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Wood and Energy in Massachusetts

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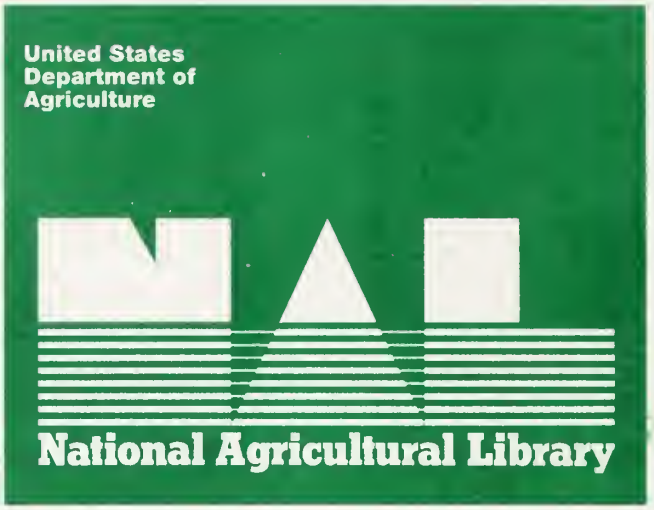
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WOOD AND ENERGY IN MASSACHUSETTS. By Mark R. Bailey, Paul R. Wheeling, and Maria I. Lenz, Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Washington, D.C. December 1982. ERS Staff Report No. AGES 821028

ABSTRACT

Telephone surveys of Massachusetts households conducted in 1979 indicate a transition to wood heating in response to a series of conventional energy price increases and uncertainty in conventional energy supplies. Massachusetts households consumed 815,000 cords of wood in the winter of 1978-79. The airtight wood stove has become the most commonly used wood-burning apparatus. Survey data of residential wood cutting, purchasing, and burning were analyzed by household tenure, wood-burning apparatus, and county. Residential use of wood for energy constitutes a new demand on the forest resource, increases local income and employment, displaces fuel oil and electricity, and may compromise household safety. The 1979 fuelwood survey is compared to a later 1982 survey.

Key words: Massachusetts, wood energy, residential energy demand, forest resource, wood-burning stoves, cordwood, fuelwood, renewable energy, energy substitution, New England.

OTHER FUELWOOD REPORTS

A report on wood and energy will be published for each New England State during the 1982 summer and early fall. Presently, Wood and Energy in Vermont (ERS, USDA Report No. AGES 820126), Wood and Energy in New Hampshire (ERS, USDA Report No. 820604) and Wood and Energy in Maine (ERS, USDA Report No. 820817) are now available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Order by report title and number.

DEDICATION

This report is dedicated to John H. Miner, who from 1976 was the Chief, Resource Conservation and Development Branch of the Soil Conservation Service, USDA. Mr. Miner, who retired from the Service in December 1980, was an ardent supporter of the Resource Conservation and Development Program, and was especially supportive of the New England Fuelwood Study of which this report is a part.

PREFACE

Wood and Energy in Massachusetts is the fourth of a series of reports stemming from the New England fuelwood study initiated on October 1, 1978, by the Economic Research Service (ERS) at the request of a number of resource conservation and development (RC&D) areas located throughout the region (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut). These RC&D areas wished to have an economic analysis of the feasibility of using wood as an alternative energy source and an estimate of the impacts of wood energy on the State economies. Four objectives were established:

1. Analyze wood energy supply and demand.
2. Determine Btu costs of alternative fuels.
3. Identify and examine present and potential barriers to adoption of wood energy.
4. Examine the economic impact of wood energy adoption upon State economies in New England.

After conducting a literature review (8), the researchers decided to examine only the residential sector because, while there was a growing body of information regarding wood energy used in the commercial and industrial sectors, there was little regionally consistent information regarding residential use of such energy. The study was a highly cooperative effort that included ERS, the RC&D program administered by the Soil Conservation Service (SCS), local RC&D areas, State energy offices, and many other local agencies.

Wood and Energy in Massachusetts presents information on residential use of wood energy obtained from a household survey conducted in 1979 which obtained detailed information from more than 2000 households. The Massachusetts survey confirms that a broadly based transition to cordwood use has occurred in household heating (fuelwood is used interchangeably with firewood and cordwood in this report). This energy shift has significantly changed the use of conventional energy and added to demands placed upon forests.

Interviewing for the Massachusetts fuelwood survey was initiated and supervised by Ted Cady, RC&D Forester of the Berkshire-Pioneer Valley RC&D area, and coordinated by Bill Obear at the former Berkshire-Franklin Resource Conservation and Development Office. The survey was conducted using the methodology and questionnaire jointly developed by ERS, representatives from participating RC&D areas, various State energy offices and concerned individuals. RC&D areas and State energy offices sponsored the surveys in Maine and Rhode Island. The RC&D areas in Connecticut sponsored the surveys there. The Vermont Energy Office and the New Hampshire Governor's Council on energy conducted the surveys in their States. An additional, more recent Massachusetts wood energy survey was sponsored by the Massachusetts Department of Environmental Management, Division of Forests

and Parks and the Berkshire-Pioneer Valley RC&D Area. These agencies contracted with the Research Group of Northampton, Massachusetts which conducted a survey of over 2000 households during the spring of 1982. Comparisons between these surveys are made in this report when data comparability permits.

The New England fuelwood surveys were conducted under strict guidelines. To insure reliable results, estimation techniques included a carefully prepared questionnaire, a three-way stratification of results, and rigorous testing for eight different forms of response bias. The surveys were conducted by the above noted agencies within each State which compiled and organized the data. These agencies forwarded the data to ERS for analysis. New England is now the only U.S. region with detailed and comparable State-by-State information on the residential use of wood energy and the resulting displacement of conventional energy sources.

ACKNOWLEDGMENTS

The survey of household wood use in Massachusetts would not have been possible without the energy and concern of Ted Cady, former RC&D Forester. Major contributions were also made by survey coordinator Bill Obear, who currently heads the Pioneer Fuel and Fibre Co.; by Forester Jane Difley, who initially proposed the fuelwood study; and by Carolyn Harper, who wrote a fuelwood market report based upon preliminary survey results (3).

The contribution of many groups was required to achieve this large survey effort. These groups include: the Massachusetts Office of Energy Resources, the Franklin Conservation District, the Greenfield CETA Consortium, the Massachusetts Grange, the RC&D Resource Inventory Crew, the Franklin County Energy Task Force, the Massachusetts Department of Environmental Management's Division of Forests and Parks, and the New England Wood Energy Advisory Council.

Appreciation is also tendered the following individuals who provided many helpful suggestions and assistance in the development of the study and in the preparation of this report: John Wenderoth, Cliff Jones, Robert McKusick, Sheryl Davies, Beth Green, Charles Taylor-Brown, Daniel Vining, James Sayre, Debra Ritter, Curtis Mildner, Steve Morgan, Sandra Bodmer-Turner, Alan Turner, Roger French, Francis Holt, Roy Gray, Donald Jones, Kay Wilhelm, Helene Blank, Frances McDevitt, Joseph Barse, William Crosswhite, Dwight Gadsby, Anthony Grano, John Hostetler, Melvin Cotner, Velmar Davis, Neal Kingsley, Jerry Jolly and Robert Francis.

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HIGHLIGHTS

Most Massachusetts residents have experienced sharp increases in home heating costs since 1974, and as a result, many installed wood-burning stoves or central wood-fired heating systems. Major findings of this study are:

* Over 815,000 cords of wood were burned by Massachusetts households during the 1978-79 winter.

* Over 9 percent of all Massachusetts households and 17 percent of owner-occupant households used wood-burning stoves or central wood-fired heating systems during the 1978-79 winter.

* Wood energy supplied 7 percent of all energy demanded by by Massachusetts residents. This energy was converted into 6 trillion Btu's of residential space heat.

* By substituting wood, Massachusetts residents are displacing $76 million in petroleum and $31 million in electricity. Residents spent approximately $33 million of these savings on the purchase of cordwood.

* Residents relying upon the more expensive conventional home heating fuels are more likely to have installed wood-heating equipment than those who have access to a less expensive fuel.

* Homeowners who use airtight wood stoves burn approximately 3.4 cords per household during a winter and estimate that they derive 60 percent of space heat from wood.

* Residents using wood stoves are more likely to make energy conservation improvements and are more likely to lower thermostat settings than those not burning wood.

* Purchased wood supplied 38 percent of the cordwood obtained for the 1978-79 winter. Although a majority of cords were cut by household residents for their use, 42 percent of wood-burning residents purchased some portion of their wood.

* Splitwood constituted 56 percent of cords purchased. Ninety-two percent of cords purchased were hardwood; 82 percent were delivered.

Wood and Energy in Massachusetts

Mark R. Bailey
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Maria I. Lenz

INTRODUCTION

Since the 1973-74 oil embargo, Massachusetts households, like those in the other New England States, reacted to the resulting energy crisis by substituting wood energy for fuel oil and electricity. This transition from conventional energy sources to wood energy resulted in the burning of 815,000 cords of wood by Massachusetts households during the winter of 1978-79 (table 1) and almost 997,000 cords during the 1981-82 winter (6). 1/ Increased fuelwood consumption is resulting in larger demands upon the forest resource, displacement of fuel oil and electricity, and an increase of energy dollars spent in local economies.

This report describes how Massachusetts families obtain cordwood, volumes of fuelwood burned, trends in fuelwood use, and the relationship between fuelwood cut and the forest resource.

While the 1982 survey contains a number of differences from the previous survey (Appendix), it is nevertheless mentioned throughout this report wherever the data are comparable. The later survey results substantiate many of the relationships identified in the New England fuelwood surveys.

REASONS FOR THE TRANSITION TO WOOD

Wood was the major energy source in New England until the early 1900's. Forests covered only 20 percent of the land area by the mid-1800's, due to the need for farmland. As the population grew, demand for wood for building and fuel continued to grow until the supply was outstripped by the latter half of the 1800's. Fuelwood deficits were made up by imports from the Canadian Maritime Provinces (1). (Underscored numbers in parentheses refer to items in the references.) Demand for fuelwood peaked during the late 1800's, and coal became more and more popular. Demand for fuelwood declined precipitously after widespread adoption of petroleum-burning furnaces. Forest acreage expanded as demand for wood energy declined and the region's economy shifted to

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Bailey, an ERS agricultural economist, is the New England Fuelwood Study leader. Wheeling, formerly an ERS community planner, was the deputy leader of the study. Maria Lenz is an economic and statistical assistant with ERS.

1/ Gross volume values of the 1982 survey were adjusted downward in the same amount as the original survey (17 percent) to account for survey bias and to make the two surveys results more comparable.

Table 1--Residential wood use in Massachusetts by household groupings, winter of 1978-79

Household group 1/	Households in wood use group	Volume of wood burned 2/
	Number	Cords 3/
Owner-occupant	1,155,664	718,368
Not burning wood	705,314	--
Using only fireplace	258,742	220,523
Using open wood stove	53,166	100,238
Using airtight wood stove	122,715	332,313
Using a wood furnace	15,727	65,294
Rental-occupant	845,207	66,685
Not burning wood	781,385	--
Burning wood	63,822	66,685
Second and seasonal homes	56,135	30,323
Not burning wood	33,942	--
Burning wood	22,193	30,323
Total	2,057,006	815,376

1/ Household classifications are stratified by tenure categories which indicate owner-occupied dwelling units, rental occupied dwelling units, and second and seasonal dwellings, which may not be occupied throughout the year. Stratification by tenure allows use of census data to control the estimate for differential telephone answering rates.

2/ Estimates of the volume of wood burned are reduced 17% from volume reported by respondents to correct for response bias. Major forms of response bias identified by subsurvey and resurvey are under-reporting of not-at-home households, and over-reporting of the volume burned due to imprecise knowledge of the cord measure.

