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THE USE OF WOOD AS FUEL IN NORTH AMERICA: PROSPECTS AND PROBLEMS

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ABSTRACT

The increases in wood use for heating and power generation since the 1973 oil embargo have been staggering. More wood burning leads to positive and negative ramifications for the affected economies and the local environments. This article describes and evaluates efforts by state and federal governments to mitigate negative tradeoffs of increased wood burning in the United States and Canada.

Ever since the Arab oil embargo of a decade ago shocked North American energy users and producers, an astounding array of ramifications in the energy field has been emerging. One of these ramifications is the renewed interest in the oldest energy resource of the human race: wood. The increases in wood use for heating and power generation since the embargo have been staggering. Much research has been done because of this renewed awareness of wood as a renewable fuel [1-3]. This article systematically examines the positive and negative aspects of the shift toward increased fuel wood use and the degree to which the problems of wood combustion are being mitigated by governments at all levels in the United States and Canada.

Limited research has been done on this policy-making aspect of wood use [4]. Much of the exposure of these concerns has been concentrated primarily in the local press with some references occurring in national publications for popular consumption [5]. We feel that this is a particularly important area of concern which deserves closer scrutiny at the municipal, state/province, and federal government levels.

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WOOD ENERGY PRODUCTION

Positive Aspects

According to the U. S. Department of Energy, more than 5.7 million homes use wood as the primary source of heat in the United States [6]. This is a heat equivalent of one-half of all nuclear power production in 1980. From 1972 to 1977 the number of wood stoves in the U. S. increased from 250,000 to 2,000,000 [7]. The increase in the use of wood has not only come about in residential wood combustion increases but also in wood energy systems at a much grander scale using varying forms of pyrolysis (from slow to rapid heating) and combustion which are able to convert wood to various energy forms [3].

Some argue that wood is simply a form of solar energy which is renewable and part of a natural cycle which is being speeded up with efficient burning [8]. Many feel that the increased use of wood will help this natural cycle through better forest management and a revitalized wood industry [9]. This new view encompasses the "total tree concept" whereby the entire above ground tree is used. The caveat usually included as a disclaimer is that this new management might become mismanagement if proper precautions are not taken with delicate forest ecosystems [10].

Several northern forest states and Canadian provinces have produced studies showing the surplus quantities of wood available for energy production. The Energy Branch of Environment Canada has prepared a study of the energy potential of forest biomass in Canada [11]. Several interesting findings came out of this representative report:

- large amounts of biomass are available in Canada and these are sustainable (maybe even expandable) during the years 1981-2000;
- there is a surplus of wood that can be the primary source until the 1990's which could then be replaced by wood from intensively managed tree plantations;
- total quantities of biomass in 1981 were 112 million oven dry tons (0Dt)/year) which is equivalent to 150,000 m^3/day of crude oil;
- this biomass total is expandable to 120 million 0Dt/year by the year 2000;
- over 70 percent of this biomass (excluding salvage) can be delivered for less than $46/0Dt (Canadian $);
- there are thirty-eight forest regions in Canada, and all are capable of supporting large biomass conversion facilities;
- all but nine of these regions have over 1 million 0Dt/year available; and
- it is felt that even with increases in pulp wood demand, increases in biomass from forest residue and tree plantations can be made.

As of 1981 in North America most wood energy was produced and used by the forest products industry itself. In 1981, 1.2 to 1.3 quads of energy/year (a quad = 1,000,000,000,000,000 BTUs) were being generated by waste products at wood mills [3]. Although refuse wood is being burned successfully in many boiler types, some researchers feel that the only truly economically viable use of wood is the burning of mill waste in situ [12].

In spite of many drawbacks, there is still a considerable effort being made to promote wood energy production at a large scale. For example, another study commissioned by Environment Canada concerns the forest resource in Newfoundland [13]. Work is being done to try to marshal the large reserves of "non-utilized" material for energy production in that province. Three requirements which must be met to allow this large-scale use were stated in the study:

- the requirement for readily available technology for efficient harvesting;
- the requirement to overcome or ameliorate the distance decay function of wood location *vis a vis* use location; and
- the requirement for some mechanism to concentrate forest biomass.

