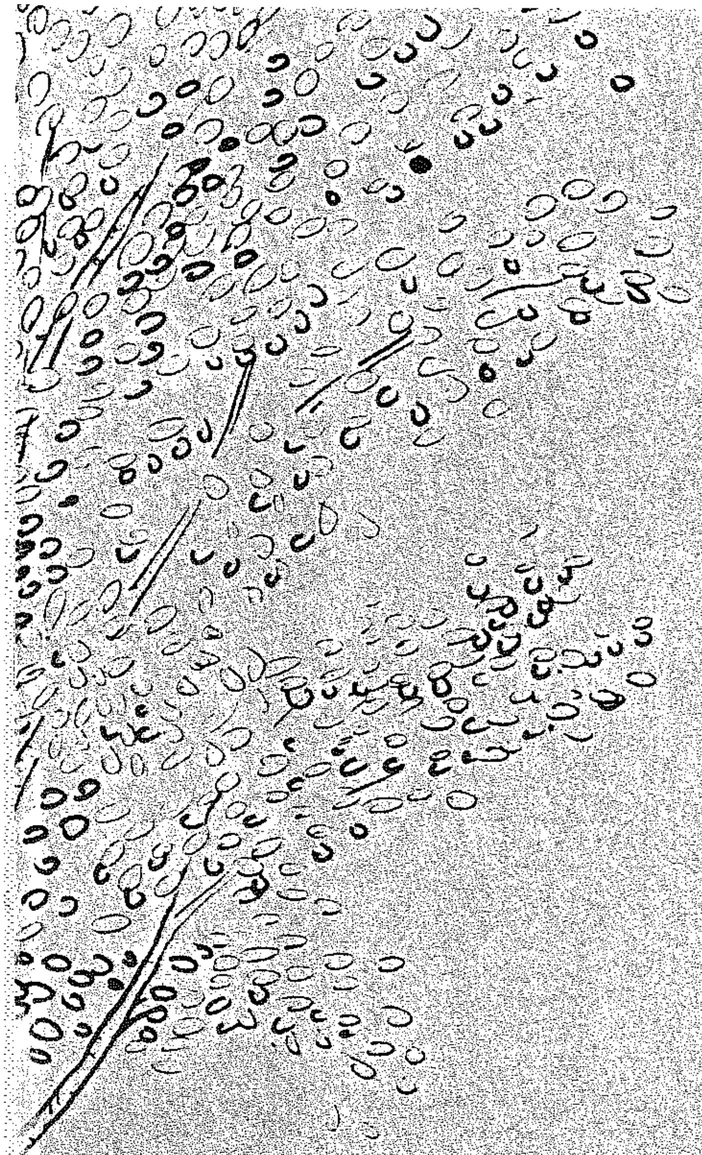
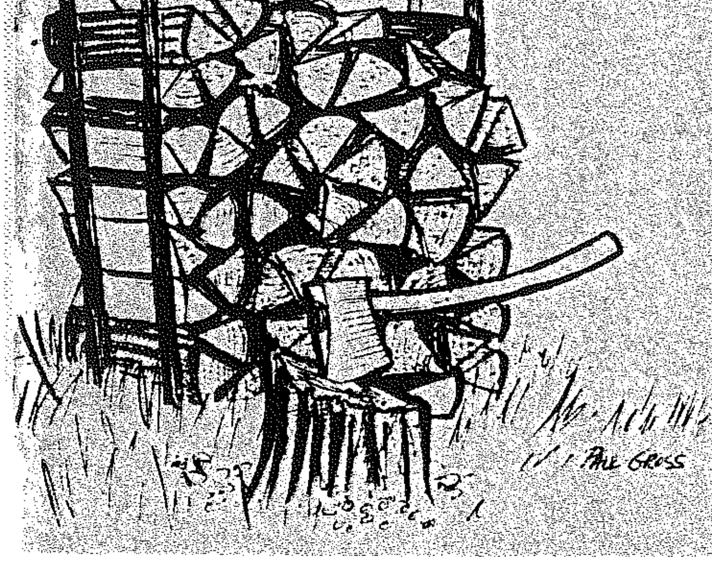


February 1982

A.E. Res. 82-11

ECONOMIC ASPECTS OF WOODFUEL USE IN NEW YORK STATE

by
Michael Slott



Department of Agricultural Economics
Cornell University Agricultural Experiment Station
New York State College of Agriculture and Life Sciences
A Statutory College of the State University
Cornell University, Ithaca, New York 14853

It is the policy of Cornell University actively to support equality of educational and employment opportunity. No person shall be denied admission to any educational program or activity or be denied employment on the basis of any legally prohibited discrimination involving, but not limited to, such factors as race, color, creed, religion, national or ethnic origin, sex, age or handicap. The University is committed to the maintenance of affirmative action programs which will assure the continuation of such equality of opportunity.

Abstract

This report examines several aspects of woodfuel use. Total costs of home heating are analyzed for wood-fueled versus conventional heating systems. When total heating costs over a 20 year period are levelized to an annual equivalent figure the results partly explain the increase in the sale of woodburning systems. Costs in nominal dollars show that heating with wood is more expensive than coal or natural gas, but is cheaper than heating with oil or electricity. The levelized costs for wood, oil, and electric resistance heating are: $3200, $3700, and $5000 respectively. The same analysis of an appropriately sized electric heat pump system yields an annual equivalent cost of $3500.

Productive forestland in New York State is described in the context of fuelwood supply. The biological supply potential has been estimated to be 18.24 million dry tons of wood biomass per year. Technical and institutional constraints suggest that 14.21 million dry tons per year is all that may reasonably be considered available.

The capital and operating costs of a modern whole tree chipping operation are estimated. The average cost resulting from this scale of operation suggests that 16 dollars per ton (1979 dollars) is a lower limit on the price of wood chips for industrial woodburning.

Two uses of fuelwood that have the greatest potential for consuming substantial portions of annual growth are residential heating and firing the boilers of electric utilities. In light of the estimated floor price of wood chips the specifications of the Burlington Electric Department's proposed McNeil Station are examined. The levelized cost of woodfired generation, based on the Burlington Electric Department's numbers is 24.69 cents per kWh. This does not appear competitive with coal and nuclear power.

The report ends by contrasting the capital requirements, costs, and wood consumption of these divergent approaches to utilizing wood energy. The analysis shows that per household capital costs would be lower and more homes could be heated if direct residential burning were the prevailing technology.

Acknowledgments

Throughout the many months that have been spent writing this report, Duane Chapman has been a most tolerant and loyal advisor. As chairman of my special committee the job of pushing and guiding me has been his.

I'm also grateful to two other good men. Jon Conrad was the first professor at Cornell with whom I had the opportunity to work. Timothy Mount has stood by the agreement we made when I first asked him to be on my committee.

Because of the fairly long interval over which this work has been spread, I must especially acknowledge the durable patience of each of my committee members.

Finally, a special tip of the hat is warranted for the generous help that Douglas B. Monteith, at Syracuse University, has given me during the work.

Copies of this report can be obtained from:

Professor Duane Chapman
Department of Agricultural Economics
Cornell University
Warren Hall
Ithaca, New York 14853

Table of Contents

List of Tables and Figures

Chapter 1

INTRODUCTION

Wood has become again a primary heating fuel for many people in New York State. A survey by the Cooperative Extension Service suggests that 1.7 million cords of wood were burned for residential heat during the 1978 - 79 heating season.[1] The relative magnitude of this figure is illustrated by the following comparison. Assuming a cord of New York hardwood contains 2.5 tons of wood, this 1.7 million cords is equivalent to 4.25 million tons of wood. In 1978 the total tonnage of wood harvested from New York forests for lumber, pulp, paper, veneer, and specialty mills combined was approximately 4.197 million tons.[2]

The high cost of oil and electric heat indicate that this consumption of wood is rational in the best tradition of economic theory. As this report will show, heating a home with wood can be cheaper than heating with fuel oil or electric systems in much of New York. The importance of recognizing this penetration of wood into the residential heating fuels market is heightened by the fact that unregulated natural gas prices are also rising dramatically.

---

[1] Pellerin, et.al. Wood Energy Survey 1979, Cooperative Extension, and Agricultural Engineering Department, Cornell University.

[2] Burry, Harry W., Forest Biomass Use and the Primary Wood-Using Industries of New York., SUNY-Syracuse, February 1980.

The chapters of this report vary greatly in terms of how much of the content is original work by the author. This fact is presented both to help the reader judge the author's contribution to the subject area and to help explain the sequence of chapters. One might reasonably expect the subject matter to follow the logic of the production process (i.e. from forests to firewood). The report begins with demand for fuelwood and heating cost simulations because the major work of the author is embodied in these areas.

Chapter two is concerned with the demand for fuelwood in the residential heating market. Prices of conventional heating fuels are compared and wood is shown to be cheapest. The prices were collected by the author from the actual sellors in the Ithaca area. Natural gas and electricity prices were taken from the 1980 annual report of NYSEG. Heating oil prices were obtained from Agway petroleum, Inc. Wood prices were taken from classified ads in the Ithaca Journal.

In chapter three a long term heating cost simulation which incorporates capital and variable costs and tax effects is used to compare conventional and wood heating systems. The cost simulation model is described and results are presented. The conclusion that wood is one of the best heating alternatives is reviewed within scenarios of higher investment in insulation. Also, a scenario wherein gas prices are equivalent to those of oil is shown to indicate that further shifts to wood heating are probable.

This cost simulation model and the assumptions made about heating system costs comprise the largest part of the author's original work in this report. The assumptions about heating system costs and efficiencies are based on conversations with Ithaca area merchants and contractors.

Chapter four is concerned with describing the forest wood resources of New York State. Forested acreage is contrasted with other forested regions of the United States. An important study by Syracuse University of the biomass potential of New York's forest is reviewed. Finally, an estimate is offered for the feasible and reasonable amount of wood that New York can afford to harvest from its forest.

Chapter four is somewhat long when considered as a review of the work of others. The most important part of the content is concerned with the biomass availability study of the School of Forestry at Syracuse University. Nevertheless, the scope and importance of their work requires this much space in this report. The material has been paraphrased and compressed so that little more than their conclusions remain. It is felt by the author that these conclusions are necessary to the perspective this report attempts to convey.

The harvesting technology that extracts a maximum of biomass from the forest is known as whole tree chipping.

Chapter five investigates the costs of production for a modern chipping operation and estimates the resulting minimum price of chips. This chapter recapitulates Jerome Hass's analysis of whole tree chipping's profitability. What is new are Syracuse University's assumptions about the required capital equipment. As such, the chapter is offered here as an updated version of other people's work. Its value to the report is in the way it describes the scale of investment necessary to harvest wood. The derived price of wood chips is also significant to the report and needed updating.

Chapter six examines the proposed Joseph C. McNeil generating station of the Burlington Electric Department. A levelized cost of woodfired electrical generation is calculated and compared with costs calculated for coal and nuclear power by Duane Chapman.

In chapter seven the relative merits of using wood for a residential heating fuel versus using wood to generate electricity are presented. Also in this chapter the author investigates the relevance of electrical generation with wood chips.

In the last chapter the important points of the report are summarized and conclusions are drawn.

Chapter 2

RESIDENTIAL DEMAND FOR FUELWOOD

A history of household firewood consumption in New York State is not available. There is, however, an anecdote to the effect that the last time New York residents burned as much wood as they do now was in 1929. In that signal year 1.8 million cords of wood were used by the residential sector.[3] Since then, wood as a primary cooking and heating fuel has been replaced by coal, oil, natural gas, and electricity.

Heating Fuel Prices

Renewed interest in woodburning can be attributed, in part, to the rising prices of heating oil, natural gas, and electricity. In this regard the demand for fuelwood conforms well to the traditional model of demand. One would expect the key determinants of demand for wood to be its price, the price of substitute goods, and disposable income.[4] There are also significant non-pecuniary factors. A rough examination of the prices of heating fuels over the last decade does show that the prices of oil and natural gas

---

[3] An oral presentation by Robert Sand (Cotton-Hanlon, Inc.) to the 1980 Winter meeting of the Society of American Foresters -- New York Section.

[4] Fuelwood seems to have been an inferior good in the past. The current return to wood by the middle class reverses a pattern of consumption that favored cleaner, more convenient fuels in times of rising income.

have risen. However, their rate of increase has not been greater than that of wood. Table 2.1 shows typical prices of wood, oil, natural gas, and electricity in nominal dollars. The prices are shown in terms of their historical marketing units and units of heat energy they contain. The relative cheapness of wood is slightly exaggerated; woodburning systems do not generally deliver as large a portion of their fuel's potential Btu's into the home as the other systems. The following tables and figures illustrate the relative position of wood prices compared with conventional fuels in the context of the likely energy efficiency of their heating system.

It is interesting to note in figure 2.2 of the series that the price of wood seems to track the price of oil. Whether oil prices are acting as price leaders in the wood market is open to speculation. This orderly relationship was not anticipated by the author when the data were collected.

Natural gas is generally cheaper than all other heating fuels. However, many customers who would like to use natural gas simply do not live close enough to a gas line to tie into the system. In fact, it is only in the last couple of years that partial deregulation and confidence about supply have made this fuel more widely available. There remains a large backlog of people who would like to hook up.

