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EVALUATION OF A WISCONSIN UTILITY HOME ENERGY AUDIT PROGRAM*

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ABSTRACT

In February 1978, the Wisconsin Power and Light Company (WPL) offered its residential gas-space-heating customers free on-site energy audits. Between then and June 1980, they audited about 19,000 homes. In September 1979, WPL decided to evaluate their audit program. The data they assembled included natural gas consumption records, the need for specific weatherization measures (as determined during their energy audits), and customer reports of their demographic characteristics and recent energy conservation practices and measures. This information was available for samples of customers that had received an audit in 1978 and for samples of customers that had *not* participated in the WPL program. Comparison of the data across the two groups showed considerable similarity. Program participants and nonparticipants were much alike in terms of pre-audit gas consumption, demographic characteristics, adoption of conservation practices, and attitudes on energy issues. The two groups differed significantly only with respect to conservation measures; this difference was probably due, in part, to the 1978 audits. These findings are somewhat weakened by the low response rate to the mail survey among nonparticipants.

Regression equations were developed to explain natural gas use for the two heating seasons after the 1978 audit. The results showed the importance of floor area, age of house, household income, number of occupants, and temperature setting on gas use. The equations also showed that the 1978 audits had a statistically significant effect on annual gas use. Households that had an audit in 1978 reduced their consumption by 8 MBtu/year (8%) because of the audit. However, a regression equation estimated for the heating season before the audit showed that the audit group consumed 7 MBtu less than did the nonaudit group, which suggests that the audit only saved about 1 MBtu/year.

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INTRODUCTION

Households in the U.S. consumed about 16 Quads of energy in 1980 for space heating, water heating, air conditioning, and operation of appliances [1, 2], more than one-fifth of the national total. Improving efficiency of residential energy use is important because of high and rising fuel prices, scarcities and occasional shortages of fuels, and the very long lifetimes of the nation's housing stock.

Because of these factors, many government and utility programs had been developed to encourage improved energy efficiency. Although some programs seek to improve efficiency of new homes and new household appliances and equipment, most of the effort is focused on reducing energy use in existing homes. This focus is appropriate because only a small fraction of the nation's appliance stock and an even smaller fraction of the housing stock are replaced each year. Thus, the largest potential for improved energy efficiency is in changed household practices (e.g., thermostat settings for space and water heating) and in installation of retrofit measures (e.g., weatherstripping, insulation, replacement burners for furnaces) [3].

Unfortunately, our understanding of how these conservation programs work is quite meager. This is a natural consequence of their newness: insufficient experience has accumulated with these programs to determine unambiguously their energy-saving effects and cost-effectiveness [4, 5].

This paper discusses data collected from one such program (conducted by the Wisconsin Power and Light Company, WPL) [6-8]. The data are used to address two issues. First, do participants in the WPL home energy audit program differ from nonparticipants? Second, how much energy has been saved (beyond that due to rising fuel prices and other nonprogram factors) because of the program?

WPL provides electric, gas, and water services to customers in central and southern Wisconsin. No towns with populations larger than 50,000 are served by the utility. Approximately 90,000 of the roughly 300,000 residential customers purchase gas from WPL.

In February 1978, WPL began a program that offered free on-site home energy audits to their residential gas-heating customers. The audits included a detailed examination of the structure (windows, doors, caulking, insulation levels in floor, walls, ceiling, and around heating ducts) and a subsequent meeting with the customer to discuss recommended retrofit measures.[1] By June 1980, WPL had audited about 19,000 homes, almost one-fourth of their residential gas space heating customers.

In September 1979, WPL decided to evaluate their program, focusing on owner-occupied households. A random sample of 466 audited households was

[1] The WPL program is similar to the federal Residential Conservation Service (RCS) [9,10]. The RCS also requires on-site home energy audits; in addition, the RCS requires the gas or electric utility to provide assistance to the customer with installation and financing of recommended measures.

selected for analysis. Because of their interest in examining differences between audit and nonaudit households, they also selected a random sample of 384 customers who had not requested an audit as of September 1979 to serve as a comparison group.

