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Residential Energy-Tax-Credit Eligibility: A Case Study for the Heat-Pump Water Heater

Steve M. Cohn
N. Scott Cardell

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RESIDENTIAL ENERGY-TAX-CREDIT ELIGIBILITY: A CASE STUDY FOR THE HEAT-PUMP WATER HEATER*

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ABSTRACT

This report describes the methodology and results of an analysis to determine the eligibiltiy of an energy-efficient item for the residential energy tax credit. Although energy credits are granted only on a national basis, an attempt to determine the tax-credit eligibility for an item such as the heat-pump water heater (HPWH) analyzing national data is inappropriate.

The tax-credit eligibility of the HPWH is evaluated for the ten federal regions to take into consideration the regional differences of:

(1) HPWH annual efficiency,
(2) Existing water heater stocks by fuel type,
(3) Electricity, fuel oil, and natural-gas price variations, and
(4) Electric-utility oil and gas use for electricity generation.

A computer model of consumer choice of HPWH selection as well as a computer code evaluating the economics of tax-credit eligibility on a regional basis were developed as analytical tools for this study.

The analysis in this report demonstrates that the HPWH meets an important criteria for eligibility by the Treasury Department for an energy tax credit (nationally, the estimated dollar value of savings of oil and gas over the lifetime of those HPWH's sold during 1981-1985 due to the tax credit exceeds the revenue loss to the treasury).

A natural-gas price-deregulation scenario is one of two fuel scenarios that are evaluated using the equipment choice and tax-credit models. These two cases show the amounts of oil and gas saved by additional HPWH units sold (due to the tax credit during 1981-1985 (range from 13.9 to 23.1 million barrels of oil equivalent over the lifetime of the equipment.

1. INTRODUCTION

This report describes the methodology and results for determining the eligibility of the heat pump water heater (HPWH) for the 15% residential energy tax credit granted by the Department of Treasury.

With the 1978 Energy Tax Act[1] and the 1980 Crude Oil Windfall Profits Tax Act,[2] the U.S. Congress has created tax incentives that encourage individual consumers and firms to purchase items that conserve energy as well as items that utilize renewable energy sources. For approved conservation items, the Energy Tax Act provides a tax credit of 15% for the first $2000 purchased for a maximum credit of $300. For items driven by renewable energy sources, a tax credit of 30% of the first $2000 spent and 20% of the next $8000 for a maximum tax credit of $2200. The tax credit for conservation items applies only to those homes built before April 1, 1977 with both acts allowing the above energy savings investments to be between April 1977 and December 1985. The motivation behind the energy tax credits is to reduce foreign oil imports by lowering the initial costs of energy saving equipment and processes. The Energy Tax Act states that an energy efficient item is considered eligible for an energy tax credit if the dollar value of savings of oil and gas due to the tax credit over the lifetime of the equipment exceeds the revenue loss to the treasury.

In 1980 the Crude Oil Windfall Profit Tax Act amended the 1978 Energy Tax Act by authorizing the Department of Treasury and Energy Secretaries to add items to the list of items eligible for the residential energy tax credit.

The HPWH is considered a candidate for the residential energy tax credit because it has significnt energy efficiency improvements over conventional electric water heaters and will also potentially displace oil and gas-fired water heaters. In general, energy tax credit incentives offered by the treasury are justifiable to the extent that they reduce distortions of the free market by overcoming market failures such as consumers facing too low a price of oil due to regulation, or fuel oil not being priced at its true national security value.

The following three criteria have been suggested as being needed to evaluate a proposed investment tax credit that is intended to reduce oil imports:[3]

(1) Does the tax incentive reduce oil imports when all effects are taken into account?

(2) Will the value of oil and gas saved because of the tax incentive (if there are net savings) exceed the social costs from diverting scarce capital from other uses?

(3) Given the administrations budgetary objectives, is the value of oil and gas saved sufficient to justify the revenue loss to the Federal government?

Only the third criteria will be considered in this report. The first criterion concerns the effect of equipment utilization or fuel use rate of the item or system where increases in efficiency of new systems may offset, to some extent, increases in fuel prices. For example, assume that a new high efficiency oil space heating system, subsidized by a Federal energy tax credit, is retrofitted in an existing single-family house. Two effects on energy consumption will result from this tax incentive: (1) the new system requires a reduced amount of energy to produce the same temperature level as the original oil furnace, and (2) by reducing fuel expenditures to the household, they are motivated to raise their thermostat from its previous lower and more uncomfortable level. It is uncertain which of the two effects outweigh the other, although it is probable that energy savings will result from the tax credit for the oil furnace retrofit.

The second criteria of whether the value of oil and gas saved due to the tax incentive exceeds the social costs from diverting scarce capital from other uses will not be considered either. To analyze this criteria one must estimate the subjective social cost per dollar of income transferred from the general taxpayer to investors in conservation and renewable energy. No data currently exists which establishes the social weights to be placed on Federal revenue transfers from one group to another.

The third criteria, concerning whether the value of oil and gas saved by the item is sufficient to justify the revenue loss to the federal government, is considered in detail in this report. To aid in this analysis, two computer models have been developed; one to regionally allocate annual replacement sales (both with and without the tax credit) of the HPWH to the ten U.S. federal regions and another to simulate the conditions of eligibility for the energy tax credit, accounting of primary oil and gas savings on a regional basis. High efficiency water heaters purchased for new homes would not be considered eligible for the energy tax credit since eligibility is restricted only to those homes built before April 1977.

Estimating consumer choice for the HPWH and sales on a national basis is unrealistic and not appropriate for the following reasons:

(1) There is considerable regional variation in HPWH efficiency due to climatic differences. The annual performance factor of the HPWH (PF = annual electric resistance water heater electricity consumption ÷ HPWH annual electricity consumption) differs by a factor greater than two depending on geographical location. For example, a HPWH located inside the conditioned space of a home in Tampa, Florida with a heat pump for space heating achieves a performance factor (PF) of 2.07. The same HPWH located in a home in Boston, Massachusetts with an oil-fired space heater has a PF of only 0.92.[4] These two extreme cases point out the fact that, other factors being equal, HPWH's should be a far more attractive water heater replacement in warmer climates.

(2) Not only does the efficiency of the HPWH vary by geographical region but also with location in the home and space heating fuel type. According to an experimental HPWH study conducted at ORNL,[4] a HPWH located in Knoxville, Tennessee has a significant variation of annual PF's depending on home location and space heating fuel type (Table 1).

(3) Although the level of existing water heater regional stocks varies proportionally with the general household population, water heating saturation by fuel type differs widely across regions. For

Table 1. Heat pump water heater annual performance factor variation - Knoxville, Tennessee

HPWH Home location	Space heating fuel type	PF
Unconditioned space	-	1.78
Conditioned space	High performance heat pump	1.69
Conditioned space	Low performance heat pump	1.65
Conditioned space	Resistance heat and medium performance A/C	1.35
Conditioned space	60% efficiency gas heat and medium performance A/C	1.09

example, Region 6 (Southwest) has over 10% of water heaters in the U.S., but 73% of those are gas fired, which are at present unlikely candidates for replacement by HPWH's due to the relatively low price of natural gas. 68% of the water heaters in region 4 are electric resistance, coupled with the warm climate in the southeast indicates a large demand for HPWH's relative to other regions. Table 2 shows the current water heater population for single family housing units in the United States for the 10 federal regions by water heater fuel type (water heaters in multi-family housing are omitted).

The regional stocks of water heaters in multi-family housing are excluded from this analysis since only energy conservation items being replaced in single-family homes are legally eligible for the energy tax credit (removing water heaters located in apartments from the national stock of water heaters lowers the total U.S. stock from 80.4M units to 55.3M water heaters).

Table 2. Regional stock of residential water heaters-1980*
(Omitting multi-family units)
(Millions of units)

Region	Electricity	Gas	Oil	Other	Total
1	1.07	1.00	0.57	0.12	2.76
2	0.80	2.20	0.82	0.16	3.98
3	2.30	2.91	0.32	0.30	5.83
4	7.83	2.48	0.03	0.71	11.05
5	4.09	6.91	0.08	0.48	11.56
6	1.51	4.74	0.03	0.44	6.71
7	0.91	2.13	0.01	0.29	3.34
8	0.67	1.11	0.00	0.09	1.87
9	1.31	4.73	0.00	0.16	6.20
10	1.73	0.20	0.02	0.03	1.98
US	22.22	28.41	1.87	2.78	55.28

*Regional stock of water heaters are compiled from data in reference 5.

(4) The fuel price variation across regions is large and this affects the relative attractiveness of the HPWH in comparison with conventional electric as well as oil- and gas-fired water heaters. Annual electricity cost for operating electric resistance water heaters vary from $166 in region 10 to $637 a year in region 2 (the U.S. average is $300/year).[6,7] Table 3 gives a regional comparison of annual fuel costs for conventional electric, heat pump, oil- and gas-fired water heaters as well as current EIA regional forecasts of annual growth rates of electricity and fuel oil prices.

Table 3. Annual expenditures for water heater operation - 1980 $'s*

Region	Annual fuel costs for elec. resistance water heaters	Annual fuel costs for heat pump water heaters	Annual fuel costs for oil-fired water heaters	Annual fuel costs for gas-fired water heaters	Annual growth rate of elec. prices (%) 1981-1995	Annual growth rate of oil prices (%) 1981-1995
1	453.5	290.8	250.3	167.6	0.8	4.7
2	537.3	319.7	253.4	148.3	0.9	4.8
3	342.2	202.4	231.2	112.6	1.1	4.8
4	263.0	143.6	221.3	96.1	1.4	5.0
5	245.0	157.0	186.0	84.1	0.8	4.9
6	288.7	156.0	223.1	100.5	2.1	4.8
7	371.8	237.0	233.7	101.6	0.8	4.8
8	317.2	214.4	228.1	90.1	-1.1	5.1
9	300.3	157.4	201.8	86.4	0.9	4.9
10	165.9	92.2	237.2	149.2	1.6	4.9
US	300.3	168.6	240.6	102.3	1.2	4.8

*Estimates of regional water heater energy consumption (Refs. 4 and 7) and regional energy prices and price forecasts (Ref. 6) are used to prepare Table 3.

The above four regionally dependent factors of HPWH efficiency, water heater location in the home, fuel type availability and current as well as forecasted fuel and equipment prices all enter as factors for homeowners to consider in selecting a replacement water heater.

In summary, we assume that the consumer makes a rational choice when deciding whether to replace his existing water heater with one of the same fuel type or an alternative fuel type. His choice is largely based on this perception of the present value of future discounted fuel and equipment costs for all of the water heater choices.

In addition to the necessity of estimating HPWH replacement sales on a regional basis, it is also required to analyze regionally the amount of oil and gas used in electric utility generation that would be saved by replacing conventional water heaters by HPWH's. This marginal fuel use analysis for electric utilities is described in Chapter 3.

2. WATER HEATER CHOICE

Two scenarios of water heater choice are analyzed in this study. The first scenario assumes that all households (omitting multi-family housing units) will consider the replacement of their conventional water heating system when its useful life is over with either one of the same fuel type or a HPWH. It is assumed that households will be facing fuel price increases as projected by the Department of Energy's Energy Information Administration.[6]

The second scenario considered is a natural gas deregulation case where is it assumed that natural gas prices rise to 70% of oil prices by the end of 1981 and are assumed to have an annual growth rate of 1% greater than that of oil through the end of the lifetime of those HPWH units purchased in 1985. This will allow the price of natural gas to become far more attractive for owners of gas-fired water heaters to consider replacing their worn-out systems with a HPWH.