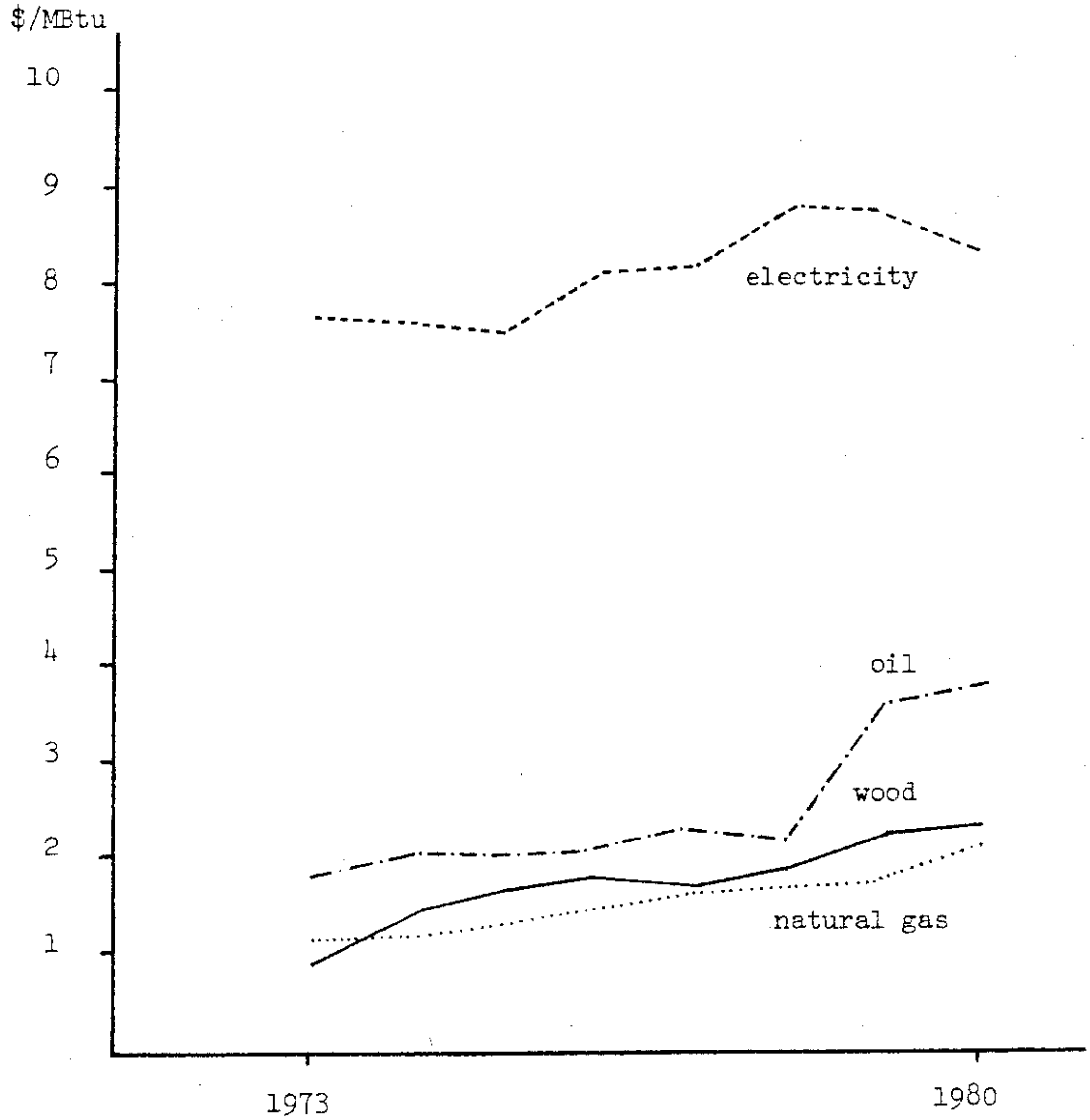


Figure 2.1 REAL PRICES OF HEATING FUELS IN CENTRAL NEW YORK, 1973 - 1980

(prices are in 1972 dollars)

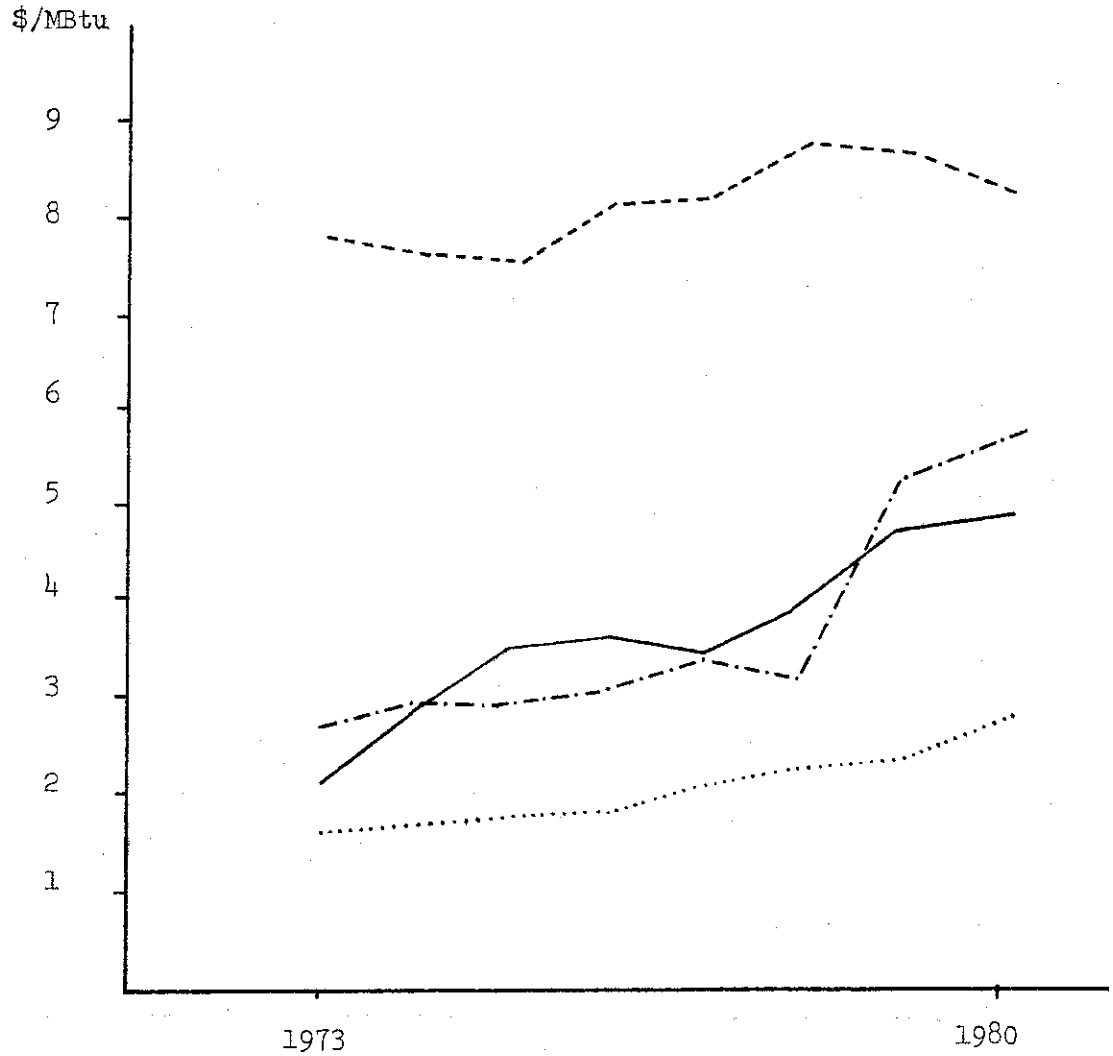


Figure 2.2 ADJUSTED PRICES OF HEATING FUELS IN CENTRAL NEW YORK, 1973 - 1980

(prices are in 1972 dollars per MBtu delivered)

Table 2.1

Fuel Price Comparison
(1970 - 1980)

Prices per marketing unit:

year	N.G.	No.2 Oil	Electricity	Wood
	($/Mcf)	(c/gal)	(c/kWh)	($/cord)
1970	1.09	----	2.44	---
1973	1.40	28.6	2.80	20-3
197[illegible]	1.60	33.9	3.01	25-[illegible]
197[illegible]	1.85	36.9	3.26	50
1976	2.05	39.4	3.71	50-60
1977	2.48	47.1	4.00	50-60
1978	2.79	48.6	4.59	60-75
1979	3.18	85.9	4.98	75-100
1980	4.08	99.9	5.25	100

Prices in dollars per MBtu:

year	N.G.	No.2 Oil	Electricity	Wood
1970	1.07	----	7.15	---
1973	1.38	2.05	8.20	1.11
1974	1.58	2.44	8.82	1.67
1975	1.82	2.65	9.55	2.22
1976	2.02	2.83	10.87	2.44
1977	2.44	3.38	11.72	2.44
1978	2.75	3.49	13.45	3.00
1979	3.13	6.17	14.59	3.89
1980	4.02	7.18	15.38	4.44

Table 2.2

Real Fuel Prices

(1972 dollars per MBtu)

year	N.G.	No.2 Oil	Electricity	Wood
1970	1.17	---	7.80	---
1973	1.30	1.94	7.75	1.05
1974	1.37	2.11	7.63	1.44
1975	1.44	2.10	7.58	1.76
1976	1.52	2.13	8.17	1.83
1977	1.72	2.39	8.28	1.72
1978	1.81	2.29	8.83	1.97
1979	1.88	3.71	8.77	2.34
1980	2.21	3.95	8.45	2.44

Prices adjusted for System Performance Factors:

year	N.G.	No.2 Oil	Electricity	Wood
1970	1.46	---	7.80	---
1973	1.63	2.77	7.75	2.10
1974	1.71	3.01	7.63	2.88
1975	1.80	3.00	7.58	3.52
1976	1.90	3.04	8.17	3.66
1977	2.15	3.41	8.28	3.44
1978	2.26	3.27	8.83	3.94
1979	2.35	5.30	8.77	4.68
1980	2.76	5.64	8.45	4.88

Notes on Table 2.1 and Table 2.2

Fuel Prices:

-- Natural gas and electric prices are based on average residential revenues from NYSEG's 1980 Annual Report. Prices to heating customers would be slightly lower due to incentives built into the rate structure.

-- These oil prices are average prices paid to AGWAY Petroleum Corporation in Ithaca, New York.

-- Wood prices were obtained from the classified sections of March issues of the Ithaca Journal. These are typically the highest wood prices found among the advertisements for cut, split, and delivered 'seasoned' wood.

Energy Content Conversion Factors:

1.015 MBtu per million cubic feet of N.G.
139,200 Btu per gallon of No.2 heating oil.
3,413 Btu per kilowatt-hour of electricity
22.52 MBtu per cord of New York Hardwood.

Fixed weighted price index (1972 weights) :

(taken from the Economic Report of the President 1981)

Year	Index (1972 = 100)
1970	91.7
1973	105.8
1974	115.6
1975	126.0
1976	133.1
1977	141.6
1978	152.3
1979	166.3
1980	182.0

System Performance Factors used in the computation of delivered heat:

N.G.	No.2 Oil	Electricity	Wood
.8	.7	1.00	.5

Just as wood has been substituted for high priced oil and electric heat, the current round of natural gas price increases could drive gas users in the rural and suburban home heating market to woodfuel. If no other fuel is priced lower it is reasonable to suppose that as much wood will be burned as can be obtained. A question that will soon become important is whether this quantity will exceed the forests ability to regenerate.

The only other fuel that is currently cheaper than wood is coal. At 1980-81 retail prices near 100 dollars per ton and with an average energy content of 27 million Btu's per ton, coal is significantly cheaper than any other fuel.[5] That is, 3.70 dollars per million Btu. Moreover, the energy efficiencies of coal stoves and furnaces are generally better than those of wood. The author does not understand why wood is prefered to coal in the home heating market. Probably it is the fact that consumers own trees or have ready access to them.

The Significance of Free Wood

The survey by Cooperative Extension found that only about 14 percent of the firewood consumed in rural and suburban areas was delivered.[6] This implies that the market price of delivered wood is irrelevant to a significant portion of

---

[5] Personal conversations with dealers and merchants.

[6] Pellerin, et.al. Table 4, page 8.

fuelwood consumers. The use of this market price to make economic points is rationalized as follows: The price of delivered wood may be considered a marginal cost price. Although many current users are not effected by it, this is the price which new fuelwood consumers must consider. It is the price against which leisure and recreational values must trade.

Wayne Stoddard, working with Thomas Weaver and Timouthy Tyrrell, recognized the split between wood-buying consumers and wood-cutting consumers. Using regression analysis to analyze the importance of various determinants of the demand for wood, he found it necessary to run regressions for buyers and cutters seperately.

Stoddard's work is titled Household Demand for Firewood in Rhode Island. It explores the determinants of demand for fuelwood as evidenced by a survey of 281 households. The survey instrument was a 36 item telephone questionaire applicable to the 1977-78 heating season.

The Rhode Island survey reveals levels of woodburning similar to those of New York State. Overall, 28 percent of Rhode Island households burned wood. In rural areas 48 percent heated with wood; in urban areas 23 percent did. Among these woodburning households 20 percent were first year wood heaters. Among households using woodstoves the sample share of first year users was 50 percent.

The Rhode Island survey asked households why they heated with wood. More than half the first year woodburners indicated that they wanted to reduce their conventional fuel bills.

Stoddard's demand equations can not be said to indicate anything very surprising about demand for fuelwood. With multiple correlation coefficients of .54 and .23 for wood-buyers and wood-cutters it seems unlikely that levels of consumption could be forecast accurately.

His results do indicate that wood-buying households are easier to model than wood-cutting households. The wood-buying household sample size was 26 and the wood-cutting household sample population numbered 53. Nevertheless the equation for wood-buying households explained much more of the variance in cordage consumed than the regression on wood-cutting household data.

Stoddard's paper is not written with the same objectives as this part of the report, but it is worth mentioning briefly. His modeling effort may be interpreted to support two small points made by this report. First, the poor multiple correlation coefficient of his regression on woodcutting household data suggests the nonpecuniary nature of this sector's decision making. Second, better results with the woodbuying household data indicate that the use of a market price of wood to predict increments in consumption may be reasonable. This only follows if new entrants are

Table 2.3

Rhode Island Cordwood Demand
Generalized Least Squares
Regression Analysis

The dependent variable: cords per household in 1978.

	Wood-Buying Households		Wood-Cutting Households	
Coefficient	Value	t-statist.	Value	t-statist.
Constant	.85	.52	.98	.51
Wood Price	-.03	-1.24	-.02	-.32
Income	.30	2.97	.20	.28
Fuel Cost	.16	.37	.06	.33
Why Burn	.83	1.61	1.94	2.01
Benefits	--	--	.02	.41
	R-sq = .54		R-sq = .23	

Note: As a dummy variable Why Burn = 1 if the primary reason for the household's wood consumption is to save on conventional fuel costs.

