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Wood and Energy in New Hampshire

Mark R. Bailey
Paul R. Wheeling



WOOD AND ENERGY
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ABSTRACT



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.

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

This paper was prepared for limited distribution to the research community outside the U.S. Department of Agriculture.

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 New Hampshire is the second 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 (6), 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, and State energy offices.

Wood and Energy in New Hampshire presents information on residential use of wood energy obtained from two household surveys. The first survey, conducted in 1979, obtained detailed information from more than 800 households. The second, or followup survey of 200 households, conducted a year later, provided estimates of fuelwood use in 1979-80 and more information on likely impacts of the increase in residential demand for wood energy on the State forest resource base (fuelwood is used interchangeably with firewood and cordwood in this report). The New Hampshire surveys confirm that a broadly based transition to cordwood use has occurred in household heating. This energy shift has significantly changed the use of conventional energy and added to demands placed upon forests.

The New Hampshire Governor's Council on Energy sponsored and conducted the 1979 and 1980 surveys using the methodology and questionnaire jointly developed by ERS, representatives from participating RC&D areas, and various State energy offices. The RC&D areas in Maine, Massachusetts, Connecticut, and Rhode Island sponsored the surveys in their States; the Vermont Energy Office conducted the surveys in Vermont.

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 seven 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 authors acknowledge a number of people and organizations that made significant contributions to the New Hampshire report. Jamie Dammann, formerly wood energy officer of the New Hampshire Governor's Council on Energy, made major contributions to this study. The Governor's Council on Energy was responsible for collecting the original data and distributing study results within New Hampshire. David Brooks, formerly of the Governor's Council on Energy and now a doctoral student at Oregon University, and David Cross initiated the survey effort in New Hampshire. Maria Lenz, an ERS economic and statistical assistant, computed many results presented in this report.

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: Ted Cady, John Wenderoth, Cliff Jones, Sheryl Davies, Beth Green, Charles Taylor-Brown, Daniel Vining, Francis Holt, Roy M. Gray, Donald F. Jones, Kay Wilhelm, Helene Blank, Frances McDevitt, Joseph Barse, William Crosswhite, Dwight Gadsby, Anthony Grano, John Hostetler, Melvin Cotner, Velmar Davis, James Sayre, Debra Ritter, Robert McKusick, Carolyn Harper, Jerry Jolly, and Robert Francis.

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HIGHLIGHTS

Most New Hampshire 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:

- * Fifty percent of owner-occupant households in New Hampshire use wood-burning stoves or central wood-fired heating systems.
- * Ten percent of owner-occupant households installed their first wood-heating apparatus in 1979, contributing to a 28-percent increase in residential wood use.
- * Homeowners who use airtight wood stoves burn an average of 4.6 cords per household during a winter and estimate that they derive 68 percent of space heat from wood.
- * Almost 504,000 cords of wood were burned by New Hampshire households during the winter of 1979-80.
- * Purchased wood supplied 47 percent of the cordwood obtained for the winter of 1979-80. Although a majority of cords were cut by household residents for their use, 55 percent of wood-burning residents purchased some portion of their wood.
- * Splitwood constituted 47 percent of cords purchased. Ninety-two percent of cords purchased were hardwood; 90 percent were delivered.
- * Wood supplied 22 percent of all energy demanded by New Hampshire residences. This energy was converted into nearly 5 trillion Btu's of residential space heat.
- * Residents relying upon fuel oil or electricity for their home heating fuel are more likely to have installed wood-heating equipment than those who have access to natural gas, a less expensive fuel.
- * By substituting wood, New Hampshire household residents are displacing \$39 million in petroleum and \$27 million in electricity. Residents spent approximately \$18 million of these savings on the purchase of cordwood.
- * Each year, almost 1 percent of households that heat with wood experience house fires directly related to the use of wood.

Wood and Energy in New Hampshire

Mark R. Bailey
Paul R. Wheeling

INTRODUCTION

Since the 1973-74 oil embargo, New Hampshire 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 504,000 cords of wood by New Hampshire households during the winter of 1979-80. Increased fuelwood consumption is resulting in larger demands upon the forest resource, displacement in fuel oil and electricity, and an increase of energy dollars spent in local economies.

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

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 (2). (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 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

Bailey, an ERS agricultural economist, is the New England Fuelwood Study leader. Wheeling, an ERS community planner, is the deputy leader of the study.

TRANSITION TO CORDWOOD USE IN NEW HAMPSHIRE

embargo. Petroleum accounts for over 75 percent of the energy used in New England, and over 75 percent of the petroleum consumed is imported. Petroleum accounts for 70 to 80 percent of the energy consumed in New Hampshire and between 60 to 70 percent of conventional energy demanded by residences. Heating requirements of a New Hampshire household are 159 percent of the national average. As a result, New Hampshire 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.

Use of wood heat in New Hampshire in 1970 was well above the national average which was less than 1 percent of homeowners (6). Still, only about 5 percent of the State's homeowners used wood-heating appliances, and much less heat was provided per wood-burning stove. 1/ During the 1979-80 winter, 50 percent of New Hampshire's homeowners used wood-fired heating equipment, up 9 percent from the previous year.

Trends in Residential Wood Use

Total numbers of wood stoves and wood-burning furnaces installed in New Hampshire in 1976, 1977, 1978, and 1979 were 20,000, 21,000, 22,000, and 26,000, respectively. These installations overstate the transition to wood heat because some replaced or upgraded previously existing wood-burning equipment.

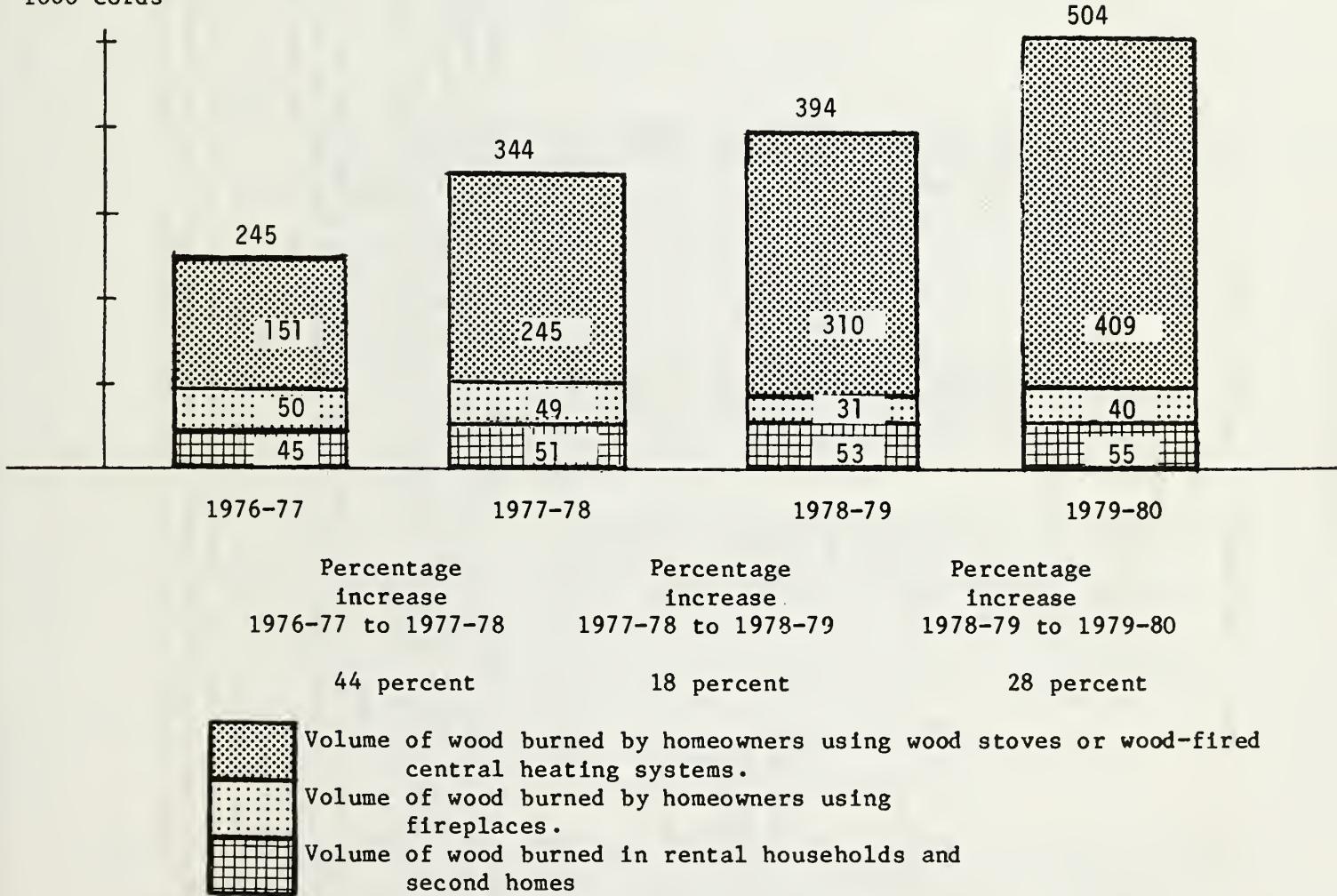
Estimates of the volume of wood burned in residences during the winters of 1976-77 through 1978-79 were developed from the 1979 New Hampshire fuelwood survey. Trends in residential wood use -- the fuelwood volume differences between the surveyed winter and the previous winters -- is based primarily upon when wood-burning equipment was installed and the type of equipment, if any, used prior to that date. The 1980 resurvey permitted a more refined estimate of the wood-burning trend by surveying the wood use of homeowners in the winter following the original survey and by incorporating the preliminary estimate of the 1980 census to reflect the increasing number of households. The annual increase in residential wood use has averaged 30 percent over the four-winter period from 1976-77 to 1979-80 (fig. 1). Of the 673 owner-occupant households responding to questions in the initial survey, 39 percent used a wood stove during the winter of 1978-79. The majority of these households used a wood stove during the previous winter (31 percent of all owner-occupant households), while 3.1 percent changed from fireplace to stove use, and 4.6 percent changed from not burning wood to stove use. Approximately 5