Using DOE supplied forecasts of future HPWH national sales to 1985,[8] a market penetration model of equipment choice is developed and based on the comparative economic advantages of the four types of water heaters (conventional electric, heat pump, oil- and gas-fired), characteristics of which are described in Tables 2 and 3. Estimating the market penetration of technologically new consumer durables is a difficult and important question. It incorporates important aspects of the economic theories of discrete decision making, technological diffusion and decision making under uncertainty. This question has received substantial attention in the recent economic literature. However, there is currently no readily available methodology to perform these analyses. Furthermore, the data and computational requirements of the best available techniques are severe.[9,10] Fortunately, when the penetration can be respecified for one scenario, the conditional analysis for a second scenario is greatly simplified. When, as in our case, the key concern is the relative penetration of the two cases, the estimates will generally be robust to errors in the prespecified penetrations. The penetration model will be described after providing the background on the specifics of water heater choice.

Water heater population, operating costs, the installed cost of the water heater alternatives, and equipment lifetimes characterize the water heater choices. Table 4 gives estimates of the installed costs and lifetimes of the four water heater alternatives. A fuel switching charge of $50 is assumed for consumers who select a water heater of a different fuel type from the one being replaced.[12]

Table 4. Estimates of installed costs and lifetimes of water heater alternatives*

Type	Installed cost (1980 $'s)	Lifetime (years)
HPWH	$700	12
Elec. resist.	250	10
Oil-fired	525	15
Gas-fired	250	10

*Estimates of costs and equipment lifetimes are found in Ref. 11.

The forecasted national sales of the HPWH before the tax credit is shown in Table 5. These forecasts are based on a survey of manufacturers.[8]

Table 5. HPWH sales in thousand of units

Year	1981	1982	1983	1984	1985
Sales	79	196	317	415	528

The following procedure is used to allocate the forecasted sales of HPWH's across the 10 federal regions as well as for the replacement of the three potential types of units - electric resistance, oil- and gas-fired.

The present value of the discounted annualized costs for each k^{th} alternative is as follows:

$$PV_{kt} = CC_k + \int_t^{LT+t} FC_k \, e^{-r_k \tau} d\tau \qquad (1)$$

where r is the implicit discount rate facing the consumer between the HPWH and either conventional electric, oil- or gas-fired water heaters, CC_k is the initial capital cost for each of the four alternatives,

FC_k is the annual fuel cost of electricity, oil, or gas,

$FC_{kt} = FC_{ok} e^{g_k(t-1980)}$ where FC_{ok} is the initial fuel cost for 1980 and g_k is the annual growth rate of fuel prices.

Substituting FC_{kt} into equation (1) and finding the solution to the integral gives:

$$PV_{t,\ell} = CC \;\; + FC_{t,\ell} \, [e^{(g_\ell - r_k)LT_\ell} - 1]/(g_\ell - r_k) \qquad (2)$$

where

ℓ = HP and k = ER, oil, or gas

or

ℓ = k = ER, oil, or gas.

The annualized cost for each alternative is calculated such that:

$$AC_{t,\ell} = \frac{r_k}{1-e^{-LT_\ell \cdot r_k}} \quad PV_{t,\ell}[+ r_k \cdot FSC_1 \quad \text{if } \ell = \text{HPWH and } k = \text{oil or gas}] \qquad (3)$$

where

FSC is the fuel switching charge for converting from oil or gas to a HPWH.

This equipment choice framework considers the discrete decision between two alternative methods of identically meeting a specified need. For systems having the same operating lifetime, consumers will choose the system which has the lowest present discounted (or "life-cycle") cost. For systems with different lifetimes, the system with the lowest annualized cost (as defined in Equation 3 above) will be chosen. For this case, the alternatives are such that in any given year a critical r_k exists, such that for r_k less than critical value, one alternative will be chosen by an individual if his personal r_k is greater than the critical value, and the other alternative will be chosen if his personal r_k is less than the critical value. At r_k equal to the critical value, the two alternatives will have identical annualized costs. Thus for each region and year, we solve for the critical r_k by an iterative procedure that minimizes the difference between $AC_{t,HP}$ and the appropriate alternative - $AC_{t,ER}$, $AC_{t,oil}$, or $AC_{t,gas}$. This critical r_k is denoted as $r_{j,k,t}$ where j is the region, k is ER (electric resistance), oil or gas; and t is the year.

If it is known how many individuals have personal discount rates less than the calculated critical values, we could directly forecast the penetration. However, where the attributes of one of the alternatives are uncertain, the distribution of discount rates for individuals choosing that alternative will be shifted toward higher personal discount rate values. In other words, uncertainty about an alternative increases the extent to which consumers discount the potential future benefits from choosing that alternative. Lack of information about an alternative has the same effect on personal discount rates as uncertainty about attributes of alternatives.

The HPWH is a new technology with which consumers have little experience. Consumer's lack of information and uncertainty about the HPWH should lead to their using higher discount rates that those found for decisions among well-known alternatives. Unfortunately, there are no economic studies that provide an adequate method of determining exactly what the distribution of personal discount rates for this decision would be. However, for a given functional form, the distribution of discount rates can be determined if the total sales are known for a specified case. We know from economic theory that the cumulative distribution function should have a value of zero for zero or negative discount rates and a smooth S-shaped form for positive discount rates. Furthermore, as discussed above and in footnote 11, the results are not sensitive to either the precise values of total sales or the functional form chosen, as long as the new alternative is a relatively small percent of sales. Therefore, we choose for the functional form of the cumulative distribution of discount rates over individuals:

$$F(r) = \frac{r^2}{\alpha + r^2} \quad .$$

This is the simplest functional form that has a shape and characteristics indicated by economic theory (the choice model developed in this report can be considered an example of a general economic model described in Appendix A). The shape of this cumulative distribution function for two values of α is shown in Figure 1.

Consumers with discount rates less than $r_{j,k,t}$ (for the appropriate j,k,t) will choose the HPWH. Hence, the fraction choosing the HPWH is $\frac{r^2_{j,k,t}}{\alpha + r^2_{j,k,t}}$. Note that the median consumer's discount rate is the square root of α (if $r_{j,k,t}$ is equal to $\sqrt{\alpha}$, one-half of the consumers will choose the HPWH).

When the solution of the critical discount rates, $r_{j,k,t}$, are found as described above, their values are substituted into the following relationship:

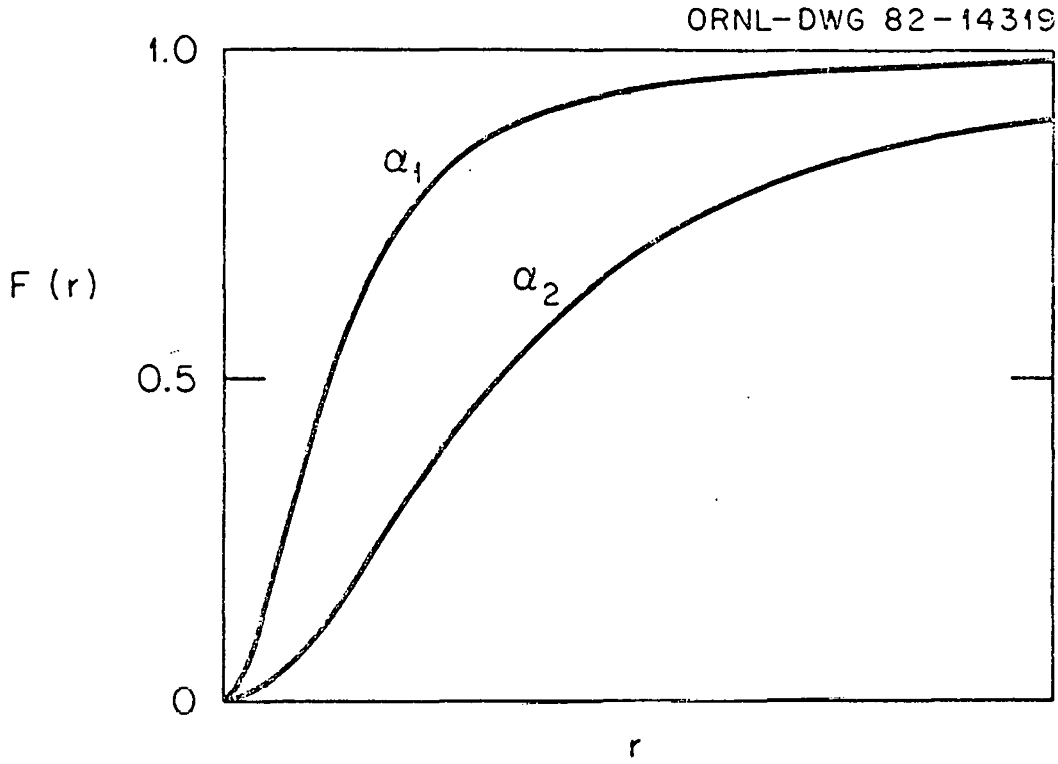

Fig. 1. Functional form of the cumulative distribution of personal discount rates. Parameter values for $\alpha_1 = 0.1$ and $\alpha_2 = 0.7$.

$$\sum_{k=1}^{3}\sum_{j=1}^{10} \frac{r^2_{j,k,t}}{\alpha + r^2_{j,k,t}} WH_{j,k} = S^b(t) \qquad (4)$$

where the summation is over the k alternatives and j regions,

$r_{j,k,t}$ is the implicit rate,

$WH_{j,k}$ is the number of WH's by fuel type coming up for replacement,

$S^b(t)$ is the baseline sales of HPWH nationally for year t.[8]

The expression $r^2_{j,k,t}/(\alpha + r^2_{j,k,t})$ is the proportion of water heaters of the k^{th} type being replaced in region j. The parameter α is a constant calculated by solving equation (4) through an iterative procedure. The reader should note that this makes the determination of α dependent upon the assumed national sales of the HPWH before the tax credit. However, as noted earlier, estimates are robust to errors in these prespecified sales levels.[13]

For the incentives case (applying the 15% tax credit), the cost of the HPWH and appropriate fuel switching charge is reduced by 15% and the $r_{j,k,t}$ parameters are solved for again. The α values from the base case and the new $r_{j,k,t}$ values are used in equation (4) to forecast the sales in the incentive case.

