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Wood and Energy in Vermont

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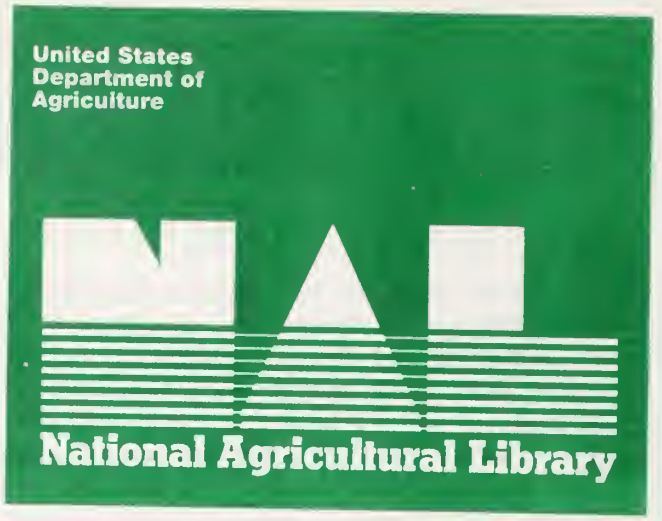

ABSTRACT

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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: Vermont, wood energy, residential energy demand, 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 Vermont is the first 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, Vermont, New Hampshire, 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 Vermont 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 550 households. The second or followup survey, 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 Vermont 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 Vermont Energy Office 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 Governor's Council on Energy conducted the surveys in New Hampshire.

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 Vermont report. Alan Turner, formerly the wood energy specialist of the Vermont Energy Office and presently the biomass program manager for the Northeastern Solar Energy Center, led the survey efforts. David Lamont, the present wood energy specialist, ably took over and contributed many pertinent suggestions.

Maria Lenz, an ERS economic and statistical assistant, displayed a great deal of dedication in computing 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, 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 L. Cotner, Velmar Davis, James Sayre, Debra Ritter, Robert McKusick, Carolyn Harper, Jerry Jolly and Robert Francis.

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HIGHLIGHTS

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

* Over 40 percent of all Vermont households and 55 percent of owner-occupant households use wood-burning stoves or central wood-fired heating systems.

* Eight percent of all Vermont households and 11 percent of owner-occupant households installed their first wood-heating apparatus in 1979, contributing to a 24 percent annual increase in residential fuelwood use.

* Homeowners who use airtight wood stoves burn an average of 4.4 cords per household during a winter and estimate that they derive 60 percent of space heat from wood.

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

* Over 389,000 cords of wood were burned in Vermont households during the winter of 1978-80.

* Purchased wood supplied 44 percent of the cordwood obtained for the winter of 1979-80. Although a majority of cords were cut by household residents for their use, 53 percent of wood-burning residents purchased some portion of their wood.

* Splitwood constituted 58 percent of cords purchased. Ninety-five percent of cords purchased were hardwood; 93 percent were delivered.

* Residents harvested 21 percent of all the cordwood they obtained from the 3 percent of productive forestland that is owned in private woodlots of less than 20 acres. Vermont residents harvested less wood from small residential woodlots than in any other New England State.

* In total 68 percent of the volume of wood harvested by residents for their use was cut from trees and portions of trees not currently suitable for lumber.

* Wood energy supplied 30 percent of all energy demanded by Vermont residents and 33 percent of all 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, Vermont residents are displacing $48 million in petroleum and $5 million in electricity. Residents spent approximately $13 million of these savings on the purchase of cordwood.

* Each year, about 1 to 2 percent of households that heat with wood experience house fires directly related to the use of wood.

WOOD AND ENERGY IN VERMONT. By Mark R. Bailey and Paul R. Wheeling, Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Washington, D.C. March 1982. ERS Staff Report No. AGES 820126.

INTRODUCTION

Since the 1973-74 oil embargo, Vermont 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 nearly 400,000 cords of wood by Vermont households during the winter of 1979-80. Increased fuelwood consumption results 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 Vermont 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 contined 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 embargo. Petroleum accounts for over 75 percent of the energy used in New England, and over 75 percent of the petroleum

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

consumed is imported from foreign sources. Petroleum accounts for 60 to 70 percent of the energy consumed in Vermont and between 70 to 80 percent of conventional energy demanded by residences. Heating requirements of a Vermont household are 167 percent of the national average. As a result, Vermont residents have keenly felt the increasing cost of home heating, and their desire to lower heating costs has been a central factor contributing to the transition to wood heat.

TRANSITION TO CORDWOOD USE IN VERMONT

Use of wood heat in Vermont in 1970 was well above the national average which was less than 1 percent of homeowners (6). Still, only about 15 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, 55 percent of Vermont's homeowners used wood-fired heating equipment, up 11 percent from the previous year.

Trends in Residential Wood Use

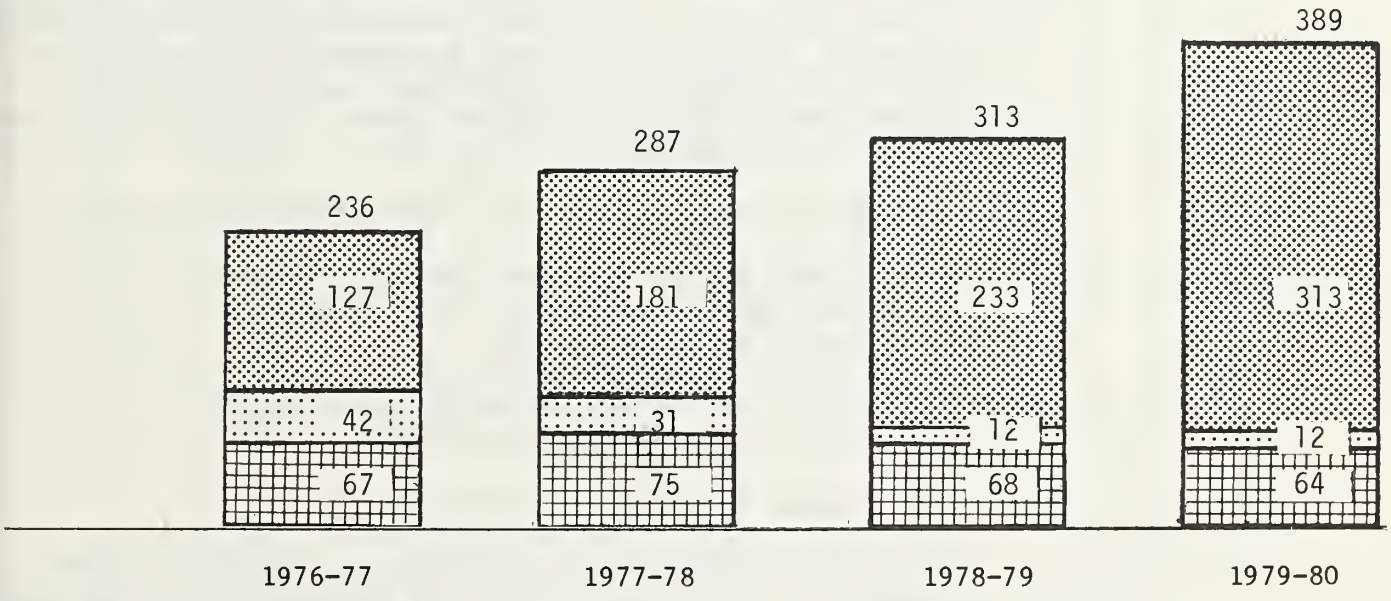
Total numbers of wood stoves and wood-burning furnaces installed in Vermont in 1976, 1977, 1978, and 1979 were 15,700, 17,600, 27,800, and 18,900, respectively. These installations overstate somewhat the transition to wood heat because some replaced or upgraded previously existing wood-burning equipment.