Source: Stoddard, W., Weaver, T., and Tyrrell, T., 'Household Demand for Firewood in Rhode Island' Journal of Northeastern Agricultural Council Volume 7, Number 1, April 1979, page 21.

taken to be wood-buyers rather than wood-cutters.

Stoddard's presentation of the survey results and his analysis by regression equations support the premise that the number of woodburning households is growing rapidly. What is frustrating about this kind of demand modeling is that it doesn't forecast or even address the entry of new households into the woodburning sector. Stoddard notes that one of the implications of his demand model is that wood-buying households would burn one more cord of wood each if conventional fuel prices rose by six dollars per million Btu. While this kind of cross-price elasticity is interesting, it is not indicative of the cross price elasticity of aggregate demand. Entrance by some of the other 72 percent of Rhode Island households into the woodburning sector will have a greater effect on consumption than marginal changes in the buying of wood by those who now burn wood.

Residential Demand for Woodburning Systems

The kind of woodburning systems in the market also determine the amount of wood that will be burned. Furnaces, which tend to be the main source of heat in a home, are run nearly continuously. Moreover, they heat the whole home rather than just a portion of it. Accordingly, they consume a great deal more wood over the winter than stoves and modified fireplaces. A knowledge of the installed woodburning equipment in the residential sector of New York State would be useful data for estimating the State's annual consumption of firewood.

In a study by Cooperative Extension related to the wood-user survey it was noted that in New York State from 1977 to 1978 sales of woodstoves increased by 48 percent.[7] This portion of the study surveyed dealers, and it revealed that wood furnaces also jumped in sales over the same period. In the case of wood furnaces the increase in sales was 32 percent.[8] The tabulations were that annual sales jumped from 11,607 tc 17,278 for woodstoves and from 2,564 to 3,372 for wood furnaces. These figures apply only to 16 distributors of stoves and 8 distributors of furnaces -- out of a known total of 125 distributors and manufacturors throughout the State. Thus the annual sales of woodburning equipment could well be greater than 100,000 units for that year.

The sale of 100,000 woodburning systems is quite significant for the consumption of fuelwood. Cooperative extension's wood user survey found that an average of 3.67 cords of wood were burned in each woodstove and that slightly more than 8 cords were burned in each furnace that winter.[9] Given such average levels of consumption, 100,000 new heating systems would add more than a quarter of a

---

[7] Ibid, page 12.

[8] Ibid, page 5.

[9] Ibid, page 13.

million cords of wood to the State's total annual consumption of fuelwood.

The surge in demand for woodburning heating systems is perhaps explained by many factors. Some of them are intangibles. It seems reasonable that fear of an oil embargo and the satisfaction of seeing next year's heating fuel stacked neatly in the yard are both habits of thought that have contributed to the sales of woodstoves and furnaces. However, there is one very concrete fact that permits these intangibles to come into play. When all the costs are taken into account, a full twenty years of heating with wood is cost competitive with, and often significantly cheaper than, heating a home with other fuels.

Chapter 3

LONG RUN HEATING COST COMPARISONS

The previous chapter began with a comparison of the prices of various fuels. Consumers should be aware that fuel bills represent only a part of the total cost of heating a home. The cost of fuel is a highly visible and ongoing expense, but total heating cost must also include the expense of buying the equipment. To be realistic, many factors, such as the design of the building, its orientation, and the materials used in walls, affect heating costs and are virtually inseparable from the cost of the home. For the purposes of this analysis the situation has been greatly simplified.

Even with simplification, computing the cost of heating

---

[1] This cost calculation is adapted from: Duane Chapman, 'Taxation and Solar Energy', Consultant Report -- California Energy Commission June 1979, pp. 98.

The model described here was developed by the author, and used previously in:

D. Chapman, K. Cole, and M. Slott, 'Energy Production and Residential Heating: Taxation, Subsidies, and Comparative Costs', prepared for the Ohio River Basin Energy Study.

Kathleen Cole, Comparative Space and Water Heating Costs in New York State, Dept. of Agcicultural Economics staff paper number 80 - 8, Cornell University February 1980.

Kathleen Lynn Cole, Tax Subsidies and Comparative Costs for Utilities and Residential Heating in New York ,Master's Thesis, Cornell University, January 1981.

is very complicated. Beyond the costs of a suitable stove or furnace and wood to fire it, there are financing and maintenance costs. For additional complexity, part of the home's assessed value must be attributed to the heating system; therefore some part of the property tax payment must be considered a heating expense.

Built into the Federal and State personal income tax systems are provisions which partially offset the above costs. In calculating taxable income the payments of local property tax and interest on loans are both deductable. Since the heating system accounts for some of the property tax paid, it follows that it must account for some of the income tax saving that results. In the same manner the cost of borrowing money to buy and install the system is partially offset by income tax savings. Lastly, payment of state and local sales taxes may also be deducted from gross income. Sales tax may be a component of installation and maintenance expenses, and is certainly a component of fuel costs.

To put matters concisely, each year the cost of heating a home may be expressed by the following general equation:

$$\text{Annual Heating Costs} = \text{Finance Payment} + \text{Maintenance Expense} + \text{Fuel Cost} + \text{Property Tax} - \text{Tax Savings}$$

Finance and property tax payments are assumed to stay constant over the 20 year period, but inflation changes the fuel, maintenance, and tax components.

Because of the variation in annual heating costs it is useful to consolidate the stream of annual costs into one base year present value term. Such a lump sum present value term would be sufficient to allow a comparison among different heating systems with their differing streams of costs. To put a heating cost term into the same scale as other elements of a household's budget, the cost simulation generates an annual equivalent cost term.

The annual equivalent cost is a quantity more easily explained by describing its derivation than by any attempt at concision. For each of 20 years, expenses and tax savings are added to generate that year's net cost of heating. Each year's cost is discounted back to its value in terms of 1980 dollars. These present value terms are summed up into one aggregate that represents 20 years' worth of heating service. This is the lump sum present value referred to in the above paragraph. The annual equivalent cost term recognizes a preference for money now, rather than later, by treating the present value of aggregate cost as a principle to be paid off like a mortgage. It is as if the entire present value of the stream of heating costs was borrowed from a bank and repaid with interest in equal annual installments. It should be noted that the equal payments and the 'real world' uneven payments would, in the end, be of identical worth.

Operating Definitions and Equations

The first step in the cost simulation program assigns values to the 14 exogenous variables listed in table 3.1. These values must be specified by the user and constitute a scenario. The following paragraphs make explicit the operating definitions and equations used in the computations.

The finance payment, or system payment (SP), is simply the total capital cost of buying and installing the heating system (CPTLC) spread by an amortization factor (AMF) over the repayment period of the loan (POL).

$$SP = CPTLC * AMF$$

$$\text{where } AMF = \frac{DISCR * (1 + DISCR) ** POL}{[(1 + DISCR) ** POL] - 1}$$

The annual maintenance expense (AME) is assumed to be a 'clean & check' whose price in the base year (CAME) rises along with the cost of living at the general inflation rate (INFIR).

$$AME = CAME * (1 + INFIR) ** YR$$

Fuel costs (AFC) are a function of the price of fuel in the base year (FUELC), the heating needs of the home (AHBTU), and the energy efficiency of the heating system (EEOS). The first year's fuel costs would be:

Table 3.1

Exogenous Variables
for Cost Simulation

1) CPTLC ... Capital Cost of System (dollars)

2) LIFET ... Expected Life of System (years)

3) CAME .... Base Year Maintenance Expense (dollars)

4) DISCR ... Discount and Interest Rate

5) PRTXR ... Property Tax Rate

6) SITXR ... State Personal Income Tax Rate

7) FITXR ... Federal Income Tax Rate

8) PCI ..... Repayment Period of Loan (years)

9) FUELC ... Base Year Fuel Price ($/MBtu)

10) AHBTU ... Annual Heating Load (MBtu)

11) EEOS .... Energy Efficiency of System

12) SLSTR ... Sales Tax Rate

13) INFLR ... General Inflation Rate

14) RCIR .... Rate of Real Price Increase for Fuel

FUELC * AHBTU / EEOS

Subsequent yearly fuel costs would depend on the rate of inflation (INFLR) and the rate at which the the real price of fuel increases (RCIR):

AFC = AFC(-1) * (1 + INFLR) * (1 + RCIR)

Property tax may vary with the county of residence. Tompkin's County, where Cornell is located, sets its valuations and rates (PRTXR) so that annual tax (PTX) equals 2.556 percent of market value. The assessed value of a home with a heating system in place will not be effected by the retrofitting of a new one. Nevertheless, if a heating system is purchased and installed in a new home, its share of the property tax expense is:

PTX = CPTLC * PRTXR

Basically, both state and federal tax savings (STX & FTX) result from the deduction of interest expense, property tax payments, and sales tax payments from otherwise taxable income. The computations of tax savings are easier to explain if they are broken down into these categories:

(a) deduction of interest payments:

The interst component of the system payment (SP) varies over the entire period of repayment according to the following formula:

Interst Expense(t) = CPTLC * DISCR * H(t)

where, H(1) = 1

and, H(t) = H(t-1) * (1 + DISCR) - AMF

for t = 2, 3, ... , POL

(b) deduction of local property tax payments:

These payments are assumed to be constant over the period of analysis.

(c) deduction of sales tax payments:

The amount of sales tax paid each year will depend on the amount of fuel purchased each year. It will also depend on whether the heating system was purchased as part of a new home or was retrofitted on an existing home. In the case of the system being purchased as part of the new home, the buyer does not pay any sales tax.

In New York State 7 percent is added to the price of a good as sales tax. In the case of retrofitting it is assumed that the entire sales tax expenditure would be deducted in the first year even though the system payments are spread out over 4 years. The following formula computes sales tax payments (SLSTX) with an appropriate dummy variable.

$$SLSTX(t) = SLSTR * AFC(t) + (SLSTR*CPTLC*DUMMY(t))$$

where DUMMY(t) equals zero when $t > 1$

The tax savings on New York State Personal Income Tax result from the deduction of the above expenditures from taxable income each year. The State Tax Savings (STX) will thus be the total of these deductions times the marginal tax rate of the State (SITXR). Thus:

STX(t) =

((CPTLC*H(t) *DISCR)+(PTX)+(SLSTX(t))) * SITXR

The Federal Income Tax Savings (FTX) are similarly computed except that the savings from the State Income Tax increase the Federal taxable income. Thus:

FTX(t) =

((CPTLC*DISCR*H(t))+(PTX)+(SLSTX(t))-(STX(t))) * FITXR

Finally each year's total tax savings are simply the sum of the State and Federal Income Tax Savings.

The preceding calculations define the five components of each year's heating cost. These annual costs [C(i)] can be reduced to a present value term as expressed in the following equation:

$$P.V. = \sum_{i=0}^{i=(LIFET-1)} \frac{C(i)}{(1 + DISCR) ** i}$$

When this aggregated cost term is multiplied by an amortization factor which is calculated for a period equal to the life of the system, the result is the annual equivalent cost of heating with the system.

Annual Equivalent Cost = (P.V.) * AMF

$$\text{where } AMF = \frac{DISCR * (1 + DISCR) ** LIFET}{[(1 + DISCR) ** LIFET] - 1}$$

Model Assumptions

What follows is a discussion of the economic and financial assumptions of the model. These assumptions, together with other general features of the cost simulation model, are presented in table 3.2. Table 3.3 goes on to list assumptions specific to each heating system. These values are the basis for the comparison of heating system costs that will follow.

It is assumed that the characteristics of the home are such that 116 million British thermal units (MBtu) are required each year. This heating load is the amount of energy that must be released into the structure to maintain an ambient temperature of 65 degrees Fahrenheit. As used here it represents the heating needs of a middle income family. It is based on heat loss calculations for a hypothetical 4-bedroom house in a location with about 7000 heating degree days.[2]

The choice of an inflation rate for the next 20 years is not an act of precise judgement. There are two inflation rates in the model. One is a general inflation rate of 9 percent. The other is a 3.5 percent rate of increase in real fuel prices. The two are not additive; they are

---

[2] There are about 7000 heating degree days each year for central New York State. Source: The American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc., ASHRAE Guide and Data Book, 1970., as quoted in: Bruce Anderson, The Solar Home Book, Brick House Publishing Co., Inc. Andover, Massachusetts, appendix 1.4, pp. 273

Table 3.2

General Assumptions for Heating Cost Analysis

Climate	7000 degree days
Annual Heating Load	116 MBtu 58 MBtu (insulated)
General Inflation	9 percent
Real Rate of Fuel Price Increase	3.5 percent
Interest and Discount Rate	12.27 percent
Expected life of System	20 years
Financing Period	20 years (new home) 4 years (retrofit)
Amortization Factors	.33109 (4 years) .136151 (20 years)
Property Tax Rate	2.556 percent
Sales Tax Rate	7 percent
NY State Personal Income Tax Rate	14 percent
Federal Personal Income Tax Rate	28 percent

Table 3.3

Heating System Assumptions
for Cost Simulations

Type of System	Purchase Cost	Energy Efficiency	Base Year Fuel Cost
	(dollars)		(dollars/MBtu)
Forced Air Furnaces:			
Coal	3500	.7	3.70
N.G.	2500	.8	4.02
Wood	3000	.5	4.44
Oil	3200	.7	7.18
Electrical Systems:			
Heat Pump	5500	1.8	15.38
Electric Resistance	1800	1.0	15.38
Stoves:			
Coal	1000	.5	3.70
Wood	1000	.4	4.44

multiplicative. The increase in nominal fuel prices works out to be 12.815 percent:

$$(1 + .09) * (1 + .035) = 1.12815$$

The author's choices are based on intuition rather than analysis of past inflation rates. The author perceives general inflation to be exacerbated by price increases in material and energy imports. As the economic power of the rest of the world grows the prices we pay for these inputs will continue to increase. Fuel costs are accordingly set to rise by more than the general inflation rate. What may hold general inflation down in this country is a culturally ingrained aversion to 'double-digit' rates of inflation. The author presumes this will be translated into political decisions which, although they may not be in the public interest, will keep general inflation at 9 percent.