Scenario 1

Tables 6.A.1 through 6.A.5 show the output of the equipment choice model for scenario 1, where HPWH sales are allocated to the federal

TABLE 6.A.1. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1981

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	6.39	6.6	20.58	1.29	2.3	11.74	0.00	0.0	0.00	7.68	2.9	13.38
2	8.96	12.4	29.11	0.45	0.5	5.72	0.00	0.0	0.00	9.41	2.4	12.05
3	9.72	4.7	17.14	4.37	13.7	30.70	0.00	0.0	0.00	14.09	2.5	12.41
4	22.06	3.1	13.88	0.84	28.1	48.26	0.00	0.0	0.00	22.90	2.3	11.94
5	3.21	0.9	7.24	0.98	12.3	28.92	0.00	0.0	0.00	4.19	0.4	4.70
6	6.23	4.6	16.93	0.69	23.0	42.14	0.00	0.0	0.00	6.92	1.0	7.95
7	3.36	4.1	15.97	0.07	7.2	21.43	0.00	0.0	0.00	3.43	1.1	8.08
8	0.76	1.3	8.74	0.00	15.1	32.51	0.00	0.0	0.00	0.76	0.4	5.00
9	5.76	4.9	17.50	0.00	17.3	35.27	0.00	0.0	0.00	5.76	0.9	7.37
10	0.61	0.4	4.84	0.98	49.1	75.81	2.26	10.3	26.09	3.85	2.1	11.42
SUM	67.07	3.4	14.38	9.67	5.1	17.98	2.26	0.1	2.07	79.00	1.5	9.49

REGIONAL LEVEL ALPHA: 0.5960610

TABLE 6.B.1. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1981 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	9.18	9.5	25.06	2.80	4.9	17.53	0.00	0.0	0.00	11.97	4.5	16.85
2	12.09	16.8	34.68	1.17	1.4	9.27	0.00	0.0	0.00	13.25	3.3	14.37
3	14.51	7.0	21.20	9.83	30.7	51.42	0.00	0.0	0.00	24.34	4.4	16.47
4	34.72	4.9	17.58	1.69	56.4	87.74	0.00	0.0	0.00	36.41	3.7	15.16
5	6.47	1.8	10.32	2.31	28.9	49.19	0.00	0.0	0.00	8.78	0.8	6.81
6	9.29	6.8	20.91	1.48	49.5	76.37	0.00	0.0	0.00	10.77	1.6	9.94
7	5.11	6.2	19.92	0.16	15.7	33.36	0.00	0.0	0.00	5.27	1.7	10.04
8	1.42	2.4	11.98	0.00	30.9	51.59	0.00	0.0	0.00	1.42	0.8	6.83
9	8.56	7.3	21.60	0.00	38.7	61.29	0.00	0.0	0.00	8.56	1.3	9.00
10	1.53	1.0	7.68	1.56	77.9	144.97	3.41	15.5	33.06	6.49	3.6	14.95
SUM	102.87	5.1	17.98	20.99	11.2	27.37	3.41	0.1	2.55	127.28	2.4	12.10

REGIONAL LEVEL ALPHA: 0.5960610

The discount rate the median consumer would use to evaluate the heat pump water heater: 77.20%.

TABLE 6.A.2. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1982

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	15.07	15.7	20.79	5.17	9.1	15.24	0.00	0.0	0.00	20.25	7.7	13.93
2	19.49	27.1	29.40	2.83	3.5	9.13	0.00	0.0	0.00	22.32	5.6	11.80
3	23.81	11.5	17.40	10.84	33.9	34.54	0.00	0.0	0.00	34.65	6.2	12.40
4	56.03	8.0	14.18	1.62	54.1	52.44	0.00	0.0	0.00	57.65	5.9	12.06
5	8.42	2.3	7.39	2.49	31.1	32.44	0.00	0.0	0.00	10.91	1.0	4.75
6	15.66	11.5	17.42	1.42	47.2	45.65	0.00	0.0	0.00	17.08	2.6	7.86
7	8.25	10.1	16.16	0.21	21.4	25.17	0.00	0.0	0.00	8.47	2.7	7.99
8	1.83	3.0	8.53	0.00	37.8	37.65	0.00	0.0	0.00	1.83	1.0	4.85
9	14.00	11.9	17.72	0.00	39.6	39.06	0.00	0.0	0.00	14.00	2.2	7.23
10	1.72	1.1	5.11	1.47	73.6	60.62	5.65	25.7	28.37	8.85	4.9	10.98
SUM	164.29	9.2	14.44	26.06	13.9	19.36	5.65	0.2	2.05	196.00	3.7	9.45

REGIONAL LEVEL ALPHA: 0.2329268

TABLE 6.B.2. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1982 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	20.75	21.5	25.29	10.19	17.9	22.51	0.00	0.0	0.00	30.94	11.7	17.61
2	24.82	34.5	35.01	6.01	7.3	13.58	0.00	0.0	0.00	30.84	7.8	14.02
3	34.25	16.8	21.49	19.09	59.7	58.69	0.00	0.0	0.00	53.34	9.5	15.67
4	85.31	12.1	17.91	2.40	79.9	96.12	0.00	0.0	0.00	87.70	8.9	15.13
5	16.59	4.5	10.48	4.57	57.1	55.73	0.00	0.0	0.00	21.16	1.9	6.65
6	22.44	16.5	21.46	2.25	74.9	83.27	0.00	0.0	0.00	24.68	3.7	9.51
7	12.14	14.8	20.13	0.40	40.4	39.76	0.00	0.0	0.00	12.54	4.0	9.79
8	3.38	5.6	11.75	0.00	61.9	61.47	0.00	0.0	0.00	3.38	1.9	6.63
9	20.04	17.0	21.84	0.00	66.9	68.63	0.00	0.0	0.00	20.04	3.1	8.69
10	4.14	2.7	7.98	1.82	91.1	154.66	7.81	35.5	35.79	13.77	7.7	13.90
SUM	243.84	12.2	17.98	46.73	24.9	27.76	7.81	0.2	2.42	298.38	5.6	11.77

REGIONAL LEVEL ALPHA: 0.2329268

The discount rate the median consumer would use to evaluate the heat pump water heater: 48.26%.

TABLE 6.A.3. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1983

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	23.09	24.0	21.00	11.62	20.4	18.92	0.00	0.0	0.00	34.71	13.2	14.57
2	27.85	38.7	29.69	6.42	10.3	12.65	0.00	0.0	0.00	36.27	9.2	11.87
3	37.76	18.2	17.66	16.51	51.6	38.61	0.00	0.0	0.00	54.27	9.7	12.26
4	92.02	13.1	14.49	2.09	69.8	56.87	0.00	0.0	0.00	94.12	9.6	12.18
5	14.36	3.9	7.53	3.66	48.3	36.14	0.00	0.0	0.00	18.22	1.6	4.77
6	25.38	18.7	17.92	1.91	63.5	49.36	0.00	0.0	0.00	27.29	4.1	7.76
7	13.14	16.0	16.34	0.38	37.8	29.13	0.00	0.0	0.00	13.52	4.3	7.89
8	2.85	4.7	8.32	0.00	57.1	43.16	0.00	0.0	0.00	2.85	1.6	4.71
9	22.05	18.7	17.93	0.00	57.0	43.06	0.00	0.0	0.00	22.05	3.5	7.07
10	3.16	2.0	5.38	1.68	84.0	85.70	8.88	40.3	30.75	13.71	7.6	10.75
SUM	261.65	13.1	14.51	46.47	24.7	21.43	8.88	0.3	2.00	317.00	6.0	9.42

REGIONAL LEVEL ALPHA: 0.1398061

TABLE 6.B.3. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1983 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	30.62	31.8	25.53	20.55	36.0	28.07	0.00	0.0	0.00	51.17	19.4	18.36
2	33.97	47.2	35.34	15.78	19.2	18.25	0.00	0.0	0.00	49.75	12.6	14.17
3	52.45	25.3	21.78	24.33	76.0	66.60	0.00	0.0	0.00	76.78	13.7	14.92
4	135.58	19.2	18.25	2.66	88.8	105.05	0.29	0.1	1.23	138.54	14.1	15.17
5	27.59	7.5	10.64	5.91	73.8	62.77	0.00	0.0	0.00	33.50	2.9	6.52
6	34.98	25.7	22.01	2.56	65.5	90.64	0.00	0.0	0.00	37.55	5.7	9.18
7	18.70	22.8	20.34	0.61	61.1	46.87	0.00	0.0	0.00	19.31	6.1	9.52
8	5.23	8.7	11.52	0.00	79.0	72.46	0.00	0.0	0.00	5.23	2.9	6.43
9	30.49	25.9	22.08	0.00	80.7	76.51	0.00	0.0	0.00	30.49	4.8	8.38
10	7.27	4.7	8.27	1.90	95.1	164.89	11.37	51.7	38.66	20.54	11.4	13.43
SUM	376.87	18.8	18.02	74.30	39.5	30.23	11.66	0.4	2.29	462.84	8.7	11.55

REGIONAL LEVEL ALPHA: 0.1398061

The discount rate the median consumer would use to evaluate the heat pump water heater: 37.39%.

TABLE 6.A.4. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1984

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	28.73	29.8	21.21	16.78	32.9	22.80	0.00	0.0	0.00	47.51	18.0	15.26
2	33.07	45.9	29.99	16.48	20.1	16.32	0.00	0.0	0.00	49.56	12.5	12.30
3	48.21	23.3	17.93	20.33	63.5	42.93	0.00	0.0	0.00	68.54	12.3	12.16
4	120.84	17.1	14.80	2.35	78.2	61.57	0.37	0.1	1.20	123.55	12.6	12.35
5	19.43	5.3	7.68	4.82	60.2	40.03	0.00	0.0	0.00	24.24	2.1	4.80
6	33.00	24.3	18.42	2.19	72.8	53.29	0.00	0.0	0.00	35.19	5.3	7.72
7	16.81	20.5	16.53	0.51	51.2	33.34	0.00	0.0	0.00	17.32	5.5	7.82
8	3.53	5.9	8.11	0.00	69.5	49.07	0.00	0.0	0.00	3.53	1.9	4.57
9	27.99	23.7	18.15	0.00	67.9	47.30	0.00	0.0	0.00	27.99	4.4	6.97
10	4.56	2.9	5.65	1.77	88.7	91.07	11.23	51.1	33.23	17.57	9.8	10.71
SUM	336.17	16.8	14.62	67.22	35.8	24.27	11.60	0.4	1.99	415.00	7.8	9.47

REGIONAL LEVEL ALPHA: 0.1058419

TABLE 6.B.4. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1984 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	37.12	38.5	25.77	30.05	52.7	34.35	0.16	0.1	1.22	67.32	26.6	19.07
2	39.31	54.6	35.67	28.01	34.2	23.43	0.00	0.0	0.00	67.32	17.0	14.72
3	65.27	31.5	22.08	26.95	84.2	75.16	0.00	0.0	0.00	92.22	16.5	14.46
4	173.48	24.6	18.59	2.78	92.5	114.56	4.64	1.7	4.28	180.90	18.4	15.47
5	36.56	9.9	10.80	6.59	82.4	70.36	0.00	0.0	0.00	43.15	3.8	6.46
6	44.17	32.9	22.58	2.70	90.2	98.49	0.00	0.0	0.00	46.88	7.1	8.99
7	23.35	28.5	20.54	0.74	73.9	54.76	0.00	0.0	0.00	24.09	7.6	9.33
8	6.49	10.8	11.30	0.00	87.1	84.55	0.00	0.0	0.00	6.49	3.6	6.25
9	37.75	32.0	22.33	0.00	87.2	84.97	0.00	0.0	0.00	37.75	5.9	8.16
10	10.11	6.5	8.57	1.93	96.7	175.68	13.67	62.2	41.69	25.71	14.3	13.29
SUM	473.60	23.7	18.12	99.75	53.1	34.59	18.47	0.6	2.51	591.82	11.1	11.52

REGIONAL LEVEL ALPHA: 0.1058419

The discount rate the median consumer would use to evaluate the heat pump water heater: 32.50%.