Estimates of the volume of wood burned in residences during the winters of 1976-77 through 1978-79 were developed from the 1979 Vermont 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 since changes in dwellings and associated changes in wood-burning equipment (new equipment, replacement of similar equipment, and upgraded equipment) were considered. The annual increase has averaged 18 percent over 1976-77 to 1979-80 (fig. 1). Of the 419 owner-occupant households responding to questions in the initial survey, 36 percent used a wood stove during the winter of 1978-79. The majority of these stove users used a wood stove during the previous winter (28 percent of all owner-occupant households), while 4.5 percent of homeowners changed from fireplace to stove use, and 3.3 percent changed from not burning wood to stove use. Approximately 7 percent of homeowners used a central wood furnace during the winter of

1/ The 1970 figure of 15 percent was derived by extrapolating data back in time. Data sources included the two surveys conducted as part of the New England Fuelwood Study and two previous surveys (see (9)).

1978-79, including 5.5 percent who previously used a wood furnace and 1.9 percent who installed one during 1978. Those installing a central wood furnace were fairly equally divided between households previously not burning wood, using a fireplace, or using a wood stove. Finally, about 1.6 percent of households discontinued wood use. Overall, owner-occupant households using fireplaces declined from 15 percent to 9 percent during 1978.

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



Percentage increase 1976-77 to 1977-78	Percentage increase 1977-78 to 1978-79	Percentage increase 1978-79 to 1979-80
22 percent	9 percent	24 percent

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

Estimate of the change in wood use use during 1979 was determined from the 199 respondents of the 1980 resurvey who indicated both the year of their last change in wood-burning apparatus and the type of wood-burning equipment, if any, utilized before that. The analysis included factors such as

effects of moving from a residence with a different type of wood-burning apparatus and replacement of one stove by another The survey response indicates a 24-percent increase in wood us during 1979 (table 1).

The increase in wood use during 1979 is largely due to the net increase of 13,000 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 45 during the winter of 1978-79 to 55 during the winter of 1979-80. During 1979, a total of 13,500 homeowners began to use airtight wood stoves, with 10,600 homeowners using such stoves for the first time an the remaining 2,900 having used traditional wood burning stove previously. An additional 1,000 homeowners who installed an airtight wood stove had been previously using a different airtight wood stove, and a similar number of households stoppe using airtight wood stoves during 1979.

Net change in wood burned is calculated from the following:

1. Change in type of wood-burning apparatus used and the resulting change in average number of cords burned.

2. Change in average volume of wood burned per central wood-fired system.

3. Change in number of households.

The Vermont 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 th most 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 strongly 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 begin to 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 Vermont were heated by that energy source. During the same pre-embargo period, the marginal cost of wood supplied heat was higher

Table 1--Changes in Vermont residential wood use during 1979, by household groups

Household group 1/	Households 2/ in wood use groups		Household change in equip. use during 1979	Volume of wood burned		Change in volume of wood burned relative to 1978-79
	Jan. 1979	Jan. 1980		Winter 3/ 1978-79	Winter 1979-80	
	-----Number-----			-----Cords-----		Percent
Owner occupant	120,431	123,577	3,146	245,472	325,379	33
Not burning wood	54,556	44,173	-10,383	--	--	--
Using only fireplace	11,115	11,405	290	12,027	12,340	3
Using open wood stove	14,161	10,908	-3,253	46,398	35,606	23
Using airtight wood stove	29,408	41,985	12,577	124,834	178,729	43
Using a wood furnace	11,191	15,106	3,915	62,213	98,704	59
Rental occupant	53,951	55,252	1,301	35,908	32,055	-11
Not burning wood	42,512	46,523	4,011	--	--	
Using only fireplace	1,135	496	-639	521	230	-56
Using open wood stove	4,851	2,808	-2,043	16,135	9,814	-39
Using airtight wood stove	4,262	4,951	689	19,252	22,011	14
Using a wood furnace	1,191	474	-717	4/	4/	4/
Second and seasonal homes	24,663	24,663	--	31,841	31,841	--
Not burning wood	10,723	10,723	--	--	--	--
Burning wood	13,940	13,940	--	31,841	31,841	--
Total	199,045	203,492	4,447	313,221	389,275	24

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 differential 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/ Insufficient data are available to estimate wood use in these households.

than fuel oil supplied heat, and thus, 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 Vermont 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 air tight stoves increased. Compared to those households that use inefficient, non-airtight stoves, those using airtight stoves typically burn 30 percent more wood per year, and derive more than a 30 percent increase in wood supplied heat. Vermont 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 Vermont

Period installed	Open woodstove	Airtight stove	Wood furnace
		Percent	
Before 1974	52	34	14
1974-76	19	63	18
1977-79	17	64	19

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, 57 percent of the Vermont homeowners using fuel oil as a conventional fuel use wood heat, as compared to 30 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 by industries that could convert to wood-fired boilers -- from electrical utilities that could convert to wood and from 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, cost of the stove, and locating adequate cordwood supplies.

Excess Demand on the Forest Resource

Residential long-term fuelwood demand on the forest resource in Vermont 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. Vermont, like New Hampshire, exports cordwood to more densely settled areas.

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

Perceived problem	Vermont	Maine	New Hampshire	Massachusetts	Connecticut	Rhode Island
			Percent 1/			
Time and effort in cutting wood	10	24	19	20	45	6
Price of fuelwood	8	32	23	15	53	4
Locating adequate supplies to purchase or cut	4	21	13	9	35	3
Potential hazards of burning wood	66	38	56	49	34	47
Cost of stove	4	37	13	13	27	5
Inconvenience in handling	29	11	26	20	0	21
			Number			
Sample base	186	229	247	779	83	150

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

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 Vermont, as well as the other States in New England, together with increased burning of wood, have also

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

Home Insurance Policy Premiums

With increasing use of fuelwood has come 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 comtemplating a supplementary premium for houses that use wood stoves if the incidence of house fires resulting from the operation of wood-burning apparatuses increases much further. Such premiums could dampen the demand for new equipment and fuelwood.

State Liability Laws

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

WOOD CONSUMPTION AND ENERGY CONSERVATION BY VERMONT HOUSEHOLDS

Vermont 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 time heating).

Residential Use of Wood for Energy

Vermont families burned 389,000 cords of fuelwood during the 1979-80 winter (table 1). Forty-three percent of all

households and 55 percent of homeowners used a wood-burning stove or central wood-fired heating system. Forty-four percent of the homeowners interviewed reported wood as the fuel which "now provides most of the space heat" for their residence. The increase in residential wood use has varied between 10 and 20 percent per year, reflecting initial installations of wood-heating equipment and some upgradings of existing equipment. The substitution of wood energy has resulted in a more healthy State economy because dollars that would have been spent on imported oil remain in the State to be spent on local goods and services, including locally produced fuelwood. More information on the economic impacts of wood energy substitution appears in a forthcoming report.2/

Patterns of Cordwood Use

The primary stress on fuelwood resources is not due to rural wood stove use. Intensity of fuelwood use per unit of land area is largely determined by population; thus, areas with more households generally burn a larger total volume (table 4 and fig. 2).