The interest and discount rate are set at 12.27 percent. Considering inflation, this implies a 3 percent real rate of interest. Nominal interest rates have historically been 2 to 3 percent higher than general inflation.[3] Thus, this rate of interest is probably realistic.

The interest rate is most important in its application toward calculating the financing costs of the heating

---

[3] Chapman, D., Cole, K., and Slott, M., Energy Production and Residential Heating: Taxation, Subsidies, and Comparative Costs Prepared for the Ohio River Basin Energy Study, U.S. Environmental Protection Agency, Washington D.C., 1980.

system. The bias that a low interest rate introduces is to make more capital intensive heating systems cost less.

The expected life of all the heating systems is set to 20 years. Probably heating systems can last longer than this. The undiffering 20 year period of analysis may mask the virtue of longer lived systems, but the author thinks such simplification is warranted.

Payments for the heating system are spread over this 20 year expected life. In reality many system purchases must get financed in a shorter period. The economic justification for spreading the payments out over this length of time is that heating services flow across this period. This payment structure also corresponds to the arrangements for buying a new home.

Because the analysis is most applicable to home buyers, the assumption of a middle-class income is reasonable. The marginal personal income tax rates for state and federal taxable income also follow from this assumption. For example, the marginal personal federal income tax rate on married individuals filing joint returns was 28 percent when taxable income in 1979 was between 20,200 and 24,600 dollars.*

Fuel costs were discussed in the previous chapter. Costs

---

* source: 1980 Federal Tax Course, Commerce Clearing House, Inc. Chicago, Illinois, page 3042.

used in the base year of the simulation are those found for fuels in 1980. These prices are intended to be representative of those in central New York in general.

Costs of various heating systems are also meant to represent the same year and locale. The costs were estimated based on information gained by personal interview of several merchants of heating systems in the City of Ithaca. The author's conclusions were also influenced by discussions with a builder of speculation grade homes and a retired property tax assessor.

What is important about the costs is that they are reasonable and reflect the relative costs of the various heating systems. For example, all forced air furnaces require a chimney, but natural gas requires only an inexpensive one while the others require masonry chimneys. This explains most of the 500 to 1000 dollar difference in the price of natural gas versus other furnace systems.

The coefficients of performance for the various heating systems were also chosen to reflect the rankings of the systems. The author feels that the rankings are correct. The absolute values of the coefficients are reasonable but cannot be considered mean values for some samples of systems.

Results of Cost Simulation Runs

The results of the first set of cost simulations are summarized in table 3.4 as annual equivalent and levelized cost terms for each system. The levelized cost is the system's annual equivalent cost divided by the amount of heat the system releases into the home over the year.

From the annual equivalent costs of the different systems it can be seen that even if wood is purchased at 100 dollars per cord it is still cheaper to heat with wood than with oil or electricity. Coal and natural gas systems, on the other hand, are so cheap that they're nearly in a class by themselves. Electric resistance heating is also in a cost class by itself; it's terribly expensive.

Supplemental systems, in this case stoves, are also analyzed. The amount of heat that the stoves were presumed to contribute was estimated to be 28.9 million Btu per year.[5]

In addition to their small contribution to the annual heating requirements of the home, stoves are presumed to contribute nothing to the amount of property tax paid by the home owner. In all other respects the methodology of

---

[5] This level of heating was derived by multiplying the average amount of wood burned in wood stoves (3.67 cords) by the energy content of wood (22.5 MBtu/cord) and the assumed coefficient of performance of woodstoves (.35) in general.

Table 3.4

Heating System Results from Cost Simulations

Type of System	Annual Equivalent Cost (116 MBtu) (dollars)	Levelized Cost (dollars/MBtu) delivered	An.Eq. Cost with Insulation (58 MBtu) (dollars)
Forced Air Furnaces:			
N.G.	1930	17	1152
Coal	2160	19	1342
Wood	3198	28	1824
Oil	3654	32	2067
Electrical Systems:			
Heat Pump	3468	30	2146
Electric Resistance	5030	43	2650
Stoves:			
Coal	737	26	
Wood	1022	35	

Note that when wood is free (e.g. a wood-cutting rather than wood-buying household) the annual equivalent costs of heating with wood are 405 and 166 dollars for furnaces and stoves respectively. In terms of the delivered heat costs the wood furnace and wood stove then are rated 3.49 $/MBtu and 5.75 $/MBtu.

computing the annual equivalent costs of stoves is the same as that for primary heating systems.

As a consequence of their unequal heat output, the heating costs of stoves and furnaces are not comparable in straightforward annual equivalent terms. In the middle column of table 3.4 the annual equivalent cost of each system is divided by the amount of heat that that system releases into the home. The result of this division is a standardized quantity that permits the cost effectiveness of stoves and furnaces to be directly compared. The results are surprising.

At a levelized cost of 35 dollars per delivered MBtu woodstoves are nearly the least cost effective heating system evaluated. Only electric resistance heating is more expensive.[6] In terms of this levelized cost analysis the brisk sales of woodstoves is a paradox. The question is: what is wrong with the analysis?

The paradox of woodstove popularity is typical. The problem is not so much in the methodology, but in the assumpticns. To begin with, many of the first households to acquire woodstoves spent, as do-it-yourselfers, much less than 1000 dollars. Their cash outlay may have been less than 200 dollars. Likewise, as we have seen, a majority of

[6] The prevalence of electric resistance heating can be attributed to its popularity with developers. It's cheap and easy to install.

fuelwood is not purchased at a delivered price of 100 dollars per cord. For these concrete reasons a realistic annual equivalent cost could be much lower than that used for this analysis. The footnote to table 3.4 makes the situation more clear. Given free wood, woodstoves make sense.

There is an additional, somewhat intangible, problem of comparing the cost effectiveness of woodstoves and conventional heating systems. One cannot set a thermostat on a woodstove and ignore it for several days. Everytime the heat is needed the wood has to be handled. This situation is powerfully conscious-raising. A great deal more conservation is likely to result. This change in lifestyle is not really quantifiable. If the homeowner is willing to make do with half the delivered heat that he might otherwise have purchased, the value of those delivered Btu may be said to have increased. Perhaps instead of assuming a heat output of 28.9 MBtu from 3.67 cords of wood, these 'wood' Btu should be considered equivalent to 50 MBtu of conventional heat.

All these factors and other intangibles may be invoked to explain the paradox of woodstove sales. The most compelling factors are that people cut their own wood and that the attention required by woodstoves changes the way people use energy. To quantify such things as the value people place on fuel gathering labor is conceptually simple. One can assume that the labor is worth no more than the difference between their costs and the total market price of wood. Unfortunately, application of this concept shows that it is not a complete explanation.

Making a cord of 16 inch split logs out of a tree, and transporting this to ones hearth, requires about 10 man-hours. If the household valued its own labor at more than 10 dollars an hour, purchasing a cord of cut, split, and delivered wood for 100 dollars would be a bargain. Alternatively, if even half the time spent getting the wood is considered leisure, the opportunity value that might be placed on an hour of work could be as much as 20 dollars.

The exclusion of the capital investment necessary to fell, buck, haul, cut, and split firewood simplifies the above opportunity valuation and still no concrete point can be made. Valuation of lifestyles is even more ambiguous. The conclusion to be made with respect to economics and woodstove sales is that consumers are either unmindful of costs or they are mindful of more important things.

<u>Insulation Scenarios</u>

The previous section presented the results of cost simulations where the amount of heat needed by the household was quite high. This tends to penalize heating systems with higher fuel costs. To phrase it another way, it favors capital intensive systems by raising the relative share of the expense attributable to fuel. In order to check that the relatively good ranking of wood heat was not just an artifact of very high fuel usage, simulations were made of home heating where insulation had already reduced the amount of heat needed by the home. The annual heating load was set at 58 MBtu (a very modest amount for a 4 bedroom home) and the costs were recalculated. The results in the last column of table 3.4 are not very different. Heat pumps, because of very high capital costs, proved more expensive than the oil heating system. The relative position of wood furnace heating was unchanged.

Scenarios of Oil Equivalent Fuel Costs.

It is a serious question whether or not wood, coal, and natural gas prices can remain uncoupled from what is primarily an oil energy crisis. In order to check alternative rankings of heating systems, cost simulations were run which raised the prices of wood, natural gas, and coal to that of oil. The increase was spread over the five years from 1980 to 1985. All the while the price of oil was assumed to rise, the prices of the other fuels simply rose faster until the costs per MBtu were the same. If all prices are presumed to be the same than the analysis is very simple. All that matters are the capital costs and energy efficiency of the systems. What is more interesting is the scenario wherein only natural gas becomes as expensive as oil. It has already been mentioned that since natural gas is cheaper than wood there is no economic rationale for people to convert from gas to wood. When natural gas prices are assumed to rise to those of oil, home heating costs do not become greater than wood heating costs. In terms of annual equivalent costs the price of natural gas heating rises from 1930 dollars to 2798 dollars. Even this dramatic increase leaves natural gas heat cheaper than wood furnace heating which is 3198 dollars. Nonetheless, the tremendous difference in cost between wood and natural gas is narrowed significantly by these assumptions.

In order to examine a more dramatic price increase for natural gas the model was run using the base year price of heating oil (7.18 dollars per MBtu.) as a price of natural gas. This scenario brought the annual equivalent cost of natural gas heating to nearly the same level as wood furnace heating. Natural gas annual equivalent costs worked out to 3153 dollars. The implications of this analysis are that when natural gas prices equal heating oil prices it will cost just about as much to heat with natural gas as with wood.

Summary

When analyzed over a 20 year period wood, even at a market price of 100 dollars per cord, is competitive with most conventional heating fuels. The annual equivalent cost calculations suggest three cost classes of heating systems. Electric resistance heating at 5030 dollars per year is most expensive. In the middle grouping of wood, heat pump, and oil furnace systems, wood is the least expensive over the long run. Coal and natural gas systems are well below wood in their annual equivalent cost. However, if the analysis is done with natural gas priced as high as oil, a natural gas system's annual equivalent cost joins the middle group at 3155 dollars per year.

In New York State natural gas accounts for 36 percent of the Btu's used in residential space heating.[7] This large share of the home heating market makes any potential shift by consumers of natural gas to wood heat very important. The recent increased rate of sale of woodstoves probably didn't involve many households that currently heat with natural gas. If dramatic increases in the price of natural gas promote a shift of these households to wood heat, the result would likely be very high wood prices and a large increase in the amount of wood cut for fuel.

---

[7] New York State Energy Office, New York State Energy Master Plan and Long Range Electric and Gas Report, Final Report March 1980 - Appendices, (Albany: State Energy Office, 1979); page 41.

Chapter 4

A DESCRIPTION OF NEW YORK FORESTS

This chapter describes New York's wood resources and contrasts them with those of other forested areas of the United States.[1] It is hoped that this overview will help the reader to judge the appropriateness of fuelwood consumption in the context of our relative resource wealth.

Acreage

New York State has a total land area of 30.6 million acres. It is relatively well forested; over half of New York is forest land. Table 4.1 shows the absolute acreage and the relative proportions of various classes of land within New York. Note that 14.5 million acres are classified as commercial forest land. This is land that is distinguished from other forest land by it's ability to produce crops of industrial wood.[2] Some productive forest land is withheld by statute from legal harvesting and is called productive reserve land rather than commercial forest land.

---

[1] Most of the descriptive statistics in this chapter are taken or derived from statistics found in: USDA, Forest Service, Forest Statistics of the U.S., 1977. U.S. Government Printing Office, Washington D.C., 1978.

[2] Industrial wood is defined to be all roundwood products except fuelwood.

Table 4.1

Land Areas of New York

Land Classification	Acreage	Share of Area
Forest land:		
Commercial	14,489,000	.473
Productive Reserve	2,480,900	.081
Other (unproductive)	407,800	.013
total forest	17,377,700	.568
Range Land	1,800	.000
Other Land	13,232,300	.432
Total Land	30,611,800	1.000

Source: USDA, Forest Service, Forest Statistics of the U.S., 1977, U.S. Government Printing Office, Washington D.C., 1978, pp. 1

For the U.S. as a whole, just less than one third of total acreage is classified as forest land, and only 21.5 percent of all land is classified as commercial forest land. While New York is well above this national average, the comparison with a national average is inappropriate. It must be noted that rainfall is insufficient to sustain natural forest in many areas of the United States. The West Gulf, the Great Plains, and the Rocky Mountains are large areas whose lack of forest considerably depresses the national average. Since their lack of forest can not be attributed to the land use practices of their populations it seems irrelevant to compare them with New York's level of forestation. On the other hand, lack of forest in New York is directly attributable to land use decisions because trees can grow almost anywhere in New York State. From the point of view of land use policy and woodfuel's place in the total energy supply, what is meaningful is not absolute forested acreage but the opportunity costs associated with allowing potentially productive forest land to be unforested. Thus, in addition to pointing out that New York is 57 percent forested, it should be noted that most of the unforested acreage could be forested.

Comparing New York to regions that are noted for their forests gives a truer picture of the relative forestation of the State.[3] New England, at around 80 percent, is

---

[3] Regions are defined as follows:

considerably more forested than either New York or the rest of the Middle Atlantic region . The South, after one excludes the Western Gulf States, is 60 percent forested, and this puts it slightly ahead of New York's 57 percent. Perhaps the big surprise among regional comparisons is that New York is about as forested as Washington and Oregon. Their combined forest cover amounts to 51 percent of their total land area. There are, however, areas of these states that can't naturally sustain forests.

Before ceasing to contrast acreage, it should be mentioned that although New York ranks 19th among all states in absolute forest acreage, it ranks 3rd in the amount of forest land set aside as productive reserve. There continues to be some controversy over the amount of potential commercial forest land that is excluded from legal harvest.

On a more speculative note, it should be questioned whether New York's forest acreage has stopped expanding. A considerable amount of farm land (almost 2 million acres) has reverted to forest since World War II.[4] The Forest

---

New England: Conn.,Maine,Mass.,N.H.,R.I.,and Vermont

Mid-Atlantic: Del.,Md.,N.J.,N.Y.,Penna., and W.Va.

South: N.Car., S.Car., Va., Fla., Ga., Ala., Miss., Tenn., and the West Gulf States of -- Ark., Okla., and Texas.