1/ The 1970 figure of 5 percent was derived by extrapolating data back in time.

percent of homeowners used a central wood furnace during the winter of 1978-79, continuing previous use. Finally about 4.8 percent of all owner-occupant households discontinued wood use during 1978. Overall, owner-occupant households using only fireplaces declined from 19 percent to 5 percent during 1978.

Figure 1--Trend in residential wood use, four winters, 1976-1980, New Hampshire

1000 cords



The increase in wood use during 1979 is largely due to the net increase of 21,000 owner-occupant households using wood-burning stoves and central wood-fired heating systems (table 1). This change increased the percentage of homeowners using wood-fired heating equipment from 41 during the winter of

Table 1—Changes in New Hampshire residential wood use during 1979, by household groups

| Household group 1/ | Households 2/ in wood use groups | | Household change 4/ in equip. use during 1979 | | Volume of wood burned Winter 3/ 1978-79 | | Change in volume of wood burned relative to 1978-79 | |
|-------------------------------|-------------------------------------|-----------|---|---------|--|---------|--|--|
| | Jan. 1979 | Jan. 1980 | Number | Number | Winter 3/ 1979-80 | 1979-80 | Percent | |
| Owner-occupant | | | | | | | | |
| Not burning wood | 205,003 | 210,692 | 5,689 | 340,992 | 449,061 | 32 | | |
| Using only fireplace | 96,074 | 77,959 | -18,118 | -- | -- | -- | | |
| Using open wood stove | 24,200 | 27,390 | 3,190 | 30,827 | 40,226 | 30 | | |
| Using airtight wood stove | 21,648 | 25,283 | 3,635 | 65,055 | 76,201 | 17 | | |
| Using a wood furnace | 51,951 | 72,689 | 20,783 | 197,983 | 301,430 | 52 | | |
| 11,130 | 7,374 | 7,3756 | -3,756 | 47,127 | 31,204 | -34 | | |
| Rental-occupant | | | | | | | | |
| Paying for heat, not burning | 94,996 | 97,605 | 2,609 | 24,636 | 25,313 | 3 | | |
| Paying for heat, burning wood | 45,192 | 46,433 | 1,241 | -- | -- | -- | | |
| Heat included, not burning | 12,912 | 13,267 | 355 | 22,454 | 23,071 | 3 | | |
| Heat included, burning wood | 35,047 | 36,010 | 963 | -- | -- | -- | | |
| Second and seasonal homes | | | | | | | | |
| Not burning wood | 1,845 | 1,895 | 50 | 2,182 | 2,242 | 3 | | |
| Burning wood | | | | | | | | |
| Total | 322,162 | 341,422 | 9,260 | 394,304 | 503,908 | 28 | | |

Note: -- = not applicable

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 different telephone answering rates.

2/ Estimates of the number of dwelling units owner-occupant and rental-occupant are derived from the preliminary report of all housing units of the 1980 census and tenure reported by the 1970 census. Members of the tenure classes are termed households for convenience.

3/ Estimates of the volume of wood burned are reduced 17 percent from volume reported by respondents to correct 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.

4/ The year-to-year difference in the number of households (and volume of wood burned) within a particular sub-group of owner-occupant households is subject to survey variance which may be large relative to the annual change. This survey difference is evident for owner-occupant households using a wood-burning furnace. For this relatively small group, reasonable survey variance indicates that the number of households may have remained constant or grown slightly during 1979, as is expected. Survey variance has relatively less effect on difference between year-to-year group totals.

1978-79 to 50 during the winter of 1979-80. Of those homeowners installing an airtight wood stove, 82 percent were using a wood-burning stove for the first time, 6 percent had previously used a traditional wood-burning stove, and 12 percent had been using a different airtight wood stove.

Net change in wood burned is calculated from the following:

1. Change in type of wood-burning apparatus used.
2. Change in average volume of wood burned per apparatus.
3. Change in number of households.

The New Hampshire surveys, as well as the other New England State surveys, give no indication that the increase in wood use will not continue, especially if the relative costs of conventional fuels continue to rise. Further, the surveys do not record the recent increase in wood use which is expected in response to the 1981 petroleum price decontrol and subsequent rises in fuel oil prices. 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 New Hampshire 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 New Hampshire 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 40 percent more wood per year and more than double wood supplied heat. New Hampshire households are consequently experiencing greater displacements of fuel oil and electricity, as well as larger savings in heating costs.

Table 2--Proportion of various wood-burning apparatuses installed in New Hampshire

| Period installed | Open wood stove | Airtight stove | Wood furnace |
|------------------|--------------------|-------------------|-----------------|
| <u>Percent</u> | | | |
| Before 1974 | 54 | 24 | 22 |
| 1974-76 | 26 | 66 | 8 |
| 1977-79 | 24 | 66 | 10 |
| : | | | |

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, 46 percent of the New Hampshire homeowners using fuel oil as a conventional fuel also

use wood heat, as compared to 19 percent of those using natural gas (the least expensive source of energy).

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. At the same time, 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 and approach that of conventional energy. Then, 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 households 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.

Excess Demand on the Forest Resource

Residential long-term fuelwood demand on the forest resource in New Hampshire is but a small fraction of the State's renewable resource base. Although there are New England areas utilizing wood at levels above sustainable yield, shortages have not occurred there because of large standing stocks and importation of cordwood. New Hampshire, like Vermont, exports cordwood to more densely settled areas.

All current demand (residential and industrial energy, cordwood exports, pulp, timber products, recreation, and wildlife) is being met. There are concerns, however, that as the demand for cordwood increases, cordwood and stumpage prices and the potential for overcutting may rise.

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 New Hampshire, 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.

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

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

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

Home Insurance Policy Premiums

The increasing use of fuelwood has resulted in more house fires. While the majority of house fires 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 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 contemplating 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 stumps are given away.

WOOD CONSUMPTION AND ENERGY CONSERVATION BY NEW HAMPSHIRE HOUSEHOLDS

New Hampshire 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

New Hampshire families burned 504,000 cords of fuelwood during the 1979-80 winter (table 1). Thirty-five percent of all households and 50 percent of homeowners used a wood-burning stove or central wood-fired heating system. Thirty-two percent of homeowners reported wood as the fuel which "provides the most heat" for their residence. Recent increases in residential wood use have averaged roughly 30 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

Patterns of Cordwood Use

information on the economic impacts of wood energy substitution appears in a forthcoming report. 2/

Impact of Wood-Burning Equipment on 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. 2).