Impact of Wood-Burning Equipment on Cordwood Use

There are a variety of wood-burning appliances, ranging from traditional open wood stoves to relatively sophisticated airtight stoves and central wood-fired heating systems. Of the 124,000 Vermont homeowners using wood-burning appliances in 1979, 15,000 used central wood-burning furnaces, 42,000 used airtight wood stoves, and 11,000 used open wood stoves. Over half the wood consumed by households in Vermont 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). Households using airtight wood stoves burn a average of 4.4 cords of wood during the heating season. The actual volume burned over a winter varies greatly, however, ranging from roughly 3 to more than 6 cords per year. Airtight wood stoves in Vermont provide an average of 53 million Btu's of available space heat per household during a winter, assuming a 50 percent operating efficiency. Such a stove could provide half the heating requirements of a home requiring 90 to 100 million Btu's of space heat per year. Vermont homeowners, however, estimate that their airtight wood stoves provide up to 60 percent of space-heating needs.

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

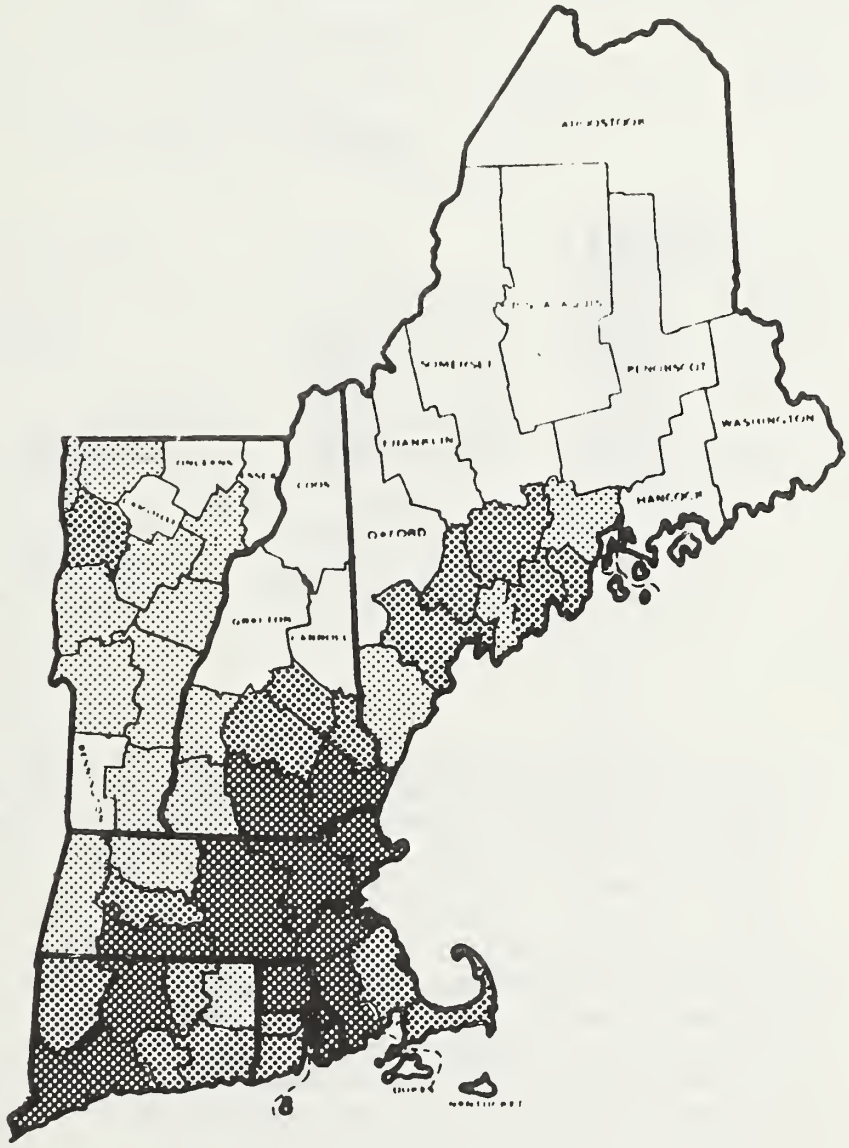
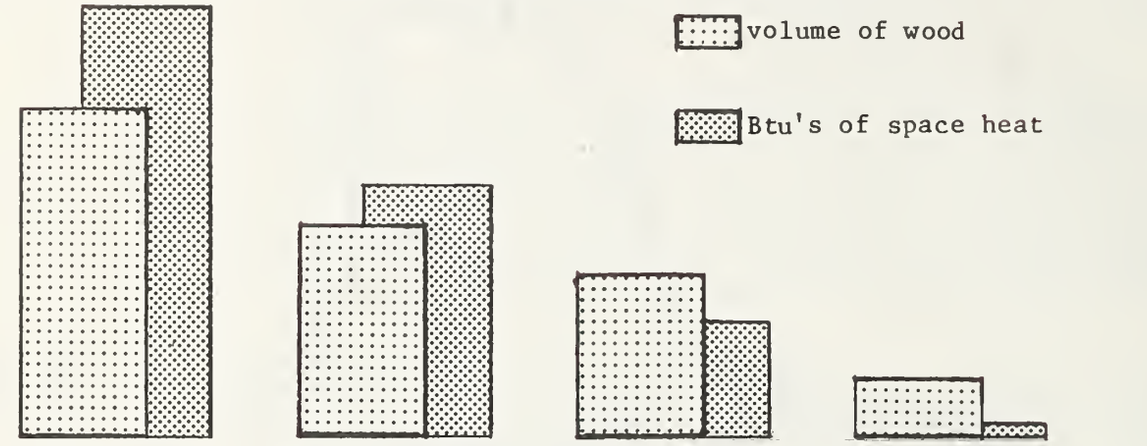


Figure 3--Average volume of fuelwood burned and available heat per household, by type of apparatus used, winter, 1979-80, Vermont



The New England 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 may be due to a lack of information on the amount of useful energy which a household can derive from a cord of wood. Also, residents installing and operating wood-burning equipment may use less energy than they previously used, and wood-burning equipment may provide a quality of heat that results in less demand for fuel.

During the 1978-79 winter, households using airtight stoves reported 43 to 62 percent of space heat needs from wood. The lower estimate is a minimum calculated by conservatively estimating the energy in the wood burned and equipment burning efficiency. The upper limit is derived from the respondents' estimates of the percentage of heat supplied by wood. In contrast to all households, owner-occupant households derive a slightly higher percentage of space heat from the same apparatus type (table 5).