[4] USDA, The Timber Resources of New York, Forest Service Resource Bulletin NE-20, 1970, pp.16.

Service believes that this kind of abandonment has stabilized in New York. Nonetheless, there remains considerable farm acreage of low productivity. It is difficult to say why abandonment won't continue.

Species

New York forests, like those of the rest of the Middle Atlantic region, are mostly hardwood. For New York 75 percent of net volume is hardwood. It is reasonable to assume that the greater amount of wood biomass available for fuel conforms to the same species distribution. The Middle Atlantic region as a whole is 87 percent hardwood; and so one might conclude that New York forests are of a piece with some large regional forest type. Unfortunately, the typology is not so straightforward. The Middle Atlantic states comprise a region that extends across many soil types, elevations, and climates. Northern New York grows forests that are very similar to those of New England. Spruce and other conifers are a major part of the wood stock. However, the Southern Tier's forests have more in common with those of Pennsylvania where hardwood species predominate. Tables 4.2 and 4.3 enumerate by region the net volumes of important hardwood and softwood species found in the East.

Table 4.2

Net Volume of Hardwood Growing Stock on Commercial Timberland of Selected Regions, By Species

(million cubic feet)

Hardwood Species	New York	Mid-Atlantic	New England	South
Select white oaks	276.4	4283.2	497.9	10,426.4
Select red oaks	889.5	5769.5	2017.6	4,715.1
Other white oaks	254.0	4647.8	59.4	9,698.9
Other red oaks	139.5	4123.5	788.6	20,444.6
Hickory	284.9	2372.5	203.1	8560.5
Yellow birch	433.3	836.8	1658.9	52.9
Hard maple	2206.7	4758.8	3160.5	549.4
Soft maple	1799.7	6729.7	4142.9	4,234.8
Beech	862.2	2526.1	1346.4	1,238.7
Sweetgum	.0	394.5	.0	12,862.2
Tupelo & blackgum	.0	404.8	.0	10,381.2
Ash	667.3	1852.1	860.8	2,984.0
Basswood	423.5	1010.5	87.8	355.7
Yellow poplar	42.9	2625.9	.0	7,536.4
Cottonwood & aspen	464.0	1140.7	1056.8	586.2
Black walnut	2.7	191.3	.0	259.8
Black cherry	352.6	2893.7	217.7	291.1
Other hardwoods	859.5	3472.3	2374.4	9,098.8
TOTAL	9958.7	50033.7	18472.8	104276.7

Table 4.3

Net Volume of softwood growing
Stock on Commercial Timberland
of Selected Regions, By Species

(million cubic feet)

Softwood Species	New York	Mid-Atlantic	New England	South
Longleaf and slash pines	.0	.0	.0	16,783.3
Loblolly and shortleaf pines	.0	657.0	.0	64,133.5
Other yellow pines	23.7	1266.3	109.0	8,133.4
Eastern white and red pines	1442.8	2290.7	4918.8	1,203.3
Spruce and balsam fir	738.5	925.5	14,210.8	23.3
Eastern hemlock	1229.1	2348.3	2741.9	372.7
Cypress	.0	.0	.0	5486.2
Other softwood	170.2	267.7	1708.4	669.0
TOTAL	3,604.3	7,755.5	23,688.9	96,804.7

Source: USDA, Forest Service, Forest Statistics of the U.S., 1977 U.S. Government Printing Office, Washington DC., 1978, pp. 69.

Timber Volume and Biomass Estimates

While acreage, as a fixed input, is pertinent to long run expectations about wood yield from our forests, any harvest policy must recognize the crop of trees now standing and growing in the forest. As of January 1977 the estimated net volume of wood on New York's commercial timberland was 16,397.4 million cubic feet.[5] Closer scrutiny of this figure illustrates the difficulty of using Forest Service numbers to answer question about fuelwood quantity.

By definition, net volume is gross volume less the volume of rotten wood. Unfortunately, the measure and definition of gross volume excludes a considerable amount of biomass that is pertinent to the issue of fuelwood. For example, seedlings and saplings (i.e. trees less than 5 inches in diameter at breast height [dbh]) are excluded from measures of gross volume. Also excluded from gross wood volume, and hence from net volume, are the branches and tree tops that would be left in the forest after conventional harvesting. Furthermore, it ought not be assumed that small trees are inevitably young trees. If a stand of trees is sufficiently dense, competition for sunlight and nutrients may result in even 20 year old trees being less than 5 inches dbh. Thus a

---

[5] Op.Cit., pp.33.

considerable, and variable, portion of usable biomass is excluded from the Forest Service statistics.

Historically, this problem is an artifact from the period when the users of Forest Service data were presumed to be from the woodusing industry which was primarily interested in the volume and species of harvestable trees. The Forest Service is aware of this problem and is adapting its survey procedures so that it can tabulate biomass.

The appropriate measure of fuelwood quantity is its mass together with a measure of moisture content. For the reasons listed above it is difficult to derive biomass estimates from the measures of volume published by the Forest Service.

The Wood Biomass

The previous section emphasized the problem of applying Forest Service data to an estimate of biomass. For the purposes of this report biomass is defined to be the wood and bark found above ground in trees. Small saplings and branches are included; roots, stems, and leaves are excluded. The rationale is to consider only the biomass that can reasonably be expected to emerge from the forest in an operation as thorough as whole tree chipping.

Douglas Monteith's work, Whole Tree Weight Tables for New

York, underlies all the following estimates of biomass.[6]

The whole tree weight tables are tables of average weight for various portions of trees found in New York State. The tables enable one to estimate the weight of a tree or its parts, green or oven-dry, so long as the diameter at breast height is known. The tables were compiled by sampling species of New York trees in representative growing conditions around the State. The trees were hoisted by a crane and physically weighed. They were methodically trimmed and cut into sections of specified diameter. Each of the portions were weighed in turn. Slices and wedges of the green trees were dried and weighed. The comparison of their weights before and after drying was used to estimate dry weights. Finally, the data were condensed into weight tables using ordinary least square regression analysis.

Subsequent work to identify the available biomass in New York forests has recently been completed at the University of Syracuse's School of Forestry.[7]

Monteith's weight tables were given to the Forest Service which then applied them to primary data from their survey plots. The biomass estimates from these plots were

---

[6] Monteith, D.B., Whole Tree Weight Tables for New York, College of Environmental Science and Forestry, AFRI Research Report No. 40, State University of New York, Syracuse, April 1979, pp.64.

[7] Burry, Canham, Monteith, and Neuroth., The Availability of Forest Biomass In New York (review draft 4/24/80), School of Forestry, SUNY--Syracuse, Syracuse, New York

extrapolated to the rest of the State using information about land use from several sources. Included were Cornell University's Land Use and Natural Resource (LUNR) study, earlier surveys by the College of Environmental Science and Forestry at Syracuse University, and information obtained from the New York Department of Environmental Conservation on publicly owned forest land.

In the Syracuse study the nearest classification of land to what is here called commercial timberland is 'total non-preserve land.' Their total biomass figure for this class of land is 1.1604 billion conventional tons of dry biomass. Discounting this figure by five percent (for leaf and stem material) suggests a total of 1.1023 billion dry tons of wood biomass.

For the rest of this report, the biomass estimates made by Burry, et. al. will be used as the biomass potential for New York. This study will be refered to as the Syracuse study.

Net Growth of Biomass

The figures for annual growth of wood presented in the section that described New York forests were applicable to growing-stock volume. For reasons already presented it is not possible to make estimates of total net growth of biomass from those figures. The Syracuse study indicates that there is annual growth of about 19.2 million dry tons.[8] Again, discounting 5 percent for leaf mass, this implies that total wood biomass growth is about 18.24 million dry tons per year. Were this growth to be distributed evenly over the entire 14.5 million acres of commercial forest land, it would amount to 1.26 dry tons of wood biomass per acre per year. It is interesting to note that this works out to about 19.62 million Btu worth of seasoned wood or a little less than a cord per acre. The Syracuse study also suggests that about two-thirds of this biomass would not be suitable for industrial use.[9] In other words, much of the forest's annual biomass increment to the standing wood is not useful as factor inputs to the paper, lumber, or veneer industry (except perhaps as fuel).

Limitations Imposed by Geography

The above wood biomass figures, both for standing trees and annual growth, are totals for New York State land that is legally harvestable. It remains to be asked what portion of this wood is technically harvestable. Again the Syracuse study has the best available estimate. Their rule of thumb is that if the forest has less than a 30 percent slope and is within 3 kilometers of an all-weather road then the wood on it can be obtained 'readily'. Areas not meeting these criteria would only be accessible if special investment in

---

[8] *Ibid*, page 97.

[9] *Ibid*, page 97.

road building and harvesting equipment were made. The Syracuse study finds that about 93 percent of New York State forest meets the criteria of ready accessability.[10] I consider that a like percentage of the wood biomass and annual growth is thus geographically available. This brings the practical supply of wood biomass in terms of stock and flow down to: 1.02 billion dry tons standing and 16.91 million dry tons annual growth.

Social Constraints on Biomass Availability

Wood biomass, whether harvested for fuel or some other use, will come from land that is classified as commercial forest land. Such land is the greater part of New York's forest. Recall that it constitutes more than 80 percent of forested acreage. Table 4.6 shows how the ownership of commercial forest land is distributed within the public and private sectors. More than 85 percent of commercial forest land is owned by firms and individuals that do not make direct commercial use of the wood. Companies and individuals that do operate wood-using plants own not quite a tenth of this land. Slightly less than five percent is owned by the State, and local and Federal lands combined barely exceed one percent.

The above statistics serve to show that the private non-industrial forest owner is a most important social actor

---

[10] Ibid, page 18.

Table 4.6

Ownership of Commercial
Forest Land in New York

Ownership	Acreage	Share
Private:		
Farm	3,583,000	.247
Other private	8,833,700	.610
Forest Industry	1,180,300	.081
Public:		
County and City	123,100	.008
State	711,400	.049
Federal	57,500	.004
Total	14,489,000	.999

Source: USDA, Forest Service, Forest Statistics of the U.S., 1977, U.S. Government Printing Office, Washington DC., 1978, page 1.

with respect to control of the wood resources of the State. There may be as many as 300,000 owners of woodland in New York State.[11] Surveys by Hugh Canham in the late sixties showed that 41 percent of this land was held by non-farm working owners, 14 percent by retirees, 6 percent by private organizations and clubs, and 20 percent by farmers.[12] To further describe the private non-industrial owners of forest land it is useful to examine the statistics of socio-economic status from Canham's 1969 surveys.[13] These owners were mostly 40 to 65 years old. Owners with 1969 income less than 6,000 dollars held 34 percent of total commercial forest land. The 6 to 10 thousand dollar income class held 21 percent of commercial forest land. Perhaps surprisingly, only 18 percent of this land was held by owners whose income exceeded 10 thousand dollars in 1969. As might be expected, the level of education correlated well with income, and the older owners tended to have less education.

This description of forest ownership suggests that there are a number of small tracts of forest land. In his own words Canham puts it succinctly:[14]

---

[11] Canham, Hugh O., Forest Ownership and Timber Supply, School of Environmental and Resource management, State University of New York, Syracuse, New York, 1973, page 98.

[12] Ibid, page 8.

[13] Ibid, pages 7 and 10.

[14] Burry, Canham, Monteith, and Neuroth., The Availability of Forest Biomass In New York (review draft 4/24/80), School of Forestry, SUNY--Syracuse, Syracuse, New York, page 33.

> 'Over half (55 percent) of the private forestland in New York, 7.3 million acres, is in tracts less than 250 acres in size; one third, 4.5 million acres, is in tracts of less than 100 acres; one fifth, 2.7 million acres, is in tracts under 50 acres in size. At the other end of the spectrum, 28 percent of the private forest land, 3.8 million acres, is in large tracts, those over 1,000 acres in size.'

The land discussed in the above quote includes the land held by the wood-using industry. The large tracts are most likely to be held by the industry.

The implication for biomass availability is that permission to harvest the forests will have to be obtained from people whose age, income, and education vary across the range found in rural society. The relatively low income of so many woodland owners is particularly intriguing because of the questions of equity versus resource management that it introduces.

Canham found that slightly more than 20 percent of the landowners were not planning to allow timber harvest anytime in the future.[15] Personal Conversation with Canham, as well as other foresters, suggest that this apparent constraint is not necessarily binding. In their view, it is not required that each woodlot owner contract for the harvest of his trees. It is sufficient that they be willing to sell their land to others who would do so. The average length of land

---

[15] Ibid, page 40.

tenure is such that at the present rate of turnover more than 80 percent of the commercial forest land could be sold over the next 25 years.[16] Thus, if future rounds of buyers are sympathetic to harvesting, opposition of even 20 percent of current owners would have little effect on long term supply.

This report takes a more conservative view of the issue of social availability of wood biomass. There is no way to predict the future cohort of woodlot owners. Opposition to fuelwood harvest could grow as more logging is practiced. It is perhaps prudent to accept the survey findings at face value and assume that 20 percent of private non-industrial owners will not permit harvest. If we consider that these owners control about 85 percent of commercial forest land, and that the geographic constraints discussed previously also apply to their land, then their opposition can only reduce the available biomass by:

20 percent * 85 percent * 93 percent

This amounts to slightly less than 16 percent of the total commercial forest land. So finally, the stock and flow of available biomass has been whittled down to 857 million dry tons (standing wood) and 14.21 million dry tons annual growth per year. Table 4.7 recapitulates all the arithmetic of these sections on biomass potential and availability.

---

[16] Canham, Hugh O., <u>Forest Ownership and Timber Supply</u>, School of Environmental and Resource management, State University of New York, Syracuse, New York, 1973, page 91.