There also seems to be a push toward large-scale use of wood for electricity generation and wood by-product production. Burlington, Vermont already has a 50 MW wood-fueled power generating plant on line. A feasibility study for a similar 25 MW plant in northwestern Minnesota has also been completed which reached a favorable conclusion [9]. Several areas in Canada are looking toward large-scale wood gasification facilities. In northern Saskatchewan, fifteen communities are being considered for local gasification plants [14]. There are enough local forest resources to provide for at least 4 million BTUs/hour in gas for each community for at least the next fifty years. The harvest areas are considered so small that regeneration of forest over this fifty years can be maintained. The Saskatchewan Power Corporation also indicates that this wood use will provide better electrical service and increased local employment.

Wood use for energy production is also rising in Europe. For example, Hinrichsen predicts that wood will be a major part of Sweden's energy diet by the year 2000 [15]. Much of this will come from tree plantations using hybrid tree varieties bred for increased tree growth and BTU potential.

There is considerable evidence that wood energy, in whatever form, is a major, renewable energy alternative. Tremendous increases in residential and industrial use are being promoted by some segments of the wood products industry and by governments. This trend has created an interest in wood energy unlike that since the late nineteenth century. This is not without high cost. We now turn our attention to the negative aspects of the increase in wood energy use.

Negative Aspects

Free-market economists have been telling us for years that there is no such thing as a free lunch. Using wood for large-scale energy production and home heating is one of the best examples of this axiom. There are several areas where energy production from wood generates very high costs for this seemingly free energy supply. Production of wood energy is relatively inefficient; it has large-scale adverse effects upon other wood product industries; it has serious environmental effects on the forest ecosystems where wood is harvested; and of course it produces extensive air pollution problems. Williams states it very well when he says, "wood, of course, is one of the least suitable fuels for wood stoves." [16]

The energy content and conversion efficiencies of wood are low compared to other hydrocarbon fuels [15]. Pimental, Chick, and Vergara give some very revealing statistics in their study [17]:

- you need to add 1.2 million Kcal of energy to the 4.7 million Kcal already in wood to make 3.2 million Kcal of oil through pyrolite conversion (54% efficiency);
- producing methane from wood gives only a 23 percent efficiency;
- making charcoal from wood is only 25 percent efficient with the possibility of a 33 percent efficiency in the future; and
- direct burning of wood for electricity generation is only 25 percent efficient at best.

The trend towards wood use on a grand scale may be only a very short term, partial solution for our energy problems. Hansson states, "If the U. S. were to burn the entire annual growth of over 2000 million hectares of commercial forest, only 10 percent of its energy requirement would be replaced. Wood used in the materials systems causes an energy saving that is far beyond the energy it liberates on burning." [18]

The competition for wood is now intense, but in the future the rivalry between the factors vying for wood in all its forms will become very severe. Mitchell gives us food for thought when he asks [19]:

> To what extent – given demand for lumber and veneer and particle-board and paper, for purity of watershed and diversity of wildlife, for public recreation and private amenity – given these, to what extent can people have their forest and burn it, too?

Not only will we take wood away from other wood products industries, but we will decrease the amount of land used for other productive purposes (especially if we move toward tree plantations) [17], and we will cause local pollution hazards to increase which in turn will put a burden on industry to further clean their emissions [1]. In fact we already see this occurring. In Winslow, Maine, a Scott paper mill was forced to radically reduce its already low emissions because the increased use of wood for home heating added significant pollution to the air. The Scott mill was viewed as being the easiest target for pollution reduction by the state [20].