3/ The term cord has traditionally referred to a stack of wood 4 feet high, 4 feet deep, and 8 feet long. In Massachusetts, cordwood, by law, must be sold by the cubic foot, with a cord equalling 128 cubic feet of closely stacked wood and air. This wood is cut to stove length and split before stacking.

manufacturing, idling much agricultural land which reverted to forest. By 1970, forestland encompassed nearly 80 percent of land in the region.

Fuel oil prices, in constant 1972 dollars, have increased approximately 240 percent in New England since the 1973-74 oil embargo. Petroleum accounts for over 75 percent of the energy used in New England, and over 75 percent of the petroleum consumed is imported from foreign sources. Petroleum accounts for 75 to 85 percent of the energy consumed in Massachusetts and between 50 and 60 percent of conventional energy demanded by residences. Heating requirements of a Massachusetts household are 132 percent of the national average. As a result, Massachusetts residents have keenly felt the increasing cost of home heating, and their desire to lower heating costs has been a central factor contributing to the transition to wood heat.

TRANSITION TO CORDWOOD USE IN MASSACHUSETTS

Use of wood heat in Massachusetts in 1970 was well above the national average which was less than 1 percent of homeowners (8). Still, less than 3 percent of the State's homeowners used wood-heating appliances, and much less heat was provided per wood-burning stove. 1/ During the 1978-79 winter, 17 percent of Massachusetts' homeowners used wood-fired heating equipment as either their primary or supplementary source of space heat; during 1981-82, it was 19 percent.

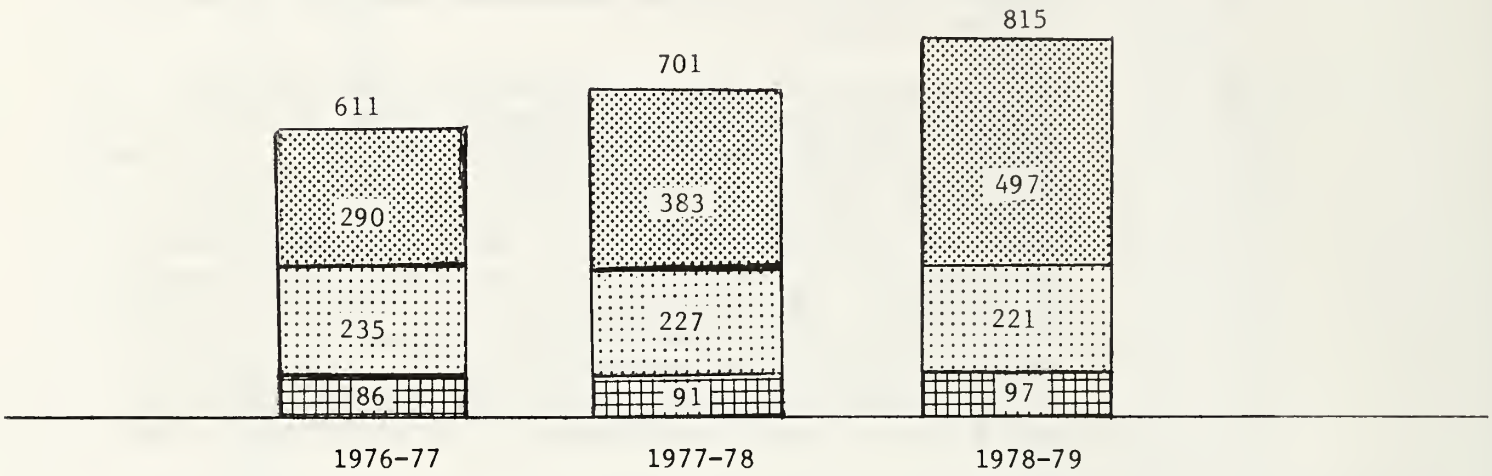
Trends in Residential Wood Use

Total numbers of wood stoves and wood-burning furnaces installed in Massachusetts in 1976, 1977, and 1978 were 8,000, 12,000, and 12,000, respectively. These installations overstate the transition to wood heat because some replaced or upgraded previously existing wood-burning equipment.

Estimates of the volume of wood burned in residences during the winters of 1976-77 through 1978-79 were developed from the 1979 Massachusetts fuelwood survey. Trends in residential wood use -- the fuelwood volume differences between the surveyed winter and the previous winters -- are primarily estimated from when wood-burning equipment was installed and the type of equipment, if any, used prior to that date. The annual increase has averaged 15.5 percent over 1976-77 to 1978-79 (fig. 1). Of the 1659 owner-occupant households responding to questions in the survey, 20 percent used a wood stove during the winter of 1978-79. The majority of these stove users used a wood stove during the previous winter (16 percent of all owner-occupant households), while 2 percent of homeowners changed from fireplace to stove use and 2 percent changed from not burning wood to stove use. Approximately 2 percent of

1/ The 1970 figure of 3 percent was derived by extrapolating data back in time.

Figure 1--Trend in residential wood use, three winters, 1976-1979, Massachusetts, Thousands of cords



percentage increase 1976-77 to 1977-78	percentage increase 1977-78 to 1978-79
15 percent	16 percent

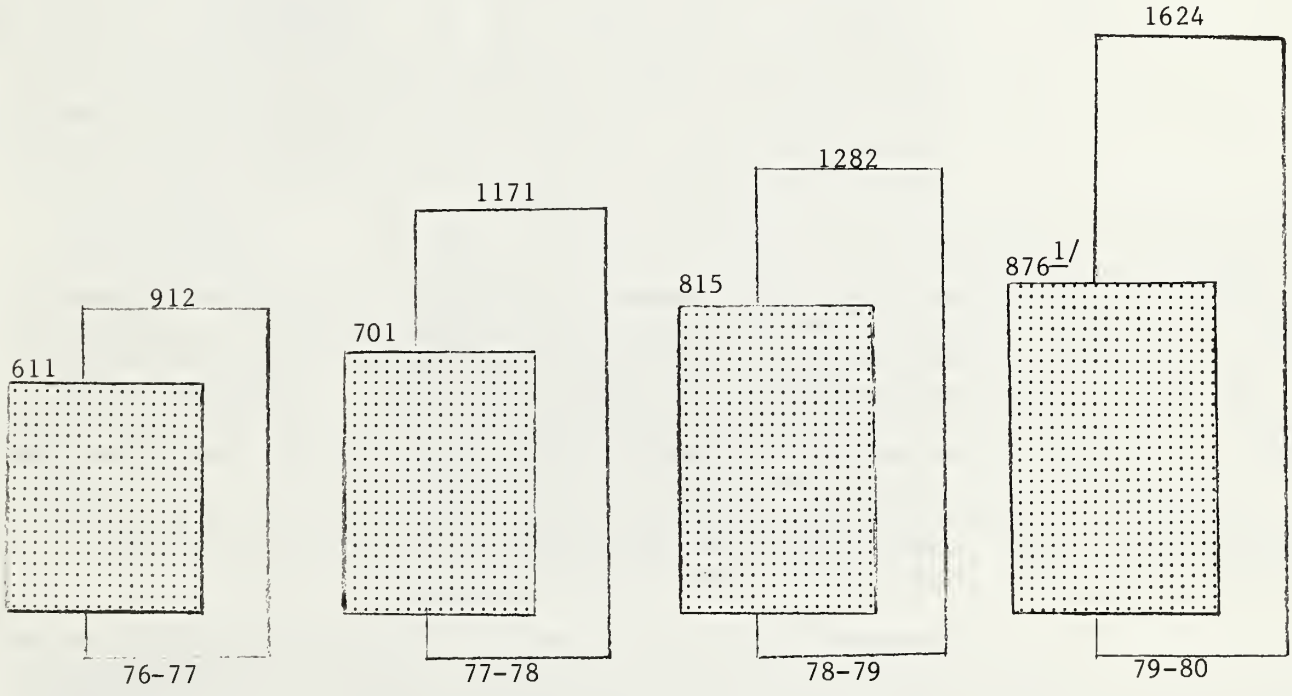
Volume of wood burned by homeowners using wood stoves or wood-fired central heating systems.
Volume of wood burned by homeowners using fireplaces.
Volume of wood burned in rental households and second homes

homeowners used a central wood furnace prior to and during the winter of 1978-79.

The initial surveys in Maine, New Hampshire and Vermont show a 19 percent annual increase in cordwood consumption between 1976 and 1979. Massachusetts wood use was at a slightly lower rate (15.5 percent) than this Northern New England trend (fig. 2).

Follow-up surveys in Northern New England States show a 27 percent annual increase between 1978-79 and 1979-80. The 1982 Massachusetts fuelwood survey, however, indicates only a 11.1 percent increase during this time. While the use of wood energy is increasing in Massachusetts, the lower percentage growth is due primarily to the relatively higher use of fireplaces (less volume of wood is burned in fireplaces) and possibly a function of fewer logging/pulp operations in the State resulting in higher fuelwood prices. Additionally, the fact that on a

Figure 2--Trends in residential cordwood use, comparing surveyed winters in Northern New England and Massachusetts in thousand cords



1/ The Massachusetts volume figure was estimated by taking the 1982 survey results (adjusted by ERS to correct for response bias), and assigning a straight line trend between the winters of 1978-79 and 1981-82.

Note: Northern New England is comprised of Maine, New Hampshire, and Vermont.

percentage basis, more households utilize natural gas which is the least expensive conventional energy source available. As the use of fireplaces continues to decrease and the installation of more efficient wood-burning apparatuses increase, a higher percent gain in the volume of fuelwood is expected.

The Massachusetts survey, as well as the other New England State surveys, gives no indication that the increase in wood use will not continue, especially if the relative costs of conventional fuels continue to rise. The rational response to increasing conventional heating fuel prices indicated by the survey findings implies that an increase in wood energy use will occur if and when natural gas is decontrolled (assuming a price increase will result). As the costs of conventional energy rise relative to the cost of wood energy, more households will substitute wood energy.

Prior to the oil embargo of 1973-74, fuel oil was relatively low in price, and as a result, most residences in Massachusetts were heated by that energy source. During the same pre-embargo period, the marginal cost of wood supplied heat was higher than fuel oil supplied heat, and most cordwood was burned for aesthetic purposes rather than as a substitute for conventional energy. The increases in fuel oil prices that followed the 1973-74 petroleum embargo, however, had a profound impact upon the use of wood for energy not only in Massachusetts but in all of New England as well.

Consumers realized that even with the increased prices of fuel oil, the non-airtight stoves that dominated the market were too inefficient to make wood energy competitive with conventional energy. As a result more efficient stoves were designed and built and the users were able to extract more energy per pound of wood burned. The increased efficiency made wood supplied heat significantly lower in price than that supplied by fuel oil. As a consequence, a very high proportion of the stoves installed since 1974 have been of the efficient airtight type (table 2). The increased wood-burning efficiency of such stoves made the marginal cost of wood less than that of fuel oil, and as a result, the average amount of wood burned in airtight stoves increased. Compared to those households that use inefficient, non-airtight stoves, those using airtight stoves typically burn 20 percent more wood per year and derive a greater amount of heat. Massachusetts households are consequently experiencing greater displacement of fuel oil and electricity, as well as larger savings in heating costs.

Table 2--Proportion of various wood-burning apparatuses installed in Massachusetts

Period installed	Open wood stove	Airtight stove	Wood furnace
		Percent	
Before 1974	47	35	18
1974-76	32	58	10
1977-79	10	81	9

Future Use of Wood for Energy

Future residential demand for wood energy is a vital matter to those concerned with forest resource management, energy planning, air quality management, forestry-related employment, and wood stove manufacturing. Reliable projections of wood energy demand are now impossible because changes in major influences on wood use, which include prices of fuel oil, electricity, and natural gas, cannot be predicted. However, relationships identified in this analysis point to at least six factors having influence on the use of wood energy: relative cost of energy, perceived problems with wood use, excess demands on the forest resource, air pollution abatement regulations, increased home insurance rates, and state liability laws.