Table 4.7

Summary Accounting of Biomass Availability From Commercial Timberland in New York State

(million dry tons)

	Standing Stock	Annual Growth
Biological Potential	1160.4	19.2
net of leaf mass (5 percent)	1102.3	18.2
net of inaccessable (7 %)	1020.0	16.9
net of no-sale (20 percent)	857.0	14.2

Chapter 5

WHOLE TREE CHIPPING PRODUCTION COSTS

It has been estimated that about 3000 people harvest and market timber on at least a part time basis.[1] Close to one third of the loggers surveyed by Monteith and Tabor reported that they did not work full time in logging.[2]

The capital investment involved in a logging operation can be a very small or great amount. The technology runs a gamut that recapitulates the entire course of the industrial revolution. However, the business of getting a lot of wood out of the forest requires roughly a quarter of a million dollars worth of buildings and equipment. Monteith and Tabor found that for those willing to respond to the questions, the average capital investment was more than 121 thousand dollars.[3] This average is based on historical costs. Replacement costs for this capital would be much higher.

The capital costs of a modern whole tree chipping operation are a serious barrier to entry. The following paragraphs analyze the fixed and variable costs of a large scale whole tree chipping operation.

---

[1] Monteith, D.B., and Tabor David, Profile of New York Loggers, Applied Forestry Research Institute, Research Report No.38, SUNY--Syracuse, February 1979.

[2] Ibid, Appendix A, page A-1.

[3] Ibid, page 10.

The Syracuse study advises that the capital equipment listed in table 5.1 would be necessary to sustain a WTC business. Note the considerable cost that would be incurred if this capital were purchased new.

From assumptions about production one may derive an average cost or price for wood chips. What is necessary is that an annual level of production be assumed and that a price be set on each unit of production such that gross receipts cover variable costs and allow a reasonable return on investment. The following calculations follow a format developed by Cornell Professor Jerome Hass.*

Production Specifications

To begin with it is necessary to make some assumptions about production. At 10 vans per day, 23 tons per van, and 260 days per year, the total production works out to be 59,800 tons per year. For the purposes of calculation we shall assume that this system can produce 60,000 green tons of wood chips each year. Furthermore, if equipment is presumed to last 12,000 operating hours, then 260 days per year, and 8 hours per day usage imply a duration of 5.77 years of service. We shall assume 6 years is a reasonable operating life for the equipment.

---

* As described in a lecture in early 1979.

Table 5.1
Capital Equipment Costs and Labor Assumptions for Whole Tree Chipping Operation

item (quantity)	retail price (1000)	required labor (people)
Grapple-skidder (1)	70	2
Feller-Buncher (2)	65 ea.	4 ea.
Chipper (1)	150	3
Tractors (2)	42 ea.	2 ea.
Chip Vans (5)	11 ea.	
Pickup (1)	10	
Log Haul Trailor (1)	5	
Misc. (Chains, winch, saws)	10	
	514	21

Notes on Table 5.1 :

a) The inventory of Capital Equipment is largely taken from Burry, Canham, Monteith, and Neuroth. (the Syracuse study) pp.110

b) Labor and price estimates are based on a presentation by Professor Jerome Haas to Professor Duane Chapman's Resource Economics class in the Spring of 1979.

Operating Costs

Rounding down from the characteristics in table 4.1, let us assume that there are 20 full time employees associated with this project. At 15 dollars per hour and 2000 hours per year this yields a 600,000 dollar cost of labor.

The next largest cost turns out to be fuel. At 10 gallons of fuel per hour of operation, times 5 machines, times 2000 hours the fuel consumption will amount to 100,000 gallons per year. Assuming 1 dollar per gallon this results in 100,000 dollars per year fuel costs. It is reasonable to add 10,000 dollars for insurance and 10,000 dollars for miscellaneous expenses. Thus, total operating costs would be:

600 + 100 + 10 + 10 = 720 thousand /year.
or 60,000 dollars per month.

Financing Expense

It will be necessary to borrow the money to purchase the equipment listed in table 4.1. It can also be assumed that two months operating costs must be on hand to start this business up. Thus it will be necessary to borrow from a bank 514 thousand dollars for the equipment and 120 thousand dollars cash. We shall assume a loan of 634,000 dollars. Let this loan be paid off over the operating life of the equipment at 15 percent interest per year. The result is annual bank payments of 167,526 dollars for six years.

From these assumptions it can be seen that the cash outlay for each year will be 720,000 dollars operating expense plus 167,526 dollars loan payment; Altogether, annual cash flow must be 887.5 thousand dollars just to cover costs. Since roughly half a million dollars is invested, a 20 percent return to capital would add about 100,000 dollars per year to expected earnings. Thus, almost a million dollars a year (987.5 thousand) is what the operation has to earn to make it as a competitive business. Spread over 60,000 green tons of woodchips this level of earnings averages out to be 16.46 dollars per green ton of chips. Assuming that this green wood has a moisture content of 60 percent, the energy content of the wood should average close to 4600 Btu per pound.[5] Therefore 16.46 dollars per green ton is about 1.8 dollars per MBtu.

The preceeding analysis was expressed in terms of 1979 dollars. The fact that the Burlington Electric Department paid an average price of slightly more than 18.50 dollars per green ton in January 1980 somewhat corroberates the above cost estimation.[6]

The large investment required to begin a high technology logging operation has important consequences for the

---

[5] See appendix on energy content of wood.

[6] U.S. Department of Energy, Energy Information Administration, Cost and Quality of Fuels for Electric Utility Plants -- January 1980., DOE/EIA - 0075(80/01), page 8.

potential supply of wood biomass. It is true that many loggers now in business achieve a reasonable rate of return. It is unlikely that new entrants, facing higher capital costs and without experience in the range of services the business involves, will be able to succeed. But if production of wood biomass for fuel is going to expand rapidly new entrants to the logging business will have to succeed. The cost of logging, both the initial capital costs and the variable costs of fuel and maintenance, are rising rapidly with the price of petroleum based energy. Unless the prices that loggers receive from the wood using industry go up dramatically it is difficult to see how any major expansion of wood biomass harvests can come about.

Chapter 6

ELECTRIC POWER GENERATION

In considering the potential components of demand for fuelwood it is hard to imagine a more voracious consumer than an electric utility burning wood in its boilers. The Burlington Electric Department's (B.E.D.) proposed Joseph C. McNeil station is the example most readily at hand. Proposed to come on line in the mid-1980's, this 50 megawatt plant will burn about 500,000 green tons of wood chips each year.[1] Such consumption of wood chips in New York State would require all of the annual growth of biomass from about 250,000 acres. Indeed, if this scale of electrical generation is the most efficient that wood fueled plants can achieve, then all the commercial timberland in New York State could only support about 2274 megawatts of generating capacity. This estimate is based on the quantity of growth that chapter three suggests is technically and socially available. Since New York currently has more than 30,000 MW of generating capacity, this potential use of New York forests is not particularly impressive.[2]

---

[1] Burlington Electric Department, Wood-Fired Electric Power Generation: An Alternative for New England ... The Joseph C. McNeil Station., Burlington, Vermont. pages 4-1 and 1-1, respectively.

[2] The actual 1981 figure (before purchases and sales are added in) is 30,363 MW. This figure is quoted from: New York Power Pool, Report of Member Electric Systems Volume 2 (Long Range Generation and Transmission Plan 1981) April 1, 1981. page 28.

Levelized Costs of Electrical Generation

Future coal and nuclear generating costs in New York have been compared in levelized terms of cents per kilowatt-hour by Duane Chapman.[3] These estimates can be compared to the levelized cost of a wood-burning steam generating plant. The calculations that follow are based upon assumptions that accord with the expected costs of the McNeil generating station. The basic equation is as follows:[4]

$$IC = \frac{K * fcr * 100}{8766 * cf} + OM + FUEL$$

where, IC is levelized costs (cents per kWh)
K is capital costs (dollars per kWe)
fcr is fixed charge rate
cf is capacity factor
OM is operating and maintenance costs (cents/kWh)
FUEL is fuel costs (cents/kWh)

the following paragraphs explain the values that are substituted into this equation.

The capital cost (K) is simply the amount of money entered into the rate base divided by the generating

---

[3] Chapman, Duane., The Economic Status of Nuclear Power in New York, Department of Agricultural Economics staff paper No. 80-7, Cornell University, Ithaca, New York, February 1980, 29 pages.

[4] This single equation approach to levelized cost is attributed to K.A. Gulbrand and P. Leung. It is here taken from:

Chapman, Duane., Nuclear Economics: Taxation, Fuel Cost, and Decommissioning California Energy Commission, November 1980. page 4.

capacity of the plant. Table 6.1 shows the costs and funds used during construction of a hypothetical plant whose construction would occur from 1980 through 1983. This hypothetical plant happens to have the same total expenditure as that anticipated for the McNeil station, namely 76.45 million dollars. When funds used during construction are included in the cost calculations, it appears that the amount actually going into the rate base would be almost 11 million dollars greater than the 76.45 million cited by the E.E.D.

This brings capital costs to 87.195 million dollars. Thus, for wood fired generating capacity of 50 MW, the capital costs are:

$$K = 1744 \text{ \$/KWe}$$

The fixed charge rate (fcr) is a factor that aggregates several costs linked to the capital costs of the plant (K). The assumption is that certain administrative costs (adm), insurance costs (ins), and property taxes (ptx) are a function of the size and value of the plant. Therefore, instead of breaking out separate estimates of their per kilowatt-hour costs it is simpler and just as accurate to augment the capital cost term by small appropriate fractions. This is in addition to a capital recovery factor (crf) which defines an annual charge that would permit the utility (over the life of the plant) to recapture the costs of the plant with a margin of profit. Thus,

Table 6.1

Representative costs for a 50 MW
Wood-Fired Steam Generating Plant

[million dollars, except colums (1) and (2)]

(1) Year	(2) Proportion of Investment	(3) Actual Investment Expenditure	(4) AFUDC	(5) Cumulative Investment with AFUDC
1980	.10	6.200	.326	6.526
1981	.15	10.231	1.222	17.979
1982	.25	18.756	2.872	39.607
1983	.50	41.263	6.325	87.195
total	1.00	76.450	10.745	

Notes on Table 6.1

Total actual investment expenditures total 76.45 million dollars according to :

> Burlington Electric Department: Wood-Fired Electric Power Generation: An Alternative for New England ... The Joseph C. McNeil Station., Burlington, Vermont. page 3-13.

The distribution of construction costs represented by the fractions in column (2) is hypothetical.

Actual investment expenditures in column (3) are calculated by multiplying the proportion of investment in column (2) times the discounted aggregate value of the plant (62.00 million dollars) times (1.10) ** t. This uses the Burlington Electric Department's own assumption of 10 percent escalation in construction costs.

The AFUDC rate is .105 : This is the rate for 1980 of Orange and Rockland according to their 1980 Federal Energy Regulatory Commission - Annual Report Form 1. page 228A.

Allowances for funds used during construction (AFUDC) are derived from the above assumptions in accordance with the work :

> Duane Chapman., Nuclear Economics: Taxation, Fuel Cost, and Decommissioning ; California Energy Commission, November 1980. pages 16 - 18.

fcr = crf + adm + ins + ptx

In this case the fcr is estimated to be .171. This is based on a crf of .131 that derives from an operating life of 30 years and a capital cost of 12.7 percent. Administrative and insurance components of the fixed charge rate are together assumed to be .015. Property taxes are estimated by the Burlington Electric Department to amount to 2.5 percent of property value.[5] Thus:

fcr = .171 = .131 + .015 + .025

The capacity factor(cf) is here defined to be the proportion of time that the plant is operating. This is assumed to be 60 percent, hence:

cf = .60

The resulting capital cost component of levelized cost is 5.66 cents per kilowatt-hour.

Operating and maintenance costs have been estimated for the base year by the B.E.D. Their figure is 1,232,000 dollars in 1984.[6] Given equal inflation and discount rates, the present value of 30 years worth of O & M expenditures

---

[5] This percentage is derived by dividing the B.E.D.'s estimate of annual payments in lieu of property taxes (2,265,000 dollars) by the 87.195 million dollars the plant adds to the rate base.
Source:
Burlington Electric Department: Wood-Fired Electric Power Generation: An Alternative for New England ... The Joseph C. McNeil Station., Burlington, Vermont. page 7-6.

[6] Ibid, page 3-14.

would be simply :

30 * 1.232 million dollars

Multiplying this figure by the crf, which amortizes the sum over 30 years, yields an O & M annual equivalent cost of 4.828 million dollars. Dividing this number by the number of kWh's likely to be produced (50,000 KW * 8766 hrs. * .60 = 263 million kWh's) yields a per kilowatt-hour cost of 1.836 cents.

The annual fuel costs per kWh are derived in a similar fashion. My calculations assume the plant comes on line in 1984 and burns 500,000 tons of green chips. Escalating the cost of wood chips derived in chapter 5 at an annual rate of 9 percent yields:

chip cost = [(1.09) ** 4] * 16.46 * 500,000

= 11.617 million dollars

Again, this is a base year figure that needs to be multiplied by 30 and the amortization factor. The result is an annual equivalent fuel cost of 45.52 million dollars per year. After division by kWh's of electricity this works out to be:

FUEL = 17.19 cents per kWh.

Substituting all these terms back into the levelized cost equation gives the result:

levelized cost = 24.69 cents/kWh.

Coal, Nuclear, and Wood Power Cost Comparison

It is interesting to compare this levelized cost of wood-fired electrical generation with the costs of coal and nuclear plants estimated by Chapman.[7] In his analysis the levelized costs of generation for plants operating from 1990 to 2019 are 21.5 cents/kWh for nuclear and 25.1 cents/kWh for coal. In order to compare these costs with wood-fired generation costs it is necessary to discount the values by the 9 percent inflation rate over the 6 years. This yields levelized costs of 12.8 and 15.0 cents per kWh for nuclear and coal power respectively. It would appear that wood-fueled electrical generation is not cost effective when compared to coal and nuclear power.

Before resting with this conclusion it is worth contrasting the assumptions made in this report with those Chapman used to estimate levelized costs for coal and nuclear power. Table 6.2 itemizes the assumptions common to all three cost estimates.

A brief construction period would seem advantageous. And yet, wood's capital cost is much higher than that of coal; the short construction period doesn't seem to have helped wood much. The reality is that coal's capital costs are much higher than the assumptions imply. The new Somerset

---

[7] Chapman, Duane., The Economic Status of Nuclear Power in New York, Department of Agricultural Economics staff paper No. 80-7, Cornell University, Ithaca, New York, February 1980, page 11.