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

County	Volume burned 1978-79	Volume burned 1979-80	Percentage of State total 1979-80
	----Cords----		Percent
Chittenden	49,896	63,821	16
Washington	34,917	44,250	11
Windsor	32,467	39,011	10
Rutland	30,297	36,067	9
Addison	24,172	33,159	9
Windham	25,274	31,699	8
Franklin	22,747	29,692	8
Orange	20,003	25,754	7
Caledonia	19,967	24,374	6
Bennington	17,952	20,478	5
Lamoille	12,794	15,780	4
Orleans	13,177	14,361	4
Essex	6,717	8,584	2
Grand Isle	2,842	2,848	1
Total	313,221	389,275	100

The wood-burning apparatus heavily influences the magnitude of fuelwood consumption and conventional fuel savings (fig. 3 and table 5). 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 Vermont. Once installed, characteristics of the wood stove and its placement largely determine the volume of wood burned and conventional energy displaced. A subsequent increase in the cost of the conventional fuel does not generally result in a significant change in the volume of wood burned in wood stoves already installed. Of course, the volume of wood burned by a household is influenced by access to fuelwood, cost of the fuel displaced by wood at the time of the installation, housing type, and the extent to which the home is insulated.

Newly developed apparatuses which increase wood-burning efficiency (e.g., the forced-air stick furnace and designs (incorporating catalytic converters) may change fuelwood demand.

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

Apparatus	Wood burned	Available heat 1/	Estimated savings in conventional fuel 2/	Homeowner estimate of percentage of heat from wood 3/	Average daytime thermostat settings 4/	Efficiency assumed for study
	Cords	Btu x 10^6	Dollars	Percent	Degrees	Percent
Open fireplace	0.8	1	148	16-17	66	5
Efficient fireplace	1.4	5	113	16-18	67	15
Traditional wood stove	3.4	25	282	31-47	64	30
Airtight wood stove	4.5	54	474	53-67	63	50
Wood furnace (combinations incl)	5.9	78	488	53-84	64	55

1/ Available Btu's estimated at 24 x 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 determined by the New Hampshire fuelwood survey based upon data provided by the New Hampshire Governor's Council on Energy for similar household groups in New Hampshire.

Cost Relationships of Conventional and Wood Energy

The 1980 Vermont survey recorded both primary and secondary heating fuels in order to identify the cost of heating using the conventional fuel available to the household. Household decisions resulting in the use of wood are primarily a function of the relative price differences between conventional energy sources and wood energy. This conclusion is supported by the fact that 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. Fifty-seven percent of homeowners using fuel oil and 67 percent of homeowners using electricity for heating have installed wood-fired heating equipment. Only 30 percent of homeowners who use the relatively less expensive natural gas have installed a wood stove or central wood-fired heating system.

Relative cost relationships between Btu's supplied by wood and conventional fuels further explain the rational economic behavior of Vermont residents (table 6). The price differential between fuel oil and wood energy (airtight stove) was 34 percent in 1978 and increased to 100 percent in 1981. While the divergence between electricity prices and wood energy actually decreased, the difference in 1981 was still above 100 percent.3/

Use of Energy Conservation Measures

Vermont 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 households' 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

3/ Vermont households pay the lowest rate per kilowatthour of any State in New England.

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

Energy source and burner	Applicable unit	Cost/unit		Energy per unit	Typical burner efficiency factor	Available energy	Cost/million Btu's		Relative cost per mil. Btu's 1/	
		1978	1981				1978	1981	1978	1981
		Dollars		Million Btu's	Percent	Million Btu's	Dollars		Percent	
Wood, airtight stove	cord	60	85	2/ 24	50	12	5.00	7.00	100	100
Central system	cord	60	85	2/ 24	55	13.2	4.55	6.44	91	91
Electricity, Resistance	kWh	3/0.044	4/0.05	0.0034	100	0.0034	12.88	14.64	258	207
Natural gas Furnace	1000 cu.ft.	3/3.57	5/6.50	1.0	70	.70	5.10	9.28	102	131
LP gas (propane), Furnace	gallon	3/.35	5/.80	.090	70	.63	5.50	12.56	110	177
#2 fuel oil, Furnace	gallon	3/.55	5/1.27	.1387	65	.090	6.10	14.00	122	198

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 hard 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. Dep. Energy, July 1979.
4/ Average price/kWh, 1980.
5/ Price estimates from Vermont Energy Office, Sep. 1981.

majority had made insulation improvements (table 7). At least 18 percent of Vermont homeowners improved their insulation each year. Homeowners using an airtight wood stove were approximately 20 percent more likely to improve insulation than households not burning wood or using an open fireplace.

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

OBTAINING CORDWOOD IN VERMONT

Vermont households obtain fuelwood through purchase and/or household harvesting of such wood. While wood-burning residents cut somewhat more wood than they purchased, more than 50 percent of them purchased at least some part 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. Just over half of the cordwood marketed in Vermont 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

Vermont residents purchased nearly 170,000 cords and cut over 219,000 cords for their own use during 1979 (table 8). For the previous winter, they purchased 126,000 cords and cut 215,000 (table 9). During 1979, owner-occupants obtained 80 and 81 percent of the wood purchased and cut, respectively, even though they constituted only 33 percent of all households. Homeowners using airtight wood stoves purchased 84,000 cords during 1979, constituting the largest market

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

Apparatus	Making insulation improvement	Installing storm windows	Caulking or weather stripping	Sample size
	--------Percent----------			Number
Owner-occupant household not burning wood	55	31	N/A	149
Owner-occupant household using an open fireplace	38	31	31	16
Owner-occupant household using an efficient fireplace	39	17	28	18
Owner-occupant household using a traditional wood stove	46	22	22	46
Owner-occupant household using an airtight wood stove	63	33	31	105
Owner-occupant household using a central wood furnace	45	30	21	33
All homeowners	54	30	16	367

Note: N/A = not available.

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

Household group	Volume cut	Volume purchased	Portion purchased	Households purchasing wood
	----Cords----		Percent	Number
Owner occupant	184,063	141,316	43	43,533
Using only fireplace	7,160	5,180	42	6,231
Using open wood stove	17,102	18,504	52	6,179
Using airtight wood stove	94,405	84,324	47	23,674
Using a wood furnace	65,396	33,308	34	7,449
Rental occupant	17,109	14,946	47	7,621
Using only fireplace	--	230	--	953
Using open wood stove	6,616	3,198	33	2,858
Using airtight wood stove	10,493	11,518	52	3,810
Using a wood furnace	--	--	--	--
Second and seasonal homes burning wood	18,150	13,691	43	4,372
Total	219,322	169,953	44	55,525

Note: -- = insignificant amount.

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 respondents' household. The less detailed resurvey recorded volume of wood burned and percentage of that wood purchased. Vermont households obtained 9 percent more wood during 1978 than was burned during the winter of 1978-79. Similarly, more than 389,000 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

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

Household groups	Cut by households	Purchased	Total acquired	Portion purchased	Average volume purchased
	-------Cords 1/-------			Percent	Cords
Owner occupants using fireplaces	7,100	7,600	14,700	52	1.7
Owner occupants using wood stove or furnace	171,100	89,900	261,000	34	4.0
All other households burning wood (incl. renters)	37,100	28,800	65,900	44	3.3
Total	215,300	126,300	341,600	37	3.6

1/ rounded to nearest 100.

wood-burning stoves. Families who install wood-fired heating equipment often have a tendency to build up a large inventory to carry over into following winters. This is especially true for families that 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, Vermont

County	Method of acquisition			Portion purchased 1/
	Self-cut	Purchased	Total acquired	
	----------Cords 2/--------			Percent
Addison	21,800	7,800	29,600	26
Bennington	6,500	4,600	11,100	42
Caledonia	9,400	7,500	16,900	44
Chittenden	30,300	22,000	52,300	42
Essex	7,700	3,500	11,200	32
Franklin	15,900	9,200	25,100	37
Grand Isle	1,500	1,100	2,600	41
Lamoille	9,100	7,700	16,800	46
Orange	23,200	6,200	29,400	21
Orleans	8,100	5,900	14,000	42
Rutland	18,700	12,500	31,200	40
Washington	24,200	14,500	38,700	37
Windham	16,200	11,400	27,600	41
Windsor	22,700	12,400	35,100	35
Total	215,300	126,300	341,600	37

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

Purchased wood accounted for 37 and 44 percent of the wood obtained by households during 1978 and 1979, respectively (tables 8 and 9). The 7 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 types

of questions. However, households installing stoves since 1974 have greater tendency to purchase some of their wood (table 11).