Relative Cost of Energy

The most influential factor on future demand for wood energy is the change in relative costs of heating with alternative fuels. Three survey findings substantiate this conclusion:

1. Residential household use of wood-fired heating equipment is disproportionately concentrated in those households displacing more expensive heating fuels. For example, 23 percent of the Massachusetts homeowners using electricity as a conventional fuel use wood heat. During 1978, fuel oil and natural gas were only 35 and 33 percent of the cost of electricity per Btu of heat provided (table 6). The rate of use of wood heat by homeowners using fuel oil as a conventional fuel was 16 percent, and for natural gas, only 9 percent.

2. A greater percentage of New England homeowners use wood heat in areas of relatively low cordwood prices.

3. The installation rate of wood-fired heating equipment has paralleled increasing petroleum prices.

Increases in the relative price of fuel oil, electricity, and natural gas will likely spur an increase in wood use. Likewise, increases in the relative price of cordwood would decrease wood use by households purchasing wood. There is a huge latent wood energy demand in industries that could convert to wood-fired boilers -- including electrical utilities and alcohol plants. If such demands were realized, the relative price of wood energy could increase to such a level that other alternative energy sources, particularly coal and solar, would become more competitive.

Perceived Problems with Wood Use

Growth of residential wood use has been somewhat dampened by several problems which non-wood-burning homeowners presently associate with wood use. Such homeowners most frequently identify potential hazards of burning wood as the major reason why they do not use wood (table 3). Renters identify problems concerned with getting permission from the landlord, cost of the stove, and locating adequate cordwood supplies.

Excess Demand on the Forest Resource

A major implied objective of the Massachusetts fuelwood study was to assess the ability of the State's forest resources to meet the multitude of demands presently being experienced (residential and industrial use of wood energy; cordwood exports; pulp and timber products; recreation and wildlife; aesthetics, etc.). While the long-term renewable resource base for wood and forest demands is difficult to assess due to the present condition of the forest resource and land ownership patterns, large and dense standing stocks of low quality trees can provide a resource for many years of harvesting. Thus, current harvesting can be well above sustainable yield without seriously damaging the forest resource base. For example, the most recently completed Massachusetts survey suggests that the impact of harvesting wood for energy has greater impacts in Middlesex and Norfolk counties and on Cape Cod where the number of cords that were cut by homeowners exceeded estimated annual growth as measured on the merchantable bole basis (6). However, given the present lack of relevant data concerning the forestry supply and demand relationships, definitive statements cannot be made regarding the time period when excessive demands may begin to adversely affect the forest resource. In addition, ownership land holding patterns and objectives usually permit current

Table 3--Perceived problems with wood use by owner-occupant households not burning wood, 1979, New England

Perceived problem	Massachusetts	Maine	Vermont	New Hampshire	Connecticut	Rhode Island
			Percent 1/			
Time and effort in cutting wood	20	24	10	19	45	6
Price of fuelwood	15	32	8	23	53	4
Locating adequate supplies to purchase or cut	9	21	4	13	35	3
Potential hazards of burning wood	49	38	66	56	34	47
Cost of stove	13	37	4	13	27	5
Inconvenience in handling	20	11	29	26	0	21
			Number			
Sample base	779	229	86	247	83	150

1/ Percentages do not add to 100 since more than one reason was often given by each respondent.

cordwood harvesting by the landowners. In the longer term, however, these same ownership patterns and landowner objectives may limit future availability. Currently, in most areas of Massachusetts, all wood and forest resources demands are adequately met.

Potential Pollution Regulations

Increased wood burning has raised pollution levels to the point that some areas now control the use of wood energy (Portland, Oregon and Vail, Colorado). Topographical characteristics of Massachusetts, as well as the other States in New England, together with increased burning of wood, have also resulted

in locally increased ambient pollution levels. As use of wood for energy continues to increase, degradation of air quality may result in environmental controls and public awareness that could limit increases in household use of wood for energy.

Home Insurance Policy Premiums

More house fires have occurred as the use of wood energy has increased. While the majority of house fires associated with fuelwood use results from improper installation of wood-burning equipment, a number of such fires are a result of chimney fires. The chimney fire problem is further exacerbated by the increasing number of airtight stoves. Maximum stove efficiency is a function of adequate oxygen, fuel, and burning temperature. Too much air results in excess heat going up the chimney; too little air results in a cooler fire, a cooler flue, and an increase in creosote (condensed gases) production. Many households operate airtight stoves with too little air which, while extending the period between reloadings also increases creosote formation. Creosote buildup increases the potential of chimney fires and related house fires. This problem can be minimized by cleaning the chimneys and letting the stove burn hot for specified periods on a regular basis as recommended by manufacturers.

A number of insurance companies will not issue household insurance premiums to mobile homes using wood stoves. Many insurance companies are comtemplating a supplementary premium for houses that use wood stoves if the incidence of house fires resulting from the operation of wood-burning apparatuses increases much further. Such premiums could dampen the demand for new equipment and fuelwood.

State Liability Laws

State liability laws may constrain wood cutting. Prior to the resurgence of cordwood use, owners of forestland may have been liable for injuries received by individuals cutting wood on their land. As a result, many landowners did not permit individuals to cut wood on their property, and thus accessibility to fuelwood sources was limited. Some New England States have countered this legal constraint by implementing legislation limiting homeowner liability if cordwood stumpage is given away.

WOOD CONSUMPTION AND ENERGY CONSERVATION BY MASSACHUSETTS HOUSEHOLDS

Massachusetts families have responded to increasing heating costs and uncertain energy supplies by adopting fuelwood heating, making heat conservation improvements, and changing thermostat operations (lowered settings, zoned heating, and timed heating).

Residential Use of Wood for Energy

Massachusetts families burned 815,000 cords of fuelwood during the 1978-79 winter (table 1) and about 997,000 cords in 1981-82 (6). During 1979, over 9 percent of all households and 17 percent of homeowners used a wood-burning stove or central wood-fired heating system. The increase in residential wood use recently has varied between 15 and 16 percent per year, reflecting initial installations of wood-heating equipment and some upgradings of existing equipment. The substitution of wood energy has resulted in a more healthy State economy because dollars that would have been spent on imported oil remain in the State to be spent on local goods and services, including locally produced fuelwood. More information on the economic impacts of wood energy substitution appears in a forthcoming report. 2/

Patterns of Cordwood Use

The primary stress on fuelwood resources is not due to rural wood stove use. Intensity of fuelwood use per unit of land area is largely determined by population; thus, areas with more households generally burn a larger total volume (table 4 and fig. 3).

Impact of Wood-Burning Equipment on Cordwood Use

There are a variety of wood-burning appliances, ranging from traditional open wood stoves to relatively sophisticated airtight stoves and central wood-fired heating systems. Of the 450,000 Massachusetts homeowners using wood-burning appliances in 1979, 16,000 used central wood-burning furnaces, 123,000 used airtight wood stoves, and 53,000 used open wood stoves. Almost half of the wood consumed by households in Massachusetts was burned in airtight wood stoves.

Massachusetts had a much higher incidence of fireplace use than did the Northern New England States - nearly a third of the wood was burned in fireplaces in 1979. However, the most recent survey confirms the trend away from inefficient fireplaces toward the more efficient airtight stoves and furnaces. In the 1981-82 winter, only 16 percent of the cordwood was burned in fireplaces. Thus, as in Northern New England, fireplace users have become a relatively insignificant marketing channel.

The average number of cords a household is likely to burn, and the number of Btu's that may be expected, depends on the type of apparatus used (fig. 4). Households using airtight wood stoves burned an average of 3.4 cords of wood during the 1978-79 heating season. The actual volume burned over a winter varies greatly, however, ranging from roughly 3 to 6 cords per year. Airtight wood stoves in Massachusetts provide an average of 46 million Btu's of available space heat per household

2/ Mark R. Bailey, Paul R. Wheeling and Maria I. Lenz. "Wood and Energy in New England: A Regional Perspective," New England Fuelwood Study. Econ. Res. Serv., U.S. Dept. Agr. Forthcoming.

Figure 3--Intensity of residential demand for fuelwood, 1978-79, New England

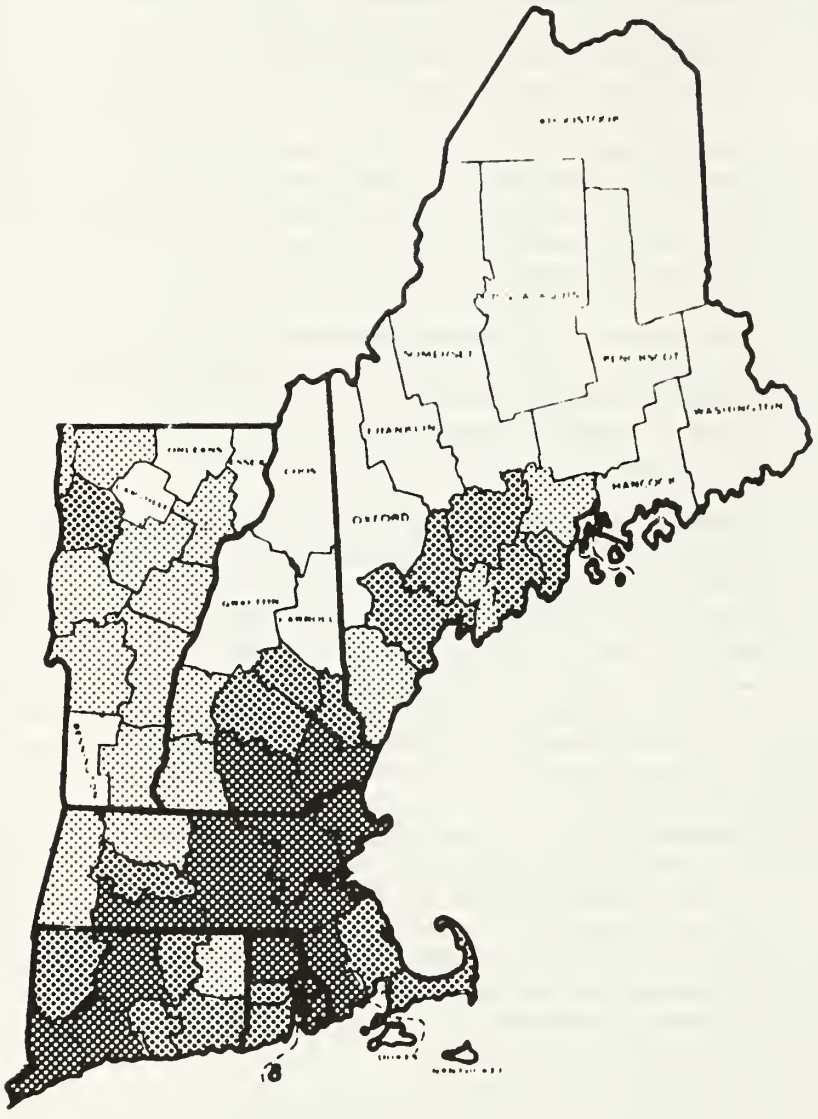
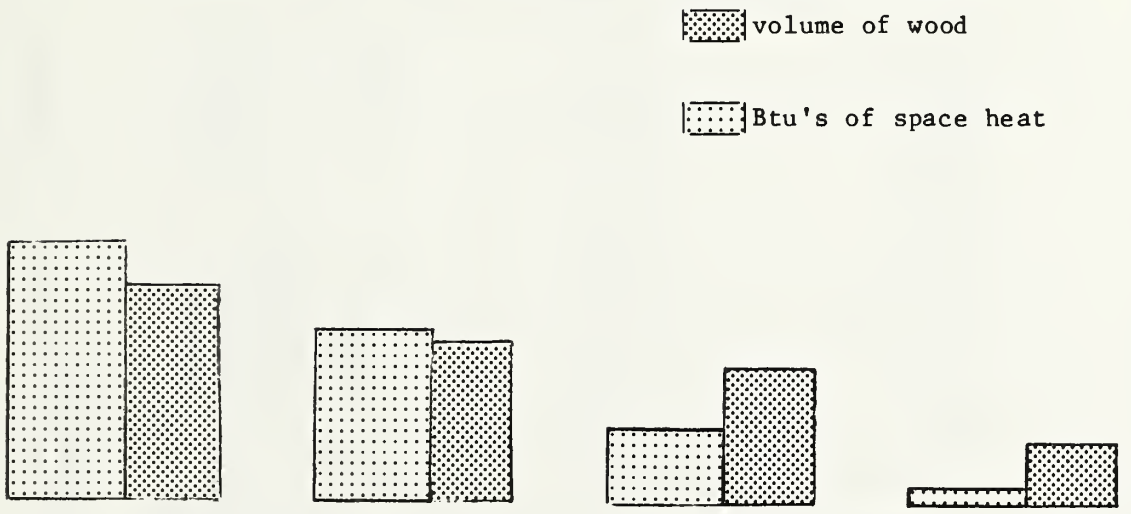