TABLE 6.A.5. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1985

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	34.53	35.9	21.42	26.75	46.9	26.95	1.23	1.1	3.04	62.50	23.7	15.99
2	37.99	52.8	30.28	27.21	33.2	20.20	0.00	0.0	0.00	65.20	16.5	12.72
3	59.47	28.7	18.19	23.47	73.3	47.53	0.00	0.0	0.00	82.94	14.8	11.96
4	153.35	21.8	15.11	2.53	94.4	66.56	4.89	1.8	3.87	160.77	16.4	12.69
5	25.55	6.9	7.83	5.63	70.4	44.15	0.00	0.0	0.00	31.18	2.7	4.81
6	41.31	30.4	18.94	2.40	60.1	57.45	0.00	0.0	0.00	43.71	6.6	7.63
7	20.80	25.4	16.72	0.64	63.5	37.83	0.00	0.0	0.00	21.43	6.8	7.71
8	4.27	7.1	7.91	0.00	78.9	55.41	0.00	0.0	0.00	4.27	2.3	4.44
9	34.34	29.1	18.37	0.00	76.6	51.78	0.00	0.0	0.00	34.34	5.4	6.83
10	6.39	4.1	5.93	1.64	91.9	96.74	13.42	61.0	35.83	21.65	12.0	10.61
SUM	418.00	20.9	14.73	90.47	48.1	27.60	19.53	0.6	2.27	528.00	9.9	9.52

REGIONAL LEVEL ALPHA: 0.0821167

TABLE 6.B.5. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1985 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	43.49	45.2	26.00	38.58	67.7	41.47	4.33	3.9	5.80	86.40	32.8	20.03
2	44.08	61.2	36.01	41.90	51.1	29.29	0.00	0.0	0.00	85.99	21.7	15.09
3	78.40	37.9	22.37	28.69	69.7	84.40	0.00	0.0	0.00	107.09	19.2	13.95
4	214.19	30.4	18.94	2.85	95.0	124.68	16.36	6.0	7.24	233.40	23.8	16.02
5	47.01	12.8	10.96	7.06	88.2	78.52	0.00	0.0	0.00	54.07	4.8	6.41
6	53.65	39.5	23.15	2.80	93.3	106.85	0.00	0.0	0.00	56.45	8.5	8.76
7	28.17	34.4	20.75	0.83	83.1	63.47	0.00	0.0	0.00	29.00	9.1	9.09
8	7.83	13.0	11.07	0.00	92.1	97.69	0.00	0.0	0.00	7.83	4.3	6.07
9	45.14	38.3	22.57	0.00	91.5	94.01	0.00	0.0	0.00	45.14	7.1	7.91
10	13.62	8.7	8.87	1.95	97.7	187.08	15.63	71.0	44.88	31.20	17.4	13.14
SUM	575.60	28.8	18.22	124.67	66.3	40.21	36.32	1.2	3.11	736.59	13.9	11.50

REGIONAL LEVEL ALPHA: 0.0821167

The discount rate the median consumer would use to evaluate the heat pump water heater: 28.66%.

regions replacing the appropriate number of electric resistance, oil- and gas-fired water heaters coming up for retirement each year from 1981 through 1985. Region 4 (Southeast) captures the largest share of new HPWH sales largely due to the fact that slightly over one-third of the U.S. stock of electric water heaters are located in region 4, in addition to a relatively warm climate (i.e., higher HPWH efficiency).

In 1981, replacements of oil- and gas-fired water heaters make up 15% of total U.S. HPWH sales (this fraction increasing to 21% in 1985). This increase is primarily due to fuel oil and natural gas prices that are expected to climb at an annual rate of 4.8%/yr. compared to a forecasted electricity price annual growth rate of 1.2%/yr. through 1985.

Tables 6.A.1 through 6.A.5, in addition to presenting HPWH replacements of electric, oil- and gas-fired water heaters, give estimated regional implicit interest rates which are considered to be the rate of return that the consumer would achieve if he purchased a HPWH (i.e., the higher the interest rate the larger fraction of consumers would choose a HPWH in his region). The percent columns to the right of the columns for replacements of electric, oil- and gas-fired water heaters represent the percentage of those water heaters coming up for replacement at the end of their useful life that are replaced by the HPWH.

Implicit rates of return in 1981 for owners of electric resistance WH's converting to HPWH's average 15% and range from 4.8% in region 10 to 29.1% in region 2 (this is mainly due to the wide variation in electric

WH annual costs - $537/yr. for region 2, vs. $166/yr. in region 10). The average implicit rates of return of oil-fired WH owners selecting a HPWH is approximately 33%. This is due to an annual cost of $237 for operating an oil-fired WH in region 10, whereas for a HPWH it is only $92. In other regions the HPWH and oil-fired WH annual costs are much closer, thus making the HPWH selection less worthwhile reflected by the relatively low implicit interest rates.

In the incentives case (Table 6.B.1 though 6.B.5), the sales of the HPWH are increased considerably over the assumed baseline national sales of the HPWH from 1981 thorugh 1985. In 1981, U.S. sales of the HPWH due to the tax credit are 61% higher than the baseline forecasts. The increase in HPWH sales due to the tax credit in the time period of 1982 though 1985 fall from a 52% increase in 1982 to a 40% increase in 1985.

Scenario 2 (Natural gas price deregulation case)

Tables 7.A.1 through 7.A.5 show the output of the equipment choice model for scenario 2 where fuel prices follow an assumed natural gas deregulation path (this price scenario is described in Chapter 2). The large increase in HPWH replacements of gas water heaters from scenario 1 to scenario 2 come mainly at the expense of electric water heaters. This pattern of replacements continues through 1985 although an increasing percentage of HPWH replacements are made at the expense of oil WH's by 1985. Ten percent of the HPWH sales replace gas WH's in

TABLE 7.A.1. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1981

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	5.11	5.3	23.58	1.02	1.8	11.74	2.50	2.3	13.26	8.63	3.3	16.01
2	7.25	10.1	29.11	0.35	0.4	5.72	0.00	0.0	0.00	7.61	1.9	12.17
3	7.74	3.7	17.14	3.55	11.1	30.70	1.33	0.4	5.61	12.61	2.3	13.21
4	17.50	2.5	13.88	0.71	23.5	48.26	4.28	1.6	10.99	22.49	2.3	13.33
5	2.53	0.7	7.24	0.80	10.0	28.92	0.37	0.0	1.92	3.70	0.3	4.97
6	4.96	3.6	16.93	0.57	19.0	42.14	4.37	0.8	7.99	9.90	1.5	10.73
7	2.67	3.3	15.97	0.06	5.7	21.43	0.00	0.0	0.00	2.73	0.9	8.10
8	0.60	1.0	8.74	0.00	12.3	32.51	0.00	0.0	0.00	0.60	0.3	5.01
9	4.59	3.9	17.59	0.00	14.1	35.27	0.61	0.1	2.97	5.19	0.8	7.88
10	0.48	0.3	4.94	0.86	43.2	75.81	4.21	19.1	42.30	5.55	3.1	15.53
SUM	53.43	2.7	14.41	7.91	4.2	18.23	17.66	0.6	6.56	79.00	1.5	10.69

REGIONAL LEVEL ALPHA: 0.7564791

TABLE 7.B.1. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1981 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	7.38	7.7	25.06	2.23	3.9	17.53	4.18	3.8	17.28	13.78	5.2	20.44
2	9.87	13.7	34.68	0.92	1.1	9.27	0.00	0.0	0.00	10.80	2.7	14.56
3	11.61	5.6	21.20	8.29	25.9	51.42	3.38	1.1	8.99	23.28	4.2	18.13
4	27.65	3.9	17.58	1.51	50.4	87.74	8.13	3.0	15.24	37.29	3.8	17.29
5	5.12	1.4	10.32	1.94	24.2	49.19	2.49	0.3	4.98	9.54	0.8	8.00
6	7.43	5.5	20.91	1.31	43.5	76.37	9.72	1.9	11.99	18.46	2.8	14.75
7	4.08	5.0	19.92	0.13	12.8	33.36	0.00	0.0	0.00	4.21	1.3	10.09
8	1.12	1.9	11.98	0.00	26.0	51.59	0.00	0.0	0.26	1.12	0.6	6.85
9	6.85	5.8	21.60	0.00	33.2	61.29	2.60	0.5	6.15	9.45	1.5	10.66
10	1.21	0.8	7.68	1.47	73.5	144.97	5.95	27.0	52.96	8.63	4.8	19.53
SUM	82.31	4.1	18.02	17.79	9.5	28.12	36.45	1.2	9.45	136.66	2.6	14.13

REGIONAL LEVEL ALPHA: 0.7564791

The discount rate the median consumer would use to evaluate the heat pump water heater: 86.98%.

TABLE 7.A.2. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1982

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	10.64	11.1	20.79	3.57	6.3	15.24	8.27	7.5	16.82	22.49	8.5	18.02
2	14.33	19.9	29.40	1.92	2.3	9.13	0.15	0.1	1.46	16.40	4.1	12.26
3	16.57	8.0	17.40	8.17	25.5	34.54	6.68	2.1	8.61	31.42	5.6	14.39
4	38.52	5.5	14.18	1.32	44.1	52.44	13.45	4.9	13.43	53.30	5.4	14.14
5	5.68	1.5	7.39	1.86	23.2	32.44	4.81	0.6	4.71	12.35	1.1	6.18
6	10.90	8.0	17.42	1.12	37.5	45.65	15.57	3.0	10.35	27.60	4.2	12.32
7	5.72	7.0	16.16	0.15	15.4	25.17	0.00	0.0	0.00	5.87	1.9	8.10
8	1.23	2.0	8.53	0.00	29.0	37.65	0.13	0.1	1.95	1.37	0.7	5.13
9	9.76	8.3	17.72	0.00	30.5	39.06	4.83	0.9	5.71	14.59	2.3	9.02
10	1.16	0.7	5.11	1.30	65.1	80.62	8.16	37.1	45.30	10.62	5.9	14.79
SUM	114.51	5.7	14.54	19.42	10.3	20.02	62.06	2.0	8.40	196.00	3.7	11.54

REGIONAL LEVEL ALPHA: 0.3479141

TABLE 7.B.2. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1982 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	14.96	15.5	25.29	7.25	12.7	22.51	12.74	11.6	21.35	34.94	13.3	23.07
2	18.75	26.0	35.01	4.13	5.0	13.58	1.11	0.5	4.00	23.99	6.1	14.98
3	24.25	11.7	21.49	15.92	49.8	58.69	13.43	4.2	12.34	53.60	9.6	19.21
4	59.49	8.4	17.91	2.18	72.6	96.12	23.29	8.5	18.02	84.96	8.7	18.17
5	11.27	3.1	10.48	3.77	47.2	55.73	13.97	1.8	8.07	29.02	2.6	9.55
6	15.89	11.7	21.46	2.00	66.6	83.27	30.23	5.8	14.63	48.12	7.3	16.54
7	8.54	10.4	20.13	0.31	31.2	39.76	0.00	0.0	0.00	8.86	2.8	10.00
8	2.30	3.8	11.75	0.00	52.1	61.47	0.72	0.6	4.54	3.02	1.7	7.66
9	14.22	12.1	21.84	0.00	57.5	68.63	12.37	2.4	9.20	26.58	4.2	12.30
10	2.80	1.8	7.98	1.75	87.3	154.66	10.57	48.1	56.74	15.12	8.4	17.88
SUM	172.48	8.6	18.12	37.30	19.8	29.35	118.42	3.8	11.71	328.21	6.2	15.14

REGIONAL LEVEL ALPHA: 0.3479141

The discount rate the median consumer would use to evaluate the heat pump water heater: 58.98%.