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 105,000 New Hampshire homeowners using wood-burning appliances in 1979, 7,000 used central wood-burning furnaces, 73,000 used airtight wood stoves, and 25,000 used open wood stoves. Almost two-thirds of the wood consumed by households in New Hampshire was burned in airtight wood stoves.

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. 3 and table 5). Households using airtight wood stoves burn an average of 4.6 cords of wood during the 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 New Hampshire provide an average of 55 million Btu's of available space heat per household during a winter, assuming a 50 percent efficiency. Such a stove could provide half of the heating requirements of a home requiring 90 to 100 million Btu's of space heat per year. New Hampshire homeowners, however, estimate that their airtight wood stoves provide up to 68 percent of space-heating needs.

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.

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

Figure 2--Intensity of residential demand for fuelwood, 1978-79, New England

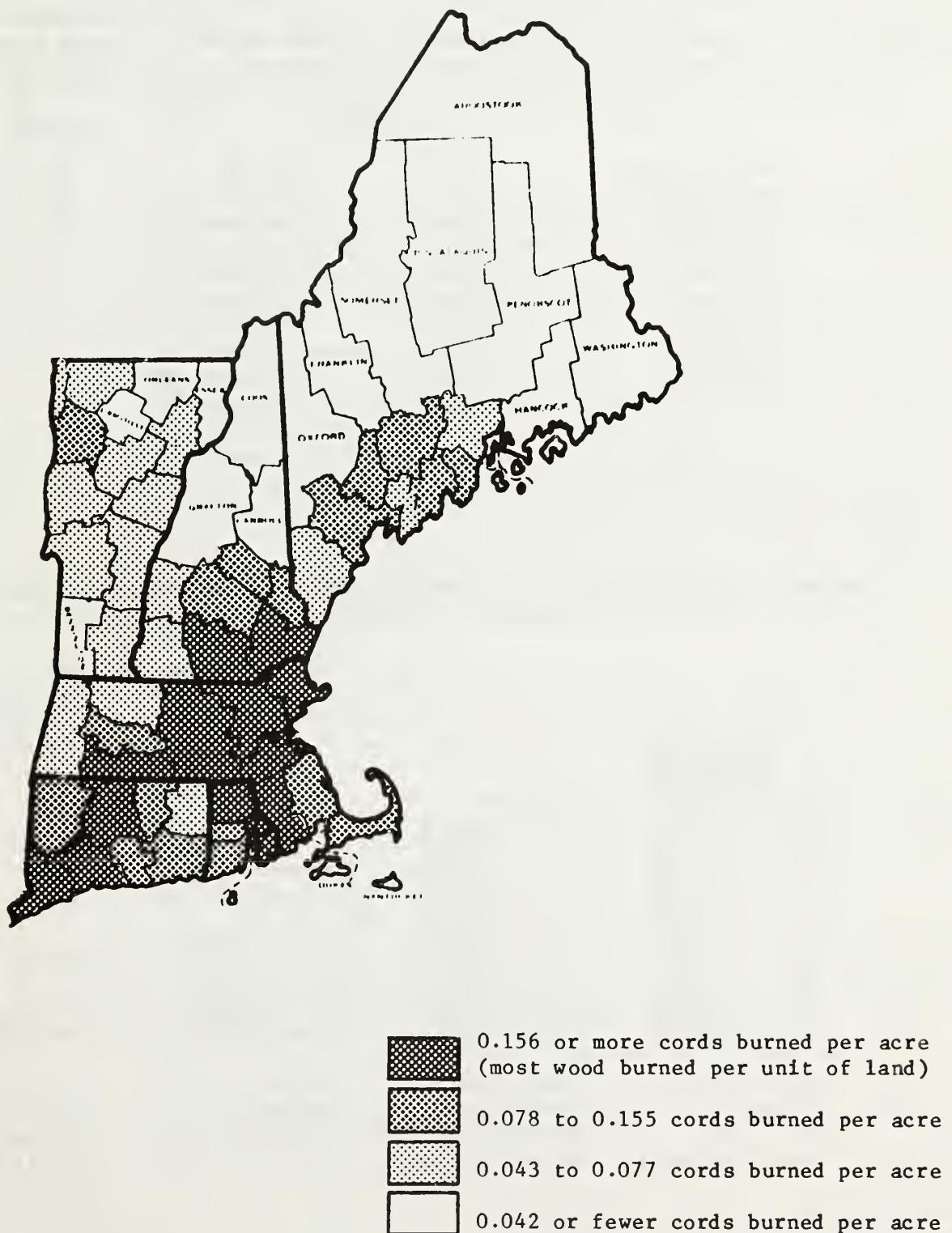
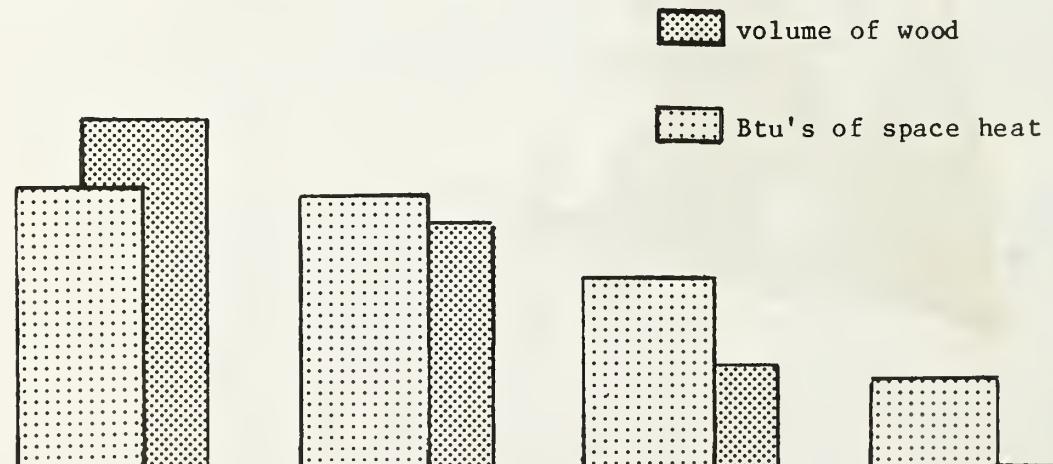


Table 4--Volume of cordwood burned in New Hampshire households, by county

| County | Volume burned | Volume burned | Percentage of State total |
|-------------------|---------------|---------------|---------------------------|
| | 1978-79 | 1979-80 | 1979-80 |
| : -----Cords----- | | | |
| <u>Percent</u> | | | |
| Hillsborough | 97,541 | 135,090 | 27 |
| Rockingham | 78,987 | 103,780 | 21 |
| Merrimack | 46,265 | 55,554 | 11 |
| Strafford | 25,157 | 43,242 | 9 |
| Grafton | 34,427 | 39,565 | 8 |
| Cheshire | 27,060 | 35,242 | 7 |
| Belknap | 23,767 | 27,153 | 5 |
| Carroll | 23,844 | 22,147 | 4 |
| Sullivan | 17,761 | 21,735 | 4 |
| Coos | 19,496 | 20,401 | 4 |
| Total | 349,305 | 503,908 | 100 |
| : | | | |

Figure 3--Average volume of cordwood burned and available heat per household, by type of apparatus used, winter, 1979-80, New Hampshire



Wood-burning
furnace
4.7 cords
77 million Btu's

Airtight
wood stove
4.6 cords
55 million Btu's

Open
wood stove
3.3 cords
25 million Btu's

Fireplace
1.7 cords
4 million Btu's

During the 1978-79 winter, households using airtight stoves reported 53 to 68 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 figure is derived from the respondents' estimates of the percentage of heat supplied by wood. In contrast to other households, owner-occupant households derive a slightly higher percentage of space heat from the same apparatus type.

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 New Hampshire. 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.

Cost Relationships of Conventional and Wood Energy

The 1980 New Hampshire survey recorded both primary and secondary heating fuels in order to identify the relative cost relationship between heat supplied by wood and by the conventional fuel of a household. Information on relative cost served as a base in analyzing the household decision to use wood heat. The price differential between purchased wood and fuel oil in New Hampshire resulted in heat provided by fuel oil costing 113 percent of that provided by wood in 1978 and costing 194 percent of heat provided by wood in 1981 (table 6). Households using the more expensive energy sources, electricity and fuel oil, have a greater tendency to install wood-burning equipment than households using the least expensive energy source, natural gas. Forty-six percent of homeowners using fuel oil and 75 percent of homeowners using electricity for heating have installed wood-fired heating equipment. Only 19 percent of homeowners who use the relatively less expensive natural gas have installed a wood stove or wood-fired heating system.

