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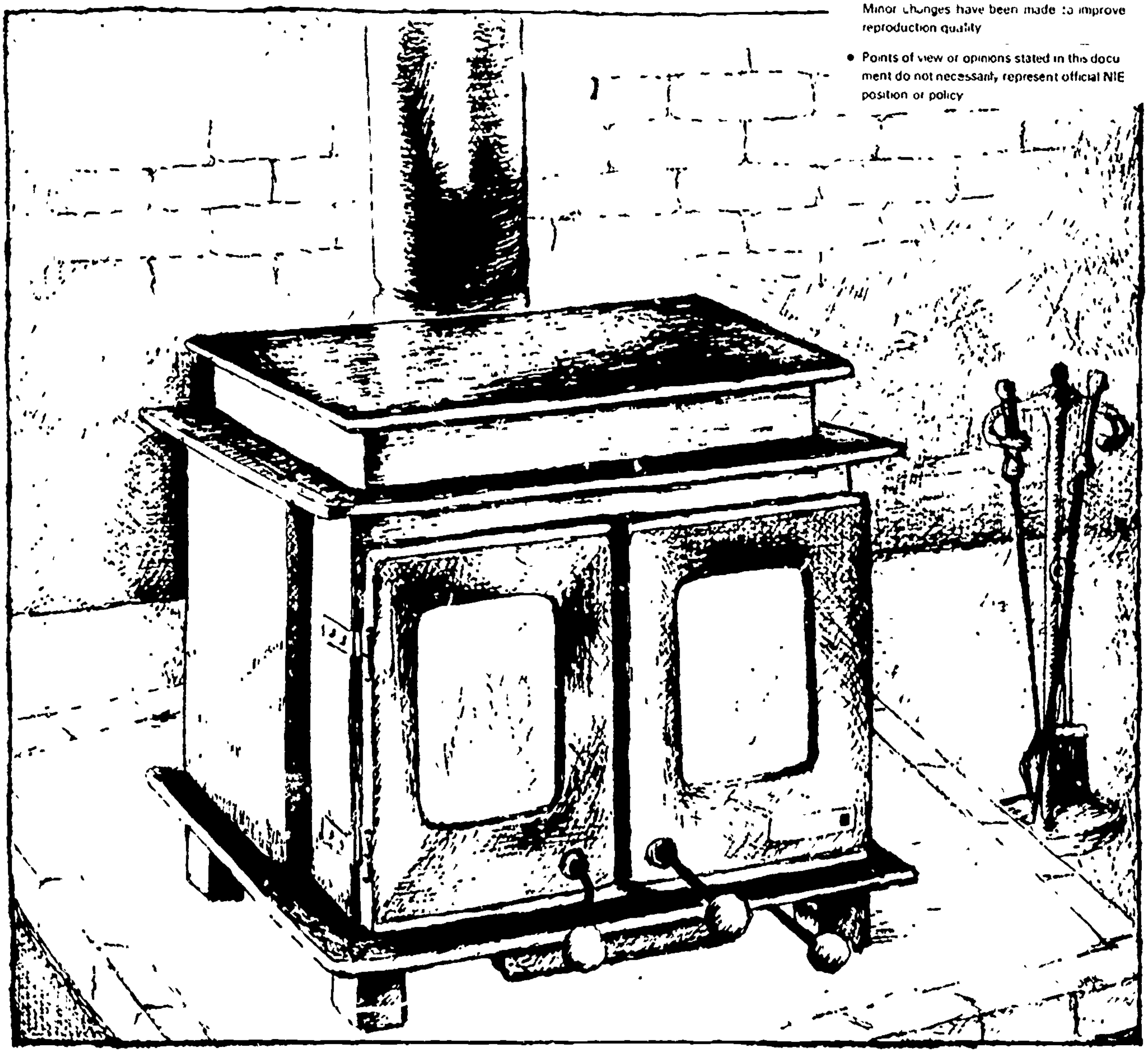
ABSTRACT

This seven-part guidebook provides information to assist decision makers and other individuals involved in the residential wood energy fuel cycle. It can be used as a tool for designing or implementing programs, strategies, and policies that encourage, prevent, or mitigate safety or air emission related impacts of residential woodburning equipment and practices. It can also assist the private sector interests in their decisions to improve technology, provide education, encourage better maintenance and operation of woodburning equipment, and to work with government to achieve solutions to present or emerging problems, particularly at state and local levels in the Great Lakes region. Part I provides introductory comments and a discussion of the role wood plays as fuel. Parts II to V examine, respectively: residential wood combustion technology (discussing fireplaces and wood stove design, chimney systems, and other topics); residential wood heating trends; emissions from residential wood combustion (considering characteristics of wood combustion emissions, measuring emissions, alternative control strategies, and other topics); and fire safety. Conclusions and recommendations are offered in part VI. Appendices (which include a glossary, a list of educational materials, and a list of resource contacts) are provided in part VII. (JN)

Residential Wood Combustion Emissions and Safety Guidebook



Great Lakes Regional Biomass Energy Program

January 1985

Great Lakes Regional
Biomass Energy Program

Residential Wood Combustion Emissions and Safety Guidebook

Prepared for the
Council of Great Lakes Governors
by
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We are grateful for the patient guidance provided by Great Lakes Biomass Energy Project Director, David Bancroft, from the Council of Great Lakes Governors.

The Project owes a special debt of gratitude for the unstinting labors of Hiram College Student Research Interns, Penny Graham and Krista Van Den Bossche, who performed research, writing and production tasks far beyond the original requirements of the project; and to Lucy Barnett, who provided her professional expertise to assist in all phases of research, writing and editing of the Guidebook.

The comments and suggestions our reviewrs strengthened the Guidebook. In particular, we wish to thank Don Wichert of the Wisconsin Division of State Energy, Michael Sciacca of the Wood Heating Alliance, Dave Wilson of the Coalition of Northeastern Governors, Patricia Engle of the Michigan DNR Air Quality Division, Steven Morgan of Technical Development Corporation, Dave Lamont of Vermont Department of Public Service Conservation and Renewable Energy Unit and David Bancroft, Project Director, Council of Great Lakes Governors.

Several reviewers raised substantive questions and comments that, because of the printing schedule could not be incorporated into the Guidebook text. Responses to these comments can however be found in Appendix E in the back of the guidebook.

FOREWORD

Preparation of this Guidebook involved a number of tasks including a literature search and review of published information regarding residential wood combustion technology, emissions and safety factors; a limited technology assessment; design and administration of a questionnaire to obtain information on woodstove control policies being used or considered; and a project team review of possible solutions to woodheat safety and emissions problems. The Guidebook was then designed and written. Following a review of the first draft and assessment of the research findings, the project team developed a set of conclusions and recommendations for the Great Lakes region states to consider.

The Project Team operated under a grant to the Hiram College Environmental Resource Center from the Council of Great Lakes Governors. The project was a joint effort by the Environmental Resource Center and Condar Company. The Project was coordinated by Mimi Becker, Co-Director of the Environmental Resource Center. Stockton G. Barnett of Condar Company was the Senior Scientific Investigator and James Cowden of Hiram College and Lucy Barnett of Condar served as Senior Research Associates. Richard Cornelison of Condar provided planning and research assistance. Hiram College Student Intern Research Assistants were Penny Graham, Karen Hannan and Krista Van Den Bossche. Policy analysis was the responsibility of Mimi Becker and James Cowden. Technology assessment was the responsibility of Stockton Barnett. Primary authors of key sections of the Guidebook are as follows:

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Residential Woodheating Trends: P. Graham with L. Barnett, J. Cowden and M. Becker

Emissions: M. Becker and S. Barnett with K. Hannan

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EXECUTIVE SUMMARY

Growth and Benefits of Woodheating

The use of woodfuel for residential heating has grown dramatically over the past decade in response to the spiraling cost of conventional heating fuels. Though residential woodfuel use data for the Great Lakes states is sketchy, estimates indicate that 29 to 34% of the residents heat with wood. Approximately 20% use wood as their primary heating fuel. Woodheat is attractive to many homeowners because it is economical and it provides the homeowner with energy independence. Woodheat has important social benefits as well - it is a renewable resource; it reduces U.S. dependence on imported fossil fuels; and wood harvesting and marketing activities create local jobs.

Considering that the long term price of oil, natural gas and electricity is expected to rise, we can expect a corresponding increase in woodfuel use, especially in heavily forested regions, such as in the Great Lakes states, that have no petroleum reserves.

Safety, Health, Economic and Environmental Impact of Residontial Woodheat

Though residential wood heating has many benefits to individuals and to society it is not without costs. A greater incidence of house fires is attributed to residential wood burning than to all other types of heating systems combined. The fire reporting systems, which detail the specific causes of woodheat related fires, are poorly coordinated and data is incomplete. However, available data indicates that the main cause of fires is from creosote-fueled chimney fires, especially where poor installation and maintenance practices are used. The associated property loss, injury and death and the increase in insurance rates and fire service costs reflect the seriousness of the safety problem.

The deterioration in air quality caused by wood heater emissions poses a significant health hazard, especially in geographic regions having poor air dispersion. Wood smoke contains noxious, toxic and irritating materials including a number of carcinogenic compounds. The seriousness of the relatively high concentration of carcinogens (ie, POM's, Benzo(a)pyrene) in wood smoke has just recently been recognized in studies conducted by the US EPA. The US EPA feels the problem is serious enough to propose woodstove emissions regulations.

Wood smoke pollution can also have serious economic impacts. Extensive residential woodheater use can reduce the air shed capacity, and in some cases has actually caused areas to approach or exceed NAAQS minimum standards for criteria pollutants. This has resulted in limitations on industrial expansion, has forced industries to spend more on air pollution abatement equipment, and/or has had a negative impact on tourism. Because of good air dispersion, the Great Lakes region has not suffered as serious a pollution problem as mountain valley regions have. However, growth in woodstove use could change this situation.

Unmanaged woodharvesting activities can also result in overharvesting and cause soil erosion.

The Relationship between Wood Combustion Emissions and Fire Safety

One important factor that should be considered in assessing woodheat policies and programs is that woodsmoke emissions and woodheat fire hazards are closely related. Creosote is one component of wood stove emissions; it condenses on chimney walls and acts as fuel for chimney fires. Chimney fires are the main cause of wood heat related house fires. Consequently the greater the emissions in a wood heat system the greater the fire hazard.

Current Efforts to Control Woodheat Related Problems in the Great Lakes States

To date, little has been done in the Great Lakes States to address the wood smoke pollution problem since it has been a low priority concern relative to the air pollution problems generated by the Midwest smokestack industries. Based on the amount of woodburning and the EPA findings regarding carcinogens in woodsmoke a more thorough evaluation of woodsmoke pollution in the Great Lakes states is certainly advisable.

The fire safety issue has received much greater, though fragmented, attention by both public and private sector organizations in the Great Lakes states. The main efforts have been to educate stoveowners regarding proper installation, operation and maintenance procedures. Some states and localities have implemented laws regulating installations, however for the most part these have had little impact because of inadequate enforcement.

Considering the current level of health and fire hazards from residential wood heating and the potential growth in woodfuel use, the Great Lakes states would be wise to plan and implement policies to control the negative effects of wood burning before these problems reach unmanageable levels.

Context for Establishing Woodheat Control Policies

The primary basis for control of wood smoke emissions and fire safety, at present, are state laws and local ordinances. States such as Oregon and Colorado have passed legislation requiring the use of clean burning stoves that meet statewide emission standards. While it does not presently address residential sources of air emissions, the Federal Clean Air Act can be used in non-attainment areas through amendment of the State Implementation Plans. The US EPA proposes a new Total Particulate Standard, PM10, that will concentrate regulatory activities on air particulate emissions under 10 micrometers in diameter. Many wood smoke particulates are less than 2 micrometers in diameter. Expansion of New Source Performance Standards (NSPS) or National Emission Standards for Hazardous Air Pollutants (NESHAP) to regulate woodstove emissions is also being considered.

Since the technology is now available to manufacture economical, clean burning wood heaters, wood stove emissions regulation can be a workable longterm solution for air pollution problems resulting from residential woodheating. Testing methods have been developed to evaluate the relative emissions and efficiency performance of woodheaters. Several states in the west have adopted these methods as a basis for implementing woodstove certification programs to reduce woodheat produced air pollution.

Because fire safety is closely tied to the emissions levels of woodstoves, regulations requiring clean burning stoves should also reduce woodheating fire hazards.

Policy Alternatives for Reducing Woodheat Fire Hazards and Air Pollution

Both remedial and preventive programs will be necessary to reduce woodheat related fires and/or air pollution since a large number of woodheaters are already in the field. The following table lists some alternative policies that may be used to address safety or emissions problems. The table also indicates whether the policy is most appropriate as a preventive(P) or remedial(R) measure, and lists certain considerations in using the policies.

POLICY ALTERNATIVES FOR FIRE SAFETY AND EMISSIONS CONTROL FOR WOODHEATING SYSTEMS.

POLICY	SAFETY PROGRAMS	EMISSIONS PROGRAMS	CONSIDERATIONS
Ban use of woodstoves	State law or local ordinance (P)	State law or local ordinance (P)	Unnecessarily restrictive policy since safer and cleaner technology is now available.
Regulate time or frequency of woodstove use		Air pollution alert (R)	Unlikely to be effective long term policy, especially if voluntary.
Regulate stove owner operating practices	Annual permit system with chimney cleaning requirement (P & R)		How often chimney cleaning is needed varies greatly depending on type of equipment, installation and operating practices.
Regulate wood stove density		Permit system (P)	Unnecessarily restrictive unless allowances are made for clean burning stoves.
Regulate installations	Building/fire codes(P)		Difficult to enforce, especially for existing single family dwellings. Requires properly trained inspectors.
Regulate equipment type	Building codes(P)		Require that woodheat equipment meet certain standards. Can require safety monitoring equipment. Need performance standards for equipment.

(Policy Alternatives continued)

	Stove certification program - clean burning stove requirement(P)	Stove certification program - clean burning stove requirement(P)	Does not affect polluting stoves already in place, but could be effective longterm program. Requires testing standards.
	Ban unsafe equipment(P)		Useful only for blatantly unsafe equipment. Does not address installation deficiency.
		Require stove be retrofit with a catalyst (R)	Reliable retrofit technology is still in the developmental stages.
Provide financial incentives	Insurance premium reduction for safe installations and/or maintenance (P & R)		Require properly trained inspectors. (Insurers must be charging differential rates.)
		Tax credit or subsidy for clean burning stoves or retrofits(P)	Additional cost of cleanburning stoves is paid back in fuel savings in 1-2 years. Tax incentives most appropriate in highly polluted areas.
Provide financial disincentives	Refuse to underwrite insurance for unsafe installations or charge high rates (P & R)		Could be effective if all underwriters adopted this policy and used properly trained inspectors.
		Pollution charges (P)	Charge imposed on dirty burning stoves. Difficult to enforce unless applied state-wide at the dealer level.
Education	Evaluate and publicize equipment safety ratings. (P)	Evaluate and publicize equipment performance ratings(P)	Requires that stoves be tested to safety & performance standards. Since many stoves are manufactured out-of-state this would be more effective implemented at national level.
	Consumer education on safe installation operation & maintenance. (P & R)	Consumer education minimizing emissions (P & R)	Relatively easy to implement. Best combined with inspection program.
	Training for installers inspectors, dealers and sweeps(P & R)		Certification or licensing requirement would be best way to to ensure participation.

Based on the limited program impact assessments available for review it is evident that stoveowner, dealer, installer, inspector and sweep education is an essential component for success in a woodstove safety program. A mandatory inspection program (via insurance agencies) appears to be a policy that could contribute significantly to fire safety. A long term solution to the major woodheat fire safety problem - creosote - would be the required use of clean burning stoves. Preliminary assessment indicates that education coupled with a woodstove emissions certification program might be the most effective long term means to address both the woodstove emissions and woodheat safety problems. Existing woodstove certification programs are not yet fully implemented so no data is yet available on their effectiveness. However if states were to coordinate their certification programs, the financial burden to the state regulatory agencies, to manufacturers and ultimately to consumers would be minimized and the certification programs would be more likely to achieve optimum success.

Information and Research Needs

A good deal of the information needed for effective woodheat policy planning and implementation is incomplete or totally lacking. Specific data on causes of woodheating fires is very incomplete as is data on the contribution of woodsmoke to air pollution in the Great Lakes region and data on the amount of woodfuel burned in residences.

A number of agencies and organizations throughout the U.S. are conducting evaluations of wood heat equipment safety and performance. However, nationwide standards do not exist for evaluating woodstove performance (efficiency and emissions) so conflicting test results have been issued. If state regulatory agencies and standards organizations can coordinate their woodstove performance assessment programs, this problem should be resolved. Indoor air pollution from woodheaters is another research area needing greater attention.

A comprehensive policy study needs to be conducted 1) to compile the data needed to quantify the potential impact of policy alternatives for emissions and safety control, 2) to determine which program alternatives are most cost effective, 3) to determine which programs are the most politically feasible and the most likely to produce the desired results and 4) to then develop a coordinated long-term plan for addressing the woodheat emissions and safety problems in the Great Lakes states.

I. INTRODUCTION AND BACKGROUND

A. PURPOSE OF THIS GUIDEBOOK

The purpose of this Guidebook is to provide information to assist decision-makers and other actors involved in the residential wood energy fuel cycle. It identifies related safety and air pollution problems and it discusses ways for preventing or solving those problems that have been specifically identified as having an impact in the Great Lakes region. The information has been obtained and organized to provide greatest assistance to public sector decision-makers at the state and local level. It can be used as a tool for designing or implementing programs, strategies and policies that encourage, prevent or mitigate safety or air emissions related impacts of residential woodburning equipment and practices. It can assist the private sector interests in their decisions to improve technology, provide education, encourage better maintenance and operation of woodburning equipment, and to work with government to achieve solutions to present or emerging problems, particularly in the Great Lakes region.

While the Guidebook is organized to consider specific emissions or safety problems separately, it should be stated that **many technologies or practices that are directed toward the achievement of safer woodburning equipment operation can also act to reduce emissions - and wood consumption.** Specific note is made of this emissions-safety relationship because the institutional arrangements for addressing or regulating residential woodheating safety issues have traditionally been accomplished through different agencies (State Fire Marshals' Offices, local building codes, etc.) than those related to air pollution from woodburning activities (local air pollution control districts, the zoning board, state environmental protection agencies). The section of the Guidebook that reviews ways of addressing problems and makes recommendations specific to the Great Lakes states, identifies a number of alternatives for developing or improving coordination between these institutions so that the objectives of improved residential woodheat safety and reduced emissions can be more effectively achieved.

The Guidebook provides background and technical information about the evolution and use of residential woodburning equipment and practices; the relationship between safety and emissions problems; the woodburning process; the characteristics and hazards of emissions from residential woodburning; the methods for measuring woodstove emissions; the type of woodheating equipment being used and its installation, operation and maintenance; the regulatory, educational and technological tools available and in use; and specific information regarding residential heating and related safety and emissions problems in the Great Lakes region. Key federal policies or regulatory tools are also summarized or provided in some detail to indicate the context within which various alternatives may or must be considered.

Information about the present status of residential wood fuel use and any safety or emissions problems or policies in the Great Lakes states was obtained through correspondence and interviews with state and local agency personnel and with key private sector interests such as the Wood Heating Alliance. Federal level agencies with current responsibilities were also contacted and interviewed, as were key states outside the region where present problems related to residential woodfuel use are being addressed or are under consideration. This information is presented in the appropriate section of the Guidebook.

The appendices have been included to provide additional information and to indicate sources of technical assistance.

It should be noted that cleaner burning woodstove technology is evolving rapidly and there are already a small but growing number of clean burning stoves on the market. Key states such as Oregon, Colorado and Massachusetts are implementing statewide woodburning policies that are primarily targeted to reducing emissions. Additional information of interest to Great Lakes states will be available from those states upon request.

B. THE ROLE WOOD PLAYS AS A FUEL

Wood is an important resource in the American economy due to its abundance, its wide distribution in much of the nation, its versatility as an energy source, its relative energy efficiency, and the fact that it is a renewable resource. The potential for energy extraction from the unused portions of the nation's wood resources (residues from logging, from wood processing, from defective and dead trees and from urban wood wastes) is estimated at 10 quads annually. The Forest Service estimates that 600 million dry tons of residues are available annually, and that half of these could be recovered economically within the next decade to increase wood's contribution to 8 percent of the nation's energy budget. Wood residues are a fuel source for home heating. Their use as industrial and utility fuels is growing. They can be used in a variety of forms - from logs to chunks or chips, wood pellets and briquettes, or pyrolysis products such as charcoal.(1)

Historically, wood supplied up to 90% of U.S. energy needs. As fossil fuels became cheaper, though, our reliance on wood as an energy source declined. In 1970, wood energy use was less than 1 percent in the United States. However, after the 1973 oil embargo and the increasingly high cost of oil and natural gas, more and more people began returning to wood as a fuel.(2) A 1980 estimate by the General Accounting Office indicated that 7.5 million homes in the U.S. used wood for all or part of their heating needs.(3) Wood has become the favorite alternative fuel. It cannot totally replace oil, coal or nuclear power in the energy future, but it provides an avenue for limiting our dependence on imported, expensive and increasingly scarce fuels.(4)

1. Historical Background

Wood heating in America today shows little resemblance to wood heating of 200 years ago in colonial New England. In those days 30 cords of wood might be burned in open fireplaces in a home each year. Even though a large amount of wood was burned, much of the home was still cold because homes were uninsulated. Today tighter construction and the use of insulation in contemporary homes reduces heat loss 5 to 10 times compared to colonial homes. Also, contemporary closed metal wood stoves, "airtight stoves", as they are called, and wood furnaces have proven to be much more energy efficient than the open colonial fireplaces.(5) The net result is that most contemporary homes can be heated with less than 5 cords of wood. The benefits of airtight woodstoves have not come without costs, however. Airtight stoves produce a lot more creosote in the chimney - a serious fire hazard.

Over the years, manufacturers' research and development efforts have been directed toward providing the technology and equipment for increased efficiency and safety in new and existing wood heating appliances. These efforts have resulted in a number of different designs in fireplaces, wood stoves and wood furnaces. Though modern wood burning technology has come a long way since the colonial fireplaces, it continues to evolve. The most radical changes in technology have occurred over the past five years.

2. __Woodburning Environment - House Design__

Although new and developing technology is likely to improve wood heat appliance efficiency, the environment in which wood heating systems are installed in modern homes contributes a great deal to energy efficiency. Today's homes lack the sprawling rooms and high ceilings which allowed considerable heat loss in earlier construction. New materials and methods of home design and building are in use, directed to the conscious limitation of heat loss through insulation, storm windows or double glazing, and the sealing of the building envelope. Energy efficient house designs have approximately one third the heat loss that older uninsulated homes have. (See Table 1.1.)

Table 1.1: HEAT LOSS FROM DIFFERENT TYPES OF SINGLE DWELLINGS

Type of House	Heat Loss Btu/Sq. Foot/Degree Day
Uninsulated (generally more than 50 years old)	About 8 - 9
Lightly insulated (built from about 1930 - 1965)	About 6 - 7
Moderately insulated with storm windows (standard modern construction with R 19 ceiling and R 11 walls)	About 5
Energy efficient (R 40 ceilings and R 20 walls)	About 3
Super insulated (R 40 ceiling and walls, special energy efficient window coverings)	About 2

These better insulated, more tightly constructed home designs are well suited for wood heat. Since there is much less heat loss, acceptable temperatures can generally be maintained in rooms furthest from the heat source. Many homeowners who live in older, more poorly insulated homes use wood as a supplementary heat source.

The heat loss advantages of new construction techniques have also produced some disadvantages for woodheating. Well insulated newer homes require much lower heat output from woodstoves. Unfortunately, when stoves are operated at low burn rates, more creosote and emissions are generated. Since many homeowners use oversized stoves, relative to the space to be heated, this problem is magnified. Years ago, before airtight stoves, this problem was much less severe because stoves had to be operated at higher (and thus cleaner) burns in order to keep the uninsulated houses warm.

A second problem with tighter and better insulated homes is that the air exchange is greatly reduced, thereby increasing the health risks associated with indoor air pollution. (See section 4-c-1-a)

Changes in homeowner attitude and behavior have contributed to the acceptance of wood heat. The kind of homeowner who heats with wood tends to be a person who is more energy conscious and is willing to make adjustments in life style. According to a recent survey by the U.S. Department of Agriculture, homes with wood stoves tend to be more energy efficient, since their owners invest in other energy conservation products to a greater degree than the rest of the population. (6)

Wood heat has proven to be a very satisfactory heat source for many people. There are some very positive aspects of wood burning that have contributed to its popularity.

3. <u>Why Woodheating Has Become So Popular</u>

In the post-embargo days of the middle and late 1970's, use of woodstoves grew because they offered the homeowner his own secure energy supply, unaffected by the volatile arena of world energy politics. Woodheat also dramatically reduced heating bills, most noticeably for people who cut their own wood. It was expected that rather small savings would have occurred for people who bought their wood, but surprisingly these savings were large. This unexpected bonanza of savings to the homeowner has fueled continued growth in woodheating to this day.

The reasons why wood heat provides greater than expected savings have only recently been investigated by the scientific community. Unexpectedly, the results have revealed important fundamental facts about home heating systems.

Let us look at a typical example of a home that was using 700 gallons of oil at $1.10/gallon or $770/year. Using the generally assumed 65% delivered efficiency and 145,000 BTU/gallon of oil, the oil delivered 66 million BTU of heat annually. Since there are 20,000,000 BTU/cord of hardwood and woodstoves average 50% efficiency, then (66,000 x 20,000,000 x 2) or 6.6 cords of wood would be needed for an equivalent amount of heat from wood. At $100/cord, annual heating cost using wood should be $660; or a savings of $110/year.

However, in actual practice, woodburners generally save close to half on their fuel bills by converting to woodstoves. Therefore, some fundamental error must be present in the above calculations. Barnett (7) evaluated energy use from various heating sources in calorimeter houses and reviewed the literature on the subject. The results demonstrated that oil (and gas) furnaces were far less efficient than generally assumed. They average only about 40% net delivered efficiency on a seasonal basis. Many additive factors contribute to their poor performance including such things as heat loss throughout the duct system and through the crawl space or basement walls.(8) Thus our example house, that was assumed to deliver 66 million BTU/year from oil heat, was actually delivering only 40 million BTU. Therefore, only 4 cords of wood, costing $400, should be needed to produce an equivalent amount of heat, and savings would be 48%. In real life, savings are often even greater because when using wood heat, the average daily house temperature is lower than the previous temperature because the stove runs out of fuel and can't maintain house temperature late at night. Also, the distal parts of the house (usually bedrooms) are not kept as warm from the single heat source woodstove.

In summary, although woodheat use initially grew in the 1970s out of need for homeowner energy independence, woodheat has continued to grow because it has been far less expensive than it originally was expected to be. Search for an explanation revealed that conventional central systems are wasting much more energy than was assumed. Woodheat has served to point out disadvantages of central systems and may well pave the way towards general use of far more efficient spot heat systems where the heater delivers its heat directly to the intended living space.

A summary of net delivered efficiencies and relative heating costs for several heating systems is shown in Figure 1.1 and Table 1.2. These cost comparisons indicate where one might expect future growth in various types of heating systems, as consumers attempt to minimize heating costs.

It should be noted that recent dramatic increases in woodheat efficiency have taken place with the development of high technology catalytic heaters. Delivered efficiencies have risen from 50% to 75-80%. This makes wood heat even more attractive from a cost point of view. Note in Figure 1.2 that catalytic woodheat is, by a considerable margin, the lowest cost source of heat available.

FIGURE 1.1. HOME HEATING SYSTEM EFFICIENCY.

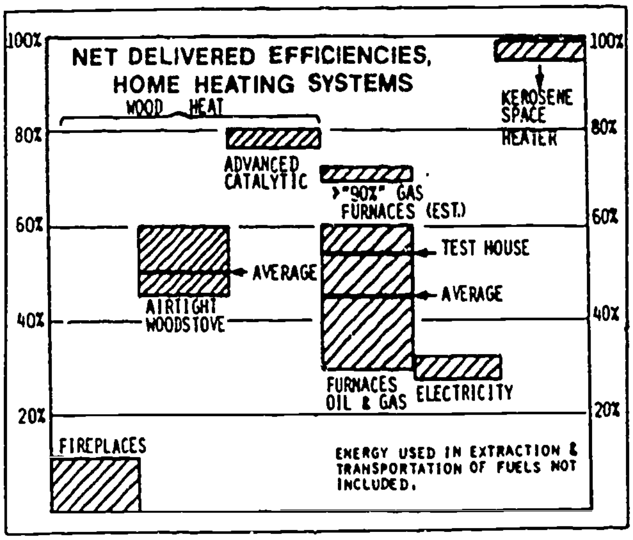
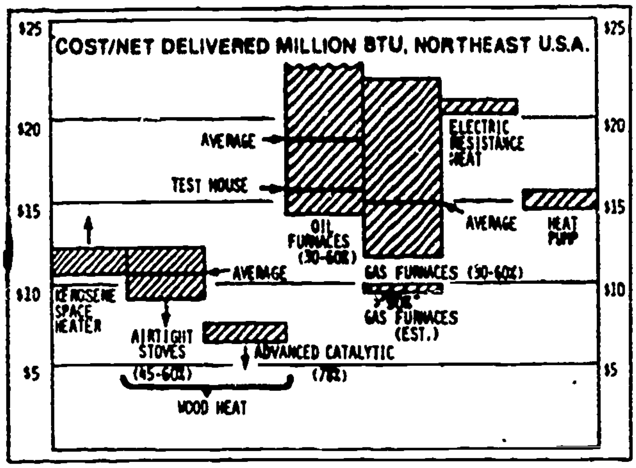


TABLE 1.2. AVERAGE FUEL COSTS FOR HOME HEATING ENERGY SOURCES

	Price per unit	Price per gross one million BTU
Oil	$ 1.20/gallon	$ 8.57
Kerosene	1.40/gallon	10.60
Propane	.92/gallon	10.11
Natural Gas	.68/therm	6.80
Electricity	.069/KWH	20.21
Wood	105.00/cord	5.25

FIGURE 1.2. WOODHEAT COST PER BTU.



(From Stockton G. Barnett.)

NOTES

(1)"The Nation's Unused Wood Offers Vast Potential Energy and Product Benefits." GAO, March 3, 1981.

(2)<u>Heating With Wood.</u> U.S. Department of Energy, May 1980.

(3)"The Nation's Unused Wood Offers Vast Potential Energy and Product Benefits." GAO, March 3, 1981.

(4)<u>Heating With Wood.</u> U.S. Department of Energy, May 1980.

(5)Shelton, Jay W. <u>The Woodburner's Encyclopedia</u>.

(6)"USDA: Stoveowners' Homes More Energy Efficient." <u>Wood 'n Energy</u>, August 1983, p. 11.

(7)Barnett, S. G., "Ranking of Home Heating Systems Using Calorimeter Houses." <u>Wood 'n Energy</u>, September 1984, pp. 55-61.

(8)Op cit, p. 55.

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II. RESIDENTIAL WOOD COMBUSTION TECHNOLOGY

A. FIREPLACE AND WOODSTOVE DESIGN

Woodstoves and fireplaces have been used as residential space heaters for centuries. Of the two, fireplaces are currently used more for their recreational and aesthetic values than for heating.

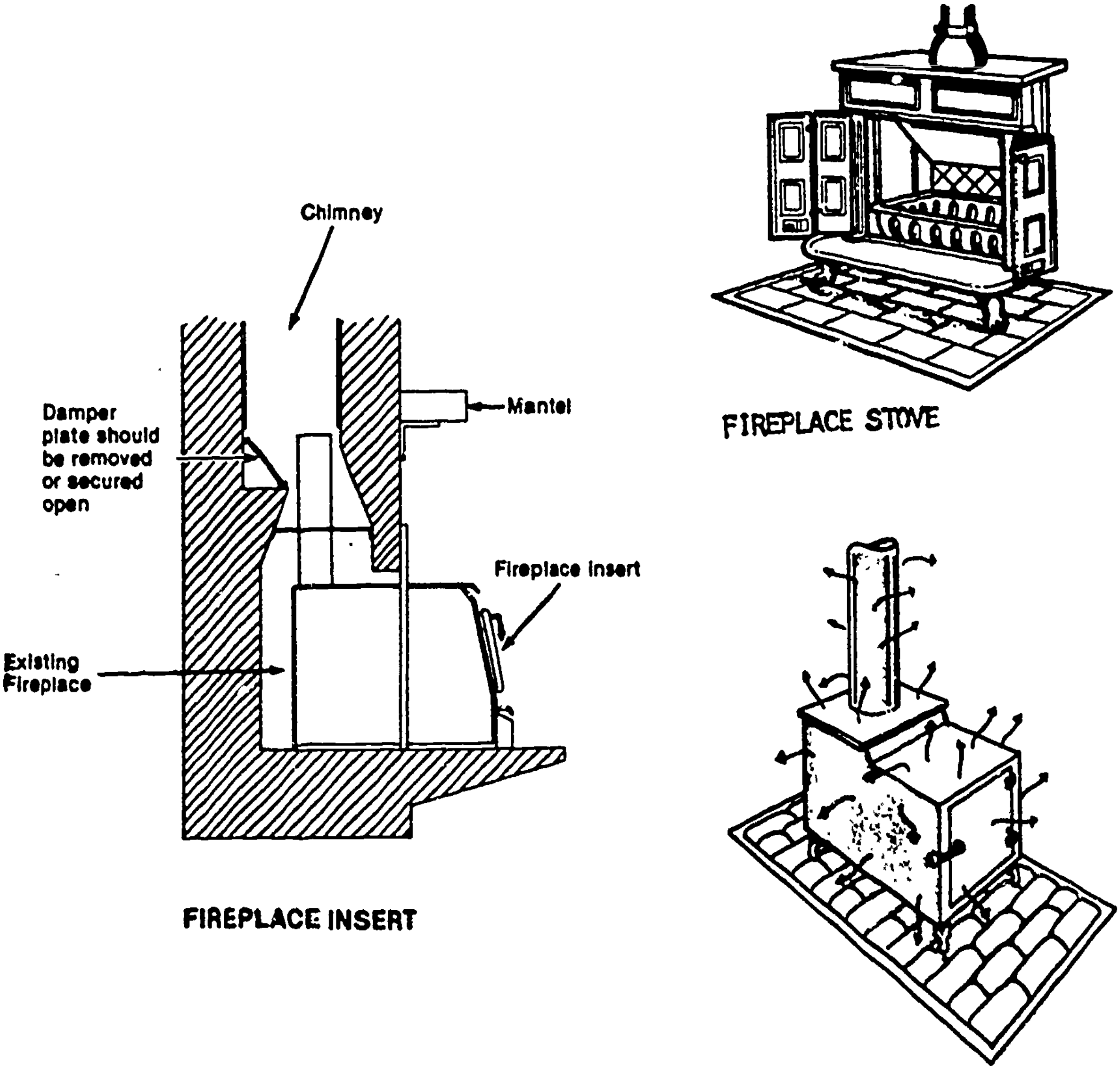
Fireplaces are very inefficient relative to newer woodheat technologies. Because air not needed for combustion is drawn from the room into the fireplace and up the chimney, the air exchange rate in a residence may more than double during burns. This greatly increases the infiltration of air from outside. Consequently, while fireplaces do produce local heating, the overall effect on the house may be to actually reduce interior temperatures.

The air exchange rate in fireplaces can be reduced by installing glass fireplace screens (which unfortunately also allow more heat to escape up the chimney) or by using damper controls in the chimney.(1) The efficiency of a fireplace can also be improved by circulating room air through tubes passing through the fire, or by drawing combustion air from outside the house.(2) Though the efficiency of fireplaces can be improved somewhat, air tight wood stoves can still achieve greater efficiency.

Wood stoves have a significantly higher efficiency than fireplaces due to the use of far less excess air and to the circulation of air around the stove and/or radiation of heat from stove surfaces. There are basically three types of solid fuel appliances (Figure 2.1): 1) Fireplace Inserts, 2) Fireplace Stoves, and 3) Room Heaters. The descriptions, taken from the National Fire Protection Association Standard 211, are as follows:

> **Fireplace Insert:** A factory-built, field installed product consisting of a firebox assembly designed to be installed within or partially within the fire chamber of a fireplace and which uses the fireplace flue to vent the products of combustion. Underwriters' Laboratory includes heat exchangers in this category.
>
> **Fireplace Stove:** A free-standing, chimney connected, solid fuel burning heater having its fire chamber open to the room.
>
> **Room Heater (Woodstoves):** A self-contained, free-standing, heating appliance intended for installation in the space being heated. Room heaters may be circulating or radiant types. The circulating types have an outer jacket surrounding the heat exchanger arranged with openings at top and bottom so air circulates between the outer jacket and the heat exchangers. These may be either gravity or fan fed. The radiant type woodheater radiates heat from stove surfaces. A third variety is a room heater/fireplace stove combination designed to be operated with the fire chamber either open or closed.

FIGURE 2.1. BASIC TYPES OF SOLID FUEL APPLIANCES AS DEFINED BY NFPA STANDARD 211.



A. Fireplace Insert (Tennessee Valley Authority. Safe and Sound Masonry Chimneys. May 1983, p. 9.)

B. Fireplace Stove (TVA, Safe and Sound Warm Heat. September 1981, p. 4.)

C. Radiant Room Heater (TVA, Safe and Sound Warm Heat. September 1981, p. 4.)

Room heaters, more commonly called "woodstoves", can also be categorized as "airtight" or "non-airtight". Actually, airtight conditions are unachievable, so the term refers to appliances with relatively tight joints that greatly restrict excess air from entering the firebox, thereby making it possible to control the rate of combustion by adjusting the draft opening. Most older woodstoves, such as Franklin-type heaters built before the early 70's, are likely to be non-airtight. They allow substantial amounts of air to enter through poorly sealed joints and doors. Because draft air to the combustion chamber cannot be well controlled, these stoves are much less efficient than the newer, more tightly built wood stoves. The most advanced woodstoves combine an airtight design with a catalytic combustor. These stoves lead woodheating appliances in combustion and heat transfer efficiency.

1. **Materials and Durability**

Stoves can be made of a variety of materials such as ceramic, tile or soapstone, but the vast majority of stoves are made of steel (plate or sheet) and/or cast iron. There are good and bad aspects to each of these materials:

> **Cast Iron.** Cast iron is an alloy of iron ores, carbon, and silicon. It is melted, then poured into molds designed for a particular stove. Physically, cast iron is much stiffer and less susceptible to distortion than steel. Thus, cast iron is preferable for doors and door frames where small distortions could result in significant air leakage. Because of cast iron's stiffness, it is also susceptible to cracking. Cast iron cannot "give" much. If the center of a cast iron stove is much hotter than the rest, because the fire or a hot coal is against it, the thermal stress can crack it.(3)

> **Steel.** Sheet steel is molten steel which has been rolled into sheets. Steel is relatively soft and malleable. If stressed, it bends, often permanently. Some steel stoves develop slight distortions in their walls due to thermal stress. The stove's functioning is rarely impaired by such distortion.(4)

Both steel and cast iron are susceptible to corrosion. Some oxidation (rusting) of the stove walls from the inside due to the fire is unavoidable. The rate of oxidation at very high temperatures is much higher than at normal stove temperatures. Thin-walled stoves operated at very high temperatures have been known to burn out in one season.

2. **Thermal Properties of Materials**

Overall, both steel and cast iron are suitable materials for stoves. The thermal properties of steel and cast iron are virtually identical. A steel stove with walls as thick as a cast-iron stove will have just as much heat storage capability. Stoves with very thin walls do not retain enough heat for efficient combustion and therefore tend to produce a lot of creosote.

Ceramic tile and soapstone are sometimes used in stove construction. These materials have a lower thermal conductivity than cast iron and steel and about twice the specific heat. Thus, they require more time to heat up and they store heat for longer periods. In addition, most masonry materials have a tendency to crack under thermal stress.(5)

3. <u>Fire Brick or Metal Liners</u>

Fire brick and metal liners are used in the firebox to lessen cracking of cast iron, distortion of steel, and corrosion of both materials. The liners are easy to replace and keep the main stove body from getting too hot, too fast. While they protect the stove from thermal stress, they also help maintain high firebox temperatures for more complete combustion. Thick stove walls are also less susceptible to thermal stress problems. Liners are most useful in thin-walled stoves.

4. <u>Combustion and Draft Air Flow in Woodfired Appliances</u>

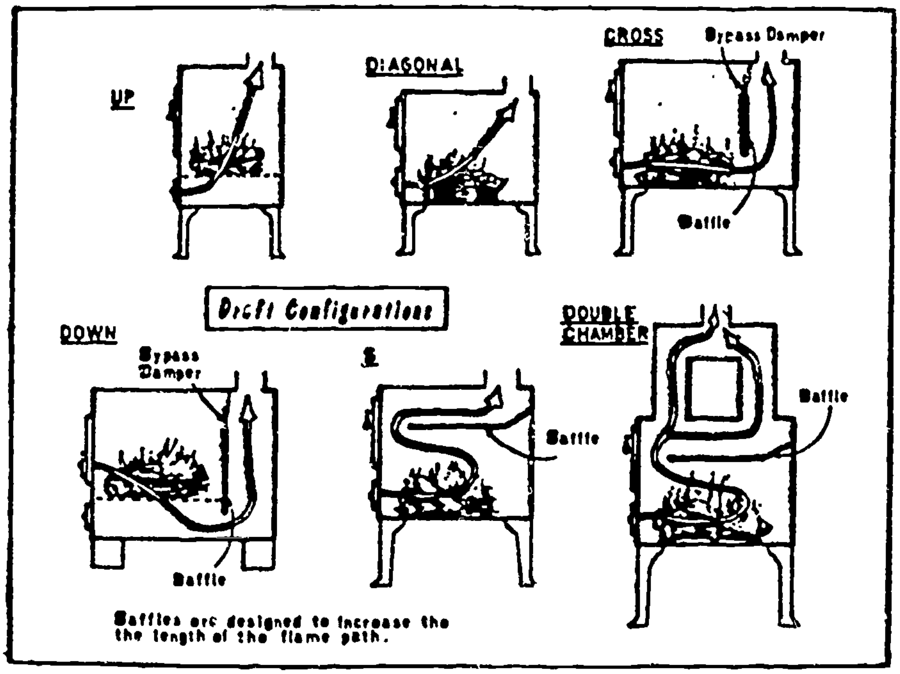
The combustion of wood involves four processes or phases: moisture evaporation, pyrolysis with subsequent gas vapor burning, and surface char burning. These processes occur successively within any local particle of wood, but in actual combustion systems there is an overlap such that all three processes occur at the same time within a combustion chamber. This overlap is particularly significant when fuel is loaded within the combustion space for prolonged burning or when fresh wood is added to only partially burned fuel already in the firebox.

The completeness of combustion in a woodburning appliance is dependent on the airflow pattern through the unit. Combustion of volatile gases can potentially supply a majority of the heat. However, in appliances with poor draft control, volatile gases escape up the chimney before they can be heated enough to burn. Fireplaces, for instance, do not retain gases long enough to burn them completely. Conventional airtight woodstoves suffer from the same problem at low burn rates because there is not a high enough temperature to completely combust the gases before they leave the firebox. At high burn rates, temperatures are high and combustion more complete in airtight woodstoves. The heated walls and tops in woodstoves keep the fire hotter so the gases can be burned more completely. Some stoves also have a baffle adjacent to the firebox. This creates a longer heated flame path which allows the gases to burn more efficiently at high burn rates.

The main woodstove combustion air flow patterns are updraft, diagonal and s-flow as illustrated in Figure 2.2. Non-catalytic airtight stoves using these configurations can burn at approximately 50-55% overall efficiency. Theoretically the maximum overall efficiency that can be achieved from wood combustion is about 80% without significant water condensation problems occuring in the stack.

Updraft air flow type stoves are designed to allow primary air to enter at the base of the stove and pass through to the stovepipe at the top or back. Secondary air enters above the wood to assist in the ignition of unburned volatiles in combustion gases. This design has no baffles. Combustion is fairly complete, but gases remain in the combustion chamber for a rather short time. Therefore, much of the heat goes up the chimney, particularly at high burn rates. This limits the thermal efficiency of the stove.

FIGURE 2.2. COMBUSTION AIR FLOW PATTERNS IN WOOD STOVES.



(From: "Stoves." Cooperative Extension Service, The Ohio State University, p. 3.)

Baffles can be used to create a downdraft, a crossdraft, or an S-draft. The S-flow stove is the most popular design in the United States. S-flow stoves are equipped with both primary and secondary air inlets like the updraft stoves. Gases are not allowed to exit directly up the flue as a metal baffle plate is located several inches above the burning wood to lengthen the retention time. The plate also absorbs heat and reflects and radiates much of this back to the firebox resulting in slightly improved combustion and enhancing heat transfer from the gas phase. Thus, combustion enhancements only occur at rather high burn rates when temperatures of over 1100 degrees F can be maintained in the "secondary burn" region. The major problem with S-flow stoves is that the gases are often cooled below creosote condensing temperatures, creating deposits of creosote in the flue.(6)

Although these combustion air flow patterns are quite different, the emissions from them are almost the same. The only exceptions are: 1) some crossdrafts and S-flow stoves are slightly cleaner burning at higher burn rates, and 2) some updraft stoves are somewhat dirtier burning if the vertical dimension of the stove is great. Basically, under normal home woodburning conditions (low burn rates), a conventional airtight woodstove is essentially a box containing a relatively cool smoldering fire.

Regardless of airflow pattern, the temperature needed for nearly complete combustion (1100 degrees F) is rarely achieved unless the firebox size is very small. (7)

5. Firebox Size

Though airflow pattern has some impact on combustion efficiency, it is not nearly as important as the firebox size. The smaller the firebox, the cleaner the burn. Ironically, the main reason this principle holds true is that small fireboxes limit stove owners to small wood loads. Load size is directly proportional to the amount of emissions generated. People who own large stoves tend to stoke them with large wood loads; consequently, they produce dirtier burns. (8)

B. WOODHEAT APPLIANCE EFFICIENCY

Too often the term "efficiency" is used in a very poorly defined or misleading manner in woodstove advertising claims or even in woodburning technology conferences and educational programs. The relative performance of various models of woodstoves cannot be accurately compared unless the appropriate measurements of efficiency are used and stoves are compared based on the same types of measurements. The following section discusses what each of the efficiency measurements are and and it discusses some of the factors that affect each of these efficiency measurements.

1. Definition of Efficiency

Wood combustion efficiency is a measure of how completely a woodstove burns the fuel. In order to be **efficient**, a woodstove must do two jobs well:

1. It must burn the fuel as completely as possible so that as little smoke and carbon monoxide as possible are emitted from the chimney. (**Combustion efficiency** is the measure of how well this is done.)

2. The heat generated in the stove must be transferred from inside the stove to the room with as small a loss of heat up the chimney or out the back of the stove as possible. (**Heat transfer efficiency** is the measure of how effectively this is done.)

For the purpose of the manual, **overall thermal efficiency**, then, is the amount of **usable heat** a residential woodburner gets out of wood compared to how much potential heat the fuel actually contains. The overall thermal energy efficiency of a given stove is the product of the two component efficiencies (combustion efficiency x heat transfer efficiency).(9)

$$\textbf{Combustion efficiency} = \frac{\text{heat generated in combustion}}{\text{energy content of the fuel (higher heating value)}}$$

$$\textbf{Heat transfer efficiency} = \frac{\text{useful heat energy output}}{\text{heat energy generated in combustion}}$$

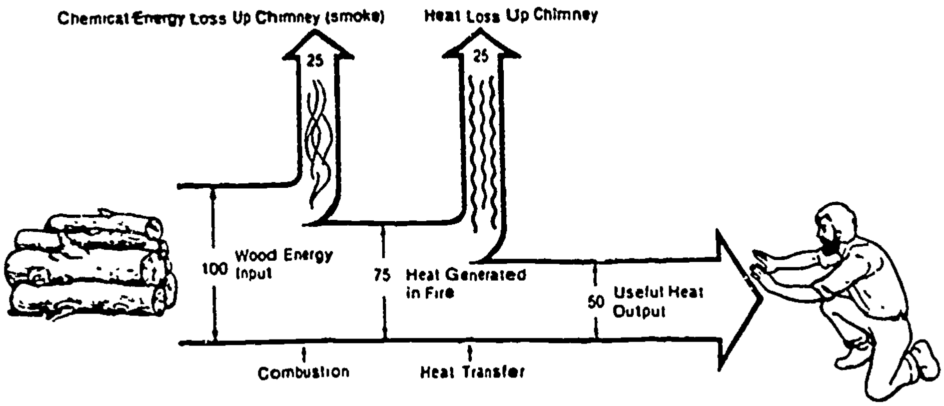
Overall thermal efficiency = [Combustion efficiency] x [heat transfer efficiency]

=

$$\frac{\text{useful heat energy output}}{\text{energy content of the fuel}}$$

Figure 2.3 illustrates this relationship.

FIGURE 2.3. ENERGY FLOW DIAGRAM FOR A TYPICAL WOOD STOVE.



(Shelton, Jay. Advanced Wood Burning Tecnnology Evaluation: Summary Report. Albany, NY: New York State Energy Research and Development Authority, September 1983, p. 21.)

2. **Factors Affecting Efficiency**

By monitoring the stove's temperature, it is possible to determine whether or not airflow is correct for an efficient burn. The optimum stove side-wall temperature for efficient burning in most airtight woodstoves is between 300-450 degrees F. Through the use of manually adjustable draft controls it is possible, to a degree, to mix air into the fire to enhance combustion with a minimum of heat lost up the chimney. Recently developed automatic thermostats can be used to control air mix more effectively and much more conveniently. These thermostats close gradually, admitting enough air to maintain steady combustion and generally reduce wood use by 20%.(10)

With better operating practices, using smaller fuel loads and more air, most wood heaters would perform with combustion efficiencies of 70 to 90% rather than 65 to 70%. Advanced clean burning high technology catalytic woodstoves can achieve combustion efficiencies of 90% or higher, even at very low burn rates (under 2 pounds of wood per hour) and heat outputs of 6000-7000 Btu per hour.(11)

High combustion efficiency, however, is not the same as high overall energy efficiency. It does not address heat transfer energy losses within the residence or up the chimney. Heat transfer efficiency is an important ingredient in overall efficiency. By optimizing both air/fuel ratios and stack temperatures, heat transfer efficiencies of 85% are possible. If attempts are made to exceed this value, problems arise, the most serious of which is a lack of draft. Smoke may emit into the room from the stove under such conditions and it is difficult to start the stove.

Additionally, low stack temperatures can cause excessive water condensation.(12)

Wood burning space heaters are rated for overall energy efficiency as follows:

Open heaters and inefficient closed heaters	30-45%
Typical conventional heaters	45-55%
Advanced heaters with both high combustion and high heat transfer efficiencies	70-80%

Current research in homes has shown that a 75 - 80% efficient heater will consume over 40% less fuel while accomplishing the same heating task in a home as a 50% efficient heater.(13) Thus high efficiency stoves will save money and effort and, as will be discussed in the next section, produce less creosote and air pollution.

3. Combustion Inefficiency Creates Safety and Emissions Problems

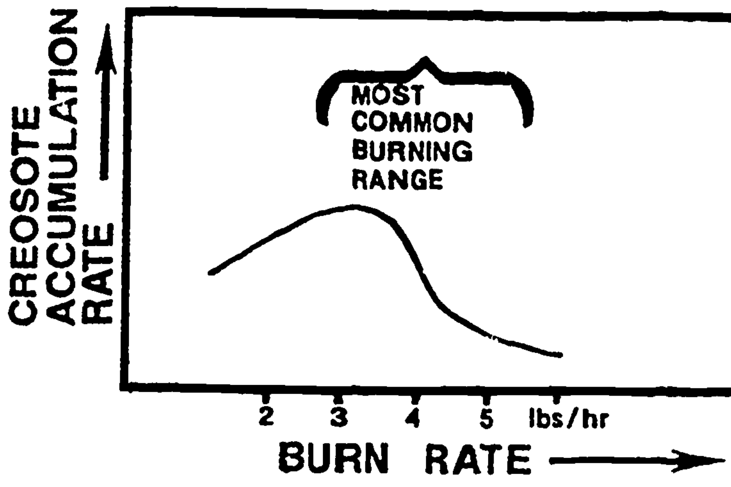
Poor combustion efficiency associated with low burns in non-catalytic stoves causes both safety and emissions problems. Research shows that the fastest creosote accumulation rates in stovepipes and chimneys coincide with burn rates of about three pounds per hour.(14) This is by unfortunate coincidence also the most common burn rate in homes, explaining why the creosote problem is so prevalent.(Figure 2.4)

Creosote accumulation is what causes chimney fires to be a common hazard in woodburning. The insurance industry in both the U.S. and Canada reports that losses in property and life from residential fires caused by woodstoves are escalating. Atlantic Canada reported that two-thirds of the fires attributed to residential woodburning resulted from improper operations and creosote-clogged chimneys.(15) Creosote accumulation is especially hazardous when it occurs in improperly installed woodheat systems.

In addition to the creosote problem, unburned particulate emissions from flue gases have contributed significantly to air pollution problems in parts of the country where residential woodburning is extensive and where local weather conditions result in poor air circulation. For example, in Denver, Colorado; Portland, Oregon; and Missoula, Montana, air quality studies indicate that at times more than 50% of the particulates in winter air stem from residential woodburning.(16)

The use of properly operated and maintained, energy efficient woodburning appliances could address both safety and emissions problems.

FIGURE 2.4. RELATIONSHIP BETWEEN CREOSOTE ACCUMULATION AND BURN RATE.



(From Stockton G. Barnett talk presented at 1982 Wood Heating Alliance Annual Meeting.)

C. NEW WOODFUEL APPLIANCE TECHNOLOGY

The time has come when a wood stove can no longer be just a cast iron box with a door and flue collar. Some modern stoves are designed with the objectives of increasing heating efficiency, reducing air pollution potential, limiting creosote accumulation and improving the safety of operation.

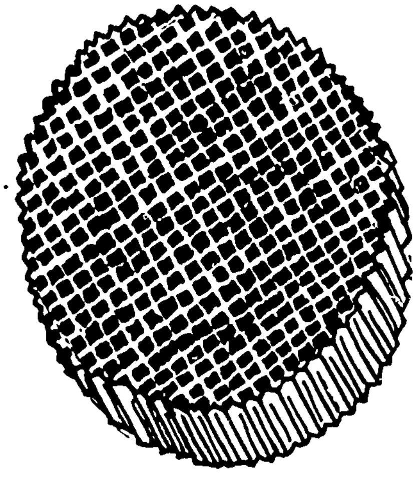
Energy efficient stoves must meet two criteria: 1) the fuel must be burned as completely as possible so that the gas phase contributes more significantly to the burning process rather than going up the chimney as smoke, and 2) the appliance must transfer as much heat as possible to the room, limiting the amount of heat lost up the chimney. A New York State laboratory study found advanced stove designs that had spectacular increases in efficiency. These newer technologies include catalytically assisted combustion and to a lesser extent improved non-catalytic combustion designs. Whereas a fireplace stove may have an overall energy efficiency of 35 to 40%, the best of the advanced stoves reached overall efficiencies of 70 to 75%.(17) The heating efficiency is also reflected in lowered emissions, particularly in catalytic stoves. Residential wood combustion has caused air pollution (carbon monoxide and unburned particulate hydrocarbons) in many regions. With a properly designed catalytic system, even smoky, low-burning fires can approach complete combustion.

1. Catalytic Combustors

Catalytic combustors can either be built into a stove, or incorporated into a device which is installed on or near the stove's flue collar (a catalytic retrofit). Currently available catalytic combustors are round or square units made of ceramic. They have a honeycombed appearance. (Figure 2.5) All of the surfaces of a combustor are coated with a catalyst of platinum and/or palladium.

A catalyst is a substance that triggers a chemical reaction, allowing the reaction to take place at lower temperatures than at which it normally would. The catalyst itself is left essentially unchanged by the reaction.(18) In the case of wood smoke, normal thermal combustion requires about 1100 degrees F; catalytic combustion requires about 500 degrees F. The former temperature is rare in woodstoves whereas the latter is present almost all the time. The volatized wood is broken down into its original components by catalytic action: water vapor, carbon dioxide, and heat.