Table 11--Method of obtaining fuelwood, Vermont

Period of wood stove installation	All wood self-cut	Self-cut and purchased	All wood purchased
		Percent	
Before 1974	65	5	30
1974-76	49	21	30
1977-79	53	14	33

Although only 44 percent of wood burned was purchased for the 1979-80 winter, 53 percent of households burning wood purchased some of it. The 170,000 cords of wood purchased in Vermont in 1979 were bought by 56,000 households. During 1978, 51 percent of homeowners cut all of their wood, 31 percent purchased all of their wood, and 14 percent both purchased and cut, and 4 percent acquired no wood during 1979. This final group may represent families who burn wood which they stored during previous years. The homeowners that varied most from this pattern of wood acquisition were those using central wood-fired heating systems. This group cut 71 percent of its wood.

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). Information from the 1979 Vermont survey does not reveal the pattern of relationships existing in most other New England States, where residents purchasing all their wood typically burn less than those cutting all of their wood. The 1980 resurvey in Vermont provides data closer to this pattern.

Table 12--Average volume of fuelwood burned by apparatus and method of acquisition, winter, 1978-79 and 1979-80, Vermont

Wood-burning group	All wood self-cut		Self-cut and purchased		All wood purchased	
	1978-79	1979-80	1978-79	1979-80	1978-79	1979-80
	Cords					
Owner-occupant using a fireplace	1.2	1.3	1.0	--	1.3	1.0
Owner-occupant using a traditional wood stove	4.0	--	4.8	--	3.4	3.9
Owner-occupant using an airtight wood stove	4.8	4.9	5.3	4.6	4.0	3.8
Owner-occupant using a central wood furnace	6.1	7.4	4.1	--	6.4	6.0

Note: -- denotes insufficient sample size.

Characteristics of Purchased Cordwood

Purchased fuelwood 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 accompany the purchase. Splitwood, the most popular form of purchased wood, accounted for 58 percent of purchased wood in 1978 and 21 percent of all wood acquired. Roundwood accounted for 35 percent, while slabwood and manufacturing waste was 7 percent of the purchased firewood.

About 35,000 households purchased wood which had been split by the supplier and 18,000 purchased roundwood in 1979. Just

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.

over half of all wood purchased in Vermont is splitwood of less than 4 feet (table 13).

Table 13--Volume of fuelwood purchased, by form and length, 1978, Vermont

Category	Cords purchased	Proportion of purchased wood in category	Proportion of all acquired fuelwood in category
	Cords 1/	-------Percent-------	
Roundwood	44,200	35	13
Greater than 4 ft.	33,400	26	10
4 ft.	--	--	--
Less than 4 ft.	10,800	9	3
Splitwood	73,300	58	21
Greater than 4 ft.	3,400	3	1
4 ft.	4,900	4	1
Less than 4 ft.	65,000	51	19
Manufacturing waste and slab	8,800	7	3
Total	126,300	100	37

Note: -- = negligible amount.
1/ Rounded to nearest 100 cords.

Household cordwood purchases in Maine and New Hampshire 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 the householder can then process.

Cordwood price varies according to the number and kind of services provided. Major seller services are bucking, splitting, seasoning, delivering, and stacking. Price also varies with the size of the sale, time of year, price of conventional space heating fuel, and distance from major fuelwood harvesting operations. For example, one would expect to pay a significantly higher price for a cord of split

hardwood, cut to 18-inch lengths, delivered and stacked in Boston in January than for a cord of 8-foot long roundwood delivered to a central Vermont household in July.

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

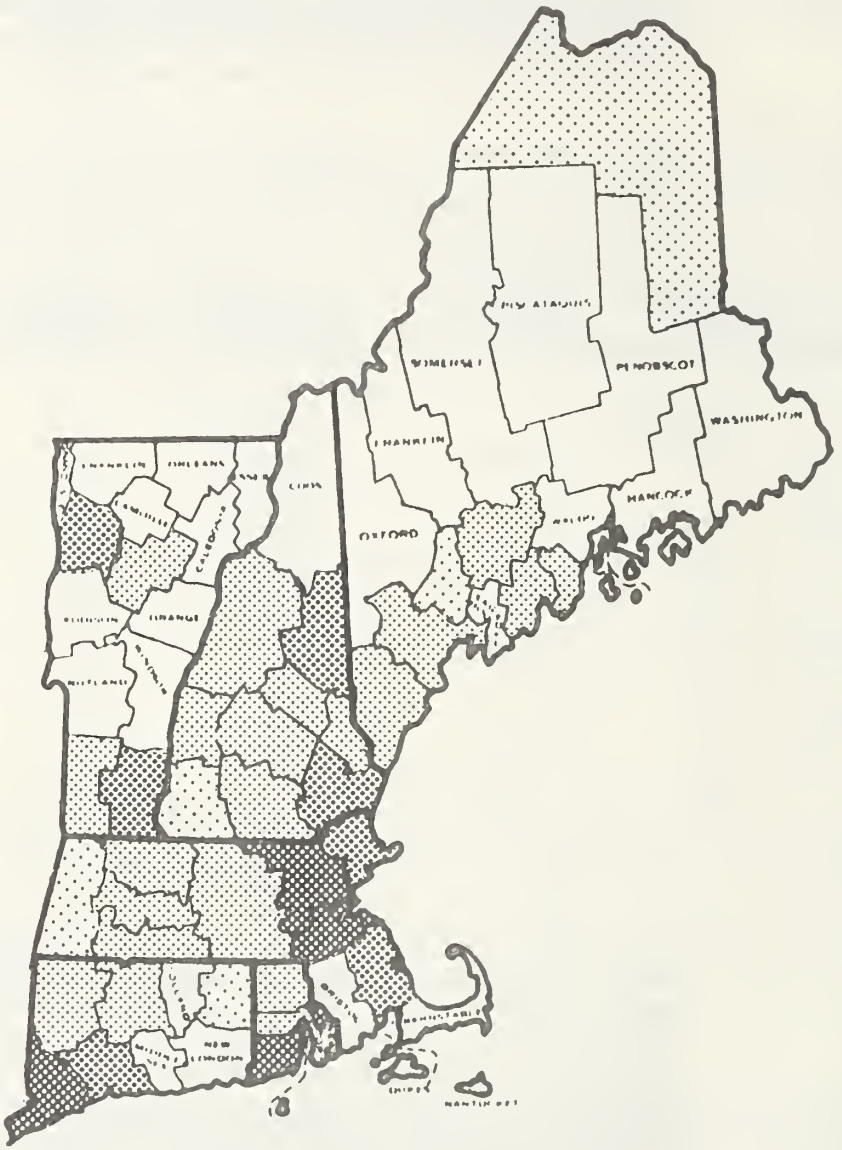
State	Purchases split	Purchases hardwood	Purchases delivered	Purchases seasoned	Purchases made early
			Percent		
Maine	35	94	81	61	64
New Hampshire	47	92	90	64	72
Vermont	58	95	93	67	62
Massachusetts	56	92	82	82	49
Rhode Island	83	87	81	75	34
Connecticut	59	85	79	81	35