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

| Apparatus | Cords | Btu x 10 ⁶ | Dollars | Percent | Degrees | Percent |
|------------------------------------|-------|-----------------------|---------|---------|---------|---------|
| Open fireplace | 1.6 | 2 | 154 | 16-17 | 66 | 5 |
| Efficient fireplace | 1.7 | 6 | 127 | 16-20 | 67 | 15 |
| Traditional wood stove | 3.3 | 23 | 282 | 31-52 | 64 | 30 |
| Airtight wood stove | 4.6 | 55 | 367 | 53-68 | 63 | 50 |
| Wood furnace: (combinations incl): | 4.7 | 62 | 425 | 53-78 | 64 | 55 |
| | | | | | | |

1/ Available Btu's estimated at 24×10^6 (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 based upon findings of the resurvey covering the winter of 1979-80.

Table 6—Relative cost of alternative heating fuels, 1978 to 1981, New Hampshire

| Energy source and burner | Applicable unit | Cost/unit : 1978 : 1981 | Typical | | | Cost/million Btu's : 1978 : 1981 | Relative cost per mil. Btu's 1/ : 1978 : 1981 |
|--------------------------|-----------------|-------------------------|-----------------|-----------------------------|------------------|----------------------------------|---|
| | | | Energy per unit | burner : efficiency: factor | Available energy | | |
| Wood, airtight stove | cord | 59 | 4/85 | 2/ 24 | 50 | 12.0 | 4.92 7.08 |
| Central system | cord | 59 | 4/85 | 2/ 24 | 55 | 13.2 | 4.47 6.44 |
| Electricity, Resistance | kWh | 3/.0546 | 5/.06718 | 0.0034 | 100 | 0.0034 | 16.00 19.69 |
| Natural gas Furnace | 1000 cu.ft. | 3/3.57 | 5/5.59 | 1.04 | 70 | .728 | 4.90 7.68 |
| LP gas Furnace | gallon | 3/.349 | N/A | .0955 | 70 | .0669 | 5.22 N/A |
| #2 fuel oil Furnace | gallon | 3/.501 | 4/1.26 | .1387 | 65 | .0902 | 5.56 13.76 |

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 New Hampshire Governor's Council on Energy.

5/ Price averages for 1980 provided by the New Hampshire Governor's Council on Energy. Estimates for 1981 not available.

Use of Energy Conservation Measures

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.

New Hampshire 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 17 percent of New Hampshire homeowners improved their insulation each year.

Lowered thermostat settings are more likely to be found in those homes using wood heat. 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 (table 6). These lower settings save an additional 10 to 15 percent savings 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. The relationship between use of wood-heating apparatuses and individual energy conservation improvements is not as well defined in New Hampshire as in other New England states where households not burning wood or burning wood only in an open fireplace are consistently less likely to make an energy conservation improvement (table 7).

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

| Apparatus | Making | | Installing | | Caulking | |
|--|------------|-------|------------|--------|-----------|------|
| | insulation | storm | or weather | Sample | stripping | size |
| | Percent | | | | Number | |
| Owner-occupant household not burning wood | 54 | 35 | | N/A | 226 | |
| Owner-occupant household using an open fireplace | 45 | 33 | | 25 | 51 | |
| Owner-occupant household using an efficient fireplace | 67 | 30 | | 33 | 27 | |
| Owner-occupant household using a traditional wood stove: | | | | | | |
| Owner-occupant household using an airtight wood stove | 51 | 34 | | 35 | 86 | |
| Owner-occupant household using a central wood furnace | 47 | 33 | | 26 | 175 | |
| All homeowners | 58 | 31 | | 25 | 36 | |
| | 51 | 33 | | 28 | 601 | |

Note: N/A = not available.

OBTAINING CORDWOOD IN NEW HAMPSHIRE

New Hampshire households obtain cordwood through purchase and/or household harvesting of wood. While wood-burning residents cut more wood than they purchased, more than 53 percent of them purchased at least some of their cordwood. Market demand for cordwood is directly related to density of population, density of owner-occupant households, and density of households with airtight stoves. Almost half of the cordwood marketed in New Hampshire is sold as splitwood.

Seller services such as bucking, splitting, delivering, and stacking all influence cordwood price. Market demand for purchased cordwood will likely increase due to both an increase in the number of households using wood-fired heating equipment and an increase in the percentage of cordwood purchased.

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. Harvesting by residents does not seem to be directed at improving the quality of their woodlots since only a very small proportion of such operations received guidance from professional foresters. 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 by Households

New Hampshire residents purchased 239,000 cords and cut 265,000 cords of wood for their own use during 1979 (table 8). For the previous winter, they purchased 189,000 cords and cut 238,000 (table 9). During 1979, owner-occupants using a wood-burning stove or central wood-fired heating system obtained 79 and 83 percent of the wood purchased and cut, respectively, even though they constituted only 34 percent of all households. Homeowners using airtight wood stoves purchased 153,000 cords during 1979, constituting the largest market group. Although wood burners using only fireplaces purchase a higher percentage of their wood than those using wood stoves, the total volume of fireplace wood is a relatively insignificant portion of marketed fuelwood.

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 10 and 4).

While estimated volume of wood burned is comparable between the two surveys, volumes of wood purchased and cut by residents are not precisely comparable, due to differences in survey methods. The 1979 survey separately recorded volume of wood burned, purchased, and cut by respondent's household.

Table 8--Cordwood obtained for the winter of 1979-80, by household group,
New Hampshire

| Household group | Volume cut | Volume purchased | Portion purchased |
|---------------------------|------------|------------------|-------------------|
| -----Cords----- | | | |
| <u>Percent</u> | | | |
| Owner-occupant | 238,463 | 210,598 | 47 |
| Using only fireplace | 18,429 | 21,797 | 54 |
| Using open wood stove | 48,678 | 27,523 | 36 |
| Using airtight wood stove | 148,401 | 153,029 | 51 |
| Using a wood furnace | 22,955 | 8,249 | 26 |
| Rental-occupant | 8,363 | 16,950 | 67 |
| Second and seasonal homes | 18,206 | 11,328 | 38 |
| Total | 265,032 | 238,876 | 47 |
| : | | | |

Table 9--Cordwood obtained for the winter of 1978-79, by household group,
New Hampshire

| Household group | Volume cut | Volume purchased | Total acquired | Portion purchased | Average volume purchased |
|--|------------|------------------|----------------|-------------------|--------------------------|
| -----Cords 1/----- | | | | | |
| <u>Percent</u> <u>Cords</u> | | | | | |
| Owner-occupant using fireplaces | 13,900 | 18,600 | 32,500 | 57 | 1.4 |
| Owner-occupant using wood stove or furnace | 194,100 | 135,800 | 329,900 | 41 | 4.2 |
| Other households burning wood | 29,600 | 34,500 | 64,100 | 54 | 1.9 |
| Total | 237,600 | 188,900 | 426,500 | 44 | 3.3 |
| : | | | | | |

1/ rounded to nearest 100.

The less detailed resurvey recorded volume of wood burned and percentage of that wood purchased. New Hampshire households obtained 8 percent more wood during 1978 than was burned during the winter of 1978-79. Similarly, more than the 504,000 cords of wood burned may have been obtained for the winter of 1979-80, but this was not determined. Volume of wood obtained is expected to be greater than the volume burned if this difference is largely due to the installation of new wood-burning stoves. Families who install wood-fired heating equipment have a tendency to build up a large inventory to carry over into following winters. This is especially true for families who purchase green wood for seasoning. The wood remaining after the burning season also results from warmer than normal winters, and as a hedge against uncertainty in conventional energy supplies.