TABLE 7.A.3. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1983

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	14.08	14.6	21.00	6.95	12.2	18.92	15.30	13.9	20.40	36.32	13.8	20.31
2	18.36	25.5	29.69	4.79	5.8	12.65	2.98	1.2	5.66	26.13	6.6	13.49
3	22.36	10.8	17.66	11.73	36.7	38.61	15.81	4.9	11.57	49.89	8.9	15.89
4	53.11	7.5	14.49	1.67	55.7	56.87	24.41	8.9	15.91	79.19	8.1	15.05
5	7.93	2.2	7.53	2.69	33.6	36.14	15.91	2.1	7.42	26.53	2.3	7.85
6	15.06	11.1	17.92	1.46	48.6	49.36	30.80	5.9	12.72	47.32	7.2	14.10
7	7.69	9.4	16.34	0.25	24.8	29.13	0.00	0.0	0.00	7.94	2.5	8.13
8	1.58	2.6	8.32	0.00	42.0	43.16	1.47	1.2	5.60	3.05	1.7	6.62
9	13.08	11.1	17.93	0.00	41.9	43.06	13.85	2.7	8.39	26.93	4.2	10.65
10	1.73	1.1	5.38	1.48	74.0	85.70	10.49	47.7	48.48	13.70	7.6	14.58
SUM	154.97	7.7	14.71	31.02	16.5	22.56	131.01	4.2	10.62	317.00	6.0	12.79

REGIONAL LEVEL ALPHA: 0.2576494

TABLE 7.B.3. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1983 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	19.44	20.2	25.53	13.35	23.4	28.07	22.14	20.1	25.48	54.94	20.9	26.06
2	23.51	32.6	35.34	9.39	11.4	18.25	6.82	2.8	8.64	39.71	10.0	16.95
3	32.19	15.6	21.78	20.24	63.3	66.60	27.86	8.7	15.67	80.29	14.4	20.79
4	80.67	11.4	18.25	2.43	81.1	105.05	39.38	14.4	20.85	122.48	12.5	19.18
5	15.50	4.2	10.64	4.84	60.5	62.77	34.69	4.6	11.10	55.03	4.8	11.45
6	21.52	15.8	22.01	2.28	76.1	90.64	54.32	10.4	17.31	78.12	11.8	18.59
7	11.33	13.8	20.34	0.46	46.0	46.87	0.00	0.0	0.00	11.79	3.7	9.97
8	2.96	4.9	11.52	0.00	67.1	72.46	3.41	2.0	8.60	6.36	3.5	9.66
9	18.76	15.9	22.08	0.00	69.4	76.51	28.43	5.5	12.20	47.19	7.4	14.34
10	4.03	2.6	8.27	1.83	91.3	164.89	12.96	58.9	60.75	18.81	10.5	17.36
SUM	229.90	11.5	18.29	54.82	29.2	32.57	230.01	7.4	14.31	514.72	9.7	16.63

REGIONAL LEVEL ALPHA: 0.2576494

The discount rate the median consumer would use to evaluate the heat pump water heater: 50.76%.

TABLE 7.A.4. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1984

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	15.09	15.7	21.21	10.08	17.7	22.80	21.18	19.3	24.03	46.34	17.6	22.75
2	19.49	27.1	29.99	8.12	9.9	16.32	8.99	3.7	9.67	36.61	9.2	15.71
3	24.25	11.7	17.93	13.83	43.2	42.93	25.61	8.0	14.51	63.69	11.4	17.65
4	58.45	8.3	14.80	1.83	61.0	61.57	33.56	12.3	18.43	93.84	9.6	16.01
5	8.75	2.4	7.68	3.19	39.8	40.03	30.71	4.0	10.10	42.64	3.8	9.72
6	16.71	12.3	18.42	1.62	54.0	53.29	44.93	8.6	15.11	63.26	9.6	16.02
7	8.30	10.1	16.53	0.31	31.5	33.34	0.13	0.1	1.15	8.75	2.8	8.29
8	1.60	2.6	8.11	0.00	49.9	49.07	4.05	3.3	9.12	5.65	3.1	8.80
9	14.12	12.0	18.15	0.00	48.0	47.30	24.97	4.8	11.05	39.09	6.1	12.57
10	2.03	1.3	5.65	1.55	77.4	91.07	11.57	52.6	51.84	15.15	8.4	14.93
SUM	168.78	8.4	14.94	40.52	21.6	25.80	205.70	6.6	13.06	415.00	7.8	14.33

REGIONAL LEVEL ALPHA: 0.2422035

TABLE 7.B.4. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1984 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	20.72	21.5	25.77	18.67	32.8	34.35	29.43	26.8	29.75	68.82	26.1	29.28
2	24.80	34.4	35.67	15.16	18.5	23.43	16.02	6.6	13.10	55.97	14.1	19.97
3	34.68	16.8	22.08	22.40	70.0	75.16	41.58	13.0	19.02	98.65	17.6	22.78
4	88.01	12.5	18.59	2.53	84.4	114.56	51.54	18.9	23.75	142.08	14.5	20.26
5	16.92	4.6	10.80	5.37	67.1	70.36	57.71	7.6	14.11	80.00	7.0	13.54
6	23.63	17.4	22.58	2.40	80.0	98.49	74.13	14.2	20.04	100.16	15.2	20.81
7	12.15	14.8	20.54	0.55	55.3	54.76	1.43	0.6	3.86	14.14	4.5	10.63
8	3.02	5.0	11.30	0.00	74.7	84.55	7.43	6.1	12.53	10.45	5.7	12.13
9	20.12	17.1	22.33	0.00	74.9	84.97	45.27	8.7	15.19	65.40	10.2	16.63
10	4.58	2.9	8.57	1.85	92.7	175.68	13.99	63.6	65.02	20.43	11.4	17.62
SUM	248.63	12.4	18.54	68.94	36.7	37.45	338.53	10.8	17.15	656.10	12.3	18.47

REGIONAL LEVEL ALPHA: 0.2422035

The discount rate the median consumer would use to evaluate the heat pump water heater: 49.21%.

TABLE 7.A.5. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1985

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	15.84	16.5	21.42	13.54	23.8	26.95	27.34	24.9	27.76	56.72	21.5	25.30
2	20.33	28.2	30.28	12.21	14.9	20.20	17.70	7.3	13.56	50.24	12.7	18.40
3	25.74	12.4	18.19	15.75	49.2	47.53	37.06	11.6	17.47	78.55	14.0	19.52
4	62.88	8.9	15.11	1.97	65.5	66.56	43.43	15.9	21.01	108.28	11.0	17.01
5	9.43	2.6	7.83	3.64	45.5	44.15	49.64	6.5	12.76	62.71	5.5	11.67
6	18.12	13.3	18.94	1.76	58.6	57.45	60.83	11.7	17.55	80.71	12.2	18.02
7	8.77	10.7	16.72	0.38	38.0	37.83	2.24	1.0	4.75	11.39	3.6	9.32
8	1.58	2.6	7.91	0.00	56.8	55.41	7.72	6.3	12.55	9.30	5.1	11.19
9	14.91	12.6	18.37	0.00	53.5	51.78	38.78	7.5	13.70	53.69	8.4	14.63
10	2.31	1.5	5.93	1.60	80.1	96.74	12.50	56.8	55.40	16.42	9.1	15.31
SUM	179.92	9.0	15.18	50.65	27.0	29.40	297.24	9.5	15.65	528.00	9.9	16.04

REGIONAL LEVEL ALPHA: 0.2330992

TABLE 7.B.5. REGIONAL HPWH DISPLACEMENT OF ELECTRIC RESISTANCE AND OIL AND GAS-FIRED WATER HEATERS (REPLACEMENTS IN THOUSANDS)

ANALYSIS FOR THE YEAR: 1985 INCENTIVES CASE

REG#	REPLACE ELECTRIC	%	INTER. RATE	REPLACE OF OIL	%	INTER. RATE	REPLACE OF GAS	%	INTER. RATE	REPLACE OF TOTAL	%	INTER. RATE
1	21.65	22.5	26.00	24.20	42.5	41.47	36.73	33.4	34.18	82.59	31.4	32.84
2	25.74	35.7	36.01	22.06	26.9	29.29	28.08	11.6	17.49	75.88	19.2	23.51
3	36.60	17.7	22.37	24.11	75.3	84.40	56.73	17.7	22.41	117.44	21.0	24.90
4	93.95	13.3	18.94	2.61	87.0	124.68	64.07	23.5	26.75	160.64	16.4	21.37
5	18.06	4.9	10.96	5.81	72.6	78.52	84.91	11.2	17.12	108.77	9.6	15.71
6	25.40	18.7	23.15	2.49	93.0	106.85	95.27	18.3	22.93	123.16	18.7	23.12
7	12.77	15.6	20.75	0.63	63.3	63.47	6.01	2.6	7.84	19.42	6.1	12.33
8	3.01	5.0	11.07	0.00	80.4	97.69	12.64	10.4	16.41	15.65	8.6	14.79
9	21.15	17.9	22.57	0.00	79.1	94.01	64.75	12.4	18.20	85.90	13.5	19.04
10	5.09	3.3	8.87	1.88	93.8	187.08	14.85	67.5	69.56	21.81	12.1	17.94
SUM	263.41	13.2	18.80	83.79	44.6	43.29	464.05	14.8	20.16	811.24	15.3	20.50

REGIONAL LEVEL ALPHA: 0.2330992

The discount rate the median consumer would use to evaluate the heat pump water heater: 48.28%.

1981, increasing to 33% in 1985. As in scenario 1, the replacement sales of the HPWH for the incentives case show a large increase over the baseline sales (Tables 7.B.1 through 7.B.5). In this natural gas price deregulation case the increases in sales of the HPWH due to the tax credit exceed the HPWH sales increase due to the tax credit scenario.[14] For the incentives case where gas prices are deregulated, the HPWH sales increase is 76% in 1981 falling to a 55% increase in 1985.

The choice model results for the incentives case assumes that individuals have perfect information concerning fuel price increases, expenditures and equipment lifetimes. The model omits information such as reliability and future repair costs that would aid the consumer in selecting the most cost effective water heater. There is no reason to believe that these omissions introduce any systematic bias in our estimate of the relative changes that could be expected due to the tax credit.[15]

In the analysis of both scenario 1 and 2 it is assumed that a HPWH purchased as a replacement for an electric, oil- or gas-fired unit will be located in the unconditioned space of the home (basement or attached garage with garage door). This assumption is necessary since no information exists which defines by region the location of water heaters in the home by space heating fuel type. In most regions of the U.S. HPWH energy savings are less when located in the conditioned space of the home. Therefore, this assumption could lead to an overestimate of HPWH energy savings. However, in some regions of the U.S., HPWH energy savings are greater when located in conditioned space. Therefore, if HPWH's are selectively installed in their most effective locations, energy savings will be greater. On balance, the authors expect HPWH location in the home will have little effect.