Information for the evaluation came from three sources (Table 1 and 2, and Figure 1). Utility billing records and weather data were used to develop estimates

Table 1. Information Sources for Audit and Nonaudit Households[a]

	Number of Households	
	Total	*With Estimates of Floor Area*
Audit households		
1. Fuel bills, 1978 audit	91	83
2. Fuel bills, 1978 audit, questionnaire	48	44
3. Fuel bills, 1978 and 1980 audits	58	55
4. Fuel bills, both audits, questionnaire	269	254
Totals	466	436
Nonaudit households		
1. Fuel bills	172	0
2. Fuel bills, questionnaire	58	0
3. Fuel bills, 1980 audit	50	44
4. Fuel bills, 1980 audit, questionnaire	104	98
Totals	384	142

[a]Both groups of households were gas space heating customers of WPL during the October 1977 - April 1980 period and lived in single-family homes that they owned (tenant-occupied homes and multi-family homes were excluded from the present analysis).

Table 2. Information Available on Audit and Nonaudit Households by Source

WPL Records	*1978 and 1980 Audits*	*1980 Questionnaire*
1. Gas use for three winters T1 - 11/77 through 3/78 T2 - 11/78 through 3/79 T3 - 11/79 through 3/80 2. Heating degree days[a]	1. Status on twenty-one weatherization measures 2. Age of home 3. Floor areas of home and of attic. 4. Presence of fireplace, stove 5. R-value of attic insulation	1. Demographic characteristics 2. Conservation practices adopted 3. Conservation measures taken. 4. Energy-related attitudes

[a]WPL assigned heating degree values to each household based on its location relative to the nearest weather station and the billing dates for which gas consumption was reported.

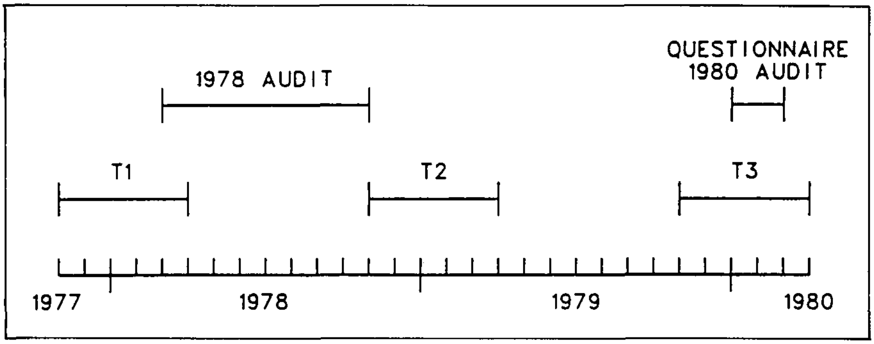

Figure 1. Timing of WPL audits and other data collection activities.

of annual space heating gas consumption[2] for each household in the audit and nonaudit samples for three heating seasons: 1977/78 (preaudit), 1978/79, and 1979/80.

The second source of information was the energy audits. Audit customers were defined as those that received a WPL home energy audit between February 1978 and October 1978, which is between heating seasons 1 and 2. Both audit and nonaudit customers in the evaluation samples were offered similar audits in January and February 1980 (during heating season 3). This was the second audit for the audit group and the first for the nonaudit group.

Finally, a twenty-seven page questionnaire was distributed to all households in both groups at the time of the second audit. The survey included questions on household energy-information sources, attitudes and opinions on energy policy, conservation practices and measures implemented, and demographic and economic characteristics of the household. The completed survey forms were to be mailed back to WPL in postage-paid envelopes provided with the questionnaires.

In principle, the research design for the WPL evaluation yields a great deal of valuable data. Unfortunately, this potential was not fully realized because of nonresponse (i.e., many households did not return the questionnaire[3] and/or did not accept an audit in 1980) and incomplete responses (not all audit or mail survey questions were answered by the auditors and households, respectively).

[2] WPL defined gas space heating consumption as $\sum_{i=Nov}^{March} (Q_i - Q_{base})$, where $Q_{base} = 0.5\,(Q_{July} + Q_{Aug})$ is the estimated non-space heating component of monthly household gas consumption (e.g., for water heating and cooking). This adjustment for base fuel use was done separately for each household. Unfortunately, the definition of base load is complicated by seasonal changes in energy use. For example, increased use of hot water in the winter and colder water intake temperatures result in greater use of energy for water heating in the winter than in the summer. Similarly, people take vacations more frequently in the summer than in the winter and this too leads to an underestimate of base fuel use (when defined on the basis of July and August bills). This, in turn, leads to an overestimate of heating fuel consumption.

[3] The great length of the questionnaire was undoubtedly partly responsible for the low response rate.