Table 10--Cordwood obtained by households, by county, winter, 1978-79, New Hampshire

| County | Method of acquisition | | | Portion purchased 1/ |
|--------------|-----------------------|-----------|----------------|----------------------|
| | Self-cut | Purchased | Total acquired | |
| : | -----Cords 2/----- | | | Percent |
| Belknap | 11,000 | 15,400 | 26,400 | 58 |
| Carroll | 19,700 | 10,400 | 30,100 | 34 |
| Cheshire | 23,900 | 8,900 | 32,800 | 27 |
| Coos | 14,000 | 11,600 | 25,600 | 45 |
| Grafton | 20,400 | 24,900 | 45,300 | 55 |
| Hillsborough | 55,300 | 28,400 | 83,700 | 34 |
| Merrimack | 25,800 | 29,100 | 54,900 | 53 |
| Rockingham | 44,700 | 39,000 | 83,700 | 47 |
| Strafford | 8,800 | 12,700 | 21,500 | 59 |
| Sullivan | 14,000 | 8,500 | 22,500 | 38 |
| : | | | | |
| Total | 237,600 | 188,900 | 426,500 | 44 |
| : | | | | |

1/ Percentages calculated from nonrounded data.

2/ Rounded to nearest 100.

Purchased wood accounted for 44 and 47 percent of the wood obtained by households during 1978 and 1979, respectively (tables 8 and 9). The 3 percent difference between the two winters suggests that households are beginning to rely more on purchased cordwood, but the data does not conclusively

indicate a trend because the surveys utilized different questions. However, households installing stoves since 1973 have greater tendency to purchase their wood (table 11).

Although only 47 percent of wood burned was purchased for the 1979-80 winter, 55 percent of households burning wood purchased some portion of it. The 239,000 cords of wood purchased in New Hampshire in 1979 were bought by 81,000 households. During 1978, 43 percent of owner-occupant households cut all of their wood, 40 percent purchased all of their wood, 13 percent both purchased and cut, and 4 percent acquired no wood. This final group may represent families who burn wood stored during previous years.

Table 11--Method of obtaining cordwood, by installation date, 1978, New Hampshire

| Period of wood stove installation | All wood household | Wood cut by household | All wood purchased | Percent |
|--------------------------------------|-----------------------|--------------------------|-----------------------|---------|
| Before 1974 | 55 | 17 | 28 | |
| 1974-76 | 44 | 13 | 43 | |
| 1977-79 | 46 | 14 | 40 | |
| | | | | |

The method of obtaining wood relates to the average volume of wood burned in a household. Homeowners using airtight stoves burn less wood if all of their wood is purchased (table 12).

Characteristics
of Purchased
Cordwood

Purchased firewood comes in many forms: roundwood and splitwood of varying lengths and slab and other forms of manufacturing waste. 4/ There are also a number of services (splitting, delivering, stacking) that may or may not

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

accompany the purchase. Splitwood accounted for 47 percent of purchased wood in 1978 and 21 percent of all wood acquired. Roundwood accounted for 50 percent, while slabwood and manufacturing waste was 3 percent of purchased firewood (table 13).

Table 12--Average volume of cordwood burned by apparatus and method of acquisition, winter, 1978-79, New Hampshire

| Wood-burning group | All wood cut by household | Wood cut and purchased | All wood purchased |
|--|---------------------------------|------------------------------|-----------------------|
| : | : | : | |
| Owner-occupant using a fireplace | 1.4 | 1.8 | 1.4 |
| : | : | ----- <u>Cords</u> ----- | |
| Owner-occupant using a traditional wood stove | 3.2 | 3.6 | 3.6 |
| Owner-occupant using an airtight wood stove | 4.4 | 3.8 | 4.1 |
| Owner-occupant using a central wood furnace | 4.1 | 6.7 | 3.4 |
| : | : | | |

Household cordwood purchases in New Hampshire and Maine contain a higher percentage of unsplit wood in lengths of 4 feet or longer (table 14). 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.

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 New Hampshire household in July.

Table 13--Volume of firewood purchased, by form and length, 1978, New Hampshire

| Category | : Cords purchased | Proportion of purchased wood | | Proportion of all acquired wood | |
|---------------------------------|----------------------|---------------------------------|--|------------------------------------|--|
| | | : in category | | : in category | |
| | | | | -----Percent 2/----- | |
| | | | | | |
| | | <u>Cords 1/</u> | | <u>Percent 2/-----</u> | |
| Roundwood | : 94,200 | 50 | | 22 | |
| Greater than 4 ft. | : 44,500 | 24 | | 10 | |
| 4 ft. | : 32,300 | 17 | | 8 | |
| Less than 4 ft. | : 17,400 | 9 | | 4 | |
| | | | | | |
| Splitwood | : 89,800 | 47 | | 21 | |
| Greater than 4 ft. | : 1,900 | 1 | | 0 | |
| 4 ft. | : 5,700 | 3 | | 1 | |
| Less than 4 ft. | : 82,200 | 44 | | 19 | |
| | | | | | |
| Manufacturing waste and slab | : 4,900 | 3 | | 1 | |
| | | | | | |
| Total | : 188,900 | 100 | | 44 | |
| | | | | | |

1/ Rounded to nearest 100 cords.

2/ Numbers may not add due to rounding.

Table 14--Characteristics of household firewood purchases, 1978, New England

| State | : Purchases : split | : Purchases : hardwood | : Purchases : delivered | : Purchases : seasoned | : Purchases : made early |
|---------------|------------------------|---------------------------|----------------------------|---------------------------|-----------------------------|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | <u>Percent</u> | |
| | | | | | |
| 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 |
| | | | | | |

Characteristics
of Cordwood
Harvested By
Households

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 New Hampshire. Split cordwood prices varied somewhat across the State: \$49 in Cheshire County, \$58 in Hillsborough County, and \$62 in Carroll and Windham Counties (fig. 4). 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 price in Concord, New Hampshire, was \$90 during early winter. 5/

New Hampshire families cut 265,000 cords of wood for their own use in preparation for the winter of 1979-80 (table 8). This was 53 percent of the wood burned by residences. Although the volume of wood cut by residents during 1979 increased over that cut during 1978 (238,000 cords), the percentage of wood cut rather than purchased was 3 percentage points lower than the percent cut in 1978. In all, 90,000 households or 61 percent of households burning wood during the winter of 1979-80 cut some or all of their cordwood.

During 1978, 71 percent of wood harvested by New Hampshire residents was cut from family-owned land and 12 percent was cut from a neighbor's land. In terms of land use, 77 percent of wood harvested by households was cut from privately owned, basically residential woodlots, and 49 percent was obtained from privately owned (residential) woodlands of 25 acres or less (table 15).

Harvesting of wood by households is concentrated on certain types of land. A 1972 New Hampshire forest survey estimated that there are 4,692,000 acres of commercial forestland in New Hampshire with 2,283,000 acres or 49 percent privately owned by individuals (table 15, col. 5). 6/ A 1973 survey of 433 forestland owners in New Hampshire indicated the size

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

6/ Commercial forestland is defined by the U.S. Forest Service as forestland producing or capable of producing a certain level 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.

Figure 4--Processed cordwood prices by county, 1978, New England
(Estimated from a 39-county sample of split cordwood prices)