Our current knowledge of industrial practices in wood harvesting and the environmental controls necessary to prevent ecosystems damage are poor. The consequences of large-scale tree harvesting (especially whole tree harvesting) are complex and extremely site specific [21]. Several research studies have tried to determine the impacts of increased wood energy use upon forest ecosystems. This list of impacts is long but probably far from exhaustive [3, 10, 12, 14, 22]:

- soil compaction, disturbance, erosion;
- soil moisture and structure changes, especially in thin soil areas of the boreal forest zone;
- increased organic matter decomposition and loss;
- loss of N_2 fixing bacteria and other nutrients;
- altered forest succession;
- wildlife species changes;
- monoculture problems with disease and pests;
- water pollution from pesticides and chemical fertilizers;
- no slash left to stabilize slopes; and
- increases in forest land area must come from current agricultural land.

In addition, we cannot harvest the vast amounts of wood necessary by selective cutting (e.g., Burlington, Vermont electric project), nor are we certain of annual growth rates to satisfy the demands [7, 19]. Plotkin sounds a critical warning when he admits a current lack of knowledge about the scientific consequences of wood harvesting [21]. We are rushing headlong into something about which we know very little.

With all of the above concerns, probably the most critical local effects of the increase in wood combustion are the increased pollution levels caused by local generation of wood smoke. According to Deis, the particulate emissions from residential wood combustion are greater than for most forms of coal and twenty-five times greater than for oil for each BTU produced [20]. Wood heats about 6.8 percent of all homes in the United States [23] but accounts for 25 percent of all particulate pollution, 41 percent of all hydrocarbons in the atmosphere, and 77 percent of all carbon dioxide (CO_2) from residential combustion sources. (Residential combustion includes everything except electric heating.) The particulate emissions from wood burning stoves are greater than for any other source. This is particularly serious since 80 percent of these particulates are in the inhalable size range ($<$ 2um) [1, 2].

Although the NO_x and SO_x emissions appear to be low [24], there is a very wide range of particularly potent pollutants contained in wood smoke. Included in this list are phenols, formaldehyde, acetaldehyde, benzo (a) pyrene, methyl benzanthracene, and carbon monoxide (CO) [3]. What is even more disturbing is that what is good for fuel efficiency (i.e., low oxygen combustion) causes greater air pollution emissions from wood fires [25]. As less oxygen is allowed in the burning chamber, more polycyclic organic matter (POM) is released as well as other particulates. All in all, recent studies show a lengthy array of pollution types including seventeen priority pollutants, up to fourteen carcinogenic compounds, six cilia tonic and mucus coagulating agents, and four co-carcinogenic or cancer promoting agents [1].

As a final review of the pros and cons of increased wood combustion, we have prepared a list of advantages/disadvantages (see Table 1). This list gives a good representation of the effects of increased wood use.

REGULATORY CONTROL OF WOOD USE

Federal Control and State Actions

The above discussion indicates that there needs to be some control on residential wood combustion to attain or maintain acceptable levels of total or respirable particulate matter [4]. This statement was made in reference to the United States clean air standards and it is most likely true of the Canadian standards as well. No federal control in either country is yet in place even though the need exists and has been recognized by other countries (e.g., Great Britain) [16]. Not only are federal controls lacking, in some circumstances the federal governments actually exacerbate the problem. The U. S. Department of Energy publication, "Heating with Wood," promotes the low oxygen combustion rates which cause the worst pollution [8]. In a report received by the Canadian Forestry Service concerning wood gasification plants in northern Saskatchewan, the research on air pollution studied only the levels of SO_x, NO_x, and particulates. Only the last of these is a hazard caused by wood combustion; these researchers were looking for the wrong substances.

Few states and no Canadian provinces have controls. Oregon has passed stove design restrictions to be put into effect in 1986, and Colorado will do the same in 1987. Such areas as the Yukon, Canada, that have regions of high smoke pollution levels have no such restrictions in sight [26]. There are two basic methods of reducing emissions of pollutants in any given area: one is to reduce the number of units emitting pollution; the other is to make each unit more pollution-free with better technology. Both Oregon and Colorado are concentrating on the second reduction technique – requiring a more pollution-free firing unit. The salient aspects of the expected Colorado statute include:

- establishing criteria and procedures to test new stoves for compliance;
- setting emission performance standards for new stoves;
- prescribing the form and content of each new stove designed to meet these standards;
- establishing procedures to administer the program of certification; and
- establishing structural design specifications to minimize emissions from fireplaces.