Table 6.2

Levelized Costs and Comparative Assumptions

assumptions	coal	nuclear	wood
construction period	7 yrs.	10 yrs.	4 yrs.
size of plant	850 MW	1000 MW	50 MW
capital costs (year) $/KW	689 (78)	1250 (79)	1744 (84)
adjusted to '84	1156	1923	1744
operating life	35 yrs.	30 yrs.	30 yrs.
fuel costs (year) $/MBtu	1.23 (78)	na.	1.83 (80)
adjusted to '84	2.06	na.	2.58
general inflation rate	.09	.09	.09
fuel inflation rate	.09	.09	.09 cost of
capital	.127	.127	.127

Levelized Costs			
cents per kWh	21.5	25.1	24.7
adjusted to 1984	15.0	12.8	24.7

plant being built by NYSEG is forecast to cost 1060.9 million dollars (excluding AFUDC) and is being designed to 625 MW of capacity.[8] The capital cost in this case is 1697 $/KWe. Since the plant is scheduled to come on line in 1985 the capital costs ought to be discounted by 9 percent. So the cost is 1557 $/KWe. This adjusted figure is still significantly higher than the assumed capital cost of coal power.

The understandable low estimate of cost escalation is a problem for fuel as well. Coal, as of May 1981, has had a 12 month average delivered cost of 1.80 dollars per million Btu in New England.[9] Adjusting this figure to 1984 suggests a fuel price of 2.33 dollars per million Btu. This is 13 percent higher than the adjusted coal price in table 6.2.

To be fair, wood prices may also rise to higher than has been estimated. However, extrapolation from the price based on 1979 production costs seems to be fairly accurate. Wood chip costs to the Burlington Electric Department were 2.03 dollars per million Btu in May of 1981.[10] When this figure is adjusted up to 1984 dollars the price is 2.62 dollars per million Btu. This is not so far from the anticipated price

---

[8] New York Power Pool, Report of Member Electric Systems Volume 2 (Long Range Generation and Transmission Plan 1981) April 1, 1981, page 42 and page 74.

[9] U.S. Department of Energy, Cost & Quality of Fuels for Electric Utility Plants May 1981, Energy Information Administration, Washington, D.C., page 30.

[10] Ibid, page 8.

in the table of 2.58 dollars per million Btu.

<u>Fuelwood Procurement for Utilities</u>

Chips for utilities can be supplied by the wood-using industry or by loggers with whole tree chipping operations (WTC). Both kinds of suppliers benefit from the constancy of demand that is characteristic of the generating station. Utilities can accept even 'barky' chips virtually around the clock. The desirable nature of utilities as consumers is illustrated by the fact that Burlington Electric could readily buy chips at 12 dollars per ton during the same period (Summer 1978) that pulp mills were offering 14 dollars per ton.[11]

The ability of sawmills to provide fuelwood to utilities is easily shown by the relative percentages of residues and product that result from their operations. By weight mills produce bark (14 percent), chips (22-23 percent), sawdust (12-15 percent), and finally lumber (49-50 percent).[12] From the point of view of sawmill operation, wood chips may rise in status from being a useful waste product to being a proper joint product with cash value. The impact that this revenue potential might have on the milling business is

---

[11] Burlington Electric Department, <u>Wood-Fired Electric Power Generation: An Alternative for New England ... The Joseph C. McNeil Station.</u>, Burlington, Vermont. page 4-19.

[12] Burry, Canham, Monteith, and Neuroth., <u>The Availability of Forest Biomass In New York (review draft 4/24/80)</u>, School of Forestry, SUNY, Syracuse, New York, Appendix A, page 1.

beyond the scope of this report. Qualitatively it seems reasonable to expect a positive impact on profitability, greater demand for wood, and more logging as a result.

Chapter 7

DIRECT BURNING FOR HOME HEAT VERSUS WOOD-BASED ELECTRIC HEATING

The levelized costing of wood-fired electrical generation suggests that this use of wood is not cost effective. However, if coal prices and coal plant costs rise more rapidly than those of wood the situation could change.

Let us examine the levels of service that full utilization of wood fuel could make possible:

Chapter three stated that 14.21 million dry tons of wood biomass were available for harvest each year. This figure is based on the growth rates of trees and the geographic and institutional constraints on harvesting. However, there would be considerably more biomass than this available for the next several years. This is so because the forests of New York are cluttered with trees that should be thinned in order to promote higher quality (and quantity) of growth.

Thus, 14.21 million dry tons per year is a conservative estimate of the harvestable wood biomass. Nonetheless, it is necessary to reduce this figure still more before we have a quantity that may be considered 'available' fuelwood. This follows because in 1978 the wood-using industy required 4.197 million tons of wood from New York forests. It is the author's opinion that competition among users of wood for fuel and users of wood for fiber and structural material is inevitable. Nonetheless, let us subtract this figure from the total annual growth figure.[1] What remains are approximately 10 million dry tons of wood harvestable and available for home heating.

Such a quantity of dry wood amounts to roughly 12 million tons of seasoned wood if one assumes a 20 percent moisture content. At 6500 Btu per pound of seasoned wood, this 12 million tons represents .156 quads of energy. Assuming heating efficiencies of 50 percent and heating loads of 100 million Btu per year, this figure represents enough heat energy to warm .78 million households each winter. If one presumes that energy requirements will drop 50 percent due to better insulation and design of homes, it is easy to imagine one million or more households heating with wood in New York State.

Let us now contrast this situation with the number of households that could heat their homes if wood were used to generate electricity. We have already established that there are 10 million dry tons of wood available. In the case of home heating systems that directly burn wood we converted this to seasoned wood with a moisture content of 20 percent. Steam generating plants use green chips which

---

[1] It should be noted that this implies that the wood-using industry's level of consumption is measured in dry tons. This may not be so, in which case the residual left for fuel would be considerably greater.

we will assume have a moisture content of 60 percent. This means that what is available is 16 million tons of green chips.

Recall that the 50 MW plant was presumed to use 500,000 tons of green chips each year. Simple division implies that 16 million tons would suffice for 32 such plants. Operating at 60 percent capacity these plants would add slightly more than 8.4 billion kilowatt hours to the New York State power grid. It is patently rediculous to consider all this electricity available for heating; much of it isn't generated during the heating season. However, since it could still displace oil power in the off season, we will pretend that all of it could be said to supply heat. Using the conversion 3413 Btu per kilowatt hour and assuming that 100 million Btu are required per household, it turns out that this electricity would suffice to heat about 287,216 homes.

So we see that, whereas using the wood to produce electricity would allow 0.29 million households to keep warm, direct burning provides heat for 0.78 million households. Since insulation would effect both technologies in the same proportion we can assume that this ratio of effectiveness will continue to favor direct burning in the future. The only factor that might change is the 50 percent efficiency of wood-burning systems. Improvements in this technology would further improve the relative merits of direct burning.

Let us tally up the aggregate funding necessary to realize each of these uses of wood. This analysis begins with the assumption that the wood is available in appropriate form. In other words, it excludes the necessary investments in wood harvesting equipment and wood handling equipment. Since wood is a geographically diffuse energy resource and home heating is a geographically diffuse end use, it is improbable that the total costs of collecting the wood are greater in the case of direct burning in homes than collection for centralized steam generating plants. In both cases it is assumed that all the available wood is removed from the forests.

Thus, the tally for each technology's capital costs is the sum of power plant and heating system installation costs. Recall from chapter 2 that electrical resistance systems were assumed to cost 1800 dollars and wood furnace systems went for 3000 dollars. Table 7.1 summarizes the contrasts between electrifaction and direct burning.

The point of table 7.1 is that while generating electricity with wood may be a clever alternative to non-renewable or radioactive power plant fuels it involves considerable opportunity costs. The author is not particularly in favor of burning all the woods up for home heating via any technology, but feeding it to steam plants seems particularly wasteful.

Table 7.1

Cost and Effectiveness Comparison of

Direct Burning versus Electrifaction

Item	Direct Burning	Electrical Generation
Delivered Heat Energy	.078 Quad	.0287 Quad
Number of Households	.78 million	.287 million
Power Plant Costs	na.	2.4 billion $
Heating System Costs	2.3 billion $	.5 billion $
Total Capital Costs	2.3 billion $	2.9 billion $
Cost per Household	3000 dollars	10,000 dollars

It should also be noted that electric heat pumps cost 5500 dollars, but their efficiency is 180 percent. Because of this the same amount of electricity would result in .0517 quad of delivered heat. This would suffice for .517 million households at 100 MBtu per year. However, heating system costs would total more than 2.8 billion dollars. Adding the cost of plants, this still works out to over 10,000 dollars per household.

The author feels that if the people who are to heat with the wood were given the choice over which technological path to purchase, they would very likely advocate the cheaper approach.

Speculations

The preceding sections contrast direct burning of wood with consumption of electricity generated by fuelwood. Two facts would appear to make that comparison moot. First, New York now has excess generating capacity. Second, as this report has shown, home heating with electricity is a most expensive alternative. The logical force of these facts suggests that an explanation is in order. Why might generation of electricity with wood be promoted?

Robert Young, from the Burlington Electric Department (B.E.D.), related the following to the 1980 Winter meeting of the Society of American Foresters:

In the mid-1970's the B.E.D. felt it worthwhile to build additional electric generating capacity. Unfortunately, nuclear power faced stiff opposition and no municipality wanted to site a dirty coal plant nearby. Only a woodfired plant was politically acceptable. The fuel would be renewable and locally supplied. The fact that the plant would also be able to burn coal did not obtrude upon the public perception that this was a good renewable technology.

The cost of wood chipping is linked directly to oil prices. The connection derives from both the embodied energy of the capital equipment and from the diesel fuel the machinery uses. Thus wood chip prices may be expected to rise with those of oil based energy costs. Unfortunately, from the point of view of those supplying wood chips, the obvious substitute for wood chips is coal. To date coal prices have not been as high as oil prices. It is possible that coal will remain cheaper than wood chips in terms of dollars per million Btu. Since a regulated utility like the B.E.D. must hold its costs down, it is possible that the McNeil Station will burn a lot of coal. If this proves to be the case, the McNeil Station may be viewed as just another small coal fired generating station. Thus, via the back door of renewable resource technology the B.E.D. has managed to overcome the considerable political and institutional obstacles to new plant construction.

With respect to the uncompetitively high price of electric heat, the story continues as follows: Public perception that fuel for the plant will be renewable and local has biased expectations about the relative future price of electricity versus other fuel prices. Since 1975 (related Bob Young) 80 percent of new construction has used all electric heating. The public consciousness has been lowered to the point that a plebescite (requiring a 2/3rd's majority) to allocate 1.5 million dollars of Burlington money for conservation failed.

Other utilities have taken note. 57 out of 90 utilities surveyed by the B.E.D. have indicated a serious interest in buying capacity, capital, and energy associated with the McNiel Station. The B.E.D's experience may serve not only as a demonstration of technical feasibility, but also as a new approach to the problem of new plant siting and static sales.

It is the author's opinion that construction of woodburning plants could very well lead to the combustion of coal mixed with wood chips or even wood chips alone. Habits of thought similar to those which create an advocacy of woodfired plants could conceivably require them to burn wood. This would be a misallocation of resources in the opinion of the author.

Chapter 8

SUMMARY AND CONCLUSIONS

This report begins with the surprising premise that more wood is extracted from New York forests to heat homes than for all other purposes combined. This assertion is based on a three county telephone survey conducted by the Cooperative Extension Service. The survey concluded that 1.7 million cords of wood were burned for residential heat during the winter of 1978 - 1979.[1] The question that rapidly follows is: How much wood is available for fuel in New York State?

A study by researchers at Syracuse University concludes that a considerable amount of wood is available.[2] The biological supply is 18.24 million dry tons per year. Technical and institutional constraints suggest that 14.21 million dry tons is all that could be harvested. Since the wood-using industry requires 4.2 million dry tons of wood, 10 million dry tons is what appears to be available for energy use.

If the figure 1.7 million cords is transformed into dry tons the current burning of wood can be compared to the

---

[1] Pellerin, et.al., Wood Energy Survey 1979, Cooperative Extension Service, and Agricultural Engineering Department, Cornell University.

[2] Burry, H.B., Canam, H.O., Monteith, D.B. and Neuroth, D.E., The Availability of Forest Biomass in New York (Review Draft) Syracuse University, 1980.

potential flow of wood from the forest. 1.7 million cords is roughly equivalent to 3.4 million dry tons of wood. New Yorkers may thus be said to be burning about one third of the available wood fuel supply each year.

In the short run New York forests could supply considerably more than this. New York forests are reportedly thick with trees whose removal would actually increase annual growth. This wood represents a depletable resource that should be mined intellegently. If, in the name of this surplus stock, the wrong trees are cut the yield of New York forests could be depressed.

Pressure on the forest resource by our energy hungry society should be anticipated. The price of wood makes it an attractive option for many households seeking cheaper heat. Even at 100 dollars per cord, wood is cheaper than many other fuels. Coal and natural gas are both cheaper, but deregulation of natural gas makes it unlikely to remain so.

As consumers become more concerned about heating costs it is assumed that some form of life cycle cost accounting will be the criterion for choosing a heating system. A methodology of calculating long term heating costs is explained in the report.

Comparisons among heating systems are made in terms of an 'annual equivalent' cost. This is the annual payment one would make to a bank if one had borrowed all the money required to finance 20 years of heating service with a heating system. Application of this concept to a system of electric resistance heating illustrates the usefulness of the methodology. Electric resistance heat is cheap from the point of view of system purchase and installation, but the high cost of electricity makes it the most expensive of all the alternatives when viewed over 20 years. Table 8.1 shows purchase costs and fuel prices as of 1980 for several heating systems. The table also shows the annual equivalent costs that were calculated for these systems. When these assumptions and results are presented in this manner certain conclusions are obvious.

The results suggest three classes of expensiveness. Electric resistance heating at 5030 dollars is most expensive. In the middle group of wood, heat pump, and oil furnace systems, wood is the least expensive. The coal and natural gas systems are well below wood in their annual equivalent cost. However, if the analysis is done with natural gas priced as high as oil, a natural gas system's annual equivalent cost joins the middle group at 3155 dollars.