For example, the nonresponse rate (fraction of households not taking a 1980 audit or not completing the mail questionnaire) is much higher for nonaudit households than for audit households. For example, 70 percent of the audit households accepted an audit in 1980 compared with only 40 percent of the nonaudit households. This nonresponse bias is significant with respect to energy use among the nonaudit households. Those nonparticipants who agreed to have an audit in 1980 used almost 9 percent more gas in T1 than did the nonparticipants who refused the offer of an audit in 1980 [8].

On the other hand, complete data were available for all households in both groups for gas consumption, the key dependent variable in this analysis.

CHARACTERISTICS OF AUDIT AND NONAUDIT HOUSEHOLDS

An important issue concerns differences between households that had a WPL audit and those that did not. Because the audit was voluntary, a problem of self-selection may occur [5]. Without careful analysis of the participants and nonparticipants, one cannot arbitrarily assume that the two groups of households are from the same population. These potential differences between groups complicate analysis of the energy savings that can be attributed to the WPL energy audit (see p. 312); analysis of energy savings must include adjustments for these differences. In addition, examination of these differences can guide marketing strategies to reach different groups of households that have not responded to the offer of a free audit [11].

The characteristics of both groups are compared (Tables 1 and 2) in terms of space heating natural gas consumption for three winters, demographic characteristics, reported conservation practices and measures, and auditor findings on the need for thermal improvements.

Natural Gase Use

Gas consumption was less for the audit group than for the nonaudit group for each of the three winter heating seasons (Table 3); however, the difference between the two means was statistically significant (at the 5% level) for only the third year. Normalizing gas consumption by the living space in the dwelling unit showed the same patterns; gas consumption for audited homes was less in each season than for nonaudited homes and the difference between the means was significant only for the third season.

These results suggest that the two groups of households were drawn from the same population. The differences in gas consumption during the third winter may have been due to the actions audited households took after the 1978 audit; (see also p. 312).

The gas consumption data show declines in energy use from year to year. Gas consumption for both groups declined by about 2 percent between the

Table 3. Space Heating Natural Gas Use for Audit and Nonaudit Households[a]

	Audit Group		*Nonaudit Group*		
	Mean	*CV*[b]	*Mean*	*CV*[b]	
	(n = 436)		*(n = 142)*		*Ratio*[c]
Consumption (MBtu)[d]					
T1	105	0.40	108	0.36	0.97
T2	102	0.40	106	0.37	0.96
T3	88	0.42	93	0.37	0.94
Normalized consumption ($kBtu/ft^2$)[d]					
T1	71.4	0.32	72.3	0.34	0.99
T2	70.0	0.33	71.9	0.36	0.97
T3	59.7	0.35	62.6	0.36	0.95

[a]These results include all those households for which a floor area estimate was available (Table 1).

[b]The coefficient of variation (CV) is the ratio of the standard deviation to the mean.

[c]Ratio is the ratio of audit to nonaudit means.

[d]The time periods refer to different winter heating seasons: T1 is the 1977/78 season, T2 is the 1978/79 season, and T3 is the 1979/80 season.

first and second winter and by almost 15 percent between the second and third winters. These declines were partly due to rising natural gas prices and a mild winter in 1979/1980.[4]

The distribution of natural gas consumption values are nearly the same for the audit and nonaudit groups. The standard deviation is 32 to 42 percent of the mean for both groups, for both measures of gas consumption (Table 3).

Socioeconomic Characteristics

As with annual natural gas use, the two groups are quite similar in terms of several socioeconomic characteristics (Table 4). The differences between the two groups in terms of household income, dwelling unit floor area, years in present home, and plans to move in the future are statistically insignificant. On the other hand, the audit group, on average, had a higher education level (0.6 years), had fewer household members (0.3 people), had more people in the household older than sixty-five years (0.2 people), and had slightly more expensive homes ($5600); these differences, although small, were all statistically significant at the 5 percent level or better.

[4]The average price of natural gas increased from $2.76/MBtu in T1 to $2.91/MBtu in T2 and $3.39/MBtu in T3 (in terms of 1979 - $). The average number of heating degree days for the three heating seasons was: 6349 for T1, 6351 for T2, and 5728 for T3.