Figure 4--Average volume of cordwood burned and available heat per household, by type of apparatus used, winter, 1978-79, Massachusetts



Wood-burning furnace	Airtight wood stove	Open wood stove	Fireplace
4.6 cords	3.4 cords	2.9 cords	1.3 cords
60 million Btu's	40 million Btu's	20 million Btu's	3 million Btu's

The wood-burning apparatus heavily influences the magnitude of fuelwood consumption and conventional fuel savings. The airtight wood stove, which has recently dominated installations, shows a consistent pattern of wood consumption per household across most New England States and from year-to-year in Massachusetts. Once installed, characteristics of the wood stove and its placement largely determine the volume of wood burned and conventional energy displaced. A subsequent increase in the cost of the conventional fuel does not generally result in a significant change in the volume of wood burned in wood stoves already installed. Of course, the volume of wood burned by a household is influenced by access to fuelwood, cost of the fuel displaced by wood at the time of the installation, housing type, and the extent to which the home is insulated. Newly developed apparatuses which increase wood-burning efficiency (e.g., the forced-air stick furnace and designs incorporating catalytic converters) may change fuelwood demand.

Table 4--Volume of cordwood burned in Massachusetts households, by county, winter, 1978-79

County	Volume burned	Percentage of State Total
Worcester	152,970	19
Middlesex	131,112	16
Essex	108,612	13
Norfolk	87,862	11
Hampden	64,731	8
Bristol	58,622	7
Plymouth	57,779	7
Hampshire	35,905	4
Berkshire	35,375	4
Barnstable	29,889	4
Franklin	28,388	4
Suffolk	20,820	3
Dukes	2,194	--
Nantucket	1,116	--
Total	815,376	100

Note: -- = negligible amount.

during a winter, assuming a 50 percent operating efficiency. Such a stove could provide almost half of the heating requirements of a home requiring 90 to 100 million Btu's of space heat per year. Massachusetts homeowners, however, estimate that their airtight wood stoves provide 60 percent of space-heating needs (table 5).

The New England survey respondent estimates of the proportion of space heat provided by wood were significantly higher than estimates derived by calculating the amount of conventional energy displaced by the volume of wood burned. Owner-occupant residents using both an airtight stove and an oil-fired central furnace consistently reported conventional fuel cost reductions that reflect a greater than one-for-one value of wood heat substitution. This difference may be due to a lack of information on the amount of useful energy which a household can derive from a cord of wood. Also, residents installing and operating wood-burning equipment may use less energy than they previously used and wood-burning equipment may provide a quality of heat that results in less demand for fuel.

During the 1978-79 winter, households using airtight stoves reported supplying 48 to 60 percent of space heat needs from wood (table 5). The lower estimate is a minimum calculated by conservatively estimating the energy in the wood burned and equipment burning efficiency. The upper limit is derived from the respondents' estimates of the percentage of heat supplied by wood.

Table 5--Wood-burning characteristics averaged for owner-occupant households, by apparatus type, winter, 1978-79, Massachusetts

Apparatus	Wood burned	Available heat 1/	Estimated savings in conventional fuel 2/	Homeowner estimate of percentage of heat from wood 3/	Average daytime thermostat settings 4/	Efficiency assumed for study
	Cords	Btu x 10^6	Dollars	Percent	Degrees	Percent
Open fireplace	1.0	1	53	6-11	66	5
Efficient fireplace	1.6	5	86	15-20	67	15
Traditional wood stove	2.9	16	281	34-40	64	30
Airtight wood stove	3.4	37	417	48-60	63	50
Wood furnace (combinations incl)	5.8	70	561	59-62	64	55

1/ Available heat calculated from an estimated 24 million Btu's per cord times average number cords burned, times assumed efficiency of wood-burning apparatus.

2/ Based largely upon fuel oil costing 55 cents per gallon. Savings are an average of homeowner estimates.

3/ Values on left side calculated from estimates of dollar savings and cost of conventional fuel; values on right side estimated as a percentage by respondent.

4/ Estimated thermostat settings determined by the New Hampshire Fuelwood survey based upon data provided by the New Hampshire Governor's Council on Energy for similar household groups in New Hampshire.

Cost Relationships of Conventional and Wood Energy

Information on relative costs served as a base in analyzing the household decision to use wood heat. The price differential between purchased wood and fuel oil in Massachusetts resulted in heat provided by fuel oil costing 113 percent of that provided by wood in 1978 and costing 162 percent of heat provided by wood in 1981 (table 6). Households using more expensive energy sources have a greater tendency to install wood-burning equipment than households using less expensive energy sources.

These patterns of relative cost and tendency to install wood-burning equipment indicate that household decisions resulting in the use of wood heat are primarily a rational attempt to lower heating costs.

Use of Energy Conservation Measures

Massachusetts households also reduce heating costs through home improvements and thermostat operations directed at energy conservation. Improvements in existing homes may include upgrading insulation, installing storm doors and windows, caulking, and weather stripping. Changes in thermostat operations, which include lower thermostat settings and heating less than the entire home, decrease a household's heating demand. While a wood stove may provide normal or higher than normal temperatures in a central or often used room, peripheral areas of the home may cool to the thermostat setting or lower. Lower temperatures during periods when the wood stove is not attended also may result in energy cost reductions.

Respondents addressed five specific types of energy conservation improvements. Most homeowners indicated that they had made one or more of these home improvements during the past 3 years. Although few had installed solar water heat, performed furnace maintenance, or improved caulking and weather stripping, many had installed storm windows and a majority had made insulation improvements (table 7). At least 15 percent of Massachusetts homeowners improved their insulation each year. Households utilizing the more efficient wood-burning apparatuses were more likely to make greater energy conservation investments than those households not burning cordwood or those using fireplaces or traditional wood stoves.

Table 6--Relative cost of alternative heating fuels, 1978 to 1981, Massachusetts

Energy source and burner	Applicable unit	Cost/unit		Energy per unit	Typical burner efficiency factor	Available energy	Cost/million Btu's		Relative cost per mil. Btu's 1/	
		1978	1981				1978	1981	1978	1981
		Dollars		Million Btu's	Percent	Million Btu's	Dollars		Percent	
Wood, airtight stove	cord	59	4/103	2/ 24	50	12.0	4.92	8.58	100	100
Central system	cord	59	4/103	2/ 24	55	13.2	4.47	7.80	91	91
Electricity, Resistance	kWh	3/.0533	4/.06148	.0034	100	.0034	15.61	18.08	317	210
Natural gas Furnace	1000 cu. ft.	3/ 4.17	4/ 6.00	1.00	70	.70	5.95	8.57	121	100
LP gas Furnace	gallon	3/.350	N/A	.095	70	.066	5.30	N/A	107	N/A
#2 fuel oil Furnace	gallon	3/.50	4/1.25	.1387	65	.090	5.55	13.89	113	162

Note: N/A = not available

1/ Computed by dividing the energy price by the price of wood energy in an airtight stove.
2/ Btu/cord of wood weighted according to volumes of hardwood and softwood consumed in a typical residential cord.
3/ Price data from State Energy Fuel Prices by Major Economic Sector from 1960-1977 (some for 1978): Preliminary Report and Documentation, U.S. Dept. Energy, July 1979.
4/ Price estimates for 1981 from Massachusetts Office of Energy Resources.

Table 7--Owner-occupant household energy conservation improvements, by apparatus, winters, 1976-79, Massachusetts

Apparatus	Making insulation improvement	Installing storm windows	Caulking or weather stripping	Sample size
	--------Percent----------			Number
Owner-occupant household not burning wood	43	30	23	914
Owner-occupant household using an open fireplace	41	28	22	240
Owner-occupant household using an efficient fireplace	46	36	40	58
Owner-occupant household using a traditional wood stove	52	24	26	89
Owner-occupant household using an airtight wood stove	62	40	37	230
Owner-occupant household using a central wood furnace	59	41	35	34
All homeowners	46	31	26	1565

The total percentage of homeowners reporting conservation improvements in Massachusetts is consistent with that of the states of Northern New England. However, 6 percent more airtight stove owners in Massachusetts reported improvements. The pattern of fireplace owners is usually consistent with or slightly lower than that of Northern New England.

Lowered thermostat settings are more likely to be found in those homes using wood heat in the more efficient burning apparatuses. Questions concerning thermostat settings were included in the resurvey of household wood use in New Hampshire, where wood use is somewhat similar to Massachusetts. New Hampshire households using an airtight wood stove reported an average daytime thermostat setting of 63 degrees and a nighttime setting of 60 degrees, several degrees lower than those not burning wood or using only a fireplace. These lower settings save an additional 10 to 15 percent of space heat.

Energy conservation improvements, lowered thermostat settings, and the substitution of wood for a more expensive heating fuel are measures which tend to occur, in combination, in certain households. This suggests that these measures are part of an overall household strategy directed at the reduction of heating costs. Households not burning wood are consistently less likely to make energy conservation improvements (table 7).

OBTAINING CORDWOOD IN MASSACHUSETTS

Massachusetts households obtain cordwood through purchase and/or household harvesting of such wood. While wood-burning residents cut more wood than they purchased, more than 42 percent of them purchased at least some part of their cordwood. Over half of the cordwood marketed in Massachusetts is sold as splitwood. Market demand for cordwood is directly related to density of population, or more specifically, to density of owner-occupant households.

Seller services such as bucking, splitting, delivering, and stacking all influence cordwood price. Market demand for purchased cordwood will likely continue to increase since both the 1979 and 1982 surveys show that the percent of purchased wood burned has increased over previous years.

The bulk of cordwood harvested by residents is cut on family-owned lots attached to their residence. As a result, such harvesting is concentrated on a small portion of forestland. While harvesting by residents may not be directed primarily at improving the quality of their woodlots, a larger proportion of such operations received guidance from professional foresters than in other New England States. (see discussion in the Harvesting Cordwood and Land Use Characteristics Section). The wood they cut was not suitable for producing lumber and most of the wood cut was dead, blown down, rotten, or residue from land clearing operations.

Volume of Cordwood Purchased and Cut

Massachusetts residents purchased over 351,000 cords and cut nearly 568,000 cords of wood for their own use during 1978 (table 8). During 1978, owner-occupants using a wood-burning stove or central wood-fired heating system acquired 61 percent of all wood obtained by residences even though they constituted only 9 percent of all households. Homeowners using wood stoves and furnaces purchased more than 200,000 cords during 1978, constituting the largest market group. As a whole, wood burners using fireplaces tend to purchase a higher percentage of their wood than those using wood stoves. In Massachusetts, since many more households used fireplaces, 33 percent of the total volume of cordwood sold was purchased by fireplace users. This market outlet has and will undoubtedly continue to decrease as more efficient wood-burning apparatuses are installed by those presently using fireplaces.