As consumers examine the alternatives, wood heat may be displacing oil and electric heat. With decontrol of natural gas prices, even those with access to natural gas may begin to consider wood heat. Parenthetically, the author would

Table 8.1

Heating System Analysis :
Summary of Assumptions and Results

System	Purchase Cost	1980 Fuel Price	An.Eq. Cost
	(dollars)	(dollars/MBtu)	(dollars)
Forced Air Furnaces:			
N.G.	2500	4.02	1930
Coal	3500	3.70	2160
Wood	3000	4.44	3198
Oil	3200	7.18	3654
Electrical Systems:			
Heat Pump	5500	15.38	3468
Electric Resistance	1800	15.38	5030

also predict a rise in the residential consumption of coal. The reason for the greater popularity of wood is probably related to its visibility and widespread availability.

Thus, heating with wood is cost competitive and likely to increase in popularity. From the point of view of the forest resource, New York can probably afford to triple its level of wood heating. But, it will not be long before wood consumption as fuel begins to compete with utilization of wood for structural material and fiber.

The residential heating market is not the only segment of our energy intensive society that has discovered the fuel value of wood. The energy crisis has put the electric utility industry in a very difficult position. Wood is probably being considered as a fuel for steam generating plants in several places. Adapting Duane Chapman's calculation of long term production costs for power plants to a hypothetical wood-fired plant reveals that wood is not much more expensive than coal. Unfortunately, even if all 10 million dry tons of wood per year were allocated to electric utilities it would only displace about 5 percent of current electrical capacity.

The author feels that burning the annual growth of our forest to produce electricity would be poor public policy. Direct burning in homes is more efficient in terms of solving the needs for space heat. As seasoned wood the 10 million dry tons of annual wood growth amount to 12 million tons. This is a potential of 156 trillion Btu. By comparison, natural gas, oil and electricity now contribute to New York's space heating energy requirements about 269 TBtu., 445 TBtu., and 8 TBtu., respectively.[3]

It seems likely that, under the pressure of rising energy prices, demand for fuelwood will increase. It will not be able to displace a very large portion of our conventional fuel consumption. Nonetheless, it should be viewed as a significant component of the solar energy, small hydro, and conservation package of New York's energy opportunities. It is already developing most rapidly, from the point of view of displacing imported energy. Its impact on jobs and economic productivity are positive.

The only problem with it is that burning wood is potentially depleting. Overinvestment in conservation and solar energy (by whatever definition) at worst imposes pecuniary costs that are largely borne by the investors. While wood heat is philosophically solar-renewable, it is not free and renewable in the world we live in. On the contrary, the fuel is bought and sold, and this only happens once from the point of view of the owner. The land has alternate uses, but trees take a long time to grow. If, as one should probably expect, we cut more fuel than the forest

---

[3] State Energy Office, New York State Energy Master Plan and Long-Range Electric and Gas Report ; Final Report March 1980, Appendices, page 41.

grows, we will exacerbate our problems. We will certainly run low on wood. Prices will go up, and people who rely on wood, as on other fuels, to keep warm will have to pay or be subsidized.

If the harvest from the forest is not excessive wood will provide a continuing source of heat for a large number of households in New York State. It is a significant part, albeit not the only part, of the solution to New York's dependence on imported, non-renewable energy.

APPENDIX A

The Energy Content of Wood

<u>Nota</u> <u>Bene</u> : Much of the material in this appendix is adapted from:

Shelton, Jay and Shapiro, Andrew B. <u>The Woodburners Encyclopedia</u> ,Vermont Crossroads Press, Inc., Waitsfield, Vermont 1978.

Appendix A

THE ENERGY CONTENT OF WOOD

The energy value of wood (measured in British thermal units) can be derived from the physical quantity and moisture content (M.C.) of the wood. The report consistently uses the following conversion factors :

-- 80 cubic feet of wood per cord

-- 30 pounds of oven dry wood per cubic foot

-- 36 pounds of seasoned wood per cubic foot

-- 48 pounds of green wood per cubic foot

-- 8600 Btu per pound of oven dry wood (zero moisture)

-- 6500 Btu per pound of seasoned wood (M.C. = .2)

-- 4600 Btu per pound of green wood (M.C. = .6)

What follows in this appendix is an explanation of the assumptions that underly these factors.

The relative density of oven dry wood is the weight of any fixed volume of that wood divided by the corresponding weight of that same volume of water. It can vary greatly from .3 for western red ceder, which is a softwood, to .9 for live white oak that is a very dense hardwood.[1]

All the weight-to-volume conversion factors above assume that the relative density of wood is .5 (i.e. half as heavy

---

[1] These statistics and a table of the relative densities of oven dry wood of many species can be found in: Shapiro, and Shelton The Woodburners Encyclopedia, Vermont Crossroads Press, Waitsfield, Vermont 1978. pages 18 - 21.

as water). Water weighs 62.3 pounds per cubic foot, so wood of this relative density would weigh about 31.15 pounds per cubic foot. The use of 30 pounds per cubic foot as a conversion factor is perhaps conservative, but it's certainly reasonable. Even within a species the density of the wood can vary by more than 10 percent, so this rounding off is not very significant.

Green wood has a moisture content that varies from about 40 to 60 percent of the weight of the dry wood The use of a moisture content of 60 percent is reasonable and supported by the work of Douglas B. Monteith.[2] It is rather high for softwoods, but hardwoods constitute such a large portion of the biomass that the judgement call is reasonable. The assignation of a 20 percent moisture content for well seasoned wood is also arbitrary and reasonable.

While all wood has a potential heat content of about 8600 Btu per pound, the water content absorbs much of this in the combustion process at it changes phase from liquid to gas. To compute how much heat is available from wood fuel of more than zero moisture content the following subtractions from 8600 Btu per pound must be made:

The first component which must be subtracted is the energy it takes to change the moisture in the wood to gas.

---

[2] Monteith, Douglas B., Whole Tree Weight Tables for New York Applied Forestry Research Report No. 40, SUNY, Syracuse, New York 1979.

Technically, these Btu are only lost if the steam leaves the heating system before condensing. Upon condensing the steam gives up the heat its phase change absorbed. Since condensation in most woodfired systems brings with it the problems of creosote, these calculations will assume that the steam does not turn back to liquid within the system. This evaporation energy (latent heat) is 1050 Btu per pound of water.

A tiny fraction of the initial dampness in the wood is adsorbed on the molecular surfaces of the wood. A small, but not insignificant, amount of energy is required to strip these water molecules off the wood. This energy must also be subtracted from the potential 8600 Btu per pound of water free wood. At a moisture content of 20 percent this bond breaking energy is slightly more than 100 Btu per pound of water.

When a pound of wood is completely burned there are produced .54 pounds of water. This is a function of the chemical reactions of combustion and is an addition to the moisture present in the wood before firing. Once the water takes form in the fire, whether or not it came from the dampness or the combustion reactions is nearly irrelevant. This water too absorbs as latent heat 1050 Btu per pound evaporated.

The arithmetic behind the conversion factor of 6500 Btu per pound of seasoned wood is shown in the following steps:

1) The high heat value of a pound of seasoned wood is simply the high heat value of oven dry wood multiplied by the amount of oven dry wood in a pound of seasoned wood.

   .8333 * 8600 Btu. = 7166.66 tu.

2) The latent heat of the moisture in seasoned wood must be subtracted. This would be:

   .166 lbs. water * 1050 Btu. = -175.00 Btu.

3) Also the bond breaking energy for this water must be subtracted. This would be:

   .1666 lbs. water * 100 Btu. = -16.66 Btu.

4) Lastly, the latent heat of the combustion pcoduct water must be subtracted. this would be:

   .8333 * .54 S 1050 Btu. = -472.5 Btu.

The result is the low heat value of a pound of seasoned wood. It works out to be 6502.5 Btu. This is pretty close to 6500 Btu. and will have to do. Similar calculations would substantiate the other conversion factor for green wood's heat content.

BIBLIOGRAPHY

Allen, John R. and Rowley, F.B., 'Tests To Determine The Efficiency of Coal Stoves', _American Society of Heating and Ventilating Engineers_ Vol. 26, 1920

Barlow, Thomas J., 'The Giveaway in the National Forests' _The Living Wilderness_, December 1979.

Bousquet, Danial., 'Electric Power From Vermont Wood', _The Northern Logger_, Vol.27, No.7, January 1979.

Bowersox, T.W., 'Forest Energy Resources Of Northcentral Pennsylvania' _Northern Logger and Timber Processor_ November 1976.
also
Paper No. 5109 in the _Journal Series_ of the Pennsylvania Agricultural Experiment Station (22 June 1976).

Burlington Electric Department, _Wood-Fired Electric Power Generation: An Alternative for New England -- The Joseph C. McNeil station_ The B.E.D., Burlington, Vermont.

Burry, H.B., Canham, H.O., Monteith, D.B. and Neuroth, D.E., _The Availability of Forest Biomass in New York (review draft)_ SUNY, Syracuse, New York 1980.

Canham, Hugh O. _Forest Ownership and Timber Supply_ SUNY, Syracuse, New York 1973.

Chapman, Duane. _Nuclear Economics: Taxation, Fuel Cost, and Decommissioning_, Consultant Report prepared for the California Energy Commission, 1111 Howe Ave., Sacramento, California, November 1980., 113 pages.

Chapman, Duane., Cole, Kathleen., Slott Michael., _Energy Production and Residential Heating: Taxation, Subsidies and Comparative Costs_., Ohio River Basin Energy Study, Office of Research and Development, U.S. Environmental Protection Agency., Washington D.C., March 1980, 43 pages.

Cole, Kathleen, _Comparative Space and Water Heating Costs in New York State_. Staff Paper No. 80-8, Department of Agricultural and Resource Economics, Cornell University, Ithaca, New York 1980.

Conrad, Jon M. _Forest Management with Multiple Objectives_ (review draft) Cornell University, Ithaca, New York 1980.

Cormier, Joseph., 'Forests: A Significant Energy Resource' _The Northern Logger_, Vol.27, No.7, January 1979.

Ferguson, Roland H. and Mayer, Carl E., The Timber Resources of New York U.S.D.A. Forest Service Resource Bulletin NE-20, 1970.

Fox, Roy and McGaw, Cynthia., Section 480a New York State's Approach to Forest Taxation A Public Policy Review , A.E.Ext.79-32, Cornell University, Ithaca, New York 1979.

Lessem, Don., 'The Coming of Wood Co-ops' publication unknown , March 1980.

Frank, Ellen Ferley., 'The Yankee Forest: Plundered or Preserved by Wood Heat?' New Roots (for the Northeast) Number 9, January - February, 1980.

Meadows, Dennis L. (editor), Beyond Growth - Essays on Alternative Futures, Yale University School of Forestry and Environmental Studies Bulletin No. 88, New Haven: Yale University Press, 1975.

Monteith, Douglas B. Whole Tree Weight Tables for New York AFRI Research Report No. 40 SUNY, Syracuse, New York 1979

Monteith, Douglas B. and Taber, David W., Profile of New York Loggers ,AFRI Research Report No. 38, SUNY College of Environmental Science and Forestry, Syracuse, New York 1979.

Morrow, Robert R., 'Potential Iosses Associated with Harvesting Forest Biomass for Energy' Conservation Circular Vol. 17, No. 9, Cornell University, Ithaca, New York, 1979.

New York State Conservation Department and State University College of Forestry Industrial Roundwood Production and Consumption in New York State 1963 - 1964 D.E.C. 1965

New York State Department of Environmental Conservation, Bureau of Forest Marketing and Economic Development, Stumpage Price Report, Number 16, Januacy 1980.

Oglesby, R.T. and Morrow, R.R. Heating Cornell With Wood - An Overview, Cornell Univecsity, Ithaca, New York 1978.

Palmer, L., McKusick, R., and Bailey, M., Wood and Energy In New England (A Review and Bibliography) USDA; Economics, Statistics, and Cooperatives Service., Bibliographies and Literature of Agriculture No. 7., U.S. Government Printing Office: 1980 O-620-406/5157 Region 3-1.

Pellerin, Roger A., Markwardt, Everett D., and Koelsch, Richard K., Wood Energy Survey 1979, Cooperative Extension, Cornell University, Ithaca, New York.

Saint Lawrence County Planning Board, 'Testimony in the 1979 New York State Energy Planning Board Hearings' September 4, 1979.

Schurr, Netschert, Eliasberg, Lerner, and Landsberg (RFF,Inc.)., Energy in the American Economy 1850 - 1975, Johns Hopkins Press, Baltimore 18, Maryland, 1960.

Shelton, Jay and Shapiro, Andrew B. The Woodburners Encyclopedia ,Vermont Crossroads Press, Inc., Waitsfield, Vermont 1978.

Skonberg, Paul V. and Collins, Lodowick U. Concept Development of an Ulban Firewood Coop (midpoint repoct 1/80), Center for Community Technology, Providence, Rhode Island

Stanturf, John., 'Wood as an Energy Resource', Conservation Circular Vol. 17, No. 9, Cornell University, Ithaca, New York, 1979.

Smith, David M., 'Energy Aspects of Wood' The Northern Logger , Vol.27, No.7, January 1979.

Society of American Foresters, Task Force of, Forest Biomass As an Energy Source Study Report, Society of American Foresters, Washington,D.C. 1979.

Syracuse Student Chapter of Society of American Foresters, Environmental Effects of Home Wood Burning, unpublished manuscript presented in March 1980.

Taber, David W. New York State's Timber Resource and Wood-using Industry, FERS Regional Report -- July 1972 State University College of Forestry, Syracuse, New York.

USDA, Forest Service, An Analysis of the Timber Situation in the United States 1952-2030 (review draft), U.S. Government Printing Office 1980.

U.S. Comptroller General, The Nation's Unused Wood Offers Vast Potential Energy and Product Benefits , General Accounting Office, Report to The Congress, EMD-81-6, 3 March 1981.

Weaver, Thomas F. and Hutton Edward, Burning Fuelwood in Rhode Island, Does It Pay? , Cooperative Extension Service Circular 183, University of Rhode Island , Kingston, R.I.