Table 4. Mean Socioeconomic Characteristics of Audit and Nonaudit Households[a]

	Audit Group		*Nonaudit Group*
Household income (1979 - $)	19,800		19,700
Education level (years)	13.8	b	13.2
Number of household members	2.9	b	3.2
Number of people older than 65 years	0.5	b	0.3
Floor area of house (ft^2)	1,560		1,590
Value of the house (1979 - $)	51,800	b	46,200
Time in present home (years)	13.7		13.6
No plan to move from home (%)	79		83

[a]These data are from the household responses to the 1980 questionnaire, with 317 audit households and 162 nonaudit households.
[b]These differences are significant at the 5 percent level or better.

Conservation Practices and Measures

Based on household responses to the 1980 mail survey, household conservation practices (actions that rely on occupant behavior rather than on capital improvements) were quite similar across the two groups (Table 5). More than half of the respondents from both groups reported taking seven of the thirteen conservation practices "in the last year or so." The differences between the two groups are not significant for ten of the thirteen practices. Only for three–turning down thermostats during the day and at night, and closing and opening drapes as appropriate–is the audit group more likely to have adopted the practices. The results for the two groups suggest that the audit group is somewhat more conservation-oriented than is the nonaudit group; however both groups report having adopted many conservation practices. Simple averages across all thirteen practices show that 59 percent of the audit group and 54 percent of the nonaudit group reported that they had adopted these practices.

The 1980 mail survey also asked questions about several conservation measures (capital improvements to the structure or energy-using equipment); the responses are summarized in Table 6.[5] Here the differences between the two groups are more significant than for the socioeconomic characteristics of the reported conservation practices. The audit group was much more likely to have completed the following conservation measures: adding insulation to the attic, the attic access panel, the sill box, the basement walls, the hot water pipes, and the hot water heater; differences between the means for the two groups are significant at

[5]The questions allowed four possible responses: had been done, started but not complete, will do sometime, do not intend to do. Only the first response (i.e., completed) is tabulated in Table 6. Note that the responses give no indication of *when* something was done.

Table 5. Reported Conservation Practices by Audit and Nonaudit Households[a]

	% Responding Yes		
	Audit		Nonaudit
Clean furnace filters regularly	82		80
Have furnace cleaned and adjusted	55		45
Close off rooms during heating season	50		46
Turn down thermostat			
at night	80	b	68
during the day	68	b	51
Make sure furniture is not blocking heating ducts	73		74
Install flow restrictors in showers and faucets	10		10
Turn down hot water temperature	58		53
Use cold water in washing machine	59		56
Dry clothes on outside line	47		48
Close drapes at night, open during daylight hours	83	b	74
Close heat vents in rooms not in use	54		53
Use lower wattage light bulbs	38		38

[a]These data are from the household responses to the 1980 questionnaire, with 317 audit and 162 nonaudit households.
[b]These differences are significant at the 5 percent level or better.

Table 6. Reported Conservation Measures by Audit and Nonaudit Households[a]

	% Responding that Action has been Completed		
	Audit		Nonaudit
Caulking	51		36
Weatherstripping	61		47
Attic Insulation	61	b	42
Attic access panel insulation	52	b	31
Crawl space insulation	46		48
Storm windows	81		71
Storm door (to garage entrance)	45		50
Sill box insulation	52	b	22
Basement wall insulation	22	b	11
Heating duct insulation	10		16
Hot water pipe insulation	16	b	6
Water heater insulation	20	b	8

[a]These data are from the household responses to the 1980 questionnaire, with 317 audit and 162 nonaudit households.
[b]These differences are significant at the 5 percent level or better.

the 5 percent level or better for these six measures. On all but three of the other conservation measures the audit group was more likely to report completion of the measure than was the nonaudit group.

Taking simple averages across all the responses shows that the audit group reported completing 43 percent of the measures, compared with 32 percent for the nonaudit group. The difference is much larger for the conservation measures (Table 6) than for the conservation practices (Table 5).

The WPL audits conducted in 1978 and 1980 provide additional information on the need for conservation measures in both groups of homes. The audit data are probably more reliable than are the survey data because the audit data were collected by neutral professionals; thus there should be fewer errors and less likelihood of a postive response bias in the audit data.