3. NATIONAL FUEL OIL AND NATURAL GAS SAVINGS

This chapter deals with the methodology of calculating the savings of fuel oil and natural gas in the U.S. by the additional sales of the HPWH due to the granting of the residential energy tax credit. A realistic approach for calculating oil and gas savings is crucial since a proposed conservation item is considered eligible for an energy tax credit only if the dollar value of savings of oil and gas due to the tax credit over the lifetime of the equipment exceeds the revenue loss to the treasury due to the tax credit. The revenue loss to the treasury during the tax credit period of 1981 through 1985 is represented by:

$$\sum_{t=1}^{5} (S_t^i + S_t^b) \cdot P_t^c \cdot 0.15 \cdot (1 + DR/100)^{-t}$$

where

S_t^i = incremental replacement sales/yr. due to tax credit (unit/yr.)

S_t^b = baseline replacement sales/yr. without tax credit (unit/yr.)

P_t^c = price of item for year t (1980 $'s)

DR = real discount rate

For the oil and gas used in electric utility generation that would be saved by replacing conventional water heaters by HPWH's a marginal fuel use analysis for electric utilities is required. By marginal fuel use, it is meant that, in general, any electricity saved by the replacement of an energy efficient electrical item over a less efficient one will be generated by the most expensive fuel used in a utility system.

In other words, any reduction in load (either peak or base) is generally at the expense of oil and natural gas if these fuels are used by utility in electric generation.

A discussion of the methodology used to estimate the savings of electric utility oil and natural gas use due to replacement sales of the HPWH is presented in Appendix B.

4. ENERGY TAX CREDIT ELIGIBILITY MODEL METHODOLOGY

The Residential Energy Tax Credit model uses the following relationships to calculate savings of oil and gas on a regional basis for electric utilities for the lifetime of HPWH's sold during the five year period that the tax credit ruling is in effect.

Savings of oil and gas:

1. Oil and gas savings due to replacing an electric resistance water heater with a HPWH:

$$\sum_{t=1}^{5} S_{t,k}^{i,e} \left(Q_k^{ER} - Q_k^{HP}\right) \sum_{t^*=t}^{t+LT-1} \left(F_{t^*}^{o} + F_{t^*}^{g}\right)_k \cdot D_{t^*}$$

2. Oil and gas savings due to replacing an oil- or gas-fired WH with a HPWH:

$$\sum_{t=1}^{5} S_{t,k}^{i,j} \sum_{t^*=t}^{t+LT-1} \left[Q_k^{j} - Q_k^{HP} \left(F_{t^*}^{o} + F_{t^*}^{g}\right)_k \cdot D_{t^*}\right]$$

where

$F_{t^*}^{o}$ and $F_{t^*}^{g}$ are the fractions of electrical energy generated by oil and gas in year t by region k.

$S_{t,k}^{i,e}$ and $S_{t,k}^{i,j}$ are the incremental sales due to the tax credit for HPWH's replacing electric resistance and oil- or gas-fired WH's for the t^{th} yr. and k^{th} region (j = oil or gas).

Q_k^{ER} is annual regional energy consumption of electric resistance water heater (BOE Primary).

Q_k^{HP} is annual regional energy consumption of HPWH's (BOE Primary).

The expression $D_{t^*} = 0.9e^{-(t^*-1)/\bar{c}}$ incorporates a decay function to approximate the reduction in savings of oil and gas in electric generation to account for utilities consuming oil and gas in decreasing amounts over the lifetime of the HPWH. $\bar{c}$ is an appropriate constant to calibrate the decay function to its assumed value in the year 1997 as discussed in Section 6.

$ value of savings of oil and gas

1. The $ value of savings of oil and gas for HPWH's replacing electric resistance WH's for region k is represented as:

$$\sum_{t=1}^{5} S_{t,k}^{i,e} (Q_k^{ER} - Q_k^{HP}) \sum_{t^*=t}^{t+LT-1} PF_{t^*,k} (1 + DR/100)^{-t^*} \cdot D_{t^*}$$

2. $ value of saving of oil and gas for HPWHs replacing gas- or oil-fired WH' for region k:

$$\sum_{t=1}^{5} S_{t,k}^{i,j} \sum_{t^*=t}^{t+LT-1} [Q_k^j \quad P_{t^*}^j - Q_k^{HP} \cdot PF_{t^*,k} \cdot D_{t^*}] (1 + DR/100)^{-t^*}$$

where

$PF_{t^*,k}$ is the regional primary energy price of fuel oil and gas used in electric generation per year =

$$F_{t^*,k}^o \cdot P_{t^*}^o (1 + PRM/100) + F_{t^*,k}^g \cdot P_{t^*}^g$$

where

$P_{t^*}^o$, $P_{t^*}^g$ are the world prices of fuel oil and gas and PRM is the oil price premium is percent reflecting a national security value (assumed to be between 20% and 30%).[16]

5. ADDITIONAL TAX CREDIT MODEL ASSUMPTIONS

The provisions of the Windfall Profit Tax Act infer that any oil or gas used in the manufacture of the proposed item must be subtracted from the estimated savings in oil and gas obtained in the use of the item. This may not be economically justifiable since consumer expenditures on the HPWH mean less spent on other goods and their included energy. However, in accordance with the act we subtract it. A study by Bruce Hannon[17] provides the imbedded energy required for 355 commodities including agricultural, industrial, and even commercial services. The energy intensity matrix is organized by the 355 commodities and 6 fuel types. The unit of measurement is in Btu/(1972 producer $). Refrigeration and heating equipment is used as a proxy for the HPWH. Imbedded in the manufacture of the HPWH is approximately 32,000 Btu of oil and gas/(1972 producer $). This value is adjusted for 1980 $'s and multiplied times the approximate manufacturers cost to arrive at the total oil and gas energy content in manufacturing.

The unit lifetime of the HPWH is estimated to be 12 years in this study. The 1980 ASHRAE Systems Handbook[18] describes the following equipment lifetimes:

Equipment	Service Life (years)
Heat pump (commercial)	15
(Air-to-air) heat pump (commercial)	19
(Water-to-air) air conditioner (commercial wall)	15

In addition, the Department of Defense[19] lists refrigeration compressors as having a lifetime of 15 years.

The estimated price of the items shown in Table 8 is an arithmetic average of four HPWH manufacturer's price forecasts.[8] The price in 1980 $'s are shown in Table 8.

Table 8. Estimated cost of HPWHs

Year	1981	1982	1983	1984	1985
Price*	721	696	689	700	700

*1980 $'s, reference 8.

(Installation charges of $110 are included in these values.) A real discount rate of 7% was considered appropriate by the Federal Energy Management Program[20] and utilized in all computer runs of the model. Estimated forecasts of world prices of oil is reported by the Department of Energy[6] with the world price of natural gas calculated as the average of Canadian and Mexican gas prices.[6] The gas price is calculated by an algorithm relating it to the world oil price (P_t^o) as follows:

$$\text{Mexican gas price} = 0.134\ (P_t^o) \qquad (\$/\text{MCF})$$

$$\text{Canadian gas price} = 0.177\ (P_t^o) - 0.33$$

$$\text{Average} = (0.311P_t^o - 0.33)/2 = 0.156P_t^o - 0.165\ (\$/\text{MCF})$$

This relationship is assumed to hold from 1981 through 1985.

6. TAX CREDIT ELIGIBILITY ANALYZED FOR TWO CASES

To determine the elgibility of the HPWH for the residential energy tax credit, two cases are considered. Case I assumes fuel prices to increase from 1981 through 1997 (1997 is the lifetime end of those HPWH units sold in 1985) according to the mid-range fuel price forecasts reported in the Department of Energys' Annual Report to Congress.[6] The effects of this case, as described in Chapter 2, are that the HPWH replaces primarily electric resistance and oil-fired water heaters (82% and 15% respectively of total HPWH replacement sales), with replacements of gas-fired water heaters amounting to only 3% to 4% of total HPWH replacements from 1984 through 1985.

Case II is a natural gas price deregulation scenario where natural gas prices are assumed to 70% of fuel oil prices at the end of 1981 and have an annual fuel price growth rate 1% greater than that of oil through 1985. The results of the equipment choice model show HPWH replacements of gas-fired water heaters to range from 23% to 56% of total HPWH replacement sales from 1981 through 1985 under the natural gas deregulation scenario. These sales come mainly at the expense of electric resistance WH's but with an increasing share coming from oil WH's.

In addition to analyzing the tax credit eligibility for the two cases considering different fuel price scenarios, three options varying the increase in HPWH sales due to the tax credit are also evaluated.

Tables 9 and 10 summarize the results of the tax credit eligibility model both with and without a natural gas price decontrol scenario.

Option 1 allows the equipment choice model to determine the increase in HPWH sales due to the effective 15% price decrease of the HPWH. The effective price elasticity produced by the choice model may seem high, but economists generally expect new technologies to have high price elasticities while on the early part of their market penetration curve. Indeed, as economists would expect, our results show the price elasticity declining as HPWH sales increase. In the base case it declines from 3.4 in 1981 to 2.6 in 1985. This option is further divided into three levels of oil/gas use in electric generation. The 10%, 25%, and 50% values represent the percent of oil/gas used in electric generation in 1997 as a percent of 1981 use. This range of values accounts for the uncertainty of future electric utility use of oil/gas in electricity generation.

Case I, assuming only moderate increases in natural gas prices, shows a substantial oil/gas savings for the economy even when the percent of oil/gas used in electric generation drops to 10% of its 1981 use by 1997. Increasing this electric utility oil/gas use percentage to 50% has little effect on increasing the savings of oil and gas through 1997. As oil and gas used in electric generation decreases (which reduces the oil/gas savings when replacing conventional electric WH's by HPWH's) an offsetting increase in oil/gas savings occurs as an increasing

Table 9. Primary energy savings of oil/gas due to the energy tax credit
($BOE \times 10^6$)

Option		Primary energy savings of oil/gas for the U.S. ($BOE \times 10^6$) Case I Without NG deregulation	Case II With NG deregulation	
Allowing equip. choice model to determine increase in HPWH sales	10%†	13.92	33.27	Option 1
	25%†	14.56	28.64	Option 1
	50%†	15.31	23.08	Option 1
-1 Elasticity	25%†	5.23	7.17	Option 2
-3 Elasticity	25%†	15.69	21.51	Option 3

†% of oil/gas used in electric generation in 1997 as a percent of 1981 use.

Table 10. Net $ value of savings of oil/gas due to the energy tax credit with and without a natural gas price deregulation scenario

Option		Net $ value of savings of oil/gas for the U.S. ($\$'s \times 10^6$) Case I Without NG deregulation	Case II With NG deregulation	
Allowing equip, choice model to determine increase in HPWH sales	10%†	234.9	654.14	Option 1
	25%†	250.0	534.03	Option 1
	50%†	267.8	389.42	Option 1
-1 Elasticity	25%†	17.21	41.97	Option 2
-3 Elasticity	25%†	271.39	376.65	Option 2

†% of oil/gas used in electric generation in 1997 as a percent of 1981 use.

amount of oil/gas-fired WH's are replaced by HPWH's. In Case II, where natural gas prices are deregulated, primary energy savings of oil/gas increase substantially as the percent of oil/gas used in electricity generation declines. In this case, as 1997 is approached, the HPWH's replacing an increasing percentage of gas water heaters show larger oil/gas savings due to this reduction in oil/gas used in electricity generation.