Considerable county-to-county differences are evident in the market demand for cordwood. The volume of wood purchased by residents in a county parallels the volume of wood burned and county population (tables 9 and 4).

Households installing stoves since 1973 have greater tendency to purchase their wood (table 10). Purchased wood accounted for 38 percent of the wood obtained by households during 1978 (tables 8 and 9). Fifty-three percent of homeowners cut all of their wood, 29 percent purchased all of their wood and 13 percent both purchased and cut. An additional 4 percent acquired no wood during 1978. This final group may represent families who burn wood acquired during previous years. During 1982, 44 percent (452,000 cords) of the wood obtained was purchased.

Table 8--Cordwood obtained for the winter of 1978-79, by household group, Massachusetts

Household groups	Volume cut by households	Volume purchased	Total acquired	Portion purchased	Average volume purchased
	-------Cords 1/--------			Percent	Cords
Owner occupants using fireplaces	140,100	112,600	252,700	44	1.2
Owner occupants using wood stove or furnace	362,100	200,900	563,000	35	3.1
Other households	65,700	37,700	103,400	36	1.8
Total	567,900	351,200	919,100	38	2.2

1/ rounded to nearest 100.

Table 9--Cordwood obtained by households, by county, winter, 1978-79, Massachusetts

County	Method of acquisition			Portion purchased
	Self-cut	Purchased	Total acquired	
	Cords 1/			Percent 2/
Barnstable	21,500	11,100	32,600	34
Berkshire	29,700	7,500	37,200	20
Bristol	45,300	28,300	73,600	38
Dukes	1,700	700	2,400	29
Essex	72,800	48,900	121,700	40
Franklin	21,900	9,300	31,200	30
Hampden	35,500	36,400	71,900	50
Hampshire	22,100	19,600	41,700	47
Middlesex	107,100	55,900	163,000	34
Nantucket	800	400	1,200	33
Norfolk	68,000	48,500	116,500	41
Plymouth	38,500	28,400	66,900	42
Suffolk	12,900	10,800	23,700	46
Worcester	90,100	45,400	135,500	33
Total	567,900	351,200	919,100	38

1/ Rounded to nearest 100.
2/ Percentages calculated from nonrounded data.

Table 10--Method of obtaining cordwood, by installation date, Massachusetts

Period of wood stove installation	All wood cut by household	Wood cut and purchased	All wood purchased
	Percent		
Before 1974	70	16	14
1974-76	58	13	29
1977-79	58	20	22

In most New England States the method by which wood is obtained relates to the volume burned by households. Residents using a particular apparatus typically burn less if all of their wood is purchased rather than harvested (table 11).

Table 11--Average volume of cordwood burned by apparatus and method of acquisition, winter, 1978-79, Massachusetts

Wood-burning group	All wood cut by household	Wood cut and purchased	All wood purchased
	----------Cords----------		
Owner-occupant using a fireplace	1.0	1.2	1.0
Owner-occupant using a traditional wood stove	3.0	3.0	2.5
Owner-occupant using an airtight wood stove	3.5	4.2	3.0
Owner-occupant using a central wood furnace	4.5	6.6	2.5

Characteristics of Purchased Cordwood

Purchased firewood comes in many forms: roundwood and splitwood of varying lengths, and slab and other forms of manufacturing waste. 3/ There are also a number of services (splitting, delivering, stacking) that may or may not accompany the purchase. Splitwood accounted for 56 percent of purchased wood in 1978 and 21 percent of all wood acquired. Roundwood accounted for 38 percent, while slabwood and manufacturing waste was 6 percent of purchased firewood (table 12).

3/ Roundwood refers to cordwood not processed by splitting lengthwise. In other reports, notably USDA Forest Service resource reports, roundwood refers to timber used in its original form as distinguished from industrial byproducts. Thus, the USDA Forest Service would use the term roundwood to describe this wood.

Table 12--Volume of firewood purchased, by form and length, 1978, Massachusetts

Category	Cords purchased	Proportion of purchased wood in category	Proportion of all acquired wood in category
	Cords 1/	-------Percent-------	
Roundwood	134,600	38	15
Greater than 4 ft.	25,100	7	3
4 ft.	74,800	21	8
Less than 4 ft.	34,700	10	4
Splitwood	194,500	56	21
Greater than 4 ft.	2,800	1	1
4 ft.	19,700	6	2
Less than 4 ft.	172,000	49	18
Manufacturing waste and slab	21,900	6	2
Total	351,000	100	38

1/ Rounded to nearest 100.

Household cordwood purchases in Maine and New Hampshire contain a higher than average percentage of unsplit wood in lengths of 4 feet or longer (table 13). Residents in these States also purchase a greater percentage of their wood. These characteristics may be the result of a more viable logging or pulping industry which can offer households home delivery of wood which can be processed by the purchaser.

Table 13--Characteristics of household firewood purchases, 1978, New England

State	Purchases split	Purchases hardwood	Purchases delivered	Purchases seasoned	Purchases made early
			Percent		
Maine	35	94	81	61	64
New Hampshire	47	92	90	64	72
Vermont	58	95	93	67	62
Massachusetts	56	92	82	82	49
Rhode Island	83	87	81	75	34
Connecticut	59	85	79	81	35

Cordwood price varies according to the number and kind of services provided. Major seller services are bucking, splitting, seasoning, delivering, and stacking. Price also varies with the size of the sale, time of year, price of conventional space heating fuel, and distance from major fuelwood harvesting operations. For example, one would expect to pay a significantly higher price for a cord of split hardwood, cut to 18-inch lengths, delivered and stacked in Boston in January than for a cord of 8-foot long roundwood delivered to a central Vermont household in July.

During 1978 and through the winter of 1978-79, a cord of wood cut to stove length, split, and delivered cost an average of $59 in Massachusetts. Split cordwood prices varied somewhat across the State: $48 in Berkshire county, $56 in Norfolk county, $75 in Middlesex county and $110 in Suffolk county. (fig. 5). The median price was $60 for the 39 New England counties reporting sufficient samples of split cordwood prices for 1978.

A more recent indication of cordwood prices is provided by a 1980-81 review of newspaper classified advertisements across New England. The price of a cord of seasoned hardwood -- cut to stove length, split, and delivered locally -- depended upon location and ranged from $70 to $125 a cord. The prices in Massachusetts ranged from $80 in Pittsfield to $125 in New Bedford. 4/

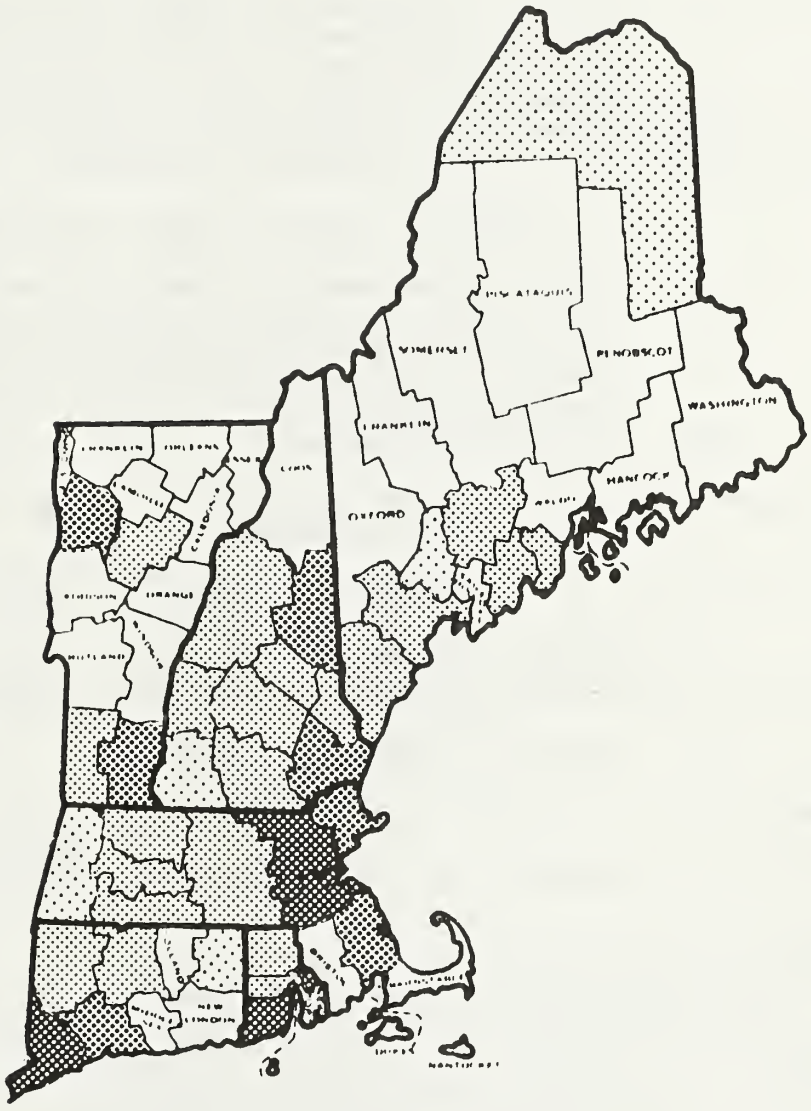
Harvesting Cordwood and Land Use Characteristics

Massachusetts families cut 568,000 cords of wood for their own use in preparation for the winter of 1978-79 (table 8). This volume represents 70 percent of the wood burned by residences. In order to assess potential impacts of this harvesting, it is first necessary to determine where these 568,000 cords were cut.

Survey information from across New England on the volume harvested, land ownership patterns, and the land use indicates the importance of the small woodlot attached to the residence. Cross-referencing the relationships of land use and land ownership in Massachusetts shows that 31 percent of the wood cut by families (table 16) and 19 percent of all the cordwood obtained (175,900 of 919,000 cords in 1978) were from woodlots smaller than 25 acres which were owned by the harvesting family rather than other private parties, the public, the forest industry, or a farming household (table 15). However,

4/ Information provided by the Northeast Solar Energy Center, Boston, Massachusetts, 1981.

Figure 5--Processed cordwood prices by county, 1978, New England
(Estimated from a 39-county sample of split cordwood prices)



the small, family-owned woodlot supplies a smaller than average portion of residential cordwood in Massachusetts when compared with all New England States (table 16). Additionally, an estimated 30 percent of all wood obtained by households in Massachusetts (table 14, col. 4) is harvested from the 13 percent of commercial forestland which is in small, individually owned woodlots (table 14, col. 5).

In terms of lot size and amount of wood burned, residents using a small woodlot to supply their cordwood cut and burn less wood than those utilizing larger woodlots. The average volume of wood which Massachusetts households harvested from private, largely residential woodlots smaller than 25 acres averaged 2.1 cords whereas harvesting on larger private woodlots averaged about 4.0 cords. This pattern is consistent throughout New England.

Table 14--Source of cordwood harvested by residents for their own use, by land use, 1978, Massachusetts

Category of land use	Volume of cordwood harvested	Portion of all household-cut wood	Average volume cut per household	Portion of all wood acquired	Portion of commercial forestland in category 1/
	Cords	Percent	Cords	----Percent----	
Small private (smaller than 25 acres)	274,000	48	2.1	30	2/ 13
Large private (25 acres or larger)	151,200	27	4.0	17	2/ 56
Farm woodlot	53,800	9	3.2	6	3/ 9
Public land	40,300	7	3.0	4	13
Forest industry	14,300	3	3.3	2	1
Other land use	34,300	6	3.7	3	8
Total	567,900	100	2.7	62	100

1/ See (4).
2/ See (5). Small private in (5) is defined as less than 20 acres; large private in (5) is defined as 20 or more acres.
3/ This category of commercial forestland includes all farmer-owned commercial forestland. Such forestland is not necessarily located on farms.