All of these criteria are designed to reduce pollutants from each unit. There may also be a program of *voluntary* no-burn days meant to reduce the total number of units polluting during critical periods.

Table 1. Advantages and Disadvantages of Increased Wood Combustion

Advantages	*Disadvantages*
Environmental Issues	
Renewable resource	Air pollution
Little or no sulfur or radioactivity	High ash content
Low levels of nitrous oxide emissions	Very high levels of polycyclic organic matter (POM)
Does not exacerbate acid rain problems	Health hazard
Use of a waste (in industry)	Emissions contain various toxic, irritating, and carcinogenic agents
Use of waste wood to make artificial wood logs	Contributes to acute and chronic health effects of air pollution; some problems: chronic and acute bronchitis, common cold, pneumonia, emphysema, asthma, cancer
	Heating with wood can create pollution indoors
	Both soot and smoke are carcinogenic to the *skin and lungs*
	Pollutants can cause poor visibility and health problems
	Wood burning stoves can contribute a substantial proportion of air pollution in an area
	Emission control devices impractical
	Small-scale energy production makes environmental control difficult
	Water pollution from soil and nutrient runoffs (forests)
	Soil depletion (forests)
	Nutrient loss through forest removal (soil)
	Run-off from ash and other conversion and combustion by-products
	Destruction of wildlife habitats
Consumer Uses	
Well matched for direct use in industrial and residential heating	Carbon monoxide poisoning
Technologically feasible	Difficult to achieve complete combustion
Economically competitive	Transport problem with delivery; bulky; *labor intensive*
Large energy saving	As home fuel: bulky, need for large storage area
Wood stoves (airtight) are efficient as far as producing "cheap" energy	As home fuel: needs to be dried; time/space consuming
Save money by reducing overall heating costs	Many stoves used poorly, below their potential best performance because of lack of information
Harvesting wood yourself will reduce heating costs even more	More home fires because of improperly used equipment, creosote deposits in chimneys, improperly installed appliances, and poor quality appliances
Gathering and preparing wood is a healthy exercise	*Burn injuries*
	Injuries from equipment employed to cut wood (mainly chain saws)

Table 1. (Cont'd.)

Advantages	*Disadvantages*
	Gathering your own wood requires time, labor, equipment, and a source of wood New crimes: pirating of wood and trees Increase in illegal harvesting
Political Issues	
Domestically available Helps preserve fossil fuels Reduce dependency on petroleum Lessen dependence on gas for transport with alcohol fuel from biomass or waste wood	Pollution causes some local concern especially if it impacts economically
Regional Issues	
May generate regional employment	Reduce potential employment in some regions Logging: high accident and death rates Wood harvested for energy useful for other purposes Threatens the supply of lumber, pulp-wood, pulp, and other wood products Increase price of commercial wood Its use can be prohibited in some areas because of pollution Industries have to reduce their pollution so that pollution in the region does not exceed air quality standards Pollution aspect may discourage new industry
Aesthetic	
Aesthetic and highly emotional appeal of a wood fire	Visual change in forest character Irresistible pressure on remaining stands of scenic, old growth timber Destroys tourist areas
Forestry Issues	
May promote more intensive management and better environmental practices in forest products industry Conservation-minded cordwood cutting may help revive forests Using low quality species in a woodlot can improve the productivity of the stand Decrease in forest fires through removal of debris	Destruction of forests Deforestation Depletion of growing stocks Failure to generate new growth Reduced forest productivity Ecological change in forest character Damage to marginal wood lands Most affected sites will have fewer years to recover before they are again logged Erosion and accelerated leaching Loss of organic soil through removal of biomass Damage or loss of ecosystems Burning is one of the least efficient uses of wood fiber

Local Government Actions

Except for these two noted exceptions, any regulatory initiatives must come from local governments. The range of responses to wood smoke pollution for local governments varies from voluntary no-burn days to very strict design specifications for stoves to zoning/land use code changes.

