological breakthroughs that have transformed wood heating since the mid-1980s: ceramic glass doors and glass air wash systems. Until ceramic glass was introduced, the only option was tempered glass which couldn't tolerate the extreme temperatures developed inside modern wood stoves. A glass door that threatens to shatter at any moment could never be successfully used in stoves. The ceramic glass now used is not damaged at all by heat and is tough enough to stand up to the rigors of wood heating. Glass door breakage is now rare. Glass air wash was introduced at around the same time as ceramic glass appeared. The system involves directing the primary air for combustion through a narrow strip above and behind the glass panel. Being cooler and therefore less dense than the combustion gases, the air falls in a curtain between the glass and the fire, keeping soot and creosote tars from collecting on the glass. The majority of new wood stoves have shatterproof glass panels that stay clear for days, and for the best systems, weeks of continuous use. Only in the past twenty years has it been possible to view a beautiful wood fire that efficiently heats a home. This is a true breakthrough that has changed the character of wood heating forever.

Fuelwood and the Economy

The Woodlot Owner

As interest in wood heating increases, so do opportunities for woodlot owners to enter the fuelwood market or expand current operations. Most new converts to wood heating tend to live at the urban fringe and in and around smaller towns, meaning the majority do not own woodlots and will be buying their winter wood supply.

The production of firewood is not a high profit business, mainly because of high processing costs and a relatively inelastic retail price environment. The fuel feedstock is inherently hard to handle and does not lend itself to automation. Labour inputs are higher on a cost per heat energy basis than for any other energy source. Many woodlot owners who currently produce firewood for sale are willing to accept a lower hourly labour rate than industry averages for similar work. In most cases the fuelwood is co-produced with more profitable products like saw and veneer logs, which in effect, subsidizes the fuelwood operation.

Larger commercial fuelwood producers automate their operations to the extent possible to reduce labour inputs. Because stacking the wood correctly for effective drying is labour intensive, some producers simply create large random piles as the wood comes off the conveyor from the processor. This approach substantially reduces labour inputs but raises questions about the resulting moisture content and readiness for burning. Wood heating industry leaders are increasingly recommending that their customers purchase firewood a full year in advance so it can be correctly stacked and given longer to dry.

For the private woodlot owner the fuelwood market is challenging, certainly physically, but also because it is isolating by its nature so the sharing of knowledge among participants is not common. Customer demands are also changing. The increasing use of advanced EPA certified stoves results in more customers demanding wood that is dryer and split more finely. In a traditional business like firewood production, such changes in practice can meet with resistance.

On the other hand, fuelwood production has a high energy return on energy invested (EROEI) ratio, mainly because human labour is not usually considered in the calculation. This means that if the price of conventional energy sources does rise in the future as predicted, and since energy inputs to fuelwood are a smaller portion of total price than with the other sources, fuelwood should theoretically become increasingly competitive with all other heating fuels. This bodes well for the future viability of the fuelwood business and for rural employment.

In terms of maintaining a high EROEI, high quality and low purchase price, the preferred pattern is for the user to buy the fuel green, just as it is split, and stack it in their own yard a year in advance.

The Household Energy Budget

The extent to which fuelwood use affects the household budgets depends on a number of factors such as how the fuel is used and to what extent it is processed by the user.

Firewood is used in three distinct ways, each having a different impact on the household budget. First, firewood can be burned in a decorative fireplace which does not contribute significantly to home heating because of low efficiency. In the case of conventional fireplace use, the cost of firewood can be considered an entertainment expense, providing no tangible benefit to the household budget.

The second way firewood is used is to supplement the use of other heating fuels. Supplementary use may take the form of part-time heating, or for the heating of a section of the house, like a basement family room or an extension to the house. The impact of supplementary wood heating on the household budget can range from inconsequential if the use is casual and infrequent to substantial if wood provides most of the heat for the house. It is worth noting that the practices of the insurance industry tend to cause a distortion in the statistics on primary and supplementary use of wood. Families that heat primarily with wood have been influenced by experience with the insurance industry to say that wood is a supplementary heating fuel because many insurance companies either refuse coverage or apply large surcharges to householders who claim to heat primarily with wood.

> "The NRCan study[19] sheds light on this issue [primary versus supplementary use] and offers some surprises. It reveals that Canadians who report the use of wood as a supplementary fuel use it to provide a large part of their total heating needs. For example, 60 percent report using their stove more than four hours per day in winter, and a further 15

> percent use theirs between one and four hours each day. With 75 percent using their stove every day, this is much more than casual supplementary use." - Scoping Study: Reducing Smoke Emissions From Home Heating With Wood[20]

The study findings suggest that when homeowners claim to use wood as a supplementary fuel they may mean that it is used to supply more than half of heating needs. Where wood supplies more than half of heating needs, its use can have a substantial impact on the household budget, especially if the wood is processed mostly by the householders.