Table 15--Source of cordwood harvested by residents, by land use, 1978, New England

Land use	Maine	New Hampshire	Vermont	Massachusetts	Rhode Island	Connecticut
			Percent			
Small private (smaller than 25 acres)	53	49	33	48	74	64
Large private (25 acres or larger)	25	28	34	27	26	18
Farm woodlot	14	8	23	9	--	5
Public land	--	--	5	7	--	5
Forest industry land	4	6	3	3	--	--
Other	4	8	2	6	--	8
Total 1/	100	100	100	100	100	100

Note: -- = negligible amount.
1/ May not add to 100 because of rounding.

A series of questions in the fuelwood survey were designed to ascertain the degree to which household harvesting of cordwood is "threatening" commercial forestland in the State. 5/ During 1978, 62 percent of wood harvested by Massachusetts residents was cut from family-owned land and 17 percent was cut from a neighbor's land. In terms of land use, 75 percent of wood harvested by households was cut from privately owned, basically residential woodlots, and 48 percent was obtained from privately owned woodlots of 25 acres or less (table 14 and 15). Harvesting of fuelwood by households is concentrated on certain types of land. For example, of the 2,797,700 acres

5/ Commercial forestland is defined by the U.S. Forest Service as forestland producing or capable of producing a certain level of crops of industrial wood and not withdrawn from timber utilization. The definition excludes narrow strips of trees, trees in heavily settled areas, and trees in inaccessible areas.

Table 16--Cordwood harvesting by residents on small, family-owned woodlots, 1978, New England

State	Volume of wood cut on family-owned, private woodlots of less than 25 acres	Portion of wood harvested by households on family-owned, private woodlots of less than 25 acres	Portion of total cordwood burned
	Cords 1/	Percent	
Maine	125,400	42	22
New Hampshire	114,000	48	29
Vermont	53,700	25	16
Massachusetts	175,900	31	21
Rhode Island	33,700	49	31
Connecticut	345,600	58	51
Total	848,300	44	29

1/ Rounded to nearest 100.

of commercial forestland in the State, 2,432,300 acres, or 87 percent, is in private ownership, with 79 percent (1,918,300 acres) of this land privately owned by individuals (5). Eight-seven percent of these owners have commercial forestland holdings of 50 acres or less, which represents 33 percent of the total privately owned forestland that is producing or capable of producing a reasonable crop of wood.

In order to indicate the impact of household cordwood harvesting on the forest resource, the 1979 survey recorded the extent to which respondents utilized professional forestry assistance in marking for harvest. In Massachusetts, 23 percent of wood cut by residents was marked by a forester, the highest in New England (table 17). This suggests that the wood cut from these lots was of such a quality that it could not be used for timber products.

Table 17--Use of professional foresters to mark wood cut by residents for their own use, 1978, Massachusetts

Category of land use	Volume of wood cut by residents	Portion of wood marked by forester
	Cords 1/	Percent
Small private	274,000	12
Large private	151,200	19
Farm woodlot	53,800	13
Public land	40,300	83
Forest industry land	14,300	75
Other	34,300	44
Total	567,900	23

1/ Rounded to nearest 100.

However, between the two surveys there has been an apparent increase in the number of cords households cut (less than 15 percent in 1978 and 39 percent in 1981) that came from trees which were greater than 5 inches in diameter at breast height. As a result, the harvesting of this class of tree may indeed have longer term, more serious impacts upon timber product harvesters and their customers than presently experienced (6).

RELATED ISSUES

The transition to wood energy has produced major changes in forest resource use, conventional fuel imports, household income, local employment, and household safety. This section places findings of the survey within the context of available State-level data on these issues.

Economic Impact of Residential Wood Energy 6/

Massachusetts residents displaced $76 million of petroleum and $21 million of electricity during 1980 through the substitution of wood energy for conventional heat sources (based upon

6/ A more detailed analysis involving use of an input-output model will appear in a forthcoming report (see footnote 2).

home heating oil priced at $1.00 per gallon and electricity at $59 per 1,000 kWh in 1980).

The path of these savings through the local economy resulted in multiplied economic benefits, increasing local employment and household income.

Dollars not spent by households on imported fuel travel one of two paths through the State economy. Some of the dollars purchase cordwood. During 1978, 352,000 cords of wood were purchased by 220,000 Massachusetts residents. The average price per cord (reflecting purchases of all forms of wood) was $52. Conservatively increasing the volume of wood purchased and the average price per cord to reflect increases since the survey date, the value of cordwood purchases during 1980 is estimated to be at least $33 million. This was paid by residents to the wood processing and harvesting industry, which in turn spent a high percentage of its gross income on the employment of local labor. The value of cordwood purchases by Massachusetts residents represents less than 24 percent of all dollars saved through wood energy substitution.

Most remaining dollars saved by substituting wood heat effectively increase household buying power. Some are spent to purchase wood-burning stoves and wood-harvesting equipment. Most of the remaining $81 million were spent by residents for a broad spectrum of household purchases, from food, clothing, and durables to vacations. These expenditures benefit the local economy much more than expenditures for fuel oil. Dollars paid to a local fuel oil distributor are largely sent out of the State in exchange for refined petroleum. Dollars spent for locally produced goods or services are often respent locally by the person supplying those goods or services, multiplying the effect of the original purchase.

Changes in Conventional Energy Demand

Wood has emerged as a major source of energy for the residential sector, considerably lowering demand for fuel oil and electricity. Massachusetts residents use 27 percent of all energy consumed in the State whereas, nationally, only 21 percent of energy is consumed by residences.7/ This definition of the residential sector excludes gasoline used in automobiles. The U.S. Department of Energy estimates that Massachusetts households demanded 304 trillion Btu's during 1978, and that petroleum provided 58 percent of this. However, the Department of Energy does not collect or include data on residential wood energy consumption.

7/ Residential sector consumption estimates are based upon 1978 data from the State Energy Data Report, U.S. Dept. Energy, Energy Information Adm., Apr. 1980, p. 257, revised to correct overestimation of LPG.

Considered in the context of available Department of Energy data, wood energy constitutes 7 percent of the total energy demanded by Massachusetts residences, with petroleum providing 54 percent (table 18). The energy content of the wood

Table 18--Energy demanded by residences, by fuel type, 1979 Massachusetts

Energy form	Energy demanded 1/	Portion of all energy demanded
	Trillion Btu's	Percent
Petroleum	172.3	54
Natural gas	85.3	27
Electricity	37.2	12
Wood	24.3	7
Coal	.11	--
Total	319.2	100

Note: -- = negligible amount.

1/ Estimates of residential consumption of conventional fuels are based upon the State Energy Data Report, U.S. Dept. Energy, Energy Information Adm., Apr. 1980, p. 193. Estimates are revised to correct for overestimation of LPG consumption and to remove generation and transmission losses included only for electrical energy. Residential electrical consumption as tabulated by DOE includes an additional 94.1 trillion Btu's. Approximately 31 percent of the indicated wood energy in Massachusetts is burned in fireplaces and provides little useful energy.

demanded by Massachusetts households during the winter of 1978-79 is estimated at 24.3 trillion Btu's according to data provided by the 1979 Massachusetts fuelwood survey (table 19).

Wood burns at lower efficiencies than conventional fuels and therefore produces less useful energy per Btu of fuel. More efficient wood-burning devices would help households now using wood heat to consume less wood, but this would also encourage more households to convert to wood heat. The Massachusetts wood conversion rate of 0.37, which resulted from deriving 9 trillion Btu's of space heat from wood with a heat content of 24 trillion Btu's, is slightly lower than that obtained by residents of most States. This lower conversion rate is associated with the relatively high portion of wood being burned in relatively low-efficiency equipment. However, as the 1982 survey shows, wood consumption in fireplaces has decreased, and as a result, the conversion rate is now higher.

Table 19--Energy from wood combustion in residences, by household group, winter, 1978-1979, Massachusetts

Household group	Estimated volume of wood burned	Energy content of wood burned 1/	Wood-burning efficiency	Useful energy from wood	Equivalent fuel oil displaced 2/
	Cords	Trillion Btu's	Percent	Trillion Btu's	Mil. gals.
Owner-occupant	718,368	17.25		6.10	67.5
Using only fireplace	220,523	5.29	10	.53	5.8
Using open wood stove	100,238	2.41	30	.72	7.9
Using airtight wood stove	332,313	7.98	50	3.99	44.3
Using a wood furnace	65,294	1.57	55	.86	9.5
Rental-occupant burning wood	66,685	1.60	13	.21	2.3
Second and seasonal homes burning wood	30,323	.72	3/ 19	.14	1.6
Total	815,376	19.57	40	6.45	71.4

1/ Cordwood measures in Massachusetts are for 128 cubic feet of stacked wood and air which often is hardwood, cut to stove length and split. Such wood, well seasoned, can provide 24 million Btu's per cord on average.

2/ Energy is calculated at 138,700 Btu's per gallon or 5.825 million Btu's per barrel. Oil-burning efficiency assumed at 65 percent. The conventional fuel savings estimated by survey respondents is well above this estimate which is calculated upon the basis of volume of wood burned. This estimate does not include savings in conventional energy which are correlated with use of wood-burning equipment, such as lowered thermostat settings and zonal heating.

3/ Efficiency of wood combustion in second homes is calculated from the reported mix of wood-heating appliances.

Wood used in Massachusetts residences displaces an equivalent of 71 million gallons of fuel oil (table 19, col. 5). This figure reflects the volume of fuel oil which would have been displaced by the volume of wood burned if wood had been substituted only for fuel oil. While a portion of this displaced energy is provided by other conventional fuels, fuel oil is by far the most common conventional fuel used in Massachusetts residences (table 20).

Table 20--Conventional fuel available to homeowners for space heating, 1979, Massachusetts 1/

Fuel	Homeowners
	Percent
#2 fuel oil	69
Electricity	9
Natural gas	20
Propane	1
Kerosene	1
Total	2/ 100

1/ Calculated upon a sample base of 1683 homeowners.
2/ Households heating only with wood and which have no alternative fuel available in the dwelling account for 4.4 percent of homeowners.

Fuel oil and electricity represent the majority of the conventional energy being displaced by wood energy both because they are available to 78 percent of owner-occupant households and because they are relatively higher in cost per unit of energy.

The Massachusetts 1979 survey shows the heavy reliance on fuel oil and electricity as primary heating fuels by Massachusetts residents (table 20). This is a substantially larger proportion than primary fuel consumption in the Northeastern States (U.S. Department of Energy). 8/ In these States, the

8/ In addition to New England, States in this region include Maryland, Delaware, Pennsylvania, New York, and New Jersey.

primary fuels of fuel oil and kerosene supply 47 percent of dwellings. However, natural gas, which can be delivered at low cost by pipe to more densely settled areas, supplies 41 percent of households. Electricity supplies 11 percent and propane supplies 1 percent. This relationship explains why the residents of Massachusetts, on the average, substitute more wood energy for conventional fuels than the residents in the Northeast.

Cordwood Demand and the Forest Resource

The relationship between the forest resource and cordwood demand gives rise to two central questions:

1. Will the satisfaction of fuelwood demand lead to overharvesting or deterioration of the resource?

2. Will the supply of cordwood constrain the increasing use of cordwood as a substitute for conventional fuels?

Residents obtain cordwood both by purchasing and by selfcutting. Analysis must consider these two sources separately as well as their interaction. The wood supplied by residents harvesting for their use largely depends on privately owned small woodlots, which are usually a part of the residence. A considerable percentage of these woodlots are not large enough to provide all of the wood required by the household on a sustainable yield basis. As a result, after several years of harvesting trees considered excess stock, many residents may begin to purchase an increasing portion of their cordwood to prevent destruction of their woodlots.