Missoula, Montana is an example of this first approach. The initial attempt by Missoula was a relatively lax voluntary no-burn policy. This made little impact on air pollution levels. Then the local government initiated watered down regulations permitting citations to be given during pollution alerts to people ignoring the no-burn order. There is little support in Missoula for even this slightly stronger regulation; the high pollution levels continue. Another example of the low-key approach is occurring at Whitehorse, Yukon Territory. A study carried out in 1981-1982 revealed high levels of pollution in a suburb of Whitehorse (Riverdale) especially during periods of severe atmospheric inversion [26]. The recommended solutions to this problem are public education and the *investigation* of regulatory means.

At the other end of the regulatory spectrum are several local governments in Colorado. These include the City of Aspen, Pitkin County (Aspen is the county seat), the City of Vail, and Eagle County (Vail is in Eagle County). Aspen, Vail, and Pitkin County all have regulations in place to control pollution levels. Eagle County is developing similar regulations now. These local governing bodies are using both of the regulating philosophies of high technology/low-pollution stoves/fireplaces and a lower number of such devices. All of these areas have regulations which include the following aspects [27-29]:

- lowering of the allowable number of stoves in new residential units (e.g., one per single family dwelling, one per *building* for hotels, motels, inns, or time-sharing condominiums);
- allowing none (or only one) solid fuel burning device in restaurants or bars;
- allowing only one device per unit in a duplex containing a minimum square footage (e.g., 1200 ft.^{2} for Eagle County);
- requiring each device to be low polluting (e.g., 65×10^6 gm/joule of useful heat output);
- requiring that each unit meet the standards established by the Oregon Method #7 or EPA Test Method #5 (these are relatively strict tests for emissions from stoves);
- requiring that all devices be constructed so that more heat is generated than is lost through an exchange (this restricts those devices which are aesthetic only);
- allowing no burning of coal (the exception is devices that have been installed prior to the passage of the ordinance); and
- governing agencies would be allowed some leeway in enforcement to preclude "practical economic hardships."

It is obvious that these local governments are serious about reducing pollution levels. They are not merely relying on the hope that public education and voluntary no-burn days are going to solve the problem. One reason for this vigorous attack is that they perceive that increases in pollution could have an economic impact on the local areas. These places are mountain resorts which rely on the beauty of the surrounding natural environment to bring in income. If the areas are perceived as being highly polluted, there may be a decrease in tourism and skiing – in other words loss of income and increased unemployment.

CONCLUSIONS

There are certain economic advantages to using wood combustion and/or wood conversion to supplement the total amount of energy available in both the United States and Canada. Some of these economic advantages are more perceived than real (e.g., compete with other uses for wood), but most arguments in favor of wood use are based on these advantages nonetheless. The majority of disadvantages are based on the general environmental degradation characteristics of expanded wood use. There are sound economic reasons for not using wood for burning (e.g., again, the burning of wood versus other economic uses for wood), but most of these are subtle and long term and are not perceived as very important.

In spite of the evidence showing high pollution production from wood combustion, no national regulations exist in either the United States or Canada. No Canadian provinces and only two states have or are implementing wood combustion regulations. The impetus for control of wood use has devolved to local governments. In some cases this control is merely suggestion or education to persuade people to reduce emissions. Other local governments have taken a stronger attitude toward reducing wood smoke pollution. Some of the strictest regulations in either country are in the tourist/skier dominated economic areas of central Colorado. These strict regulations will probably lower emissions by both reducing the number of units polluting and by reducing the pollution emitted from individual units. This apparent difference between attitude probably evolves from the economic bases of the different areas. Where pollution is seen as an economic drawback, strong action has been taken. Where using wood for economic growth is advantageous, little is being done to control emissions. If wood smoke pollution is as serious as the scientific evidence indicates, it must be shown that it is economically advantageous to reduce pollution levels. In all likelihood, it is only the economic aspect of pollution that will spur stricter regulations and lowered air pollution.

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