The third form of firewood use is primary heating, a practice that is most likely to occur in rural areas, and is the type of use that is most likely to have the biggest positive impact on household budgets. Considering that fossil fuel inputs to firewood are low, a household that is willing to put in the labour can save between one and two thousand dollars each year by heating primarily with wood. There are few if any other examples of 'consumer choices' that can reduce basic living expenses to that extent.

How Wood Heating Strengthens the Local Economy

Rural areas tend to have large 'trade deficits' on consumer goods and most commodities. Their 'exports' are usually based on their natural resources such as mining, agricultural and forest products. Revenue from external sources is commonly in the form of tourism and recreation expenditures by non-residents. Overall, as population, industry and political decision-making concentrates in large cities, rural areas have not fared well economically.

Every household makes significant energy expenditures each year and when a rural household consumes oil, gas or electricity, little of the total expenditure stays within the area to support local enterprise or employment. The economics of fuelwood production and consumption in rural areas are distinctly different; in fact they are unique in the field of energy. One of the few studies we found that addresses this question was published in 1980.

> "In the simplest sense, a healthy economy in Renfrew County depends on as much money coming into the County as leaves it…When we purchase energy from outside the County, there is a net dollar outflow… Rapidly rising [conventional] energy costs are somewhat like a drain which has been opened on our economy. Ever increasing amounts of money are removed by this drain, without having created either jobs or income within the County… This report estimates that fuelwood consumed in Renfrew County in 1979 was 55,000 cords. The total value of this wood is in excess of 3 million dollars, but this wood replaces nearly 5 million dollars worth of fuel oil and electricity. This fuel replacement prevented a very substantial percentage of that 5 million dollars from leaving the county's economy."[21]

A household that produces its own fuelwood supply saves up to $2,000 each year on its budget, an amount that can be used to reduce expenses in a household of marginal income, or that can be spent on other goods and services like home improvements. This household trades its own labour for big savings in household operating expenses.

A woodlot owner who produces and sells firewood provides employment and income to the area. If that same producer practices effective management, the quality and value of the woodlot are enhanced at the same time. When a local household buys its winter fuel supply from a neighbour, that transaction has a multiplying effect by keeping the money circulating within the community, increasing local incomes and job creation.

Local economic activity, including jobs and incomes, is increased through the use of fuelwood as a substitute for fuels purchased from outside the community. In a time of uncertainty about the future price and security of supply of conventional energy sources, fuelwood provides some price stability for residents of rural areas, as well as a sense of security because, if necessary, each household could produce its own fuel supply with a relatively small outlay of cash.

The Personal, Family and Community Dimensions of Wood Energy

Personal Achievement and Satisfaction

There are few sources of documentation and analysis of the non-technical aspects of wood heat, and yet most people who heat with wood seem to hold strong feelings about their practice, even though these are sometimes difficult to articulate. A doctoral thesis by Eastern Ontario resident Wendy Milne[22] provides more and better insights into the social dimensions of wood heating than any other document reviewed. The other primary source is quotations from correspondence posted on the woodheat.org[23] web site.

The production of fuel for heating the family home during cold winters is an accomplishment with significant meaning for the people who do the work. The feelings are clearly powerful, but are rarely acknowledged in the media or in mainstream discourse.

> "I find myself staring at my woodpile going, yeh!!! You know, cutting it, splitting it and getting off your own property, there is quite a bit of satisfaction in that." - a producer/user of wood fuel Milne, 2003

> "Splitting wood is a favourite pastime of mine. There is nothing better than that perfect swing and watching the two pieces fall from the stump where one log once stood. Sort of like what a golfer must feel on a perfect drive." - Jim, woodheat.org

Beyond the satisfaction of producing one's own fuel, the practice of wood heating also creates strong attachments linked to the feeling of the warmth and the sense of security and control wood heating offers.

> "I never thought someone could get so addicted to wood heat. It beats TV any day." Eric, woodheat.org

> "Once they have burned that stove for about a month and half, they would probably burn that stove for the rest of their life because it is addictive." - a wood stove dealer, Milne 2003

Wood heating is sometimes viewed as a masculine activity, but upon closer examination the involvement of women in the practice of wood heating becomes more evident.

> "At first I was worried about having a fire going at night while we sleep. But now, after I have started the fire, tended and watched it from start to finish, I feel comfortable knowing what is happening inside that firebox." - Doris, woodheat.org

> "I gotta tell you, I just LOVE this heat!!! We always feel warm - a nice, toasty warm. I've never experienced this kind of heat before. Oh yeah, I'm hooked!" Cindy, new user, woodheat.org

The Woodlot, Hearth and the Family

Wood heating is best viewed as a lifestyle choice as much as a fuel choice. This is borne out by the words of people who heat with wood.