A proportion of the cordwood marketed is sold by enterprises whose primary employment is in supplying either pulp or timber products. These enterprises are able to separate trees and sell them to the markets that represent the highest valued use for their product. These firms are competitive at current market prices. Integration of wood products within a harvesting operation makes cordwood production dependent upon the harvesting for other wood products since a smaller proportion of profit is derived from fuelwood. This relationship is limited to current price relationships.

Production efficiency is also limited by the size of woodlots. Small woodlots, which characterize most of New England, result in higher transportation costs of harvesting equipment to the site, and higher administrative costs to the harvester. Small woodlot owners are usually more concerned with environmental controls, which increases the cost of harvesting (5). Quality of most timber stands in the State is relatively poor. Much of the past timber harvesting resulted in highgrading, wherein the best trees were harvested and the poorest were left. Remaining trees became parent stock for much of the present tree populations and, as a result, present stands are of lower quality, which decreases production efficiency in terms of

annual growth. Cordwood use and the resulting market demand provide an opportunity to harvest this lower quality timber and could improve overall quality of remaining timber stands.

Transportation of cordwood also affects local supply. In areas which have a few large woodlots and a limited number of sawmills that use cordwood co-products, local residential demand raises cordwood prices and imported wood provides much of the supply. Cordwood is commonly transported up to 100 miles to reach higher priced markets. Many densely settled areas of New England that possess limited forest resources now burn more wood than the forests within the area can supply in the long term, given current management practices.

Cordwood in these areas of intense use will eventually be supplied from two sources: wood locally available on a sustainable basis and wood purchased from suppliers operating in a much larger market region.

Several broadbrush efforts have been made to estimate the potential supply of wood energy within the next 20 years. These estimates largely depend upon the area of land in forest and current forest conditions (table 21). An estimate of annual available biomass for Massachusetts was made by the Biomass Subcommittee of the New England Energy Congress (7). That estimate included a renewable yield (cull increment, annual mortality, annual thinning of poletimber stands, mill residues, and logging residues) and a nonrenewable yield (land clearing, existing cull, and one-time thinning) which would reduce the overstocked forests over 20 years. Estimate of total wood energy potential per year in Massachusetts is given

Table 21--Forestland use in New England

State	Commercial forestland	Productive reserved	Unproductive 1/	Proportion of land in forest
	1,000 acres			Percent
Connecticut	1,806	2/ 30	25	69.7
Maine	16,894	221	634	89.7
Massachusetts	2,798	104	50	58.9
New Hampshire	4,692	2/ 55	238	86.2
Rhode Island	395	9	--	60.2
Vermont	4,430	2/ 44	20	75.7
Total	31,015	463	967	80.5

Note: -- = negligible amount.
1/ Incapable of producing 20 cubic feet per acre per year of industrial wood (all roundwood products except fuelwood).
2/ Includes some acreage used for Christmas tree production.
Source: U.S. Forest Service resource bulletins NE-26, NE-36, NE-43, and NE-46.

by the final report of the New England Energy Congress as 73 x 10^{12} Btu's, which is an equivalent of 4 million cords per year (7). The committee also noted the present lack of an established supply network as the major limit to biomass supply. Another estimate of the annual energy potential that could be derived from Massachusetts' biomass was made by Glidden and High. This estimate which includes rough and rotten standing stock depleted over 20 years, annual cull increment, annual mortality, annual net growth, logging residues, and manufacturing residues amounted to 77 x 10^{12} Btu's (2).

The 1979 residential cordwood demand from within the State is estimated at 919,100 cords (acquired during 1979). Industrial wood energy demand is over 49,000 cords per year, largely supplied by mill residue and manufacturing wastes. Current export demand can be estimated as high as 50,000 cords per year, but this figure could increase considerably. These approximate figures suggest that Massachusetts' current wood energy demands are well below its current wood energy supply potential. However, this relationship must be evaluated relative to the rapid increase in use of wood energy and the availability of the potential supply.

Safety and Wood Energy

Resurgence of wood energy has resulted in an increased incidence of chimney and housefires. Wood-burning respondents indicated whether they had experienced a fire within the last 6 years and how the fire started. As a survey of all households, rather than a survey focused on households experiencing a hazardous event, the survey is useful in estimating the frequency of fires. Other surveys made by Shelton (10) and Peacock (9) have focused on those experiencing fires. These efforts provide a better sample for understanding causes of housefires related to use of stoves and furnaces fueled by wood.

Under 1 percent of Massachusetts households experience a housefire associated with the burning of firewood each year. Four percent of households burning wood (33 observations of 773 sample points) experienced a housefire associated with wood use during the 6-year period (1973 to 1979). For homeowners using an airtight wood stove, 6 percent (15 of 241) experienced such a fire during the same period. Most of the fires (19 of 30) started as a chimney fire. The frequency of housefires caused by burning wood in Massachusetts is typical of New England, just below the 5 percent of all New England wood-burning households that have experienced such a fire during the 6-year period.

Some 70 percent of those households using airtight wood stoves had installed a smoke detector; 56 percent of non-wood-burning households had installed them. The installation rate of

smoke detectors, together with the fact that only 10 percent of households using airtight stoves clean their chimneys less than once a year, suggest that this group of wood-burning households recognizes the increased safety problems associated with wood energy.

Over 70 percent of wood-or coal-related chimney or housefires result from faulty installation (10). Poor maintenance or inadequate clearance caused 16 percent of such fires, operator error caused 11 percent, and faulty equipment caused 2 percent. Peacock confirms faulty installation as the primary cause of fires, and lists nine major causes of accidents related to wood burning (9):

1. Use of unvented equipment inside a dwelling.
2. Installation of wood-burning equipment too close to combustible framing and furnishings.
3. Placement of flammable solids and liquids too close to wood-burning equipment.
4. Use of flammable liquids to kindle a fire.
5. Overloading of wood-burning equipment, leading to operation well beyond design limits.
6. Ignition of clothing or other fabrics during loading, unloading, cleaning, or use of wood-burning equipment.
7. Contact burns received from hot surfaces of wood-burning equipment.
8. Use of defective or improper chimneys.
9. Ignition of creosote and carbon deposits on the inside of chimneys leading to chimney fires.

Peacock reported that 94 percent of the accidents occur in one and two-family dwellings. About 55 percent of the accidents were related to the wood-burning unit itself, 35 percent resulted from malfunction of the chimney, and 10 percent resulted from the chimney connectors on freestanding stoves.

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NOTE ON SURVEY COMPARISONS

Comparisons of results between the ERS 1979 analyzed survey and the 1982 Research Group analyzed survey are limited primarily because of methodological differences and definitional differences. These differences are summarized below:

1. The 1982 survey did not incorporate survey bias checks. In this report, prior to making comparisons of volumes burned, the 1982 survey results were decreased 17 percent to reflect the bias factors identified in the 1979 ERS analyzed survey, and thereby make the survey results more comparable.

2. The sample size in the latter survey was 87 percent the size of the earlier survey.

3. No distinction was made between non-airtight and airtight wood stoves. With regard to volumes of wood burned all stoves in these classifications are called wood stoves. Categories of wood-burning apparatuses mentioned are fireplaces, modified fireplaces, wood stoves, and wood furnaces. The only instance in which they are referred to separately is during discussions of apparatus efficiencies.

4. There was a difference in apparatus efficiency factors. ERS estimates of efficiency factors for wood-burning equipment are considerably more conservative.

	ERS	Residential Fuelwood Study
open fireplace	5%	No estimate
efficient fireplace	15%	20%
open wood stove	30%	30%
airtight wood stove	50%	60%
wood furnace	55%	70%

APPENDIX I:
SURVEY METHODS 1/

Discussion of Survey Bias

Telephone surveys of Massachusetts households were conducted in 1979 as a means to estimate the volume of cordwood consumed by residences during the winter of 1978-79. Telephone surveys, like other types of surveys, have survey bias. Bias is the difference between the estimated value of a statistic obtained by random sampling and the true value. There are conditions giving rise to bias in any survey technique; the result may be an estimate (for example, volume of cordwood burned) that is much different than the true value (in this example, volume of cordwood actually burned). There are a number of survey biases associated with telephone surveys, as well as biases that result from "uncheckable" information During the design phase, eight potential forms of survey bias were identified, and where necessary, steps were developed to insure minimum influence by these biases. These sources of survey bias were:

1. Households without telephones could not be interviewed. Thus, there was no means to ascertain whether their wood-burning practices differed from those households interviewed.

2. Households with unlisted telephone numbers could not be selected for interview since published telephone lists were used as the surveyed population.

3. Hard-to-reach or not-at-home households may burn less wood since no one is at home during typical working hours.

4. Households that refuse to be interviewed create a possible source of bias.

5. Households that refuse to answer individual questions also create a possible source of bias.

6. The system through which volunteer enumerators were chosen in several States resulted in a potential source of bias in that one geographical area may have had a higher number of sample points and thus may have created an over-weighting of data from that area.

1/ A detailed description of methods will appear in a forthcoming report (see text footnote 2).

7. In some States, the wood use of rental households not paying separately for their own heating fuel was estimated with data from other States where this household group was interviewed.

8. A final form of bias is the under- or overestimation of actual cordwood volume reported by each respondent.

In order to insure precise estimates, steps were taken to first identify whether the potential source of bias was present and whether the bias would have a significant impact upon estimated statistics. Coefficients were developed to adjust the gross estimates derived from survey response in order to mitigate the bias impacts. Methods employed in developing the adjustment coefficients included subsurvey, resurvey, and stratification of response. The potential biases were analyzed as follows:

1. Households without telephones: This may be the least understood source of bias since the use of a telephone survey precludes the inclusion of this houshold group, and as a result, it is impossible to estimate the volume of fuelwood that this group consumes. However, given the fact that a very small percentage of households are without phones, that they tend to be located in rural areas, and that there is no evidence that this household group has something other than a random distribution of wood-burning characteristics, it was assumed that the bias resulting from not interviewing this group was minimal. Any bias stemming from this group would probably result in an insignificant underestimation of total cordwood consumption. Similarly, presence of households with more than one telephone may result in bias, but this group's wood use is expected to be similar or slightly less than that of the one-telephone household.

2. Households that have unlisted (unpublished) telephone numbers may constitute up to 10 percent of households. Generally, this group of households tends to be concentrated in urban areas and to be heavily female-headed. In order to estimate the potential amount of bias stemming from this group, a subsurvey was conducted in Maine to determine if this group was significantly different in their wood-burning characteristics. An

analysis of a "plus-one digit" dialing survey suggested little bias from this group. 2/

In addition, Clyde L. Rich, who has investigated this problem, notes:

> Because many of the differences are small and the non-published population is small, samples drawn from telephone directories have virtually the same demographic characteristics as samples which include non-published numbers. 3/

3. Hard-to-reach household bias was estimated by analyzing separately the data derived from households which responded on the third or later call. This analysis indicated that a significant bias was present. As a result, gross cordwood volume estimates were reduced by 9 percent.

4. Bias resulting from households that refused to participate in the survey was estimated by recalling them. On the recall, it was explained why they were being called back. Recalls were very effective in that very few of the households declined to answer the questions. Analysis of that data indicated that no bias was present.

5. Households that refused to answer specific questions contributed no bias in that their refusals were centered upon questions dealing with socioeconomic information (age and sex of head of household, household income, etc.) and not upon questions dealing with household wood-burning characteristics.

6. Through geographically stratifying survey estimates, bias resulting from an uneven distribution of sampled households was negated.

7. Except in Vermont, rental households who did not pay for their heat separately from their rental payment were not surveyed because:

   a. The vast majority are apartment dwellers with little opportunity to use wood.

2/ "Plus-one digit" dialing refers to a process where the last digit of a published number is increased by one, and then called.

3/ Clyde L. Rich, "Is Random Digit Dialing Really Necessary?" J. Marketing Research, Aug. 1977.

b. Unless heating costs are separated from the rental payment, such households have little economic incentive to convert to a nonconventional fuel.