Comparison of the 1978 and 1980 results for the audit group only shows that the need for improvement was less in 1980 than in 1978 for each of the fourteen

Table 7. Auditor Findings on Retrofit Needs for Audit and Nonaudit Households[a]

	% Needing Improvement		
	Audit		*Nonaudit*
	1978	*1980*	*1980*
Caulk			
windows and doors	75	47	73
where materials meet	43	21	43
shell openings	57	34	73
sills	81	58	75
Weatherstrip			
doors	59	33	64
windows	37	25	36
Storm			
doors	26	17	28
windows	9	5	13
Insulate			
attic	82	56	71
attic access panel	87	65	80
under floor[b]	85	72	6[c]
basement walls[b]	95	78	73[c]
sill box[b]	89	59	92
heating ducts[b]	90	64	7[c]

[a]These data are from the 1978 and 1980 auditor reports, with 436 audit homes in 1978, 309 audit homes in 1980, and 142 audit homes in 1980.

[b]These measures were checked by the WPL auditor only if the attic could *not* be insulated to R-38.

[c]Fewer than twenty nonaudit homes were checked for these three measures.

measures; these differences are all statistically significant at the 5 percent level or better (Table 7). These results suggest that audited households made substantial improvements to the structure of their homes after the initial audit.

Comparing the 1978 results for the audit households with the 1980 results for the nonaudit group shows few differences. The only significant difference is the need for caulking at openings in the house: the need for this measure among nonaudit households was much greater in 1980 than was the need among audit households in 1978. (On the other hand, nonaudit households in 1980 were less likely to need attic insulation than were the audit households in 1978.) These results suggest that the audit households in 1976 were much like the nonaudit households in 1980 in terms of the technical energy efficiency of their homes.

Comparing the 1980 audit results across the two groups, on the other hand, shows large and significant differences. On virtually every measure the audit households were less likely to need improvement than were the nonaudit homes.

The audit results reveal two important findings. First, both audit and nonaudit homes needed to make many improvements before their first audit; there was considerable potential to reduce space heating consumption in most homes, as identified during the initial audit. Second, those customers who volunteered for an audit in 1978 made substantial energy-efficiency improvements to their homes. For example, more than one-fourth of these households added attic insulation, caulked, and weatherstripped their homes.

The purpose of this section was to compare the two groups of households—those that asked for and received a WPL home energy audit in 1978, and those that did not. Because the two groups are self-selected (rather than randomly selected from the same population), it is important to see how they differ.

The comparisons suggest that the two groups are actually quite similar—in terms of the factors measured. They appear to differ primarily in their request for an audit in 1978 and not in much else. Their use of natural gas for space heating is essentially the same (except for the third heating season), their socioeconomic characteristics are similar, and their propensity to adopt conservation practices is also similar. The two groups differ primarily with respect to reported adoption of conservation measures and the need for conservation measures as determined in 1980; comparing the 1978 audit results with the 1980 results for the nonaudit group again shows considerable similarity.

Unfortunately, the high nonresponse rates among nonaudit households for the 1980 audit and the twenty-seven page questionnaire complicate conclusions concerning comparability of the two groups. As noted earlier, nonparticipants who accepted an audit in 1980 had significantly higher gas use than did nonparticipants who declined an audit in 1980.

ENERGY-SAVING EFFECTS OF THE 1978 WPL AUDIT

The simple comparisons of annual space heating gas consumption presented earlier (Table 3) suggest that audit households did not significantly reduce their gas consumption in the second heating season (the first after receiving their energy audit); however, the reduction in energy use, relative to the nonaudit group, in the third heating season was statistically significant. This suggests that the effects of the WPL audit were not felt until two years after homes had been audited. However, this simple comparison ignores all the factors (structure characteristics, demographic characteristics, etc.) that influence energy use.

Model Specification

Gas consumption data for the two groups for the second and third heating seasons were analyzed (using multivariate regression equations) to examine more carefully the influence of various independent variables, including the presence (or absence) of an audit in 1978. Data from both audit and nonaudit households are pooled together; audit households are identified in the equations by a dummy variable (set equal to 1 if the household received an audit in 1978, equal to zero otherwise). The magnitude of this coefficient and its statistical significance are used to estimate the energy-saving effects of the 1978 audit program.

Other variables on the right hand side of the regression equations serve two functions. First, they ensure that the estimate of the effects of the audit program do not "pick up" the effects of other factors that might influence energy consumption; that is these other variables partly correct for problems that arise due to self-selection. Second, the coefficients and significance of these variables show their importance with respect to household gas use.

Unfortunately, the nonresponse bias (missing data elements) associated with these variables means that the number of households included in the regression equations is much much less than the total sample (230 vs 850). Perhaps more important, the households included in the regression equations may not be representative of the total population of 850 households; we know it is not for the nonaudit households.