FIGURE 2.5. CURRENTLY AVAILABLE CATALYTIC COMBUSTORS ARE CERAMIC HONEYCOMBED UNITS WITH A PLATINUM AND/OR PALLADIUM COATING.



The catalytic combustor provides for a secondary combustion zone to burn the woodsmoke byproducts as fuel. In a catalytic stove, the combustor is placed in a special chamber at the top of the firebox. (Figure 2.6) The catalyst will not operate until it reaches a firing temperature of 500 degrees F. A hot kindling fire is needed in most stoves to reach this temperature from a cold start. In all catalytic stoves a bypass damper is necessary to control the path of volatile gases. During start-up the bypass damper is left open so that there is sufficient draft to maintain a kindling fire. Once firing temperature is reached, the bypass damper is closed and gases are forced to pass through the catalyst. The visual appearance of a combustor is not an accurate indication of its catalytic activity. Combustors only begin to glow during the upper limits of catalytic activity (1100 degrees F or higher). For this reason a probe thermometer is used as an indication of catalytic activity. The effectiveness of catalyst activation varies greatly as a function of stove and catalytic design. Consequently, effective emissions reduction is also a function of stove design.

Once the catalytic reaction begins, the hydrocarbons and carbon monoxide begin burning within the combustor. Temperatures in the combustor average about 1200 - 1400 degrees F. Most of the flammable substances burn, and much of the wood's Btu content, which would normally be wasted is captured. The gases that would normally end up as creosote or air pollution create heat instead.(19)

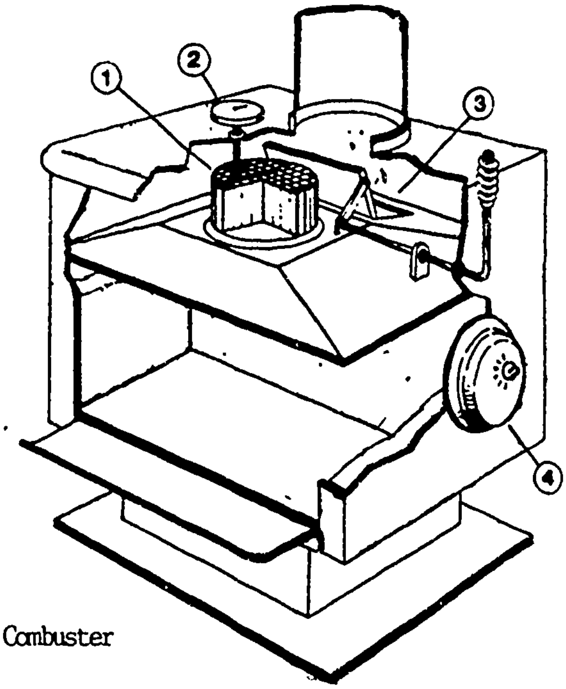
Recently designed steady state automatic thermostats provide an effective solution to some of the control problems of catalytic stoves. This control produces a steady supply of gaseous fuel to the catalyst so that the combustor stays active and a steady heat output is generated. The control system uses a bimetallic coil to make quick air-flow adjustments. This maintains the stove's surface temperature within 30 degrees F. of the dial setting. A thermostatic control is original equipment on some new stoves and can be mounted on most models that have rotary or spin draft caps. (See Figure 2.6 at the end of this section.) (20)

Thermostatically controlled woodstoves designed around catalytic combustors have several advantages over conventional airtight stoves. Wood usage is reduced by an average of over 40 percent. Creosote formation is reduced by 90%. Emissions of particulates, toxic polycyclic organic materials (POM's), and carbon monoxide are reduced by 95, 75 and 60 percent respectively. Simply stated, the combustion of wood is much more complete in a properly designed and operated catalytic stove; there is less pollution. (21)

A catalytic stove designed with a good control system is relatively easy to use. However, there are special installation and operation considerations. First, the flue pipe and connection to the heater must be properly seated and completely sealed. Any leakage will reduce efficiency and could cause acrid smelling condensation to leak into the living area. Second, only well seasoned, untreated wood should be burned in a catalytic stove. Burning coal, trash, aluminum, zinc, colored paper, plastics, gift wraps, chemical chimney cleaners, painted wood, pines with high pitch content and fireplace logs may "poison" the catalyst. (22) Third, well designed catalytic stoves have heat exchange systems that transfer most of the heat generated by the combustor into the living space. Thus catalytic stoves have cool flue gases and therefore produce relatively low draft. If installed in a chimney system with poor draft, a catalytic stove will not function properly. Finally, combustors do deteriorate over time and must be replaced. Improvements in catalytic technology however are increasing their durability.

Nearly 60 manufacturers now offer catalytic heaters, with price tags ranging from $150 to $400 above a comparable conventional stove. An Oregon Lung Association survey revealed that fewer than 50% of future stove buyers would voluntarily spend $100 or more for a clean-burning efficient stove. (23) This points to the need for state or local emission standards where there is a problem and for public education regarding the benefits of safer, more efficient low emission stoves.

FIGURE 2.6. INTERIOR DESIGN OF A CATALYTIC STOVE.



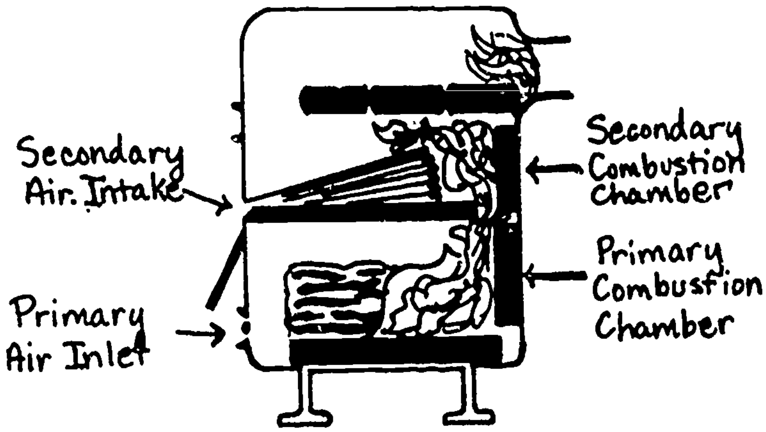
1. Dome Assembly for Combuster
2. Probe Thermometer
3. Bypass Baffle
4. Thermostat

Catalytic combustor (1) sits in an opening in the dome. When the bypass baffle (3) is closed, all combustion gasses pass through the catalyst and are ignited. A probe thermometer (2) is used to monitor catalytic activity. An automatic thermostat (4) is used to insure a steady flow of gases to the catalyst so that the catalyst stays active and an even burn is produced.

2. <u>Improved Combustion Design</u>

Attempts have been made to design stoves which efficiently burn the volatiles from wood combustion in a secondary combustion chamber, without the use of a catalyst. Basically, these stoves are designed so that the heated volatiles, which are generated in the primary combustion chamber, pass into a secondary chamber. Here they are mixed with air, heated and ignited. (Figure 2.7) In order to achieve secondary combustion the stove must be designed such that the secondary combustion chamber is kept at 1100 degrees F or higher, the temperature needed to ignite the volatiles.

FIGURE 2.7. IMPROVED COMBUSTION DESIGN STOVES.



To date several stoves, referred to as "improved combustion designs", have been developed utilizing this technology. These stoves have shown an improved average combustion efficiency over that for conventional airtight stoves at high burn rates but not at low burn rates. However, they do not approach the combustion efficiency of catalytic stoves at the burn rates most commonly used by homeowners (3 to 4 lb/hr). (24)

There is one serious technical obstacle to successfully employing the secondary combustion principle in residential woodburning applications - it is very difficult to maintain the 1100 degree F temperatures needed to ignite gases when the stove is burning at the low burn rates common in residential wood burning. Small fire boxes are required to keep the secondary chamber hot enough for efficient combustion of volatiles. Because of the small fireboxes, frequent stoking (every 2 to 4 hours) is necessary. Consequently, these stoves are impractical for the many stoveowners who want or need stoves that can maintain long burns, especially during the night.

Because a number of states have passed or are considering legislation requiring clean burning stoves, the improved combustion designs are being followed with great interest. However, only one design, currently on the market, appears that it could possibly meet woodsmoke emissions standards for 1988 for noncatalytic stoves in Oregon. Ironically, this stove is not a new "improved" design, but rather an old design with a small fire box.

The woodstove industry seems confident that continued research and development efforts can result in advances in secondary combustion design that will overcome combustion deficiencies at low burn rates. Over time this technology may advance enough to perform acceptably at low burn rates. It is questionable, however, whether this will be accomplished without the use of some device, such as an electric heating coil, that can supplement the heat in the secondary chamber so that temperatures remain above 1100 degrees F at all burn rates. One researcher has demonstrated that it has been the small firebox size, not the secondary chamber design that has had the greatest impact on combustion efficiency in the "improved combustion design" stoves.(25) If this is correct, then catalytic or electric heating assistance in the secondary chamber will be necessary if the firebox is to be enlarged to a practical size.

3. **Pellet Burners**

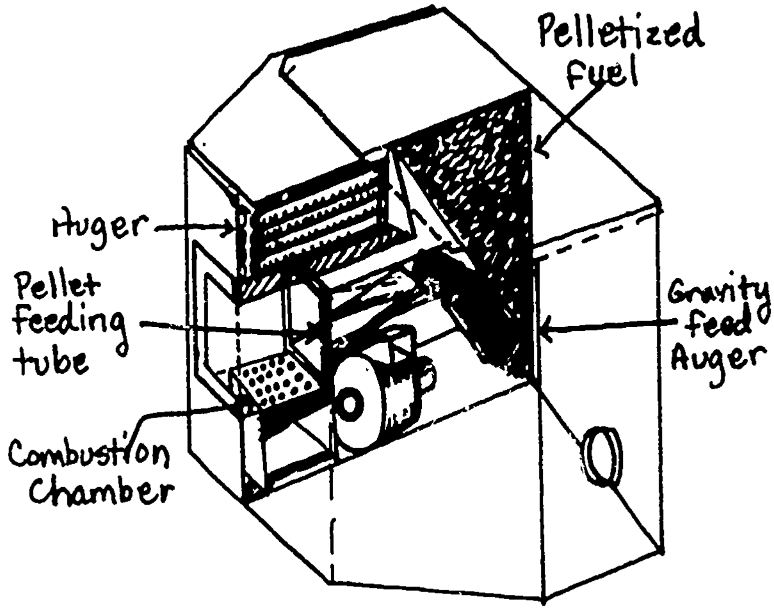
Woodfuel heaters have been developed that burn a new wood fuel product referred to as "wood pellets". Wood pellets are manufactured from wood residues and, according to the Vermont Agency for Environmental Conservation, produce significantly lower levels of pollutants than conventional burning of round logs dc when burned.(26) The Vermont tests indicated that a third or less grams of particulates, including POM's, are produced per kilogram of fuel, compared to logs. Pellets typically have less water content than cordwood but its higher heating value is not higher than cordwood.

Pellet heaters are on the market that range in price from approximately $900 to $1400. These stoves have an auger system that automatically feeds pellets into the fire chamber. (Figure 2.8) The feed rate can be adjusted for the desired heat output. A blower is used to induce a draft in the system. Because the pellets are augured in a few at a time, and thus there is a good fuel/air mix, these systems maintain high fire box temperatures. Therefore high combustion efficiency is achieved - in one case as high as the best catalytic stoves. With high combustion efficiency, there is little creosote produced. However, these devices will not operate automatically in the event of a power failure.

Since few pollutants and virtually no creosote are produced, some manufacturers claim that a class A chimney is not needed for pellet burners. They claim a venting system similar to a drier vent hook up, would be sufficient. However, venting systems were researched by Condar Company (27) for catalytic stoves. Catalytic stoves produce essentially the same emissions as high efficiency pellet burners. These studies showed that if emissions are not vented up and away from the house, the chimney effect of most houses and winds cause odorous volatile emissions to be sucked back into the homes through air leaks in the house. This can result in serious indoor air pollution conditions for the stove owner and nearby neighbors. Additionally, for pellet burners, if electricity should fail, the draft inducer will go off and the system cannot maintain a positive draft. Consequently, as the fire begins to cool, due to lack of fuel (the auger requires electricity to operate), all the combustion products will be sucked through the draft opening and leaks in the stove, into the living area. Obviously, it would be quite hazardous to install a pellet burner without an adequate chimney system. Regardless of manufacturer's claims, some pellet burners to date have not been safety approved for installation unless a class A chimney system is used.

About five years ago, Island Associates on Prince Edward Island studied a pellet burning system. The pellets were stored in the basement and "after two to three weeks of operation a fine light colored (pellet) dust was observed to cover all surfaces in the basement near the furnace." Although concentrations of this dust after one burning season did not appear to approach the level at which a dust explosion was a danger this factor must be considered when examining the longer term safety questions with low moisture content fuel such as wood pellets."(28)

FIGURE 2.8. ILLUSTRATION OF A PELLET BURNER.



Pellet burners use an auger to gradually move pelletized fuel from a storage hopper into the fire chamber. Those pellet burner designs using a gravity feed auger system, rather than a horizontal feed system, reduce the possiblity of backburning.

One final safety concern is that backburns may occur in pellet burners, especially in systems that do not use gravity feed. A backburn occurs when pellets in the auger and hopper ignite.

In summary, it appears that pellet burners can provide a practical, although somewhat more expensive, alternative to log burners, but only in areas where there are large quantities of wood residues and processing plants available to pelletize the residues.

E. CENTRAL WOODHEATING SYSTEMS: FURNACES AND BOILERS

Some homeowners prefer installing a central woodfuel heating system rather than installing a woodheater in the living area. These systems are similar to central oil or gas except that they use wood chips, pelletized wood or cord wood as fuel.

Central systems use a woodfuel furnace and a hot water or hot air heat distribution system. Woodfuel furnaces are used in 4 percent of all U.S. woodburning homes or one percent of all households and are used predominantly as a primary heat source. (29)

Woodfuel furnaces can be obtained that will heat any size home and are designed for using either hot air or water transfer mediums. In most cases, a woodburning furnace is designed to replace an existing furnace, using the pipes and vents currently in place. Woodburning furnaces require more maintenance than a conventional oil boiler. The fire must be fed, the ash box cleaned out, and the heat exchanger must be cleaned more frequently due to rapid creosote buildup. A multi-fuel furnace burns wood or wood residues with oil or gas acting as a backup. These furnaces are thermostatically controlled. If no heat is needed, the damper is closed off so that the fuel hardly burns; when heat is needed, the dampers open to feed the fire.

Wood furnaces generally have less **net delivered efficiency** than airtight woodstoves. Net delivered efficiency refers to the amount of usable heat that is actually delivered to the living area per unit of fuel burned. Although a woodburning furnace may have a similar efficiency to that of a woodstove, a furnace installation suffers from significant heat distribution losses through pipes and duct systems. The net delivered efficiencies for central woodheat systems are generally less than 35%. (30) The average furnace uses 8 cords of wood per year. Therefore, in order for a central woodburning heat system to be cost effective, a large supply of woodfuel must be available at a low price. Because of higher combustion efficiency, pellet fuel furances may have higher net delivered efficiency than cord wood furnance have.

Central heating systems that employ either hot-water or steam-heat distribution systems, use a woodfired boiler to heat the water. Despite common belief, most wood and coal burners do not boil water but only heat it, although they are called "hot water boilers". Residential solid-fuel steam boilers are available, but demand is not very high. Part of the reason may be the potential danger of any system that heats water.(31)

F. CHIMNEY SYSTEMS

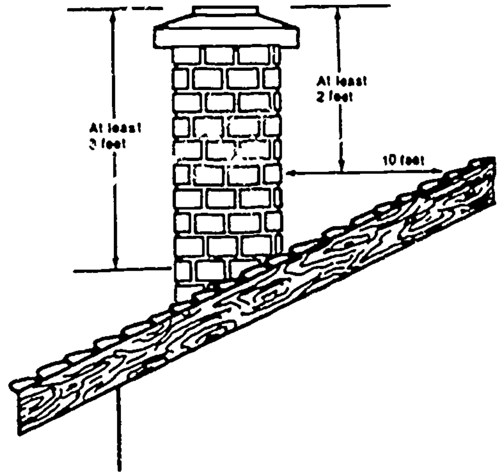
The two functions of a chimney in a wood stove, furnace, or fireplace are to carry the undesirable combustion products (smoke,etc.) out of the house and to supply the draft necessary to feed air to the fire.

1. Draft

The pressure difference between a point inside the chimney, stovepipe or stove and the air just outside (at the same elevation) is termed draft. A draft is created because hot air is lighter than cold air, and therefore tends to rise. This effect is often called "buoyancy". Draft is a measure of the force making gases flow. At a place where the draft is high, air would be drawn hard into any opening; but if the opening is small, not much air would be let in.(32)

There are two major factors that affect draft. The speed at which flue gases lose temperature in flue pipes and chimneys is important. Chimneys located inside (within the four walls of the home) stay warmer and, therefore, keep the flue gases hotter, resulting in improved draft. Outside chimneys cool quickly, thereby reducing draft. Chimneys with any form of insulation (pre-fabricated metal chimneys) also keep the flue gases hotter, giving better draft. The height of the chimney is also important. Draft varies directly with the height of the chimney. Optimum draft and safety conditions require that the chimney be at least 3 feet high and at least 2 feet higher than any part of the roof within ten feet, measured horizontally (Figure 2.9). (33)

FIGURE 2.9. 3-FOOT, 10-FOOT, 2-FOOT RULE.



CHIMNEY HEIGHT

(From: Tennessee Valley Authority. Safe and Sound Masonry Chimneys. May 1983, p. 16.)

There are other factors that influence draft:

- Excessive bends, elbows and dampers increase resistance and reduce flow.

- The cross sectional dimensions of the chimney and flue pipe can be too small or too large for a particular stove design. This may adversely affect flow and performance.

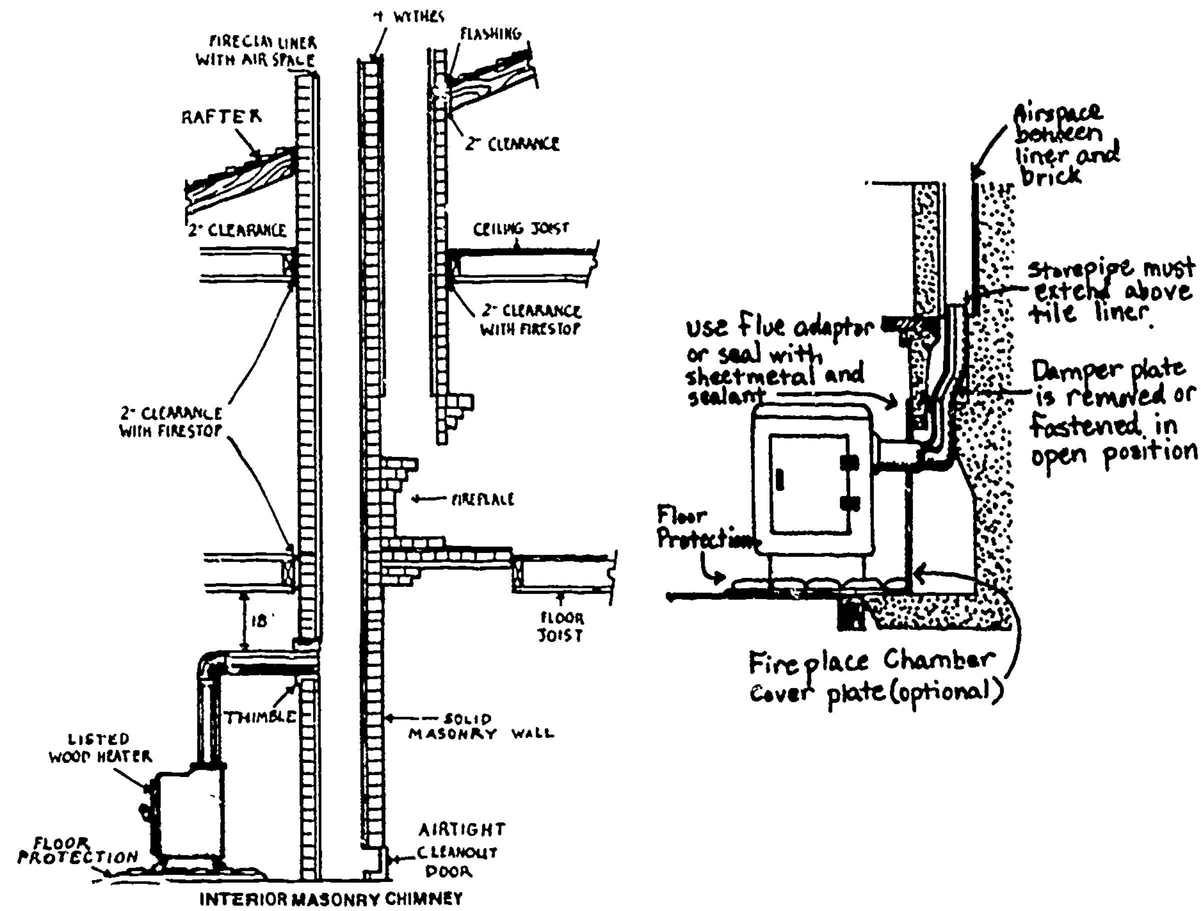
- High winds may sharply increase or decrease flow depending on wind direction and the location of the chimney in relation to roof, trees, and/or other high objects.

- The lower flue gas temperature of more efficient stoves results in reduced draft. High efficiency stoves are more difficult to operate in marginal conditions.

- A hotter chimney can boost draft.
- Thin air at high altitude results in low flow rates. Marginal installations will operate less effectively at higher altitudes than at sea level. (34)

The two safest chimneys for wood burning systems are: 1) a masonry chimney with a fireclay, composition or metal liner or 2) a properly installed, high temperature stainless steel double or triple-wall metal chimney.(35) Figures 2.10 and 2.11 illustrate how these two types of systems are installed and what components make up the systems.

FIGURE 2.10. VENTING INTO A MASONRY CHIMNEY SYSTEM AND FIREPLACE

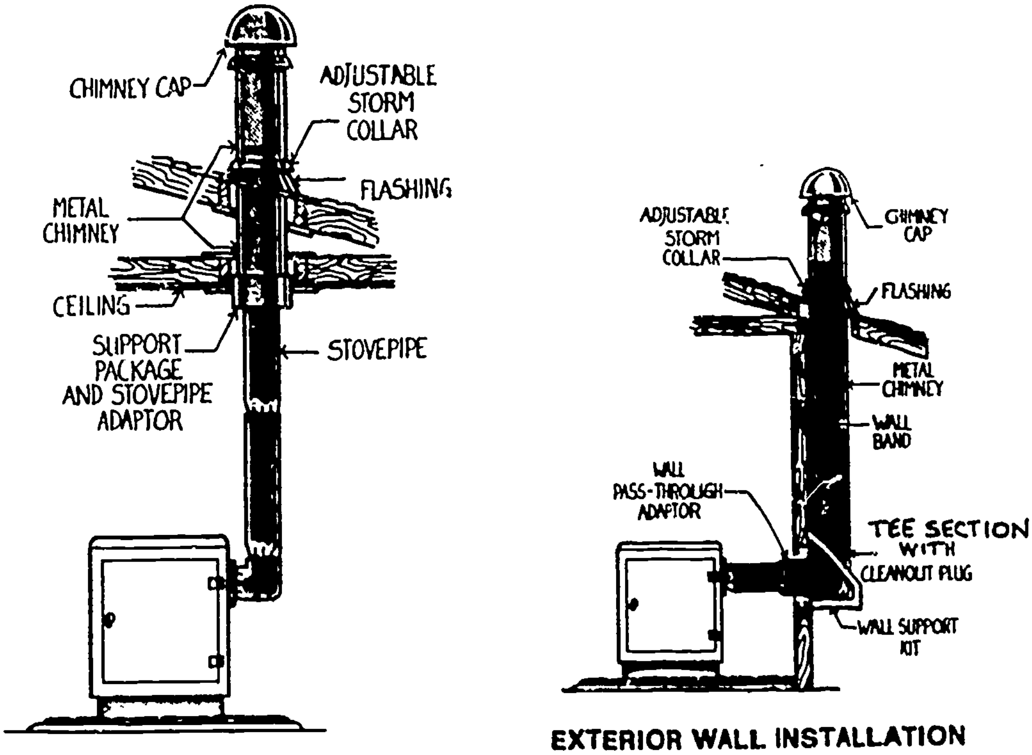


(Left diagram from: TVA, Safe and Warm Wood Heat, p.11)

2. **Masonry Chimneys**

Masonry chimneys are the old standard in wood heating. Masonry chimneys are usually built of brick, but special concrete blocks or stone are also used. The strength of the foundation and the thickness of the chimney wall will depend on the height of the chimney and the type of materials used. Tile liners are standard in masonry chimneys and contribute to both the safety and durability of the chimney. (Figure 2.10) An airspace between the fireclay liner and the brick chimney wall is necessary to allow for expansion and thermal stress so that the liner does not crack. (36)

FIGURE 2.11. WOODSTOVE INSTALLATIONS USING A PREFABRICATED METAL CHIMNEY SYSTEM



STANDARD CEILING CHIMNEY INSTALLATION

EXTERIOR WALL INSTALLATION

Prefabricated metal chimneys can be installed within the house (left illustration) or on an exterior wall (right illustration). The interior installation is preferred since the chimney stays hotter, thereby increasing draft and reducing creosote accumulation. In either installation, safe clearances to combustibles must be observed. (Adapted from: Tennessee Valley Authority, Safe and Warm Wood Heat, 3rd ed., September 1981.)

3. **Metal Chimneys**

Factory-built metal chimneys are easier to install (can be done by homeowners themselves) than masonry chimneys and are less expensive. Since these sytems can be heavy they do require structural support.

There are many types of prefabricated chimneys. Most are designed for gas or oil fueled appliances; wood stoves require the highest temperature chimneys. To withstand the high temperatures, prefabricated chimneys have two, three and sometimes four walls with either air spaces or insulation in between. (Figure 2.12) The innermost layer is generally stainless steel, which can withstand the high temperatures and corrosive environment associated with woodburning. Metal chimneys tested to 2100 degrees F are the safest for woodburning. Single wall metal chimneys should not be used for residential wood burning appliances.(38)

Several designs of "All-Fuel" or "Solid Fuel" metal chimneys that have been approved for wood heater use are:

- **Double wall insulated chimneys.** This type consists of a double walled stainless steel pipe packed with a mineral insulating product. These chimneys are tested to a maximum of 1700 degrees F.(39) Some designs of this chimney can buckle and collapse in severe chimney fires because of thermal expansion differences between materials.

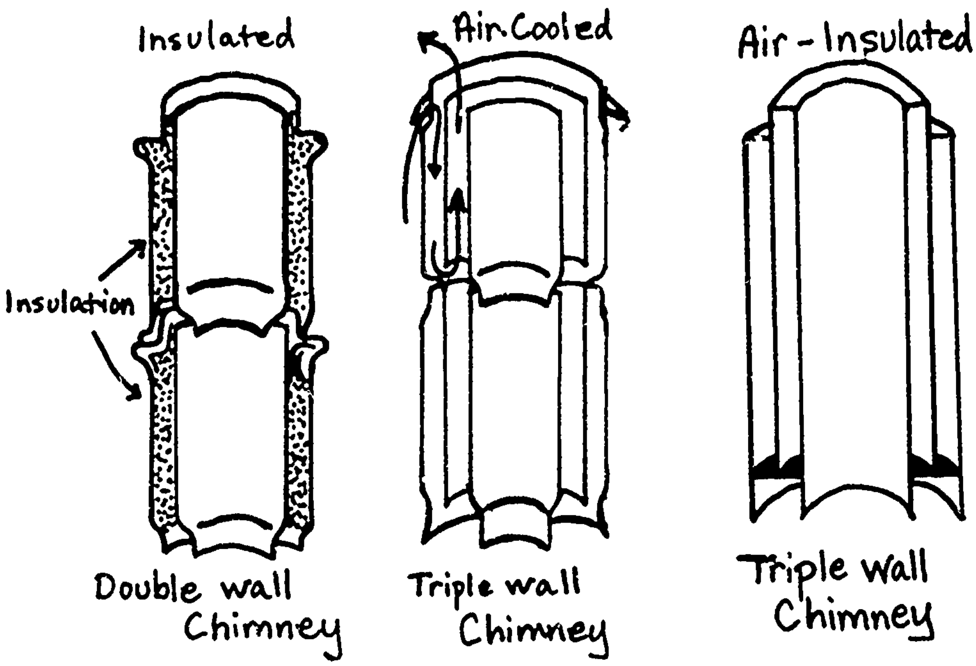
- **High temperature double walled chimneys.** These chimneys consist of two walls made of Type 304 stainless steel. They are tested to 2100 degrees F.

- **Air insulated triple wall chimneys.** These chimneys have internal baffling and provisions to allow air exchange between the two outer shells at each joint. This produces a warmer chimney which improves draft and reduces creosote buildup. The safest of the triple walled chimneys are those tested to 2100 degrees F with a type 304 stainless steel liner.(40)

- **Insulated triple wall** (not illustrated). This is a relatively new chimney on the market. The inner pipe is made of heavy refractory material. (41).

The life expectancy of prefabricated chimneys has not yet been determined because they have not been in use a long enough time. Some chimneys which have stainless steel metal parts are still in service after 20 years of use. Trash or plastics contain chemicals which cause corrosion in chimney flues.(42)

FIGURE 2.12. SEVERAL TYPES OF PREFABRICATED METAL CHIMNEYS.



(Adapted from: Tennessee Valley Authority, Safe and Warm Wood Heat, 3rd ed., September 1981, p. 6.)

TABLE 2.1. COMPARISON OF MASONRY WITH PREFABRICATED METAL CHIMNEYS

	Advantages	Disadvangages
MASONRY CHIMNEYS	very durable	more expensive
	good heat storage	high heat loss results in more creosote and soot deposits and slightly less draft
PREFABRICATED METAL CHIMNEYS	less expensive	not as durable
	easy installation	corrodible
	keep flue gases warmer, allowing a stronger draft and less creosote buildup	dangerous in a chimney fire

4. **Chimney Reliners**

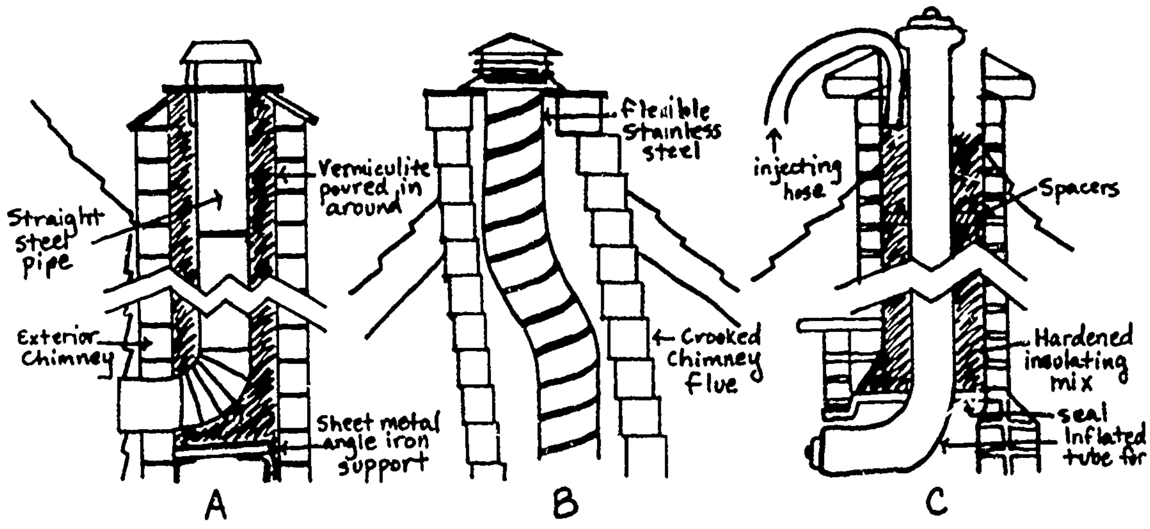
Chimney reliners are stainless steel and/or tile pipes, or can be poured-in-place concrete liners that are installed inside a new or existing chimney flue. Tile and porcelain-coated heavy-guage steel reliners can be installed in straight flues. Stainless steel pipe, flexible stainless tubing and poured-in-place concrete reliners can be used in straight flues or in flues with bends (Figure 2.13). Sometimes insulation is poured between the chimney flue and the stainless steel or tile reliner in chimney systems that are on exterior walls.(43)

Reliners can potentially resolve a number of deficiencies in chimney systems, as indicated in Table 2.2.(44) However, reliner technology is relatively new and a number of problems and questions have arisen in applications of the currently available technology - most center around durability and heat expansion of materials used for reliners. Further development, testing and field experience will eventually define the appropriate standards for safe relining systems, taking into consideration the wide variety of conditions found in existing chimney systems.

TABLE 2.2. CHIMNEY RELINERS CAN BE USED TO CORRECT A NUMBER OF CHIMNEY SYSTEM DEFICIENCIES

Chimney System Deficiency	Effect of Reliner
Flue diameter larger than stove collar diameter resulting in poor draft and excessive creosote accumulation.	Reliner can be used to reduce flue diameter to appropriate size to improve draft and thereby reduce creosote accumulation
Existing masonry is cracked or is in contact with combustibles.	Installation of a reliner can correct these safety problems.
Chimney on outside wall stays cool causing excessive creosote accumulation.	A reliner will act as an insulating chamber to help keep flue gases hotter, thereby reducing creosote accumulation and improving the draft. If insulation is poured in between the reliner and chimney flue (Figure 2.12), this effect will be even more pronounced.
Chimney cleaning is difficult and expensive for inserts (which must be removed) and/or for chimney systems with cracks, bends, smoke shelves and irregular interior surfaces.	By installing a reliner from the stove to the chimney top, thorough chimney cleaning will be facilitated. Systems with inserts can be cleaned with the insert still in place.

FIGURE 2.13. CHIMNEY RELINER SYSTEMS.



(A) shows a straight steel pipe with insulation poured between pipe and chimney flue. (B) shows flexible stainless steel tubing installed in chimney system with bends. (C) shows a pour-in place insulating concrete system.

5. **Chimney Tops**

The use of chimney tops on prefabricated metal chimneys is commonplace (Figure 2.11), but their use on masonry chimneys is less common. Chimney tops serve a number of purposes:

- They keep out rain and snow,
- exclude birds and animals,
- prevent sparks from escaping (if equipped with a spark screen), and
- help prevent wind-driven down drafts.(45)

6. **Stovepipe**

Stovepipe is defined as a thin gauge metal pipe through which smoke and unburned volatiles pass from the stove to the chimney flue. (Figure 2.11) Stovepipe is most commonly used as a chimney connector. Some factory-built fireplaces are connected directly to their factory-built chimneys without use of a chimney connector. Proper chimney connectors are important for safe woodburning. Connectors should be made of non-combustible corrosion-resistant material capable of withstanding the high flue gas temperatures produced by the woodheat appliances and of sufficient thickness to withstand physical damage.(46) A safe connector is constructed from 24-gauge (or heavier) blue or black sheet metal and should be the same diameter as the pipe collar on the heater.(47)

Three reasons for using heavy gauge material are:

- The higher mechanical strength and rigidity lessens the chances of the pipes sagging, distorting, or moving. This is important during physically violent chimney fires.

- The thicker gauge pipe has greater resistance to corrosion from creosote.

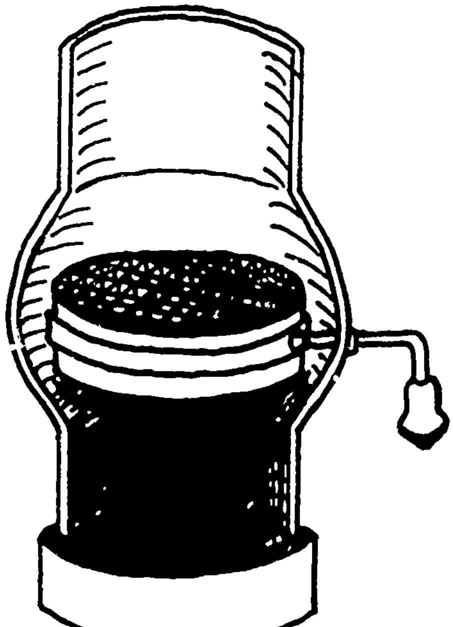
- The thicker walls will take longer to burn through (High temperatures cause slow but inevitable oxidation or burnout of steel).

F. ACCESSORIES FOR WOODHEATING SYSTEMS THAT AFFECT EFFICIENCY AND SAFETY

1. Catalytic Retrofits

Catalytic retrofits can be installed on most conventional stoves. They generally fit inside or just above the flue collar of the stove. (Figure 2.14) Prices for catalytic add-ons range from are as low as $70 to over $300 and average about $130. On the average, currently available retrofits can raise the overall energy efficiency of the conventional airtight stove by roughly 10 percent.(48) However, increased draft caused by some retrofits causes the stove to burn wood more rapidly. Wood savings are often less than would be expected.

FIGURE 2.14. CATALYTIC RETROFIT.



Catalytic retrofits will not perform equally well on all stoves. Fuel load size, wood species and moisture content, the leakiness of the fit of the retrofit on the stove, the leakiness of the stove, air inlet setting and draft conditions all have a marked effect on the performance of catalytic add-ons. Retrofits do not work as well as catalytic stoves for a number of reasons. First, there is less chance that a correct air/fuel ratio and properly heated secondary air will be present in a retrofit installation. Secondly, the larger distance between the retrofit and the wood fire means cooler smoke temperatures. This makes it more difficult to reach the firing temperatures necessary to activate the catalyst.(49)

Most catalytic retrofits are installed in the flue pipe near the stove's flue collar. Generally the system is designed so that the flue gases can bypass the catalytic combustor when necessary.

The potential emissions reduction from retrofits is not yet known. A study sponsored by New York State ERDA showed about 50% reduction. However, only one stove was used in the study and it was much smaller than average stoves used in homes.(50) This caused catalyst gas feed temperatures to be anomalously high for a given output and distorted results in an optimistic direction, especially at a low heat output. Evaluation of retrofit performance is needed, using a variety of stove-retrofit brand combinations which reflect the real world stove mix. Additionally, since retrofits are sensitive to operational conditions and procedures, the studies must be conducted in actual homes, using homeowners as operators. Performance relative to catalyst age is also not yet known.

In general, catalytic retrofits are not consistent in performance. Little is known about their quantitative performance, but when working properly, they can reduce emissions and creosote formation quite significantly. However, since the retrofit catalytic causes higher stack temperatures and increased draft (thereby increasing the combustion rate) and since most of the heat produced by a retrofit goes up the chimney, retrofits have little effect on wood use and net delivered efficiency.

2. **Flue Dampers**

A flue damper is a valve or plate located on the downstream side of the combustion chamber in the flue. This device is used to control the flow of gases out of the stove. Dampers in the flue are of two types - manually operated and automatic, such as the barometric type. Dampers can increase stove efficiency by slowing the burn rate. However, they reduce flue gas temperatures, thus causing creosote to condense on the flue walls. **Manually operated** flue dampers are usually recommended for systems that have unusually high drafts or for leaky stoves.

Barometric draft regulator-type dampers are designed to reduce excessive draft by admitting ambient air into the appliance chimney, chimney connector, vent or vent connector. Barometric dampers in flue pipes are not recommended for woodstove use. When a chimney fire occurs, the damper automatically opens, thereby feeding the fire and causing hazardous conditions. Although one laboratory study indicated that barometric dampers reduce creosote formation in flue pipes(51), this has never been demonstrated in the field. Chimney sweeps have found increased creosote formation on stoves equipped with barometric dampers, probably caused by reduced draft and lower burn rates. Unpublished studies of a field installation also showed no creosote reduction (52).

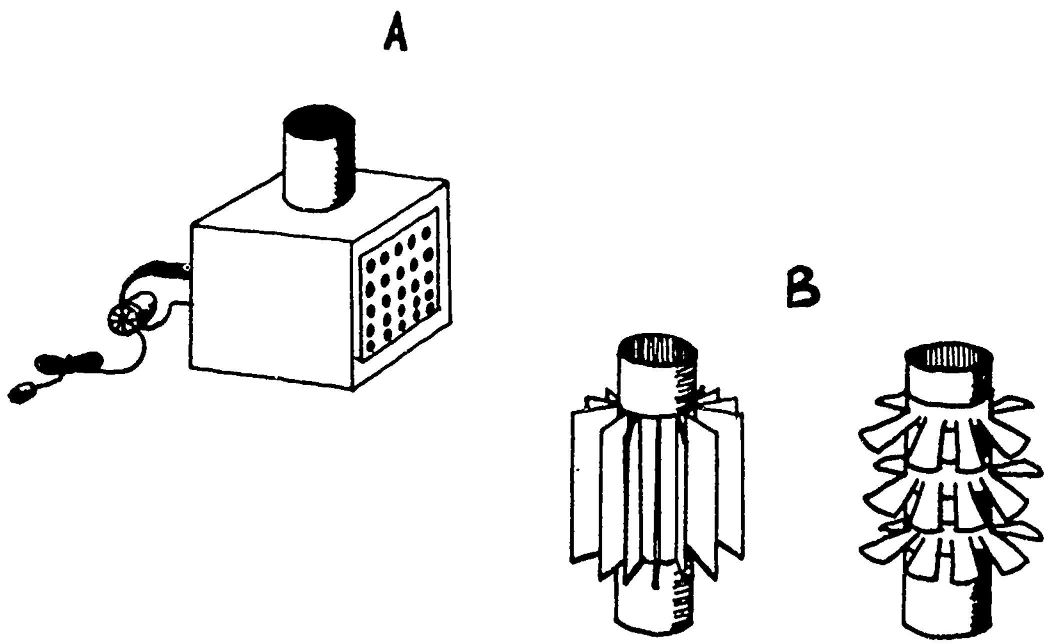
In summary, manually operated dampers can increase efficiency in high draft or leaky stove situations, but they also increase creosote accumulation and therefore should be used with caution. The use of a barometric draft control is not recommended because of the uncontrolled fire hazard.

3. **Heat Exchangers**

The heat exchanger principle has two applications in woodheat systems: in the stove or in the flue. **Blowers and fans** built onto the backs or sides of stoves enhance heat exchange. They can improve the **effective** efficiency of the stove by circulating the heat throughout the room to provide a more even room temperature. Otherwise, much of the heat radiated from the stove would normally just build up in the walls and ceilings surrounding the stove, creating heat loss. In some instances, where fans and blowers are used, the stack temperature may also be lowered (because heat is removed from the stove) and therefore overall efficiency is increased as well.

Exchangers attached to the flue are generally referred to as heat extractors, heat reclaimers, heat robbers or heat savers. (Figure 2.16)

FIGURE 2.15. HEAT EXCHANGERS ATTACHED TO THE FLUE.
(A: ACTIVE TYPE. B: PASSIVE TYPE.)



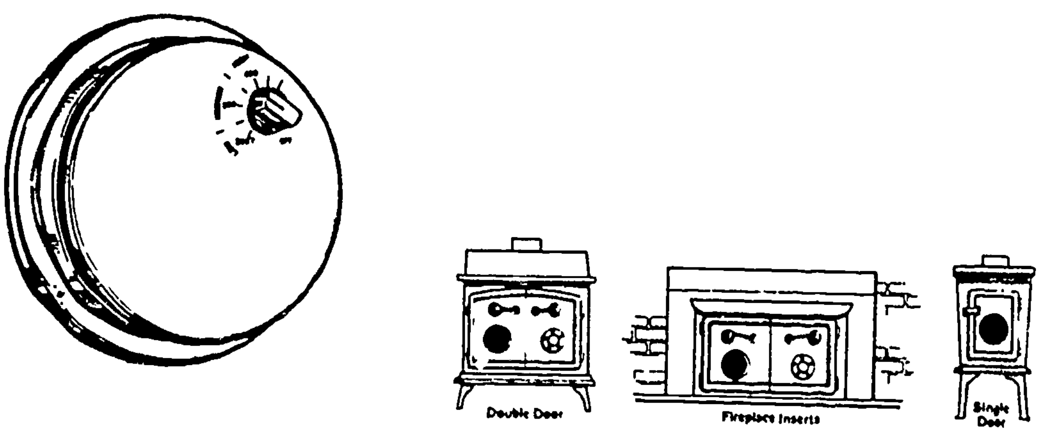
There are two types of heat exchangers that can be installed in the flue pipe: 1)**active**, which use a blower or fan to help transfer heat by forced convection, and 2) **passive**, which operates by radiation and natural convection. An active heat exchanger uses a device consisting of tubes that go through the fluepipe. Heat is withdrawn from these pipes by blowing air over them with a fan. The passive type is made up of a band of fins that are attached to the flue pipe. The fins increase the heated area of the pipe and thus increase heat radiation from the pipe.

Both types of flue heat exchangers can provide significant increases in efficiency, but only when the flue gas temperatures are high. Heat extractors can be useful and economical in systems where heat transfer efficiency is low, but are unnecessary in systems with high efficiency. Heat extractors take heat from the flue gases, which results in less draft and more creosote accumulation. Therefore, it is not recommended to add a heat extractor to a system with marginal draft, or to a system with much creosote accumulation already.(53)

Heat extractors can burn out. The inner portions of the tubes in tube-type extractors are very susceptible to burn out due to the high temperatures there. The use of heavy gauge material or stainless steel will prolong the useful life of the device. Also, the operation of a fan or blower can alleviate some of the heat and lessen the chances of burnout and the resulting fire hazard.(54)

4. <u>Retrofit Thermostats (Bimetallic coil type)</u>
A retrofit thermostat is a circular device that fits over a draft opening on spin draft control stoves. (Figure 2.17) This device uses a bimetallic coil which senses stove temperature and automatically opens or closes a proportionally shaped draft opening, as needed, to maintain a preset stove temperature.

FIGURE 2.16. AUTOMATIC THERMOSTATIC DRAFT CONTROL.



(Recommended installations.)

This unit replaces a spin draft cap and is used to automatically control the burn rate.

(Courtesy of Condar Co., Hiram, Ohio.)

An automatic retrofit thermostat can increase the overall efficiency of a woodstove since wood consumption is decreased by approxiately 20%. An automatic thermostat can also be used to reduce creosote (SEE Creosote discussion in the Fire Safety section of this Guidebook). However, if a stoveowner uses the thermostat to keep the stove at a low burn rate, creosote accumulation will be increased, and frequent chimney cleaning will be necessary. Retrofit thermostats are recommended for increasing woodstove efficiency, room comfort and safety, **if used according to directions.**

5. <u>**Hot Water Heating Devices**</u>

Manufacturers market several types of heat exchangers for heating hot water. These heat exchangers use heat from a woodstove to heat water, that can then be used for hot tap water, heating rooms other than that in which the wood heater is located, and for many other purposes. No substantive research has been done to determine the relative efficiency of these systems. A greater research need is for a safety assessment of wood water heating systems since extreme pressure can build up in closed water heating systems if a pressure relief valve is not installed or fails to operate properly. It is recommended that if a closed hot water heating system is used, it should be installed with care and operated with caution. Any closed system must have a pressure relief valve.

The types of hot water heat exchangers that are presently available include stovepipe coils, U-type heat exchangers, exterior-mounted heat exchangers, and plate- and tank-type exchangers. (Figure 2.17)

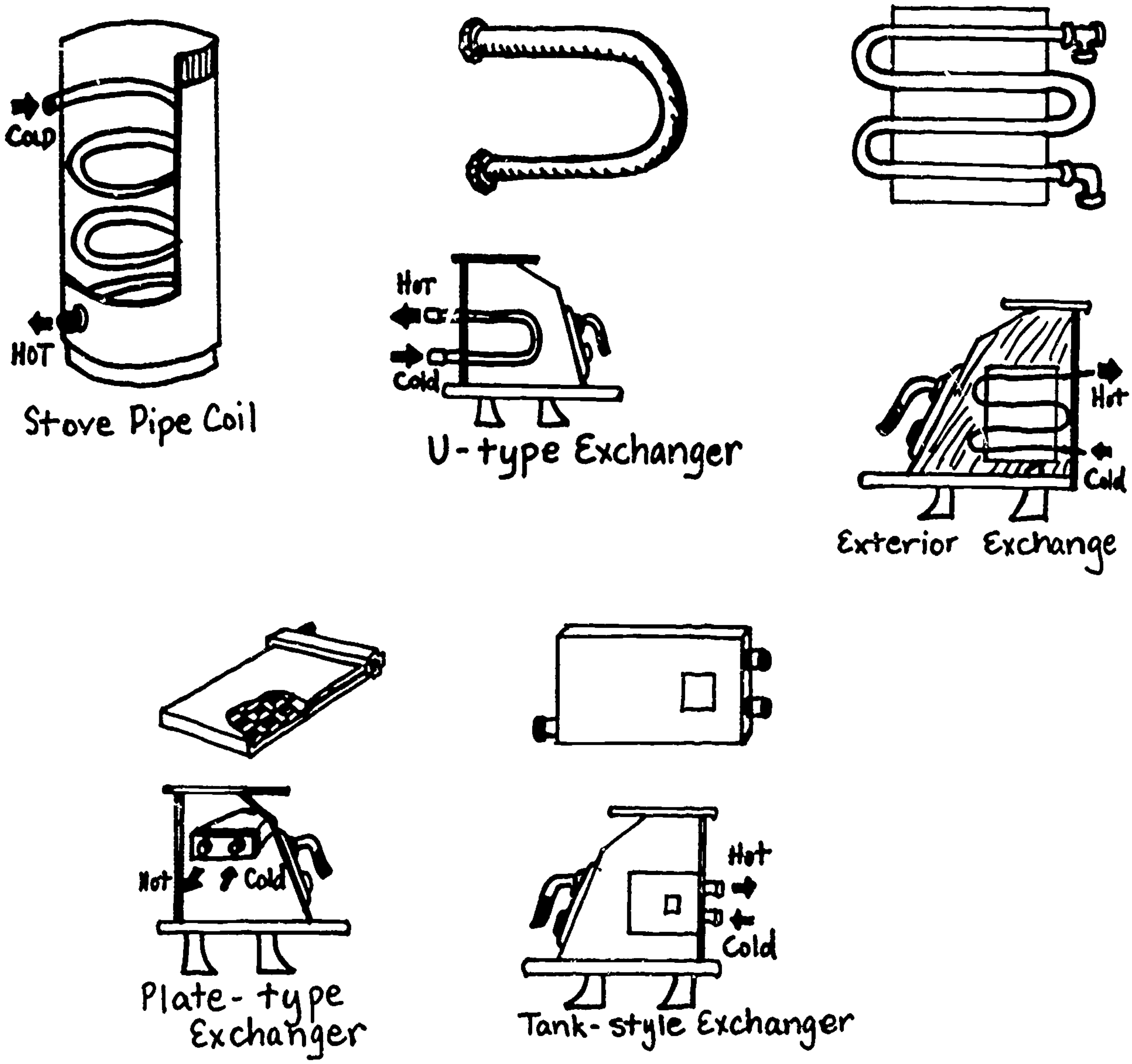
Stovepipe coil hot water heating exchanger systems that use copper coils (the most common material) are inexpensive, easily obtainable, and can be installed into almost any stove. They are suitable for large amounts of hot water production in heaters that are not airtight and have consistent high stack temperatures. Unfortunately, copper coils are not only the most common material used for stovepipe coils, but also the weakest. The coils must never be run dry because they can soften and lose their strength, leak or rupture. Also, in airtight or controlled combustion heaters they cause the flue gases to cool to very low temperatures, thereby increasing creosote build-up.

U-Type heat exchangers are one of the oldest types of hot water exchangers. This type will fit into almost any heater and is most efficient when placed directly in the firebox. **Exterior** heat exchangers do not come in direct contact with the fire because they are mounted on an outside wall of the stove. They last longer than internal units and do not take up the firebox space that internally mounted units do. They do not form an ash or creosote build-up on the exchanger since they are externally mounted. However, these units produce less hot water than internally mounted units and are not well suited to stoves that have firebrick-lined interiors that reduce the exterior wall temperature.

Plate type heat exchangers are solid pieces of steel that are drilled to create inner waterways through which the water flows. They can be used as a baffle when installed inside the stove or they can be mounted on an exterior wall. They have a good hot water output because of their large thermal mass and heat transfer surface.

Tank style heat exchangers can also be used as baffles inside the firebox, or mounted on an interior or exterior side wall, but exterior mounting reduces the unit's efficiency by up to 50%. These exchangers come in many shapes and sizes to fit various heaters. They may cause water discoloration if they are made of anything but stainless steel.(55)

FIGURE 2.17. SEVERAL TYPES OF HEAT EXCHANGERS FOR WOODSTOVES USED TO HEAT WATER.



G. SUMMARY

There is a great deal of variety in the types and styles of woodfuel appliances available to homeowners. These systems vary in overall thermal efficiency and safety. Overall thermal efficiency is the product of combustion efficiency (how completely the fuel is burned) and heat transfer efficiency (how effectively the heat is transferred from the appliance to the living space). Appliances with high combustion efficiency produce the least creosote and air pollution. High combustion efficiency, however, does not always translate into high overall efficiency. For example, fireplaces and nonairtight stoves have relatively high combustion efficiency but very poor heat transfer efficiency since heated gases flow out the chimney before the heat can be absorbed by the appliance and radiated into the living space. Therefore these systems have low overall heat transfer efficiency.

Since airtight conventional stoves are often burned at relatively low burn rates, they have, on the average, lower combustion efficiency than fireplaces. However, they have very good heat transfer efficiency and therefore, greater overall efficiency than fireplaces and non-airtight stoves.

Catalytic stoves and possibly pellet burners have high combustion efficiency coupled with high heat transfer efficiency over a wide range of outputs. Therefore, overall efficiency for catalytic appliances and pellet burners greatly exceeds that for conventional airtight and non-airtight appliances. In fact the overall efficiency approaches the theoretical optimum (80% overall) for wood heater efficiency. However, improved thermal combustion design stoves have not yet performed nearly as well at at low burn rates most commonly experienced in homes.

Chimney systems are necessary to provide draft air to the fire and to carry combustion products out of the house. Chimneys are exposed to extreme temperatures and to moisture and corrosive chemicals. Therefore, they must be made of very durable materials. Chimney systems can be made of masonry or metal. Insulated metal chimneys are less costly and often provide better draft than masonry, however, they are generally not as durable.

There are a number of accessories that can be installed on a stove to improve overall stove efficiency and/or safety. These accessories are designed to improve combustion efficiency or to improve heat transfer efficiency. Those that improve combustion efficiency generally have a positive effect on safety since less creosote is produced. Most accessories that increase heat transfer efficiency, unfortunately also tend to increase creosote accumulation because often they reduce flue temperatures to the creosote condensation point. When any accessory is installed, frequent creosote inspections should be done until the stoveowner can gauge, through experience, how frequently chimney cleaning is needed.

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(35)Tony Anthony, October 1983, pp. 69-70.

(36)Safe and Sound Masonry Chimneys, p. 16.

(37)Shelton, Wood Heat Safety, p. 19.

(38)Shelton, Wood Heat Safety, p. 16.

(39)Tony Anthony, October 1983, pp. 69-70.

(40)Tony Anthony, October 1983, pp. 69-70.

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(44)Shelton, August 1983, pp. 39-40.

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(46)NFPA 211, 5-2.1

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(51)Shelton, Advanced Woodburning Technology Evaluation, p. 9.

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III. RESIDENTIAL WOOD HEATING TRENDS

A. The Impacts of Residential Wood Heating

Because wood heat has found such an appropriate niche in our energy environment, it is unlikely that a significant reduction in residential wood fuel use will occur in the near future. In fact, as conventional fuel prices increase, an increase in residential wood use is inevitable. Currently wood fuel use in the commercial sector is growing even more rapidly than in the residential sector in a number of states. This growth in wood fuel use has had a noticeable impact on individuals and society in general. Not all of it has been favorable. In many cases those who enjoy the benefits of wood burning are not the ones who are shouldering the costs.

Table 3.1 summarizes the advantages and disadvantages of residential wood burning. A brief discussion of these advantages and disadvantages of residential wood burning follows. Most of the research that documents the magnitude of the impact of wood burning is discussed in more detail in other sections of this guidebook.