The minimal wood use of this group was estimated for the other New England States through use of data from the Vermont survey.

8. Potential bias from faulty reporting of cordwood volumes was approached through a double survey which compared results of the standard questionnaire with one which contained an indepth discussion of the cord and other wood measures. That survey took place in the five counties surrounding Burlington, Vermont. An overestimation of 9 percent occurred. Thus, gross estimates less the adjustments for hard-to-reach households were reduced by an additional 9 percent. While it is certainly recognized that a ground-truth check would have been ideal, budget and time constraints precluded such an effort. 4/

Survey Sample Design

The six States had different spatial objectives relative to the survey. Massachusetts, for example, wished to estimate wood use on a county-by-county basis, whereas Rhode Island and Vermont wished to have data only on a Statewide basis. New Hampshire collected sufficient data to provide estimates for each of three regions of the State. All States collected data from enough sample points to permit a rigorous statistical assessment of residential wood use at the State level (App. table 1).

Telephone numbers were generated in such a way as to assign each household an equal probability of being surveyed. The selection procedure used telephone books to find noncommercial household telephone numbers in a randomly started, standardized manner. Selected numbers were pursued, within reason, according to a series of call-back rules until a survey was completed. If any number could not be surveyed, it was replaced with another number found by continuing the standardized procedure.

4/ Ground-truth check could be conducted as follows: A subsample of the sampled households is asked how many cords are presently in inventory. Then, the interviewer would travel to those households and actually measure the wood stacks to determine bias of household estimates.

Appendix table 1--Total sample collected, by State, 1979

State	Number of usable questionnaires
Maine	1,152
New Hampshire	813
Vermont	555
Massachusetts	2,359
Rhode Island	301
Connecticut	446
Total	5,626

Survey Precision in Massachusetts

Interviewing in Massachusetts to determine residential wood use during the winter of 1978-79 resulted in a sample of 2114 respondents (App. table 2). Stratification by tenure and county allowed use of census data to correct for sampling bias. Use of stratification precluded use of 245 responses which had not recorded all information required to stratify. Combination of survey and census data resulted in the estimate of households by type of wood-burning apparatus (App. II). Precision of this estimate is determined by the percentage of all respondents of a strata using a form of wood-burning apparatus and the sample for that strata.

Appendix table 2--Stratified sample of household respondents, Massachusetts, 1979

Group	Sample size
Second or seasonal home occupant not burning wood	26
Second or seasonal home occupant burning wood	17
Rental household with heat included not burning wood	27
Rental household with heat included burning wood	3
Rental household paying for heat separately not burning wood	334
Rental household paying for heat separately and burning wood	39
Owner-occupant household not burning wood	970
Owner-occupant household using only an open fireplace	254
Owner-occupant household using an efficient fireplace	61
Owner-occupant household using a traditional open wood stove	95
Owner-occupant household using an airtight wood stove	249
Owner-occupant household using a central wood-fired heating system	39
Total	2114

Reported consumption of cords by type of apparatus allows estimation of the residential use of wood based upon the above estimated household group populations (App. table 3). Reported volumes burned are corrected for identified faulty response bias associated with poor understanding of the cord measure. The resulting average volume burned by apparatus type has a precision or standard error related to the distribution of reported responses together with the sample size.

Appendix table 3--Precision of average volume burned by apparatus for owner-occupant households, winter, 1978-79, Massachusetts

Apparatus	Total respondents	Average volume burned per household	Standard error of average	Sample for average volume
	Number	--------Cords--------		Number
Open fireplace	254	0.96	.05	239
Efficient fireplace	61	1.57	.20	58
Traditional wood stove	95	2.83	.21	93
Airtight wood stove	249	3.35	.13	235
Wood furnace (combinations incl.)	39	4.56	.51	37

The resulting estimate of residential wood use has a level of precision or standard error which is a function of both the standard error of the percentage of households within a group and the standard error of the average volume burned by that group. The standard error for the Massachusetts Statewide estimate of cordwood use by residents during the winter of 1978-79 is 56,306 cords or 7 percent of the 815,376 cords burned (App. table 4).

Appendix table 4--Standard errors for estimates of fuelwood burned, Massachusetts, winter, 1978-79

Wood-burning group	SE Mass	Berkshire	Essex	Franklin	Hampden	Hampshire	Middlesex	Suffolk	Worcester	Standard errors for groups
					Cords					
Second home	7282	336	1092	184	202	160	158	0	603	7404
Rental with heat included	6770	586	2620	190	2002	456	5230	6550	2183	11503
Rental paying separately	1902	258	1486	133	1131	249	3669	2574	1777	5522
Owner-occupant using an open fireplace	13019	866	6063	398	4347	880	7928	2791	5339	18055
Owner-occupant using an efficient fireplace	9067	1457	4796	373	1826	879	1348	1273	4469	11618
Owner-occupant using a traditional wood stove	16629	1584	5823	1394	3616	2188	3610	1621	10127	21236
Owner-occupant using an airtight wood stove	32802	3533	17296	2062	8530	3070	11455	0	11965	41799
Owner-occupant using a central wood furnace	10540	1331	0	1104	5553	1186	0	0	12135	17135
Standard errors for counties	42635	4350	20077	2793	12010	4179	15804	7847	21207	56306

APPENDIX II: TABLES OF BASIC FINDINGS

The following tables present basic findings of the Massachusetts survey of residential wood use during the winter of 1978-79. Information on wood burned, purchased, and harvested by households is comparable to estimates to be published for all other New England States. Together, these estimates constitute an integrated estimate of residential wood use by county for New England.

The household groups used in appendix tables 5 and 6 are defined as follows:

Group 1 - Second or seasonal homes not burning wood
Group 2 - Second or seasonal homes burning wood
Group 3 - Rental household with heat included not burning wood
Group 4 - Rental household with heat included burning wood
Group 5 - Rental household paying for heat separately not burning wood
Group 6 - Rental household paying for heat separately and burning wood
Group 7 - Owner-occupant household not burning wood
Group 8 - Owner-occupant household using only an open fireplace
Group 9 - Owner-occupant household using an efficient fireplace
Group 10 - Owner-occupant household using a traditional wood stove
Group 11 - Owner-occupant household using an airtight wood stove
Group 12 - Owner-occupant household using a central wood furnace

The household groups used in appendix tables 7 and 8 are defined as follows:

Group 1 - Second or seasonal homes not burning wood
Group 2 - Second or seasonal homes burning wood
Group 3 - Rental household with heat included not burning wood
Group 4 - Rental household with heat included burning wood
Group 5 - Rental household paying for heat separately not burning wood
Group 6 - Rental household paying for heat separately and burning wood
Group 7 - Owner-occupant household not burning wood
Group 8 - Owner-occupant household using only a fireplace
Group 10 - Owner-occupant household using a wood stove or furnace

Appendix table 5--Number of households stratified by wood-burning category, apparatus, type, and county, Massachusetts, winter, 1978-79

	Barnsta	Berkshi	Bristol	Dukes	Essex	Frankli	Hampden	Hampshi	Middles	Nantuck	Norfolk	Plymout	Suffolk	Worcest	Total
Group 1	14520	1140	1345	1404	3700	622	684	542	535	740	0	6667	0	2044	33942
Group 2	9494	745	880	918	2419	407	447	354	350	484	0	4359	0	1336	22193
Group 3	5825	10144	47138	306	45315	3281	34627	7895	90470	190	42987	24655	113306	37769	459907
Group 4	448	780	3626	24	3486	252	2664	607	6959	15	3307	1589	8716	2905	35377
Group 5	2405	6155	19463	126	35689	2355	29210	5679	84671	78	17749	8528	65411	43958	321478
Group 6	108	684	871	6	3757	1178	811	947	12759	4	795	382	2929	3216	28445
Group 7	16632	20668	54268	926	73519	6513	61704	12398	175539	445	85368	50728	65152	81454	705314
Group 8	5300	2771	17294	295	21826	1063	13866	4576	81989	142	27205	16166	12692	14810	219995
Group 9	1097	1270	3578	61	11487	532	4160	1919	2102	29	5629	3345	846	2693	38747
Group 10	1645	1501	5367	92	5744	1794	2773	2066	8409	44	8443	5017	846	9424	53166
Group 11	3107	5773	10138	173	21826	3988	11093	6494	15767	83	15948	9477	0	18849	122715
Group 12	183	693	596	10	0	798	2080	443	0	5	938	557	0	9424	15727
Totals	60765	52323	164566	4339	228767	22782	164118	43920	479550	2258	208368	127470	269898	227882	2057007

Appendix table 6--Volume of wood burned by the residential sector, in cords, Massachusetts, winter, 1978-79

	Barnsta	Berkshi	Bristol	Dukes	Essex	Frankli	Hampden	Hampshi	Middles	Nantuck	Norfolk	Plymout	Suffolk	Worcest	Total
Group 2	12972	1018	1202	1254	3305	556	611	484	478	661	0	5956	0	1826	30323
Group 4	297	517	2402	16	2309	167	1765	402	4610	10	2191	1053	5774	1925	23437
Group 6	164	1040	1325	9	5712	1791	1234	1439	19398	5	1208	581	4453	4890	43248
Group 8	3801	3146	12402	212	20080	1235	16506	3698	58620	102	19510	11593	8281	16961	176148
Group 9	1362	3250	4445	76	8561	818	3300	2317	1741	36	6992	4155	1051	6272	44375
Group 10	2452	4247	8000	136	10464	5711	5454	6253	7590	66	12585	7478	1261	28540	100238
Group 11	8082	19281	26370	450	58180	14800	27227	19473	38674	216	41482	24649	0	53428	332313
Group 12	759	2876	2476	42	0	3311	8635	1838	0	20	3895	2314	0	39127	65294
Totals	29889	35375	58622	2194	108612	28388	64731	35905	131112	1116	87862	57779	20820	152970	815376

Appendix table 7--Volume of wood purchased by the residential sector, in cords, Massachusetts, winter, 1978-79

	Barnsta	Berkshi	Bristol	Dukes	Essex	Frankli	Hampden	Hampshi	Middles	Nantuck	Norfolk	Plymout	Suffolk	Worcest	Total
Group 2	2162	170	200	209	551	93	102	81	80	110	0	993	0	304	5054
Group 4	186	323	1501	10	1443	104	1103	251	2881	6	1369	658	3609	1203	14648
Group 6	68	431	550	4	2370	743	512	597	8048	2	501	241	1848	2029	17944
Group 8	3500	2409	9136	190	12069	1106	12786	2842	26991	92	19960	10675	4414	6457	112628
Group 10	5193	4173	16945	289	32465	7268	21892	15874	17875	139	26656	15839	890	35428	200925
Totals	11109	7506	28332	702	48898	9314	36394	19645	55876	349	48486	28406	10761	45421	351199

Appendix table 8--Volume of wood harvested by households for own use, in cords, Massachusetts, winter, 1978-79

	Barnsta	Berkshi	Bristol	Dukes	Essex	Frankli	Hampden	Hampshi	Middles	Nantuck	Norfolk	Plymout	Suffolk	Worcest	Total
Group 2	9629	756	892	931	2454	412	453	359	355	491	0	4421	0	1355	22509
Group 4	186	323	1501	10	1443	104	1103	251	2881	6	1369	658	3609	1203	14648
Group 6	108	686	874	6	3768	1181	814	949	12796	4	797	383	2937	3226	28528
Group 8	2220	5010	11590	191	22162	1292	7462	3199	41566	92	17907	4514	6087	16782	140076
Group 10	9345	22957	30491	520	42950	18915	25713	17307	49463	250	47964	28501	259	67517	362151
Totals	21488	29731	45348	1658	72776	21905	35545	22066	107061	842	68037	38478	12893	90083	567912

* U.S. GOVERNMENT PRINTING OFFICE: 1982-380-930: ERS-1262