Separate equations were developed to estimate gas consumption for the second and third heating seasons. A variety of independent variables were included to explain variations in household gas consumption (Table 8).

Higher incomes are expected to lead to greater gas consumption, both because of additional gas-using appliance holdings and because of greater utilization of that equipment; i.e., higher income households spend more money on goods and services, including energy. The number of household occupants is likely to increase energy use (particularly for water heating); however, the effect of this variable on *space heating* energy consumption is unclear. Given a housing unit of fixed floor area, the number of occupants might have a negative influence on energy use because of the "free heat" from their bodies.

From an engineering perspective, space heating energy use (Q) can be described by $Q = U \cdot A \cdot (T_{inside} - T_{outside})$, where U is the thermal transmittance of the building shell (related to insulation levels), A is the exterior area of the house, T_{inside} is the temperature inside the house, and $T_{outside}$ is the ambient temperature. This equation shows that larger homes (more floor area) are likely

Table 8. Definitions of Variables Used in Natural Gas Consumption Equations

Abbreviation[a]	*Source*[b]	*Definition*
Income	Q	Total household income ($)
Number Occupants	Q	Total number of people in household
Floor Area	A	Floor area of dwelling unit (ft^2)
Temperature	Q	Average household temperature setting ($^\circ F$)
House age	A	Age of the house (years)
Dummy variables		
Audit	A	1 if house was audited in 1978
Education	Q	1 if at least one household member graduated from college
Conservation attitude		
Pro	Q	1 if household strongly committed to conservation
Con	Q	1 if household definitely not committed to conservation
Secondary heat source		
Wood stove	Q	1 if household has wood stove
Fireplace	Q	1 if household has fireplace
Electric heater		
Permanent	Q	1 if household has permanent electric heater
Portable	Q	1 if household has portable electric heater

[a]These abbreviations are used in Tables 9 and 10.
[b]Q = 1980 mail survey
A = WPL home energy audit
W = WPL company records

to use more energy for heating. Higher inside temperatures also lead to greater energy use. The age of the house also influences energy use: older homes generally have less insulation and are more leaky (and also have less efficient heating equipment than do newer homes); this leads to a higher U value and therefore to higher energy use for older homes. Finally, heating degree days, a measure of the severity of the winter, is related to the average outside temperature; increases in HDD lead to higher energy use. The very limited cross-sectional variation in HDD led to regression coefficients that were statistically insignificant; therefore HDD was dropped from the final equations.

Households that received an audit in 1978 are hypothesized to have adopted more conservation measures (which reduces the U value of their house); the coefficient for the audit dummy should therefore be negative.

More education should lead to greater awareness and understanding of the opportunities to save energy; the coefficient of this dummy should therefore be negative.

Households that expressed attitudes in favor of conservation should use less energy so the coefficient for this dummy variables is expected to be negative. (Alternatively, households with large fuel bills may be particularly interested in conservation). The reverse is true for the second conservation attitude dummy variable.

If the household used a secondary heating source (wood stove, fireplace, portable or permanent electric heater), *gas* energy use should be reduced.[6] Thus the coefficients for these dummy variables are expected to be negative.

The price of natural gas is not included in the present analysis even though it is surely an important determinant of gas use. Although gas prices increased from year to year, there was almost no variation across households for a given year, a situation analogous to that for HDD. This lack of cross-sectional variation prevented us from including this variable in the equations.

Regression Results

The regression equations were estimated using ordinary least squares [12]. The equation for T2 explained more than one-third of the variation in gas heating energy use; the equation for T3 explained almost half the variation (Table 9). The coefficients for income, number of occupants, floor area, temperature setting, age of house, audit dummy, and use of stove as a secondary heating source were statistically significant (at the 10% level or better) in both equations.

As expected, household income has a positive effect on gas use. A 1 percent increase in income leads, in the long-run, to a 0.1 percent increase in gas use (Table 10). The number of occupants has a negative influence on gas consumption; increasing the number of household members by one person reduces gas consumption by 2-3 MBtu (a reduction of almost 3%).[7]

Floor area has a substantial influence on gas consumption. A 1 percent increase in living area increases consumption by about 0.5 percent.

Increasing the inside temperature by 1°F increases gas consumption by almost three MBtu (an increase of about 3%). This is consistent with prior analysis of the effects of thermostat setting on space heating energy use [13].

The older the house the greater its space heating energy consumption; a one year increase in the age of the house leads to a 0.2-0.3 MBtu increase in energy use (an increase of 0.2-0.3%).