TABLE 3.1: THE ADVANTAGES AND DISADVANTAGES OF RESIDENTIAL WOOD BURNING

	Advantages	Disadvantages
Individuals	economics independence	safety hazards insurance costs
Community	employment	fire service local air quality
State/Region	use of renewable resources economics energy independence	air pollution life/property loss

Residential wood burning has significant advantages both to individuals and to society as a whole. As discussed earlier, the economics of wood fuel use, especially in regions with significant wood resources, make wood a practical alternative to conventional heating fuels for homeowners. Also many homeowners value the "energy independence" that wood burning affords.

Local regions benefit from increases in employment opportunities and the associated economic gains generated by local wood harvesting and distribution activities. Of importance at the national policy level is that wood heat has helped slow the drain on our nation's nonrenewable energy resources and it is helping the U.S. move toward its goal of energy independence. Since the drop in oil prices in the early 80's the growth in residential wood use has halted. However wood fuel use in the commercial sector continues to grow. A number of states are actively encouraging commercial use of wood fuel. New York, a petroleum poor state is looking to wood fuel as a means to reduce dependence on imported fuel supplies and to create jobs in the state.

Wood as a fuel source does not come without its disadvantages. As mentioned earlier there are serious fire safety hazards associated with residential wood heating. Insurance companies report that wood heating has greatly increased the number of residential fires and the amount of bodily injury and property damage losses. Most of these losses can be significantly reduced by improved woodstove operation, maintenance and technology. Reduced indoor air quality, from both the wood stove within a house and smoke coming from nearby wood burning homes, is another problem of wood burning that is catching the attention of public health officials.

Homeowners who heat with wood save money at the expense of society in general. Because of the associated fire risk of wood heat, insurance premiums for homeowners have increased. Since most insurance carriers do not distinguish between wood burners and nonwood burners in assigning insurance rates, all policy holders bear the added cost of fire insurance. Wood heating has also placed greater demands on community fire services. Because fire service is financed mainly out of general tax revenues, the entire community is forced to share in the added cost of protecting wood burners. Wood burning also decreases local air quality, especially in mountainous regions. In some areas the impact of wood smoke on air quality has been serious enough to reduce or halt economic growth because of lack of air shed capacity for industrial growth and because of reduced aesthetics. Wood smoke pollution also has had noticeable regional health impacts, especially on young children and the elderly who are at high risk for respiratory illness.

The use of wood for fuel also puts greater demands on total wood resources within states. Competing uses for wood drives up the price of wood. Increased wood harvesting causes more soil erosion. If appropriate forest management planning is not done to accommodate wood fuel usage, especially in the event of another energy crunch, the public will suffer.

It is apparent that the many benefits that residential wood burning provides to individuals and society in general can be outweighed by the costs unless efforts are made to ensure that people burn wood in the safest and least polluting manner possible. Because both the fire hazards and air pollution caused by wood burning are tied to wood stove emissions, reducing emissions should help alleviate each of these problems. Reducing emissions has a number of economic benefits including a reduction in fire related costs, a reduction in health care costs, a reduction in fuel costs (cleaner burning stoves are more efficient), less drain on our forest resources and the removal of constraints to tourism and industrial expansion caused by air pollution. The public health impacts of air pollution and fire hazards also are reduced.

Can we solve the health, safety and economic problems generated by wood stove emissions? The technology to reduce emissions is available and economically viable. However discovering what it takes to get homeowners to adopt safer technology and operating procedures has proven to be a difficult task. Because wood stove use increased so rapidly and unexpectedly, the institutional safeguards to direct and ensure its safe use are not in place. States and local governments are searching for ways to control and reduce the negative impacts of residential wood burning and to amplify its advantages. This guidebook will address many of the issues related to this goal.

B. HOW MANY STOVES?

It is virtually impossible to obtain an accurate count of wood burning appliances in the United States. Tallies and estimates vary from 14,200,000 (1) to 28,700,000 (2) wood burning appliances in homes in 1980 and from 10,960,000 (3) to 39,900,000 (4) residential woodburners in 1981. Although the figures are wide-ranging, the most common estimate is that there are currently about 28,000,000 woodburning appliances of all types used for home heating in the United States.(5)

A Corning Glass Works survey that was conducted in mid-1981 revealed that ownership of stoves is fairly evenly distributed throughout the country except in New England, where the owner-to-nonowner ratio is almost twice the national density. (6)

Figures can be deceiving, though. Not all wood heaters are used for primary heat, and the types of woodburning appliances used for various purposes are different. Fireplaces are, by far, the most popular wood heating device. However, of those households that use wood for primary heat, 75% use wood stoves or furnaces, while of those who use wood for secondary heating, 87% use fireplaces and fireplace inserts.(7) Relatively few households use non-airtight stoves. The few that do are concentrated in the Northeast and South regions and in rural areas. These stoves are used mostly for primary heat. Also, controlled combustion stoves make up one-fourth of the wood heater population, and 60% of their owners consider them as primary heat sources. There are only 800,000 woodburning furnaces (amounting to only 4% of all woodburners) in the United States. Eighty-seven percent of these furnaces are used for primary heat.(8)

A report prepared by Housing Industry Dynamics of Crofton, Maryland, contains information on the installation of stoves, fireplaces, furnaces and inserts in 1982 for the 48 continental states in regional and national summaries.

The data is fr m two "intensive national surveys conducted each January."(9) The first was a survey by mail of 40,000 homebuilders to obtain data concerning installations of fireplaces and stoves in new homes. The second survey was conducted by telephone among 15,000 consumers to obtain information about fireplace purchases for use in existing homes.(10)

In 1982, more than 1.1 million fireplaces were installed in residences. The 612,000 units installed in new homes were more numerous than the 507,000 installed in existing homes through remodeling and repairs. However, of the nearly 1.8 million wood or coal burning stoves that were purchased for homes in 1982, only 20,000 stoves were for new homes, and the rest were installed in existing homes, according to the Housing Industry Dynamics national survey.(11) [These figures are the result of compiling information obtained through the previously mentioned surveys and may be considered to be overestimated.]

TABLE 3.2. FIREPLACES, STOVES, INSERTS AND FURNACES PURCHASED IN THE UNITED STATES - 1982.

Type of Appliance	New Construction	Repair And Remodeling
Fireplaces	612,000	507,000
Stoves	20,000	1,791,400
Inserts	0	830,700
Furnaces	0	210,700

To complement the fireplace inserts and wood and coal burning furnaces purchased for installation in existing homes, and their other wood burning appliances, consumers also purchased more than 12 million accessories such as grates, gas logs, metal screens, glass doors, log racks or holders, and tool sets.(12)

TABLE 3.2.A. INSTALLATION OF ACCESSORIES IN EXISTING HOMES - 1982 U.S. TOTAL.

Type of Accessory	Total Number Sold
Tool Sets	572,410
Log Racks or Holders	288,480
Grates	144,020
Glass Doors	110,280
Metal Screens	88,790
Gas Logs	10,610

FIGURE 3.1. NINE CENSUS REGIONS AND STATES INCLUDED. (FIGURES GIVEN ARE FOR THESE REGION DIVISIONS.)

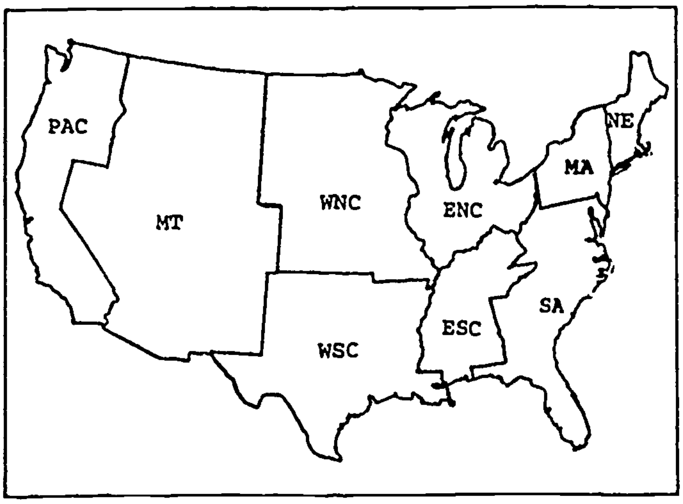

TABLE 3.3. NINE CENSUS REGIONS AND STATES INCLUDED. (FIGURES GIVEN ARE FOR THESE REGION DIVISIONS.)

Region	States Included
New England (NE)	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Middle Atlantic (MA)	New Jersey, New York, Pennsylvania
East North Central (ENC)	Illinois, Indiana, Michigan, Ohio, Wisconsin
West North Central (WNC)	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
South Atlantic (SA)	Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virgina
East South Central (ESC)	Alabama, Kentucky, Mississippi, Tennessee
West South Central (WSC)	Arkansas, Louisiana, Oklahoma, Texas
Mountain (MT)	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming
Pacific (PAC)	California, Oregon, Washington

(Housing Industry Dynamics, 1983.)

TABLE 3.4. FIREPLACES INSTALLED IN NEW AND EXISTING HOUSING - 1982.

Region	No. of Fireplaces Installed
NE	13,000
MA	63,000
ENC	127,000
WNC	85,000
SA	198,000
ESC	72,000
WSC	258,000
MT	96,000
PAC	176,000

TABLE 3.5. STOVES INSTALLED IN NEW AND EXISTING HOUSING - 1982.

Region	No. of Stoves Installed
NE	150,000
MA	217,000
ENC	275,000
WNC	192,000
SA	297,000
ESC	178,000
WSC	100,000
MT	155,000
PAC	199,000

Three-fifths of the stoves purchased by consumers were strictly woodburning. One-third (657,000 units) burned both wood and coal. Strictly coal-burning stoves accounted for only 3% of total stove sales, and these were most popular in the New England and Middle Atlantic areas.(14)

The most popular chimney material for stove chimneys was masonry (60% of the total chimneys), pre-fabricated metal chimneys were second with 20%.(15)

According to Housing Industry Dynamics, 831,000 fireplace inserts and 211,000 furnaces were purchased in 1982. Nearly 90% of the furnaces sold were wood burning and only 10% were coal furnaces.(16)

1. <u>Fuelwood Consumption</u>

American woodburners burned 42 million cords* of wood during the 1980-81 heating season, according to a nationwide telephone survey of households conducted by the Forest Products Laboratory of the U.S. Department of Agriculture, Forest Service, and the University of Wisconsin Survey Research Laboratory.(17) This amount equals about 37 percent of the total overall wood energy consumption (18), and about one-fourth the amount of wood used for all other wood products in the U.S. It is estimated that woodburners buy only 25% of their fuelwood and cut 75% themselves.(19)

Pennsylvania and New York are large woodburning states. Pennsylvania residents burned 3,094,844 cords of wood during the 1981-82 heating season (21), and New York residents burned more than 3.3 million cords in the same period.(22)

The 42 million cords of fuelwood burned during the 1980-81 heating season produced 0.8 quad (quadrillion = 10^{15} Btu) of energy. This is about 9 percent of the gross energy of fossil fuels used by homeowners.(23) A study published in "Progress in Biomass Conversion" set the annual wood consumption rate slightly higher at 0.9 quad for the residential sector and

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*A cord of wood is a common measure of firewood and pulpwood, equal to the amount of wood in a carefully stacked (parallel) pile of wood, 4 feet high, 8 feet wide, and 4 feet deep. The amount of solid wood in this 128-cubic-foot pile is usually estimated to be between 80 and 90 cubic feet.(20)

1.5 quads annually for industry.(24) These wood consumption figures show that U.S demand for residential wood heat has increased 600% since 1973.(25)

2. **Where The Wood Is Burned**

Although half of all homeowners who burn wood use fireplaces, they consume only one-fourth of all the fuelwood used. This is because only 10% of fireplace owners use them for primary heat, 56% use fireplaces for secondary heat, and 34% use fireplaces only for aesthetics. (26)

Another one-fourth of all fuelwood burned is used by insert users, who amount to one-quarter of all woodburners. Insert users consume an average of 1.8 cords each per year, and 30% of all inserts are used for primary heat, while 57% are used as secondary heat sources.(27)

Non-airtight stove users, who are five percent of all woodburners, use seven percent of all fuelwood used, an average of 2.3 cords each for the 1980-81 heating season. Forty-one percent of these stoves are used for primary heating, and in 50% of these stoves, wood is used as a secondary fuel.(28)

Controlled combustion stoves (airtight stoves) are used by another one-fourth of woodburners. These stoves use 38% of the total fuelwood used, but produce 71% of all wood-generated heat. Two-thirds of airtight stove owners use them for primary heat.(29)

Although only 70-80% of all woodburning equipment owned is actually used, in 1981, that amounted to 21 million out of 28 million homes that had woodburning equipment. This was **36% of all the homes in the United States**.(30)

3. **Who Burns The Wood?**

People from a variety of social and economic backgrounds are now using residential woodburning equipment. Woodburners used to be a mostly rural people, but a mid-1981 Corning Glass Works survey found that more woodburning equipment sales were being reported in urban areas and to consumers with higher income levels, as compared to the former mostly-rural market.(31)

Using data from a nation-wide study of 15,000 homes by the Simmons Market Research Company, the average 1981 wood stove consumer was profiled by the research department at Rodale Press Inc. The survey results revealed that an equal number of men and women bought stoves and that they were usually married, with an average age of 38. Woodburners are energy conscious and are likely to have installed storm doors or windows and insulation. The highest concentration of wood stove purchasers was in the East Central region. The Northeast was second, and the South and Pacific states were also close. However, the amount of sales in the West Central states was only half the amount sold in the East Central region.(32)

In a survey conducted by Del Green Associates for the U.S. Environmental Protection Agency in the spring of 1981, three areas were surveyed to obtain data on residential woodburning in the Pacific Northwest. Area A was located in Multnomah County, Oregon, just outside the Portland city limits. Area B was located in Bellevue, a community four miles outside of Seattle, Washington. Area C was located just north of Spokane, Washington. The following charts contain demographic data about woodburners which was obtained during these surveys.(33)

TABLE 3.6. PERCENTAGE OF HOMES OWNING WOODBURNING EQUIPMENT. (PERCENTAGE OF ALL HOUSEHOLDS SURVEYED.)

Type of Woodburning Equipment	Area A	Area B	Area C
Fireplaces And/Or Inserts	36.9%	97.1%	97.0%
Wood Stoves	31.7%	13.5%	11.7%
Woodburning Furnaces	1.6%	1.3%	1.3%
No Woodburning Device	41.3%	1.3%	1.3%

(Del Green Associates, February 1984, p. 17.)

On a national scale, 38 percent of homeowners use woodburning equipment, compared to 9 percent of those who rent their homes. More upper-income and higher-education households use woodburning equipment than low-income or less-educated households. Thirty-three percent of high-income ($40,000+) households use woodburning equipment as compared to 4 percent of those households that earn $10,000 or less. Woodburners are only 4 percent of homeowners with eight years of education or less, while 22 percent of those with 4 or more years of college burn wood.(34) It is obvious that homes with woodburning equipment are becoming more widely distributed, and not confined to rural areas any longer.

TABLE 3.7. GENERAL HOUSEHOLD INFORMATION. (PERCENTAGES GIVEN ARE OF ALL HOUSEHOLDS SURVEYED.)

Parameter		Area A	Area B	Area C
Own Home		84.0%	96.0%	95.6%
Rent Home		16.0%	4.0%	4.4%
Type of Residence:	Single Family Home	96.9%	99.5%	94.3%
	Duplex	2.1%	0%	0%
	Condominium	0%	0%	0%
	Apartment	1.0%	0%	0%
	Mobile Home	0%	0.5%	0%
Size of Residence (Average)		1404 sq. ft.	2311 sq. ft.	1719 sq. ft.
Rooms Heated:	All	54.9%	43.2%	62.5%
	Some Closed Off	45.1%	56.8%	37.5%
	Percent (If Any) Of House Not Heated	34.0%	29.1%	30.9%
Normal Number of Inhabitants (Number of People)		2.5	3.1	3.0
Occupation of Head of Household:				
Science/Administration/Teacher		15.7%	63.2%	40.0%
Clerical/Technician/Sales		22.9%	21.7%	31.0%
Service/Military		8.9%	3.8%	5.8%

TABLE 3.7 continued

Parameter		Area A	Area B	Area C
Farm/Forest		1.3%	1.2%	1.4%
Production		51.3%	10.1%	21.9%
Age of Head of Household:	Under 25	2.5%	0.3%	0.7%
	25-34	20.3%	10.6%	7.0%
	35-44	13.5%	23.3%	21.6%
	45-54	12.1%	28.6%	27.4%
	55-64	22.1%	28.9%	25.8%
	Over 65	29.5%	8.2%	17.4%
1980 Household Income Before Taxes:				
Less than $10,000		28.4%	2.3%	8.6%
$10,000 to $19,999		36.0%	11.6%	17.7%
$20,000 to $29,999		25.4%	22.7%	34.8%
$30,000 to $39,999		8.0%	23.5%	23.0%
$40,000 to $49,999		1.1%	17.6%	9.8%
More than $50,000		1.1%	22.4%	6.1%

(Del Green Associates, February 1984, pp. 42-46.)

C. WOOD ENERGY USE AND TRENDS IN THE GREAT LAKES STATES

The use of wood for residential heating is increasing. Between 1972 and 1981 national sales of wood stoves increased at an average rate of 21% per year.(35) The U.S. Department of Energy is encouraging wood energy use and the goal for 2000 AD is 5.4 quadrillion Btu/year from wood (three times the 1981 wood energy input). The use of wood resources for residential fuel is one indication of the actual and potential problems, if any, related to pollution from woodsmoke and wood heat safety. A brief description of residential use of fuelwood is provided for the Great Lakes states.

The use of fuelwood by states in the Great Lakes Region is summarized in the table below.

TABLE 3.8. FUELWOOD USE IN THE GREAT LAKES STATES.

Season of Survey	State	Sample Size	Percentage of Households That Burn Wood	Estimated Total No. of Cords Burned
Great Lakes States:				
1981-82	Mich.	2,060	34%	2,863,358
1979-80	Minn.	2,157	33%	1,307,000
1981-82	Ohio	2,556	31%	2,075,428
1979-80	Wisc.	2,232	29%	1,371,445
	*Ind.	NA	NA	NA
	*Ill.	NA	NA	NA
	*Iowa	NA	NA	NA

(Table 3.10 continued.)

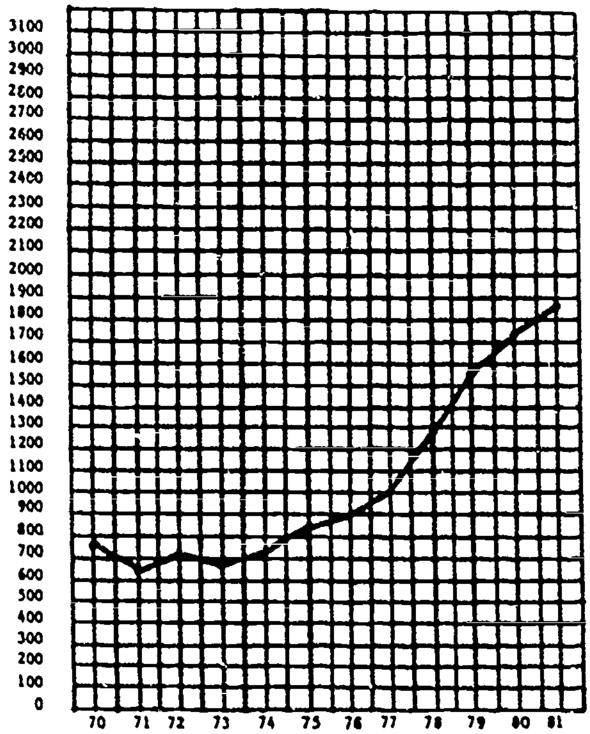
Season of Survey	State	Sample Size	Percentage of Households That Burn Wood	Estimated Total No. of Cords Burned
Other States:				
1980-81	Penn.	2,74(	31%	3,094,844
1980-81	N.Y.	2,496	21%	3,388,270

*NA=Not Available=No fuelwood surveys were available. (Data obtained from state fuelwood surveys.)

1. Illinois

The only information available on wood energy use and trends in Illinois is compiled in Figure 3.2.

FIGURE 3.2. RESIDENTIAL WOOD ENERGY CONSUMPTION ESTIMATE - ILLINOIS. (Thousands of short tons.) 1970 - 1981



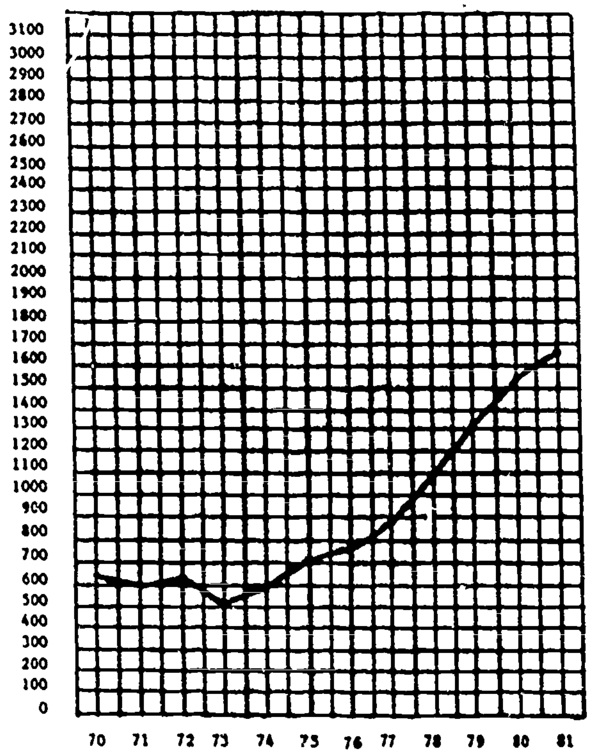
Note: Figures are expressed in oven dried tons. One oven dried ton equals 17.2 million Btu on the average.
(Data derived from Table A4: Residential Sector Wood Energy Consumption, estimates by state for 1970-81; Energy Information Administration, Office of Coal, Nuclear, Electricity and Alternative Fuels. U.S. Department of

Energy, August 1982.)

2. Indiana

No formal survey of residential woodfuel use has been done to date. However, the Department of Natural Resources plans to conduct a study if funding is approved. Crude estimates are that there are 300,000 to 500,000 woodburners in the state. Wood is abundant and can be cut on state land for a small (less than $3.00) permit fee. It is expected that residential wood combustion (RWC) will increase as the cost of conventional fuels increase. No data is available on the amount of woodfuel used by the commercal/industrial sector though use is also expected to increase over time. The state endorses both residential and commercial/industrial woodburning. Wood fuel is not, however, addressed in the state's energy plan.(36) Figure 3.3 shows an estimate of residential wood energy consumption in Indiana over a ten year span showing the steady increase in wood energy use.

FIGURE 3.3. RESIDENTIAL WOOD ENERGY CONSUMPTION ESTIMATE - INDIANA.
(Thousands of short tons.)
1970 - 1981



Note: Figures are expressed in oven dried tons. One over dried ton equals 17.2 million Btu on the average.

(Data derived from Table A4: Residential Sector Wood Energy Consumption, estimates by state for 1970-1981; Energy Information Administration, Office of Coal, Nuclear, Electricity and Alternative Fuels. U.S. Department of Energy, August 1982.)

3. <u>Iowa</u>

Wood energy use in Iowa is not as extensive as in the other Great Lakes states. Whereas the other Great Lakes states have increased consumption steadily in the last decade, little change has been noted in Iowa. An estimate of residential wood energy consumption for Iowa in 1970 was 115,000 short tons as compared to the 1981 estimate of 171,000 short tons, a relatively insignificant increase.

4. <u>Michigan</u>

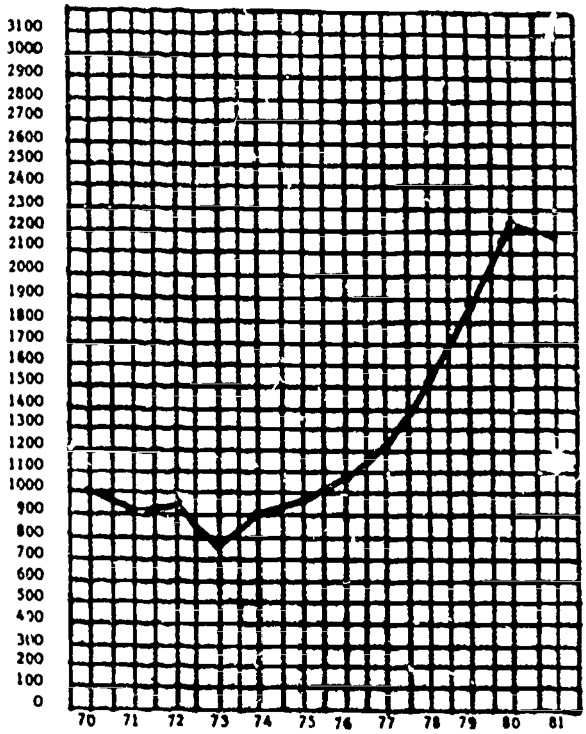
During the 1982-83 heating season, 3,142,212 cords of fuelwood were consumed in Michigan. It is estimated that 32.1% of all households (1,026,666 households) used this wood as an energy source for residential heating. Twenty percent of Michigan residences use wood for primary or secondary home heat or for recreational use in fireplaces. The table below indicates woodfuel use practices of the residential wood heating population.

TABLE 3.8: TYPE OF WOOD FUEL USE IN RESIDENTIAL WOOD BURNING POPULATION

Residential Use	Percent of Wood User Population	Number of Cords Burned Annually Per Household
Primary Heat	28%	7.1
Secondary Heat	31%	2.6
Pleasure	41%	0.7

Results of the fuelwood survey by the Michigan Department of Natural Resources suggests that an additional 88,158 households are planning to install woodburning equipment within the next year. Figure 3.4 compiled by the Department of Energy shows that Michigan has more than doubled its wood energy consumption since 1970. Although the greatest growth in wood fuel use is expected in the commercial/industrial sector, the additional residential units will consume 325,000 cords, or an increase of 17 percent over current use. These increases will require the proper guidance in the management of forest resources to ensure the present and future quality of trees and wildlife habitat.(37)

FIGURE 3.4. RESIDENTIAL WOOD ENERGY CONSUMPTION ESTIMATE - MICHIGAN.
(Thousands of short tons.)
1970-1981



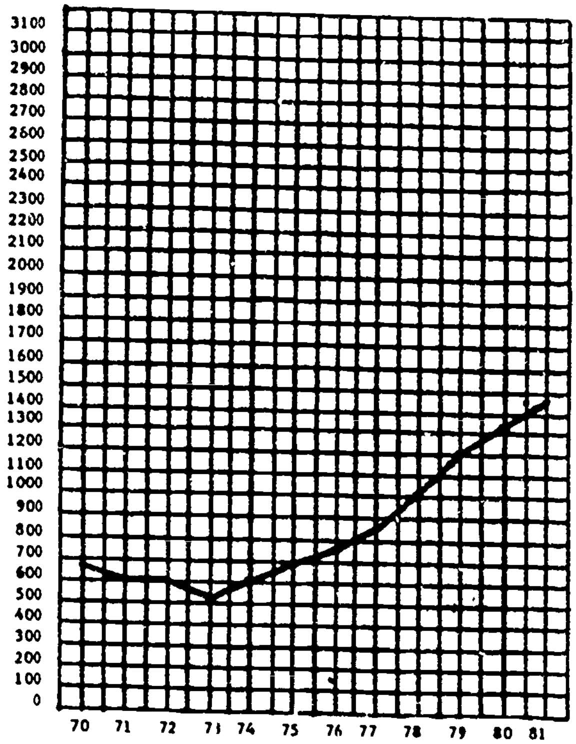
Note: Figures are expressed in oven dried tons. One oven dried ton equals 17.2 million Btu on the average.

(Data derived from Table A4: Residential Sector Wood Energy Consumption, estimates by state for 1970-1981; Energy Information Administration, Office of Coal, Nuclear, Electricity and Alternative Fuels. U.S. Department of Energy, August 1982.)

5. Minnesota

The use of wood for residential heating has had a 300% increase in Minnesota since the early 70's. In 1980, 1.3 million cords were consumed by 33% of Minnesotan households. Approximately 729,000 of these cords were burned for primary heating sources which represents 4% of the total state Btu consumption. About 21% of Minnesota households burn wood as a major or supplementary heat source. The largest group of homeowners (123,000) burned for pleasure only and were located in metropolitan areas. Figure 3.7 gives an overview of the energy consumption changes in the state since 1970.

FIGURE 3.5. RESIDENTIAL WOOD ENERGY CONSUMPTION ESTIMATE - MINNESOTA.
(Thousands of short tons.)
1970 - 1981



Note: Figures are expressed in oven dried tons. One oven dried ton equals 17.2 million Btu on the average.

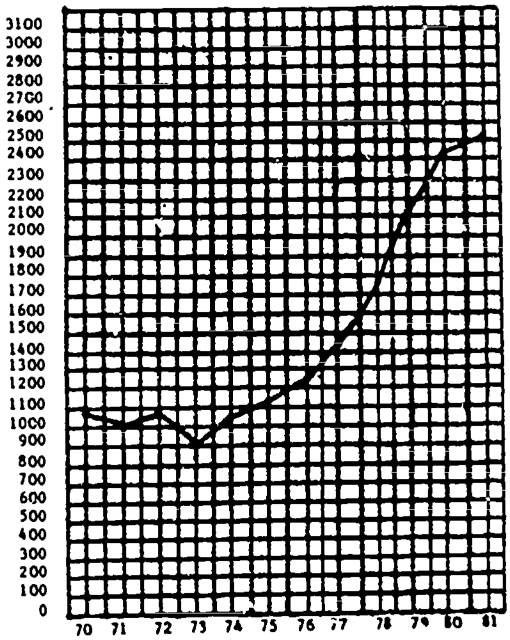
(Data derived from Table A4: Residential Sector Wood Energy Consumption, estimates by state for 1970 - 1981; Energy Information Administration, Office of Coal, Nuclear, Electricity and Alternative Fuels. U.S. Department of Energy, August 1982.)

The total drain from growing stock trees including purchased wood for residential firewood is approximately 500,000 cords/year. In addition, an expansion in the wood products industry will result in a decrease in quantity of wood available for residential woodburning. There is a need for state forest department involvement in private forest land management to promote wise use of private forest resources and thus decrease forest depletion.(38)

6. Ohio

In 1982, Ohio burned approximately 2.1 million cords of wood for home heating purposes. This figure accounted for 1,184,890 dwelling units which burned on the average 1.7 cords cords each. The 1,184,890 dwelling units accounts for 31% of all Ohio households.(39) These figures were compiled as a result of a survey by Davey Environmental Services for use as guides for the U.S. Forest Service, the Ohio Department of Natural Resources and private industry. Figure 3.6 shows increases in residential wood energy consumption in Ohio since 1970.

FIGURE 3.6. RESIDENTIAL WOOD ENERGY CONSUMPTION ESTIMATE - OHIO.
(Thousands of short tons.)
1970 - 1981



Note: Figures are expressed in oven dried tons. One oven dried ton equals 17.2 million Btu on the average.

(Data derived from Table A4: <u>Residential Sector Wood Energy Consumption</u>, estimates by state for 1970-1981; Energy Information Administration, Office of Coal, Nuclear, Electricity and Alternative Fuels. U.S. Department of Energy, August 1982.)

Wood is plentiful in the state, as approximately 27 percent of Ohio's land area is forested, a total of 7,120,000 acres. This amount is an increase of 487,000 since the 1968 survey.(40) In addition to the increase in wood resources, the survey indicated a 13 percent expected increase in the volume of wood used as fuelwood in the state. With the increase in use and wood resources, there is opportunity for increased production within the state. Residential firewood market analysis indicates that Ohio could support ten fuelwood enterprise centers in the state, increasing Ohio's employment opportunities and self-sufficiency.(41)

7. <u>Wisconsin</u>

In 1981, Wisconsin obtained 45 trillion Btu for the year or about 3% of the state's total energy use from wood burning. This amounted to about 1.6 million cords for residential heating and 0.6 million cords for industrial energy. At that time commercial use was believed to be insignificant (less than 1% of space heating needs). By state policy commercial use has been increasing since 1981 as pellets and chips are burned in public buildings and some commercial operations.(42)

In the Wisconsin residential sector, 25% of the wood is burned in fireplaces with the remainder used in wood stoves, boilers and furnaces. The residential sector use of wood accounts for about 10% of the state's total energy demand, while 2.5% of the industrial sector demand is met by wood energy.(43) Table 3.9 shows residential use of wood fuel by region in 1980.

TABLE 3.9. WISCONSIN RESIDENTIAL USE OF WOOD FUEL, BY REGION, 1980. (Thousands of cords.)

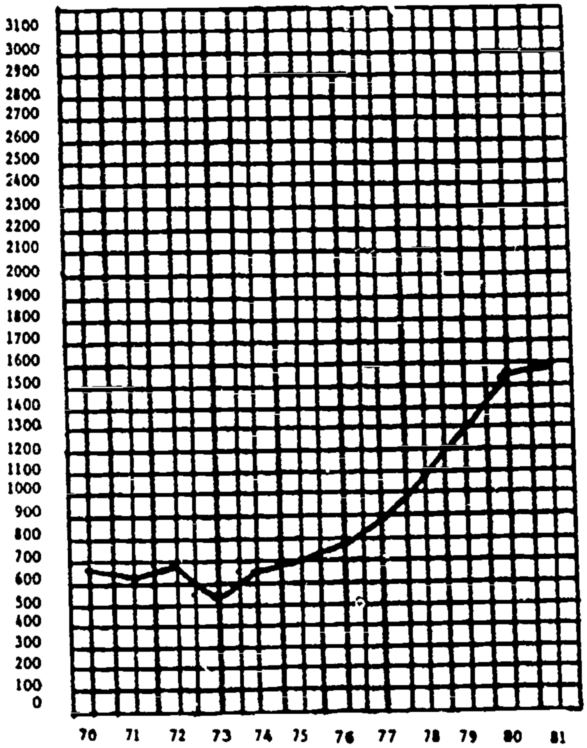
Region	Use Classification			
	Primary Fuel	Secondary Fuel	Aesthetic	Total[c]
Milwaukee Metro[a]	57.6	64.7	32.5	154.8
Dane County	25.0	13.4	10.2	48.6
Green Bay/Appleton[b]	54.4	32.8	9.7	96.9
Northwest	115.5	36.4	4.1	156.0
Northeast	67.4	42.9	1.0	111.3
Central	190.0	80.9	15.1	286.0
Southeast	114.5	68.1	14.5	197.0
Southwest	222.8	66.2	5.5	294.5
State Total[c]	847.1	405.4	92.7	1,345.2
Thousands of Tons	2,117.8	1,013.5	213.7	3,363.0
Trillions of Btu	16.9	8.1	1.9	26.9

a Milwaukee, Ozaukee, Washington, Waukesha, Racine and Kenosha Counties.
b Brown and Outagamie Counties.
c Total may differ from sum of components because of rounding.

(From: Wisconsin Department of Natural Resources, Residential Wood Fuel Survey, unpublished (1980).)

Wisconsin is an importer of most of its energy resources. Wood energy is one of the few native resources available. Well managed, wood could serve as a long term renewable energy supply. Due to the presence of a large forest products industry, sizeable amounts of low cost residue woods are available and selective cutting can be employed on many private and public woodlands. In addition to being a primary energy source, wood fuel serves as a secondary source providing space heating protection from electrical failures and rate increases. Wood fuel is less expensive, more available and locally more reliable than other sources of fuel in certain areas of the state (i.e. northern counties). Figure 3.7 shows that wood energy consumption in Wisconsin almost tripled in the last ten years.

FIGURE 3.7. RESIDENTIAL WOOD ENERGY CONSUMPTION ESTIMATE - WISCONSIN.
(Thousands of short tons.)
1970 - 1981



Note: Figures are expressed in oven dried tons. One oven dried ton equals 17.2 million Btu on the average.

(Data derived from Table A4: Residential Sector Wood Energy Consumption, estimates by state for 1970-1981; Energy Information Administration, Office of Coal, Nuclear, Electricity and Alternative Fuels. U.S. Department of Energy, August 1982.)

The Wisconsin Division of State Energy stated that wood use can increase in that state without depleting forest resources due to the fact that in 1979 only 50-80% of the state's renewable yield was used. The state indicated concern over possible environmental and safety problems that could be caused by more intensive wood burning. These included poor wood harvesting techniques, increases in air pollution and increases in residential fires.(44)

Wood use accounted for a savings of $30 million over traditional fuel during 1978 in Wisconsin.

FOOTNOTES

(1)"Industry Profile: The Solid Fuel Retailer," Wood 'n Energy, October 1983, p. 34.

(2)"New Study Cites Increased Wood Use," Wood 'n Energy, April 1983, pp. 9-10

(3)"Industry Profile: The Solid Fuel Retailer," p. 34.

(4)Ken Skog and Irene Watterson, "Who Uses Wood-Burning Equipment and Why?", Wood 'n Energy, March 1984, pp. 82-83.

(5)Skog and Watterson, p. 81.

(6)"Industry Profile: The Solid Fuel Retailer," p. 34.

(7)Skog and Watterson, p. 81.

(8)Skog and Watterson, pp. 85-86.

(9)Housing Industry Dynamics Analytical Staff, "The 1982 Overview Report for Members of the Wood Heating Alliance," (Crofton, Maryland: Housing Industry Dynamics, 1983).

(10)Housing Industry Dynamics, 1983.

(11)Housing Industry Dynamics, 1983.

(12)Housing Industry Dynamics, 1983.

(13)Housing Industry Dynamics, 1983.

(14)Housing Industry Dynamics, 1983.

(15)Housing Industry Dynamics, 1983.

(16)Housing Industry Dynamics, 1983.

(17)Skog and Watterson, pp. 81-82.

(18)"Industry Profile: The Solid Fuel Retailer," p. 34.

(19)Skog and Watterson, pp. 81-82.

(20)"States News." Wood 'n Energy, February 1983, pp 62-63.

(21)"New York Study Hails Wood Heat's Impact." Wood 'n Energy, January 1984, p. 9.

(22)Skog and Watterson, p. 86.

(23)"New Study Cites Increased Wood Use," pp. 9-10.

(24)Personal Communication, Gus Walgren, June 26, 1984.

(25)Jay Shelton and Andrew B. Shapiro, The Woodburner's Encyclopedia (Waitsfield, Vermont: Vermont Crossroads Press, August 1979), p. 96.

(26)Skog and Watterson, p. 83.

(27)Skog and Watterson, p. 84.

(28)Skog and Watterson, p. 85.

(29)Skog and Watterson, p. 85.

(30)Skog and Watterson, p. 81.

(31)"Industry Profile: The Solid Fuel Retailer," p. 34.

(32)"Industry Profile: The Solid Fuel Retailer," p. 35.

(33)Del Green Associates, "Residential Wood Combustion Study: Task 2B - Household Information Survey, Final Report" (Prepared for U.S. Environmental Protection Agency Region X (10), Seattle, Washington, February 1984), p. 9.

(34)Skog and Watterson, p. 83.

(35)Don Wichert, "Residential Wood Burning and Air Quality in Wisconsin: An Overview," ed. Barbara Samuel, Department of State Energy, March 1981.

(36)Correspondence, Don McGuire, Indiana Department of Natural Resources.

(37)Fuelwood Use in Michigan Homes: 1981-82 Survey Results. Lansing, Michigan: Department of Natural Resources--Forest Management Division.

(38)Minnesota Residential Fuelwood Demand Study, 1979-80. Minnesota Department of Natural Resources, Forestry, October 1981.

(39)Ohio Fuelwood Production and Marketing. (Kent, Ohio: Davey Environmental Servi es, June 1983), p. 32.

(40)Ohio Fuelwood Production and Marketing, p. 11.

(41)Ohio Fuelwood Production and Marketing, p. 70.

(42)Wichert, p. 1.

(43)Wichert, p. 2.

(44)U.S. Forest Service, Northeastern Area, State and Private Forestry.

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IV. EMISSIONS FROM RESIDENTIAL WOODBURNING

A. THE WOOD COMBUSTION PROCESS

Wood combustion is a complex physical-chemical process in which the hydrogen and carbon in the fuel are chemically combined with oxygen to form combustion products and to release heat energy.(1) Understanding the causes of and solutions to air emissions and related health and safety problems requires some understanding of the combustion process.

1. Stages of Combustion

Wood combustion takes place in four stages which are consecutive in a given log, but which can occur concurrently within a given woodstove fire chamber. These stages are detailed in Table 4.1.

TABLE.4.1. STAGES OF WOOD COMBUSTION. (PRIMARY.)

Temperature	Reaction
Below 395 degrees F	Water and noncombustible gases are given off.
395 - 535 degrees F	Both combustible and non combustible gases are given off; slight reaction to give off heat, but no flaming.
535 - 900 degrees F	Gases given off become ignitable and flaming occurs.
Above 900 degrees F	All gases and tars have been given off and remaining charcoal glows.

(2)

a. Stage 1: Moisture Evaporation

When wood is heated, the moisture in it evaporates to form steam. The evaporation of the water uses energy from the combustion process, thereby lowering the temperature in the combustion zone. This slows the combustion process. Research has shown that the combustion process cannot be maintained if the wood moisture exceeds 68%.(3) The wet wood requires so much energy to evaporate the water that the wood temperatures fall below those required to sustain combustion. Therefore, the moisture content of the fuel (seasoned wood vs. "green" wet wood) is a key variable.

b. Stage 2: Pryolysis

Pyrolysis involves the chemical decomposition of the wood molecules into other types of molecules because of the high temperature. As the temperature rises, combustible gases are produced. Pyrolysis begins about 100 degrees C., producing water, carbon dioxide, carbon monoxide and some low molecular weight organic acids. When it rises to about 280 degrees C. the gases generated contain heavier organic materials and wood tar (creosote) droplets. The wood will not burn until pyrolysis occurs.(4)

c. Stage 3: Gas Vapor Burning

In the early stages of woodburning, the gases near the surface of the wood will not ignite because of high concentrations of carbon monoxide and water vapor. As the rate of pyrolysis and the temperature increase, combustion can occur in the presence of oxygen. Combustion becomes more rapid when the temperature rises and turbulence mixes oxygen into the fire. Heat is generated from the burning of the gaseous hydrocarbons and carbon monoxide.

d. **Stage 4: Char Burning**

During the combustion process, the charred surface of the wood does not actually burn until oxygen comes directly into contact with the charcoal on the wood surface. This can occur only when pyrolysis and moisture evaporation have occured and the flow of gases coming out of the wood has subsided.(5)

The rate of heat release and the formation of pollutants depends on these four processes and the rates at which they occur. In wood stoves these processes all occur simultaneously within the combustion chamber.

If burning conditions are "perfect", complete combustion occurs and all of the carbon is combusted to carbon dioxide and all of the hydrogen is combusted to water with a "liberation" of energy. Complete combustion depends on the following "Three T's":

-- **Time** for the combustion reaction to occur
-- **Temperature** high enough to maintain combustion
-- **Turbulence** enough to allow sufficient mixing of oxygen and fuel.

However, complete combustion does not occur in woodburning appliances, and particulate matter, carbon monoxide, hydrocarbons and other gases are formed. These are emitted as contaminants, polluting the air. The more complete the combustion, the fewer are the emissions and more energy is available in usable form. (Complete combustion requires a combustion zone temperature over 1100 degrees F.) (6)

2. **Combustion Variables**

Combustion efficiency (in thermal, not catalytic, combustion) increases when the fuel burn rate increases.(7) The fuel burn rate indicates how rapidly the charge is being burned while the combustion efficiency indicates the completeness of the combustion reaction. If the fire burns rapidly both the temperature and turbulence (mixing of air with the fuel) usually increase, and combustion efficiency increases. There are a number of variables which affect the fuel burn rate.

3. **Air (Oxygen Supply)**

Residential wood burning equipment is designed so that the fuel is "overfed". That is, fresh wood is placed on top of the burning fuel bed. The air supply for the combustion process comes from **primary air**, which is fed under the bed (or fireplace) grate and **secondary air** which is introduced above the fuel bed. The primary air controls the rate of combustion. A deficiency or excess of primary air (oxygen) will reduce the fuel bed temperature and the rate of combustion. The secondary air controls the combustion efficiency by oxidizing unburned or partially burned combustible materials emitted from the fuel bed. (It requires 5.7

pounds of air to burn 1 pound of dry wood - i.e., the correct proportion for proper combustion.)

Overfeeding results in the interruption of the combustion process and the incomplete mixing of oxidation products. It interferes with secondary combustion, which requires enough fuel to mix with incoming oxygen at a high temperature (at least 1100 degrees F.) to support combustion of the fuel gases. It is very difficult to achieve secondary burning in most woodstove appliances, primarily because most consumers operate their woodstoves at reduced temperatures. If the woodstove is too large for the space it occupies, the heat output will be uncomfortable to the operator, so the firing rate is reduced, resulting in the lowering of combustion temperatures and secondary combustion ceases. Fuel and firing techniques used by the stove operator are also important combustion variables. These include wood species, moisture content, size and frequency of the fuel charge and are discussed in the emissions section of this guidebook.(8)

When incomplete combustion of fuelwood occurs, organic molecules (most of which are toxic) and inorganic molecules are emitted. As the fire proceeds, the flame tends to become more unstable and to burn less efficiently as a char layer is formed causing the pyrolysis products to escape to the atmosphere without having been combusted. Creosote is deposited in the stovepipe and chimney as it cools and condenses, providing the basis for a chimney fire if the chimney is not cleaned regularly. The following section of the guidebook addresses the emissions from residential wood combustion, and their potential environmental and health effects.

B. THE IMPACT OF WOOD FUEL CHARACTERISTICS AND THE COMBUSTION ENVIRONMENT ON EMISSIONS

There are two basic categories of wood: softwoods and hardwoods. The composition of these woods plays an important role in residential combustion and the resulting emissions. Materials present in wood include:

- carbohydrates (cellulose)
- terpenes
- alcohols
- inorganic constituents
- phenolic substances (lignin)
- aliphatic acids
- proteins

Cellulose (a carbohydrate) and lignin (a phenolic compound) make up more than 90% of wood substance, with the lignin composition ranging from 15-30%.(9) Unlike the hardwoods, softwoods contain a relatively large amount of resin. Unburned and partially combusted resins present in softwoods tend to condense in flues and form a creosote that is very difficult to remove.(10) Except for the resin and lignin content, all hardwoods and all softwoods are chemically similar.

The elemental composition of wood, regardless of species is about 50% carbon, 6% hydrogen and 44% oxygen, on an ash-free/moisture-free basis. Sulfur content is often undetectable and nitrogen content is usually less than 0.5%. Ash content of dry wood rarely exceeds 5% on a dry weight basis.

Mineral constituents vary between species and between trees within a species. Key minerals found in wood are: calcium, potassium, magnesium, phosphates, and silicates.

Volatile content of wood ranges from 60 to 80% on a dry weight basis, so it has a low ignition temperature and rapid heat release. Dry wood has a higher heating value than an equal volume of the same type of green wood. If green woods must be burned, better results are obtained by burning them in combination with dry wood. Moisture content can range from 10-50%, but averages about 20% for air-dried wood.(11)

1. <u>Variables</u>

There are a number of variables that affect the amount and type of emissions produced during the wood combustion process in woodstoves. The chemical makeup of wood, its physical condition when burned and its combustion environment all play a role in emissions production. Table 4.2 on the following pages describes the variables that have been determined to have an impact on emissions. The way in which these variables affect emission rates is also presented.

TABLE 4.2. VARIABLES AFFECTING RESIDENTIAL WOOD COMBUSTION EMISSIONS.

VARIABLES	IMPACT OF VARIABLE ON EMISSIONS
1. Moisture content of wood	* Green wood has the potential to produce somewhat reduced emissions because the moisture retards wood heat-up and hence volatilization of gases. However during residential woodburning, green wood generally reduces burn rate so much that the increase in emissions due to low burn rate more than offsets the green wood effect. Therefore, green wood generally increases emissions. * Overly dry wood (less than about 15% moisture) causes emissions to increase due to very rapid volatile release (too rapid a release rate for consumption by the fire). * Externally dried wood (20-25% moisture) produces lowest emissions in most cases.

(Table 4.2 continued.)

2. Burn rates/temperature	* For conventional stoves emissions increase as the burn rate decreases in an exponential manner. * The distribution of organic compounds in total emissions shifts from predominantly large creosotic particulate matter to finer sized more volatile organics as burn rate increases. High technology catalytic burning produces the latter effect but at all burn rates.
3. Time	* In conventional stoves about 50% of particulate pollution is produced within about the first quarter of the burn cycle.
4. Log Size	* Log size (diameter) has a large effect on emissions. Surface area to wood volume is the key factor - the greater the surface area to volume, the greater the emissions. When a high percentage of surface area is exposed to the fire, a large amount of gases are given off which flow up the chimney unburned. Thin logs have a large surface area to volume ratio and therefore produce a large amount of emissions when burned. <u>Log size has a greater effect on emissions than any other wood fuel characteristic.</u> Twigs and large amounts of kindling should be avoided as well as "slab wood".
5. Wood Load Size	* Emissions are generally proportional to the weight of the wood load. Therefore, small loads are preferred from an emissions and creosote standpoint. However it is difficult to convince homeowners to do this because burn time is shortened.
6. Wood Species	* Pitchy pines produce the highest emissions. Hardwoods and non-pitchy pines vary little except low density woods release volatiles faster than denser woods.

(Table 4.2 continued.)

7.	Variation in heating requirements due to house size, age and insulation.	* Well insulated energy efficient houses often produce high emissions and creosote due to low burn rates. These homes will benefit the most from high technology catalytic stoves.

This Table was prepared from data presented in the following sources: a) Stockton G. Barnett and Damian Shea, "Effects of Wood Stove Design and Operation on Condensable Particulate Emissions"; p. 228, 253-254. b) B. R. Hubble, et al., "Experimental Measurements of Emissions From Residential Wood-Burning Stoves", pp. 100-101. c) John F. Kowalczyk, Peter B. Bosserman and Barbara J. Tombleson, "Particulate Emissions From New Low Emissions Wood Stove Designs Measured by EPA Method V", p. 71. All articles found in: Residential Solid Fuels--Environmental Impacts and Solutions, ed. John Cooper and Dorothy Malek (Beaverton, Oregon: Oregon Graduate Center, 1982).

C. CHARACTERISTICS OF WOOD COMBUSTION EMISSIONS

1. Emissions Are a Problem

Residential wood combustion results in a number of atmospheric emissions and a solid residue. The atmospheric emissions include particulates, nitrogen oxides, carbon monoxide, volatile hydrocarbons, polycyclic organic materials (POMs), aldehydes, benzo(a)pyrenes and mineral constituents. The solid residue includes inert materials in the fuel (ash), unburned or partially burned wood and materials formed during combustion (creosote). The incomplete combustion of fuel results in production of the carbon monoxide and most of the particulate matter. Nitrogen oxides come from both fuel nitrogen and the combining of atmospheric nitrogen with oxygen in the combustion zone. Mineral constituents in the particulates are released from the wood matrix during combustion. Polycyclic organic materials (POMs) result from the combination of free radical species formed in the flame. Synthesis of these molecules is dependent upon a number of combustion variables.

The sulfur and trace metal content of wood are not large enough to pose air pollution problems. Wood ash is relatively non-toxic (due to its high potassium content, it has been used as a beneficial soil additive). The toxicity of wood smoke is due primarily to incomplete combustion of the pyrolysis products of cellulose and lignin.(12)

Wood combustion in airtight "controlled burn" stoves is similar to a cigarette burning. Smoldering combustion of plant material results in the production of large amounts of carbon monoxide and the synthesis of over 100 or more organic materials. The organic materials are emitted in both gaseous and condensed particulate forms.

Based on emissions testing reports, it is evident that carbon monoxide and particulate emissions from wood burning are substantially greater than from oil or gas heating. For example, particulate emissions per unit of wood heat are 25 times greater than per unit of oil. Table 4.3 on the following page shows a comparison of emissions from residential energy sources for pollutants covered by national and state ambient air quality standards.(13)

TABLE 4.3. EMISSIONS DATA FOR WOOD COMBUSTION.

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EMISSIONS DATA FOR WOOD COMBUSTION

Wood burning device	Wood type	Wood burning rate,[a] kg/min	Flow rate[b] Nm³/min	Emission factor, g/kg (g/MJ): Particulates[c]	Condensable organics[d]	Volatile hydrocarbons[e]	NO_x[f]	SO_x[g]	CO[h]	POM[i]
Fireplace	Seasoned oak	0.18	6.5	2.3 (0.13)	6.3 (0.35)	19 (1.1)	2.4 (0.13)	j	30 (1.7)	0.025 (0.0014)
Fireplace	Green oak	0.17	6.4	2.5 (0.19)	5.4 (0.40)	j	1.9 (0.14)	j	22 (1.6)	j
Fireplace	Seasoned pine	0.19	6.5	1.8 (0.10)	5.9 (0.32)	j	1.4 (0.08)	j	21 (1.2)	j
Fireplace	Green pine	0.16	6.5	2.9 (0.21)	9.1 (0.67)	j	1.7 (0.13)	j	15 (1.1)	0.036 (0.0026)
Baffled stove	Seasoned oak	0.14	1.5	3.0 (0.17)	4.0 (0.22)	j	0.4 (0.02)	j	110 (6.2)	0.21 (0.012)
Baffled stove	Green oak	0.11	0.9	2.5 (0.19)	3.8 (0.28)	j	0.7 (0.05)	j	120 (9.0)	j
Baffled stove	Seasoned pine	0.12	1.0	3.9 (0.21)	4.1 (0.23)	2.8 (0.15)	0.5 (0.03)	j	270 (15)	0.37 (0.020)
Baffled stove	Green pine	0.10	2.0	7.0 (0.51)	12.0 (0.88)	j	0.8 (0.06)	j	220 (16)	j
Nonbaffled stove	Seasoned oak	0.13	0.9	2.5 (0.14)	6.0 (0.34)	j	0.4 (0.02)	0.16 (0.01)	370 (21)	0.19 (0.011)
Nonbaffled stove	Green oak	0.11	0.9	1.8 (0.13)	3.3 (0.25)	0.3 (0.02)	0.5 (0.04)	j	91 (6.8)	j
Nonbaffled stove	Seasoned pine	0.12	0.9	2.0 (0.11)	5.6 (0.31)	j	0.2 (0.01)	0.24 (0.02)	150 (8.2)	j
Nonbaffled stove	Green pine	0.13	0.8	6.3 (0.46)	10.0 (0.74)	3.0 (0.22)	0.4 (0.03)	j	97 (7.1)	0.32 (0.024)

[a]Average burning rate during EPA Method 5, POM, and SASS train operation.

[b]Determined from average EPA Method 5 data.

[c]Front half of EPA Method 5 and POM train. Averaged when two values available.

[d]Back half of EPA Method 5. Averaged when two values available.

[e]GC/FID

[f]EPA Method 7. Average of 6 grab samples.

[g]EPA Method 6.

[h]EPA Method 3 (ORSAT) for stoves; average of 10 samples. Dräger tube for fireplace; 15 to 30 minute composite.

[i]POM train (EPA Method 5 modified with XAD resin trap).

[j]No data obtained.

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The particulates emitted by residential woodstoves may affect regional visibility and cause deterioration of the quality of regional airsheds under the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act Amendments of 1977.

Our study has indicated that concentrations of residences (400-500 residences per square km in a concentration of 4 or more km) using wood heating will tend to produce particulate emissions exceeding ambient air quality standards, when adverse meteorological conditions exist.(14)

In addition to the pollutants for which air quality standards presently exist, wood smoke contains other materials, "non-criteria pollutants", which are recognized as toxic or carcinogenic for which no ambient air standards have been established. Table 4.5 on the following page indicates some of these emissions. (See following discussion on clean air act.)

a. <u>Indoor Air Pollution</u>

While a limited amount of testing has been done to determine pollutant levels in wood burning residences, there is some evidence that the same pollutants emitted to the outside air are found at elevated concentrations inside. A study done by P. L. Moschandreas (17) found that average total suspended particulate (TSP) concentrations during wood burning periods were about three times TSP concentrations during non-woodburning times. Both primary and secondary air quality standards for TSP were exceeded indoors by respirable particulates (RSP) less than 2.5 microns in diameter. Indoor Benzo(a)pyrene (BaP) concentrations during woodstove use were five times higher than during non-wood burning periods. During the stoking of woodstoves, elevated levels of carbon monoxide were identified. While these results are from a limited series of tests, they should be considered. The potential impacts from such elevated concentrations of TSP, RSP, and BaP may have long term health implications.(18) It is known that improper installation or use of a woodstove can result in dangerous concentrations of carbon monoxide. More research is required to determine if there are significant health effects from NOx and POM emissions in the indoor environment.