In Case II - Option 1, national oil/gas savings varies from 23 x 10^6 BOE to 33 x 10^6 BOE over the lifetime of those HPWH's purchased due to the tax credit from 1981 thorugh 1985 depending upon the rate of decline of the percent of oil/gas used in electricity generation.

Options 2 and 3 show the effects of allowing all purchasers of the HPWH to respond to a -1 and -3 equipment price elasticity respectively (elasticities of -1 and, -3 correspond to 15% and 45% increases in sales, respectively, due to the implementation of the tax credit). Both options 1 and 2 assume 25% of oil/gas used in electric generation in 1997 as a percent of 1981 use. Even at the -1 equipment price elasticity value of option 2, which is low for a new technology beginning its market penetration, additional sales of the HPWH due to the tax credit provide a $17.2 million of savings of oil/gas for those units purchased between 1981 and 1985.

An example of the tax credit eligibilty model computer output is shown in Table 11 for Case II, region 1. Table 12 is the national summary of the results of the 10 federal regions for Case II - Option 2.

Table 11. Oak Ridge National Laboratory energy tax credit evaluation of heat pump water heaters

FOR ENERGY TAX CREDIT

NATURAL GAS DEREGULATION CASE - REGION 1

FUEL PRICES (1980 $/BOE)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995
FUEL OIL	32.70	33.30	34.00	34.60	35.30	36.40	37.50	38.60	39.70	40.80	45.20
NATURAL GAS	28.63	29.17	29.81	30.35	30.98	31.98	32.97	33.97	34.96	35.96	39.94

FRACTION OF PRIMARY ELECTRICITY SAVED THAT IS GENERATED BY OIL AND GAS

FUEL OIL	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97
NATURAL GAS	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03

SALES OF ITEM (THOUSANDS)	1981	1982	1983	1984	1985
(A) BASELINE-WITHOUT TAX CREDIT	8.6	22.5	36.3	46.3	56.7
(B) INCREMENTAL SALES	1.3	3.4	5.4	7.0	8.5
(C) TOTAL (A + B)	9.9	25.9	41.8	53.3	65.2
CAPITAL COST/UNIT FOR ITEM (IN 1980 $'S)	721	696	689	700	700

USEFUL LIFE OF ITEM (YRS.):	12
ASSUMED DISCOUNT RATE:	7.0 %
OIL PRICE PREMIUM:	20 %
NON-FUEL OPERATING AND MAINTENANCE COSTS/YEAR:	$ 10
MFG. USE OF OIL AND GAS/UNIT (BOE)	.82
YEARLY ENERGY COSTS (1980 $'S):	$291
YEARLY ENERGY SAVINGS (BOE PRIMARY):	4.69
SALVAGE VALUE (1980$'S)	$ 50

FRACTION OF HOMES BY FUEL TYPE RETROFITTING HEAT PUMP WATER HEATER

ELECTRICITY	.36
NATURAL GAS	.44
FUEL OIL	.21

SUMMARY

PRIMARY ENERGY SAVINGS OF OIL AND GAS DUE TO TAX CREDIT BY FUEL TYPE

TOTAL	0.74 M BOE	
ELECTRICITY		0.28 M BOE
NATURAL GAS		0.30 M BOE
FUEL OIL		0.18 M BOE
- MFG. USE OF OIL AND GAS		-0.02 M BOE

$ VALUE OF SAVINGS OF OIL AND GAS DUE TO TAX CREDIT BY FUEL TYPE

TOTAL	$	19.53 M	
ELECTRICITY		$	7.89 M
NATURAL GAS		$	6.13 M
FUEL OIL		$	5.51 M

- REVENUE LOSS TO TREASURY:	- $	16.04 M
= SAVINGS MINUS LOSS TO TREASURY	= $	3.49 M
- MFG. COST OF OIL & GAS	- $	0.70 M
= TOTAL SAVINGS	= $	2.79 M

Table 12. National summary of the results of the 10 federal regions for Case II — Option 2

```
        NATIONAL SUMMARY

  PRIMARY ENERGY SAVINGS OF OIL AND GAS DUE
  TO TAX CREDIT BY FUEL TYPE

  TOTAL                                      7.17 M BOE
    ELECTRICITY                                      2.15 M BOE
    NATURAL GAS                                      4.29 M BOE
    FUEL OIL                                         0.92 M BOE
 - MFG. USE OF OIL AND GAS                          -0.19 M BOE

  $ VALUE OF SAVINGS OF OIL AND GAS DUE TO TAX CREDIT BY FUEL TYPE

  TOTAL                         $      192.48 M
       ELECTRICITY                      $        57.51 M
       NATURAL GAS                      $       107.30 M
       FUEL OIL                         $        27.67 M

- REVENUE LOSS
  TO TREASURY:               - $      144.18 M

= SAVINGS MINUS LOSS         = $       48.30 M
  TO TREASURY

- MFG. COST OF OIL & GAS     - $        6.33 M

= TOTAL SAVINGS              = $       41.97 M


% OF ELECTRICITY SAVED THAT IS GENERATED BY  OIL/GAS AT END OF
LIFETIME OF EQUIPMENT AS A % OF 1980 : 25%
```

7. SUMMARY

The tax credit eligibility results of this study summarized in Tables 9 and 10 for the HPWH have been developed from an analysis of regional information and estimates of HPWH sales, efficiency, operating expense, existing water heater stocks by fuel type and the percent of oil/gas used by electric utilities. Even though the tax credits are granted on a national basis, the energy and dollar savings of this analysis are estimated regionally and aggregated up to a U.S. total. Examining the regional tax credit eligibility results for Case II - Option 2 (natural gas price deregulation case with a -1 equipment price elasticity and 25% of oil/gas used in electricity generation in 1997 as a percent of 1981 use) reveals only region 7 being ineligible. A sensitivity test of the tax credit eligibility model was undertaken to determine under the natural gas price deregulation scenario (Case II) the smallest equipment price elasticity that allows the HPWH to be eligibile for the energy tax credit. A price elasticity of -0.75 is found to provide a small but positive dollar value of savings of oil/gas to the economy even after the revenue loss to the treasury is subtracted out (the -0.75 equipment price elasticity is equivalent to only a 11.25% increase in HPWH sales due to the tax credit). Table 13 shows the regional results of this exercise where regions 1, 4, 5, and 7 are by themselves not eligible for the energy tax cerdit for the HPWH, but the dollar savings of oil/gas of the remaining six regions make up for this shortfall.

Table 13. Net $ value of savings of oi/gas for HPWH sales due to the energy tax credit by federal region (Millions of dollars)

Equipment price elasticity	Federal region 1	2	3	4	5	6	7	8	9	10	US
-1.0	2.79	7.25	7.71	2.99	1.57	8.94	-1.43	2.13	5.06	2.95	41.97
-0.75	-1.40	2.65	0.95	-5.12	-0.29	2.05	-1.83	1.20	0.98	0.93	0.13

Table 13 also shows for comparison the regional results of a -1 elasticity applied to the natural gas deregulation case.

The techniques for tax credit analysis described in this report are useful for evaluating new energy conserving technologies in addition to the HPWH. The Department of Energy has utilized these models to estimate the eligibility of other items produced by manufacturers who have applied to the Internal Revenue Service for a residential tax credit.

Areas needed for future research into tax credit eligibility including some shortcomings of the techniques described in this report are:

(1) More accurate data is required concerning the age distribution of the particular energy consuming equipment likely to be replaced by a new technology;

(2) The equipment choice model may not correctly reflect consumer uncertainty of reliability and future maintenance and operating costs of a new technology;

(3) Work is needed to empirically verify the functional form of the market penetration curve in the equipment choice model by analyzing the growth in sales of new technologies, in addition, the parameters of this function for a new technology is likely to depend on its stage of development and market penetration; and

(4) Research into providing more accurate estimates of oil/gas use by electric utilities would result in less uncertainty over oil/gas savings due to replacement sales of new energy conserving appliances.

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2. 96th Congress, "Crude Oil Windfall Profits Tax Act of 1980," PL 96-222, January 1980.

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9. N.S. Cardell, Z. Griliches, G. DeBartolo, "Methodology for Predicting the Demand for New Electricity-Using Goods," Electric Power Research Institute, EPRI-EA-593, December 1977.

10. S. Beggs, N.S. Cardell, and J. Hausman, "Assessing the Potential Demand for Electric Cars," Journal of Econometrics, Vol. 17, No. 1, September 1981.

11. U.S. Department of Energy, "Economic Analysis of Water Heaters," DOE/CS-0169, June 1980.

12. The estimate of $50 is judgmental and is used to account for the installation and hookup of a new fuel line for the replacement water heater (either electric or natural gas).

13. This result requires that the prespecified penetrations not approach saturation. The assumed non-incentives national sales were halved and doubled, so if the model were completely free of any "scale" effects all forecasted sales and benefits would be half or double proportionally. The total net savings value (dollar value of savings of oil/gas minus the revenue loss to the treasury) for the baseline model run is $41.97 M, for the one-half scale case $22.21 M; and for the double scale case $81.87 M, both cases being very close to proportionate.

    For the regional distribution of sales, the largest scale effects occur in 1985 for regions and fuels where the heat pump water heater has a relatively high penetration in the non-incentives case. Changing the functional form of the cumulative distribution function would be a very similar manipulation and would be expected to have similar effects.

14. We assume that the manufacturers surveyed to obtain the HPWH sales forecasts in Table 5 expected a decontrol of natural gas. This makes the assumed basis of our input data consistent with the assumptions of our forecast. An alternative approach would be to assume that the forecasts are based on a no decontrol assumption and use the α_t's from the base case. This alternative approach is equivalent to modifying the non-incentives sales in accordance with the α_t's of the base case. Since the change would be smaller than those investigated in our sensitivity test (see footnote 13), no appreciable change in our final results could be expected.

15. The available data does not contain information that would distinguish the effects of these aspects of the choice modeled above. Furthermore, as noted in Appendix A, such effects may not be distinguishable with any possible data on a two alternative choice.

16. Our use of an oil price premium reflecting the national security value of oil is based on a survey of studies by Harry G. Broadman, "The Social Cost of Imported Oil: Theoretical Issues and Empirical Estimates," presented at the IGT Symposium, " Planning for Energy Disruption," Washington, D.C., May 10-12, 1982.

17. Bruce Hannon, R.A. Heredeen, and T. Blayeck, "Energy and Labor Intensities for 1972," University of Illinois, November 1980.

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19. DOE memorandum, "Energy Conservation Investment Program Guidance," Deputy Assistant Secretary of Defense for Installation and Housing, October 21, 1977.

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APPENDIX A. A Generalized Economic Choice Model

The economic model of choice described in this appendix applies to an option like the HPWH which has high initial costs and lower operating costs than its alternatives. This choice model is a generalized economic model of which the equipment choice model described in the main body of this report is a specific case.