The effect of education level on energy use is insignificant in both equations. The effect of a pro-conservation attitude (as measured by responses to several questions in the mail survey) is positive (unexpected) and statistically significant in both years. We are unsure why a positive attitude toward conservation would lead to an increase in energy consumption.[8] The coefficients of the negative

[6] The energy efficiency of conventional fireplaces is quite low. It may even be negative if the fireplace draws in sufficient outside air and if the flue damper is not properly closed when the fireplace is not in use. Hence, use of a fireplace might actually increase gas space heating consumption.

[7] This reduction in energy use per person is more than what one computes on the basis of body heat alone [e.g., 3000 kcalorie/day x 15 hours/day x 5 months x 30 days/month/0.6 (gas furnace efficiency) = 1.8 MBtu].

[8] One possibility is that reported attitudes are a poor guide to actual energy-related behavior. Alternatively, high energy users may be particularly interested in conservation to reduce fuel bills.

Table 9. Regressions Results for Annual Space Heating Natural Gas Use (MBtu) in Audited and Nonaudited Homes[a]

	Coefficient by Heating Season	
Independent Variable[b]	*T2*	*T3*
Constant	-119.3[d]	-166.7[c]
Income	0.00055[d]	0.00041[d]
Number occupants	- 3.09[d]	- 2.30[e]
Floor area	0.0305[c]	0.0288[c]
Temperature	2.54[c]	3.06[c]
House age	0.233[c]	0.259[c]
Dummy variables		
Audit	- 8.49[e]	-6.48[e]
Education	- 0.27	-2.90
Conservation attitude		
Pro	9.06[d]	5.86[e]
Con	18.95	22.21[d]
Secondary heat source		
Wood stove	-29.9[c]	-26.5[c]
Fireplace	2.4	6.1
Electric heater		
Permanent	4.2	6.0
Portable	0.1	5.3
Number of observations	230	230
R^2	0.38	0.47

[a]Mean values for the dependent variables are 98 MBtu for T2 and 85 MBtu for T3.
[b]Definitions for the independent variables are in Table 8.
[c]Statistically significant at the 1 percent level.
[d]Statistically significant at the 5 percent level.
[e]Statistically significant at the 10 percent level.

Table 10. Elasticities of Household Space Heating Gas Use[a]

	Elasticities	
Independent Variable	*T2*	*T3*
Income	0.11	0.09
Number occupants	-0.10	-0.08
Floor area	0.47	0.51
Temperature	1.70	2.37
House age	0.08	0.10

[a]These elasticities are computed with the coefficients in Table 9, using mean values for the dependent and independent variables.

conservation attitude dummy, on the other hand, have the expected sign. Lack of concern for energy conservation leads to higher gas consumption; the coefficient is not significant for T2 but is significant for T3.

The effect of a secondary heat source is substantial and significant only for wood stoves. Use of a wood stove reduces gas space heating use by 25-30 MBtu (about 30%). The use of fireplaces or electric heaters has no significant effect on gas consumption.

The coefficients of the audit dummy have the expected (negative) sign and are statistically significant in both equations. The coefficients suggest that those households that had an audit in 1978 cut their energy use by 8.5 MBtu (9%) in T2 and by 6.5 MBtu (8%) relative to those households that did not have a 1978 audit.

The effects of the 1978 audits implied by the coefficients in Table 9 are different from those implied by the simple tabulation of energy use for the audit and nonaudit groups shown in Table 3. The tabulations showed that the audit group decreased their consumption, relative to the nonaudit group, by 2 percent in T2 and by 4 percent in T3; only the difference in T3 was statistically significant.

To further explore these differences, we estimated a regression equation for T1 (the year before the audit group received its first audit). The audit dummy variable in this equation showed a reduction of 7.3 MBtu (7%) for audited households; the coefficient was significant at only the 11 percent level. This suggests that part of the post-audit reduction in energy use was due to pre-audit differences between the audit and nonaudit households—for the subsample of households included in the regression analysis.

Thus, we are left with the following "results." A simple comparison of means across the two groups suggests that the 1978 audit yielded an energy saving of 2 to 4 percent. Regression analyses for the two post-audit years (T2 and T3) suggest a larger saving of 8 to 9 percent; however, "correction" of this result with the pre-audit difference (T1) reduces the regression estimate to 1 to 2 percent.