Indoor air pollution caused by woodstove emissions is of particular concern when the home is well insulated and tightly constructed with limited outside air exchange. There is an increased concern about health effects of indoor air pollution due to off-gassing from various building and construction materials (i.e. formaldehyde glue/resins used in paneling and furniture, urea formaldehyde foam insulation, vinyl chloride plastics, etc.) used in the home. The specific and the additive or synergistic effects of carbon monoxide, benzo (a) pyrene and other particulate hydrocarbons should be identified and evaluated.

TABLE 4.4. CARCINOGENIC COMPOUNDS OBSERVED IN SMOKE FROM RESIDENTIAL WOOD COMBUSTION SOURCES.

Compound	Carcinogenic Activity[a]	Emission Factors (g/kg)	
		Stove	Fireplace
Dimethylbenzanthracene	++++		
Benz(a)anthracene	+	.0177	.0019
Dibenzanthracene		.0010	.00018
Dibenz[a,h]anthracene	+++	*	*
Dibenz[a,c]anthracene	+	*	*
Benzo[c]phenanthrene	+++	.0025	.008
Benzofluoranthenes		.0135	.0019
Benzo[b]fluroanthene	++	*	*
Benzo[j]fluoranthene	++	*	*
Methylcholanthene		---	---
3-methylcholanthene	++++	*	*
Benzopyrenes		.009	.0015
Benzo(a)pyrene	+++	.0025[c]	.00073[c]
Indeno(1,2,3-ed)phyrene	+	---	---
Chrysene	±	b	b
Dibenzopyrenes		.0007	.0004
Dibenzo[a,l]pyrene	high	*	*
Dibenzo[a,h]pyrene	+++	*	*
Dibenzo[a,e]pyrene	+++	*	*
Dibenzocarbazoles		---	---
Dibenzo[a,g]carbazole	±	*	*
Dibenzo[c,g]carbazole	+++	*	*
Dibenzo[a,i]carbazole	±	*	*
TOTAL		.038[d]	.0059[d]

* These compounds were not specifically identified except as a group.

a Based on classification as follows: ± uncertain or weakly carcinogrnic; + carcinogenic; ++, +++, ++++, strongly carcinogenic.

b Included in the benz(a)anthracene number.

c Not to be exceeded more than once per year.

d Total will be upper limit because of the inclusion of some noncarcinogenic isomers included in the general classes measured. The benzopyrene class value was not used, only the benzo(a)pyrene value.

Source: Cooper, John, "Environmental Impact of Residential Wood Combustion Emissions and Its Implications", paper presented at the Wood Energy Institute Wood Heating Seminar VI, Atlanta, GA, (Feb. 1980).

2. **Key Woodburning Emissions**

a. **Particulates.**
Residential woodburning particulate emissions are dominated by condensed droplets of hydrocarbons. Minor inorganic ash and carbon char are also present.

Emissions from fireplaces are lower than those of woodstoves on a gm/kg basis (weight of particulate matter per weight of fuel burned). They average about 13 gm/kg.(19) But because fireplaces burn at a more rapid rate than woodstoves, their atmospheric loading (about 70 mg/hr) is generally higher than woodstoves. However, fireplaces are usually burned for only a short period of time so a fireplace's total loading per day is generally much less than that of a woodstove.

Particulate emissions from woodstoves range from 1.0 gm/kg to over 70 gm/kg. Recent research by Oregon's Department of Environmental Quality has demonstrated that average-sized airtight woodstoves emit about 35 gm/hour of particulates using a test method which heavily weights emissions values at stove outputs of 10,000 to 15,000 Btu/hr (the most common output range in temperate to north temperate climates). By contrast, high technology catalytic stoves average less than 4 gm/hr.(20)

TABLE 4.5. COMPARATIVE STOVE TEST SUMMARY

Stove Make	Model	% Efficiency[1]	Heat Output (Btu/hr) Lowest - Highest	Emissions[2] (gm/hr)	Maximum Burn Time[3] (@10,000 Btu/hr)
Arrow	ATS	69.82	8,795 - 28,902	13.6	10.1 hours
Blaze King	King Cat KEJ 1101	76.83	9,954 - 35,691	1.6	27.4 hours
Country Comfort	CC 600	66.10	9,795 - 31,925	30.7	14.5 hours
Earth Stove	1000C	77.13	11,061 - 24,282	3.3	15.9 hours[4]
Kent	Tile Fire Mobile Home	62.57	9,416 - 31,761	19.5	10.9 hours
Lopi	440T	64.13	18,590 - 36,058	17.4	4.7 hours[4]
Sweet Home	Noble Fir	60.43	7,875 - 60,455	34.1	10.2 hours
Vermont Castings	Vigilant	58.08	6,788 - 31,658	37.3	11.4 hours

Notes: 1) Averaged at three points (10,000, 20,000, and 30,000 Btu/hr).
2) Oregon weighted averages
3) Calculated from tested efficiency and cord wood loading (+ 15%)
4) Actual tested lowest burn rate and cord wood loading (± 15%)

(From: Omni Environmental Services;Memo, August 31, 1934 to Woodcutters Manufacturing Services.)

The data in Table 4.5 above is illustrative. It was obtained by an Oregon DEQ certified test laboratory, Omni Environmental Services, in tests performed on a range of stoves that included both conventional and catalytic stoves.

It has been shown that approximately 70% of the particulate emissions are less than 5 microns in diameter, with 50% being less than 2.5 microns in diameter. Particulates smaller in diameter than 2.5 microns are respirable particulates, not filtered by the lung cilia. Particles larger than 2.5 microns entering the human respiratory system are usually deposited in the upper respiratory system which is lined with cilia and bathed in mucus. The cilia move mucus and entrapped particles up to the pharnyx where it is swallowed.

Particles smaller than 2.5 microns tend to deposit deeper in the lungs where there are no cilia and where passages are not bathed in mucus. These particles are not removed as quickly as the larger particles. The longer retention time allows smaller particulates more time to dissolve, react and act as an irritant, so they tend to become more toxic than larger particles.(21) Impacts on the population at risk (the most sensitive members) and on the general population from woodburning particulate emissions need to be assessed. The rate of emission of fine particulates is affected by a number of variables such as wood moisture content, type of fuel and combustion method used. (See Table 4.6.) A number of other substances emitted in the combustion process can adhere to the particulates.

TABLE 4.6. EMISSIONS FACTORS FOR CILIA TOXIC AND MUCUS COAGULATING AGENTS OBSERVED IN SMOKE AND FLUE GAS FROM RESIDENTIAL WOOD COMBUSTION SOURCES.

	Emission Factors (g/kg)	
Compound	Stoves	Fireplaces
Formaldehyde	0.2	0.4
Propionaldehyde	0.2	---
Acetaldehyde	0.1	---
Isobutyraldehyde	0.3	0.5
Phenol	0.1	0.02
Cresols	0.2	0.06

Source: Cooper, John, "Environmental Impact of Residential Wood Combustion Emissions and Its Implications", paper presented at the Wood Energy Institute Wood Heating Seminar VI, Atlanta, GA, (Feb. 1980).

b. **Sulfur oxides (SOx).**

Because sulfur content of wood is typically less than 0.1%, sulfur oxides are not of much concern as a wood combustion emission.(22)

c. **Nitrogen oxides (NOx).**

Formation of nitrogen oxides depends primarily on the fuel's nitrogen content, amount of excess air used, design of combustion equipment and the combustion temperature. Average NOx emission factors have been found to range from 0.2 gm/kg to 0.8 gm/kg for conventional woodstoves and from 0.8 gm/kg to 4 gm/kg for fireplaces.(23) Similar results were obtained for woodstoves (0.1 to 1.4 gm/kg) by the TVA Phase 2 project. Fireplaces emit about four times as much NOx per unit of wood burned as stoves. This may be due to the higher combustion temperatures and/or more excess air in fireplaces.

Preliminary results suggest that NOx emissions are raised slightly (due to combustion temperature increases) as smoke passes through the catalyst of catalytic stoves. The increase is small however, and since NOx emissions from residential woodburning are relatively low, no problem is expected. Catalysts can be used to reduce NOx effectively (so-called three way catalysts) but extremely precise control of excess air is necessary. With woodstoves, it is not worth the effort to remove the small amount of NOx that is present.

d. **Carbon Monoxide (CO).**

Carbon monoxide (CO) is a product of incomplete combustion and is a major pollutant emitted from woodburning stoves and fireplaces. Average emissions of CO are variable and range from 91 gm/kg to 370 gm/kg for conventional woodstoves and from 15 gm/kg to 140 gm/kg for fireplaces. CO formation appears to be very sensitive to changing fuel bed conditions.(24) Recent Oregon DEQ work indicates high technology catalytic stoves emit about 10 to 50 gm/kg.

e. **Major Organic Species.**

The US EPA Source Assessment study has identified more than 50 organic species in addition to polycyclic organic matter (POMs) in the flue gas from woodburning stoves and fireplaces. Organic species emitted were dominated by napthalenes, furans, phenols, cresols and aldehydes. Total organic emissions were based on individual speciations for each condition and ranged from 0.1 gm/kg to 2.6 gm/kg for conventional wood stoves and 0.46 gm/kg to .64 gm/kg for fireplaces. Results for high technology woodstoves will not be available until EPA's current (September 1984) study is complete. Most organic species are in particulate form. Analysis of total particulate matter has shown that benzene extractables range from 42% to 67% of the total particulate mass. About 45% of the mass of benzene extractable appears in the neutral fraction of acid-base extractions. Polycyclic aromatic hydrocarbons are included in the neutral fraction. Other fractions included in the analysis identified the carboxyllic acid fraction as 15%, phenol fraction as 40% and organic base fraction as 1%.(25) See Table 4.8 in the next section (D. HEALTH HAZARDS OF WOOD COMBUSTION EMISSIONS) for specific listing of major organic species present in woodsmoke.(26)

The type and moisture content of the wood provide key variables, with emissions being more than two times higher when burning green pine than other wood types tested. It must be noted that these early EPA woodstove tests were conducted at burn rates much higher than those used in homes and the results are not necessarily applicable. Work in progress by the EPA

(September 3, 1984) should provide more valid data since appropriate burn rates are being used.

f. **Aldehydes.**

Animal experiments have identified aldehydes as the poisonous agent in woodsmoke that causes pulmonary edema. Directly or indirectly they may be harmful to plants as well.(27) Many of the studies in a Department of Energy literature-review identified high wood combustion emission factors for formaldehyde, isobutyraldehyde, and other aldehyde compounds. (See Table 4.6.) Formaldehyde, now identified as a human carcinogen, is also a mucous membrane irritant. Formaldehyde and acetaldehyde are easily photolized into radicals that are extremely reactive in the atmosphere.(28)

g. **Polycyclic Organic Matter (POM).**

POM is a byproduct of most combustion processes and is associated with particulates of less than 0.5 microns in diameter.(17) POM compounds include three classes of known organic carcinogens. These are polynuclear aromatic hydrocarbons, polynuclear heterocyclic, oxygenated compounds and alkylating agents. POMs found in workplace environments have been shown to have specific physiologic effects. They can cause severe skin diseases and are carcinogens that target the lungs and skin. Only some POM species are carcinogenic. It is important to assess the relative abundance of POM species in any given pollution stream to evaluate potential hazard properly.

Due to their potential carcinogenicity, POMs are of particular concern. A total of 3,800 metric tons of POMs nationwide were emitted from residential wood combustion.(29) More recent work by the TVA (Phase 2 Project, 1983) indicated POM emission factors to average about 0.25 gm/kg for conventional stoves over a wide range of burn rates. Results were highly variable and the 95% confidence interval is plus or minus 50%. Using the 42 million cord/year figure, about 13,000 metric tons plus or minus 50 % are emitted annually in the U.S. This value considers that 25 % of firewood is burned in fireplaces which have a POM emission factor of .03 gm/kg.(30) Both recent studies' results differ greatly from the 217 metric tons previously reported by Eimutis et al in a 1978 Emissions Source Assessment. The EPA's current study should shed light on POM reduction from high technology catalytic stoves. TVA's phase 2 study of a moderately active catalytic stove suggested about a 70% reduction to .08 gm/kg. (See Table 4.7 at the end of this section.)

h. **Benzo (a) Pyrenes (BaP).**

Benzo (a) Pyrene emissions were estimated by the National Academy of Sciences to be 50 times greater from wood combustion than from oil combustion.(31) The 1972 study estimated that the largest source of BaP in the US were the inefficient combustion of coal (410 T/year) and wood (40 T/year) from hand-fired residential furnaces and stoves. (See Tables 4.7 at the end of this section and table 4.8 in Section D.)

The chemical half-life of Benzo(a)pyrene in the atmosphere is reported to be less than a day in the presence of sunlight and several days without it. (US EPA Multimedia Environmental Goals for Environmental Assessments Vol. II MEG Charts [E-242] and Background Information, November 1977.) Its association is with particulate polyaromatic hydrocarbons (PPAH). It is considered an active carcinogen and has been shown to cause chromosome abberations in mammalian cells. Experimental evidence also shows that it is a mutagenic and teratogenic agent in mice. Benzo(a)pyrene appears on the EPA Consent Decree list with a priority of 1. It has a TLV of 0.2 mg/m^3.

The recent research conducted by Michigan DNR in Mio and underway in a USEPA study indicates that BaP is of great concern in residential wood combustion emissions. While further study of the effects of this important indicator pollutant are needed, the data obtained to date is being used by USEPA as the basis for declaration of intent to regulate woodstove emissions.

TABLE 4.7. EMISSIONS OF MAJOR POLLUTANTS FROM RESIDENTIAL WOOD COMBUSTION SOURCES.

	Woodburning Stoves			Fireplaces		
Chemical Species	g/Kg wood	lbs/ 10^6 Btu[e]	Percent Parti- culates	g/Kg wood	lbs/ 10^6 Btu[e]	Percent Parti- culates
Carbon Monoxide	160.0 (83-370)	22.0	---	22.0 (11-40)	3.0	
Volatile Hydrocarbons	2.0 (0.3-3.6)	.28	---	19.0 ---	2.6	---
NO_x as NO_2	0.5	.07	---	1.8	.25	---
SO_x as SO_2	0.2	.03	---	---	---	---
Aldehydes	1.1	.15	---	1.3	.18	---
Condensable Organics	4.9 (2.2-14)	.67	58	6.7 (5.4-9.1)	.92	74
Particulates	3.6 (0.6-8.1)	.50	42	2.4 (1.8-2.9)	.33	26
Total Particulates	8.5 (1-24)[b]	1.2	100	9.1 (7.2-12)	1.3	100
Polycyclic Organic Mat.	0.3	.04	3.5	0.03	.004	0.3
Benzo (a) Pyrene[c]	0.0025	.0003	.03	0.00073	.0001	0.008
Carcinogens	.038	.005	.45	.0059	.0008	0.06
Priority Pollutants	0.41	.06	4.8	0.063	.009	0.7
Na[d]	.005	.0007	.06	.004	.0006	.04
Al[d]	.004	.0006	.05	.002	.0003	.02
Si[d]	.003	.0004	.04	.002	.0003	.02
S[d]	.03	.004	.4	.004	.0006	.04
Cl[d]	.05	.007	.6	.05	.007	.6
K[d]	.07	.01	.8	.05	.007	.5
Ca[d]	.004	.0006	.05	.005	.0007	.05
Organic Carbon[d]	4.2	.58	49	4.2	.58	46
Elemental Carbon[d]	.7	.1	8	1.2	.16	13

[a] Values noted are from DeAngeles etal.,

[b] Range is from Butcher and Sorenson,

[c] for fireplace - .0009 g/Kg or about 0.01%
for pine needles - .003 to .03% particulates
for leaves, grass, branches - .004%
Benzopyrenes/perylene: fireplace - .0015 g/Kg or about .016%
stove - .009 g/Kg or about .1%
Assume 1/3 of above is B(a)P and averaging fireplace values
yield 0.008% for fireplace and 0.03% for stove

[d] Values listed are based on average percentages reported by Cooper et al., . g/Kg values were calculated on the basis of the g/Kg values for total particulates listed above which are from DeAngelis et al.,

[e] 16,000 Btu/Kg.

(From: Cooper, Oregon Graduate Center.)

D. HEALTH HAZARDS OF WOOD COMBUSTION EMISSIONS

The US EPA Source Assessment on Residential Combustion of Wood shows that several woodburning pollutants are carcinogenic (cancer causing), mutagenic (cause genetic mutations) or highly toxic when ingested or inhaled.(34) It reports that of the more than 100 chemical compounds found in emissions from woodburning, fourteen were carcinogenic, four were co-carcinogenic (cancer initiators or promoters) and six were highly toxic to the respiratory and/or digestive tract cells. (See table 4.8.) Seventeen of the organic compounds appear on the US EPA's Priority List of 129 Toxic Pollutants.

The particulate emissions, which are the primary risk to public health, are the respirable pollutants which can enter the lungs and, if they are small enough (less than 2.5 microns in diameter) will lodge in lung tissue where they can cause or promote the development of asthma, emphysema, chronic bronchitis or cancer.

TABLE 4.8. INITIATING OR CANCER-PROMOTING AGENTS AND CO-CARCINOGENIC COMPOUNDS IN SMOKE FROM RESIDENTIAL WOOD COMBUSTION SOURCES

Compound	Emission Factors (g/kg) Stoves	Fireplaces
Catechol	0.01	0.014
Phenols	0.1	0.02
Pyrene	0.019	0.0016
Fluoranthene	0.022	0.0016

(From: Cooper, Oregon Graduate Center.)

The gaseous pollutants include NOx, carbon monoxide and hydrocarbons. Inhaled gases can be toxic to humans. Many organic gases can cause irritation to the skin, eyes and respiratory tract. Many of these gases can irritate body tissue or interfere with body chemistry. For example, carbon monoxide replaces oxygen in red blood cells and formaldehyde irritates respiratory passages and has been found to be a carcinogen.

The polycyclic organic materials (POMs) include some of the more potent carcinogens known. The level of cancer risk from POMs and other woodburning pollutants present at low levels in the environment is not clearly known as yet. The need for additional research on this problem is evident. For example, Portland, Oregon's Air Quality monitoring program has shown that 80% of all area POM emissions come from residential woodburning.(35)

Because no ambient air standards exist for fine particulates or for any chemical component of residential wood combustion emissions other than CO and particulates, the public health protection offered under the Clean Air Act does not fully apply. US EPA is now considering a total inhalable thoracic particulate (TTP-PM_{10}) standard for particles under 10 microns in diameter.(36) This standard would have the effect of causing woodsmoke (because of its relatively small particle size) to become a relatively larger percentage of total ambient particulates and hence become a more "important" pollutant. (See discussion under the section on the Clean Air Act.) This would impact state air quality management activities.

A potential long term impact from chronic exposure to residential wood combustion emissions is an increase in cancer incidence. (Note the number of carcinogens and co-carcinogens found in significant quantities in woodsmoke). A study by Cooper (37) provides additional evidence relative to the carcinogenicity of wood smoke:

- A 1975 study indicated that cancer of the skin in chimney sweeps is associated with soot.

- Cigarette smoke contains many of the same compounds found in wood smoke.

- Industrial workers exposed to strong carcinogens such as Benzo(a)pyrene (found in wood smoke) have elevated risks for lung cancer.

- The National Research Council finds that "It appears both reasonable and prudent to take as a working hypothesis the existence of a causal relation between air pollution and the lung cancer death rate for white males increases at the rate of a 5% increase for each increment of pollution as indexed by 1 benzo (a) pyrene (BaP) unit". (38)

In a study done by Robert H. Meyer of Oak Ridge National Labs (39) there was a prediction of 40 additional lung cancer deaths per 1,000,000 population in the center of a cluster of 2,000 residences, 10% of which use wood as a primary heat source. (A Minnesota Department of Natural Resources fuelwood survey done in 1979-80 provides data to show that 14% of Minnesota residences in cities under 2,500 burn wood as a major heat source).(40)

Ames tests done on wood particulate extracts indicate that because wood smoke contains is a strong mutagen when activated by liver enzymes, thus showing its potential as an animal carcinogen. Both more animal studies and human epidemiological studies need to be performed to determine more exact impacts of wood smoke on human health.

Table 4.9 on the following page shows source severity values with a ranking of potential environmental effects of pollutant emissions from wood burning systems. The severity value is shown as a ratio of a time-average maximum ground-level concentration to some "hazard" factor.(41) For emissions of Criteria Pollutants, the hazard factor used is the primary pollution standard (under NAAQS) and for noncriteria pollutants (toxic and hazardous pollutants) it is the applicable threshold limit value for occupation exposure converted into 24-hour values and reduced by an arbitrary factor. (See Section H, part 1.)

TABLE 4.9. EMISSIONS FROM RESIDENTIAL WOOD-FIRED STOVES.

Emission Parameter	Emission Range (lb/cord)	Average Emission Factor[a] (lb/cord)	Impact Severity[b]
Criteria			
Particulates	15-75	28.1	6
SO_x	0-1.5	0.7	1
NO_x	5-35	6.3	3
Hydrocarbons	10-90	29.7	4
CO	50-450	188.1	2
Noncriteria			
Organic species:			
Polycyclic organic materials	0.05-0.13	0.1	10
Formaldehyde	0.5-17	5.3	6
Acetaldehyde	0.5-4	2.3	5
Phenols	0.3-8	3.3	2
Acetic acid	5-48	21.1	4
Elements:			
Aluminum		1.3	2
Calcium		10.2	6
Chlorine		0.1	2
Iron		0.7	2
Magnesium		2.0	2
Manganese		1.6	3
Phosphorus		1.0	5
Potassium		3.6	6
Silicon		1.6	2
Sodium		0.7	3
Titanium		0.02	-

[a] Conversion factor of g/kg to lb/cord based on

[b] Impact severity is based on a scale of 1 to 10 with 10 being most severe. Rank was established by comparing the following ratios:

For criteria pollutants: Ratio of a time-average minimum ground-level concentration to primary NAAQS.

For noncriteria pollutants: Ratio of a time-average minimum ground-level concentration to 24-hour occupational TLV (reduced by a factor of 100).

(From: J. R. Duncan, et al., "Air Quality Impact Potential from Residential Wood Burning Stoves," Tennessee Valley Authority, February 1979.

Reliable data on pollutants other than particulates and carbon monoxide are not yet available and it may be years before it is. Additionally, while the effects of high dosage of the various pollutants are known in some cases, the effects of low dosages generally associated with ambient woodsmoke are not known. Only extrapolations have been made but the degree of non-linearity of effect is not known.

It is presently impossible to assess the risks associated with woodsmoke emissions. However, emissions from residential wood combustion sources should be considered a potential threat to public health because of their highly respirable nature, the presence of hazardous chemicals, the fact that they are emitted in residential areas exposing quite large populations, and the fact that these emissions are increasing.

Finally, research is needed to determine by comparison the relative detrimental effect of the various energy sources used for home heating - oil, gas, electricity, kerosene, nuclear, coal and wood. This needs to be related in terms of toxic emissions of the various contaminants weighted (or corrected) to net BTU of delivered home heat. (This includes pollution emitted during the mixing, manufacturing etc. of the heat source).

There is also a growing concern in Wisconsin which should be a concern everywhere: Many families in this state burn scrap lumber in wood stoves and fireplaces for home heat. Much of this scrap lumber has been treated with chemicals to preserve the wood, especially if the wood is intended to be used outdoors. When these treated woods are burned, they may give off dangerous gases.(42)

Four doctors from Wisconsin and Maryland have reported in a letter to The New England Journal of Medicine, reprinted in Wood 'n Energy, January 1984, that one family in rural northern Wisconsin had developed multiple health problems caused by the burning of scrap lumber that had been treated with chromate-copper-arsenate (CCA). The accumulation of high levels of copper, chromium and arsenic in the ash and dust in their home was found to be the cause of the problems.(43)

All members of the family had symptoms that included:

> conjunctivitis; bronchitis; pneumonia; sensory hyperesthesia of the arms and legs [extremely sensitive skin, painful when touched]; muscle cramps; dermatitis over the arms, legs and soles of the feet; nosebleeds, ear infections, "blackouts and seizures"; gastro-intestinal disturbances and severe alopecia [hair loss].(44)

The symptoms were most obvious during the winter and had a tendency to disappear during the summer and the youngest children, who were known to have played on the floor, had the most serious hair loss, at times becoming nearly totally bald, and the most severe skin and respiratory problems.(45)

Through investigation, it was discovered that there were high amounts of arsenic in the hair of the parents, "but only borderline levels in the children's hair."(46) There were also extremely high levels of arsenic in the fingernails of the entire family, which suggested the presence of arsenic in the house. When a criminal source of arsenic could not be

found, samples of dust, dirt and ash were collected from the living area of the house and were found to contain "extremely high levels of copper, chromium, and arsenic (600, 1350 and 2000 ppm, respectively).

After the discovery of the contaminants in the household atmosphere, it was found that the father had been using a small wood-burning stove to heat the living area and the kitchen. Becuase they were easily available and burned extremely well, scraps of CCA-treated (outdoor grade) wood and plywood had been burned over any other type of wood. (The wood treating industry has warned against the use of treated woods as fuel as they are well aware of the hazards of burning CCA-treated wood.) Drs. Peters, Croft, Woolson and Darcey "cannot be certain to what extent each of the three elements was responsible for the broad spectrum of signs and symptoms in this family, since all three elements are known to be toxic and synergistic effects are probable."(47)

This incident appears to be an isolated one at this time; however, the popularity of woodburning is increasing, and this type of problem would not be unlikely to develop if scrap lumber were burned in homes.

E. MEASURING EMISSIONS: MONITORING AND TESTING

1. Ambient Air Monitoring of Residential Wood Combustion Emissions

Emissions from residential wood combustion substantially increases ambient air pollution under certain conditions. In particular, they contribute to existing levels of carbon monoxide, particulates, and carcinogenic compounds such as benzo(a)pyrene, causing public health risks and/or exceeding air quality standards. Maintenance of acceptable air quality may require monitoring of residential wood combustion emissions. There are two general types of source apportionment modeling that provide the basis for such monitoring currently in use. These are **source-dispersion modeling** and **receptor modeling**. A brief description of these two types is provided as background for ambient air quality monitoring of residential wood combustion emissions. This might be done if an area determines to modify a **State Implementation Plan** to include residential emissions or if a local jurisdiction wishes to develop a strategy to determine alternatives for developing residential-industrial trade-offs of specific pollutant loadings, so new development can occur. If a problem with residential wood combustion emissions must be quantified, ambient air emissions modeling might also be beneficial.(48)

Source-dispersion modeling involves direct sampling of stack emission rates or may only involve a telephone survey of woodburning residences to estimate the amount of residential wood combustion emissions. This information is then used in combination with meteorological dispersion parameters (wind speed and direction, mixing height, etc.) to predict the impact of wood combustion on ambient air quality within that region. Dispersion modeling is subject to a great deal of approximation though because of such factors as low stack heights, the impact of low inversion heights, the great number of variables random in nature which vary with time and space, and the non-linear manner in which the variables interact.

In **receptor modeling**, on the other hand, the characteristics of residential wood combustion particulates have been previously determined. From analysis of ambient air particulate samples that are collected on a filter, the contribution of residential wood combustion emissions to total ambient air pollution can then be determined by **either microscopic or chemical** methods. The **microscopic** approach utilizes optical and electron microscopes to both qualitatively and quantitatively analyze particulate emissions. Density and number of particulates may be estimated, while examination of morphology, color, and elemental contents allows for specific particulate identification. An inventory of "microscopic fingerprints" based on morphology, color, and elemental content is currently maintained as a source for comparison to aide in identification. The major limitations of the microscopic approach include poor precision, small size of organic residential wood combustion emissions, and high cost of analyzing a sufficient quantity of particles.

The **chemical approach** to receptor modeling involves the comparison of ambient chemical patterns with source chemical patterns to pinpoint sources of aerosols. A least squares multiple regression analysis is used to quantify the source contributions as obtained as a total mass on different collecting filters or as a mass of individual chemical species on a single collecting filter. The two categories of chemical analysis of emissions include: 1) **chemical mass balance** methods which "attempt to define the most probable linear combination of sources to explain chemical patterns on a single filter"(49) and 2) **multivariate methods** which "attempt to define the most probable linear combination of sources to explain either time or spatial variability in ambient chemical patterns."(50) Chemical mass balance methods provide a high degree of confidence in impact projections. Both mass balance and multivariate methods should be included in data interpretation.

Each specific analytical method has its advantages and disadvantages. The cost effectiveness and appropriateness of the analytical tools depend on airshed characteristics, potential sources, relative contribution of residential wood combustion sources, the desire to characterize most of the mass, the need to measure key indicating features, and compatibility with the sampling substrate. Information obtained from a single analytical approach many not be sufficient to quantitatively relate emissions source to ambient air impact, therefore, it may be valuable to utilize a combination of methodologies to compare and evaluate estimates. Table 4.10 on the following pages summarizes the advantages and disadvantages of the analytical methods described above.

TABLE 4.10. ANALYTICAL METHODS FOR EVALUATING THE AMBIENT AIR QUALITY IMPACTS OF RESIDENTIAL WOOD BURNING.

X-RAY FLOURESCENCE

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
+ low cost + precise and accurate if appropriately validated + capable of measuring most abundant inorganic species and common key indicating elements + 30 to 40 elements usually analyzed	- possible destruction of more volatile compounds prevalent in residential wood combustion (RWC) compounds - provides less competitive sensitivities for higher atomic numbers than monochromatic photon excitation	* maximum information obtained when membrane-type filters used * quartz fiber hi-vol filters used for quantitative determination of elements above atomic number 20

NEUTRON ACTIVATION ANALYSIS

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
+ 40 to 50 elements can be analyzed + may be essential in some airsheds to measure key indicating elements + independent of filter absorption effects	- high cost	* can be applied to high purity quartz fiber filters

ION CHROMATOGRAPHY

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
+ when used with X-ray flourescence uniquely identifies: SO_4^{-2}, NO_3^-, NH_4^+, and Na^+.	- NH_4^+ accurately quantified once in solution but difficult to interpret in terms of ambient concentration due to artifacts and potential losses - cation analysis for only Na^+ is not cost effective - NO_3^- and SO_4^{-2} difficult to interpret when samples collected on glass fiber filter because of chemical artifacts - SO_4^{-2} analysis of limited value in RWC studies	****

ATOMIC ABSORPTION SPECTROPHOTOMETRY AND INDUCTIVELY COUPLED ARGON PLASMA

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
+ excellent technique for analysis of solutions + valid results for V, Mn, and Pb with normal glass fiber hi-vol filters	- limitations when applied to aerosol samples - inadequate detection limits for some key elements - difficulties in solubizing the sample - high costs relative to X-ray flourescence - destructive nature	****

ORGANIC, ELEMENTAL, AND CARBONATE CARBON ANALYSIS BY COMBUSTION METHODS WITH PYROLYSIS CORRECTION

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
+ accurate separation of these three major carbon components + useful in apportioning contributions of RWC and resolving this source of carbonaceous material from others such as diesel exhaust	- limited applicability to amorphous carbonaceous material such as in RWC	****

(Table 4.10 continued.)

OPTICAL MICROSCOPY

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
distinguishes between organic particles such as coal, oil soot, starch, tire fragments, pollens, spores, paper fibers, etc. when greater than 2 um	- difficult to quantify - most RWC particles are less than 2 um	****

SCANNING ELECTRON MICROSCOPY

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
+ provides morphological and elemental information about individual particles + range of a few hundreths of a micron thus applicable to fine RWC emissions	- expensive - limited applicability to RWC studies because emissions highly carbonaceous	

LIQUID CHROMATOGRAPHY

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
+ less expensive + applicable to higher molecular weight compounds likely to be more stable in transport from source to reactor	****	* has not been used extensively for RWC studies

GAS CHROMATOGRAPHY-MASS SPECTROMETRY

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
+ capable of characterizing large number of the more volatile compounds	- costly - interpretation of results difficult due to likelihood of deviations from conservation of mass as a result of compound reactivity and portioning between gaseous and particulate phases - usually addresses only small portion of total organic aerosol - many of compounds produced in combustion of other organic material; depends strongly on temperature of combustion and available oxygen	****

X-RAY DIFFRACTION

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
+ applicable to a variety of relatively stable compounds + selectivity and sensitivity for determination of geological or crustal compounds	****	* quantitative analysis requires summation of mass for specific particle classes and this depends on an estimate of particle volume and density for between 1,000 to 10,000 particles * applicable to hi-vol filters but particles must be removed by vacuum or ultrasonic methods

(Table 4.10 continued.)

RADIOCARBON ANALYSIS

ADVANTAGES	DISADVANTAGES	GENERAL INFORMATION
* excellent for distinguishing between fossil carbon sources such as diesel and distillate oil emissions and modern carbon sources such as RWC emisssions	- large samples required to be a precise indicator of modern carbon (although Currie, et al. have obtained accurate results with as little as 5 mg of carbon)	* "modern" carbon sources are younger than C-14 half life (5730 years) and "fossil" carbon sources are older than C-14 half life
* concentration of C-14 in atmosphere is approximately constant with time		* fraction of modern carbon = observed aerosol radiocarbon activity / activity in pure source of modern carbon
		* in spite of the large number of potential modern carbon sources, they can be separated from PVC aerosols by: size--collect only fine particulates; time--collect during winter when natural carbon sources are minimal or when other combustion events are not permitted
		* samples must be collected with a size selective hi-vol sampler to eliminate large particle carbon (pollen, spores, wood fibers, etc.) although normal hi-vol samplers are adequate if microscopic analyses confirm minimal large size modern carbon impact
		* method expensive when applied to small carbon samples with 24-hour hi-vol samplers but cost minimized by compositing filters for a seasonal average

(Data obtained from: John A. Cooper, "Chemical and Physical Methods of Apportioning the Contributions of Emissions from Residential Solid Fuels to Reductions in Air Quality," and Frederick W. Lipfert, "An Assessment Methodology for the Air Quality Impact of Residential Wood Burning." Both articles found in: Proceedings of the 1981 International Conference on Residential Solid Fuels: Environmental Impacts and Solutions (Beaverton, Oregon: Oregon Graduate Center, 1981).

2. Measuring Emissions

a. Woodstove Testing Protocol for Measuring Emissions

There are two major components of testing protocol that must be considered when developing a wood stove certification or emissions labeling program. One component involves the technique by which emissions are sampled, measured and evaluated. The other is the burn operating procedures that will be used during emissions sampling. In practice, any operating procedure can be used with a given sampling technique and vice versa. The possible variations are numerous, each variation potentially yielding different results for a given stove. The fact that there are innumerable variations on the theme, which may yield different results, underscores the need for standardization of both emissions sampling techniques and burn operating procedures. By way of example (this is an actual situation), State A will in all probability adopt a standard emissions sampling technique that has already been accepted by State B. However State A is thinking about changing the burn operating procedures used by State B. If that happens, stove manufacturers who have been certified in State B could be required to retest in State A - a prohibitively costly requirement for many manufacturers. This situation poses a serious obstacle to maximizing the availablility of clean burning stoves that homeowners can buy. If an overall testing protocol is not standardized among states, an emissions cleanup program is unlikely to reach the high level of success that is possible.

What kinds of issues do states face in developing a stove testing protocol? There has been some heated controversy over what an appropriate testing protocol should involve. Many of the emissions sampling techniques and burn operating procedures that are being proposed or challenged by various proponents are presented and discussed in the following sections.

b. **Objectives for Woodstove Emissions Sampling Techniques**

There are a number of primary objectives that must be met before a woodstove emissions sampling technique can be successfully implemented on a widespread basis. These are:

(1). Research Techniques

Adequate woodstove emissions evaluation research techniques must be established to evaluate all pertinent aspects, e.g. priority pollutants, of woodstove emissions.

(2). **Laboratory Certification**

Routine laboratory certification procedure or procedures must be established to evaluate and certify appliances. A successful certification technique must:

* Be **adequately precise** (produce repeatable and accurate results) so that stoves can be separated into pass-fail categories on a scientifically equitable basis.

* Be of **simple** construction, composed entirely of rugged, standardized components which do not require frequent, difficult calibrations.

* Be **user friendly**, having well documented, clearly written instructions so that any competent technician can produce consistent and valid results.

* Be able to be used by manufacturers as well as test laboratories. Next to adequate precision and accuracy this is the most significant criterion. This requires low procurement costs, high reliability and extreme userfriendliness. These attributes will encourage rapid development of clean stoves because:

  - The manufacturer will have an effective, quick feedback evaluation tool available to him during stove development.

  - The manufacturer can have confidence that results he obtains in his lab will also be produced in the certification test lab. He needs a reliable tool to evaluate his progress in stove development so he can avoid costly retesting. Otherwise he will be unlikely to pursue or be successful at clean stove design.

* Entail **reasonable (low) costs** to certify a stove. This is particularly sensitive in the stove industry because many stove models will have to be tested and the industry is not cash rich. (The industry is in a shake-out period since total annual national stove sales are decreasing).

* Be a technique that has a high likelihood of being either a **nationally used technique** or an acceptable alternative (officially called an "**equivalent procedure**"). This does not necessitate that an official "national EPA standard" be established, but only that a technique be adopted that enjoys widespread use among states. Consistency is important to stove manufacturers. They will not be able to endure multiple testing if different states have different standards - either a difference in testing technique or test operating procedures.

The current situation relative to the above objectives will be assessed by first describing the historical development of testing procedures and then discussing how well the objectives have been met. Then recommendations for further work will be made.

c. **History of Certification Testing of Woodstove Emissions**

Woodstove emissions (especially particulates) have been actively investigated for only about 6 years. The locations where research has taken place, which has led to standardized techniques, are: Battelle (on EPA contract) and later TVA, Oregon's DEQ, and Condar Company. Several other methods have been investigated but there is insufficient data to verify their accuracy, reliablility or economic feasibility at this time.

(1). **Federal Government**

EPA-Battelle Protocol. About five years ago Battelle, under EPA contract, modified EPA's standard source evaluation technique for measuring particulates(EPA Method 5) especially for woodstove testing. Basically, a Method 5 passes flue gases through a fiberglass filter and then dries the cleaned flue gases in chilled glass impingers before passing them through a sampling flow meter and sampling pump. Particulates are measured as the amount collected on the filter. When sampling woodstove smoke, the overwhelming presence of liquid droplet hydrocarbons in the smoke causes the glass impinger part of the collection train to condense hydrocarbons in addition to the water of combustion which normally was trapped there. It was discovered that the condensable hydrocarbons were so abundant that additional means beyond the impingers had to be added to the system to trap hydrocarbons effectively. An X-ad resin trap was added just in front of the impingers, and a backup fiberglass filter was added at the back of the sampling train. The condensable hydrocarbons are the sum of what is collected on the front filter, X-ad resin trap, impingers, and backup filter.

This sampling system is expensive to operate and has only been used in recent years by the TVA in its extensive woodstove research program. It is however, a system that can consistently measure essentially all hydrocarbons (TVA Phase II Project results indicate an average of 97% recovery). It is unquestionably the best measure of total hydrocarbon emissions available. It also is probably the best emissions measuring technique with which to collect and study specific hydrocarbon species (POMs etc.).

In spite of the extensive development and research data obtained from this technique, the EPA has yet to designate it as an EPA reference standard. There is no EPA standard at this time.

(2). Oregon DEQ

About four years ago Oregon's DEQ, in response to serious woodsmoke problems in certain Oregon valleys, began a woodstove source testing program which eventually led to establishing a state-approved testing method as well as emissions standards for new woodstove appliances.

For its technique, Oregon chose a modification of EPA's original Method 5 which is called Oregon Method 7. Method 7 has been used in Oregon for measuring industrial stack emissions (often timber industry emissions) for a number of years. This system is basically identical to the EPA-Battelle Protocol except Method 7 lacks the X-ad trap between the front filter and impingers. As such, it is less expensive to operate Method 7 but, some (as yet undetermined amount of) hydrocarbons probably escapes the sampling system. Method 7 might be the better method for measuring condensable particulates and EPA-Battelle the better measure of total hydrocarbons.

The precision of Method 7 has been determined by Oregon's DEQ using dual simultaneous sampling trains to be definitely adequate. The standard deviation is approximately plus or minus 8% and is more precise than EPA Method 5.

In spite of its well established validity as a research tool, Method 7 does not lend itself as well as one would like to widespread routine lab certification of woodstoves. Method 7 utilizes a complicated glassware collection impinger system with many hose connections that must be tightly sealed. Even under the best of lab conditions, connections come loose and unnoticed holes develop in hoses. Retrieval of the hydrocarbons involves cleaning a multitude of items from the sampling train, carefully weighing and reweighing many beakers and properly removing hydrocarbons from the collected impinger water. All these procedures must be done with extreme care. For example, with clean stoves only 50 - 300 mg. of hydrocarbons must be accurately determined using this complicated technique. In short, Method 7 is a highly complicated procedure; a lab situation that allows for introduction of error, even with experienced technicians. Observation of the technique in action indicates that only technicians with extensive experience with Method 7 can operate it reliably. Method 7 has been used successfully for stove certification at one experienced lab, but it is very impractical for use by manufacturers in stove development and interlab consistency is likely to suffer.

(a). Oregon Emissions Test Operating Procedures

Historically emissions test operating procedures have been as varied as emissions sampling techniques. With the advent of the Oregon Woodstove Regulations, a strong movement towards standardization of procedures has developed. These procedures reflect homeowner woodburning patterns more closely than earlier procudures. In capsule form, Oregon's stove test starts when the stove is stabilized at the temperature at which the test will be conducted. Then precisely one complete charge of wood is burned. The fuel is dimensional lumber Douglas fir with all pieces nailed together into a specified geometric pattern. Wood moisture content is restricted to 16 to 20 percent (wet basis). Four stove tests are conducted at varying heat outputs. They are designed to span the range of heat outputs encountered in homes. The final average emissions calculation (in grams per hour of particulates) is actually a weighted value, obtained by weighing the individual test results according to the percentage of time a home owner burns at that particular heat output in Oregon's climate (4000 degree days). Heat outputs of about 13,000 Btu/hour net are weighted the most, with declining weights on either side. High burn rates (less than 20,000 Btu/hour) are given the least weight.

(3). Condar Company

At Condar Co. work by S. G. Barnett on woodstove emissions, has been underway since 1979. The primary early objective was to develop an easy to use, rugged, reliable and precise emissions measuring technique which provides quick feedback evaluation information for developing cleaner burning stoves. The system, now called the Condar Emissions Sampling System, uses the air dilution tunnel principle which condenses hydrocarbons into particulates in a manner almost identical to the auto exhaust dilution tunnels the EPA mobile source branch uses. However, the Condar System adapted the dilution tunnel concept to woodstove sampling rather than simply using the more costly and cumbersome dilution tunnel itself.

The Condar System was used over a 12-month period to develop Condar's clean burning stove technology. This technology is considered by Oregon's DEQ to be the Best Available Technology. Oregon set its emission standards based on the Condar stove design's performance(Hansen, DEQ memo to EQC June 8, 1984). More recently using over 100 developmental emissions tests, one of the stove manufacturers in Condar's stove technology program was able to produce a production stove that far exceeded Oregon's strictest standard in standardized certification testing.

Following a stringent evaluation, the Oregon Department of Environmental Quality has accepted the Condar Emissions Sampling System as an equivalent of their Method 7, meaning that it can be used for stove certification in lieu of Method 7. This is the only system to date which has this standing. Use of the Condar Sampler in testing labs should decrease testing costs and increase testing volume. Since many manufacturers already use the system, the development rate of clean burning stoves should sharply increase. The WHA is proposing that a second dilution tunnel type test method be considered by the American Society for Testing and Materials.

(4). **Issues to Consider in Adopting Emissions Test Operating Procedures**

Emissions test operating procedures can be designed to be scientifically complex in order to obtain detailed data under laboratory conditions. Procedures must be repeatable and results, under controlled burning conditions, consistent. Some of the criticisms of the Oregon method are listed below. These concerns should be addressed in evaluation of any similar testing system.

(a). Wood Species

"The test wood species is not representative of wood burned in most of the country." This issue is not resolved yet. Research is needed to study a wide range of stoves - for instance, Oregon's study stoves - varying only wood type in the test. The preliminary work that has been done using hardwood suggests that the same ranking and even very similar emissions numbers are produced.

(b). Type of Wood

"The use of dimensional lumber instead of cordwood distorts the results." This needs to be answered in the same manner as section (a) above.

(c). Wood Spacing

The use of 1-1/2" spacing between wood pieces distorts results." The situation is the same here as with (a) and (b), except that wood spacing must be varied in tests. No results are yet available.

(d). Wood Size

"The size of the wood charge is too small to simulate real world conditions." All available data on actual homeowner wood loading patterns indicates Oregon's value (7 pounds per cubic foot of firebox) is correct. Also if larger wood loads are used in lab testing, the tests would be longer and cost more. Conflicting data is based on laboratory tests.

(e). Draft Level

"The draft level used to test in the lab is too low." This is true. Draft levels are generally .02 to .04 inches of water and home levels start at .04 inches and go up from there (no overlap). The excessively low draft levels do markedly distort stove performance in some lab tests.

(f). Weighting Emissions Values

"The scheme of weighting emissions values emphasizes low burn rates too much." To the contrary, data obtained by Oregon's Department of Energy, the DOE's annual energy survey and direct measurement of home energy use by S. Barnett, all indicate that about 9,000-10,000 Btu/hour, not 13,000 Btu/hour, is the average heat demand for Oregon. The Oregon weighting scheme is actually the most appropriate one to use for climates up to about 6,000 degree days.

(g). Efficiency Measuring Technique

"The woodstove efficiency measuring technique used in conjunction with emissions measurements is neither a recognized technique nor has it been verified by independent evidence. Additionally, it adds unnecessary expense." These objections are valid and other more appropriate methods are available, some, like the Condar System, are far less expensive. Fortunately, since variations in efficiency measurements have only a minor effect on the final emissions value for a test series, changes can be made through time, and emissions data obtained now will not be outdated and retesting will not be necessary.

(h). Cost

"Oregon testing methods involve some overcomplicated and costly aspects." This may well be true for the efficiency testing procedures including the requirement that bomb calorimeter tests be made on sawdust from cutting the test wood. Research is needed to verify that 1) such a procedure is valid. (Less than 1% of the wood is sampled. Bomb calorimetry of wood is sensitive since the boiling points both of water and some of the wood's volatiles are very close.) 2) It has not been determined by homogenizing cuttings from entire wood loads that a significant variation in heat content/pound actually exists from load to load. The cost of the required stove tests per stove is about $6800.

(5). Discussion

(a). Assessment of Status Quo

The situation today can best be assessed by evaluating how well the earlier stated testing procedure objectives have been met.

- Adequate research techniques have been developed. The EPA Battelle protocol can investigate total hydrocarbons and chemical species effectively. Oregon's Method 7 and the Condar System can investigate particulates. The EPA-Battelle protocol probably has adequate credentials to qualify it as a national reference standard because it has the broadest based capabilities and it measures total hydrocarbon emissions and individual chemical species.

- The EPA-Battelle Protocol is not appropriate for routine laboratory certification due to its complexity, requirement of highly trained technicians and high operating cost. Therefore equivalent techniques are needed for routine field certification.

Oregon Method 7 has been used effectively as a research and certification technique. It appears to possess adequate credentials to become a national particulate standard. However, the disadvantages discussed in the previous section have become apparent - complexity leads to potential reliability problems and highly trained technicians are required.

The operating cost of Method 7 is lower than EPA-Battelle Protocol, but apparently too high for the stove industry to bear in the long term. Importantly, stove manufacturers cannot afford to buy or operate this system for stove development, or pre-testing.

(b). **Need for Standardized Emissions Test**

As of today, no decision has been made on a national certification technique. Historically, it has taken many years for EPA to adopt standards and no reason exists to expect this situation to be different now. In the meantime a defacto standard (or equivalent standards) should emerge if broad usage of any system emerges. The groundwork that Oregon has laid is adequate to make this happen. The Method 7-Condar equivalent standards satisfy all criteria necessary to encourage clean stove development and certification.

Oregon's regulations have produced a standardized set of emissions testing procedures that are in our opinion, generally acceptable. Modifications will probably take place but generally research is needed to justify such modifications. It is both in the interest of the stove manufacturers and the public that standardization of procedures (especially to the degree that the integrity of today's test results be maintained) be a high priority. Requirements to force manufacturers to retest due to procedural changes will short-circuit development and sale of clean burning stoves.

F. HOW CAN THE EFFECTS OF WOOD COMBUSTION EMISSIONS BE EVALUATED?

Enough monitoring and research has been done, to date, to indicate the nature of emissions from residential woodburning activities and the conditions under which these emissions are a problem. Sampling of emissions has been done in at least twelve major studies.(52) With the exception of one study done in 1968 by Clayton, all have been initiated since 1975 during the period of time that residential wood heating activities have increased. Some studies have measured ambient air in regions of high woodburning activity. Most have been source analysis studies of stack gases. Most of the early studies (see footnote 1) that are often quoted were conducted at burn rates and/or using fuel unrepresentative of home burning conditions. Studies conducted by DeAngeles et al.,(53) most of the Battelle studies,(54) early Tennessee Valley Authority (55) studies and some others were conducted at too high burn rates so emission factors are too low. Barnett and Shea documented in 1981 actual home burning rates and demonstrated the sensitivity of results to deviations under actual home burning conditions.(56 More recent work by the State of Oregon's Department of Environmental Quality and others has focused on burn rates appropriate to actual in-home stove use, including attention to fuel type and moisture content.(57)

Information does exist to assist in the evaluation of the importance of residential wood combustion emissions contributions in an area and to provide information about potential health or human welfare impacts. The paragraphs below provide a brief summary of these considerations.

To date no quantitative assessment of health effects directly attributable to residential woodburning has been completed. However, it has been determined that residential wood combustion may result in emissions containing substantial quantities of air pollutants of known concern due to their impacts on public health. These include: **particulates, carbon monoxide, hydrocarbons and polycyclic organic matter.**

The **US EPA Emission Source Assessment Program** established a series of criteria for comparing the relative environmental effects of emissions of different source types. These criteria include: source severity, affected population, state emissions burden and national emissions burden. These criteria are not intended to provide an absolute measure of environmental impact, but are to be used with other studies to set priorities for sources where emissions reduction may be required. Severities for individual residential sources may differ due to the variability of a number of parameters. Key parameters affecting the severity of environmental impacts from wood combustion emissions include the emission factors, wood consumption rates, duration of burning, chimney heights and wind speed, meterological conditions (inversion tendency) and topography. In addition, the hazard factors for noncriteria pollutants and the combined severity of all variables must be considered. It is also important to know how many people around an average residential wood combustion unit are exposed to high ground level concentrations. The affected population will vary with population density and will be greater in urban areas.

Impacts of residential wood combustion could be identified and monitored on a regional (airshed) or state basis as well as a purely local basis. This may become necessary if the PM_{10} standard is adopted. A compilation and analysis of data showing seasonal concentrations of criteria and selected NESHAP pollutants (i.e.: an indicator such as benzo (a) pyrene) would allow more timely identification of trends showing increases of key pollutants. A comparison to historic data would indicate where control actions should be initiated. U.S. EPA's Source Assessment: Residential Combustion of Wood, published in 1980, used historical (1972) EPA estimates of the percentage contributions from residential woodburning to total state criteria emissions. The data presented showed contributions from fireplaces and from woodstoves used for primary and secondary heating. The tables shown here illustrate historical assumptions. Table 4.11 shows state percentage criteria emissions due to residential woodburning in fireplaces; Table 4.12 shows percentage of state criteria emissions that are due to primary residential heating with wood, Table 4.13 shows the percentages of criteria emissions due to secondary residential heating with wood and Table 4.14 is an extrapolation showing the total percentage of state criteria emissions due to residential woodheating from fireplaces, and woodstoves used for primary and secondary heating. This data is given for the Great Lakes states and other key states for comparison.

TABLE 4.11. PERCENTAGE OF TOTAL STATE CRITERIA EMISSIONS DUE TO RESIDENTIAL WOODBURNING IN FIREPLACES.

State	Particulates	NOx	Hydrocarbons	CO
Illinois	0.1	0.02	0.5	0.1
Indiana	0.1	-0.01	0.7	0.1
Michigan	0.1	-0.01	1.0	0.2
Minnesota	0.2	0.03	0.8	0.2
Ohio	0.1	0.02	0.7	0.1
Iowa	0.2	0.03	0.8	0.1
Wisconsin	0.2	0.02	0.7	0.2
New York	2.4	0.1	1.7	0.4
Pennsylvania	0.1	0.01	1.6	0.3

Colorado	0.3	0.06	1.5	0.3
Maine	0.4	0.04	1.0	0.3
Massachusetts	1.2	0.05	1.5	0.4
New Hampshire	1.1	0.04	1.1	0.03
Oregon	0.3	0.06	1.2	0.3
Vermont	0.7	0.06	1.3	0.3

TABLE 4.12. PERCENTAGE OF TOTAL STATE CRITERIA EMISSIONS DUE TO PRIMARY RESIDENTIAL HEATING WITH WOOD

State	Particulates	NOx	Hydrocarbons	CO
Illinois	0.02	-0.01	-0.01	0.08
Indiana	0.07	-0.01	0.1	0.36
Michigan	0.10	-0.01	0.1	0.4
Minnesota	0.37	0.02	0.3	1.1
Ohio	0.02	-0.01	0.05	0.2
Iowa	0.07	-0.01	0.07	0.2
Wisconsin	0.20	0.01	0.2	1.0
New York	0.87	0.01	0.2	0.6
Pennslyvania	0.06	-0.01	0.2	0.6
Colorado	0.08	0.01	0.12	0.38
Maine	3.40	0.10	1.9	9.0
Massachusetts	0.25	-0.01	0.07	0.3
New Hampshire	3.46	0.04	0.8	4.0
Oregon	1.58	.10	1.6	5.7
Vermont	2.04	.07	1.0	3.9

TABLE 4.13. PERCENTAGE OF TOTAL STATE CRITERIA EMISSIONS DUE TO AUXILIARY RESIDENTIAL HEATING WITH WOOD

State	Particulates	Nox	Hydrocarbons	CO
Illinois	0.21	0.01	0.2	0.74
Indiana	0.15	-0.01	0.3	0.76
Michigan	0.53	-0.01	0.72	2.29
Minnesota	1.24	0.06	1.12	3.75
Ohio	0.12	0.01	0.27	0.86
Iowa	0.29	0.01	0.3	0.86
Wisconsin	0.46	0.03	0.50	2.40
New York	4.99	0.07	1.10	3.25
Pennsylvania	6.14	-0.01	0.39	1.35
Colorado	0.28	0.02	0.4	1.27
Maine	8.14	0.3	4.51	21.18
Massachusetts	2.55	0.04	0.77	2.90
New Hampshire	20.78	0.3	4.85	24.07
Oregon	1.35	0.09	1.35	4.92
Vermont	12.08	0.04	5.81	23.33

TABLE 4.14. EXTRAPOLATION FROM TABLES 4.11, 4.12 AND 4.13: PERCENTAGE OF TOTAL STATE CRITERIA EMISSIONS DUE TO RESIDENTIAL WOODBURNING

State	Particulates	Nox	Hydrocarbons	CO
Illinois	0.33	0.04	0.71	.92
Indiana	0.32	0.03	1.10	1.22
Michigan	0.73	-0.03	1.82	2.89
Minnesota	1.81	0.11	2.42	5.05
Ohio	0.24	0.04	1.02	1.16
Iowa	0.56	0.05	1.17	1.16
Wisconsin	0.86	0.06	1.40	3.60
New York	8.26	0.18	3.00	4.25
Pennsylvania	0.30	-0.03	2.19	2.25
Colorado	0.66	0.09	2.02	1.95
Maine	11.94	0.44	7.41	31.10
Massachusetts	4.00	-0.10	2.34	3.60
New Hampshire	25.34	0.38	6.75	28.12
Oregon	3.23	0.25	4.15	10.92
Vermont	14.82	0.17	8.11	27.02

(The above shown in tables 4.11 to 4.14 was extracted from DeAngelis, et al., originally printed in the 1972 National Emissions Report , published by USEPA in June 1974. Wood use has increased since that time, so total state emissions have undoubtedly increased.)(58) The data shown in Tables 4.10 - 4.14 is historic and should be useful for comparison with new data when it is developed.)