During 1978 and through the winter of 1978-79, a cord of wood cut to stove length, split, and delivered cost an average of $60 in Vermont. Split cordwood prices varied somewhat across the State: $58 in Washington county, $62 in Bennington and Windham counties, and $67 in Chittenden county (fig. 4). The median price was $60 for the 39 counties in the four New England States reporting ranges of prices of split cordwood purchases during 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 Burlington, Vermont, was $92 during early winter. 5/

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

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



$75 to $110 per cord
(area of highest cordwood price)

$62 to $74 per cord

$50 to $61 per cord

$49 or less per cord

Prices not available
(Generally high standard error
due to insufficient sample)

Characteristics of Cordwood Harvested by Households

Vermont families cut 219,000 cords of wood for their own use in preparation for the winter of 1979-80. This was 56 percent of the wood burned by residences. Although the volume of wood cut by residents during 1979 increased over that cut during 1978 (215,000 cords), the percentage of wood cut rather than purchased was 7 percentage points lower than that estimated by the 1979 survey. In all, 67,000 households or 63 percent of those burning wood during the winter of 1979-80 cut some or all of their cordwood.

During 1978, 61 percent of wood harvested by Vermont residents was cut from family-owned land and 23 percent was cut from a neighbor's land. In terms of land use, 67 percent of wood harvested by households was cut from privately owned, basically residential woodlots, and nearly 33 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 Vermont forest survey estimated that there are 4,430,000 acres of commercial forestland in Vermont, with 2,347,000 acres or 53 percent privately owned by individuals (table 15, col. 5). 6/ A 1973 survey of forestland owners in Vermont indicated the size distribution for lots of privately owned commercial forestland (4). Private forestland owners holding lots smaller than 20 acres comprise 57 percent of all individual, private owners of commercial forestland, yet they own but 5 percent of such forestland. Considering both of these forest resource surveys, individuals privately own, in lots smaller than 20 acres, approximately 3 percent of the land in Vermont that is producing or capable of producing a reasonable crop of wood. Thus, 21 percent of the wood obtained by households in Vermont (table 15, col. 4) is harvested from the 3 percent of commercial forestland which is in small, individually owned woodlots. This concentration of cordwood harvesting is even more pronounced in other New England States. Vermont families harvest a greater than average percentage of wood from farm woodlots and large, privately owned woodlots.

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

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

Category of land use	Volume of cordwood cut	Portion of all household-cut wood	Average volume cut per household	Portion of all wood acquired	Portion of commercial forestland in category 1/
	Cords	Percent	Cords	----Percent---	
Small private (smaller than 25 acres)	70,500	33	3.4	21	2/ 3
Large private (25 acres or larger)	72,900	34	5.1	22	2/ 50
Farm woodlot	49,400	23	5.6	15	3/ 15
Public land	10,600	5	4.5	3	10
Forest industry	7,100	3	3.2	2	15
Other land use	4,700	2	3.1	1	7
Total	215,300	100		63	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.

Cross-referencing the relationships of land use and land ownership in Vermont shows that 25 percent of the wood cut by families and 16 percent of all the fuelwood obtained for residences (53,700 of 342,000 cords in 1978) were 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 (table 16). However, the small, family-owned woodlot supplies a smaller portion of residential cordwood in Vermont than in any other New England State (table 17).

Residents using a small woodlot for their cordwood supply cut and burn less wood than those utilizing larger woodlots.

The average volume of wood which Vermont households harvested from private, largely residential woodlots smaller than 25 acres was 3.4 cords whereas harvesting on larger private woodlots averaged about 5.1 cords. This pattern is consistent throughout New England.

Table 16--Sources of cordwood harvested by residents, by land use, 1978-79, New England

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

Note: -- = negligible amount.

1/ May not add to 100 because of rounding.

In order to indicate the impact of household cordwood harvesting on the forest resource, the 1979 survey recorded the extent to which respondents utilized professional forestry assistance in marking for harvest. In Vermont, only 13 percent of wood cut by households was marked by a forester (table 18).

Table 17--Volume of cordwood harvested by residents from small, private, family-owned woodlots, 1978-79, New England

State	Volume of wood cut on family-owned, private woodlots of less than 25 acres	Portion of wood harvested by households on family-owned, private woodlots of less than 25 acres	Portion of total cordwood burned
	Cords 1/	Percent	
Maine	125,400	42	22
New Hampshire	108,200	48	29
Vermont	53,700	25	16
Massachusetts	175,900	31	21
Rhode Island	33,700	49	31
Connecticut	345,600	58	51
Total	842,500	44	

1/ Rounded to nearest 100 cords.

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

Category of land use	Volume of wood cut by households	Portion of wood marked by forester
	Cords 1/	Percent
Small private	70,500	17
Large private	72,900	11
Farm woodlot	49,400	0
Public land	10,600	52
Forest industry land	7,100	6
Other	4,700	51
Total	215,300	13

1/ Rounded to nearest 100 cords.

Results of the 1979 survey raised a number of concerns regarding increasing residential demand for wood energy and the potential impact of that demand upon the Vermont forest resource. However, information collected did not permit rigorous analysis of this relationship. For that reason, a series of questions in the 1980 followup survey collected information that would better relate residential fuelwood demand to available information on the forest resource base. Response to these questions indicates that 82 percent of the volume of cordwood harvested by households came from the larger woodlots which are included in the Forest Service definition of commercial forestland. Wood was also harvested from fence rows (9 percent), yards (6 percent), and woodlots smaller than 5 acres (3 percent).

Other information from the followup survey indicates that a large percentage of the 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) (table 19). In sum, 68 percent of the volume of wood harvested by 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.

Cross-referencing this information 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, respondents indicated that only 36 percent of that wood 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 roughly estimate that 15 percent of cordwood harvested by residents for their own use could have been used for lumber production.

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. Trees cut for land clearing provide 23 percent of wood harvested by families. The dominance of these two categories and the low percentage of cordwood marked by a forester for household harvesting 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.

Table 19--Source of wood cut by residences for their own use in terms of woodlot management, 1979, Vermont

Wood source	Portion of all wood cut by families	Volume of wood cut by families
	Percent	Cords 1/
Trees/branches blown down, dead, or rotten	33	71,500
Trees cut for land clearing	23	51,000
Small trees measuring less than 5 inches diameter at breast height	5	9,800
Wood left over from lumber or pulp harvest	7	16,200
None of the above	32	70,800
Total	100	219,300

1/ Rounded to nearest 100 cords.

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/

Vermont residents displaced $48 million of petroleum and $5 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 $51 per 1,000 kWh (1980 prices)). For Vermont residents, this

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

represents almost 3 percent of all disposable household income. The path of these savings through the local economy resulted in multiplied economic benefits, increasing local employment and household income.