The comparison of means is probably too simple an approach to yield reliable estimates because it does not account for the influence of various factors on household energy use. On the other hand, because the sample of households in the regression analysis is not representative of the full sample, it too may not yield reliable estimates. Thus we are left with a range of estimates that suggest that the 1978 audits yielded a reduction in space heating natural gas use of 1 to 9 percent during the two years following the audit. This range of savings is lower than that implied by auditor findings concerning the need for weatherization improvements (Table 7).

These regression results show that certain structure characteristics (floor, area, age of house, and use of a wood stove) are particularly influential determinants of household space heating gas use. Several occupant characteristics are also important: temperature setting, number of occupants, household income, and request for a WPL audit. (Fuel prices and heating degree days are surely important explanatory variables; however, they do not appear as significant determinants of energy use because of their very limited cross-sectional variation.)

CONCLUSIONS

During the past few years, utilities throughout the country have initiated more and larger programs to help their residential customers save energy. These programs are motivated by a variety of factors: consumer concern with, and opposition to, high and rising fuel prices; the high costs of providing additional energy to customers (due both to high capital costs and high costs for incremental fuel supplies); slower growth in electricity and gas consumption and the concomitant desire to develop new business opportunities; federal and state legislation/regulations that require such programs; and a growing realization that such energy conservation programs are often economically attractive [14, 15].

As these programs increase in size and cost, utilities must devote additional attention to careful and defensible determinations of the energy-saving effects of these programs and their cost-effectiveness (to participating customers, to nonparticipating customers, and to utility stockholders).

The WPL energy audit and subsequent data collection activities, which form the basis for the analyses reported here, provided considerable information to conduct a careful evaluation of their program. WPL collected data both from program participants and from nonparticipants. Data from the nonparticipants are essential to determine the *incremental* savings due to the program. If data were available only from the audit group, then it would not be possible to determine whether any reduction in energy use was due to the audit or due to other factors such as rising gas prices, changes in economic growth, or other conservation programs. Only with data from a comparison group can one estimate the energy savings *attributable* to the particular program.

In addition, WPL collected sufficient data on household characteristics and energy-related behaviors to permit analysis of the importance of self-selection in this program. Because households volunteered for an audit in 1978 (rather than being randomly assigned to the audit and nonaudit groups), it is likely that the two groups of households were different in other energy-related characteristics. Without sufficient data on both groups, this hypothesis could not be tested.

Finally, the WPL data included actual fuel bills for individual households. An alternative approach might rely on self-reports of conservation measures adopted and an engineering analysis of the likely energy savings from these measures. Such an approach would yield less credible estimates of energy savings than does direct analysis of actual fuel consumption records.

Our analysis of self-selection showed that, in most respects, the audit and nonaudit groups were much alike. Their average use of natural gas for space heating was essentially the same, except for the third heating season. The two groups gave similar mean responses to the 1980 mail survey in terms of demographic characteristics, attitudes on energy issues, and conservation practices. The two groups differed substantially with respect to reported conservation measures; this difference is surely due, in part, to the 1978 energy audit.

This finding of considerable similarity between the two groups is somewhat surprising. Other evaluations of residential energy audit programs found that program participants are likely to be better educated (a difference that did show up in the WPL data), have higher incomes, and live in single-family homes that they own [5]. Because the present analysis was limited to owner-occupied households living in single-family homes, differences between the two groups in housing type and housing tenure were not relevant.

Unfortunately, analysis of self-selection was hindered by two factors. First, the nonresponse rate for the 1980 audit and the twenty-seven page questionnaire were low for nonaudit households. The nonresponding nonparticipants differed significantly from the responding nonparticipants in terms of space heating gas use. Thus, there is reason to be concerned about the representativeness of the samples used in our analysis of self-selection. Second, the comparisons between the two groups rely almost entirely on self-reports, which are often incorrect.

Analysis of natural gas consumption for the second and third winter heating seasons explained roughly 40 percent of the variation in household gas use with thirteen explanatory variables. The major determinants of space heating gas use, according to the regression results, are household income, number of occupants, temperature setting, house age, house size, and use of a wood stove. In addition, the 1978 audit reduced energy use in audited homes (relative to what would have occurred otherwise) by 1 to 9 percent. Problems associated with self-selection, data quality, and nonresponse (plus lack of cross-sectional variation in fuel prices and heating degree days) prevent us from making stronger and more precise statements about the energy savings of the WPL home energy audit program.

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