There has been a tremendous increase in use of woodfuel for residential heating since 1972 and while figures were not available for direct comparison, a number of more contemporary studies have provided regional source emission data to support assumptions about increased residential sources of air pollution in areas with greater woodburning activities than in 1972. (See Section V) These include the regional scale air impact analyses conducted by the Tennessee Valley Authority, by EPA Region 10 and the state of Oregon, by the city of Portland, by Michigan Department of Natural Resources in Mio, Michigan and by the Minnesota Pollution Control Agency for the Minneapolis-St. Paul metropolitan area. These studies show that a large number of woodburning stoves in a concentrated area contribute significantly to particulate (especially inhalable particulates) air pollution.(59)

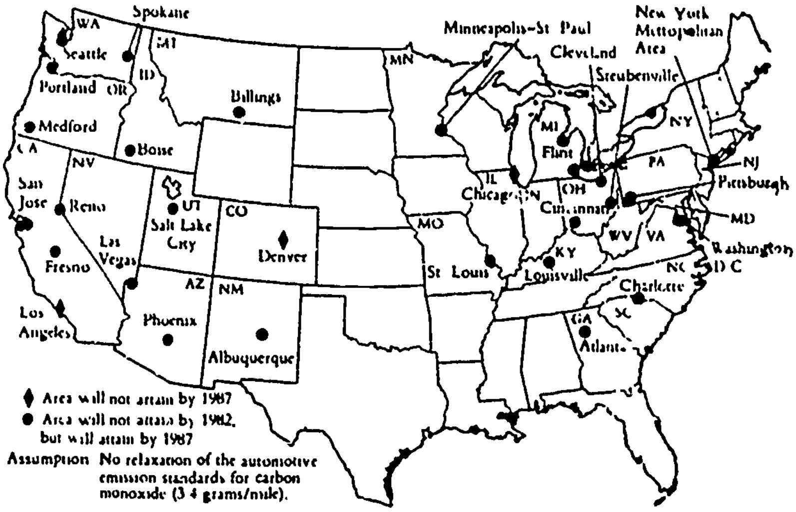
Total national emissions of criteria pollutants from wood-fired residential combustion can be compared to emissions from other residential combustion. Data show that depending on location and density, local weather conditions, burning practices, fuel type, etc., wood combustion contributes between 0.2% and 95% of the total from the residential sector.

G. RESIDENTIAL WOODBURNING AND EMISSIONS IMPACTS IN THE GREAT LAKES STATES

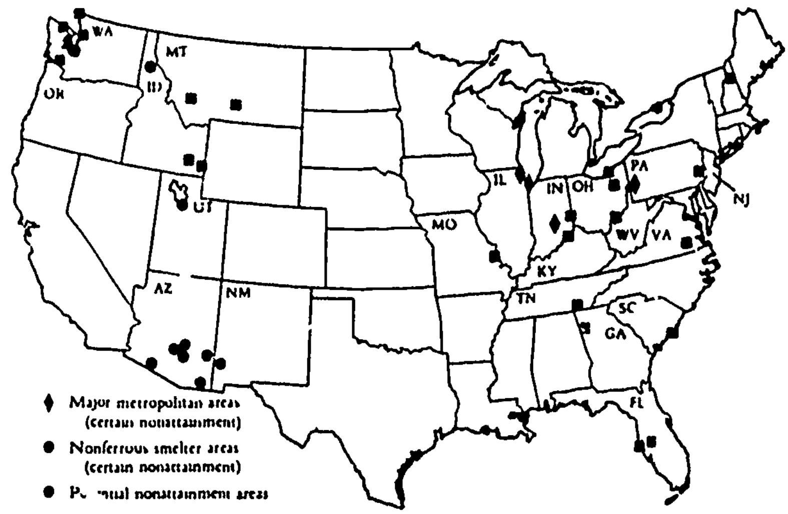
All Great Lakes states were invited to assist in developing information about the nature of the emissions problem, if any, from residential wood combustion activities. State Energy and Air Pollution Control Agencies were contacted and specific information requested by letter. Follow-up interviews were used to obtain additional data and an update on state activities. In a number of instances local air pollution control agency personnel were interviewed as were personnel in the US EPA Division of Air Pollution Control. In addition, studies and surveys the states have undertaken to determine wood fuel use were reviewed; and information provided by the insurance industry and State Fire Marshals related to safety concerns and residential fires traced to use of wood fuel were evaluated to identify possible linkages or trends that might be indicators of present or future air emissions problems. Members of the wood heating industry were also contacted and a literature review made of industry publications in an attempt to provide accurate figures regarding sales of woodheating equipment in the Great Lakes states. Researchers working on biomass energy problems in the region were also interviewed.

Although there has been a dramatic increase in the use of woodfuel for both primary and secondary residential heating in some Great Lakes states over the past ten years, local meteorological conditions, ambient air quality, population, woodstove densities and existing air pollution problems have apparently not combined to create widespread serious air pollution problems in the region. Some more localized regions (i.e., Minneapolis-St. Paul metropolitan area) have verified that residential woodburning is causing an air pollution problem of concern. A very limited amount of research or monitoring is ongoing in the Great Lakes states that would result in the identification of emissions problems traceable to RWC. Figure 4.1 on the following page illustrates the key areas in the Great Lakes which are not in compliance with the NAAQS for carbon monoxide, total suspended particulate ozone and sulfur dioxide. Note that the Great Lakes region has more areas of non-attainment for carbon monoxide, sulfur dioxide, health-based total suspended particulates than any other area of the country. This is particularly significant in terms of any additional areas that may be designated due to the PM_{10} standard. To date the Great Lakes region states have done very little research to identify the specific contributions of residential wood combustion emissions to airsheds within non-attainment areas or metropolitan areas with a high degree of residential woodburning. A state-by-state summary of problems and/or present state activity related to data collection, existing policies or the development of regulatory programs targeted to RWC is presented below.

FIGURE 4.1. GREAT LAKES REGIONS AND THE NATIONAL AIR QUALITY STANDARDS: AREAS OF CERTAIN/POTENTIAL NON-ATTAINMENT IN CONTEXT OF CONTINENTAL UNITED STATES COMPLIANCE.



Status of Compliance with the Air Quality Standard for Carbon Monoxide Assumption No relaxation of the automotive emission standards for carbon monoxide (3 4 grams/mile) (Source National Commission on Air Quality, 1981)



Areas that Were Not Expected to Achieve the Health-Based Sulfur Dioxide Standard in 1982 Actual 1982 air quality data were not available at time of printing. (Source: National Commission on Air Quality, 1981.)

(Figure 4.1 continued.)

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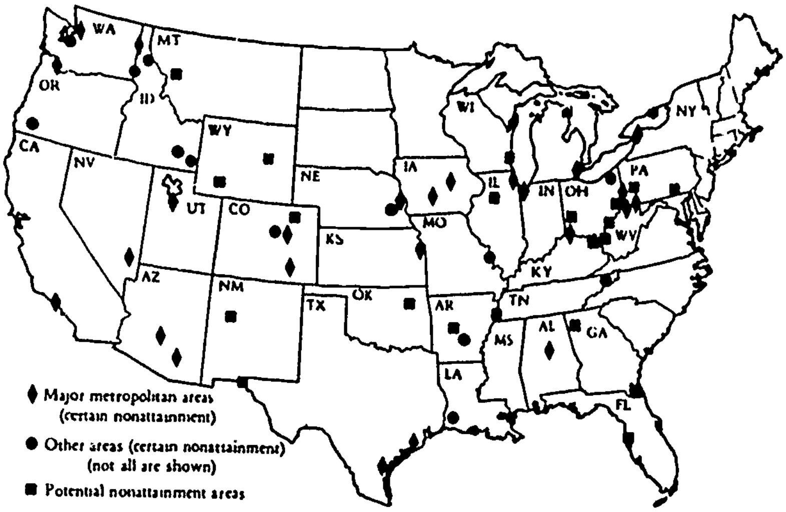
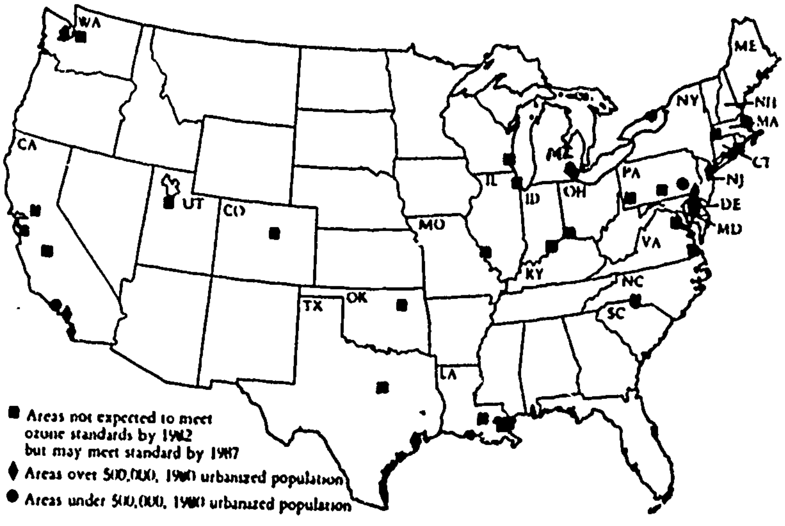


Areas Not Expected to Achieve the Health-Based Standard for Total Suspended Particulates by 1982 (Source: National Commission on Air Quality, 1981)



Areas Not Expected to Meet Ozone Standards by 1982 or by 1987 (Source: *To Breathe Clean Air*, National Commission on Air Quality, 1981)

(From: <u>State of the Environment 1982</u>. Washington, DC: National Conservation Foundation.)

1. Illinois

Illinois EPA reports that it does not have any statistics regarding air emissions that could be attributed to residential woodburning and does not believe that such activity would be a growing problem for the state. Illinois does not have any program either in place or being developed that would be directed toward assessing or controlling air pollution from residential woodburning activity.

Historically the only problem the state has had has been with a small number of wood-fired industrial boilers that could not meet the specified limitations for solid fuel combustion sources. The state has been concerned with emissions from wood products industrial operations and has adopted rules and regulations, including some standards to control dust (particulates) from woodworking by opacity and fugitive dust standards. Smoke and dust pollutants from boilers and "teepee" burners are particulates regulated by opacity, fuel combustion and incinerator standards. Hydrocarbon emissions from coating operations are regulated by organic emission standards.

The Division of Air Pollution Control within Illinois EPA indicates that it is shifting attention to more health-related problems.(60)

2. Indiana

The Indiana State Board of Health, which is responsible for air pollution control in Indiana, indicates that there is no program directed to woodburning, and no statistics exist other than those found in various journals.

Emissions from residential wood combustion have not yet posed a significant enough problem to stimulate regulatory action at the state or local levels (to the knowledge of state air pollution control officials). Complaints have been received regarding air pollution problems traceable to residential woodburning activities, but these are handled on a case-by-case basis. In most instances, Air Pollution Control inspectors from the Department of Public Health visit offenders and assess the problem. Most problems are attributable to improper burning practices: i.e., garbage burning in woodstoves or fireplaces, use of wet wood or stack height. Such inspection and individual evaluation plus an educational brochure that has been made available to the public to encourage proper burning practices comprise the present approach to residential wood combustion (RWC) emissions problems in Indiana. Local governments do have ordinances to prohibit open burning, but these do not specifically apply to RWC practices.

The topography of Indiana is relatively flat to rolling hills, and there are no mountainous areas. Except for problems that occur as a result of occasional air stagnation due to high industrial emissions and stationary weather fronts over the Gary-Hammond industrial complex, there has been relatively little problem with inversions and air stagnation. Most pollution incidents from residential woodburning are reported by neighbors and are due to smoke and odor impacts. Impacts are assumed to be local. No studies have been conducted, nor are any anticipated, to determine how much RWC contributes to air pollution within the state.(61)

Residential woodburning air pollution problems could evolve in the future as the state has developed a proactive program to encourage the use of firewood from state forests, and through their "Energy Acres" program which emphasizes private woodlot harvest and replanting with black locust trees. It has been noted (See Section III.) that citizens are responding to this program. Although no accurate estimates are available regarding residential wood heating equipment in use, crude estimates are that between 300,000 and 500,000 Indiana households use wood for fuel (1984 estimate).

3. Iowa

The Director of the Iowa Department of Water, Air and Waste Management reports that air emissions from woodstoves are not perceived to be a problem in the state. Iowa has no programs related to air emission controls from residential woodburning activity. There is no residential wood combustion data being gathered and development of emission control programs or standards is not being considered.(62)

4. Michigan

An increasing number of Michigan residents have switched to the use of woodfuel for primary or secondary heat for their homes in recent years. Michigan was aware of woodheat air pollution problems in other parts of the country and decided to determine whether or not similar problems were occurring in Michigan. The Michigan Department of Natural Resources identified areas in the state where residential woodburning emissions could be contributing to air pollution problems. It then designed and conducted an air quality monitoring study to see if woodburning emissions caused problems similar to those caused in the more mountainous western states. Mio, Michigan, a community of about 1800 people located 150 miles north of Lansing was selected for the air quality monitoring study. Mio was chosen for the monitoring study becuase it relies heavily on woodheat for residential energy needs, it is located in a river valley, has a cold, snowy climate, has a terrain more conducive to air pollution problems from woodburning than most other areas in the state, and it lacks any significant industrial loadings that could contribute substantial particulate or other pollutant loadings to the local airshed. Mio was seen as Michigan's potential for a "worst case" situation, in terms of a clean air area. The objective of the air monitoring study was to determine the effects of residential woodburning on the ambient air.

The study began in 1983. Prior to the initiation of sampling and monitoring, baseline data was collected and a survey of Mio residents was conducted to identify their woodburning equipment and practices. The survey questionnaire addressed the type of fuels being used to heat each residence, types of woodburning equipment that had been installed, the amount of wood burned, its type and age. Monitoring equipment was installed and sampling began on November 1 of 1983 and was concluded April 30, 1984. Ambient air concentrations of total suspended particulates - TSP - (soot), carbon monoxide and benzo (a) pyrene (BaP) were measured. Meteorological data was collected to determine the effect of weather and temperature on pollutant concentrations and dispersion.

The results from the study are summarized in Table 4.15 and 4.16 on the following page. The findings show that Mio woodburning emissions contribute substantially to air pollution. If these findings are extrapolated to the rest of the state, residential woodburning may be a substantial contributor to air pollution levels in Michigan. While the Mio

TABLE 4.15.
SIMULTANEOUS POLLUTANT CONCENTRATIONS

Sampling Date	TSP, 24 hr conc., ug/m³ Site No. 002	003	004	005	CO conc., ppm max 1 hr	ending hour	Max 24 hr BAP TSP, ug/m³	BAP, ng/m³	Inhal Part, ug/m³ 24 hr total	×24 hour hours	total
11/2/83	38		54	40							
11/5/83	70		—	27			70	5 6			
11/8/83	43		33	33			43	7 8			
11/11/83	9		29	12							
11/14/83	—		55	39							
11/17/83	61		34	38			61	1 6			
11/20/83	18		16	15							
11/23/83	16	21	18	12	0 4	12 14 16 21	21	1 1			
11/26/83	27	46	53	19	1 5	17	53	6 0			
11/29/83	16	V 3	12	8	0 7	10-12 22 24					
12/2/83	22	22	21	16	0 9	24					
12/5/83	40	53	65	34	2 1	6	65	2 9			
12/8/83	78	72	89	61	2 6	3 8	ʋ9	42 7			
12/11/83	14	14	38	13	0 6	1 24					
12/14/83	13	23	24	19	1 0	21					
12/17/83	25	15	19	18	2 5	24	25	5 3			
12/20/83	—	79	66	49	—	-	79	13 4			
12/23/83	—	17	17	11	1 2	17					
12/26/83	16	16	18	13	0 7	1 4					
12/29/83	19	15	13	11	0 9	17	19	2 4			
1/1/84	39	38	41	41	1 3	1 4	41	2 2			
1/4/84	—	17	20	14	1 0	17					
1/7/84	22	36	46	47	—	—					
1/10/84	25	38	49	32	3 1	23	49	8 5			
1/13/84	18	19	32	23	—	—					
1/16/84	—	32	45	21	1 5	3	45	3 8			
1/19/84	22	—	18	21	0 7	7 10					
1/22/84	—	31	33	30	—	—	33	1 8			
1/25/84	27	27	26	22	-	—					
1/28/84	41	45	57	32	2 3	3	57	4 3			
1/31/84	27	34	39	40	—	—					
2/2/84	80	68	72	57	1 6	1 3 5	72	3 1			
2/4/84	20	21	22	19	0 3	3 5 7 9	20	6 2	13	3 9a	19
2/5/84	13	16	24	11	0 4	13	24	3 4	9	—	—
2/6/84	13	15	—	12	0 9	9			7	3 9a	23
2/7/84	15	26	30	17	1 1	8	30	4 3	16	—	—
2/8/84	—	30	—	23	0 4	13			19	3 9a	32
2/9/84	65	70	71	73	2 4	9	71	3 4	58	3 9a	68
2/10/84	57	73	81	76	6 9	9	81	4 6	56	3 9a	108
2/11/84	34	32	32	26	0 8	19	34	2 7	29	3 9a	36
2/12/84	25	28	27	25	0 9	19			21	3-9a	32
2/13/84	36	29	23	25	0 9	23 24			28	3 9a	27
2/14/84	58	39	32	37	0 9	1 3			25	—	—
2/15/84	61	72	75	55	2 6	9	75	6 9	47	15-24	56
2/16/84	20	46	—	37	2 0	7			22	15 24	19
2/17/84	34	103	54	45	1 7	21 22	103	4 1			
2/18/84	40	57	33	29	0 7	1	57	2 4			
2/21/84	39	34	20	17	—	—					
2/24/84	19	57	49	25	0 7	2 7 10 11					
2/27/84	49	86	92	30	—	—	92	3 8			
3/1/84	18	41	30	14	0 9	8 10					
3/4/84	79	67	80	37	—	—	79	9 8			
3/7/84	34	48	48	—	1 5	24					
3/10/84	95	73	81	—	3 1	3	81	12 1			
3/13/84	21	26	25	24	0 8	1 9 12 21, 23 24	26	2 4			
3/16/84	—	25	25	20	1 2	15					
3/19/84	—	21	21	19	0 5	1-2 4 8-9					
3/22/84	13	21	21	14	0 9	8	21	2 2			
3/25/84	94	71	—	32	1 1	23	94	8 7			
3/28/84	33	54	80	24	1 8	1	80	2 1			
3/31/84	36	62	87	31	—	—	87	3 4			
4/3/84	66	90	124	43	—	—	66	3 6			
4/9/84	49	77	91	—	—	—	91	3 8			
4/15/84	10	10	13	—	0 3	9 17, 20, 23 24	13	2 5			
4/18/84	47	70	56	32	0 8	23	70	3 0			
4/21/84	55	73	91	47	1 0	23	73	3 2			
4/24/84	22	39	26	21	0 9	9 10					
4/27/84	67	85	92	60	0 4	4 5	85	2 2			
4/30/84	65	61	63	51	0 6	2 12-13, 18-19 21-24	61	2 2			

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TABLE 4.16
RELATIONSHIP BETWEEN BENZO(A)PYRENE AND TOTAL SUSPENDED PARTICULATES. MIO, MI (24 HR. CONCENTRATIONS)

Date	Site	TSP, ug/m³	BAP, ng/m³
11/5/83	002	70	5 6
11/8/83	002	43	7 8
11/17/83	002	61	1 6
11/23/83	003	21	1 1
11/26/83	004	53	6 0
12/5/83	004	65	2 9
12/8/83	002	78	13 6
	003	72	13 8
	004	89	42 7
	005	61	5 2
12/17/83	002	25	5 3
12/‚ ʼ	003	79	13 4
	004	66	10 4
12/29/83	002	19	2 4
1/1/84	ʋ'4	41	2 2
1/10/84	004	49	8 5
1/16/84	004	45	3 8
1/22/84	004	33	1 8
1/28/84	004	57	4 3
2/2/84	002	80	3 0
	003	68	2 6
	004	72	3 1
2/4/84	002	20	6 2
2/5/84	004	24	3 4
2/7/84	004	30	4 3
2/9/84	002	65	2 5
	003	70	2 5
	004	71	3 4
	005	73	2 7
2/10/84	002	57	2 5
	003	73	3 8
	004	81	4 6
	005	76	3 4
2/11/84	002	34	2 7
2/15/84	002	61	6 5
	003	72	5 6
	004	75	6 9
	005	55	4 4
2/17/84	003	103	4 1
2/18/84	003	57	2 4
2/27/84	003	86	3 4
	004	92	3 8
3/4/84	002	79	9 8
	003	67	3 7
	004	80	6 8
3/10/84	002	95	8 6
	003	73	9 2
	004	81	12 1
3/13/84	003	26	2 4
3/22/84	004	21	2 2
3/25/84	002	94	8 7
	003	71	6 8
3/28/84	004	80	2 1
3/31/84	003	62	3 0
	004	87	3 4
4/3/84	002	66	3 6
	003	90	3 2
	004	124	3 5
4/9/84	003	77	3 5
	004	91	3 8
4/15/84	004	13	2 5
4/18/84	003	70	3 0
4/21/84	003	73	3 2
	004	91	2 7
4/27/84	002	67	2 0
	003	85	2 2
	004	92	2 1
	005	60	1 9
4/30/84	002	65	1 9
	003	81	2 2
	004	63	2 1

From: Michigan Department of Natural Resources, Air Quality Division December, 1984

*65% of 24 hr. BaP samples were greater than 3 ng/m³

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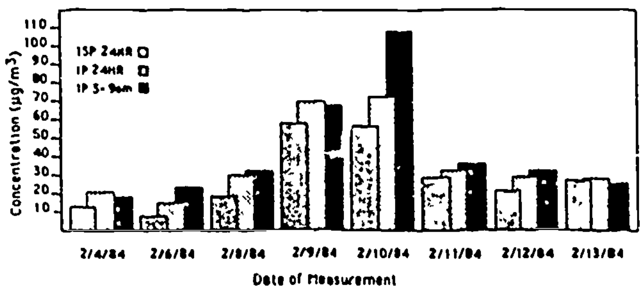
TSP levels did not exceed the National Ambient Air Quality Standards (NAAQS) of 150 ug/m^3, other areas of Michigan have major sources of TSP and the additive effect of woodburning emissions could cause NAAQS for TSP to be exceeded. This could change an area's status from "attainment" to "non-attainment" or make it impossible for a non-attainment area to meet its clean-up schedule (See Section IV.G on the Clean Air Act.), thus limiting industrial activity in the area. The important finding about particulate emissions was that a significant portion of the TSP concentration was inhalable particulates. When haze was not present, at least half of the 24-hour TSP concentration was inhalable particulates. The inhalable particulate concentration measured over a six-hour period in the early morning (when haze was more likely to be present) was found to be up to three times greater than the 24-hour average midnight-to-midnight concentrations, which is shown in Table 4.17. It shows (with Table 4.15) concentrations of inhalable particulates and compare TSP and inhalable particulate concentrations.

TABLE 4.17. CONCENTRATIONS OF INHALABLE PARTICULATES IN ug/m^3 AND COMPARISON OF TSP AND IP CONCENTRATIONS.

Sampling Date	24 Hour Concentration Coarse / Fine	Total	Equiv PM-10	Hours	<24 Hour Concentration Coarse / Fine	Total	Equiv PM-10
2/4/84	1 / 12	13	10	3-9a	1 / 18	19	15
2/5/84	1 / 8	9	7	-	-	-	-
2/6/84	0 / 7	7	6	3-9a	10 / 13	23	18
2/7/84	2 / 14	16	13	-	-	-	-
2/8/84	2 / 17	19	15	3-9a	3 / 29	32	26
2/9/84	9 / 49	58	46	3-9a	4 / 64	68	54
2/10/84	6 / 50	56	45	3-9a	11 / 97	108	86
2/11/84	2 / 27	29	23	3-9a	3 / 33	36	29
2/12/84	3 / 18	21	17	3-9a	3 / 29	32	26
2/13/84	5 / 23	28	22	3-9a	7 / 20	27	22
2/14/84	4 / 21	25	20	-	-	-	-
2/15/84	8 / 39	47	38	15-24	13 / 43	56	45
2/16/84	8 / 14	22	18	15-24	9 / 10	19	15

COMPARISON OF TSP AND IP CONCENTRATIONS AT SITE 003



From: Michigan DNR Air Quality Division December 1984

Ambient air levels of carbon monoxide were not found to be high enough to raise concern. (Mio is not a densely populated area with many other sources of CO such as a major coal-fired generating plant or a large amount of automobile traffic.) However, the study did find levels of the toxic organic compound benzo(a)pyrene (BaP), a known carcinogen, high enough to cause concern. The BaP concentrations were found to exceed 3 ng/m^3 frequently. The 3 ng/m^3 is the industrial standard in Michigan and is based on a cancer exposure risk level of one-in-one million. Because BaP is only one of a large number of potentially toxic, carcinogenic compounds found in woodburning emissions, it is assumed that significant levels of other toxic air pollutants may be present as well. (See figures and tables in the section on Health Effects.) See Table 4.16 which shows the relationship between BaP and TSP concentrations in Mio.(63)

Mio is presently classified as a clean air or "attainment" area. If a PM_{10} standard (See discussion under Clean Air Act.) is applied, its status would change. Any controls that the state or the community may wish to impose to address identified air pollution problems may be related to an objective of non-degradation of clean air areas and to concerns about the public health effects of high concentrations of the carcinogenic compound benzo(a)pyrene and its relatives. On a statewide basis, other concerns may emerge.

State regulatory policy presently exempts RWC emissions from air pollution controls. Complaints are handled in district offices on a case-by-case basis. Depending on the outcome of the Mio study and the emergence of other problems, Michigan may consider the need for State RWC emissions control policy. Some public health complaints have been received from people who are asthmatics and found their conditions aggravated by woodsmoke.

As far as state officials knew, there is no formal regulatory program applicable to woodstove emissions at the local level. The Wayne County (Detroit) Area Air Pollution Control Agency regards RWC as a "troublesome problem". The County has found that most complaints come from about six relatively small subdivision areas. Inspectors are sent out to analyze the problem (which is usually found to be related to stack height or fuel type) and to educate the wood burner on operations and maintenance practices that would result in clean(er) burning. The Agency has encouraged municipalities in areas with air quality problems to consider incorporating a permit system for wood stove installation as part of their Building Codes.(63a)

5. <u>Minnesota</u>

Minnesota notes that about 6% of its residences, statewide, use wood for space heating. This amounts to a 500% increase since the early 1970's. The Minnesota Pollution Control Agency did a study of "Air Pollution Impacts From Residential Wood Combustion in Minnesota" that was published in 1982.(64) The study noted that "criteria" air pollutants, carbon monoxide and particulates, were emitted in relatively large amounts in residential areas with a high density of woodburning appliances. This study also noted that there was concern that the emissions may exacerbate present nonattainment problems or cause other areas to exceed ambient air standards. Minnesota might have to address the problem of "offsetting" urban area residential woodburning loadings of CO and TSP with industrial and/or transportation emission reductions to attain ambient air standards. For example, Ramsey and Hennepin counties (the Minneapolis-St. Paul area) were ranked in the fifteen highest wood usage counties in the country at 319-405 cords per square mile per season. Usage density over the entire seven county Metro area is 88 cords per square mile per season.(65)

Seltz reports that on a rough calculation basis of seasonal averages (using USEPA National Emissions Data System and the non-attainment analysis performed by MPCA in 1979 and MDNR estimates regarding wood cord usage for the area), residential wood combustion may account for one-fifth (20%) of total TSP and CO emissions in the Twin City Metropolitan Area. On a short term basis it was indicated that RWC emissions might account for even larger portions of the total suspended particulates. In addition, the highest measured concentrations of respirable particulates (less than 2.5 microns in diameter) in Minneapolis appeared to be associated with residential woodburning. MPCA studies concluded that the combination of high population density, cold climate and access to wood indicates that large Minnesota cities are actual or potential trouble spots.(66)

Primarily as a result of findings and recommendations from their 1982 study, the MPCA reports that it is carrying out a number of programs to obtain data about the nature of specific RWC emissions problems, complaint handling, and public information activities. These activities include:

* **Data gathering:**

  --Determination of benzo(a)pyrene concentration on a high volume sampler filter from five selected sites for the years 1982, 1983 and 1984. This study is supported by the USEPA Filter Analysis Network.

  --A USEPA Region V (5) grant to conduct receptor modeling based on chemical analysis of selected air samples.

  --Conducting an area source dispersion model for the Minneapolis-St. Paul area based upon wood use data developed by Minnesota DNR through surveys conducted during heating seasons in 1978-79, 1979-80, and a new survey to be conducted in 1984-85.

  --Establishment of a neighborhood monitoring station during the 1984-85 heating season to monitor RSP, TSP, visibility , carbon monoxide and PM_{10} in an area with high wood burning density.

* **Public Education** efforts are limited to occasional public speaking activities, distributing brochures and responding to requests for information.

* **Enforcement** activities are handled by the MPCA enforcement units which respond to complaints from concerned citizens. Some enforcement action is taken under a MPCA rule prohibiting garbage burning in unapproved incinerators. If there is evidence that something other than wood is being burned in a home appliance, a letter is sent to the resident notifying him of the rule and requesting a response. MPCA receives a large number of complaints and with their limited legal and manpower resources they find they cannot respond further. The state does refer complainants to local authorities for follow-up or further action under local nuisance ordinances.

Minnesota does not have other standards or rules regulating residential woodburning. Its current efforts are devoted primarily to data gathering so that it can determine the nature and extent of the RWC emissions problem. From data that does exist, MPCA Division of Air Quality considers that wood combustion is a serious and growing source of air pollution. Correspondence to the Division Director indicates that there is not yet a widespread public perception of the problem. Once the data is in, the Agency will consider the development of appropriate control strategies.(67)

6. Ohio

According to a recent survey, about 31% of Ohio households burn wood. Fifty-one percent of that group has been using wood for three years or less. Only about a third of Ohio residential woodburners buy their cordwood, an indication that most of the woodburning population lives in the more rural areas where access to woodlots is available.(68)

The Division of Air Pollution Control of Ohio Environmental Protection Agency indicates that residential woodburning stoves and fireplaces are exempted from Ohio EPA regulations and that the state is not presently planning to develop emission standards for such sources. Interviews with regional division air pollution enforcement personnel indicate that relatively few complaints are received, although this varies from one division to the next. The Northeast Ohio District Air Pollution Control Enforcement Section recalls only one complaint (involving a fireplace) in 12 years. The Central Ohio Division (Columbus area) receives complaints, primarily from neighbors affected by smoke from people burning garbage or incorrectly operating their woodburning equipment. It has no legal authority to respond, so complainants are referred to the City or township. The City of Columbus has a provision relating to safe installation of woodstoves in its building code and city inspectors can gain access to check for safe installation. Or, if the complaint seems serious enough, the Ohio EPA enforcement officer will telephone the resident and discuss the problem and suggest ways to improve operations and maintenance practices to reduce the air pollution problem. Central Ohio reports an increase in complaints over the past few years due to increased numbers of woodstoves and the fact that the Columbus metropolitan area has a higher growth rate than most other Ohio regions. The Cleveland Air Pollution Control Agency reports that they receive fairly regular complaints, primarily from affected neighbors of users of woodburning equipment. The Agency met with the Cleveland Board of Building Appeals to develop a list of policy resolutions relative to residential woodburning equipment which the Board has adopted and is using. The Dayton Air Pollution Control Agency has also published a booklet encouraging use of proper woodburning operations and maintenance practices. Other problems noted were that a number of citizens are burning coal instead of wood in their woodstoves, causing SOx emissions problems.

Ohio EPA Division of Air Pollution Control reported that a USEPA estimate made in 1977 indicated that residential wood combustion sources in Ohio emitted 612 tons of particulate matter, 4 tons of sulfur dioxide, 17 tons of nitrogen oxides, 153 tons of hydrocarbons and 3573 tons of carbon monoxide. Total statewide emissions from those respective pollutants in 1977 were 1.53 million tons of particulate matter, 3.26 million tons of sulfur dioxide, 1.19 million tons of nitrogen oxides, 1.45 million tons of hydrocarbons and 5.17 million tons of carbon monoxide. Even though loadings have increased due to known increases in numbers of woodstove sales since that time, more current data regarding the actual contribution of wood combustion emissions does not exist. The EPA indicates that residential wood combustion emissions may be an evolving problem that Ohio may have to address in the future in order to protect the public health. For the present, they will continue to focus on larger (i.e. industrial) sources that are more easily controlled.(69)

7. **Wisconsin**

There currently is no wood stove regulation at the state level and none is being considered for the near future. The Department of Natural Resources (DNR) does receive complaints about wood stove emissions, mostly in the Milwaukee area. Data is being collected by the DNR on the number and subject of the complaints. Complaints are handled at the regional DNR level. Inspectors visit the homes of the offenders, assess the problem and educate the wood burner on clean burning operation procedures.

A 1981 report (**Residential Woodburning and Air Quality in Wisconsin, An Overview**) by the state DOE indicates that Wisconsin has an abundant wood supply. Increased use would benefit the state's economy, providing wood burning does not cause serious air pollution problems. Approximately 1.6 million cords are consumed by residential woodburners (25% in fireplaces and 75% in wood stoves and furnaces). Wood supplies approximately 10% of the residential energy in the state and 2.5% in the industrial sector. It was estimated that homeowners saved approximately $30 million in fuel costs by heating with wood in 1978.(70)

The state does have 19 non-attainment areas (eleven for particulates, one for carbon monoxide and seven for ozone) in the industrialized southern part of the state; however, in none of these areas have wood stoves been documented to be a major source of pollution. In 1985 the state plans to monitor 2 or 3 areas for wood smoke pollution. Recently the state's energy office sent out 650 surveys to forest service agencies, cooperative extension agencies, community and environmental action groups, health departments and others to determine if air pollution problems from wood smoke are emerging in the state. Approximately 33% reported that there was a problem with wood smoke. However, the seriousness of this pollution has not been determined.

Due to the way in which the survey proceeded, attention was concentrated on areas where information about public health impacts and safety (house fires) concerns could also be documented through data provided by physicians and fire departments. Twenty-eight places were identified as a result of the survey as being of possible concern. Presently, Eau Claire and Rhinelander were chosen from the twenty-eight listed for more intensive studies. Most of these areas are located in the Southwestern part of the state (in the Driftless Area - unglaciated) and many are along the Wisconsin River. Many complaints have been received about woodsmoke pollution in the Milwaukee area, but data collection methods are not presently adequate to allow an assessment of the nature of the air pollution problem in that region.

A new study report will list various policy options that might be considered by the state to reduce air pollution from residential wood combustion activities. Of particular interest in Wisconsin is the potential to provide a **tax rebate incentive** (similar to that already provided under state law for residential solar and wind energy systems) for those who install clean burning stoves or retrofit existing stoves to meet an emissions standard. The standard would be based on the Oregon standard setting approach, using existing testing procedures for labelling stoves and retrofit equipment. The state could also encourage voluntary labelling by industry.(71)

H. RESIDENTIAL WOOD COMBUSTION EMISSIONS AND ALTERNATIVE CONTROL STRATEGIES

1. Pollution Control Policy in the U.S: The Context for Residential Emission Control

The following section will describe the context in which residential wood combustion emissions control strategies must be developed. Measures to improve woodheat safety can be incorporated into these strategies as necessary. Then a series of case studies are provided to illustrate emission control strategies that are in place or evolving in various states in the United States. Most are combinations of various control measures described in the previous section. The case studies for Western Europe illustrate appliaction of strategies designed both for safety and emission control.

Air pollution problems from residential wood burning activities cannot be considered apart from air quality problems within any given airshed or location. Emissions from residential wood combustion are added to those from commercial and industrial sources to affect the local or regional air quality. Air pollution from commercial and industrial sources is presently regulated under the Clean Air Act Amendments of 1977. This regulatory and institutional framework that presently exists throughout the United States provides the context in which to consider residential wood burning impacts on ambient air quality and the alternatives for addressing problem areas. An understanding of the present key elements in air pollution control policy may be essential in arriving at effective strategies for reducing residential woodburning emissions where these pose a problem in the Great Lakes States or elsewhere.

The basic **objectives of the Clean Air Act are to protect public health, to protect materials and natural resources, and to prevent serious contamination of areas that already enjoy clean air.** The primary strategy for achieving these goals is a nationwide prohibition against exceeding specified levels of pollution. The **most common air pollutants** are identified as "**criteria** air pollutants". These are **sulfur dioxide, particulates** (above 5 microns), **carbon monoxide, ozone, nitrogen dioxides, hydrocarbons and lead. National Ambient Air Quality Standards** (NAAQS -- allowable concentrations in a cubic meter of ambient air) have been established. These standards have been imposed on stationary sources of pollution which are primarily commercial/industrial and on motor vehicles. National Ambient Air Quality Standards state the maximum levels of pollution permitted in the air. **Each state** must have a **State Implementation** Plan (SIP) that specifies cleanup requirements for existing sources. The SIP also specifies the control requirements and permit procedures for new sources on a case-by-case basis. **Areas with polluted air are designated "Nonattainment Areas" if they exceed NAAQS and are subject to special requirements:**

* Industrial sources must be under **air emission control permits** from EPA.

* Existing sources must install **Reasonably Available**

Control Technology (RACT).

* New or modified factories and plants must install pollution controls with **Lowest Achievable Emission Rate** (LAER) and obtain further emission reductions (offsets) from existing sources.

* Urban areas must adopt **Inspection and Maintenance (I&M) Programs.**

Areas that have cleaner air and do not exceed the NAAQS are designated as **"Attainment Areas"** and are subject to **Prevention of Significant Deterioration (PSD)** rules so that their air cannot be made dirtier by new or existing industry. In attainment areas, existing sources that can be traced to visibility impairment in the national parks must install **Best Available Retrofit Technology** (BART). New and modified factories and plants must install **Best Available Control Techology** (BACT) and must not exceed specified increments of air emissions.

In addition to the regulation of the "Criteria Pollutants" as described above, which has been the central focus of the air pollution control program to date, there are a large number of other airborne chemicals and radionuclides. These are often emitted from sources more local than those emitting Criteria Pollutants. The Environmental Protection Agency, under **Section 112 of the Clean Air Act** is required to protect the public from toxic or **hazardous air pollutants** defined as **Non-Criteria Pollutants.** These hazardous air pollutants may be implicated in causing: cancer, genetic damage, reproductive failure, neurotoxicity (damage to the nervous system) and other serious health effects. The Environmental Protection Agency has listed only seven of these **Non-Criteria** air pollutants to date: **asbestos, beryllium, mercury, vinyl chloride, benzene, radionuclides and arsenic.** Standards exist for emissions of asbestos, beryllium, mercury, vinyl chloride, and inorganic arsenic. Non-Criteria regulations are source specific and apply only to the industrial and commercial processes that are specified in the regulations. (New regulations have been under consideration for a number of years.) Some of these will not be source-specific and are considered for benzene, polycyclic organic matter (POM), benzo(a)pyrene, and airborne carcinogens. If regulations apply to all sources, that will mean any building, structure, facility or installation which emits or may emit any air pollutant. At present, Non-Criteria hazardous pollutants judged to be particularly dangerous are regulated through the **National Emission Standards for Hazardous Air Pollutants** (NESHAP) which are described as allowable concentrations in a cubic meter of ambient air.

Both Criteria and **Hazardous Air Pollutants** are further defined and regulated on the basis of two different types of standards:

Primary Air Quality Standards, which are intended to safeguard human health, allowing a margin of safety to protect sensitive members of the community such as children, the elderly, pregnant women and sick people.

Secondary Air Quality Standards which are those necessary to protect the public welfare by preventing injury to agricultural crops and livestock, deterioration of materials and property, and adverse environmental impacts.

Each state has a **State Implementation Plan** (SIP) which details how the state is working to achieve Primary and Secondary Air Quality Standards for both Criteria and Non-Criteria Pollutants. These SIPs identify enforcement or control strategies for bringing air quality in non-attainment areas to minimum federal health standards for criteria pollutants. For cleaner (attainment) areas, they must show how higher air quality will be maintained in areas subject to Prevention of Significant Deterioration (PSD) provisions. The State SIPs are also to include automobile inspection and maintenance programs.

In general most SIP's have recognized only the commercial sector, industry and automobiles as significant sources of air pollution. However during the last five years a number of states have faced a growing problem from residential woodsmoke emissions and several of these states are actively pursuing regulatory programs to reduce these emissions. A fact that these states must face in establishing effective pollution control programs for residential woodburning, is the lack of success in regulating the activity of citizens within their own homes. Enforcement may become a real problem in the U.S. if attempts are made to regulate the stoveowner himself.

That scenario is actually on the near horizon. In March of 1984, EPA proposed revisions to the standards for particulate matter, the PM-10 Standard. Data has shown that the emissions rates of criteria pollutants, such as carbon monoxide, hydrocarbons and particulates are significantly greater from residential wood combustion than from residential sources using oil and gas. Of special concern, under the public health mandates of the Clean Air Act, is the presence of polycyclic organic matter (POM) in RWC emissions. A number of POMs such as Benzo(a)Pyrene are carcinogens. (See section on Health Effects.) As previously indicated, current estimates are that residential wood combustion produces 35% of the total national burden of POM and 25% of the Benzo(a)Pyrene.(72) Most of the POMs are attached to particulates smaller than those presently regulated under the Clean Air Act. EPA has identified a growing national concern over the air pollution contributions from residential wood combustion.

Proposed PM_{10} Standard

When EPA established ambient air quality standards for particulate matter in 1971, it chose to measure their attainment using a "high volume" sampler that collects particulate materials of sizes up to 25 to 45 micrometers (um). The standards did not intend to control particulates below 10 micrometers in size. Particles collected in the manner described are referred to in the standard as "total suspended particulates" or TSP.(73)

The key proposed revision to standards for particulate matter was a recommendation that TSP as an indicator for particulate matter be **replaced** by a new indicator called PM_{10}, that includes only those particles equal to or smaller than 10 micrometers. One of the concerns about the TSP standard was that larger particulates (10 um and larger) tend to be deposited outside of the lungs (mouth, nose and throat) where they pose more limited health risks. The smaller particles, however, are able to penetrate to the tracheobronchial and alvelor regions of the respiratory tract. EPA has concluded that the pollutants penetrating deep into the lungs pose risks of interference with respiratory mechanics, aggravation of existing respiratory and cardiovascular disease, carcinogenesis and other adverse health effects.(74)

During April of 1984, EPA held public hearings on its proposals for a PM_{10} standard. The agency's implementation strategy that revises EPA guidelines for the State Implementation Plans (SIPs) is under review by the Office of Management and Budget and will be available for further public review and comment with final promulgation anticipated for the summer of 1985. If the proposed PM_{10} Standard replaces TSP as the standard for airborne particulates, this change could have significant regulatory ramifications in areas where residential wood combustion is significant. Emissions from RWC will represent a much larger fraction of the regulated pollutants than under the existing TSP standard, because ALMOST ALL RWC EMISSIONS ARE SMALLER THAN 10 MICRONS (most are between 0.1 and 2 um). Some of the currently regulated particulates such as fugitive dust which are quite large (10-45 um) will not be covered by the new standard.

One example of the potential impact of the PM_{10} standard is found in Colorado where several mountain communities routinely violate NAAQS because of fugitive dust. These areas are not presently classified as non-attainment areas because they are under EPA's Rural Fugitive Dust Policy which says that airsheds violating primary standards for TSP are treated as attainment areas if most of the particulates are from non-point sources such as unpaved country roads. However, in these same communities, the wintertime particulate loads are primarily from residential wood combustion. The Rural Fugitive Dust Policy will be eliminated if the PM_{10} Standard is adopted. Then most of these towns will be classified as NON-ATTAINMENT AREAS. In communities where the major industry is recreation, labelling the area as a "dirty air" area could have major economic repercussions. In other areas of the country, particularly metropolitan areas such as Missoula, Montana or Seattle and Tacoma, Washington, where the airsheds have substantial TSP problems caused by emissions from RWC the chance of meeting NAAQS will be slimmer than it is now. Areas such as Minneapolis-St. Paul, Minnesota or Mio, Michigan which are presently designated as "attainment" areas, but where there is substantial RWC activity may lose their Clean Air status and become "non-attainment" areas.

"Since state governments are required by the Clean Air Act to develop SIPs that attain air quality standards within a reasonable amount of time, the worsened regulatory status of these cities might force state governments to impose on the cities measures to reduce particulate pollution that would be economically and politically painful."(75)

Several residential woodsmoke emissions research and monitoring programs (US EPA, TVA, Michigan DNR and others) have obtained results showing high emissions in local ambient air, of benzo(a)pyrene (B(a)P), other polyaromatic hydrocarbons (PAH's) and carbon monoxide (CO). The US EPA results, evaluated by a modified Method 5 analyzing mostly airtight woodstove emissions, showed that a large percentage of the B(a)P's and other hydrocarbons from the woodsmoke were not trapped in the particulate filters, but were found in back-up resin traps. Due to the public health implications for populations at risk from these toxic emissions, US EPA has initiated a program to develop standards to control wood smoke emissions. There is some question as to whether the regulations will be promulgated under New Source Performance Standards (NPS) or those regulations addressing emissions of hazardous air pollutants (NESHAP) regulations. It is anticipated that the notice of intent to regulate will be published in the February or March 1985 Federal Register. (US EPA's contact person on the Agency Woodsmoke Committee is Donald F. Walters at EPA facility in Research Triangle Park, North Carolina.)

The following sections will describe the type of emissions control strategies being considered or implemented in the Great Lakes region and in various U.S. states and foreign countries.

I. Alternative Emission Control Strategies

1. Alternative Control Measures

There are numerous technology or policy oriented alternatives that can be used to control or reduce air pollution and/or to address safety problems associated with residential woodheat equipment use. There is a direct relationship between reduced emissions and reduced chimney fire hazard. This relationship should be considered in the evaluation of given and alternative policies, practices, or technologies. In addition, a number of policies or actions used together may be more effective than one alone. Thus it may be to the advantage of a state or local government, industry and consumer to devise a strategy incorporating a number of activities that are targeted to address the specific problems in ways that are appropriate to the locality in question.

Strategies may be designed for implementation by local, state or federal jurisdictions with responsibility for specific actions assigned to individual sectors of the wood burning consumer-supplier-regulatory complex. This includes stove manufacturers, stove distributors, wood suppliers, wood burners, chimney cleaners, residential insurance companies and the trade association in the private sector. The public sector includes local, state and federal air pollution and energy agencies, the Consumer Product Safety Commision, building code agencies and zoning and building inspectors, fire marshals and local fire inspectors and the authorized testing/certification laboratories and organizations as well as the appropriate legislative bodies at local, state and federal levels of government. It is important to consider **who** is to be the **target** and **who** is to have **oversight** or **authority** over any given regulatory or control strategy.

Responsibility for action has been placed primarily on the individual woodstove user to date. This makes compliance with control objectives difficult to achieve. If emissions are a problem, the most efficient and cost/effective strategy may be to control emissions at the source. This is the choice in Oregon and Colorado. Here the primary responsibility is placed on the stove manufacturers. Short term emission control strategies will require more participation among the various segments of the woodburning consumer-supplier-regulator complex. Fire safety problems not directly related to burning efficiency will be most effectively addressed through local/state fire safety and building codes, insurance company requirements and user education.

The alternatives for residential wood combustion emission control presented below can be used either singly or in combination, as a strategy to reduce pollution problems. In specific instances they can be used to increase safety. Table 4.18 presents a summary of these alternatives and it provides examples of where each policy has been implemented.

TABLE 4.18. CONTROL STRATEGIES IN USE/PROPOSED.

Element	Areas in Use/Proposed
Public Education	Alaska; Oregon; Missoula, Montana; Colorado (ski communities and elsewhere); Reno, Nevada; Washington; Wisconsin; Minnesota.
Visible Emission Limits	Juneau, Alaska; Missoula, Montana.
Mandatory curtailment of use during high pollution episodes	Medford, Oregon; Missoula, Montana; Beavercreek, Colorado; Reno, Nevada; Juneau, Alaska.
Voluntary curtailment of use during high pollution episodes	Reno, Nevada; Albuquerque, New Mexico; Vail, Colorado; Juneau, Alaska.
Reduction of wet wood burning	Juneau, Alaska; Medford, Oregon.
Weatherization requirements for stove use	Medford, Oregon; Crested Butte, Colorado.
Restrictions on wood burning:	
- Number of appliances	Telluride, Aspen, Vail and Crested Butte, Colorado.
- Design standards	Aspen, Vail and Beavercreek, Colorado.
- Emission standards (stove certification)	Oregon; Missoula, Montana; Colorado.
- Residential permitting requirements	Missoula, Montana; Beavercreek, Colorado.
- Requirement of alternate heating in new homes	Medford, Oregon.

(Adapted from: Wayne E. Grotheer, "Overview of Control Strategies for Residential Wood Combustion." Presented at the 79th Annual Meeting of the Air Pollution Control Association, San Francisco, California, June 24 1984, Reference number 84.70.1.)

Successful implementation of control strategies may depend upon public perception of the severity of the problems, the segment of the woodburning complex targeted to shoulder primary responsiblity for program implementation, the distribution of costs and benefits, and the provision of adequate technological, financial and human resources.

TABLE 4.19. TECHNOLOGY-DEPENDENT EMISSION CONTROL TECHNIQUES.

Factors Adversely Affecting Emissions	Approaches for Possible Improvements	Principal Modifications Required	Applicable to Existing Stoves
Premature Pyrolysis in Wood Magazine Within Stove	1. Prevent heating of wood inventory	Design	No
	2. Feed wood in frequent small amounts	Operation	Yes
	3. Use large wood pieces, low surface to volume ratio	Fuel	Yes
	4. Burn moderate moisture content wood to retard pyrolysis	Fuel	Yes
	5. Burn devolatilized wood, charcoal	Fuel	Yes
Pyrolysis Rate in Primary Combustion Area Exceeds Local Air Supply Preventing Complete Combustion	1. Maintain high rate of primary air supply, with ensuing high burning rates	Operation	Yes
	2. Focus air supply into limited burning	Design	Retrofit
	3. Maintain high turbulence in active combustion region	Design	No
	4. Limit quantity of fuel in active burning area, i.e. approach fuel-controlled burning	Design	No
	5. Maintain high temperatures in active burning area	Design	Retrofit
	6. Avoid short and/or frequent reductions in air supply rate	Operation	Yes
Control of Emissions in Primary Burning Area	1. Provide high level of turbulence burning area to promote mixing	Design	No
	2. Maintain high temperatures in burning area	Design	Retrofit
	3. Provide long gas residence time at the high temperatures	Design	No
	4. Duct pyrolysis products from magazine into burning area	Design	No
	5. Provide down draft combustion, with bed area reduction to accommodate low burning rates.	Design	No
Control of Emissions in Secondary Combustion Zone	1. Maintain high temperatures	Design	Retrofit
	2. Use heated secondary air	Design	No
	3. Increase combustible content of primary combustion products	Design	No
	4. Provide auxiliary combustion using an ignition source and/or supplementary fuel	Design (Operation)	No
Add-on Systems Affecting Emissions Reduction	1. Use catalytic afterburner	Design	Yes
	2. Use separately fueled afterburner	Design	Yes
	3. Add heat storage capacity to the system, permitting other modifications to be acceptable for consumer utilization	Design	Yes

(Adapted from: John Seltz, "Air Pollution Impacts From Residential Wood Combustion in Minnesota." Minnesota Pollution Control Agency, December 1982, pp. 23-24.)

a. **Specific Measures**

Institutional and regulatory alternatives for controlling residential emissions from woodfuel can be targeted to the technology used or to achieving changes in behavior of the woodfuel user. The most effective strategies combine measures that consider both objectives. The main alternatives generally incorporate one or more of the following:

- Performance rating-certification programs
- Programs which certify compliance with standards
- Fuel conservation and weatherization programs to reduce heating needs
- Efficiency/emissions/safety inspections programs (government or private)
- Education programs
- Government or trade assocation research and development programs to develop improved emission control/safety technology and management
- Incentive programs.(76)

A number of emissions reduction alternatives are related to changes in equipment design. These are summarized on the previous page in Table 4.19.

b. **Implement Performance Ratings**

These are usually trade association certification programs that are supported by voluntary member compliance. Equipment meeting performance standards set by the industry are awarded a "seal of approval" (ie, it is listed by Underwriters Laboratories, or approved by the American Society for the Testing of Metals or the Woodheating Alliance). A directory may be issued annually that lists certified equipment by manufacturer, model type and number. Engineering committees within the trade associations develop the certification programs and they are enforced by the trade association.

This approach is targeted to the manufacturer with the objective that new stove installations meet performance standards that show low emissions. It requires that all stoves be tested and emissions rating be stated on a label on the stove. This would be similar to EPA gas mileage ratings for automobiles. Oregon studies projected that such labelling would eventually lower emissions by 25% in that state.(76a) If combined with tax incentives, even lower emissions levels might be achieved, or the same levels achieved sooner. This estimate assumes that new stoves would be 75% more efficient than old or conventional woodburning stoves.

Performance tests should result in labels that provide information about:

- Applicance heat output
- Appliance efficiencies
- Stack emissions
- Compatibility with other recognized performance and safety standards

The tests used to measure compliance are designed to be reliable and can be used by all stove manufacturers.(77)

c. Wood Stove Certification for Compliance with Standards

An increasing number of experts are convinced that a wood stove certification and emissions standard program is the only effective means of controlling wood smoke pollution. Both Oregon and Colorado have based their emission control programs on this strategy. Only those specific stove models meeting the state woodstove emission standard are certified by the state to be sold in the particular governmental jurisdiction. Certification would probably have to be required by the state government and be applicable statewide to be effective. This eases the burden on stove manufacturers who bear the testing costs and who must develop or modify their designs to meet emission requirements. If a minimum certification standard is used as a state-to-state model policy, compliance will be less costly for the manufacturers. For example, Colorado will accept stoves certified under Oregon law.

Citizens could be held accountable for buying certified clean burning stoves, in order to prevent their purchase of uncertified stoves outside the jurisdiction in which they live. This could be accomplished through the use of Building Codes or woodstove installation permits specifying the use of certified clean burning stoves. Cooperation between governmental jurisdictions would be essential as the use of the stove is at the local level and will be within local air pollution districts in many metropolitan areas.

The critical component of this strategy is the development of reliable stove emisisons testing protocols. (See Section E on Measuring Emissions and Emissions Testing.)

d. Permit System

Woodstove permits can be required by local or state governments of any citizen wishing to purchase or install a woodstove in the same way that automobile licenses are required. Permits would be used to limit equipment to that designated as clean burning and/or to control the number of stoves allowed within one residence or within a given geographical area (ie, a stove density policy). Permit requirements could be such that they would be issued only to clean burning stoves (ie, those that met minimum emissions standards). Enforcement could be difficult, unless modified state minimum standards were adapted to local building codes.

e. Building Codes

These can be used to provide criteria for materials and installation procedures that will reduce fire safety hazards from woodburning equipment. BOCA and NFPA 211 model codes specifically address these. Building Codes can also be used to restrict the type and number of woodstoves that can be installed in a residence. These are useful primarily for new buildings and for rehabilitation of existing structures when building permits are required. It would be feasible to require a building permit to install a woodburning heater, if this were a problem in a particular community. Codes are addressed in more detail in the safety section.

f. Pollution Charges

State policy could require a state-wide pollution charge on any stove that did not meet a minimum emission control standard. Or policy could permit local governments to impose such charges in areas where air pollution is a problem. This charge could be imposed on new stoves purchased, but would be difficult to impose on existing woodburning stoves. Such a policy would also require manufacturer testing to determine which stoves met a given state emission standard. It would be more effective to require that stoves meet a minimum emission standard, but a pollution fee would tax those persons who chose to buy more polluting stoves. Pollution charges might have to be coupled with purchase of Stove Permits to be effectively administered. Fees would be used to monitor and enforce the program.

h. **Permits to Pollute**

Requiring the purchaser of a woodstove to apply for a permit-to-pollute would be consistent with the approach of the Clean Air Act, the basis of ambient air emission control for other sources. The permit requirements would probably specify emission control objectives or standards to be met by each stove and would specify the circumstances under which use of the stove would be curtailed, ie., air pollution alerts. In the absence of a vigorous enforcement/inspection program the permit system would have limited impact. A limited number of permits would be available in any given airshed to allow for adequate distribution of air pollution rights among various classes of polluters, including private citizens.

h. **Educational Programs**

Burning wood cleanly has three major advantages: it increases combustion efficiency thereby reducing creosote build-up and emissions. Other advantages are cost reductions due to reduced wood consumption and an increased safety factor which results in lower insurance costs and lower fire risk. An objective of increasing efficiency and reducing health risks can be encouraged by educational programs. Specific concerns to be emphasized:

Garbage should not be burned. In addition to other harmful materials, garbage often contains plastics that release toxic gases when burned.