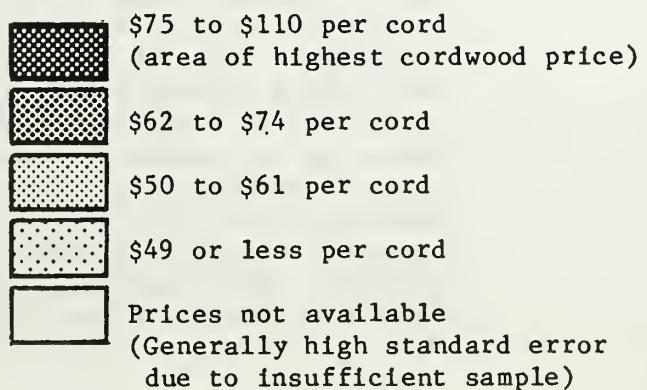
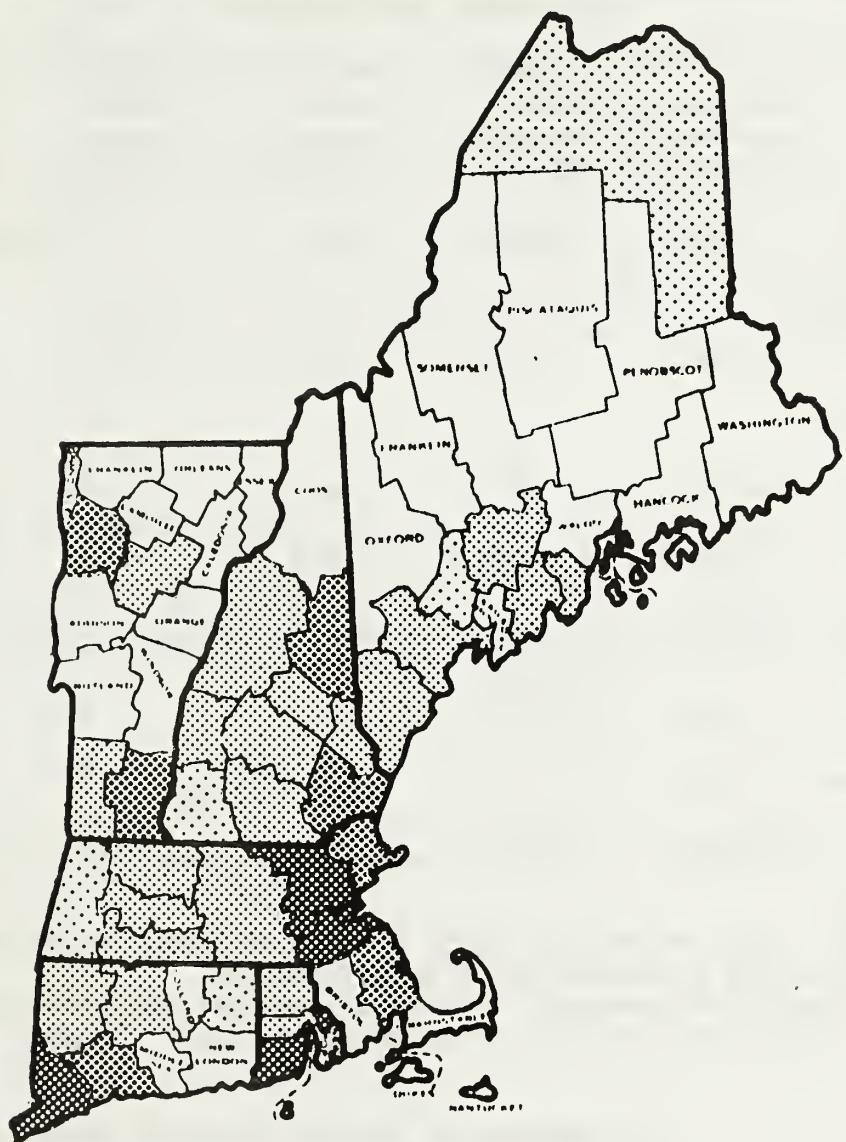


Table 15--Source of cordwood harvested by residents for their own use, by land use, 1978, New Hampshire

| 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 | <u>Percent</u> | <u>Cords</u> | <u>----Percent----</u> | |
| Small private (smaller than: 25 acres) | : 116,400 | 49 | 2.9 | 27 | <u>2/</u> 5 |
| Large private (25 acres or larger) | : 66,500 | 28 | 4.4 | 15 | <u>2/</u> 44 |
| Farm woodlot | : 19,000 | 8 | 3.9 | 5 | <u>3/</u> 5 |
| Public land | : 2,400 | 1 | 1.4 | 1 | 13 |
| Forest industry | : 14,300 | 6 | 4.8 | 3 | 20 |
| Other land use | : 19,000 | 8 | 3.4 | 5 | 13 |
| Total | : 237,600 | 100 | 3.3 | 56 | 100 |

1/ See (3).

2/ See (4). Small private in (4) is defined as less than 20 acres; large private in (4) 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.

distribution for lots of privately owned commercial forestland (4). Private forestland owners holding lots smaller than 20 acres comprise 75 percent of all individual, private owners of commercial forestland, yet they own but 11 percent of such forestland. Considering both of these forest resource surveys, individuals privately own, in lots smaller than 20 acres, approximately 5 percent of the land in New Hampshire that is producing or capable of producing a reasonable crop of wood. Thus, 27 percent of all wood obtained by households in New Hampshire (table 15, col. 4) is harvested from the 5 percent of commercial forestland which is in small, individually owned woodlots. This concentration of cordwood harvesting is even more pronounced in Maine, Rhode Island and Connecticut (table 16).

Survey information from across New England on the volume, land ownership, and land use of household wood harvesting indicates the importance of the small woodlot attached to the residence. Cross-referencing the relationships of land use and land ownership in New Hampshire shows that 48 percent of the wood cut by families or 27 percent of all the cordwood obtained (114,000 of 426,000 cords in 1978) was from woodlots smaller than 25 acres that were owned by the harvesting family rather than by other private parties, the public, the forest industry, or a farming household. The small, family-owned woodlot supplies a larger than average portion of residential cordwood in New Hampshire when compared with all New England States (table 17).

Table 16--Source of cordwood harvested by residents, by land use, 1978, New England

| Land use | : Maine | : New Hampshire | : Vermont | : Massachusetts | : Rhode Island | : Connecticut |
|--|------------|--------------------|--------------|--------------------|-------------------|------------------|
| <u>Percent</u> | | | | | | |
| | | | | | | |
| 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.

Table 17--Cordwood harvesting by residents on small, family-owned woodlots, 1978, New England

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

1/ Rounded to nearest 100 cords.

Residents using a small woodlot to supply their cordwood cut and burn less wood than those utilizing larger woodlots. The volume of wood which New Hampshire residents harvested from private woodlots smaller than 25 acres averaged 2.9 cords. Harvesting on larger private woodlots averaged 4.4 cords. This pattern is consistent throughout New England.

In order to analyze the impact of household cordwood harvesting on the forest resource, the 1979 survey recorded respondent use of professional forestry assistance. In New Hampshire, only 19 percent of wood cut by residents was marked for harvest by a forester (table 18).

Results of the surveys conducted throughout New England caused concern for the potential impact of increasing residential wood use on the forest resource. To provide more information on this resource use, the Vermont followup survey collected information that would better relate residential fuelwood demand to available information on the forest resource base. Because there are similar characteristics of wood use and acquisition in Vermont and New Hampshire, the findings of the

Vermont followup survey are important for New Hampshire. Response indicates that 82 percent of the volume of cordwood harvested by households in Vermont came from the larger woodlots which are included in the Forest Service definition of commercial forestland. Other cordwood was harvested from fence rows (9 percent), yards (6 percent), and woodlots smaller than 5 acres (3 percent). Further, a large percentage of the Vermont cordwood was harvested from categories of wood not suitable for production of lumber. These include trees or branches blow down, dead, or rotten (33 percent); trees cut for land clearing (23 percent); wood left over from lumber of pulp wood harvesting (7 percent); and small trees measuring less than 5 inches at chest height (5 percent). In sum, 68 percent of the volume of wood harvested by Vermont residents for their use is cut from trees and portions of trees not suitable for producing lumber. Only five of that 68 percent represented small trees possibly appropriate for future lumber production.

Table 18--Use of professional foresters to mark wood cut by residents for their own use, 1978, New Hampshire

| Category of land use | : | Volume of wood cut by residents | : | Portion of wood marked by forester |
|----------------------------|---|---------------------------------------|---|--|
| | : | <u>Cords 1/</u> | | <u>Percent</u> |
| Small private | : | 116,400 | | 7 |
| Large private | : | 66,500 | | 29 |
| Farm woodlot | : | 19,000 | | 1 |
| Public land | : | 2,400 | | 42 |
| Forest industry land | : | 14,300 | | 75 |
| Other | : | 19,000 | | 18 |
| Total | : | 237,600 | | 19 |

1/ Rounded to nearest 100 cords.

Cross-referencing this information from Vermont on the quality of harvested trees and the size distribution of woodlots provides information on the conflicts between cordwood and other wood products. For the 82 percent of wood which households harvested from commercial forestland, only 36 percent came from trees or portions of trees that could have produced lumber. Assuming that about half of the volume of each of these trees is suitable for lumber feedstock, it is possible to estimate that 15 percent of cordwood harvested by Vermont residences for their own use could have been used for lumber production. The families of Vermont harvest an unusually large percentage of their wood from farm woodlots and large, privately owned woodlots, suggesting that the percentage of household harvested cordwood that could have been used for lumber production in New Hampshire may be below 15 percent.