A consumer (denoted by i) is assumed to obtain a utility value equal to:

$$u_i = f_i(r) + k_i$$

where

r is the critical discount rate of the investment, f(r) is a function that is monotonically increasing in r with $f(r) > 0$ for $r > r_i^* > 0$ with r_i^* being the consumer's individual discount rate. The parameter k_i represents a possible direct reduction in utility associated with the uncertainty of the option and it is assumed that $k_i \leq 0$. The consumer will choose an option like the HPWH if $u_i > 0$.

Two alternatives provide an explanation of why consumers are less likely to purchase a new option with uncertain benefits or performance. The first is that the consumer will employ a higher discount rate in a comparison of an option with uncertain benefits with one whose benefits are more certain, than a comparison of two options having benefits and performance that the consumer is more certain of.

The second is that the uncertainty of an option per se makes the item less desirable when at the same time the consumer is using his original discount rate in evaluating the option. In reality, a consumer will probably use a combination of the above two alternatives.

Recall, that k_i is different from zero if the uncertainty about the new technology (i.e., the HPWH) reduces the utility value from the HPWH directly instead of (or in addition to) effecting the value of r_i^*. However, for this explanation we assume $k_i = 0$, because in the simple case of only two alternatives the effects of changing k_i and r_i^* are indistinguishable. For instance if $f_i(r) = 2\ell nr + b_i$ and $k_i = c_i$ then $r_i^* = e^{-b_i/2}$. But the HPWH will be chosen if, and only if, $f(r) + k_i = (2\ell nr + b_i + c_i) > 0$ which is identical to the hypothetical model $f(r) = 2\ell nr + b_i'$ and $k_i = 0$, with $b_i' = b_i + c_i$ (and thus $r_i^* = e^{b_i/2}$).

Note that in this model if b_i and c_i is distributed as logistic with location parameter g (i.e., the cumulative distribution function

$F(x) = \dfrac{1}{1 + e^{-(x+g)}}$ then we obtain the model of this report with $\alpha = e^{-g}$.

APPENDIX B. Regional Fuel Oil and Natural Gas Use for Electricity Generation

Aproximately 27% of the electricity generated by utilities in the U.S. in 1980 was fueled by oil and gas (13% oil and 14% gas). This does not mean that any base peak load reduction will be primary energy savings of 27% in oil and gas. Utilities facing a drop in demand or load will first reduce their consumption of oil and gas (if any used in electric generation) before reduction of coal, nuclear, or hydroelectric occurs. Fuel oil and natural gas are substantially more expensive than traditional base load fuels - coal, nuclear, hydro.

The regional variation in the use of oil and gas used for electricity generation is considerable. Table B.1 shows that in 1979, region 10 (Pacific Northwest) consumed 0.9% oil and gas for electricity generation, whereas for region 1 this value was 56.3%. It seems obvious that any electricity saved in region 1 will be totally oil and gas generated, but it is not clear how much oil and gas will be saved in regions where the fraction of oil and gas for electric generation is in the 10% to 20% range.

A survey of electric utilities (Appendix C) was conducted to explore the use of fuel oil and natural gas in the course of a utilities' daily power production. Only by discussing fuel allocation for electric generation with a utilities' manager of power production can one determine what hours during the day any oil or gas is used for electricity

Table B.1. Regional electricity generation by fuel oil and natural gas - 1979[*]

Region	Kilowatt hours in millions Fuel oil	Gas	Total generation[**]	% of fuels used for generation Fuel oil	Gas	Oil & gas
1	43,350	735	78,253	55.4	0.9	56.3
2	28,244	9,268	131,879	21.4	7.0	28.4
3	39,594	1,490	273,085	14.5	0.5	15.0
4	55,701	21,644	466,769	11.9	0.5	12.4
5	20,012	7,261	435,713	0.5	0.2	0.7
6	15,884	218,185	313,114	5.1	69.7	74.8
7	2,660	12,883	108,427	2.5	11.9	14.4
8	774	3,535	94,200	0.8	3.8	4.6
9	65,430	52,243	201,606	32.5	25.9	58.4
10	837	390	135,369	0.6	0.3	0.9
US	302,948	329,486	2,247,359	13.5	14.7	28.2

[*]Edison Electric Institute Statistical Year Book for 1979.

[**]Includes electricity generation by coal, nuclear, and hydro in addition to fuel oil and natural gas.

generation. This study assumes that for any particular hour of the day, if any oil or gas is used for electric generation, there will be 100% savings of oil or gas to a conservation induced load reduction during that hour. From discussions with utility power managers (Appendix C) it became apparent that any load reduction in daylight hours for most utilities consuming approximately 30% or more of oil and/or gas for electric generation per year will have direct 100% savings of oil and/or gas for the amount of electricity saved. In many cases, utilities with only a 10% to 20% yearly use of oil and/or gas for electric generation, still use that fuel for generation 16 hours per day, 5 or 6 days per week.

The particular load use pattern[20] for a conventional electric or HPWH is concentrated primarily between the early morning hours and midnight (Fig. 2). This time period coincides with the hours that a majority of electric utilities using oil and/or gas for peak load generation use those fuels. Therefore, it is assumed that the energy savings due to the replacement of an electric water heater with a HPWH for a utility using oil and/or gas during daylight hours will be entirely in oil and/or gas.

The transfer of electrical energy between federal regions also has an important indirect influence for estimating the amounts of oil and gas saved in electricity generation load reduction. For example, region 10 in the Pacific Northwest consumes oil and gas for only 0.9% of their

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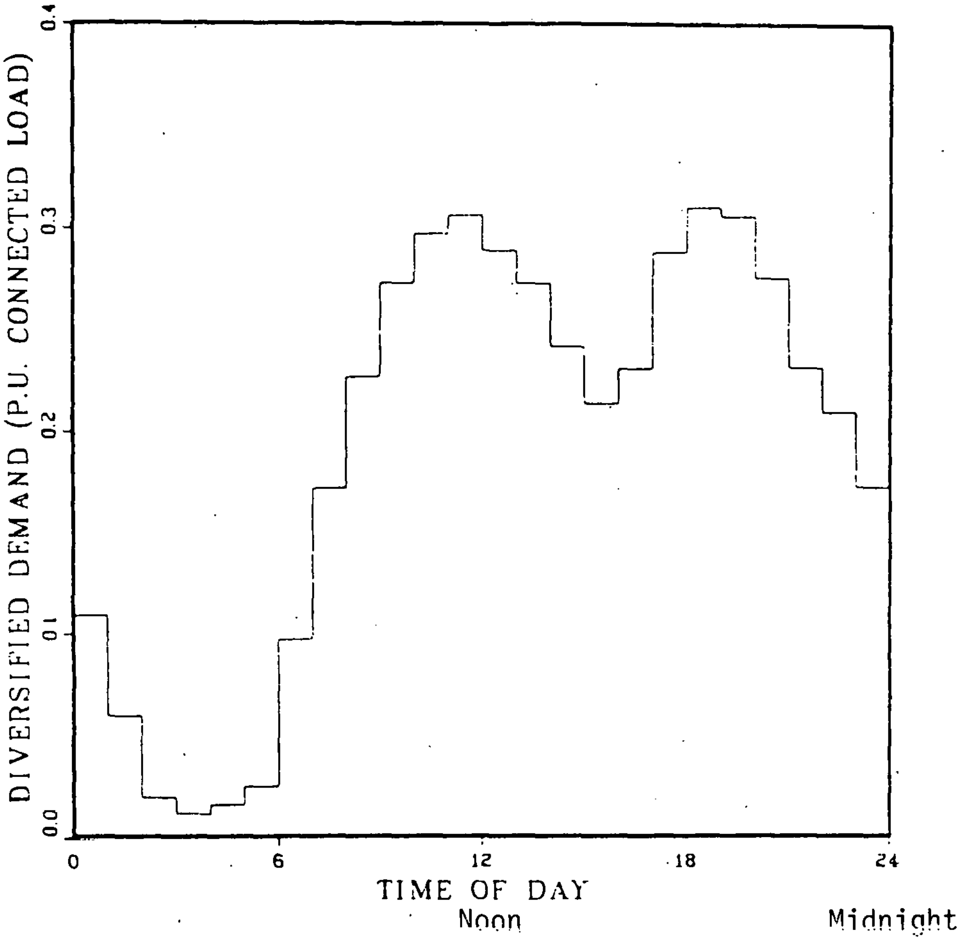

Fig. 2. Water heater diversified demand

electricity generation (the predominant power source for their generation is hydroelectric) but any reduction in their load allows utilities like Bonneville Power to sell their excess hydroelectric generated power to utilities in California which use oil and gas for 70% of their electricity generation. This transfer of electrical energy, which is widespread throughout the U.S., has as its main consequence, the reduction of oil and gas use for generation of electricity.

Combining the information from the (1) discussion with power production managers in the 10 federal regions, (2) estimates of indirect savings of oil and gas due to electrical energy transfers between and within federal regions, and (3) the regional percentages of oil and gas used for electricity generation (Table B.1), the following estimates of percentages of oil and gas regionally used for electric generation that would be saved by load reduction are obtained and presented in Table B.2.

Table B.2. Percentage of electricity saved that is generated by fuel oil and/or natural gas

Region	1	2	3	4	5	6	7	8	9	10
%	100	95	90	22.5	55	100	30	5	100	90

To be on the conservative side these percentage values are reduced by 10% and it is also assumed in the tax credit computer model that these percentages decline exponentially to a fraction of the values listed in Table B.2 to account for the expected reductions of utility use of oil and/or gas through 1985 (this estimated decline in oil/gas use is discussed in Chapter 4).

APPENDIX C. Electric Utilities Surveyed for Fuel Oil and Natural Gas Usage Patterns

The power production managers of the following electric utilities were contacted to discuss how their particular organization utilizes oil and/or gas for electric generation. This sampling of utilities are located in the federal regions where uncertainties existed concerning the proportion of oil and/or gas saved due to electricity load reductions due to new conservation technologies. The discussions were concerned primarily with:

(1) the average annual percent of electricity generated by oil/gas,

(2) percent hours/year that some oil/gas is used for electricity generation as well as the particular hours during the day,

(3) percent of electricity transferred or purchased from other utilities and their location, and

(4) future forecasts of oil/gas use in generation.

Utilities contacted were:

1. Alabama Power and Light, Birmingham, Alabama.
2. Commonwealth Edison, Chicago, Illinois, Barbara Arnold, News Information Department.
3. Detroit Edison, Detroit, Michigan, Wadi Abbu, Fuel Research Analyst.
4. Florida Power and Light, Miami, Florida, John Seelke, Power Research Analyst.
5. Georgia Power Company, Atlanta, Georgia, Chuck Whitmer, Power Supply Manager.

6. Kansas Power and Light, Topeka, Kansas, Hal Hudson, Director of Public Affairs.

7. Pennsylvania Power and Light Company, Allentown, Pennsylvania, Mr. Harsell, Power Production.

8. Public Service Company of Colorado, Denver, Colorado, Lloyd Halles, Vice President of Power Production.

9. Virginia Electric and Power Company, Richmond, Virginia, Dan Green, Power Plant Manager.

10. Union Electric Company, St. Louis, Missouri, Thomas Kennedy, Manager of Power Production.

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