Refueling the stove regularly cuts emissions. By building small hot fires and adding fuel often, fewer emissions are produced in conventional woodstoves.

Burning hot fires reduces emissions. The period of greatest pollution usually occurs during the first 30 minutes of burning before the fire is hot. By putting kindling on top of the logs as well as underneath and using dry wood a hot fire can be achieved faster.

Burn dry wood seasoned for at least a year but no less than four months. Wet wood burns slowly and produces high emissions.

Burn hardwood when possible. Research shows that hardwoods produce fewer gases and particulates than softwoods when burned.

Burning high resin softwoods also causes rapid creosote build-up, increasing chimney fire risks.(78)

i. **Subsidies**

A subsidy might be the difference in cost of a clean-burning stove and a conventional airtight stove ($200 to $400). Or it might be a percentage of this amount, as clean stove users require much less fuel. Incentives toward the purchase and installation of retrofit catalytic combustors might have the most impact due to the large number of dirty stoves in present operation. Subsidies would have to be imposed at the state or federal level due to the cost, unless they were made available only to low income families. As suggested in one study(79), the subsidies might be provided by local industries that want to expand. This would allow a specific industry in a nonattainment area to purchase air pollution rights from area residential woodburners by providing them with cost-share to purchase clean burning technology. Implementation of such subsidy options could be provided for in a State's SIP, and would require either legislation or a change in regulations.

(1) **Tax Credits**

Either federal or state governments could provide a tax credit for individuals purchasing clean burning woodburning equipment or for the retrofit of existing equipment with catalytic combustors. Enforcement or implementation would depend upon IRS or State Tax auditors, as well as the procurement of a certificate that shows the specifications for the woodburning equipment installed, with verification of inspection by a certified inspector such as a Building Inspector or Chimney Sweep.

(2) **Home Insurance Rates**

Instead of spreading the increasing cost of fires from improperly installed and maintained residential woodburning appliances among all their policy holders, insurance companies could require an affidavit from their customers that includes a statement regarding the presence of a woodburning appliance in the home. In addition, they could require certification that woodburning equipment is clean-burning (that is it meets minimum emissions requirements) and is properly maintained. Emissions requirements would depend on the creation of industry-wide emission standards for new equipment in the same way as equipment must meet UL, BOCA and CPSC requirements for fire safety. The local building inspector could be so certified or the Chimney Sweeps Association would certify its members to do such inspections for a minimum fee. If the fee were paid by the insurance companies, it could be applied to the rebate amount. Statistics have shown that properly installed, maintained and operated stoves result in fewer fires. Reducing emissions by improved stove technology would result in lower rates of particulate and creosote formation, reducing fire damage further. If a fire occurred in a home where the affidavit stated that no residential woodburning equipment was in use and there was evidence to the contrary, the fire insurance coverage would not apply.

2. **Strategies for Implementing Emission Control Measures**

a. **Use of the Clean Air Act**

This Federal policy framework for air pollution concentrates on point sources of industrial and commercial emissions and on motor vehicle emissions to the ambient (outside) air. It does not presently address air pollutants emanating from residential sources, even though these pollutants may be identical to those from other sources regulated under the Clean Air Act, and are causing new or increased air pollution problems in a given area. Indoor air pollution is not addressed by the Clean Air Act. Some work place air pollutants are addressed by the Occupational Health and Safety Act. The Consumer Product Safety Commission is considering action on some residential air pollutants.

Many strategies for reducing RWC emissions are appropriate as means for implementing objectives developed within the context of **expanding provisions of the Clean Air Act**. This could be done through amendment of the federal act, through US EPA promulgation of new regulations or through action at the State level to add specific provisions to the State Implementation Plans. Given the complexities inherent in obtaining new amendments to the Clean Air Act, the most practical solution would be to begin by amending State SIP's by state regulation, or where necessary, by adopting new state legislation to include controls on RWC emissions.

Either federal or state SIP's could develop non-source specific NESHAP regulations that apply to all sources of a pollutant. This would limit stack emissions or ambient concentrations of non-criteria pollutants. NESHAP organic emissions result from incomplete wood combustion. Any policy that increases **combustion efficiency of stoves** would address this problem. Combustion efficiency under such a policy would be increased by setting requirements for woodstoves to meet certain efficiency levels. This could be accomplished by improving operations and maintenance practices, through requiring retrofits of conventional stoves with catalytic combustors or other technology to reduce emissions, and by requiring all new stoves to meet specific emission standards through certification programs. Pollution in a local area could be controlled under NESHAP through **limits placed on numbers of woodstoves** (stove density) allowed or by **limiting increases of specific air pollutants**. In extreme cases where local industrial conditions, or meteorological conditions resulted in high ambient concentrations of non-criteria hazardous air pollutants, the local government could take action to **prohibit the use** of woodstoves altogether.(80)

(1). **Air Pollution Emergency Episode Plans (State Implementation Plans)**

Each state must include in its SIP contingency plan, plans for the control of pollution during air pollution emergencies (Sec. 110 CAA 1977). Industries may be required to curtail particular activities. Even automobile use may be discouraged. A SIP could include provisions requiring the public to limit or cease woodstove use during thermal inversions or high particulate episodes. This action would depend mainly on voluntary compliance and require extensive public education. Local communities could enact Air Pollution Emergency ordinances with specific provisions regarding compliance.(81)

b. **Consumer Products Safety Commission Regulations/Programs**

Elevated levels of carbon monoxide, hydrocarbons and particulates may be found in residences where woodburning stoves are used for cooking or space heating. These pollutants may be the result of normal stove operations, such as the addition of fuel or fire-start-up, abnormal conditions due to improper installation and maintenance, downdrafts, or damaged equipment. Many households where wood-heat is used are also well insulated to conserve energy. This results in limited air-exchange rates. Indoor air pollutants may accumulate to dangerous levels in these homes. The Consumer Product Safety Commission could provide some means to address indoor air pollution through regulation of woodburning equipment by classifying it as potentially dangerous to the consumer. Regulatory options to address the problems of indoor air pollution could include setting limits on stove emissions, mandatory labelling and application of a minimum performance standard. Local communities could use Building Codes to reduce indoor air pollution concentrations by requiring air exchange rates for new buildings or for existing buildings undergoing modifications that require a building permit. The latter strategy would decrease energy efficiency gains. Industrial Building Code requirements have provided for both energy efficiency and indoor air pollution concerns. These codes are new, but experience may provide guidance for successful implementation of such strategies in the residential sector.

c. Regulatory Options Based on Common Law

The courts are sometimes used as a tool for addressing local air pollution problems. Interviews with various local governments in the Great Lakes States about how they dealt with existing problems or complaints regarding local air pollution from residential wood-burning, indicated that they use a nuisance law. Success in dealing with major polluters of water and air has led to broad use of this law. If the charge is that the polluter is creating a **public nuisance** (ie., interfering with a right common to the general public such as pollution of an airshed), only the state or its designee can initiate action and act to restrict stove use. If the violation is deemed to constitute a **private nuisance** (ie., it interferes with the right of a person or group such as the neighborhood, and it can be proven that this is the cause of specific injury to the parties involved), a private individual can bring action based on the contention that his ability to enjoy or use his property is interfered with indirectly.

The contemporary use of **Trespass Law**, defined as an intentional invasion of one's exclusive possession of property, would require the complainant to show that he was being invaded by air pollutant particles deposited from the atmosphere originating at a traceable location.

Negligence is defined as "legal delinquency resulting when care is not exercised in an activity, whether the extent of this failure is slight, ordinary or great." It is presumed to be the duty of every person to exercise due care in conduct that may injure others. Negligence may be characterized by thoughtlessness, inattention or inadverance. If a person fails to reduce his woodburning activities during an air pollution emergency, he may be found guilty of negligence. Strict liability could be applied under conditions where a technology gets out of hand. High concentrations of woodburning stove installations could result in high emissions of carcinogenic pollutants. This liability doctrine might be applied.

Obviously Common Law remedies are difficult to apply as policy tools due to the fact that only the Public Nuisance complaint can be initiated by a governmental jurisdiction. All the others must be initiated by an individual against an individual or nearby facility. It is possible to write public nuisance regulations to apply to a city or township, but local application could be made only on the basis of state limits.(82)

d. Use of Local Ordinances

State and local governments act under public health, safety and welfare doctrines. In this capacity most have adopted building codes which regulate the construction of residential dwellings. Building codes do specify what types of materials can be used for construction and the placement of certain equipment within a structure.(83) These are primarily for safety purposes and are difficult to change. However both BOCA and NFPA 211 provisions provide guidelines for local and state model building codes that regulate safety and performance standards for building installations such as woodstoves, fireplaces and chimneys. (See Section IV on Wood Heat Safety.)

Open burning ordinances enacted by State or Local Health Departments have had limited use against air pollution from woodburning stoves or fireplaces.(84)

e. The National Environmental Policy Act

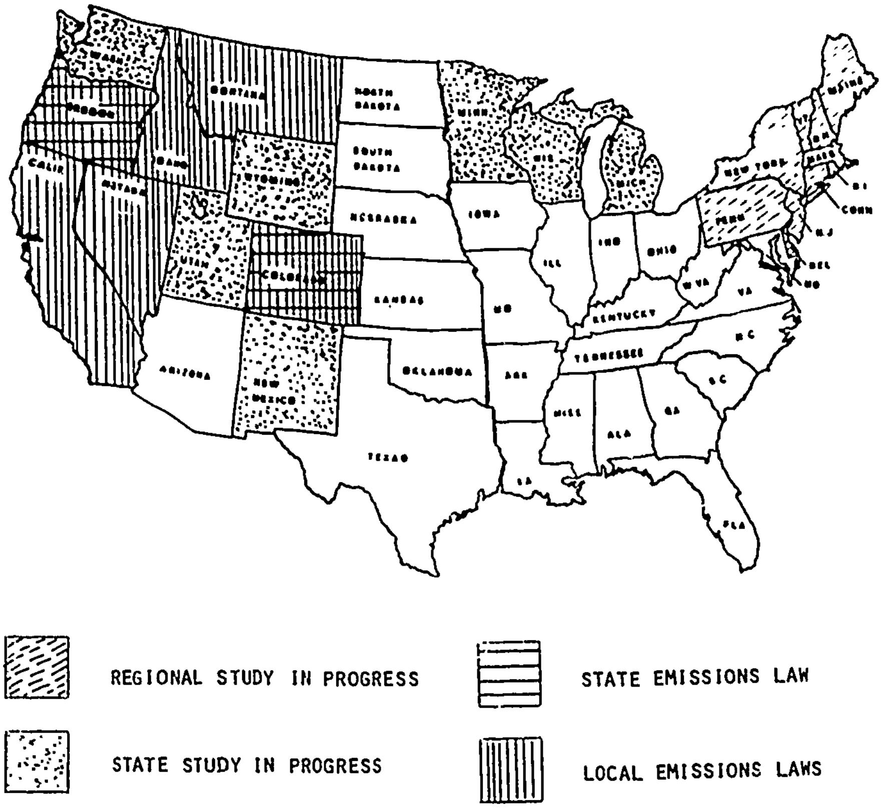
The National Environmental Policy Act has been invoked in the Tennessee Valley Authority's jurisdiction. The TVA, using federal funds, is engaged in a program to encourage residential woodburning and is providing low cost loans, education and technical assistance to homeowners who install woodstoves. The impact of emissions from 100,000 homes may eventually have to be addressed. An EIS is required under such conditions of substantial environmental impact. Strategies for limiting air emissions would appropriately be part of such a document.(85)

3. Case Studies: Application of Control Measures and Strategies

a. Introduction

Although there has been little regulatory activity related to wood stoves within the Great Lakes region, several states or local governments outside the region are actively studying emissions problems and/or developing regulatory programs to reduce woodstove emissions. Regulatory activity is being considered because woodsmoke has become a significant problem in these areas, generally because of high woodstove densities and the mountainous topography that traps woodsmoke in frequent and prolonged air inversions. The following cases are presented to indicate how these jurisictions have addressed the problem. Because Oregon's law is being used as a model by other states, it is described in detail. Figure 4.2 indicates those areas of the continental United States where emissions are of concern, and where emission control strategies exist or are being developed.

FIGURE 4.2. RESIDENTIAL WOOD COMBUSTION EMISSIONS CONTROL STRATEGIES.



b. <u>Control Strategies in States and Local Jurisdictions in the U.S.</u>

(1) <u>Oregon</u>

Oregon has used widespread public education to encourage proper use of residential woodburning equipment. Many publications have been developed and widely distributed within the state. Public education is also encouraged through the use of the media. The state's major control strategy is the limitation of sales of new wood stoves to low-emission devices.

(a) **<u>Residential Wood Combustion Emissions Control Policy</u>**

<u>Oregon's HB 2235-A Model Law</u>

In 1983, the Oregon Legislature passed HB 2235 which required the Environmental Quality commission to adopt rules by July 1, 1984 that restrict use of woodburning equipment to those devices certified as clean burning under standards. HB 2235 is an amendment to the Oregon Air Pollution Control Act (ORS 468.275 and 468.290) to provide policy for controlling the growing problem of pollution from woodburning emissions in the state. As such, it creates new provisions and amendments to establish woodburning control mechanisms. Highlights of this legislation follow according to sections of the law.

Section 1: This section adds definitions to include those relevant to the woodburning problem:

- "Air Pollution" means the presence in the outdoor atmosphere of one or more air contaminants, or any combination thereof, in sufficient quantities and of such characteristics and of a duration as are likely to be injurious to public welfare, to the health of human, plant or animal life or to property or to interfere with enjoyment of life and property throughout such area of the state as shall be affected thereby.

- "Woodstove" means a wood fired appliance with a closed fire chamber which maintains an air-to-fuel ratio of less than 30 during the burning of 90 percent or more of the fuel mass consumed in the low firing cycle. The low firing cycle means less than or equal to 25 percent of the maximum burn rate achieved with doors closed or the minimum burn achievable.

Section 2: This section specifically states that woodstoves in residential dwellings are not exempt from this air pollution act. The Oregon air pollution act does, however, exempt other residential sources of air pollution.

Section 3: Section 3 activates the amending process by stating that sections 4 through 10 be added to the air pollution act (ORS Chapter 468).

Section 4: This section is important as it states the legislative intent of HB 2235 as follows: "In the interest of the public health and welfare it is declared to be the public policy of the state to control, reduce and prevent air pollution caused by woodstove emissions. The Legislative Assembly declares it to be the public policy of the state to reduce woodstove emissions by encouraging the Department of Environmental Quality to continue efforts to educate the public about the effects of woodstove emissions and the desirability of achieving better woodstove emission performance and heating efficiency."

Section 5: Section 5 directs the Environmental Quality Commission to establish by rule the following before July 1, 1984:

1) Emission performance standards for new woodstoves;

2) Criteria and procedures for testing a new woodstove for compliance to these emission performance standards;

3) A program for certification of a new woodstove that complies with the emission performance standards when tested by an independent testing laboratory. This program will be administered by DEQ according to the criteria and procedures stated in subsection 2 above;

4) A program, including testing criteria and procedures to rate the heating efficiency of a new woodstove;

5) The form and content of the emission performance and heating efficiency label to be attached to a new woodstove; and

6) The application fee to be submitted to the department by a manufacturer, dealer or seller applying for certification of a woodstove.

Section 6: This section calls for the commission to establish an advisory committee to aid and advise the commission in the adoption of emission performance standards and testing criteria. The committee shall include, but need not be limited to, representatives from Oregon wood stove manufacturers.

Section 7: Discusses the role of woodstove manufacturers and dealers in the production of adequate woodstoves in accordance with HB 2235:

1) After July 1, 1984, a woodstove manufacturer or dealer may request the department to evaluate the emission performance of a new woodstove.

2) The commission shall establish by rule the amount of the fee that a manufacturer or dealer must submit to the department with each request to evaluate a woodstove.

3) A new woodstove may be certified at the conclusion of an evaluation and before July 1, 1986, if:

   a) The department finds that the emission levels of the woodstove comply with the emission standards established by the commission; and

   b) The woodstove manufacturer or dealer submits the application for certification fee established by the commission under Section 5.

4) As used in this section, "evaluate" means to review a woodstove's emission levels as determined by an independent testing laboratory, and compare the emission levels of the woodstove to the emission standards established by the commission under Section 5.

Section 8: This section established July 1, 1986 as the date from which a person may not advertise to sell, offer to sell or sell a new woodstove in Oregon unless:

1) The woodstove has been tested to determine its emission performance and heating efficiency;

2) The woodstove is certified by the department under the program established under Section 5.

3) An emission performance and heating efficiency label is attached to the woodstove.

Section 9: States that the provisions of the Act do not apply to a used woodstove and defines "used woodstove" as any woodstove that has been sold, bargained, exchanged, given away or has had its ownership transferred from the person who first acquired the woodstove from the manufacturer or the manufacturer's dealer or agency, and so used to have become what is commonly known as "second hand" within the ordinary meaning of the term.

Section 10: Provides that the commission shall use a portion of the net emission reductions in an airshed achieved by the woodstove certification program to provide room in the airshed for emissions associated with commercial and industrial growth.(86)

The Rules: HB 2235 was approved by the Governor of Oregon on July 5, 1983, requiring the Environmental Quality Commission to have adopted rules by July 1, 1984 which deal with certification of new woodstoves to go into effect July 1, 1986.

The Environmental Quality Commission, with the help of a Woodstove Advisory Committee developed proposed rules that cover testing procedures, lab accreditation requirements, certification application procedures and fees, labeling criteria, and emission standards (Woodstove Certification Chapter 340, Division 21, Sections 100-166). The Woodstove Advisory Committee and DEQ have proposed to phase-in stove pollution limits in two stages: one less strict phase that will begin in 1986 and another more stringent limit for 1988.

These emission performance standards and certification requirements are described below:

1) New woodstoves with minimum "heat output" of less than 40,000 Btu/hr advertised for sale, offered for sale, or sold in (the State of) Oregon within the period July 1, 1986 to June 30, 1988, shall not exceed the following weighted average particulate emission standards when tested to procedures in OAR 340-21-130:

a) (7) 15 grams per hour for a non-catalytic woodstove, or
b) (3) 6 grams per hour for a catalyst-equiped woodstove.

[Note: 9 and 4 grams per hour limits have been established for non-catalytic and catalyst-equipped woodstoves respectively, to be implemented in 1988.)

Hearings were held in locations around the state including Portland, Eugene, Medford, Bend and Pendleton. Comments from retailers, manufacturers, individual citizens and organizations were accepted as testimony on these regulations. As a result of the information gained through the public hearing process, the Oregon Department of Environmental Quality concluded that airshed needs were slightly less than originally projected due to downward revisions in population projections and that best practical catalytic stove control technology is capable of consistently complying with a 4 gr/hr standard. In essence, the Department concluded that a weaker case exists for supporting a 7/3 standard while a stronger case exists for the support of a 9/4 standard, a more reasonable and justifiable standard. A 9/4 standard should provide at least 70-74% reduction in woodstove emissions.

As of July 1, 1984, the Department of Environmental Quality began evaluation of woodstoves against these performance standards, upon request and payment of necessary fees. After July 1, 1986, no woodstove may be sold in Oregon unless it has been tested and certified as meeting the emission performance standards.(87)

(b) **Medford, Oregon**

In Jackson County, the residential wood combustion control strategy is aimed at eliminating preliminary standard violations by July, 1984:

-- **Firewood Moisture Control**: Through public education about seasoning wood; and encouraging spring firewood cutting at nearby national forests, through incentives to individuals and commercial cutters.

-- **Weatherization**: Required (to minimum cost effective levels) to install a new wood stove. A voluntary goal was set to weatherize all households in the air quality planning area by July 1984, with financial incentives including low interest loans, tax credits and help from utilities. If the primary particulate standard is not met by July 1984, the County will make weatherization mandatory.

-- **Episode Controls**: Voluntary curtailment of RWC during Air Stagnation Advisories, unless there is no alternative heat source. Mandatory curtailment if TSP exceeds the primary standard (260 ug/cu.m), or during Air Stagnation Advisories, if standard is not met by July 1984.

-- **Proper Sizing of New Wood Stoves**: To household heating requirements to be evaluated during stove permit process.

-- All new homes **must have an alternative heat source**.

-- **Public Education** on proper wood stove operation.

-- Urged DEQ to develop **certification and testing program** for RWC equipment, requiring particulate emissions of less than or equal to 5 g/kg of fuel burned. Only stoves meeting emission standards should be saleable in Oregon after July 1984. The state law took effect in 1984.

The major improvements in particulate air quality are expected to come from the weatherization (48%), moisture control (23%) and episode control (14%) strategy elements.(88)

(c) **Portland, Oregon**

A variety of weatherization programs sponsored by the city of Portland and local utilities offer no interest, or low interest loans, free home energy audits, and help in doing the work or in locating a contractor to do it. Weatherization of households is assumed to reduce the household heating requirements by 40% for the 60% of households which are poorly weatherized, and reduce total RWC emissions by 7-22%, depending on starting assumptions. (89)

(2) **Colorado**

Governor Richard Lamm signed a bill that will regulate the sale of wood heaters in Colorado beginning on July 1, 1987. Based on the Oregon policy of emission control standards, the legislation authorizes the Air Quality Commission to draw up a certification program that will include **wood stoves, fireplace inserts, and fireplaces.** The bill requires counties to adopt provisions to their building codes calling for strict design specifications for fireplaces. The Colorado law is very similar to Oregon's and Colorado will accept stoves that are certified by Oregon certification methods under a consistency provision. Under testing certification, methods approved by Oregon will also be used by Colorado. Regulations are currently being promulgated.

(a) Colorado Ski Communities

Control strategies for residential wood combustion have been adopted in five ski communities in Colorado: Telluride, Pitkin County (Aspen), Vail, Beavercreek, and Crested Butte. All of these communities have adopted limits on installations of new wood heating devices, limiting future increases in pollution. Other programs include **design standards, equipment performance standards, curtailment during episodes,** and **public education.** Specific measures in these communities vary:

Telluride: New buildings are restricted to one solid fuel burning unit.

Aspen: Installation of low polluting stoves and fireplaces is allowed but only one conventional stove or fireplace is allowed per building.

Crested Butte: Limits wood burning devices to one per building, and allows them only if the building meets very stringent insulation requirements.

Beavercreek Resort: has a unique approach to the woodburning problem. Regulations include fireplace design standards and permitting requirements, prohibition on wood stoves, restrictions on numbers of fireplaces, and an air pollution episode control system. This system consists of a heat sensor and warning light at each fireplace, wired to the central office to allow notification to the homeowner when burning must be stopped. The system allows for monitoring by the Resort company to ensure that burning has stopped. The Resort company has the power to enter the residence, extinguish the fire, and levy a fine if burning is not stopped when the warning light goes on. This control strategy is only possible because this is a private development of very expensive houses.(90)

In **Vail, Colorado,** gains in woodburning emissions control have been made. Besides a strong public education program designed to teach clean burning techniques, Vail has enacted the following measures:

-- New homes, hotels, and restaurants are prohibited from installing more than one stove or fireplace.

-- Voluntary curtailment of residential woodburning during air pollution episodes when CO or TSP exceed specified levels.

-- Coal sale or use is banned in the city limits (although not in the surrounding county where more growth is occuring).

-- Devices to improve fireplace efficiency (e.g. excess air) are required.

-- The City Engineer may establish design standards for RWC equipment.(91)

(3) **Alburquerque, New Mexico**

From a grant for $25,000 from the U.S. EPA, the Air Pollution Control Division of the Albuquerque Environmental Services Department installed a telephone system and "pollution signal light" was installed on top of a 118 foot building in a commercial area surrounded by residences where high carbon monoxide concentrations had been recorded. The signal light has lights covering a 5 foot diameter tower 35 feet high, and the signal light is shaped in the form of a candle. The light's colors are changed depending on hourly CO concentrations. The light is operated so that it is:

White when hourly CO concentrations are below 13 ppm. (Federal Standard is 9 ppm.)
Red when hourly CO concentrations exceed 13 ppm.
Blinking red when hourly concentrations exceed 26 ppm.

At levels above 13 ppm, it is suggested that individuals reduce their use of fireplaces and autos. At levels of about 26 ppm a request is made to stop using wood fires.

The system is operated between 5 p.m. and 11 p.m. during mid-November through mid-January, with one individual on duty adjusting the light based on hourly CO concentrations recorded remotely. Thus, after set up costs, system operation requires about 42 manhours per week (6 hr/day x 7 days) or about 380 manhours per year (9 weeks x 42 hrs/wk = 378), which at a loaded personnel cost of $20/hr would cost about $7600 per year.(92)

(4) **New York**

New York State has completed extensive surveys on the Wood Heat Safety issues and has substantial data to indicate the nature of that problem as being of major concern in the State. (See Section V concerning Wood Heat Safety.) However, the Department of Environmental Conservation reports that the State is not undertaking any programs presently directed to analyzing residential wood combustion problems. The Division of Air indicates that New York State in is compliance with Air Quality Standards and that even in heavy wood burning areas the Total Suspended Particulate (TSP) standard is not being violated. The State DEQ projects that there will be fewer emissions in the future as wood as a residential fuel is declining in the State.(93)

On the other hand, the State Energy Department's Master Plan projects that while overall woodfuel use will increase from 50.9 trillion Btu/year in 1982 to 61.8 trillion Btu/year in 1999 there will be increases primarily in the industrial sector. Residential wood heating use is expected to increase from 43.0 trillion Btu/year in 1981 to 47.9 trillion Btu/year in 1991 and then fall to 46.9 trillion Btu/year in 1999. It is important to note that even the declines anticipated in 1999 are 3.9 trillion Btu/year more than use in 1982. Based upon these figures New York State may anticipate some air emissions problems in areas where both industrial and residential growth occur, particularly if these are located in Upstate or mountainous areas.(94)

(5) **Pennsylvania**

The Bureau of Air Resource Management of the Department of Environmental Resources (DER) reports that Pennsylvania has no laws or regulations pertaining to control of emissions from woodburning stoves. The DER is in the process of establishing an information base on residential woodburning in the State. The Office of Resource Management of the Bureau of Forestry conducted a Pennsylvania Residential Fuelwood Use Assessment in 1980-81. This study was initiated because of the increasing use of fuelwood for space heating had aroused concern that indiscriminate cutting would damage forest resources, eliminate snags and den trees required by wildlife for habitat and lead to serious soil erosion problems. A telephone survey was conducted to assess fuelwood consumption for the winter season and submitted for statistical analysis. (See results in Section III on woodburning trends.) Significant to the emerging concern about air emissions in this mountainous state is that 30% of households are heated wholly or in part with wood and 46% of these households used woodstoves for primary or secondary heating purposes. This survey was concentrated on homestead residences and did not get data on the large numbers of "camps" or second homes located in Pennsylvania's recreational areas.

No specific problems related to air pollution from residential woodburning have been referred to the Bureau of Air Quality Control. As of 1984 no research has been conducted by the State to determine the exact nature of the emissions problem. However, the Bureau of Air Quality Control is keeping tabs on what is going on in other states and actively reviewing results of the Division of Forestry Study. They will pay particular attention during 1984-85 to any increase in particulates and other primary pollutants in non-attainment areas and review their approach to further examination of the emissions contributions from residential woodburning.(95)

(6) **Missoula, Montana**

An automated particle monitor (APM), purchased in 1978 for $15,000, provides hourly TSP levels. When particulate concentrations exceed 150 ug/cu.m. and a meteorological analysis suggests that poor dispersion conditions will continue, the Agency, among other actions:

1) Advises citizens via public media of the Alert.
2) Requests citizens to discontinue use of residential solid fuel burners.
3) Requests citizens to limit automobile driving to necessary trips only.

When levels of 300 ug/cu.m. occur and continued poor dispersion conditions are forecasted, a "WARNING" is issued which results in the following Agency actions:

1) Citizens are advised of "WARNING" by public media.
2) Citizens are strongly advised to eliminate all non-essential driving.
3) The discharge of visible emissions from residential solid fuel burners is prohibited, unless that equipment is the only heat

source.

The Missoula, Montana law was to face a ballot test in November of 1984.

(7) <u>**Other States and Local Jurisdictions Acting on RWC Emissions**</u>
In **Alaska**, regulations adopted in the city of Juneau include Opacity Standards that require officials to be able to see through the smoke.

The **California Air Resources Board** has examined emission control strategies and is providing assistance to local governments who are devising their own regulations.

The **City of Boise, Idaho** air pollution study has been completed by the State and control strategies are under consideration. Some mountain towns have adopted voluntary "no burn days".

In **Massachusetts**, increasing problems with residential woodburning emissions indicate that the problem is serious. The Department of Environmental Quality is considering following the Oregon Stove Certification Program. This could be done by amending the State Implementation Plan under the Clean Air Act and new legislation may not be necessary.

The state of **Montana** is considering various proposals to regulate wood heaters and legislation is anticipated. Specific proposals anticipated during the next legislative session are those to provide tax credits for clean burning technology.

In the city of **Virginia Beach, Virginia**, officials have begun a study to inventory wood stove emissions.

Wyoming is also studying the residential wood combustion problem and reviewing the Oregon Standard.(96)

4. Safety and Emission Control Strategies in Western Europe and New Zealand

a. Introduction

The following examples of policies and strategies for controlling residential wood combustion emissions and encouraging safe equipment installation and maintenance in other countries are provided to illustrate what is working elsewhere in the world. These specific examples are used because the application of the chosen alternatives is compatible with policies and institutional arrangements or practices in the United States.

Health inspectors in some larger western European cities have noted that nuisance complaints associated with wood and coal burning have increased rapidly in the last few years. Europeans using wood as a heating fuel are very concerned about high combustion efficiency because they want to handle and store as little fuel as possible, thus consumer demand and regulations passed in post-war years led to development of heating equipment that applies the down and cross draft principles, stoves that incorporate heat storage in their design, and large combustion equipment with auxiliary gas and oil burners and air pollution control equipment.

Co-firing with wood and coal is anticipated to become a major problem.(97)

The European regulatory response is diverse. Emission standards (limits on pollutant concentrations in stack gases) have been promulgated for particulate matter in several countries. West Germany has approached the problem of air pollution from small wood-fired equipment by specifying design criteria for the combustion equipment. Switzerland and France rely primarily on guidelines issued by non-governmental agencies such as the Association of Forest Owners and the Fire Insurance Companies.(98)

Most European countries have regulations requiring inspection and maintenance programs in home heating equipment and large central wood furnaces and boilers. These regulations have done much to control air pollution problems. Requiring efficient operation of combustion equipment is one of the least expensive means of controlling air pollution. Regulations are not especially stringent, but are supported by effective enforcement procedures that may induce better results than strict standards with inadequate enforcement.(99)

b. **West Germany**

In West Germany all installations with capacity equal to and smaller than 80 MJ/hr (75,840 Btu/hr) must either be fired with a smoke-less fuel (defined by German law) or they must be designed like a Universal-Dauerbrenner (universal slow combustion stove). The latter is a special design of down-draft stove in which combustion gases are guided so that soot and tar components have no other way to exhaust than to pass through the live-coal zone.

Germans enforce this regulation through inspection of the smaller solid fuel combustion equipment if a complaint exists and of larger size ranges by the chimney sweep guild which is charged with periodic inspections of the installations. Four weeks after installation of a new piece of equipment and once a year thereafter, the owner must have an inspection and emission measurement performed by the district chimney sweep. Emissions are tested with certified sampling instruments. Evaluation of samples is done at the Central Office of the Chimney Sweep Guild, and owners are provided with results and recommendations.(100)

c. **Switzerland**

In Switzerland, requirements of fire insurance companies, local ordinances and guidelines by several professional organizations have had a major effect on the development of solid fuel-fired equipment. For example, the Association of Cantonal Fire Insurance Companies requires a type-test of any heating appliance (most have to do with equipment safety). However, a limit of 1% volume of carbon monoxide in the flue gas is set for any equipment fired by solid fuel.

The Center for Wood Combustion of the Swiss Association of Forest Owners (SVW) promotes equipment with good combustion efficiencies. An approval stamp is given to equipment which passes an efficiency test rated 75% or greater efficiency.

As in West Germany, the chimney sweeps in Switzerland inspect and maintain heating systems. Once a year all combustion equipment and chimneys are swept and inspected, although no standards exist for solid-fuel fired equipment. A federal guideline prohibits burning of trash in fireplaces and recommends the use of dry wood only.(101)

d. <u>Sweden</u>

During the past 10-15 years, dense residential areas have been built in urban areas. Many of these residential developments have numerous homes with glass shuttered fireplaces (built for aesthetic and secondary heat purposes and to lower electrical costs). Those complaining most about air pollution problems (i.e. soot-blackened laundry and bad odors) tend to live in these dense residential areas.

In Sweden there are three main laws regulating wood combustion: the Environmental Protection Act, the Local Public Health By-Law and the Swedish Building Code. The Environmental Protection Act applies to non-residential installations, such as boilers larger than 10 MW. Installations of 10 MW and smaller, both residential and non-residential, are regulated by the Swedish Building Code. The Swedish Building Code had no guidelines for solid fuel combustion prior to 1983. By that time they were to develop policy relating to combustion techniques and emissions, particulate controls, dispersion modelling/chimney heights, disposal of solid wastes such as dry and bottom ashes, and emissions standards in type approval.

The Environmental Protection Board is to provide draft recommendations for residential wood combustion to be used by the local building and health administrations. Recommendations may be included in the Building Code. (102)

e. <u>France</u>

In France, there are some local laws or regulations that prohibit firing with either coal or wood in designated clean air zones of some larger cities. Fire insurance companies in Paris increase premiums up to three times the normal rate if wood stove heating equipment is not inspected and serviced once per year. Owners have to get a receipt for the performed inspections. If a homeowner has inspection twice a year, a bonus of up to 80% is awarded.(103)

f. <u>New Zealand</u>

New Zealand's 1972 Clean Air Act established air pollution control requirements for both industrial and domestic sources. Patterned closely on the 1956 British Clean Air Act, the New Zealand Act authorizes local governments to establish Clean Air Zones to control domestic smoke pollution. Under these provisions, control is only needed where air pollution problems exist, such as those areas which have a large space heating requirement coupled with meteorological conditions during the winter months. Within these zones the local government can apply in total or in part the following Clean Air Zone provisions:

-- Only approved domestic fuel burning equipment may be installed as new or replacement units.
-- Acceptable fuels may be prescribed. (e.g. The sulfur content of domestically burned coal must be less than or equal to 0.5%.)
-- Acceptable installation and/or operating practices for domestic fuel burning equipment may be prescribed.(104)

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(82)Mors, et al., p. 1262-1264.

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V. FIRE SAFETY

A. INTRODUCTION

Though air pollution from woodheat is a serious problem in a number of regions, it is not a problem shared in all sectors of the woodburning population. In general, where there is good air dispersion, little industrial pollution and/or a relatively low density of woodfuel systems, wood smoke pollution does not pose a problem. Regardless of topography, industrial concentration or woodstove density, however, there is one serious problem that is common to all residential woodburning areas--woodheat related fire hazards. The statistics on woodfuel related fires dramatically document the severity of this problem.

1. Woodheat Fire Hazards: Incidence and Costs

Fire prevention officials in the Great Lakes States are accumulating statistics on residential fires related to solid fuel heating. The results have been described as unexpected and startling. This parallels the alarming figures that have been developed nationally:

TABLE 5.1. National Estimates of Losses from Residential Solid Fuel Heating Equipment 1979–1983

1979–83	1979	1980	1981	1982	1983	% Change
Total Residential	757,500	721,500	757,500	733,000	676,500	- 11%
Total Nonheating	587,700	531,300	547,100	518,900	457,400	- 21
Total Heating	176,800	170,200	210,400	214,100	217,100	+ 23
Solid Fuel Heating Appliances						
Fixed Heater	9,700	11,200	22,200	39,300	47,300	+388 %
Portable Heater	800	1,100	1,200	1,900	1,000	+ 25
Fireplace	19,200	18,200	28,300	30,200	31,900	+ 66
Central Furnace	1,200	1,200	2,000	2,800	2,700	+125
Chimney Flue	27,800	31,000	47,000	44,700	46,600	+ 68
Chimney Connector	7,500	6,400	8,700	7,900	7,100	- 5
Other, Unknown	600	1,600	2,400	3,400	3,300	+450

Projections were derived by applying proportions observed in the data from all states reporting to the US Fire Administration (USFA) each year to the national aggregate estimates of fire losses. Column detail may not add to total due to rounding.

Source: National Fire Protection Association: US Fire Administration, U.S. Consumer Product Safety commissions/EPHA

TABLE 5.2 Solid Fuel Trends in Casualties Associated with Residential Heating Equipment Fires 1978-82

	1979	1980	1981	1982	1983	% Change 1979-83
Total Residential	62,500	57,900	58,500	58,000	48,540	- 22%
Total Nonheating	51,790	47,850	48,940	48,070	40,140	- 23
Total Heating	11,790	10,050	9,560	9,930	8,390	- 29
Solid Fuel Heating Appliances						
Fixed Heater	610	610	830	780	1,160	+ 90
Portable Heater	70	c/	c/	60	80	d/
Fireplace	1,030	740	900	980	740	- 28
Central Furnace	60	c/	130	80	120	+100
Chimney Flue	660	560	740	710	640	- 3
Chimney Connector	200	200	460	300	210	+ 5
Other, Unknown	c/	120	60	150	c/	d/

Some notes regarding projections and column detail: c/ means estimates less than 50; d/ means percent change was not calculated due to small sample sizes.

Source: National Fire Protection Association: US Fire Administration, U.S. Consumer Product Safety commissions/EPHA

TABLE 5.3. Trends in Dollar Loss from Residential Solid Fuel Heating Equipment Fires from 1979-1982: All Causes

Year	Fires	Percent Change	Deaths	Dollar Loss
1978	66,800		250	$134 million
1979	70,700	+ 6%	210	175 "
1980	112,000	+58%	350	N/A
1981	130,100	+16%	290	265 million
1982	140,000	+8%	250	250million

Source: Memorandum, U.S. Consumer Product Safety Commission, October 6, 1983

There were more fires for solid fuel burning equipment and a larger percentage increase over previous years than were reported for any other kind of heating equipment, including gas, electric and liquid fueled heaters. Wood burning appliances were the third leading cause of multiple deaths from fires in residential properties from 1971 to 1980.(1) During 1982, 20% of all residential fires were attributed to solid fuel heating appliances.(2)

The major causes of fires associated with these appliances were identified as improper installation, use, and maintenance of appliances, chimneys and chimney connectors. The problem was especially critical in the venting systems. In 1981, out of the 130,100 estimated fires involving heating equipment, 52,000 were attributed to chimneys, flues, or chimney connectors (85% chimneys and flues, 15% chimney connectors).(3) An earlier National Bureau of Standards study analyzed fire incident data and attributed only 13% of solid fuel related fires to product malfunctions, construction defects, design deficiencies or worn out equipment. Instead, conditions related to installation, operation or maintenance of appliances were responsible. Most of the installations were being made by the consumer and few were being inspected by building officials.

Inadequate clearance to combustibles and ignition of creosote deposits were frequently cited as contributing factors to residential solid fuel heating equipment fires.

Although the reported fire statistics related to solid fuel heating are alarming, the possibility exists that estimates may actually be low. Not all states participate in the national uniform fire reporting system (U.S. Fire Administration), nor is the reporting within each state necessarily following this format. State fire prevention officials have also emphasized that reliability of reporting is assured only in larger fire departments, and that limited experience or expertise in fire investigation in many smaller or volunteer departments can result in non-specific reporting.

These fire statistics have not gone unnoticed by public and private sector organizations involved with fire safety. There have been many and varied responses to the fire safety issue. In the following pages we will discuss some of these responses.

2. **Fire Statistics and Fire Prevention Activities in the Great Lakes States**

ILLINOIS

The State Fire Marshal's office reports statistics related to residential woodheating as follows for 1982 to 1984.

TABLE 5.4. Insurance Losses, Injuries and Deaths from Woodheat Systems in Illinois during 1982-84.

	1982	1983	1984 (six months)
Fires	250	228	116
Dollar loss	$3,280,985	1,611,960	1,031,266
Civilian injuries	154	144	72
Civilian deaths	43	26	9
Fire Service injuries	89	76	21
Fire Service deaths	1	-	-

Source: Illinois State Fire Marshal's Office

There is no overall state program for regulation of woodburning equipment in Illinois. The Fire Marshal's office has implemented an extensive education program for officials and the general public.

The Fire Marshal's office is responsible for collecting data, inspecting public institutions and conducting arson investigations. Inspection of residential installations occurs by local building inspectors and are based on local building codes where such have been adopted. No overall state building code exists and each municipality must adopt its own. The Building Officials and Code Administrators Code is the code most likely to be used. The issuance of permits for installations also varies depending upon the individual localities.

There are no licensing/certification requirements for the installers or sellers of woodburning equipment. For fire prevention control, woodstoves must be safety tested and listed by Underwriters Laboratories (UL listed). Illinois does not use the National Fire Inspection Reporting System (4)

INDIANA

The state fire Marshall's office reports 793 structural fires in the 1983-84 heating season related to heating equipment. Thirteen deaths were caused and 65 injuries, 3 serious. The dollar loss was $11,046,199. Woodburning equipment was the overwhelming cause, with improper installations, flues, chimneys, and overheating contributing a major share.

Installation of woodburning equipment is regulated under the Indiana uniform mechanical code but there are no mandated inspection programs. The Fire Marshal's office is conducting 64 hour classes for fire department personnel and building inspectors which emphasized the hazards of woodburning equipment when improperly installed or operated. A community information project on wood heat safety was undertaken by the Indiana Board of Health working with 9 county health departments and using radio, TV and printed media.

IOWA

The Office of State Fire Marshal provides educational programs on woodheat safety. For example, one program was conducted at the State Fair and others were presented through speakers bureau programs for various organizations. Public sevice announcements on radio and television were also used.

Iowa does not issue permits for woodheater installations nor does it require compliance with a state fire code or require statewide safety testing for equipment. The state building code is the Uniform Building Code, 1982 edition. Inspections that are done are carried out by local government building inspectors who follow the NFPA guidelines for stoves and chimneys. (5)

The state of Iowa participates in the National Fire Incidence Reporting System (NFIRS) and has provided the following statistics (Table 5.5) to indicate Chimney Fire losses from 1979 through 1983.

TABLE 5.5. Chimney Fire Losses from Residential Solid Fuel Heaters in the state of Iowa from 1979 to 1983.

Source	Incidents	Fire Service Injuries	Civilian Injuries	Service Deaths	Civilian Deaths	Dollar Losses
1979						
Fireplace	43	0	0	0	0	$234,475
Chimney Gas Vent Flue	41	2	1	0	0	208,852
Chimney-Vent Connector	34	0	0	0	0	237,850
TOTAL	118	2	1	0	0	681,177
1980						
Fireplace	166	2	2	0	0	760,227
Chimney Gas Vent Flue	119	0	0	0	0	550,213
Chimney -Vent Connector	87	2	1	0	0	623,101
TOTAL	372	4	3	0	0	1,933,541

(Table 5.5 continued)

Source	Incidents	Fire Service Injuries	Civilian Injuries	Service Deaths	Civilian Deaths	Dollar Losses
1981						
Fireplace	194	1	4	0	0	795,148
Chimney-Gas Vent Flue	187	4	0	0	0	521,718
Chimney-Vent Connector	75	0	0	0	0	380,029
	456	5	4	0	0	1,696,895
1982						
Fireplace	198	3	8	0	4	963,433
Chimney-Gas Vent Flue	243	4	1	0	0	1,008,135
Chimney-Vent Connector	73	1	0	0	0	639,054
TOTAL	514	8	9	0	4	2,610,622
1983						
Fireplace	209	8	1	0	0	948,189
Chimney-Gas Vent Flue	255	0	2	0	0	795,094
Chimney-Vent Connector	76	5	1	0	0	488,131
TOTAL	540	13	4	0	0	2,231,414

SOURCE: Iowa Fire Incidence Report, State Fire Marshal's Office, Correspondence.

MICHIGAN

The division of the Fire Marshal in Michigan works in consultation with local fire departments to investigate and determine the causes of and damages from fires. It also assists in developing educational programs and informational materials on fire safety.

Michgan Act 230 - Public Laws of 1972, provide basic authority for building code heating installation inspections. Local building code inspectors perform this task. The state building code is the 1981 edition of BOCA with Michigan amendments. All solid fuel stoves must meet U.L. test standards and be listed. The State does not use NFIRS. Local fire departments perform fire inspections and are responsible for fire prevention control programs and education. Since April of 1980, the Department of Labor, Division of Construction Codes has been responsible for inspection of all new heating installations unless a local jurisdiction elects to do this themselves. In 1984, the Division of Construction Codes was inspecting in sixty counties out of eighty-three. Heating equipment inspection costs $35 and most people are reluctant to pay this fee. Uniformity of administration is a problem.

At present there is a Division of Construction Code education program for inspectors to keep them current on code updates. The state is using a movie on chimney fires as well as a slide show showing proper installation and maintenance techniques and requirements for woodheater and insert installations, pre-manufactured chimneys and other woodheating equipment.(6)

MINNESOTA

In Minnesota 21% of the households use woodfuel for primary or secondary heat. The major health risks associated with woodheat in Minnesota are house fires, wood harvesting accidents and asphyxiation. In 1981, wood stoves and fire places were reported as the third largest cause of fire deaths in the state.

The State Fire Marshall's office reported that there were a total of 4,996 fires in 1-2 family dwellings in 1983, with 35.2% (1760) originating in chimneys. Fires related to solid fuel heating equipment numbered 1477 with inadequate maintenance and improper operation cited as predominant causes. Thirteen deaths resulted, with over $7.3 million in fire losses. The Fire Marshall's office reports that home fire deaths soared after the 1973 energy crisis, reached a peak of 134 in 1976, and have since declined to below 100 annually, with 61 residential fire deaths occuring in 1983.

There is no overall state program for regulation of woodburning equipment in Minnesota. Inspection of installations in new dwellings is done by local building inspectors, where they exist. The State uses the International Conference of Building Office (ICBO) code which is observed in metropolitan areas. County referenda determine applicability of this code; 77 out of 87 counties do not presently follow a uniform code. The Fire Marshall's office is responsible for compilation of data collected under the Minnesota Fire Incidence Reporting System. Of 834 fire departments in Minnesota, only 13 are full time. Fire prevention and education activities are largely dependent on these departments. At present there is no state program.

OHIO

Wood burning stoves are the major cause of household fires in 79 of Ohio's 88 counties. In some areas of the state, up to 60% of residential fires were related to wood heating. The State Fire Marshal's office indicates that the number of wood heating fires has more than tripled in the four years they have been monitoring the problem. In 1982, the 3,742 fires related to wood heating caused $11.6 million dollars in damages with 13 deaths and 123 injuries. Seventy-five percent of the fires have been caused by improper operations and use of equipment and creosote accumulations. The other 25% have resulted from improper installation.

State Fire Officials have identified 31 counties in Ohio where over 40% of residential fires were related to wood heating. These counties were targeted for wood stove safety programs. Fire Marshal personnel have been assigned to assist local fire departments and other organizations in conducting wood heating safety seminars, distributing installation and operating materials, and providing information through the media. The Ohio Insurance Institute has participated in a statewide information program through the media and in group presentations. The Ohio Chimney Sweep Guild and the Cooperative Extension Service have also aided the public information programs. The Fire Marshal's office indicates that the percentage of installations related fires has dropped from approximately 50% to 25% due, in some measure, to one concentrated education program.(7)

WISCONSIN

Fire statistics and fire prevention activities including building code enforcement are handled by the Department of Industry, Labor and Human Relations. The Fire Marshal's office is presently responsible for arson investigations. Fires associated with residential heating in 1982 numbered 3,500 with 57% related to woodburning equipment.

Wisconsin has a uniform dwelling code for one and two family dwellings. Permits are required for the installation of heating equipment but inspection is voluntary. Annual inspection for public buildings, many of which heat by wood, is mandatory under the state code administered by the safety and building division.

Education programs are conducted by the Division of Fire prevention, the Division of State Energy, the Agricultural Extension Service and by private insurance companies.(8)

B. CAUSES OF RESIDENTIAL WOODHEAT FIRE HAZARDS

Woodheat related fire hazards are attributable to four basic problems: equipment failure, faulty installation, faulty operation and inadequate maintenance. These problems often exist in combination and one problem can compound another. For example, a faulty chimney installation can lead to rapid creosote buildup which requires more frequent chimney cleaning. If frequent cleaning is not done and creosote builds up, the faulty practice of overfiring may lead to a severe chimney fire, chimney failure and a house fire. Becasue of inadequate fire reporting procedures, reliable data on specific causes of woodheat related fires is unavailable. However, the general consensus is that faulty installations are the major cause of fire losses, injury and death (9)

1. Equipment Failure

Equipment failure includes product malfunction, construction defects, design deficiencies and damaged or worn out equipment. Equipment failure has been cited in only a small percentage of the fire causes. However, the contribution of equipment failure to total fires is probably understated, if design deficiencies are adequately accounted for. Stoves that produce large amounts of creosote could probably be considered deficient designs, since creosote creates such a safety hazard.

Product malfunction generally involves the failure or breakdown of a functioning part during normal use. Examples might include sticking thermostats, broken door latches or disintegrating catlytic combustors.

When products are not built to manufacturing specifications these are considered construction defects. Misaligned doors, poorly sealed joints or substitution of inferior quality materials are construction defects.

Design deficiences are less easily defined. Some are fairly obvious, such as the lack of safety latches on doors, or spin draft caps that spin off. Other less obvious ones, are design characteristics that require more human reponse to ensure safety than stoveowners can or are willing to give.

Woodheating systems require more active and frequent attention from homeowners than conventional heating systems do. Part of the problem lies with the nature of the wood combustion process. As long as a burning log is in the fire chamber, it is impossible to cut off the fuel supply to the fire quickly. Therefore greater lead time is needed to shut down a dangerous burn condition. Since there is a great deal of opportunity for negligence or operator error in wood burning operation (fire starting, fuel loading, equipment cleaning, etc.), the problem is compounded.

Currently most woodstoves do not incorporate the automatic safety features that oil and gas systems have. Surface thermometers and stack fire alarms can alert a stoveowner to a pending problem, but the owner must be present to monitor these tools and respond to the alert. Ideally, safe equipment designs should be forgiving enough to override the more common operating errors. Clearly advances in technology that effectively automate safety functions (such as draft shutdown during chimney fires) or that eliminate or reduce a potentially hazardous conditions (such as stove designs that produce little creosote) can contribute significantly to woodheat safety.

2. **Faulty Installations**

A study by New York State Energy Research and Development Authority (ERDA) reported that of 510 woodheat installations inspected, 60% were classified as hazardous to extremely hazardous. Surprisingly, it was found that systems that were installed by professionals (dealers, sweeps, and contractors) were, on the average, no safer than those installed by stove owners. Approximately two thirds of the installations had been done by the stove owners or friends and relatives. Only 20% of all installations had been inspected by a professionally trained inspector. (10) The percentage of faulty installations reported in the study was much higher than in most other reports. However, it does show that an installation and inspection problem exists and that training for professionals, as well as stoveowners, is needed. There is much opportunity for error in installation. The following section presents the more common problem areas.

Inadequate Clearances to Combustibles. Figure 5.6 shows the National Fire Protection Association (NFPA) 211 recommendations for clearances for woodheat installations. Inadequate clearances to combustibles can lead to fires from sparks or from spontaneous combustion. Temperatures as low as 200-250 degrees F can cause spontaneous ignition of wood, especially if the wood has been exposed to drying heat over a period of time.(11) One of the most common clearance problems occurs when a stove pipe is passed through a combustible wall into a chimney flue.

TABLE 5.6. Installation Clearances Recommended by the National Fire Protection Association (NFPA 211) for Woodheating Installations.

Clearance Reducing-System	Maximum Clearance Reduction*		Minimum Clearance (unless listed for less)	
	Wall	Ceiling	Wall	Ceiling
3½" thick masonry without ventilated airspace	33%	–	24"	–
½" thick non-combustible board over one-inch glass fiber or mineral wool batts	50%	33%	18"	24"
24-gauge sheet metal over one-inch glass fiber or mineral wool batts reinforced with wire, or equivalent, on rear face with ventilated airspace	66%	50%	12"	18"
3½" thick masonry wall with ventilated airspace	66%	–	12"	–
24-gauge sheet metal with ventilated airspace	66%	50%	12"	18"
½" thick non-combustible insulation board with ventilated airspace	66%	50%	12"	18"
one-inch glass fiber or mineral wool batts sandwiched between two sheets 24-gauge sheet metal with ventilated airspace	66%	50%	12"	18"

*Percentage reduction from manufacturer's recommended clearance(s)
Note Specific conditions are related to the use of this table Consult NFPA 211 booklet for details

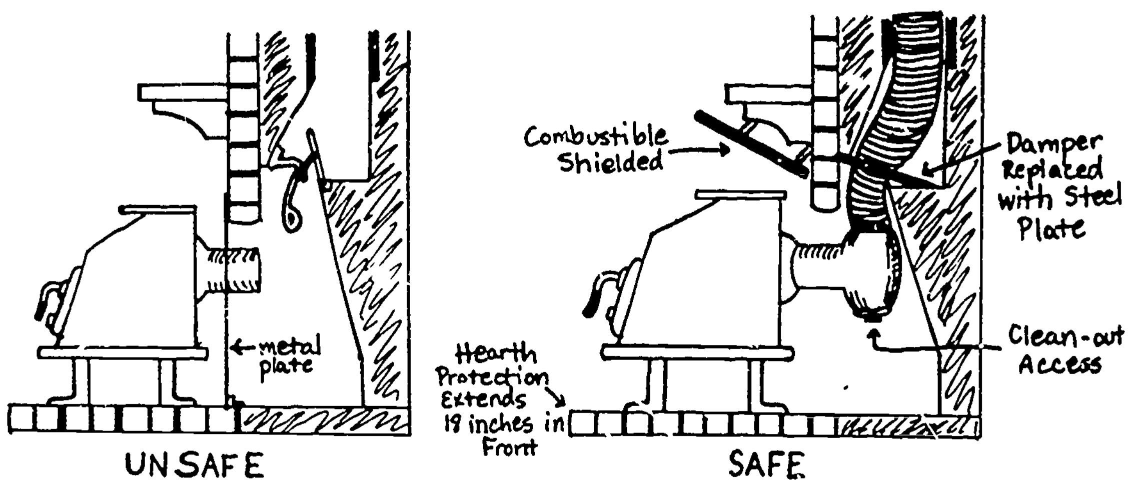
SOURCE: Wood 'n Energy, "NFPA 211 Changes", March 1984, p. 41.

Multiple Use of a Single Flue. The connection of several appliances to one flue is common in commercial and industrial buildings. In many homes, furnaces and water heaters often share the same flue. Masonry chimneys can be built for safe use by more than one appliance by having separate flues or tile liners within the overall masonry structure. Each flue or liner is an isolated, independent channel. It is safe to attach a number of appliances to the same chimney as long as only one appliance is attached to each flue and each flue is the proper size for the appliance (12).