> "People think I'm crazy when [I'm] asked about hobbies or what I'll do in retirement and I say burn wood." - Bob, woodheat.org

Wood heating is also compatible with a personal commitment to social and environmental responsibility since accountability for the associated impacts is accepted by the user.

> "Wood is the nicest thing there is. It is renewable. Trees grow again. I know a lot of the oldtimers they cut their bush so they would always have firewood and always have good trees. They learned from their Dads." - wood heat user, Milne 2003

Historically, in households that heat with wood the outdoors was the male domain where trees were felled and firewood processed, and inside the house was the female domain where fires were maintained and meals were cooked. This pattern still holds to some extent, but there is much overlap.

> "Mom actually does the largest part of the piling of the wood into the wood shed - we go through 6 - 8 full bush cords a year, so she manages that." - wood heat user, Milne 2003

Talking Fuelwood: Community Cohesiveness

Milne notes that "Participants talked in terms of wood energy being the one thing in their community that bridges class, gender, race, and philosophical divisions." Here are the words of some of her informants.

> "I think in a community of people who all use the same kind of energy, that there is a certain understanding that goes with it. I think everybody loves woodheat." - user Milne 2003

> "Wood links us in a lot of different ways. In conversation and common understanding and it is one of the ways we have of a more solid connection with the farming community." - user Milne 2003

Milne goes on to explain that "[w]ood energy is part of the culture, language and story telling of the area. One of the sayings I heard numerous times in the interviews was: 'did you hear the one about wood heating you four times: when you cut it, when you split it, when you stack it, and when you burn it'. A couple of participants also recalled the skit that the local theatre group did about how you can tell a lot about a man by his woodpile. It goes something like this: 'the wood pile leaning to the left is a socialist, the John Birch woodpile is all white, and the guy who burns 24 inch wood is the guy with the inadequacy issues'."

[1] TNS Canadian Facts for Environment Canada, Residential Fuelwood Combustion In Canada, Volume I – Report, April, 2006

[2] What is a carbon footprint - definition, timeforchange.org
http://timeforchange.org/what-is-a-carbon-footprint-definition

[3] Residential Wood Heating: the Forest, the Atmosphere and the Public Consciousness, Hendrickson, Gulland, 1993 http://www.woodheat.org/environment/forest.htm

[4] Natural Resources Canada: What is sustainable development
http://www.nrcan.gc.ca/sd-dd/whatis_e.html

[5] Huron County Stewardship Council Case Studies
http://www.huronstewardship.on.ca/index.cfm?member=casestudy

[6] NRCan booklet heating cost comparison with various fuels:
http://www.canren.gc.ca/prod_serv/index.asp?CaId=103&PgId=615

[7] EROI for various fuels, Dana Visalli 2006
http://www.energybulletin.net/14745.html

[8] EROEI.com, a web site focussed on energy return on energy invested. http://www.eroei.com/content/view/55/54/

[9] Energy return on investment (EROI) for wind energy
http://www.eoearth.org/article/Energy_return_on_investment_(EROI)_for_wind_energy

[10] Residential Wood Heating: the Forest, the Atmosphere and the Public Consciousness, Hendrickson, Gulland, 1993 http://www.woodheat.org/environment/forest.htm

[11] Town of Golden B.C. bans wood stoves.
http://www.bvldamp.ca/pdf/resources/goldenbylaw.pdf

[12] Burn it Smart and Healthy, Burn it Smart campaign.
http://www.burnitsmart.org/english/health_safety/healthy.html

[13] Burn it Smart publication: Do you have a wood smoke problem? http://burnitsmart.org/pdf/Wood_smoke_probl_CAN_color.pdf

[14] New Brunswick Lung Association web site: http://www.nb.lung.ca/programs/wood_stvs/residential.htm

[15] Michelle Rivest quoted in the Montreal Mirror, 2002
http://www.montrealmirror.com/ARCHIVES/2002/012402/news3.html

[16] New York state study of outdoor boiler performance.
http://www.woodheat.org/technology/NYreport.htm

[17] The End of Cheap Oil, Campbell and Laherrère
http://www.gulland.ca/depletion/endofcheapoil.htm

[18] Wood Energy Technology Transfer Inc.
http://www.wettinc.ca/

[19] Natural Resources Canada Survey of Household Energy Use 1993

[20] Scoping Study: Reducing Smoke Emissions From Home Heating With Wood, Gulland Associates Inc. for Environment Canada, 1997; see 2.5 Other Characteristics of the Market and the Users; Supplementary wood use is serious use
http://www.gulland.ca/scopingstudy.htm

[21] Renfrew County Energy Conservation Project, A Community Energy Study Energy Pathways Policy Research Group for Energy Mines and Resources Canada, March 1980

[22] Case Study of Wood Energy: Heating Rural Homes, Milne, 2003
http://www.woodheat.org/lore/thesis.htm

[23] The Wood Heat Organization web site:
http://www.woodheat.org/contact/feedback.htm