Household harvesting of cordwood may not, at present, improve forest productivity. Cordwood cut from trees or branches blown down, dead, or rotten constitutes 33 percent of the wood harvested by families, and trees cut for land clearing provide 23 percent of wood harvested by families in Vermont. The dominance of these two categories and the low percentage of cordwood marked by a forester for household harvesting in New Hampshire indicate that wood cutting by households may not be directed towards improving quality and productivity of woodlots. These relationships also suggest that most household woodlots have not yet been harvested to the extent that cuttings reduce growing stock on permanent forestland.

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 7/

New Hampshire residents displaced \$39 million of petroleum and \$27 million of electricity during 1980 through the substitution of wood energy for conventional heat sources (based upon home heating oil priced at \$1.00 per gallon and electricity at \$67 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

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

purchase cordwood. During 1979, 239,000 cords of wood were purchased by 81,000 New Hampshire residents. The average price per cord during 1978 for purchases of all forms of wood, as determined by the original survey, was \$55. 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 \$18 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. However, the value of cordwood purchases by New Hampshire residents represents less than 27 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 \$47 million were spent by residents for a broad spectrum of household purchases, from food and clothing 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 purchases.

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. New Hampshire residents use 29 percent of all energy consumed in the State whereas, nationally, only 21 percent of energy is consumed by residences. 8/ This definition of the residential sector excludes gasoline used in automobiles. The U.S. Department of Energy estimates that New Hampshire households demanded 43 trillion Btu's during 1978, and that petroleum provided 72 percent of this. However, the Department of Energy does not collect or include data on residential wood energy consumption. The energy content of the wood demanded by New Hampshire households during the winter of 1979-80 is estimated at 12.1 trillion Btu's (table 19). Considered in the context of available Department of Energy data, wood energy constitutes 22 percent of the total energy demanded by New Hampshire residences, with petroleum providing 56 percent (table 19).

8/ 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.

Table 19-- Energy demanded by residences, by fuel type,
1980, New Hampshire

| Energy form | Energy demanded 1/ | Portion of all energy demanded | |
|-------------|--------------------|--------------------------------|---------|
| | | Trillion Btu's | Percent |
| Petroleum | 28.4 | 56 | |
| Natural gas | 3.7 | 7 | |
| Electricity | 7.5 | 15 | |
| Wood | 11.2 | 22 | |
| Coal | .01 | -- | |
| Total | 50.8 | 100 | |
| | | | |

Note: -- = negligible amount.

1/ Estimates of residential consumption of conventional fuels are based upon 1978 data from the State Energy Data Report, U.S. Dept. Energy, Energy Information Adm., Apr. 1980, p. 257. 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 20.2 trillion Btu's.) Approximately 9 percent of the indicated wood energy in New Hampshire is burned in fireplaces and provides little useful energy.

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 New Hampshire wood conversion rate of 0.4, which resulted from deriving 4.9 trillion Btu's of space heat from wood with a heat content of 12.1 trillion Btu's, is much higher than that obtained by residents of most States. This high conversion rate is associated with the high portion of wood burned in relatively high-efficiency equipment.

Wood used in New Hampshire residences displaces an equivalent of 54 million gallons of fuel oil (table 20, 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 New Hampshire residences.

Table 20-Energy from wood combustion in residences, by household group, winter,
1979-1980, New Hampshire

| <u>Household group</u> | <u>Cords</u> | <u>Trillion Btu's</u> | <u>Percent</u> | <u>Trillion Btu's</u> | <u>Mill. gals.</u> |
|----------------------------------|--------------|-----------------------|----------------|-----------------------|--------------------|
| Owner-occupant | | | | | |
| Using only fireplace | 449,061 | 10.77 | | 4.65 | 51.6 |
| Using open wood stove | 40,226 | .97 | | .09 | .9 |
| Using airtight wood stove | 76,201 | 1.83 | | .55 | 6.1 |
| Using a wood furnace | 301,430 | 7.23 | | 3.62 | 40.1 |
| | 31,204 | .75 | | .41 | 4.6 |
| Rental-occupant | 25,313 | .61 | | .07 | .8 |
| Paying for heat, burning wood | 23,071 | .55 | | .06 | .6 |
| Heat included, burning wood | 2,242 | .05 | | .02 | .2 |
| Second and seasonal homes | | | | | |
| burning wood | 29,534 | .71 | | .14 | 1.5 |
| Total | 503,908 | 12.09 | | 4.86 | 53.9 |
| | | | | | |

Note: -- = insufficient sample.

1/ Cordwood measures in New Hampshire are for closely stacked wood 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 content set at 138,700 Btu's per gallon. 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 for mixed appliances is calculated from the reported mix of wood heating appliances.

Fuel oil and electricity represent the majority of the conventional energy being displaced by wood energy both because they are available to 86 percent of owner-occupant households and because they are relatively higher in cost per unit of energy. Two questions in the 1980 followup survey determined that fuel oil is available to 71 percent of homeowners (table 21). When asked to identify the fuel which "now provides most of the space heat for your family's residence," 32 percent of homeowners identified wood. This response, identifying households using wood as a "primary" space heating fuel, includes 33 percent of those using an airtight wood stove and 100 percent of those using a central wood-fired heating system. The 32 percent of homeowners who identified wood as providing space heat generally compares with the 50 percent who indicated use of a wood-burning stove or central wood-fired heating system.

Table 21--Conventional fuel available to homeowners for space heating, 1980, New Hampshire 1/

| Fuel | : | Homeowners |
|-------------|---|------------|
| | : | Percent |
| #2 fuel oil | : | 71 |
| Electricity | : | 15 |
| Natural gas | : | 11 |
| Propane | : | 1 |
| Total | : | 2/ 98 |
| | : | |

1/ Calculated upon a sample base of 191 homeowners.

2/ Households heating only with wood and which have no alternative fuel available in the dwelling account for 2.6 percent of homeowners.

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 and their interaction. The supply of wood for harvesting by residents 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 (4). 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 22). An estimate of annual available biomass for New Hampshire was made by the Biomass Subcommittee of the New England Energy Congress (5). 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 New Hampshire is given

Table 22--Forestland use in New England

| State | Commercial forestland | Productive reserved | Unproductive | 1/ | Proportion of land in forest |
|-------------------------|-----------------------|---------------------|--------------|-----|------------------------------|
| : | : | : | : | : | |
| : -----1,000 acres----- | | | | | |
| 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 100 trillion Btu's, equivalent to between 4 and 5 million cords per year (5). Estimate of the annual wood energy potential of New Hampshire by Glidden and High (including rough and rotten standing stock depleted over 20 years, annual cull increment, annual mortality, annual net growth, logging residues, and manufacturing residues) is 133 trillion Btu's (2).

The 1980 residential cordwood demand from within the State is estimated at 504,000 cords. Industrial wood energy demand is over 100,000 cords per year, largely supplied by mill residue and manufacturing wastes (5). Current export demand can be estimated as high as 100,000 cords per year, but this figure could increase considerably in future years. These approximate figures suggest that New Hampshire's 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 (8) and Peacock (7) 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.

Almost one percent of New Hampshire households experience a housefire associated with the burning of firewood each year. Five percent of households burning wood (23 observations of 427 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 (11 of 172) experienced such a fire during the period (one percent annually). Most of the fires (20 of 25) started as a chimney fire. The frequency of housefires caused by burning wood in New Hampshire is typical of New England as a whole. Five percent of all New England wood-burning households have experienced a housefire during the surveyed, 6-year period.