There are a number of problems with attaching two appliances to a single flue. First, if one is an open heater, sparks from the other appliance may come through the open heater. Second, the draft from one appliance may affect the other in such a way that dangerous fumes could back up into the house. Third, in the event of a chimney fire, it is much more difficult to completely shut off the air supply to the fire; if one appliance is an open heater, it would be impossible to shut off the air supply. (13) Due to ignorance or unwillingness of stoveowners to pay the cost of another chimney, multiple use of a single flue is not a rare occurrence. Codes in some states do not prohibit this practice. (14)

Improper Insert Installation. It has been a common practice to install inserts in fire places by backing the insert into the fire place opening, with no direct connection between the stove and the fireplace flue. In this type of installation, creosote and water condense on fireplace chamber walls as well as in the chimney flue. Chimney inspection and cleaning are very difficult to do. In the event of a chimney fire, it is impossible to close off the air supply. Recent NFPA 211 guidelines require that a positive connection be made between an insert (or a hearth stove) and the chimney flue. (Figure 5.1) Several woodheat experts have expressed the opinion that a safe connection requires that the connector run all the way up to the chimney top. (15)

FIGURE 5.1. Installation of a Hearth Stove or Insert into a Fireplace Using a Positive Connection.



Inappropriate Types of Chimneys. Chimneys are exposed to thermal stress from extreme temperature and corrosive combustion products. Consequently, they must be made of very resistant materials. Inappropriate chimney and/or connector pipe materials that have been used include sewer pipe, drain pipe, cast iron, aluminum pipe, and thin-guage steel. Single-walled pipe, regardless of metal type, can cause a fire hazard if used as a cracking and corrosion from flue gases, especially when not lined.(16) Metal chimneys designed for gas and oil furnaces will melt from the heat of a chimney fire.

Materials that are suitable for wood heat systems include double or triple wall stainless prefabricated chimneys and masonry chimneys with a fire clay or stainless steel liner.

Improper Sizing of a Stove and/or Chimney. Stove and chimney sizing can have a significant impact on safety. Undersize stoves can be a hazard if they are overfired to keep the home warm. Oversized stoves are often a hazard because they must be burned at low burn rates to prevent overheating. This causes rapid creosote accumulation in the chimney.

Inappropriate chimney size can affect the creosote accumulation rate and indoor air quality. Ideally, chimney diameter should match the flue pipe collar diameter on the stove. If the chimney is too large, draft will be reduced and flue gas flow will slow causing faster creosote condensation. If the chimney is too small in diameter or is too short, the chimney may have inadequate draft. In this situation the fire will be difficult to start and keep going. Combustion gases may back up into the room. If the chimney is not high enough, backpuffing may occur. Since wood smoke contains toxic and irritating materials, backpuffing can cause significant health hazards, especially to infants and the elderly who are most susceptible to respiratory problems.

Improper Installation of Water Heating Systems. Explosions, often called BLEVE's for Boiling Liquid Expanding Vapor Explosion, provide the greatest danger for central wood heating system boilers and fireplace and wood water heating accessories. As water is heated, it expands slightly, but with tremendous force. A very large expansion occurs if it is allowed to boil. Whether or not boiling occurs, the pressure continues to rise in a closed system of water that is being heated. At some point the container may not be able to take the expansive forces of the water and steam, and the container may burst.

Water heat explosions are not a frequently reported occurrence, however, the consequences of such explosions can be catastrophic. The superheated water emerging from a pressurized boiler can cause serious steam and hot water burns. The most dangerous result of such explosions are metal projectiles. Cast-iron water jackets in wood stoves can explode into pieces of shrapnel with fatal consequences.(17) Prevention of such steam and hot water explosions requires the use of adequately strong and durable materials and some means for safe release of pressure (e.g. expansion tank and/or pressure relief valves).

3. Faulty Operation.

Wood heating systems require a lot more time, attention and skill in operation than do conventional heating systems. There is a great deal of opportunity for operator error. Operator errors result mostly from ignorance. Generally the error results in minor injury or damage. However much greater damage and injury, or even death, can occur. This is especially likely when operator error is coupled with faulty installation or inadequate maintenance.

Operator errors that have been cited in fire reports include:

- The use of flammable liquids to start or stoke a fire.
- Leaving stove or ash drawer doors or draft caps opened,

resulting in overfiring.

- Leaving the spark screen off fireplaces or open heaters.
- Placing combustibles (wood, paper, furniture, clothing, etc.) on top or too close to the heater.
- Ash disposal in combustible containers or near combustibles.
- Overloading and overfiring the stove. This can cause physical damage to the stove, cause creosote in the chimney to ignite or can ignite nearby combustibles.
- Burning of toxic or corrosive materials. Burning treated wood or garbage will release toxic fumes into the outdoor air and possibly into the room when reloading or backpuffing occurs. Materials such as plastics, produce corrosive compounds as well, that will cause premature deterioration of the stove and chimney system.
- Running water heating systems dry. Running a system dry may cause a steam explosion if water is suddenly released into a hot system.

One other factor affecting woodheat safety that can be considered an operator error is inadequate planning in the event of a fire. Adequate fire safety planning requires installation of a smoke detector, planning and rehearsal of fire escape procedures, and plans for safely extinguishing fires.

4. **Inadequate Maintenance**

Poor maintenance practices are significant contributors to woodheat related fires, especially when coupled with careless operating practices and marginal or unsafe installations. Unsafe operating and maintenance practices can result in heavy creosote accumulation in the chimney system. Based on statistics from a New York ERDA study, it appears that many stoveowners are unaware of how quickly a hazardous creosote deposit can occur and how dangerous it can be. The ERDA study reported that of approximately 1300 wood burning households, 7% had never cleaned or inspected their chimneys and 6% cleaned less than once a year. Approximately 42% had never inspected their chimneys, though apparently most of these had cleaned at least once a year.(18)

Creosote is the fuel for chimney fires. Frequent chimney inspection and cleaning for airtight stove installations is essential for safe woodheating. Because creosote is such a critical maintenancerequirement, and because it contributes so heavily to high fire related losses, the following pages present a fairly extensive discussion on the nature of creosote, its causes and its control.

Description of Creosote

Creosote is a black, tar-like, highly flammable residue composed almost entirely of unburned hydrocarbons and moisture condensed from wood smoke. If wood is not completely burned, unburned hydrocarbons will be carrried up the chimney. Because the chimney's inner surface is cooler than the flue gases, some of these unburned gases and tars will condense and be deposited on the inner surface of the chimney to form creosote. Creosote is acidic with a pH of about 4. (Neutral is seven.) It is corrosive to iron, steel and galvanized steel and it is flammable. The exact composition of creosote depends upon the conditions under which it is formed and the temperature at which it is deposited. For example, if creosote condenses on a relatively cool surface, it will contain a relatively higher percentage of hydrocarbons, much water and be very fluid. It may even be seen dripping from the joints of the stovepipe. If condensation occurs on a surface of 200 degrees F or more, the creosote will be very thick and sticky like tar. With age, the residue is transformed by the heat in the chimney to a dry, hard, porous shiny material or to a flaky material. Whatever form creosote takes, it is always dark brown or black and has a very unpleasant acrid odor.

Although the new generation of clean burning stoves, particularly those designed with effective catalytic combustors, can cut the emissions from woodburning thereby reducing creosote by 90%. Some creosote formation is probably unavoidable. Proper operation and maintenance procedures can keep creosote danger to a minimum.

Factors that Affect Creosote Accumulation

Creosote research was conducted by Condar Company on conventional airtight woodstoves. The stoves were tested in actual home settings, instead of laboratory sites, in order to make findings as "true-to-life" as possible. Research results indicated that the primary factor affecting creosote accumulation in a given installation is burn rate. (19)

At high burn rates, a fire produces few 'reosotic emissions, and the stack is warm enough so that those few emissions present tend not to condense on stack walls but instead flow out the chimney.

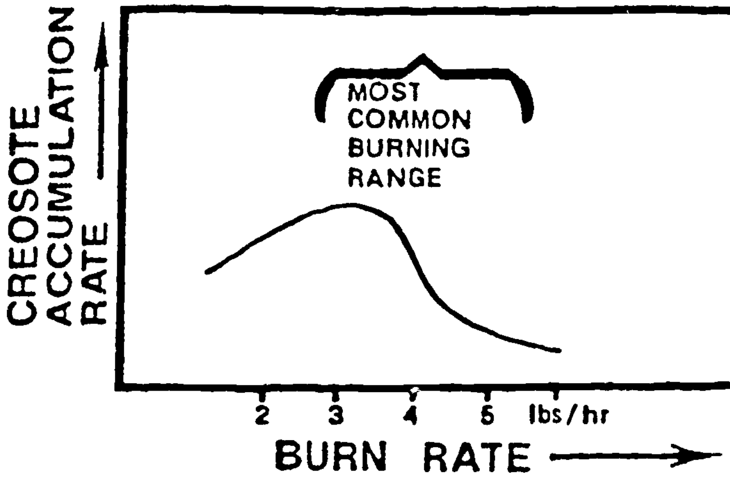
By contrast, at relatively low burn rates, large amounts of creosote are produced and the cool stack walls encourage abundant creosote condensation. Figure 5.2 shows the relationship for any given stove. Note that creosote accumulation peaks at around three pounds-per-hour burn rate for average-sized stoves. This is a very unfortunate coincidence, because three pounds-per-hour is one of the most common rates at which stoves are burned in homes. This is one reason why most woodburners have serious creosote problems. If the stove operator were to burn about four to five pounds-per-hour, creosote accumulation would be drastically reduced.

There are, of course, other factors which affect creosote accumulation rates, but they are less significant. Wood moisture has an effect, but, fortunately for the woodburner,well-seasoned, air-dried wood produces the least creosote. Green wood, and wood thoroughly dried indoors during the heating season both tend to produce more creosote.

Stove design gene: ly has little effect on creosote accumulation (with the exception of a catalytic stove design). Box stoves, step stoves, cross draft stoves, down draft stoves and thin-walled convection heaters were used in the Condar study. Only properly designed catalytic stoves displayed significant creosote accumulation reduction.

Log size and load size had some effect on creosote accumulation. Log diameter had the most pronounced effect; logs should be of the largest diameter possible and loads as small as possible to reduce creosote.

FIGURE 5.2. RELATIONSHIP BETWEEN CREOSOTE ACCUMULATION AND BURN RATE



(From S.G. Barnett talk presented at 1982 Wood Heating Alliance Annual Meeting.)

Hazards

Creosote formation is affected by four factors: smoke density, burning conditions, size of stove and the chimney. Proper operation and maintenance with respect to these factors will reduce creosote.

Creosote accounts for a large percentage of all chimney fires. Creosote buildup is extremely hazardous because of its flammability. The layers of creosote act as fuel producing very hot chimney fires. Chimney research sponsored by the Consumer Products Safety Commission focused on the effects of creosote burnout in chimneys.(20) Ignition of creosote deposits occurred when temperatures in the chimney connector reached 1170 degrees to 1300 degrees F. The average maximum fluegas temperatures inside the chimney during burnout was 1644 degrees F with a range of 1389 degrees F to 2003 degrees F. The highest test temperature obtained nearly 2500 degrees F. Such temperatures can raise the temperature of adjacent combustibles (walls, ceilings, roofs, etc.) to the ignition point. Flames can also come through cracks in older or poorly constructed masonry chimneys to ignite combustibles. In addition, the intense heat can crack the tile of a tile-lined chimney or can cause prefabricated chimney to warp and buckle. If low temperature metal pipes have been used for the connector or chimney, the pipe may actually melt. Excessive drafts caused by very hot chimney fires can cause flaming creosote to shoot out of the chimney onto the roof and surrounding combustibles.

In addition to fire damage, creosote can cause corrosive deterioration of woodheating systems. Due to its acidity, creosote causes corrosion in many materials, including steel and mortar. However masonry with tile liners or pre-fabricated insulated chimneys with stainless steel liners are corrosion-resistant. When properly installed, both types are safer than non-lined chimneys in the event of a chimney fire. Chimreys without liners which are poorly maintained are extremely hazardous. (21) While a fireplace can generate some creosote, wood stoves, especially air-tight stoves, present the greatest hazard. Airtight stoves promote a very slow, smoldering fire, a main cause of creosote buildup.

One final problem resulting from creosote is that heavy accumulations of creosote can block the flue, thereby reducing the draft and making it difficult to keep a fire going and/or causing smoke to flow into the room.

Because woodheating systems are exposed to extreme temperatures and corrosive combustion products, frequent inspection of the stove and chimney system are necessary to ensure that damaged parts and creosote build up are discovered before a fire occurs.

Techniques for Reducing Creosote Accumulation in Non-catalytic Stoves

There are a number of actions that can be taken by a stoveowner to reduce creosote accumulation. A stoveowner can reduce creosote accumulation by using woodburning practices that minimize emissions. (Table 4.2 in Section IV, the section on emissions, lists those factors that affect woodheat emissions.) Creosote production can be slowed by:

- Burning well-seasoned, air dried wood.
- Avoiding or minimizing the use of small pieces of wood such as kindling, twigs or slabwood.
- Avoiding pitchy pine.
- Keeping the firebox hot by insulating it with firebrick.
- Keeping the stack gases hot by insulating the space between the chimney walls and a metal flue liner, if used.
- Maintaining the burn rate at 4 lbs/hour or higher.

Since burn rate has the most significant effect on creosote accumulation, woodburners have used hot burning as a technique to minimize creosote accumulation. This technique is reasonably effective but can cause significant overfiring, wastage of wood, and room overheating.

Because the amount of air entering a stove controls the burn rate, an automatic draft control device can be used as an effective and convenient method for reducing creosote accumulation. It can be used to maintain a steady burn rate that produces a stack temperature just above the minimum needed for reduction in creosote accumulation.

Products, such as automatic thermostats, that are used to control burn rate, can be used as follows to reduce creosote accumulation: Figure 5.2 shows the critical burn rate of about four pounds-per-hour, **above** which creosote accumulation drops dramatically. The critical burn rate can be translated into a measurement of temperature (stovepipe or stovewall) - the **critical operating temperature**. The critical operating temperature will vary from stove to stove, depending on how that stove is installed (such as diameter and length of exposed stovepipe, presence of elbows, etc.). By using an automatic draft control to maintain temperatures just slightly **above** this critical temperature, creosote accumulation can be greatly reduced. Additionally, by being able to maintain this critical temperature, woodfuel consumption and overheating will also be reduced. Of course, in colder weather when more heat is needed to heat the living space, the stove can be burned hotter with the same favorable results. This technique can also be accomplished by manually adjusting the draft control, however, very frequent monitoring and draft adjustment will be necessary.

To determine the **critical operating temperature** for a given installation, the stovepipe and chimney should first be cleaned. Then the stove should be run at a 275 degrees F sidewall temperature for two days. After that time, the pipe and chimney should be checked for creosote buildup, using a mirror and light to peer up the chimney for a careful examination. If a signficiant amount of creosote has accumulated, the flue should be cleaned and the stove run 25 degrees hotter for two more days.

This procedure should be repeated until a significant decrease in creosote buildup occurs. **The temperature at which creosote accumulation suddenly decreases will be the "critical operating temperature" for that particular stove installation.**

If the stovepipe runs directly into a chimney and little pipe is exposed, 275 degrees F will usually be the critical operating stove sidewall temperature. If four or more feet of **exposed** interior stove pipe are present, the critical operating temperature may be 325-400 degrees F.

Once the critical operating temperature has been determined, one only needs to operate the stove 25 degrees F or so hotter than this temperature to dramatically reduce creosote accumulation.

Monitoring stovepipe temperatures can also be used as a means to control creosote accumulation. A surface thermometer placed near the top of the exposed pipe need only read 220 degrees F or slightly higher during the first 2 to 2 1/2 hours of a burn. The draft can be adjusted manually or automatically to maintain this temperature. When these readings are reached during this time period, the pipe is hot enough to avoid creosote accumulation. After about 2 to 2 1/2 hours into a burn, lower thermometer readings are acceptable because creosotic emissions no longer are being produced in large quantities.

In summary, burn rate is the main factor affecting creosote accumulation in conventional airtight stoves. Stack temperature measurement and precise draft control systems can allow homeowners to reduce creosote.

The type of woodheating system and what type of burning practices one uses will determine how often a chimney system needs to be inspected and/or cleaned. Both the stovepipe, the pipe leading up to a chimney (if any), and the chimney itself need to be inspected for creosote and damage periodically. In general, open fireplaces will need an annual cleaning if used frequently. Woodstove and insert installations may need cleaning monthly or even more frequently (every 3-4 days) if the stove is operated at very low burns. If the stoves are operated at hot temperatures less frequent cleaning is required.(22) Catalytic systems, if operated properly, may not need cleaning for several years. However, to be safe, all types of installations should be inspected frequently enough to detect creosote before it becomes a fire hazard. Experience will determine how often this should be.

Managing the creosote problem is a very important aspect of safe operation and maintenance, however there are several other factors that also create hazards in woodburning. Rapid deterioration of stoves and chimneys can occur if they are stored in damp areas, especially if there is a layer of creosote on inside surfaces of the stove or chimney. Overfiring can also cause stove and chimney deterioration, by warping, cracking or actually burning out the equipment exposed to extreme heat. An early indicator of overfiring is a change in paint color from black to grey or white. Even though woodheating systems are made out of tough materials they can easily be rendered unsafe from careless and abusive operating practices.

C. ALTERNATIVE FIRE SAFETY CONTROL POLICIES AND STRATEGIES

1. The Legal Context for Residential Woodheat Fire Safety Control

State or local governments can adopt equipment performance standards to require that equipment used by individuals is not hazardous to the public health and welfare. State and local jurisdictions can use building codes and state statutes or local ordinances as legal tools for controlling fire safety hazards.

Building Codes are adopted by state and/or local jurisdictions to protect occupants and property from fire, and to ensure the structural soundness of new and existing structures. In the case of woodheating, codes may define the type of equipment that is approved for installation and the installation practices that must be used.

Due to Constitutional home rule provisions regarding zoning authority in most Great Lakes states, local jurisdictions are not obligated to adopt state building codes. In many states, code coverage is not statewide (see Table 5.8). If local authorities choose to adopt a code, it must be at least as strict as the state code. However, since local jurisdictions have the ultimate responsibility for interpretation, inspection and enforcement, the actual application of the code may show a marked change from the original intent of the state building code and thus there is often considerable variation in how the code is applied from one jurisdiction to the next.

A local jurisdiction may use its legal authority to pass an **ordinance** to control woodheat safety hazards. Examples of ordinances that may be used to control fire safety, are bans on the use of woodheaters or on the use of certain types of woodheating equipment. With approval from the state, a local government may, by ordinance, require a **woodheating permit**. Such an ordinance may require that permits be granted before a woodheater can be installed and/or operated. (See Colorado Mountains in the emissions case studies summary comments.)

Though fire safety control is basically a local jurisdiction responsibility, officials at the national level can use several means to influence local fire safety practices. One is by providing guidance in establishing local building codes for states and local jurisdictions. This is accomplished by conducting woodheat safety research and then publishing model standards and/or codes based on the research findings. For example, the National Fire Protection Association has published Code 211, which defines safe woodheat installation practices. Many states and local jurisdictions use this model code as a basis for writing their own fire safety codes.

Education and training programs sponsored by state and national officials and the woodheating industry can also have significant influence on local officials' decisions regarding woodheat safety regulations.

One other means that national authorities can use to influence local fire safety is to regulate product safety. For example, the Consumer Products Safety Commission requires that a safety label be affixed to all woodheaters being sold. This label alerts stove buyers to minimum installation requirments for safety. The Consumer Products Safety Commission also has the authority to restrict the use made of certain types of product. For instance, it has the authority to require that when metal chimneys are installed, only high temperature prefabricted metal chimneys be used for woodstove installations.

Legal authority to influence wood heat safety also resides in the private sector. Mortgage holders can require inspection as a condition of mortgage approval. Insurance companies can refuse to underwrite an unsafe installation, or they can use premium reductions as an incentive for chimney cleaning.

2. Addressing the Woodheat Fire Safety Issues

Four distinct but interrelated problem areas related to residential woodheat safety need to be addressed in policy considerations: equipment failure, faulty installations, faulty operating practices and inadequate maintenance. Table 5.7 lists problem assessment needs, program/ policy needs and objectives, policy implementation strategies, and obstacles to implementation success for each for these problem areas. This table is not exhaustive but can be used as a guide for laying out wood heat safety strategies.

a. Equipment Failure

A number of policies and programs can be used to address equipment failure problems. First, basic research and testing programs are necessary to determine what is safe technology. As this is accomplished, minimum safety standards can be established and/or updated and woodheat products can be evaluated to determine if they meet these standards. Testing could be either a mandatory or a voluntary program depending on the authority a regulating agency has in requiring approved products.

The most commonly recognized testing program currently in place for woodheating equipment is the Underwriters Laboratories safety testing

Table 5.7

Program Needs and Alternative Control Strategies for Residential Woodheat Safety

OBJECTIVE: To eliminate avoidable hazards of residential wood heating

Hazardous Condition	Equipment Failure	Faulty Installation	Faulty Operation	Inadequate Maintenance
Problem Assessment	Determine what equipment is faulty/safe	Determine what installation practices are faulty/safe	Determine what operating practices are faulty/safe	Determine optimum maintenance practices. Assess life expectancy of various types of equipment.
Program/policy needs + objectives	.R+D on wood heat technology focused on equipment safety advances .Dissemination of information on safe equipment designs .Adoption of safer technology by manufacturers + consumers	.Dissemination of information on safe installation practices .Training + certification of stove installers + inspectors .Establishment of voluntary/mandatory inspection program	.Dissemination of information on safe operating practices .Automation of safety functions on stove or elimination of hazard producing function	.Dissemination of information on proper maintenance + cleaning .Training + certification of people doing maintenance + cleaning .Establish mandatory/voluntary inspection + maintenance program
Implementation Strategies	.Testing labs assess safety .Mandatory safety standards for manufacturing or selling .Mandatory standards for safety labeling .Educational programs for manufacturers, dealers and consumers .Tax incentives to dealers for approved equipment .Tax incentive for purchasing safe equipment .Insurance premium reduction for safe equipment .Insurance penalty for unsafe equipment	.Education program for general public,installers + inspectors .Mandatory inspection via installation permit system or insurance underwriting approval .Voluntary inspection via insurance incentive or free inspection	.Education programs for consumers with incentives to attend (insurance premium reduction, children as motivators) .Education of dealers .Require safety monitoring system (smoke alarms, chimney fire alarms, surface thermometers) .Adoption of clean-burning stoves that produced little creosote	.Insurance companies requirement for annual inspection + cleaning .Local gov't requirement for annual woodburning permit with inspection and cleaning requirement .Training + certification of sweeps
Obstacles to Implementation Success	.Resistance of industry to change-cost + "not-invented-here syndrome .Cost of testing .Motivating public to adopt new technology	.Finding strong enough incentives for stoveowner to request inspection .Convincing owners that installation is unsafe .For mandatory programs, costs of enforcement may be prohibitive or politically unappealing .Resistance by insurance companies to charge differential rates to careless woodburners	.Finding incentives to encourage stove owners + dealers to take part in education programs .Overcoming the myths + misinformation of woodburning .Cost of automating safety functions on wood heat systems	.Resistance of insurance companies to put demands on woodburners .Stove owner apathy

program. Underwriters Laboratories is a private organization founded by the insurance industry to establish minimum safety standards for different types of equipment, and to test various brands and models of equipement to determine whether they meet these minimum safety standards. Most manufactured woodheating equipment is safety tested and inspected during the manufacturing process. If the appliance passes the safety test it is "approved" and labeled accordingly. The most common safety standards used for testing solid fuel burning appliances are published by Underwriters Laboratories (UL). Those products that meet these minimum standards are referred to as "Listed" and are permitted to carry the UL label. This label ensures consumers that the product has been thoroughly tested and inspected.(2) The UL testing standards that are used for solid fuel (wood, coal and peat) appliances include:

- UL 127 For Factory-Built Fireplaces
- UL 737 For Fireplace Stoves
- UL 1482 For Solid Fuel Type Room Heaters
- UL 391 For Central Furnaces
- UL 907 For Fireplace Inserts and/or Heat Exchangers
- UL 103 For Factory-built Chimneys (23)

UL listing contributes to safety for several reasons: 1) Relatively good and complete installation and operation instructions must be supplied with listed appliances. 2) Instructions must contain safe clearances to combustible walls and floors. 3) Listed wood heaters must conform with certain basic minimum engineering and construction practices, such that the equipment does not fall apart when used and is likely to last a reasonable time. (24)

Woodstove and prefabricated chimney manufacturers are not required by law to go through safety testing; however, UL listing can increase the marketability of a product and in some areas building codes require that only listed equipment be installed. The Consumer Products Safety Commission is considering imposing restrictions on prefabricated metal chimneys used for woodheaters. Their decision to regulate is pending the results of a year long study of metal chimney-related fires. The proposed regulations will require chimneys for woodheat systems that can withstand temperatures of 2100 degrees F.

Once safe products are identified, programs can be established that encourage the voluntary <u>adoption of safe technology</u>, or that mandate the use of safe equipment. Educational programs, insurance premium reductions for safe equipment and tax credits are examples of voluntary programs. Building code restrictions, installation permit requirements, refusal to underwrite insurance on unsafe equipment, and sanctions on selling unapproved equipment are examples of mandatory programs.

Many of these programs have been tried with varying degrees of success. Educational information must come from a source that consumers trust. Manufacturers' and dealers' efforts to publicize safe equipment has not met with a great deal of success since there is virtually no policing of false or misleading advertising claims in the woodheating industry. Even if consumers turn to independent authorities for more reliable information, they get conflicting opinions. Independent authorities often are not in agreement, mainly because there are too few reliable test results available to validify "authoritative opinion" on many issues. If consideration is given, as it should be, to the wide variety of environments in which stoves are installed and operated and to the varied combinations of stoves and chimney systems, testing becomes a very complex and expensive task.

Even if products can be accurately evaluated, this does not ensure that consumers will be willing to buy the safest ones. Cost is a factor, since the cost of designing and building safer equipment is usually reflected in a high priced product. If the consumer does not perceive some benefit other than unquantified "added safety", he is less likely to pay a premium price. Consequently, ensuring that consumers buy safe equipment may require that only safe products be allowed to be sold and/or installed.

However, regulations that restrict the type of equipment that may be sold, must be flexible enough to accomodate advances in technology. The issue of metal chimneys provides a good illustration of this need. The type of metal chimneys currently in use in most installations have been cited by the CPSC as a serious fire hazard. There is a great deal of concern that these chimneys are not very durable and that as they deteriorate over time, the incidence of fires may dramatically increase. Consequently, the Commission is considering a requirement that all chimneys sold for woodheaters be made of high temperature stainless steel which is more durable and resistant to the heat and corrosive environment characteristic of conventional airtight woodheaters. High temperature chimneys could very well be the answer to the hazardous conditions produced by conventional stoves. However, high temperature chimneys would be an expensive overkill for high efficiency stoves, which are inherently safer than conventional stoves because they have cool flue gases and produce virtually no creosote. A blanket regulation requiring high temperature chimneys for all woodheat installations could effectively discourage most consumers from buying high efficiency stoves because of the total additional costs. A more appropriate requirement would be that consumers must use either high temperature chimneys <u>or</u> clean burning stoves.

One avenue for influencing consumers purchasing decisions is through **homeowners insurance**. Insurance companies can refuse to underwrite policies unless approved equipment is used. Some insurance companies have chosen this policy because they cannot absorb the high cost of woodheat fire losses. Insurance companies can take a more positive approach by providing a premium reduction if safe equipment is used. (This assumes that woodburners are being charged a higher rate than other homeowners.) Obviously to implement this type of policy, some means of inspecting the equipment, and installation, would be necessary. Insurers could use their own inspectors or rely on certified sweeps or fire inspectors.

There is one significant obstacle to insurers using premium reductions to influence homeowner behavior. Insurers are in a very competitive business. Unless all insurers within a region adopt a policy penalizing homeowners with unsafe installations, those who do would be at a competitive disadvantage. Homeowners may find it less costly to use an insurer who does not require approved equipment, even if the premium is slightly higher, than to initially buy safe equipment or to replace unsafe equipment. Currently, many of the large underwriters are not charging differential rates for woodburners - they just spread the added cost of woodheat underwriting among all policy holders. Because of the fierce competition, the large companies are unwilling to charge differential rates unless all large competitors do. (25) Thus, it may require legislative intervention to force insurers to charge rates based on the actual risk of insuring a stoveowner.

Though premium rates could effectively be used to influence new equipment purchases it may not address the problem of unsafe equipment that is already out in the field. It could be very expensive for homeowners to replace this equipment. Low income families may need some sort of public assistance in the form of low interest loans or grants to cover replacement costs.

One final stumbling block to technological advancement is industry resistance to change. One reason for this resistance is that it costs money to design and test equipment and it requires a level of technical expertise and investment that is not available in most woodheat equipment manufacturing firms. The woodheat industry does not suffer from lack of "public domain" technical expertise, however. Much free information on improved designs can be found in technical publications with a little effort. Additionally, safe technologies, such as high efficiency stoves, are available to woodstove manufacturers on either a licensing basis or through purchase of parts from stove designers.

Unfortunately, few equipment manufacturers are quick to adopt technological developments that were not designed in-house; many suffer from what has been referred to as the "Not-Invented-Here" (NIH) Syndrome. Also manufacturers, understandably, will resist being forced to abandon their own designs if it appears that their livelihood may be threatened. Consequently it takes a long time for significant changes in technology to diffuse throughout the industry. In the state of Oregon, it became apparent that legislation was the only way to spur technological advancement at a timely pace, in order to resolve the serious wood smoke pollution problem that the state was suffering. Legislation has forced manufacturers in Oregon to develop their own cleanburning technology or to adopt available cleanburning stove technologies.

b. Faulty Installations

Faulty installations are the most frequent cause of woodheat related fires. Policies developed to address installation safety must also address equipment safety. Policies must be broad enough to include the great variety in current technology and installation environments. However, policies (especially those that regulate) must also be flexible enough to adapt to the advances in technology.

A number of organizations such as the Consumer Products Safety Commission, the National Fire Protection Association, and the National Bureau of Standards, have conducted or sponsored testing programs to determine safe installations practices. Their findings have been released in the form of recommendations or guidelines for use by building code inspectors, fire marshals, insurance representatives, educators and others involved in wood heat safety.

Disseminating information regarding safe installation is obviously one of the more common and least politically controversial policies. A New York ERDA study (26) reported that the main sources of information for do-it-yourself installers were dealers, books, magazines and newspapers. However, many stoveowners indicated the information provided was too elementary or did not address their specific problems. Despite the efforts of many safety related organizations to disseminate information on woodstove installation, one third of all woodheating households interviewed had not received such information. Obviously then, more effective means of disseminating information to stoveowners are needed. In fact, information and training needs are evident in all groups - owners, dealers, contractors, sweeps and insurance agents - involved with woodheat installations. The ERDA study revealed that dealers, contractors and sweeps did as many unsafe installations as stoveowners - 60% of the installations were considered unsafe. One insurance company reported that it was able to cut its woodheating insurance losses by almost half when it trained agents to do installation safety inspections and refused to underwrite policies for homeowners who could not pass inspection.(27)

A **training and certification or licensing program for professional installers** could resolve some of the installation problems. However, since most stoveowners (according to ERDA, two thirds) do their own installations, inspection by a trained technician would be necessary to ensure the safety of these installations. Licensing of sellers, installers and servicers of solid fuel equipment has been proposed in at least one state (Minnesota). Certification of inspectors and installers from both the public and private sectors would be dependent on effective training. State inspectors are being trained in code enforcement, but uniform training of fire personnel in solid fuel safety is seen as a requirement both for inspection and for public education. The woodheat industry and government agencies involved with wood heat safety have recognized these education, training and certification needs. The Wood Heating Education and Research Foundation, the National Chimney Sweep Guild, the Tennessee Valley Authority and the Independent Safety Commission are several organizations that provide training and/or certification for installers and inspectors.

In an attempt to address the **safety information** issue the CPSC now requires that all stoves carry a permanent label that provides installation, operation and maintenance instructions. This label also informs the stoveowner that he should contact the local building and or fire officials regarding restrictions and installation inspection requirements. This label is intended to alert stove owners to the minimum safety requirements for their installations. Unless the stoveowners does contact the building or fire inspector, however, he is unlikely to have his installation inspected.

The ERDA study and other research has demonstrated the majority of stove owners do not voluntarily have their installations inspected. The ERDA study reported that even when inspected, some stoveowners were not easily convinced that they had an unsafe installation if they had not experienced any problems to date. It appears that mandatory installation safety inspections and approvals might be the most effective and realistic policy for reducing installation fire hazards. Local ordinances or state building codes can be used to mandate installation inspections. Unsafe installations jeopardize the health and welfare of the stoveowner as well as the general public, and the cost of additional fire service for unsafe installations is a cost to all taxpayers. Unfortunately, the most prevalent mandatory inspection program now in place - **building code inspection** - demonstrates a very poor record in ensuring that all or least most installations are inspected.

Building codes have been used as a means for regulating what type of woodheating equipment is used and how it is installed . Codes are adopted by state and/or local jurisdictions, and are designed to protect occupants and property from fire and to ensure the structural soundness of the building system. Codes regulate the construction of new buildings and modifications to existing buildings. The woodheating standard frequently adopted by code authorities is the **National Fire Protection Association** Code 211, entitled "Chimneys, Fireplaces, Vents and Solid-Fuel Burning Appliances." This standard was revised in 1984 to reflect current concerns regarding solid fuel appliances. Code 211 is often modified by and is interpreted by local authorities (state, county, city or town), who have final jurisdiction in establishing the rules that homeowners must follow in installing woodheating systems. Because of these modifications and interpretations, there may be considerable confusion on the part of the consumer, installer and inspector, however, local officials have final authority.

The major building codes and standards making organizations include:

The BOCA Basic Building Code - The Building Officals and Code Administratives International

The Standard Building Code - The Southern Building Code Congress International

The Uniform Building Code - International Conference of Building Officials.

The National Fire Codes - National Fire Protection Associations.

Each of these codes contain provisions that regulate the construction and installation of masonry, chimneys, fireplaces, factory built chimneys and fireplaces, fireplace stoves, room heaters and other woodburning appliances. Requirements for manufactured appliances include testing and listing by a nationally recognized testing laboratories such as UL. Safe installation clearances are also defined in these codes.

As Table 5.8 indicates, there is considerable variation among Great Lakes States in the codes adopted. Michigan and Ohio have adopted BOCA for one and two family dwellings, whereas other states have adopted state building codes, energy codes, or mechanical codes covering solid fuel appliances. Code coverage is less than statewide in many states, and even where full coverage exists, interpretation, enforcement and modifications are the responsibility of local authorities.

TABLE 5.8. Status of Residential Woodheat Fire Safety/Building Codes

This table shows a compilation of building codes, fire codes and fire safety standards that apply to solid fuel appliances and installations, as reported by state energy offices, fire marshals and building code officials. It should be noted that although individual states have adopted the codes listed below, interpretation, enforcement and specific regulation requirements may vary among building and enforcement officials at the local level.

STATE	Statewide Bldg or fire code requirement? YES	NO	NOTE:(If a state does not require a specific code, the most widely used are indicated)	Statewide safety testing? YES	NO
Illinois		x	Officials recommend following manufacturer's manual.		x
Indiana	x		Indiana Mechanical Code	x	
Iowa		x	Iowa Energy Code covers 75% of the population.		x
Michigan	x		All areas must adopt some code. BOCA is state code (1981 + amendments) Inspection and permits required.	x	
Minnesota		x	Minnesota State Bldg Code covers 80% of the population. Unlisted stoves must be inspected. Uniform bldg code 1982 ed.		x
Ohio		x	BOCA for 1&2 family dwellings. Ohio Basic BldgCode coverspublic bldgs.	x pub	x priv
Wisconsin	x		Uniform Dwelling Code for 1&2 family dwellings. Permits required. Inspection voluntary.		x
Other States:					
New York		x	N.Y. State Bldg Code		x
Pennsylvania		x	BOCA covers 33% of population. Fire and panic regs for 3 or more family dwellings.		x
Colorado		x	Uniform Bldg Code. Uniform Mechanical Code.		x
Maine	x		NFPA 211. Some towns have local stricter ordinances.	x central sys only	x
Massachusetts	x		Mass. State Bldg Code. Inspection permits required.	x	

(Table 5.8 continued.)

New Hampshire		x	NFPA 211 or Local Code - whichever is more strict		x
Oregon	x		State of Oregon Mechanical Specialty Code and Mechanical Safety & Liability Insert Code and permit required.	x	x
Vermont		x	NFPA 211 covers leased of rented dwellings.		x

Adapted from Wood 'n Energy data with addition of current state information. Wood 'n Energy,"An Overview of Codes", February 1983, pp.8-9.

Code enforcement is a common problem for building inspectors. Unless a stoveowner applies for a permit, the building department has no way of determining who has installed a woodstove in an existing home. Inspection departments do not have the funding to track down and inspect violations. However, there is an obvious need for monitoring and inspecting new installations. In most instances where fires occurred, stoves were installed by the homeowner - **without a building permit.**(28) Recently New York State enacted a law requiring that all solid fuel appliance installations in existing homes be inspected at the time of installation by a state-trained technician. Homeowners can be fined $250 for noncompliance.

There are several methods that can be used to **ensure that woodheater installations are reported** so that they can be inspected. One would be to establish an ordinance that requires dealers to report all stove buyers to the building inspector. Inspectors could then verify whether the stove owner had applied for a building permit and had had an inspection. A method that probably would foster greater compliance from dealers is a **permit system** in which dealers and/or sweeps could be licensed to sell permits. The permit issuer would receive a portion of the permit fee, payable when the permit application was submitted to the building inspector.

As discussed in the previous section on equipment safety, **insurance premiums** could be used as a tool for ensuring safe installations. Insurers could refuse to write policies for installations that had not been inspected and, where necessary, upgraded. Or, insurers could provide premium reductions for those who could show proof of inspection by a certified inspector.

c. **Faulty Operating Practices**

Overcoming faulty operating practices is for the most part an education problem. Relatively complete and understandable **printed information** is available on safe woodheating operating practices. Such organizations as the Tennessee Valley Authority, State Cooperative Extension Service, the Fire Marshal's offices, the insurance industry and the woodheat manufacturing industry have published information or provided educational programs for stoveowners. The main problem in implementing these programs is in targeting the information to those who need it and responding to the operating idiosyncracies of each woodheater installation and operator.

Unlike oil, gas and electric heating systems, wood systems require a lot of attention and a great deal more skill in operation. A person who choses to burn wood must be willing to modify his behavior to the slavish and time consuming demands of his woodheating system - frequent relighting, refueling, temperature monitoring, draft adjustment, ash removal, etc.. Inevitably, due to time constraints, forgetfulness, ignorance and/or laziness, even conscientious stoveowners at some time or another use unsafe operating practices to speed up operations or to prolong a burn. These practices might include using excessive paper or starter fluid, overfueling, leaving the door open, closing the draft way down or not reponding to chimney cleaning needs. Educators developing programs for teaching safe woodburning must take into account the factors that motivate a stoveowner to use dangerous practices. The education program must instill even stronger motivation - reasonable fear of fire or injury - to avoid unsafe practices. Unfortunately, as the ERDA study reported, many stoveowners have their own ideas about what is safe, and these are not often easy to change.

Effective education programs will not only provide general operating instructions but will also provide the stoveowner with solutions to problems specific to his own installation and woodheat needs. Printed materials and televised or live lectures can effectively provide general operating information, but specific problems require **one-to-one interaction**, preferably at the stoveowner's home where the operation of his installation can be observed. **Installers, inspectors and/or chimney sweeps are in a position to be very effective educators, if they are well trained,** since they can actually see the stove installation in operation and demonstrate safe operation. The Chimney Sweeps Guild and others have recognized this opportunity to educate and are attempting to train their members to be effective educators. The next best education vehicles are probably **woodburning workshops and televised woodburning demonstrations,** especially those that provide the opportunity to ask or call in questions.

The use of currently available **monitoring and alarm accessories** can improve woodburning safety by providing the means to more accurately monitor stove operation. Accessories that are useful include surface or probe thermometers, flue pipe fire alarms and smoke alarms. **Surface and probe thermometers** can indicate when the stove is overheating or is burning too cool (thus producing a lot of creosote). Thermometers are effective monitoring tools but require frequent reading. **Flue pipe fire alarms** audibly alert the stoveowner to a dangerous overheating situation or a chimney fire. This allows the stoveowner to respond, if he is within hearing distance of the alarm. **Smoke alarms** also can alert a stoveowner to a dangerous situation. However, smoke alarms do not usually go off until some combustible outside the stove has been ignited. Consequently these alarms do not provide as much lead time to extinguish a fire, but they are certainly better than no alarm.

Probably the most effective long-term improvements in fire safety will come from **safer equipment designs** - designs that demand less time, attention and skill on the part of the stove operator. Current efforts in this area have taken several directions. One is to design the woodheat **system to withstand a greater degree of operating abuse.** The use of high temperature chimneys is an example of this approach. A second approach involves the development of equipment with **automatic safety functions**, such as an automatic draft shutoff device that responds in the event of a chimney fire. There is to date no product on the market that does this effectively.

Probably the most effective remedy for unsafe operation is the use of stoves that reduce the the most serious hazard of wood combustion - creosote. Well designed high efficiency catalytic heaters and pellet burners accomplish this. If installed and operated properly, these stoves produce very little if any creosote, even at the lowest burn rates. Automatic thermostats available on some catalytic stoves also prevent accidental overfiring - providing the stove door is closed. Since these high efficiency burners require less frequent restarting and refueling the opportunity for operator error is reduced.

High efficiency heaters are not idiot-proof. If not operated and maintained properly they can be turned into creosote producers, just like conventional woodheaters are. However, proper operation and maintenance is not difficult for the average stoveowner. Since high efficiency stoves can greatly reduce creosote, they will probably be quite effective in reducing the number of woodheat related house fires. Experience in Oregon, where high efficiency stoves are being required because of emissions problems, should demonstrate whether high efficiency stoves can reduce fire losses. If it appears that they do, then public policy to encourage their use is in order for safety as well as emissions purposes. Use of clean burning stoves could be encouraged through an educational program stressing their advantages (safety, lowered fuel costs, reduced chimney cleaning needs, greater convenience, less air pollution, etc.) or by regulation (building codes or insurance requirements).

d. <u>**Inadequate Maintenance**</u>

Maintenance is the final link in the technology-installation-operation-maintenance safety chain. Most often it is a weakness in this link that finally triggers a house fire. **The most critical maintenance problem is dangerous creosote accumulations in chimneys.** Even unsafe chimney installations often do not cause house fires until a creosote-fueled chimney fire occurs.

How often chimneys need to be cleaned depends on the heating equipment used, how it is installed and how it is operated. Since so many variables come into play, it is difficult to come up with an all-encompassing statement on cleaning frequency. Research however has established a rule-of-thumb measure based on the thickness of the creosote accumumlation.

Stoveowners must inspect their chimneys to monitor creosote buildup. Inspections are also necessary to detect damaged or worn out equipment. It appears, however, that a large number of stoveowners do not inspect their chimney systems. According to the New York ERDA study, 42% of the stoveowners interviewed had never inspected their chimneys. Approximately 14% had never cleaned their chimneys and 6% cleaned less than once a year.

Chimney inspection and cleaning is not a simple task, especially in homes with high roofs and complicated installations. This task is often better left to a trained professional.

Obviously educating stoveowners on the necessity of doing chimney inspection and cleaning is an important need. Research on equipment durability can provide stoveowners with valuable information on life expectancy of their equipment so they can plan an inspection and replacement schedule for parts that can wear out from normal use or deterioration in chimney fires. (The Consumer Products Safety Commission is conducting this kind of research on metal chimneys.) Many organizations, both public and private, have been involved in the maintenance education efforts. Printed materials, lectures, televised demonstrations, workshops, press releases, magazine and newspaper articles, etc. have been used to describe and demonstrate safe maintenance practices. Despite these efforts the ERDA study indicated that one third of the woodburning households in New York had not received information on proper maintenance practices. Even if this deficiency is accounted for, there still appears to be a fair amount of apathy on the part of the stoveowner to follow through on safe maintenance. On a voluntary basis alone, other incentives are necessary to encourage adequate attention to maintenance.

Education does undoubtably motivate some people to inspect and clean their equipment on a timely basis. However, considering the number of serious chimney fires, it appears that a **stronger policy on chimney cleaning** might produce much better results. Local governments could pass ordinances requiring an **annual woodburning permit**. The permit could be issued based on proof of cleaning and inspection by a professionally trained technician such as a certified sweep. In cases where the homeowner chose to do his own chimney cleaning, or where the juridiction chose not to rely on sweeps for inspection approvals, the permit could be issued pending an inspection by the local fire marshal or building inspector. Considering the added costs of fire protection to local jurisdictions for woodburning homes, a permit system might be cost effective, even where the cost of the permit did not entirely cover administrative costs of the permit program. Enforcement would very likely be the biggest adminstrative problem. Obviously, without good enforcement the program would be unsuccessful.

One means for ensuring that woodheat systems are inspected and cleaned (without creating a government bureaucracy), involves the use of insurance premiums reductions as an incentive tool. Insurance companies could use **premium reductions as incentive for homeowners to have their installations inspected and cleaned once a year by a certified professional.** One company has joined forces with chimney sweeps and provides a 15% discount to policy holders with proof of inspection by a sweep. The sweeps also provide a 10% discount on services.(29) This type of program is only workable if woodburning homeowner policy holders are being charged a different rate than other policy holders. As discussed in the previous section on installations, it might take legislative action on the state level to force insurance carriers to charge differential rates. Many of the large companies are afraid to put demands on policy holders for fear of losing business to competitors who do not.

Proper inspection and cleaning does require a fair amount of expertise in woodburning technology. Considering that sloppy or inadquate inspections could easily result in death or property loss, inspectors should be required to pass suitable training and certification requirements.

3. <u>Planning the Control Strategy</u>

Several factors must be taken into consideration when planning fire safety control strategies.

The number and severity of woodheat related fires: If the relative number of fires related to woodheat is not much different than that from other sources, no regulatory action is indicated. Education may be the only need. If fires are frequent and/or severe, then regulatory as well as education policies may be needed.

New versus existing woodheater installations: Since woodheaters can last for decades and the majority of the homeowners that might heat with wood probably already own woodstoves, it cannot be expected that a policy dealing solely with new installations will have much impact on the fire statistics.

Different strategies will be needed to address both new and existing installations. The control of new installations is a <u>relatively</u> simple task, providing that a good installation reporting mechanism is incorporated in the control policy. The regulation of existing installations, presents a much greater challenge - identifying existing installations, establishing the legal authority to inspect these installations, motivating stoveowners to comply with required, and perhaps costly, changes in their woodheat systems, etc..

Local governments may find that it is possible - politically, legally and financially - to regulate new installations only. Nonregulatory woodheat safety activities, such as education programs, free safety inspections, etc., may be the only acceptable, albeit incomplete, means for local governments to address existing installations (except those in multifamily dwellings, over which most jurisdictions have regulatory authority.)

Expected growth in woodheater installations: If significant growth in woodheater installations is expected, then regulation of new installations should have a pronounced impact on the relative growth in the incidence of woodstove related house fires. If little growth is expected, then the greatest benefit will be gained if resources are directed toward resolving problems with existing installations.

Indirect policy impacts: Consideration must be given to the indirect impacts (both positive and negative) that a given policy choice might have. For instance, if local air quality is a problem or is expected to be a problem in the future, then fire safety policies favoring the use of clean burning stoves can address both the safety issue and the air quality issue. Negative impacts from this same policy might result if only one or two brands of cleanburning stoves can be made available locally. In this case the dealer with the franchise for the clean burning stove would have an unfair competitive advantage over other dealers. Also consumers would have a very limited choice in appliances and thus would be much less likely to replace unsafe equipment.

The cost and ease of policy enforcement: If funds are not available to enforce a regulatory program, then the program is unlikely to be effective. If the regulation places an excessive financial burden on the stoveowner, then he is less likely to comply.

Flexibility to adapt to new technologies: Improved woodheat technology has been evolving quite rapidly in the last two years. However, widescale adoption of these advancements has not yet occured in the market place. Policies designed for woodheat safety should be flexible enough to adapt to changes in technology that improve overall woodheat safety. For example, a blanket policy that requires the use of expensive high temperature metal chimneys for all woodstoves installations, might discourage the purchase of clean burning stoves (ones that produce little creosote) because of the total cost. Ideally, safety policies should encourage the development and adoption of safer (and reasonably priced) new technologies as a long term solution to the safety problems associated with woodheat.

Nongovernment Intervention Options: The Insurance Industry Policies The most practical and most cost effective policy for controlling woodheat related fires might be administered through the insurance industry. Insurers can exert a great deal of influence on stoveowners by refusing to underwrite unsafe installations or by charging higher rates for poorly maintained and/or unsafe installations. If a stoveowner were required to bear the actual cost of the risk that his installation imposes, then he would have more incentive to install and maintain a safe system.

Based on experience, to date, it appears that large insurers are unlikely to put very strong demands on their woodburning policy holders, unless their competition is also required to do so. Currently, most insurers just spread the added cost of covering unsafe installations among all policy holders. Even though insurance companies are very concerned about the high woodheating losses, it may require the enactment of a state law to force them to impose reasonable safety requirements on woodheat policy holders.

4. Implementing a Control Strategy

To effectively address the many factors that influence woodheat safety (equipment safety, installation, operation and maintenance, fire prevention and protection costs, etc.) a coordinated and cooperative program, involving all levels of government and the woodheat and insurance industries is necessary. Responsibilities for administering various safety policies/programs could be assigned to the organizational level which can most effectively accomplish the task c to the level that has the legal authority to do so. Table 5.9 lists several fire safety policies and programs, and the various agencies or organizations that have been, or could be involved in implementing them.

TABLE 5.9. WOODHEAT SAFETY POLICY/PROGRAM ACTIVITIES AND ACTORS

ACTIVITY	ACTORS
Firedata collection	State Fire Marshall and local fire depts.
Research on safe equipment designs, installation, operation and maintenance	National and State Agencies (CPSC, DOE, TVA, Coop Ext Service) National and Regional Associations (Wood Heating Alliance, National Chimney Sweeps Guild, NFPA, UL, BOCA, & Insurance industry associations)
Provision of education on afe equipment designs, installation,operation & maintenance	
*National organizations provide guidelines and information	CPSC,NFPA, Insurance & Woodheat industry associations
*State organizations provide workshop leaders, media programs and printed materials	State Fire Marshall, Cooperative Extension, State Dept. of Energy Forestry Depts., Insurance and woodheat industry associations
*Local organizations organize educational programs and activities and provide publicity to encourage attendence	Fire dept., Health dept. Cooperative Ext. Agency, Insurance agencies, Vocational and public schools, Local news media
Training and certification or licensing of professional installers, inspectors and chimney cleaners	Woodheat and chimney sweep assoc., Insurance associations, State fire marshal
Control policies/programs	
Legal regulatory policies:	
*National: restrictions on products	CPSC
*State: inspection requirements	State fire marshal
*Local: building code restrictions	Local building inspector
permits to install	" " "
permits to operate	Local fire inspector or air pollution agency
Financial control policies:	
Financial Penalties–	
*State: Refusal to underwrite or charge higher rate for unsafe installations or inadequate maintenance	Insurance industry (possibly with with state mandate)

(Table 5.9 continued.)

*Local: Refusal to loan or charge higher mortgage interest rates for unsafe installations or inadequate maintenance	Mortgage holding institutions
Financial incentives-	
*State: Tax Credit for safe equipment	State Legislators
Insurance premium reduction for safe installations and/or safe maintenance	Insurance underwriters

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VI. CONCLUSIONS AND RECOMMENDATIONS

This guidebook presents data and technical information on air quality problems and fire safety hazards related to the use of residential woodheating equipment in selected states of the Great Lakes region: Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio and Wisconsin. Information has been provided on other states for comparison. Based on an assessment of existing capacity for Great Lakes region states to address these issues, on alternate policies and practices in use or contemplated at federal, state and local levels, on trends associated with increased energy costs and the related use of residential woodheating, a series of findings are presented; and a series of recommendations are made. Some recommendations are designed for the political leaders of the Great Lakes region, while others are for consideration by state agencies, local governments and the woodheating, insurance and manufacturing industries.

Most of the Great Lakes states indicated limited awareness of problems related to residential woodburning. Some states stated that they had, at present, no intentions of exploring the situation to determine if specific problems or problem areas exist, or to verify the extent of known or suspected problems.

The analysis below provides information to show that all states in the region, except one, may need to be concerned about the contribution of residential wood emissions to their airsheds, and the continued increase in residential woodheat related fire and safety hazards.

One reason for looking more closely at the contribution of air pollutants from residential woodburning activities, is to determine the incremental impact of these activities in non-attainment areas. **A control strategy directed toward emissions limits on residential sources may be more cost effective and economically important to the region than offset requirements for additional controls on industrial sources in the region.**

Background and energy trend analysis: The sizeable increase in the use of residential solid fuel heating equipment since 1979, accelerated a trend noted since the early seventies. The acceleration is clearly related to the escalating cost for home heating by conventional fuels, and the availablity of modern solid fuel burning equipment. The costs of conventional fuels, primarily oil and natural gas, may be expected to increase in price as domestic (U.S.) production declines. The Department of Energy concludes that domestic crude oil production will decline as much as 28% by 1990, in the absence of major new discoveries (from 1982 production), and up to 40% by 1995. Natural gas flows from domestic production are estimated to begin a decline by 1989 and to be down to less than 50% of current production by the year 2000 (1). In the absence of major new discoveries, scarcity and increasing prices resulting from competition for the remaining production will have a bearing on the use of solid fuels, primarily wood, for home heating. In the absence of institutional and regulatory change the impacts on air quality, on fire incidence, and available wood supplies, and on an array of effects associated with woodlot and forest cropping, may create extremely difficult

TABLE 6.1

STATE	1981 POPULATION	RESIDENTIAL PER CAPITA ENERGY USE Million BTU	Rank	NORMAL DEGREE HEATING DAYS 1951 - 1980	RANK 1981 ENERGY CONSUMPTION	RANK 1980 ENERGY EXPENDITURE
Illinois	11,444,000	73 M. BTU	11	6175	4	11
Indiana	5,485,000	78 M. BTU	3	5871	10	10
Iowa	2,914,000	76 M. BTU	6	6932	26	12
Michigan	9,215,000	74 M. BTU	9	6823	8	8
Minnesota	4,113,000	68 M BTU	22	8771	23	22
Ohio	10,793,000	76 M BTU	4	5,897	3	6
Wisconsin	4,740,000	69 M BTU	18	7,665	2C	19

PER CAPITA ENERGY USE IN THE RESIDENTIAL SECTOR IN THE GREAT LAKES STATES

(US Averages: Per capita residential energy use in 1981 was 64 M/Btu, Normal Degree Cooling Days 1951-80 = 4694)

Source: State Energy Overview Energy Information Administration, Office of Energy Markets and End Use, U.S. Department of Energy, Washington, D.C. 20585 October 1983.

Table 6,2

PROJECTED EMISSIONS FROM HOME HEATING WITH CONVENTIONAL AIRTIGHT STOVES

	1970	1981	1990	1995	2000
ILLINOIS					
Wood Consumption *	737	1,830	2,836	3,989	5,581
Particulates - Kg	13,400	33,273	51,564	72,527	101,472
Carbon Monoxide - Kg	67,000	166,364	257,818	362,636	507,363
INDIANA					
Wood Consumption *	659	1,615	2,503	3,520	4,926
Particulates - Kg	11,982	29,364	45,509	59,091	89,563
Carbon Monoxide -Kg	59,909	146,818	227,545	295,455	447,818
IOWA					
Wood Consumption *	115	171	265	373	522
Particulates - Kg	2,091	3,109	4,818	6,782	9,491
Carbon Monoxide - Kg	10,455	15,545	24,091	33,909	47,455
MICHIGAN					
Wood Consumption *	964	2,191	3,396	4,776	6,682
Particulates - Kg	17,527	39,836	61,746	86,836	121,491
Carbon Monoxide - Kg	87,636	199,182	308,732	434,182	607,455
MINNESOTA					
Wood Consumption *	651	1,447	2,243	3,154	4,413
Particulates - Kg	11,836	26,309	40,779	57,354	80,243
Carbon Monoxide - Kg	59,182	131,595	203,895	286,769	401,214
OHIO					
Wood Consumption *	1,075	2,536	3,931	5,528	7,735
Particulates - Kg	19,545	46,109	71,473	100,509	140,636
Carbon Monoxide - Kg	97,927	230,545	357,364	502,545	703,182
WISCONSIN					
Wood Consumption *	692	1,509	2,339	3,290	4,602
Particulates - Kg	12,582	27,436	45,527	59,811	83,681
Carbon Monoxide - Kg	62,909	137,182	212,636	299,056	418,405

* Thousand Short Tons
Particulates projected at 20 grams per kilogram burned
Carbon Monoxide projected at 100 grams per kilogram burned

problems for the Great Lakes region. A lead time of perhaps five years exists for examination of associated problems, strategic planning and implementation.