Dollars not spent by households on imported fuel travel one of two paths through the State economy. Some of the dollars purchase cordwood, the alternative fuel. During 1979, 170,000 cords of wood were purchased by 55,000 Vermont residents. The average price per cord (reflecting purchases of all forms of wood) was $56. Conservatively increasing the volume of wood purchased and the average price per cord to reflect increases since the survey dates, the value of cordwood purchases during 1980 is estimated to be at least $13 million. This was paid by residents to the wood processing and harvesting industry, which in turn spent a high percentage of its gross income on the employment of local labor. The value of cordwood purchases by Vermont residents represents less than 25 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 $40 million were spent by residents for a broad spectrum of household purchases, from food, clothing, and durables to vacations. These expenditures benefit local economies 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. Vermont residents use 28 percent of all energy (measured in Btu's) 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 Vermont households demanded 22 trillion Btu's during 1978, and that petroleum provided 70 percent of this. However, the Department of Energy does not collect or include data on residential wood energy consumption.

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. 385, revised to correct overestimation of LPG.

Considered in the context of available Department of Energy data, wood energy constitutes 31 percent of the total energy demanded by Vermont residences, with petroleum providing 48 percent (table 20). The energy content of the wood demanded by Vermont households during the winter of 1979-80 is estimated at 9.3 trillion Btu's according to data provided by the 1980 Vermont fuelwood survey (table 21).

Table 20-- Energy demanded by residences, by fuel type, 1980, Vermont

Energy form	Energy demanded 1/	Portion of all energy demanded
	Trillion Btu's	Percent
Petroleum	14.4	48
Natural gas	1.2	4
Electricity	4.9	17
Wood	9.3	31
Coal	.04	--
Total	29.8	100

Note: -- = negligible amount.

1/ Estimates of residential consumption of conventional fuels are based upon the State Energy Data Report, U.S. Dept. Energy, Energy Information Adm. Apr. 1980, p. 385. 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 12.7 trillion Btu's. Approximately 7 percent of the indicated wood energy in Vermont 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 would also encourage more households to convert to wood heat. The Vermont wood conversion rate of 0.46, which resulted from deriving 4.3 trillion Btu's of space heat from burning wood with a heat content of 9.3 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 being burned in relatively high-efficiency equipment.

Table 21--Energy from wood combustion in residences, by household group, winter, 1979-1980, Vermont

Household group	Estimated volume of wood burned	Energy content of wood burned 1/	Wood-burning efficiency	Useful energy from wood	Equivalent fuel oil displaced 2/
	Cords	Trillion Btu's	Percent	Trillion Btu's	Mil. gals.
Owner occupant	325,379	7.81	48	3.73	41.4
Using only fireplace	12,340	.296	10	.030	.3
Using open wood stove	35,606	.855	30	.256	2.8
Using airtight wood stove	178,729	4.289	50	2.145	23.8
Using a wood furnace	98,704	2.369	55	1.303	14.5
Rental occupant	32,055	.77	43	.33	3.7
Using only fireplace	230	.006	0	0	0
Using open wood stove	9,814	.236	30	.071	.8
Using airtight wood stove	22,011	.528	50	.264	2.9
Using a wood furnace	--	--	55	--	--
Second and seasonal homes burning wood	31,841	.764	3/ 30	.229	2.5
Total	389,275	9.34	46	4.30	47.7

Note: -- = insufficient sample.

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

3/ Efficiency for mixed appliances in second homes assumed to be 30 percent.

Wood used in Vermont residences displaces an equivalent of 48 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 Vermont residences (table 22).

Table 22--Conventional fuel available to household for space heating, 1980, Vermont 1/

Fuel	All Households	Homeowners	Homeowners
	Percent 2/		Number
#2 fuel oil	67	70	86,726
Electricity	12	10	11,966
Natural gas	8	6	6,933
Propane	2	3	3,270
Kerosene	2	3	3,565
Total	3/ 91	3/ 92	112,460

1/ Calculated upon a sample base of 236 households in total and 181 homeowners.
2/ Numbers may not add to 100 due to rounding.
3/ Households heating only with wood and which have no alternative fuel available in the dwelling account for 8.1 percent of all households and 8.8 percent of homeowners. Additionally, one household heating principally with wood reported coal as a secondary heating fuel and another reported solar as a secondary heating fuel; these accounted for less than 1 percent of households.

Fuel oil and electricity represent the majority of the conventional energy being displaced by wood energy both because they are available to 80 percent of the 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 70 percent of homeowners. When asked to identify the fuel which "now provides most of the space heat for your family's residence," 44 percent of homeowners identified wood. This response, identifying households using wood as a "primary" space heating fuel, includes 72 percent of those using an airtight wood stove and 90 percent of those using a central wood-fired heating system.

The 44 percent of homeowners who identified wood as providing most of their space heat generally compares with the 58 percent who indicated use of a wood-burning stove or central wood-fired heating system. Of those identifying wood, 80 percent utilized a conventional fuel to provide a secondary source of heat. Only 9 percent of all homeowners utilize wood as the sole source of space heat. Any conventional fuel previously utilized by these households was not identified.

Heavy reliance upon fuel oil documented by the 1980 Vermont survey (table 21) contrasts with aggregate data for the Northeastern States published by the U.S. Department of Energy. 9/ Primary heating fuels in these States continue to be fuel oil and kerosene, which supply 47 percent of dwellings. However, natural gas, which can be delivered at low cost by pipe to more densely settled areas, supplies 41 percent of households regionally. In addition, electricity supplies 11 percent and propane supplies 1 percent of households.

Cordwood Demand and the Forest Resource

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

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

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

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

A proportion of the cordwood marketed is sold by enterprises whose primary employment is in supplying either pulp or timber products. These enterprises are able to separate trees and sell them to the markets that represent the highest valued use for their product. These firms are competitive at current

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

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 23). An estimate of annual available biomass for Vermont 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. The estimate of total wood energy potential per year in Vermont is given by the final

report of the New England Energy Congress as 100×10^{12} Btu's, equivalent to between 5 and 6 million cords per year (5). The committee also noted the present lack of an established supply network as the major limit to biomass supply. Another estimate of the annual energy potential that could be derived from Vermont's biomass was made by Glidden and High. This estimate which includes rough and rotten standing stock depleted over 20 years, annual cull increment, annual mortality, annual net growth, logging residues, and manufacturing residues amounted to 104.5×10^{12} Btu's (2).

Table 23--Forestland use in New England

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

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

The 1980 residential demand from within the State is estimated at 389,000 cords. Industrial wood energy demand is approaching 200,000 cords per year, largely supplied by mill residue and manufacturing wastes (5). Current export demand is roughly estimated at 50,000 cords per year, but this figure could increase considerably. These approximate figures suggest that Vermont's current wood energy demands are well below its current wood energy supply potential. However, this relationship must be evaluated relative to the rapid growth of wood energy adoption 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.

Over 1 percent of Vermont households experience a housefire associated with the burning of firewood each year. Nine percent of households burning wood (22 observations of 243 sample points) experienced a housefire associated with wood use during the 6-year period (1973 to 1979). For homeowners using an airtight wood stove, 11 percent (12 of 107) experienced such a fire during the same period. Most of the fires (17 of 27) started as a chimney fire. The frequency of housefires caused by burning wood in Vermont is the greatest in New England, well above the 5 percent of all New England wood-burning households that have experienced such a fire during the 6-year period.