Some 60 percent of those households using airtight wood stoves had installed a smoke detector; 55 percent of non-wood-burning households had installed them. The installation rate

of smoke detectors, together with the fact that only 8 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 (8). 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 (7):

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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APPENDIX I:
SURVEY METHODS 1/

Discussion of
Survey Bias

Telephone surveys of New Hampshire households were conducted in 1979 and 1980 as a means to estimate the volume of cordwood consumed by residences during the winters of 1978-79 and 1979-80. 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 certain 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 household 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, standard-ized 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 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, 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 New Hampshire

Interviewing in New Hampshire to determine residential wood use during the winter of 1978-79 resulted in a sample of 803 respondents (App. table 2). Stratification by tenure and county allowed use of census data to correct for sampling bias. Combination of survey and census data resulted in the

Appendix table 2--Stratified sample of household respondents, New Hampshire, 1979

| Group | : | Sample size |
|--|---|----------------|
| | : | |
| Second or seasonal home occupant not burning wood | : | 23 |
| Second or seasonal home occupant burning wood | : | 34 |
| Rental household with heat included not burning wood | : | -- |
| Rental household with heat included burning wood | : | -- |
| Rental household paying for heat separately not burning wood | : | 56 |
| Rental household paying for heat separately and burning wood | : | 16 |
| Owner-occupant household not burning wood | : | 295 |
| Owner-occupant household using only an open fireplace | : | 52 |
| Owner-occupant household using an efficient fireplace | : | 27 |
| Owner-occupant household using a traditional open wood stove | : | 87 |
| Owner-occupant household using an airtight wood stove | : | 177 |
| Owner-occupant household using a central wood-fired heating system | : | 36 |
| | : | |
| Total | : | 803 |

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.

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 response bias associated with poor understanding of the cord measure. The resulting average volume burned by apparatus has a 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, New Hampshire

| Apparatus | : | Apparatus | : | Average volume burned per household | Standard error of average | Sample for average volume |
|--------------------------------------|---|-----------|---|---|---------------------------------|---------------------------------|
| | : | | : | Number | -----Cords----- | Number |
| Open fireplace | : | | : | 52 | 1.41 | .12 |
| Efficient fireplace | : | | : | 27 | 1.37 | .14 |
| Traditional wood stove | : | | : | 87 | 3.22 | .24 |
| Airtight wood stove | : | | : | 177 | 4.16 | .17 |
| Wood furnace (combinations incl.) | : | | : | 36 | 4.65 | .50 |
| | : | | | | | |

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 New Hampshire Statewide estimate of cordwood use by residents during the winter of 1978-79 is 22,321 cords or 6 percent of the 394,305 cords burned (App. table 4).

Appendix table 4—Standard errors for estimates of fuelwood burned, New Hampshire, winter, 1978-79

| Wood-burning group | County | | | | | | Cords | Statewide |
|---|---------|---------|----------|------|---------|--------------|-------|-----------|
| | Belknap | Carroll | Cheshire | Coos | Grafton | Hillsborough | | |
| Second home | 649 | 1051 | 444 | 132 | 565 | 383 | 470 | 1489 |
| Rental with heat included | 84 | 27 | 118 | 84 | 137 | 696 | 184 | 349 |
| Rental paying separately | 264 | 84 | 371 | 263 | 431 | 2183 | 576 | 1095 |
| Owner-occupant using an open fireplace | 462 | 284 | 426 | 270 | 449 | 2156 | 1084 | 2149 |
| Owner-occupant using an efficient fireplace | 504 | 0 | 0 | 0 | 446 | 1657 | 810 | 953 |
| Owner-occupant using a traditional wood stove | 1473 | 1156 | 2318 | 1385 | 1537 | 5798 | 3204 | 3894 |
| Owner-occupant using an airtight wood stove | 2304 | 1853 | 3595 | 1984 | 2203 | 10221 | 4764 | 10416 |
| Owner-occupant using a central wood furnace | 1540 | 671 | 2775 | 1531 | 1061 | 6312 | 1955 | 6436 |
| Standard errors for counties | 3289 | 2532 | 5151 | 2892 | 3044 | 13871 | 6261 | 13197 |
| | | | | | | | 4584 | 3172 |
| | | | | | | | | 22321 |
| | | | | | | | | |

APPENDIX II:
TABLES OF BASIC
FINDINGS

The following tables present basic findings of the New Hampshire 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, New Hampshire, winter, 1978-79

| BELKNAP | CARROLL | CHESTER COOS | GRAFTON | HILLSBOR MERRIMAC | ROCKINGH STRAFFOR | SULLIVAN | TOTALS |
|----------|---------|--------------|---------|-------------------|-------------------|----------|--------|
| GROUP 1 | 1454 | 2352 | 994 | 295 | 1265 | 859 | 1052 |
| GROUP 2 | 2150 | 3473 | 1469 | 435 | 1970 | 1269 | 1355 |
| GROUP 3 | 1594 | 652 | 2050 | 1547 | 2630 | 12267 | 3385 |
| GROUP 4 | 84 | 34 | 103 | 31 | 138 | 646 | 178 |
| GROUP 5 | 2056 | 840 | 2643 | 1995 | 3391 | 15818 | 4365 |
| GROUP 6 | 587 | 240 | 755 | 570 | 969 | 4519 | 1247 |
| GROUP 7 | 3060 | 2013 | 7875 | 3493 | 5892 | 27776 | 9208 |
| GROUP 8 | 735 | 410 | 315 | 291 | 1219 | 5555 | 2222 |
| GROUP 9 | 919 | 0 | 0 | 0 | 1219 | 2469 | 1270 |
| GROUP 10 | 1471 | 1434 | 1890 | 1601 | 2743 | 5555 | 3809 |
| GROUP 11 | 2574 | 3277 | 3150 | 2329 | 4165 | 12345 | 6032 |
| GROUP 12 | 735 | 205 | 1260 | 873 | 609 | 3086 | 635 |
| TOTALS | 18219 | 14969 | 22507 | 13510 | 26111 | 92163 | 34956 |

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

| BELKNAP | CARROLL | CHESTER COOS | GRAFTON | HILLSBOR MERRIMAC | ROCKINGH STRAFFOR | SULLIVAN | TOTALS |
|----------|---------|--------------|---------|-------------------|-------------------|----------|--------|
| GROUP 2 | 3213 | 5198 | 2196 | 651 | 2795 | 1876 | 2324 |
| GROUP 4 | 97 | 41 | 123 | 98 | 164 | 764 | 211 |
| GROUP 6 | 1021 | 417 | 1313 | 991 | 1695 | 7859 | 2162 |
| GROUP 8 | 944 | 526 | 404 | 374 | 1565 | 7130 | 2852 |
| GROUP 9 | 1147 | 0 | 0 | 0 | 1523 | 3085 | 1587 |
| GROUP 10 | 4419 | 4303 | 5680 | 4312 | 8242 | 16694 | 11049 |
| GROUP 11 | 9308 | 12487 | 12004 | 8875 | 15872 | 47045 | 22286 |
| GROUP 12 | 3113 | 867 | 5335 | 3673 | 2581 | 13067 | 2689 |
| TOTALS | 23767 | 23894 | 27060 | 19498 | 34427 | 97541 | 46265 |

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

| BELKNAP | CARROLL | CHESTER COOS | GRAFTON | HILLSBOR MERRIMAC | ROCKINGH STRAFFOR | SULLIVAN | TOTALS |
|----------|---------|--------------|---------|-------------------|-------------------|----------|--------|
| GROUP 2 | 1266 | 2047 | 865 | 256 | 1101 | 747 | 916 |
| GROUP 4 | 12 | 5 | 15 | 11 | 19 | 89 | 25 |
| GROUP 6 | 1045 | 427 | 1343 | 1014 | 1723 | 9039 | 2218 |
| GROUP 8 | 1270 | 314 | 292 | 224 | 1872 | 6161 | 2601 |
| GROUP 10 | 11768 | 7584 | 6427 | 10126 | 20223 | 13315 | 23258 |
| TOTALS | 15360 | 10377 | 8891 | 11630 | 24938 | 20351 | 29097 |

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

| BELKNAP | CARROLL | CHESTER COOS | GRAFTON | HILLSBOR MERRIMAC | ROCKINGH STRAFFOR | SULLIVAN | TOTALS |
|----------|---------|--------------|---------|-------------------|-------------------|----------|--------|
| GROUP 2 | 2034 | 3291 | 1390 | 412 | 1769 | 1200 | 1471 |
| GROUP 4 | 50 | 20 | 64 | 48 | 92 | 384 | 106 |
| GROUP 6 | 471 | 123 | 605 | 457 | 777 | 3626 | 1000 |
| GROUP 8 | 950 | 735 | 131 | 157 | 1400 | 4608 | 2005 |
| GROUP 10 | 7465 | 15926 | 21691 | 12379 | 16363 | 45637 | 21243 |
| TOTALS | 10771 | 19665 | 23932 | 13954 | 20393 | 55255 | 44754 |

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