Wood energy consumption in the Great Lakes region showed a 131% increase between 1970 and 1981. Individual states (Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio and Wisconsin) saw their residential wood use grow by 7-9% annually over this period, with total wood fuel use growing from 4,893 thousand short tons in 1970 to 11,299 thousand short tons in 1981.

As might be expected in a northern state, the per capita residential energy use for conventional sources ranges somewhat above the national average of 64 billion BTU's and considerably above the national average normal heating degree days of 4694. Comparative figures and use of conventional energy sources as of 1981 are in Table 6.1 on the following page.

General increases in use of wood for residential heating during this period showed the sharpest increase in 1978 and 1979. This may reflect the particularly harsh winter or a response to major increases in the price of oil and the threat of natural gas shortages. In any event the increased woodfuel use was sustained, and reflected a major increase in the use of woodheating equipment up to 1983, after which a decline in stove sales was reported.

The change in use of woodheating equipment is correlated with the increasing cost of energy since 1970 (a trend that seems unlikely to reverse over the long term). A number of factors are anticipated to occur that will combine to increase the price of conventional fuels. Natural gas will be deregulated in 1985, with an accompanying price rise. Predictions by the Department of Energy are that flows from the major domestic natural gas fields will begin to slow in this decade, and will fall to perhaps one-third of the current production by the year 2000. Domestic oil field production is also slowing and a drop in production of 50% or more in the mid 1990's is predicted.

Domestic gas and oil scarcity does not necessarily translate into major price inceases or to the necessity to switch to alternate fuels if imported supplies are abundant. But upward price pressure over the long term is there. Where natural gas and oil are imported from foreign countries, or from other states, (as in each of the states concerned), savings in residential fossil fuels will translate into lower consumer expenditures for imported products and an indirect benefit to the state economy.

Wood use data is not available or is very sketchy for many of the Great Lakes states. However, woodfuel use figures that are available indicate that 29 to 34% of the homes heat with wood - approximately 20% use wood as a primary fuel source. Obviously wood is considered an acceptable and cost effective source of heat by a large portion of the population in the Great Lakes states. Considering the vast forest resources available (if managed properly) and the lack of petroleum reserves in these states, woodfuel use is very likely to continue growing. As conventional fuels become more scarce and prices increase, growth in woodfuel use will occur both in the residential and the commercial and industrial sectors.

Given the components of this scenerio, it does not seem unreasonable to anticipate a continued increase in the installation and use of woodheating equipment in the Great Lakes region through the end of the century. The following modest assumptions are made:

1. There will be a 5% annual increase in residential woodheating from 1981 through 1990, resulting in a total increase of 55%.

2. As shortages and price increases become more evident, a 7% annual increase in residential woodheating will be experienced from 1990 through the year 2000.

The implications for increased use of woodfuels and for increased emissions of particulates and CO over the period, assuming the use of conventional airtight stoves, are presented in Figure 6.1 and Table 6.2. It is also assumed that fire safety hazards will increase, especially if no additional safety programs are implemented, or if use of clean burning equipment does not increase.

This analysis is provided as additional rationale for the findings and recommendations presented below.

A. FINDINGS

Finding 1: Of critical importance is the conclusion that **the control of emissions from residential woodburning and the reduction of fire hazards, particularly from chimney fires, are inseparable so that a number of strategies can be designed to address both of these objectives.**

Finding 2: **Air pollution resulting from residential woodheating has negative impacts on human health and welfare. So do the house fires resulting from the creosotic emissions produced by woodburning equipment.**

Areas that indicate problems achieving compliance with National Ambient Air Quality Standards are shown on the maps found in Section IV below. (See Figure 4.1) The Great Lakes states have more areas than the rest of the country that are certain or potential non-attainment areas for criteria pollutants such as carbon monoxide, particulates, nitrogen oxide and sulfur oxide. The addition of either criteria or hazardous air pollutants from residential woodburning activities to already polluted airsheds, makes existing problems worse, thereby increasing public health risks and public welfare impacts in the Great Lakes states.

The public health effects from pollutants emitted by residential woodburning activities are of particular concern due to the fact that many are inhalable particulates. A number of toxic and/or carcinogenic compounds and significant ambient concentrations of carbon monoxide and benzo(a)pyrenes may be high in areas with high densities of wood combustion equipment. Residents who burn chemically treated wood scraps risk serious health problems, such as arsenic poisoning.

Finding 3: Opportunity for economic growth in some areas of the Great Lakes region may be limited due to the additive impact of air emissions **from residential woodheating to airsheds where air quality is already poor** or marginal. Such limitations are already apparent in the Minneapolis/St. Paul area.

The impact of residential woodheating emssions is of concern if it results in an increase in the annual average concentration for pollutants or results in short term high concentrations that impact the Pollution Standard Index (PSI) used to monitor human health risks. High PSI ratings indicate the need for designation as a **non-attainment area** under the Clean Air Act and are used as the basis for imposition of stringent controls for stationary and motor vehicle sources of air pollutants. A number of consequences are associated or related, including the potential for residential woodheat emissions in present attainment areas being the cause of those areas being downgraded due to poor air quality. This is of special concern when the PM10 Standard takes effect in 1985.

Finding 4: The existing regulatory structure under the Clean Air Act at both national and state levels is inadequate. It does not presently address emissions from residential sources, so the industrial sector must take action to reduce its own pollution contributions in response to impacts of residential woodheating in areas where problems exist.

Residential woodcombustion emissions added to a non-attainment area must be offset by decreasing emissions from other sources to meet NAAQS and progress deadlines. Such offsets must come (under present laws) from industrial sources or automobiles emitting the criteria pollutants. Even if offsets are available (existing sources that can do so, must install retrofit control technology or be shut down) to reduce pollutant loadings, the process of arranging for the offset can be expensive and time consuming. Litigation may be necessary. Resolution of the problem may result in decreased manufacturing production from the existing sources furnishing the offsets. New industry may hesitate to locate in the area.

Locations such as southeastern Wisconsin, and the Twin Cities in Minnesota have found that competition for airshed capacity from residential woodheating emissions is of concern.

Finding 5: Emissions from residential woodheating can be a primary source of poor local air quality in the Great Lakes region.

The studies reviewed for this manual and the Mio, Michigan study showed that wood combustion emissions from the residential sector can be a primary source of poor local air quality. The most observable effects are found in areas with unique meteorological conditions or geographic locations that are subject to frequent atmospheric inverions (i.e. river valleys, mountainous areas, low lying regions). Inversions result in a limited dispersion of air pollutants and the risk of health-threatening, high concentration of pollutants at ground level. When these natural conditions exist in areas where there is a high concentration of residential woodburning activity, local air quality may be severely affected.

Finding 6: A number of socio-economic and geophysical factors concerning people using residential woodheating equipment must be

considered in designing appropriate and enforceable safety and emission control strategies.

When a state or local government or residential woodheat manufacturer considers the willingness of the consumer to either buy residential woodheating equipment or to modify his/her behavior regarding its use, a number or variables (both economic and non-economic), must be considered. These include the consumer's value judgements regarding personal energy independence or his social contribution by switching to renewable energy sources which will help achieve a sustainable energy base; the convenience of obtaining woodfuel and of using the wood heating equipment; the "social value" of using woodheating within a given community or social group; and safety and pollution (indoor and outdoor). Awareness of the consumers' income levels is an important factor in assessing the ability or willingness to implement various voluntary measures that would require outlay of funds for retrofit or replacement of equipment without some kind of subsidy. Income level is also a consideration in using mandatory programs that require investment of economic resources to achieve compliance. It is important to be aware of whether the consumers to be targeted in a control strategy are living in rural area where woodheat is a necessary part of their economic sustenance, or whether they are urban or recreational consumers who choose to use wood heat for aesthetic or life-style reasons.

<u>Finding 7</u>: **Public awareness of the residential woodheat related safety and emissions problems and alternatives for solving them, is a critical factor in public support and acceptance of government leadership in addressing the problems.**

The vast majority of control strategies enacted to date have incorporated public education to some degree. Due to the fact that public awareness of residential wood combustion as a source of air pollution problems is limited, public education may be an essential component of any strategy to control emissions from this source. Many of the variables that affect woodstove emissions are operator controlled (firewood moisture content, firewood size, air damper setting, stove sizing, chimney maintenance, etc.) and therefore could be the subject of public education about operator practices that can be used to reduce air pollution from residential woodburning.

A number of studies have been done to estimate ranges of emission reduction from public education. An estimate of the effects of Oregon's public education efforts suggests that it has reduced emissions by 13%. Survey data there shows that more than 75% of woodburning residents follow practices encouraged by educational programs (such as keeping wood dry and seasoning wood prior to use). (2) Furthermore, it was estimated that additional emissions reductions (contributing to a total of 50%) could be realized from programs aimed specifically at changing operator behaviour relative to other variables, such as wood size, proper sizing of stoves, etc..

Public acceptance may be the critical factor in the choice of emission control and safety strategies. Real or perceived "interference" by government in activities occuring in the private residence may be significant. The use of wood for home heating has been viewed by some citizens as their contribution to energy consevation, and as a way of lowering their energy costs. Perhaps of greater significance is their feelings of independence from outside energy supplies. Unless there is a major effort to educate the public in areas where emission control strategies are, or are likely to be needed, there will very likely be active resistance from individual citizens. Success is more likely to occur if public education programs are developed to convince residential woodburners that changes in operation and maintenance practices, installation techniques or technology will result in health and safety benefits to them AND will result in reduced air pollution and longterm heating costs. With effective public education, the costs and inconvenience of change will not seem an insurmountable obstacle to policy implementation success.

Finding 8: The technology exists to increase efficiency of woodstoves and decrease emissions. Use of clean burning stoves, along with proper installation, operation and maintenance of equipment, will have a significant impact on limiting emissions and improving fire safety.

Finding 9: There is little awareness of the relationship between the rate of wood (forest) resource use and the rate of increase in overall pollution and/or safety problems.

The amount of pollution being emitted as a result of residential woodburning is a direct result of the rate and efficiency of use of the wood resources. Forested areas and woodlots are relatively numerous and the acreage is large throughout the Great Lakes states, in comparison to other parts of the country. The wood products industry is responsible for providing furniture, building materials and paper for domestic and industrial use. A future increase in woodfuel use without an appropriate change in forest management practices could cause severe economic and environmental problems in industries and areas dependent on wood resources. Pennsylvania has already noted potential problems related to increased erosion and decreased wildlife habitats as a result of citizens "reclaiming" deadfalls.

Increased harvesting rates without plans to replant will have the effect of rapidly increasing the depletion rate of the wood fuel supply. Because a time span of 30 to 70 years is required to bring a tree "crop" to harvest, it is essential to consider ways to use wood for heating fuel as efficiently as possible; to limit harvest (where possible) to those forest areas that would maintain sustainable yields over 100 year time periods; and to develop overall plans that include maintenance of the private woodlots and forests. Rural landowners may need technical assistance to guide them in maintaining their own woodlots for sustainable yields.

In forested areas where the topsoil is thin (such as northern Minnesota), a significant increase in soil erosion is caused by overharvesting. Further soil depletion occurs when deadfalls are harvested, rather than being left to decay - thus returning their nutrients to the land so the soil can be replenished and new soil formed. Over the long term, it may be difficult to continue growing trees on land suffering such abuse. Additionally, the pollution impacts of increased rates of sedimentation in streams and lakes from tree harvesting are not being addressed.

While the focus of this guidebook is on air emissions and safety problems resulting from the use of woodfuel, the wise choice of strategies for addressing air emissions and safety problems **must** acknowlege relationships to other environmental pollution and resource management problems. For instance, the impact of atmospheric deposition of toxic contaminants from residential woodheating activities, creosote deposits disposal practices, and wood forest resource depletion, or sustainability under present policy, must be addressed in evolving long term strategies.

B. RECOMMENDATIONS

INFORMATION NEEDS

Most of the Great Lakes states indicated limited awareness of problems related to residential woodburning. Some specifically stated that they had no intention, in the absence of compelling reasons, to explore the situation further. The states that have begun analysis of the nature and severity of the problem in localized areas, i.e., Minnesota and Michigan, are expressing concern about the implications for human health and safety as well as concern about the ability to encourage new economic-industrial development. Additional information is required to define the nature of the residential woodheating emissions and safety problems in the entire Great Lakes region. The priority areas for initial investigations should be those areas where noncompliance with particulate and other priority air pollutants has not been attained and where house fires have increased during the past three years. Emerging trends in wood use need to be identified so that proactive policies can be developed and implemented. Local governements need to know which local areas are of concern, so they can use their authority and act on their own initiative when that is appropriate.

Information is needed to identify attainment areas (such as Mio, Michigan), where residential woodheating activities are providing enough additional pollutant loadings to the local area (particularly in light of PM10) that the area may become a non-attainment area unless residential loadings are controlled.

Certain residential woodheating emissions can cause or exacerbate health problems. Non-attainment areas are being subjected to loadings of both criteria and non-criteria (NESHAP) air pollutants from residential sources. The additional exposure to these pollutants, especially concentrated in residential areas, is of concern. These areas need to be identified.

Information is also needed to design appropriate education and training programs and adequate compliance monitoring and enforcement programs for those policies and programs implemented to address residential woodheat safety and emissions problems in the region.

Recommendation 1: Identify Problem Emission Areas

Areas of the state or of the region which are non-attainment areas, or those which are designated as PSD clean air areas, need to be specifically identified and the impact of the proposed PM10 Standard must be assessed. U.S. EPA and the states must determine where residential woodburning activities are occurring in significant density and then must determine whether or not they were the source of significant loadings of air pollutants such as particulates, hydrocarbons, carbon monoxide, nitrogen oxides and the various organic compounds from those ares. In instances where such problems can be shown, remedial or anticipatory action may be undertaken to limit existing or furture air emissions from residential sources. States should be prepared to require woodstove certification for compliance with emissions standards as the basis for control strategies.

Recommendation 2: Identify Pollutants of Concern

Sources of atmospheric contaminants in the Great Lakes basin drainage system or to the open waters of the Great Lakes are of concern under the U.S.-Canadian Water Quality Agreement. This agreement has identified specific problems and objectives relative to toxic contaminants that affect the biota or water quality in the basin. Some attention should be given to identification of emissions such as polycyclic organic materials (POM's), including use of an indicator, such a benzo(a)pyrene that are contributed by residential woodburning. In areas where these emissions are impacting the Great Lakes system, priority should be given to remedial programs that limit contribution to the Great Lakes basin ecosystem.

Recommendation 3: Evaluate Wood Combustion Emissions Contribution

Research should be undertaken to develop reasonably accurate means of determining the residential wood combustion contribution to particulate and respirable particulate emissions in the Great Lakes states. Then monitoring should be instituted to track residential wood combustion emissions and trends. Either benzo(a)pyrene or some other POM indicator should be monitored as well as CO.

Recommendation 4: Assess Significance of RWC Loading

The scope of research requirements in each state should be identified by determining what existing data and monitoring activities are available to define residential wood combustion emissions and fire incidence related to solid fuel heating equipment. In the case of emissions, the ability to assess the relative significance of residential woodburning sources in the context of other air pollution problems is required. A series of questions need to be addressed:

1. Is the local area, region or state already suffering from poor air quality (is it a non-attainment area) or is it subject to PSD (Prevention of Significant Deterioration) requirements or NESHAP (National Emission Standards for Hazardous Air Pollutants) requirement that have not be met?

2. Is the local/regional air pollution control or state air pollution control agency or the state environmental protection

agency receiving complaints about residential wood combustion activities?

3. Does a substate region or local area suffer from poor air pollution dispersion characteristics such as air inversion or other unusual meteorological/geophysical conditions?

4. In those areas, under what conditons is it possible to see or smell woodsmoke in residential areas?

5. If those areas have been subject to air pollution alerts during the past year, is there any evidence that these occurred during periods of heavy woodfuel usage?

6. What are the approximate residential contributions of particulates, carbon monoxide, nitrogen oxides, POM's or benzo(a)pyrenes in localities of concern?

7. Is there evidence of a higher incidence of demand for industrial development in a woodburning area?

8. Are there high concentrations of residential woodburning appliances in a given area?

9. Is there greater commercialization of cordwood supplies in local areas? Are sales increasing and in what locations?

10. Is fuelwood increasingly hard to find in local forests and woodlots? Is there evidence of overharvesting?

11. Do fire records (local fire departments, fire marshals offices, insurance companies) show an increase in residential fires, fire deaths, or injuries traceable to solid fuel heating equipment? Are local reporting methods adequate statewide to identify specific causes?

12. Is there increased evidence of respiratory disease or cancer in an area with high residential woodburning activity? Is there an increase in heavy metals or arsenic poisoning that could be traceable to the burning of woodwaste from treated wood products manufacturing companies?

13. Is data on residential wood use and heating equipment sales available for correlation with fire incidence in state subdivisions, i.e., county or other jurisdictions?

14. Is there a single or coordinated regulatory approach within the state to the reduction of fire hazards related to solid fuel burning equipment in one and two family dwelling units.

Recommendation 5: Develop Monitoring Data Base

Wood use should be tracked by periodic surveys, preferrably conducted in alternate years. Additional data should be collected to summarize appliance type and use habits as a further basis for assessing potential safety and emissions problems. The Minnestota DNR survey methodology might be used as a guide.(3)

Recommendation 6: Develop Impact Studies

Wood combustion impact monitoring studies should be designed and implemented for rural and urban areas where there are concentrations of residential woodfuel users. Assessment of impacts could be carried out by government agencies with responsibilities for environmental regulation and health protection, and by the forest products and woodfuel industries.

IMPLEMENTATION OF RESIDENTIAL WOODBURNING PREVENTATIVE OR REMEDIAL PROGRAMS TO CONTROL EMISSIONS TO IMPROVE SAFETY

Once information has indicated the need for addressing particular problems, the control programs should be designed and implemented on state and local levels in the region. Based on the analysis of findings in this study, the following specific recommendations are provided regarding programs that the Great Lakes states should seriously consider, where they are not already in place.

Recommendation 7: Criteria for Control Strategy Decisions

Making decisions about the kind of woodheat safety or emissions control strategies and programs to implement is a challenge. The decisions can be guided by using appropriate criteria in evaluating proposed strategies. **Criteria that have been found useful in formulating at least one state program should be considered as a basis for designing control strategies in the Great Lakes region.** A checklist of key criteria follows:

Residential Woodburning Strategy Effectiveness Criteria

The proposed strategy should accomplish the following:

a. Reduce the residential woodburning pollution impacts.

b. Meet all the legal requirements established by the Clean Air Act, EPA or State regulations, State Implementation Plans, Consumer Product Safety Commission regulations or local ordinances.

c. Be widely applicable to residential woodheating appliances and/or practices or

d. Be particularly effective for a significant category of residential woodheat appliances or practices.

e. Reduce fire hazards and fire incidence associated with residential woodheat including equipment, installation, operation and maintenance.

f. Be fully implementable within the next fire years unless significant benefits can be realized over a longer time frame.

Additional criteria that may be considered if the above are met -

The proposed strategy should:

a. Have the potential for maximum public acceptance.

b. Minimize the cost to the individual consumer.

c. Promote energy conservation and the use of renewable energy resources.

d. Discourage the use of the most polluting woodheating equipment and practices.

e. Utilize proven technology.

f. Encourage innovative technology.

g. Have minimum probablility of circumvention.

h. Have maximum administrative feasibility for regulatory agencies in terms of minimum costs, documentable emissions reduction, timely implementation and willingness of key actors to participate.

i. Operate through use of incentives and encourage self-regulation by manufacturers and retailers to the extent practicable. (4)

Recommendation 8: Preventive Strategies

The Great Lakes states should **adopt preventative strategies to reduce wood combustion emissions from residential sources and to avoid increase in air pollution from residential woodburning activities in the future.** Such strategies should be designed to accommodate both **short term and long term pollution control measures** and to consider the present generation of equipment in homes as well as new equipment installations.

Long Term Residential Woodburning Control Strategy: States should require the use of clean burning stoves that meet emissions standards. In addition states should monitor the development of new technology, and assess and rate woodheating equipment for effectiveness in emissions control. **States should require that new equipment installations be labeled to indicate efficiency ratings.**

The most efficient emissions control strategy is to require emissions reduction at the source. Requiring stove manufacturers to produce clean burning stoves should be the basis for the long term control strategy and be targeted to new woodburning equipment installations. Major costs would be shared by government and the manufacturer and include: setting of standards, development of test methods, equipment testing, certification of stoves meeting emissions standards, monitoring impacts, and identifying improper use of certified equipment or illegal use of uncertified stoves. The manufacturers would have primary responsibility for seeing that their stoves are tested and meet emissions performance standards for clean burning equipment. Consumers would pay increased stove costs, but would be subjected to individual regulatory action only if they attemped to avoid compliance with the law requiring sale or installation of clean burning equipment. Payback benefits in reduced fuel costs should be identified.

The most cost effective approach to implement this strategy in the Great Lakes region would be to **require consistency with Oregon approved testing methods and standards.** The basic costs for research and test method development would also be beneficial to woodstove manufacturers as they would only have to bear the costs of providing equipment that met one set of certification requirements.

Short Term Strategy: Encourage, through education, incentives and other means, improved operations and maintenance practices for existing equipment and provide incentives for retrofit with catalytic combustors or for purchase of clean burning stoves.

Recommendation 9: Model Ordinances

Model local ordinances or programs to implement various alternatives for reduction of residential wood combustion emissions or improvement of woodheat safety should be identified or developed and publicized by the states.

Recommendation 10: Federal Regulations

The Great Lakes states should **use National Emissions Standards for Hazardous Air Pollutants (NESHAP) now in place and others as issued, as a vehicle for controlling emissions from residential wood burning.** If the PM10 regulation is issued by U.S. EPA, then non-point source specific emissions such as accumulated residential concentrations of POM's, including benzo(a)pyrenes and other carcinogens will be regulated. Requiring the use of catalytic combustor retrofits or the use of new equipment certified as meeting emissions standards of NESHAP pollutants (minimum PM10) are technological approaches. Banning use of residential wood combustion equipment in areas with severe NESHAP problems or on days when specific weather conditions cause temporary problems is another alternative.

Recommendation 11: Toxic Residue Control

Creosote residues that are removed from woodfuel chimney systems are toxic. Most are presently disposed of in local landfills. In areas with a high density of woodstoves, this may pose a problems since it is possible for such toxic residues to leach into public water supplies. Special public education programs should be developed to inform woodfuel users of the proper means for disposing of such residues. States should consider whether limits on placing these wastes in local landfills should be imposed and, if imposed, they should consider alternative disposal means.

Recommendation 12: Burning Efficiency and Economics

The relationship between the efficient burning of wood, energy conservation measures to restrict heat loss, and the reduction of **home heating costs, needs to be addressed in policy making.** Woodburning efficiency will provide public health benefits by reducing contaminants in unburned gaseous or particulate emissions, and extend state wood fuel resources. By using insulation, weatherization and solar technologies presently available, the use of either conventional or wood fuels can be greatly reduced. Both increased burning efficiency and reductions in home heat loss will contribute to a reduction in home heating costs. Educational efforts should support policies that:

- Encourage strict heat conservation standards for new construction.

- Require the use of high efficiency woodburning stoves that can meet specified emission standards.

- Require abatement devices (such as retrofit catalytic combustors) to meet emissions standards on residential woodburning units in areas where air pollution problems are severe.

Recommendation 13: Restrictions on Non-wood Fuel

Local ordinances to prohibit the use of woodheating equipment for garbage or trash **incineration should be encouraged.** Public education programns on the hazards of burning trash or garbage in solid fuel heating equipment will need to be coupled with any local ordinance addressing the problems. Emphasis must be placed on the health risks related to burning of plastics and the release of toxic gases as well as the damage to woodheating equipment.

Recommendation 14: Uniform State Codes

The adoption of uniform state-wide building codes for one and two family dwellings that specify safe installation of solid fuel heating equipment according to code (NFPA 211 minimum) would eliminate variable approaches within the state, minimize inspection and compliance problems, and enable standard methods of enforcement and education.

Recommendation 15: Training, Licensing and Certification

Training and licensing or certification programs should be mandatory for installers and code inspectors. Programs can be provided by state agencies or local building and fire departments, or through existing national training programs such as those provided by the Wood Heating Alliance and the Independent Safety Commission.

Recommendation 16: Equipment Certification

Legislation should be developed and passed that prohibits the sale of solid fuel heating equipment that has not been safety tested and listed by code agencies, Underwriters Laboratory or the Consumer Producst Safey Commission.

Recommendation 17: Permits

With the general agreement on the necessity for inspection of new stove installations for compliance with safety regulations, one of two options may be followed: 1) Mandatory registration of new equipment at the point of sale followed by inspections or 2) requirement of a permit to install followed by mandatory inspection.

Recommendation 18: Inspection of Existing Equipment

Regulation and inspection of older woodheating system installations should be encouraged through a cooperative program with fire insurance companies. Differential premium rates based on relative safety of the installation/equipment can be used as incentive for stoveowners to comply with codes for safe installations. Inspectors should be certified or licensed.

Recommendation 19: Technical Assistance Programs

The Great Lakes states (peferrably as a cooperative effort) should develop a technical assistance and assessment program to encourage the development and/or adoption of woodheating equipment that meets clean burning and safety objectives. The personnel in such a program could serve several functions:

- To plan and implement a stove certification program in states choosing to use a certification program to control woodsmoke emissions and/or fire safety problems.

- To review and and act as a clearing house for information related to woodheat technologies and control policies. For example, program personnel could review (for accuracy) and summarize lab tests and research findings related to woodheat technology. This information could then be made available to those officials involved with inspections and education, and to the general public.

- To administer a technical research grant program. Grants could be made available to support the development or upgrading of technologies that would provide significant air quality or safety benefits to residents in the Great Lakes region. For instance, the catalytic retrofits that are currently on the market have significant drawbacks as far as basic durability and applicability to a wide variety of stove types. Effective and durable retrofit catalytic units could significantly improve emissions and woodheat safety. State funding for basic research to upgrade this technology could be cost effective because it might provide effective and relatively inexpensive methods for controlling fire safety and emissions problems. It could eliminate the need for strict bans or limitations on woodburning in areas suffering air pollution problems.

Recommendation 20: Information Distribution

Information obtained from several states in the Great Lakes region indicates that state agencies are generally uninformed about the present or emerging problems related to residential woodburning emissions. To the extent that specific data is available from local fire departments, responsible agencies in most states are concerned about what appears to be a growing incidence of fires caused by solid fuel heating equipment. Reporting, however, remains inadequate and fire prevention and education measures undertaken by various state agencies do not represent a coordinated strategy.

Educational material on residential woodheat safety and emissions control presently being made available by state and local agencies, should be revised for technical accuracy and currency, for incorporation of state data and regulatory policy, for media use and timing in media use, and for the target audiences and distribution mechanisms. Public and consumer education material should reflect an integrated state policy and should combine safety and emissions control measures. Undated materials should indicate state rationale for regulation (fire incidence and air quality/human health impacts).

Development of new education materials should be pursued by all agencies in a coordinated program that acknowledges system relationships from wood fuel harvesting and production through the home heating cycle. The context of state energy use, including reduction of imported fuels, and the inter-sector use of wood fuels should be reflected in state planning for the residential sector.

Specific information needs include:

-Installation and use of clean burning stoves.

-Retrofitting of catalytic combustors: installation, operation and maintenance.

-Safety and health hazards of burning trash in a woodheating system.

-Relationship of insurance costs to safety in woodheater installation.

-Insurance coverage or exclusion of unreported and uninspected woodstove installations in the event of fire damage.

-Explanation of state emissions control policy and regulations for residential woodheating equipment - related to state air quality.

-Explanation of state and local fire preventions program for residential woodheating equipment, including regulatory structure and the state fire incidence.

-Sources of technical assistance for retailers and users of solid fuel equipment.

-Legal and information/education strategies to assist local governments in addressing residential woodheat safety and emissions problems.

-Technical information for woodcutters and commercial cord-suppliers on types and sizes of wood needed to achieve efficient burning. Also encourage standardization.

-Information on sustainable woodlot production. (The Farm Bureau, the Cooperative Extension Service, the Soil Conservation service, and the forest products industry are appropriate organizations for information development and distribution.)

Recommendation 21: Training for Target Groups

Technical assistance and training **should be made available** to a number of groups (at least until the implementation of the control program for residential woodburning emissions and fire hazards):

- **Retailers** of woodburning equipment - to enable them to provide guidance to their customers on the environmental and safety regulations, and the use and installation of clean burning stoves and accessories.

- **Zoning, building and fire safety inspectors** - to update their knowledge of newer technologies, state and local emissions and fire safety policies, revised regulations, and specific problem areas.

- **Pollution control personnel** - to assist in adapting ambient air quality monitoring systems to include area residential emissions problems, and to implement educational, incentive and enforcement programs.

- **Chimney sweeps** - for certification to perform safety and maintenance inspections to meet insurance requirements or local permit requirements.

- **Architects, engineers and contractors** - to encourage better design and construction and appropriate installation.

Existing educational programs and technical assistance programs and materials in the Great Lakes region that are found to be appropriate for contemporary use **should be shared through-out the region to encourage** consistency and for cost-effectiveness. States may wish to cooperate in funding the development or implementation of new programs and projects (especially those requiring training) such as seminars and workshops, user manuals, and certification or technical guidance programs.

Inasmuch as many of the variables related to fire safety and emissions from solid fuel heating equipment remain within the control of the consumer, educational programs targeted at this group are essential. Purchase of approved equipment, safe installation of stoves, chimneys and chimney connectors, operation within equipment limits and regular inspection, cleaning and maintenance affect fire safety. The selection of clean burning equipment can make a major difference in woodstove emissions, as can operational factors of wood size, moisture content, rate of feed, damper settings, heat regulation and proper maintenance. Residential energy conservation and public health aspects of wood burning emissions are also factors to consider in consumer education.

Other target populations for both consumer and technical education will be those groups performing installation and safety imspections, including retailers and installers of equipment, fire department inspectors and building and zone inspectors, chimney sweeps, air pollution control personnel and fire insurance agents. These groups and others who might be involved in public education related to wood stove emissions and safety (such as extension service agents and state public information personnel) should be considered as targets for training and education.

Both professionals and consumers can be reached by an array of information channels, but the most efficient route will be those that concentrate on target populations. For instance, purchasers of new heating equipment can be reached at the point of purchase, while users operating existing installations may be better reached through commercial wood suppliers and through cooperative programs with insurance agencies.

MONITORING RESULTS OF RESIDENTIAL WOOD COMBUSTION EMISSIONS CONTROL AND SAFETY PROGRAMS

Recommendation 22: Program Monitoring

Where residential woodheat emissions control and safety programs are adopted, their impact should be monitored and assessed to determine whether the desired results are being achieved. Programs whould be redesigned if they do not attain their goals.

There are a number of ways to evaluate whether a given policy or control strategy is having the desired impact. Each method is dependent upon the design of an appropriate monitoring system and the related information gathering and analysis systems. In developing a control strategy, the information needs for determining its effectiveness should be identified. While not exhaustive, a brief check-list is provided that illustrates the type of information that could indicate whether progress is being made.

Residential Woodheat Emissions Control and Safety Program Monitoring-Assessment

DATA COLLECTION CHECKLIST

__Ambient air quality monitoring data showing inputs of residential sources of particulates, NOx, CO, and hydrocarbons; NESHAP or PM10 emissions are increasing? Decreasing?

__Pollution Standard Index data for metropolitan areas and also air quality alert status.

__The number and types of complaints to pollution control agencies about woodburning emissions.

__The number, kind and resolution of enforcement actions initiated or dealt with that involve residential woodheat activities.

__Woodfuel sales in the area (more useful in urban areas where there is

less individual direct access to woodlots and forests).
__The demand for educational materials.

__The number and type of training/and or certification programs requested and conducted.

__The number and cause of fires traceable to residential woodburning activities.

__Residential fire insurance rates.

__New building permits applications for residential woodheat installations.

__Area woodburning equipment sales: number and type (conventional or clean burning stove, catalytic combustor retrofits, metal chimney types).

__How the air looks (opacity) and how it smells. Is it cleaner?

__Local/regional annual epidemiological profile. Note incidences of respiratory diseases, asthma, cancer cases, orher diseases having any correlation with locations identified as residential woodburning areas. (The Cancer Society,Lung Association and State Health departments are sources of data.)

COOPERATION AND COORDINATION

Airsheds do not recognize political boundaries. Therefore the Great Lakes region should consider some means of coordinating state programs to control residential woodheat emissions and safety problems.

Recommendation 23: Coordination

At a minimum, research information, educational materials and training programs could be shared to reduce costs and encourage consistency. Additionally, if residential wood combustion is verified as a major contributor to ambient outdooor or indoor particulate or CO levels, or if toxic air emissions are determined to pose an actual or potential threat in the states, control options should be considered and developed in the context of other multi-state cooperative pollution control strategies such as those developed under the U.S.-Canadian Great Lakes Water Quality Agreements or the Ohio River Sanitation Commission agreements.

Actions affecting interstate resources need coordination. To the extent possible, this should be accomplished within the existing institutional frameworks that relate to existing regional interests. The Great Lakes Commission, Ohio River Sanitation Commision, and the U.S. EPA Region V could all play a role, for example. Other existing organizations that could appropriately provide such assistance should be identified. The Council on State Governments, Council of Great Lakes Governors, and other bodies that provide assistance to those jurisdictions should be contacted for recommendations. Major industrial and trade associations could also assist; the Wood Heating Alliance, National Chimney Sweeps Guild and insurance associations, for example.

Recommendation 24: Cost, Benefits and Impacts of Preventive or Remedial Alternatives and Strategies

The information reviewed for this project revealed that the benefits of the fire prevention and emissions reduction from residential woodburning are self-evident, though these benefits have only been quantified to a very limited degree. There was little assessment of the social costs resulting from inaction to reduce fire hazards and emissions, especially in light of the probable growth in woodstove use.

Data is extremely limited on the impact and overall effectivenss of control options and strategies now in place in various location in the United States. While examination of these issues was outside the charge of this study, a number of outside technical reviewers for this manual indicated a need for such information as a guide to decision making. We agree and recommend that such evaluation be undertaken as the next step in providing information and guidance for the decision makers in the Great Lakes Region, and as a resource for others who are interested.

NOTES

(1)Energy Information Administration. Impact of Surveillance Fields on Crude Oil Production in the U.S., Department of Energy Information Service, October, 1984.

(2) Particulate concentrations are assumed to be 20 gm/kg and CO concentrations to be 100 gm/kg. The projected emissions from conventional airtight stoves are based on estimates of criteria pollutant concentrations emitted from air tight stoves identified in various documents from Oregon DEQ and the Tennessee Valley Authority. (See charts in Emissions Section IV)

(3) Figures on increase in wood use per state uses data obtained from Estimates of US wood Energy Consumption from 1949-1981, Energy Information Administration, Office of Coal Nuclear, Electricity and Alternate Fuels, U.S. Department of Energy, August 1982.

(4) Adapted from the results of the Keppner-Tregoe Decision Analysis Process described by Del Green and Associates in Task 6: Residiential Wood Combustion Study funded by the U.S. EPA Region 10 for the Oregon Wood Combustion Study.

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VII. APPENDICES

A. GLOSSARY OF TERMS

Air, Combustion	The air required to provide for the combustion of fuel and usually consisting of primary air, secondary air, and excess air.
Airtight Stove	A cast iron or steel stove with a tight-fitting door and sealed or welded seams. Air can enter the stove only through a vent (draft regulator) in the door which is opened and closed either manually or by thermostat action. Thus, burning is controlled. Airtight stoves are generally more energy efficient than other types of woodstoves.
Appliance	An appliance is utilization equipment, normally built in standardized sizes or types which is installed or connected as a unit to perform one or more functions such as clothes washing, air conditioning, food mixing, cooking, heating, refrigeration, etc.
Appliance, Residential-Type Heating	Fuel-burning and electric heating appliances except high pressure steam boilers, for heating building spaces having a volume of not more than 25,000 cu ft (708 cu m) and other heat producing appliances of the type mainly used in residences, but which may be used in other buildings, such as cooking stoves and ranges, clothes dryers, fireplace stoves, domestic incinerators, laundry stoves, water heaters, and heat pumps.
Appliance Casing (Jacket)	An enclosure forming the outside of the appliance.
Appliance Flue	The flue passages within an appliance.
Approved	Acceptable to the "authority having jurisdiction".
Ash	Solid residue which remains after combustion is complete.
Ash Receptacle Door	A door below the grate level providing access to the ash receptacle.
Authority having jurisdiction	The "authority having jurisdiction" is the organization, office, or individual responsible for "approving equipment, an installation or a procedure.

Baffle	An object placed in an appliance to change the direction or retard the flow of air, air-fuel mixtures, or flue gases.
Boiler	A closed vessel for heating water or a liquid or for generating ssteam or vapor by direct application of heat. It is usually an indirect-fired fuel-burning or electrically heated appliance.
Boiler, Combination-Fuel	A single boiler unit designed to burn more than one type of fuel (gas, oil, or solid), either separately or simultaneously, using either separate or common combustion chambers and flues.
Boiler, High Pressure	A boiler for generating steam at pressures in excess of 15 psig (103 kPa), or for heating water to a temperature in excess of 250 degrees F (121 degrees C) or at a pressure in excess of 160 psig (103 kPa).
Boiler, Hot Water Supply	A low-pressure hot water boiler having a volume exceeding 120 gal (454 L), or a heat input exceeding 200,000 Btu per hour (58.6 kwh) or an operating temperature exceeding 200 degrees F (93 degrees C) that provides hot water to be used externally to itself.
Boiler, Low Pressure	A boiler for generating steam at pressures not in excess of 15 psig (103 kPa) or for furnishing water at a temperature not in excess of 250 degrees F (121 degrees C) at pressures not in excess of 160 psig (103 kPa).
Boiler, Supplementary	A boiler designed to burn one type of fuel (gas, oil or solid) that is intended for supplementing a boiler burning another type of fuel (gas, oil or solid) by means of a common heat transfer medium.
Bond	As referring to bricklaying and masonry chimneys, the connection between brick, stone or other masonry units, formed by lapping them upon one another in carrying up the work, so as to form an inseparable mass.
Box Stove	A square or rectangular stove, made in both air-tight and non-airtight models.
Breeching	The conduit conveying flue gas from the appliance to the chimney.

Btu	Abbreviation for British Thermal Unit. The quantity of heat required to raise the temperature of 1 pound of water 1 degree F.
Bucking	Cutting wood into logs of a length and thickness suitable for burning in a stove.
Burner, Mechanical Draft Type	A burner which includes a power-driven fan, blower or other mechanism as the primary means for supplying the air for combustion.
Burner, Natural Draft Type	A burner which depends primarily upon the natural draft created in the chimney or venting system to induce the air required for combustion in the burner.
Cast Iron	An alloy of iron, carbon, and silicon especially suitable for stoves because of its durability and heat-retaining qualities.
Chimney	One or more passageway(s), vertical or nearly so, for conveying flue gases to the outside atmosphere. a. Factory-Built Chimney: A chimney composed of listed factory-built components assembled in accordance with the terms of listing to form the completed chimney. b. Masonry Chimney: A field constructed chimney of solid masonry units, bricks, stones, listed masonry units or reinforced portland cement concrete, lined with suitable chimney flue liners built in accordance with applicable Building Code requirements. c. Metal Chimney: A field-constructed chimney of metal made in accordance with applicable Building Code requirements.
Chimney Cap	A protective covering or housing for the top of a chimney intended for preventing the entry of rain, snow, animals, birds, etc. and for preventing downdrafts.
Chimney Connector	The pipe which connects a fuel-burning appliance to a chimney.
Circulating Stove	A stove with a firebrick-lined, inner firebox and an outer metal cabinet. Instead of radiating heat into the room, this stove circulates heated air by means of a blower fan.

Cleanout Opening	An opening or hole in a chimney, usually located near its base, designed to allow access to the flue for purposes of removing ash, creosote, soot and other extraneous matter that may become trapped.
Clearance	The distance between a heat producing appliance, chimney, chimney connector, vent, vent connector, or plenum, and other surfaces.
Combustible Material	Material made or or surfaced with wood, compressed paper, plant fibers, plastics, or other material that will ignite and burn, whether plastered or unplastered.
Combustion	Combustion refers to the rapid oxidation of fuel accompanied by the production of heat or heat and light.
Cord	A common measure of firewood and pulpwood, equal to the amount of wood in a carefully stacked (parallel) pile of wood, 4 feet high, 8 feet wide, and 4 feet deep. The amount of solid wood in this 128-cubic-foot pile is usually estimated to be between 80 and 90 cubic feet.
Creosote	Chimney deposits originating as condensed organic vapors or condensed tar fog. Creosote is often initially liquid, but may dry and/or pyrolize to a solid or flaky form.
Damper	A valve or plate for controlling draft or the flow of gases including air.
Damper, Automatically Operated	A damper ope ated by an automatic control.
Damper, Flue Gas	A damper located on the downstream side of the combustion chamber of a fuel-burning appliance, usually in a flue passage of the appliance or in the chimney or vent connector.
Damper, Manually Operated	An adjustable damper manually set and locked in a desirable position.
Direct Vent Appliance	A system consisting of an appliance, combustion air and flue gas connectors between the appliance and the outside atmosphere, and a vent cap supplied by the

manufacturer, and constructed so that all air for combustion is obtained from the outside atmosphere and all flue gases are discharged to the outside atmosphere.

Draft

The pressure differential which causes the flow of air or gases through a chimney, gas vent or venting system.

a. Mechanical Draft: Draft produced by a fan or an air or steam jet. When a fan is located so as to push the flue gases through the chimney or vent, the draft is forced. When the fan is located so as to pull the flue gases through the chimney or vent, the draft is induced.

b. Natural Draft: Draft produced by the difference in the weight of a column of flue gases within a chimney or vent and a corresponding column of air of equal dimension outside the chimney or vent.

Draft Regulator, Barometric

A device built into a fuel-burning appliance or made a part of a chimney connector or vent connector, which functions to reduce excessive draft through an appliance to a desired value by admitting ambient air into the appliance chimney, chimney connector, vent or vent connector. Barometric dampers in flue pipes are not recommended for woodstove use. When a chimney fire occurs, the damper opens, thereby feeding the fire and causing hazardous conditions. Although some laboratory work has indicated barometric dampers reduce creosote formation in flue pipes, this has never been demonstrated in the field. Chimney sweeps have found increased creosote formation, probably caused by reduced draft and lower burn rates. Unpublished studies of a field installation also showed no creosote reduction.

Drum or Barrel Stove

A stove made of a steel drum or barrel which was intended as a container. The conversion to a stove involves cutting holes and bolting on a door, a flue collar, and legs.

Efficiency, Energy

As applied to a wood stove, the fraction (percentage) of the chemical energy in the wood which is converted to useful heat by the stove, including the heat from an average amount of exposed stovepipe (about 6 feet).

Emissions	Effluents resulting from the combustion of a fuel including the inerts, but excluding excess air.
Excess Air	Air admitted to a burner which is in excess of the amount theoretically needed for complete combustion.
Factory-Built Appliance	A manufactured appliance furnished by the manufacturer as a single assembly or as a package set of subassemblies or parts, and including all the essential components necessary for it to function normally installed as intended.
Fan	An assembly comprising blades or runners and housings or casings, and being either a blower or exhauster.
Firebox	The body of a woodstove.
Firebrick	Brick capable of withstanding high temperatures such as in furnaces and kilns. Firebrick is often used to mean only "hard" or "dense" firebrick as distinguished from "soft" or "insulating" firebrick.
Fireplace	A hearth, fire chamber, or similarly prepared place and a chimney. a. Factory-Built Fireplace: A fireplace composed of listed factory-built components assembled in accordance with the terms of listing to from the completed fireplace. b. Masonry Fireplace: A hearth and fire chamber of solid masonry units such as bricks, stones, listed masonry units, or reinforced concrete, provided with a suitable chimney.
Fireplace Accessories	Accessories intended for field installation into or attachment to existing masonry fireplaces. This includes such items as heat exchangers, door assemblies, tubular grates and blowers.
Fireplace Insert	A factory-built field-installed product consisting of a firebox assembly designed to be installed within or partially within the fire chamber of a fireplace which uses the fireplace flue to vent the products of combustion.

Fireplace Stove	A free standing, chimney-connected, solid fuel burning heater having its fire chamber open to the room.
Flame Spread Rating	The flame spread rating of materials as determined by the Method of Test of Surface Burning Characteristics of Building Materials, NFPA 255, ASTM E84, Underwriters' Laboratories, Inc. UL 723. Such materials are listed in the Underwriters' Laboratories Inc. Building Material List under "Hazard Classification (Fire)".
Floor Protector	Noncombustible surfacing applied to the floor area underneath and extending in front, to the sides and to the rear of a heat producing appliance.
Flue	The general term for a passage through which flue gases pass from the combustion chamber to the outer air. a. Appliance Flue: The flue passage within an appliance. b. Chimney Flue: The passage in a chimney for conveying the flue gases to the outside atmosphere. c. Dilution Flue: A passage designed to effect the dilution of flue gases with air before discharge from an appliance.
Flue Collar	The portion of an appliance designed for attachment of a chimney or vent connector or a draft hood.
Flue Gases	Combustion products from fuel-burning appliances plus excess air.
Furnace, Central Warm-Air	A self-contained indirect-fired or electrically heated appliance designed to supply heated air through ducts to spaces remote from or adjacent to the appliance location. a. Forced-Air-Type Central Furnace: A central furnace equipped with a blower which provides the primary means for circulation of air. b. Gravity-Type Central Furnace: A central furnace depending primarily on circulation of air by gravity.

c. Gravity-Type Central Furnace with Integral Fan: A central furnace equipped with a fan as an integral part of its construction and operable on gravity systems only. The fan is used only to overcome the internal resistance to airflow.

d. Gravity-Type Central Furnace with Booster Fan: A central furnace equipped with a booster fan which does not materially restrict free circulation of air by gravity flow when such a fan is not in operation.

Furnace, Combination Fuel	A single furnace unit designed to burn more than one type of fuel (gas, oil or solid), either separately or simultaneously, using either separate or common combustion chambers and flues.
Furnace Duct	A central furnace designed for installation in a duct of an air distribution system to supply warm air for heating and which depends for air circulation on a blower not furnished as part of the furnace.
Furnace, Supplementary	A furnace designed to burn one type of fuel (gas, oil or solid) that is intended for supplementing a central warm-air furnace burning another type of fuel (gas, oil or solid) by means of a common warm-air supply plenum.
Header	With reference to chimneys, a beam set at right angles to floor or roof joists to provide support and framing around the opening.
Hearth	The floor area within the fire chamber of a fireplace or a fireplace stove.
Hearth Extension	The noncombustible surfacing applied to the floor area extending in front of and at the sides of the hearth opening of a fireplace or a fireplace stove; also as applied to the floor area beneath an elevated overhanging fireplace hearth.
Heat Exchanger	A chamber in which heat resulting directly from combustion of fuel, or heat from a medium such as air, water or steam is transferred through the walls of the chamber to air passing through the eschanger, or in which heat from electric resistors is transferred to the air.

Ignition Temperature	The minimum temperature of a flammable mixture of gases at which it can spontaneously ignite.
Liner or Stove Liner	A layer of metal or brick placed immediately adjacent to a side or bottom of a stove, intended either to protect the main stove structure from getting too hot, or to insulate the combustion chamber, making it hotter and thus promoting more complete combustion. Liners are usually designed for easy replacement.
Listed	Equipment that has been tested for compliance with standards and has been found to meet these standards by an approved testing and/or certification laboratory.
Parlor Stove	An old-fashioned stove popular in Victorian times, often ornately decorated. It functions similarly to a Franklin stove and is still manufactured.
Pyrolysis	The chemical destruction of wood by the action of heat alone, in the absence of oxygen and hence without burning. The products of pyrolysis are gases, tar fog and charcoal.
Radiant Stove	A stove without the outer jacket that circulating stoves have. Radiant stoves transfer more than half their energy output in the form of radiation.
Range, Room Heater Type	A range having a separate room heater section.
Roof Jack	A factory-made assembly conveying flue gases through a roof and which includes a flue-gas passageway, insulating means, flashing, and cap.
Room Heater, Fireplace Stove, Combination	A chimney-connected, solid-fuel burning room heater which is designed to be operated with the fire chamber either open or closed.
Room Heater, Solid Fuel	A chimney-connected, solid-fuel burning room heater which is designed to be operated with the fire chamber closed.
Room Large in Comparison with the Size of the Appliance	A room having a volume equal to at least 12 times the total volume of a furnace and at least 16 times the total volume of a boiler. Total volume of furnace or boiler is determined from exterior dimensions and is to include fan compartment and burner vestibule,

when used. When the actual ceiling height of a room is greater than 8 feet (2.44 m), the volume of the room is to be figured on the basis of a ceiling height of 8 feet.

Sealed Combustion System Appliance	See definition for Direct Venting Appliance.
Smoke Developed Rating	The smoke developed rating of materials as determined by the <u>Method of Test of Surface Burning Characteristics of Building Materials</u> NFPA 255, ASTM E84, Underwriters' Laboratories Inc. Standard UL 723.
Smoke Test	A procedure for ascertaining the tightness of a chimney and for detecting any cracks in a masonry chimney flue or deterioration or breaks in the integrity of a factory-built or metal chimney flue. The procedure involves igniting a smoke bomb or building a smoky fire in a fireplace or solid fuel burning appliance, covering the chimney termination and checking for smoke escapage through chimney walls.
Solid Fuel	Wood, coal and other similar organic materials and any combination of them.
Solid Fuel Burning Appliance	A chimney-connected device that burns solid fuel designed for purposes of heating, cooking, or both.
Spark Arrestors	Screening material or a screening device attached to a chimney termination to prevent the passage of sparks and brands to the outside atmosphere.
Stovepipe	Single-walled metal pipe and fittings intended primarily to be used for chimney connectors but also sometimes for chimneys.
Sustained Yield	The rate at which wood can be harvested from an area forever, without decreasing the area's productivity. Sustained yield harvesting involves taking wood at a rate no larger than the rate at which new wood is growing.
Thimble	A fixed or removable ring, tube or lining usually located in the hole where the chimney connector or vent connector passes through a wall or enters a chimney or vent.

Trimmer	With reference to chimneys, the longer floor or roof framing member around a rectangular opening into which the end of a header is joined.
Venting	Removal of combustion products as well as noxious or toxic fumes to the outer air.
Venting System (Flue Gases)	A continuous open passageway from the flue collar or draft hood of a fuel-burning appliance to the outside atmosphere for the purpose of removing flue gases.
Vent Cap	A protective covering or housing attached to the vent termination intended for preventing entry of snow, rain, animals, etc. and for preventing downdrafts.
Vent Connector	The pipe which connects a fuelburning appliance to a gas vent or type L vent.
Vent Gases	Products of combustion from fuelburning appliances plus excess air, plus any dilution air in the venting system above a draft hood or draft regulator.
Vented Appliance	An indirect-fired appliance provided with a flue collar to accomodate a venting system for conveying flue gases to the outer air.
Volatiles	Gases released during the burning of wood.
Wall Protector (Shield)	Noncombustible surfacing applied to a wall area for the purpose of reducing the clearance between the wall and a heat producing appliance.
Wash	A slight slope or beveled edge of the top surface of a chimney designed to shed water away from the flue liner.
Water Heater	An indirect-fired fuel-burning or electrically heated appliance for heating water to a temperature not more than 200 degrees F (93 degrees C), having an input not greater than 200,000 Btu or 58.6 kw per hour and a water containing capacity not exceeding 120 U.S. gal (454 L).
Wythe	With reference to masonry chimneys, a cource, thickness or a continous vertical section of masonry separating flues in a chimney.

B. EDUCATIONAL MATERIALS

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Burning Solid Fuel Safely. Building Officials and Code Administrators International, 17926 South Halstead, Homewood, Illinois 60430.

Chimney Fires: The Creosote Problem. Tennessee Valley Authority, Office of Power, Division of Conservation & Rates, Solar Applications Branch, Credit Union Building, Chattanooga, TN 37401.

Control of Emissions from Residential Wood Burning by Combustion Modification. EPA-600/57-81-091, NTIS PB81-217655, Center for Environmental Research Information, Cincinnati, Ohio 45268.

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Fire Extinguishers. Tennessee Valley Authority.

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How Does Your Chimney Stack Up? Wood Heating Alliance, 1101 Connecticut Avenue, NW, Suite 700, Washington, D.C. 20036.

Improve Your Woodlot by Cutting Firewood. Insert No. 19. Division of Forestry, Department of Natural Resources, 613 State Office Building, Indianapolis, IN 46204.

Jenkins, John and Richard Vacca. Wood for Home Heating: Safety and Wood Heating Systems. Wisconsin Division of State Energy, 101 S. Webster St., 8th Floor/DOA, P.O. Box 7868, Madison, Wisconsin 53707, Phone 608-266-8234.

Jorstad, Robert K. Wood for Home Heating: Chimneys--Problems and Solutions. Wisconsin Division of State Energy, 101 S. Webster St., 8th Floor/DOA, P.O. Box 7868, Madison, Wisconsin 53707, Phone 608-266-8234.

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Wood Fuel Heating Tips. American Family Mutual Insurance Company, P.O. Box 7430, Madison, Wisconsin 53783, October 1981.

C. RESOURCE CONTACTS: Government Agencies
Energy/Public Health/Air Pollution

Great Lakes States

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Environmental Protection Agency
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National Wood Energy Assoc.
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Wayne Terpstra
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APPENDIX D - COMMENTS AND RESPONSES

Several reviewers raised questions and comments that were not incorporated into the Guidebook. We have provided brief responses with some identification of specific sources of information that will assist in answering the questions raised.

Comment: A question was raised concerning the adequacy of Oregon's Method 7 emissions test method as a precise measurement parameter for testing woodstove emissions. The lack of discussion of the proposed ASTM protocal as an equivalent to Method 7 was also questioned.

Response: Data providing the basis for our discussion includes (among other sources: 1. Oregon Environmental Quality Commission's Memorandum (RE: Agenda Item A, June 6, 1984: "Proposed Adoption of Woodsove Certification Rules, OAR 340-21-100 through 340-21-166 as Revisions to the State Implementation Plan.) 2. December 14, 1984 letter to Jim King of Colorado Air Quality Agency from John F. Kowalczyk, Manager Air Planning, Oregon Air Quality Division.

Comment: The figures used in the Guidebook to describe wood loading patterns are inaccurate.

Response: Review Stockton G. Barnett, Director of R&D, Condar Co. & Member ASTM E-6 Subcommittee .54 paper presented to ASTM addressing "The Issue of Wood Loading Factors of Woodstoves: How Much Do Homeowners Load into Their Stoves?", January 14. 1985.

Comment: The case studies and the document in general are primarily descriptive regarding policies in effect, and no attempt was made to evaluate policy effectiveness, difficulties encountered or costs related to specific alternative strategy implementation.

Response: Research to establish this data was beyond the scope of this project, but the recommendation has been made that research to establish this information base be undertaken in the near future to provide tools for decision-makers.

Comment: The contention that woodsmoke contains mutagenic (gene damaging emissions) is disputed.

Response: There is a large body of data concerning pollutants of concern found in woodsmoke. (See section IV). The Benzo(a)pyrene is a key example, but there are many other POM's as well. Many of these are also potent carcinogens. See US EPA: MULTIMEDIA GOALS FOR ENVIRONMENTAL ASSESSMENT, Vol. II, MEG Charts and Background Information, EPA-600/7-77-1366 and other toxicity data. B(a)P is identified as a mutagen, a teratogen and a carcinogen. The lowest dose to induce carcinogenicity is 2ug/k while the lowest dose resulting in teratogenic effects is 240 mg/kg. US EPA has taken the results of recent woodsmoke emissions monitoring tests so seriously in terms of risks to human health, that it is proposing national emissions control standards for woodstoves.