Some 57 percent of those households using airtight wood stoves had installed a smoke detector; only 43 percent of nonwood-burning households had installed them. The installation rate of smoke detectors, together with the fact that only 6 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, according to one study (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.

REFERENCES

(1) Dalton, M. M., J. H. Herrington, O. B. Durgin, and R. A. Andrews. Household Fuelwood Use and Procurement in New Hampshire. Research Rpt. 59. N.H. Agr. Exp. Sta. (cooperating with N.H. Timberland Owners Assoc.), Univ. New Hampshire, Durham, N.H., Oct. 1977.

(2) Glidden, William T., Jr. and Colin J. High. The New England Energy Atlas, Resource Policy Center, Thayer School of Engineering, Dartmouth College, 1980, p. 14.

(3) Kingsley, Neal P. The Forest Resource of Vermont, Resource Bull. NE-46, Forest Serv., U.S. Dept. Agr., 1977, p. 31.

(4) Kingsley, Neal P. and Thomas W. Birch. The Forest Landowners of New Hampshire and Vermont, Resource Bull. NE-51, Forest Serv., U.S. Dept. Agr., 1977, p. 33, table 2.

(5) New England Energy Congress. Final Report of the New England Energy Congress. May 1979, p. 152.

(6) Palmer, Lynn, Robert McKusick, and Mark Bailey. Wood and Energy in New England: A Review and Bibliography. BLA-7, Econ. Stat. Serv., U.S. Dept. Agr., Apr. 1980.

(7) Peacock, Richard D. A Review of Fire Incidents, Model Building Codes, Standards Related to Wood-Burning Appliances. Rpt. NBSIR 79-1731, Center for Fire Research, Nat'l Bur. of Stds.

(8) Shelton, J. W. Analysis of Fire Reports on File in the Massachusetts State Fire Marshall's Office Relating to Wood and Coal Heating Equipment. Rpt. NBS-GCR-78-149, Nat'l Bur. of Stds., Feb. 79.

(9) Vermont Energy Office. Final Report on the Use of Wood as a Heat Source and the Quality of Insulation in Vermont Households. Prepared by Action Res. Inc. Burlington, Vt. (two vols., 1976 and 1978).

APPENDIX I:
SURVEY METHODS 1/

Discussion of Survey Bias

Telephone surveys of Vermont 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. 2/

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

2/ Volunteer enumerators were not used in Vermont.

7. In some States, the wood use of rental household residents paying separately for their own heating fuel was estimated rather than surveyed whereas in other States, this household group was interviewed. 3/

8. A final form of bias is either the under- or over-estimation of cords reported by each responding household.

In order to insure the most precise estimates possible, 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 analysis in order to mitigate the bias impacts. Methods employed in developing the adjustment coefficients included subsurvey, resurvey, and stratification of response. The identified potential biases were analyzed as follows:

1. Households without telephones: This may be the least understood source of bias since the use of a telephone survey precludes the inclusion of this houshold group, and as a result, it is impossible to estimate the volume of fuelwood that this group consumes. However, given the fact that a very small percentage of households are without phones, that they tend to be located in rural areas, and that there is no evidence that this household group has something other than a random distribution of wood-burning characteristics, it was assumed that the bias resulting from not interviewing this group was minimal. Any bias stemming from this group would probably result in a slight, 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

3/ All household groups were surveyed in Vermont.

different in their wood-burning characteristics. An analysis of a "plus-one digit" dialing survey suggested little bias from this group. 4/

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. 5/

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 results, bias resulting from an uneven distribution of sampled households was negated.

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

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

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

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

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. Given the many forms in which cordwood was sold (full cord, half cord, pick-up truck load, rick, run, etc.), it was found that 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. 6/

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. The other States wished to collect data that would result in estimates for one or more regions. All States collected data from enough sample points to permit a rigorous statistical assessment of residential wood use at the State level. Appendix table 1 summarizes the number of households sampled in each State.

Telephone numbers were generated in such a way as to assign each household an equal probability of being surveyed. The selection procedure used telephone books to find noncommercial household telephone numbers in a randomly started, standardized manner. Selected numbers were pursued, within reason, according to a series of call-back rules until a survey was

6/ Ground-truth check is described 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 accuracy of household volume estimates.

completed. If any number could not be surveyed, it was replaced with another number found by continuing the standardized procedure.

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

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

Survey Precision in Vermont

Interviewing in Vermont to determine residential wood use during the winter of 1978-79 resulted in a stratified sample of 549 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, Vermont, 1979

Group	Sample size
Second or seasonal home occupant not burning wood	10
Second or seasonal home occupant burning wood	13
Rental household with heat included not burning wood	38
Rental household with heat included burning wood	2
Rental household paying for heat separately not burning wood	48
Rental household paying for heat separately and burning wood	15
Owner-occupant household not burning wood	196
Owner-occupant household using an open fireplace	20
Owner-occupant household using an efficient fireplace	18
Owner-occupant household using a traditional open wood stove	46
Owner-occupant household using an airtight wood stove	110
Owner-occupant household using a central wood-fired heating system	33
Total	549

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 identified faulty response bias associated with poor understanding of the cord measure. The resulting average volume burned by apparatus type has a precision or standard error related to the distribution of reported responses together with the sample size.

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

Apparatus	Total respondents	Average volume burned per household	Standard error of average	Sample for average volume
	Number	----Cords----		Number
Open fireplace	20	0.76	0.18	15
Efficient fireplace	18	1.41	.43	15
Traditional wood stove	46	3.45	.44	44
Airtight wood stove	110	4.53	.21	105
Wood furnace (combinations incl.)	33	5.87	.70	28

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 Vermont Statewide estimate of cordwood use by residents during the winter of 1978-79 is 16,356 cords or 5 percent of the 313,221 cords burned (App. table 4).

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

Wood-burning group	County														
	Addison	Benning-ton	Cale-donia	Chitten-den	Essex	Frank-lin	Grand Isle	La-moille	Orange	Or-leans	Rut-land	Wash-ington	Windham	Windsor	Statewide
	Cords														
Second home	613	265	414	790	334	500	694	147	470	903	1,170	477	855	644	2,426
Rental with heat included	36	59	58	227	9	62	4	27	27	39	104	98	84	87	318
Rental paying separately	228	478	472	1,827	71	500	34	217	219	312	841	789	673	703	2,569
Owner-occupant using an open fireplace	362	324	207	623	0	192	263	0	0	183	359	231	215	0	1,018
Owner-occupant using an efficient fireplace	0	671	423	1,330	0	0	539	0	0	374	1,145	328	442	0	2,108
Owner-occupant using a traditional wood stove	920	1,962	1,753	2,007	870	1,459	0	1,336	1,820	1,554	1,986	1,883	1,350	2,946	6,339
Owner-occupant using an airtight wood stove	2,957	2,996	2,550	5,491	1,412	2,629	0	2,101	2,548	2,115	3,200	3,352	3,311	4,182	11,264
Owner-occupant using a central wood furnace	2,924	1,679	2,127	3,846	1,445	3,067	0	1,350	3,018	0	2,651	2,640	2,241	3,172	9,040
Standard errors for counties	4,328	3,846	3,837	7,425	2,226	4,357	918	2,844	4,380	2,824	4,926	4,772	4,386	6,095	16,356

APPENDIX II: TABLES OF BASIC FINDINGS

The following tables present basic findings of the Vermont 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 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

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