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Evaluation Plan for State Gas Heating System Retrofit Pilot Programs

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OPERATED BY
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FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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Energy Division

EVALUATION PLAN FOR STATE
GAS HEATING SYSTEM RETROFIT PILOT PROGRAMS

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and Renewable Energy

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EXECUTIVE SUMMARY

This report presents a detailed plan for the evaluation of state gas heating system retrofit pilot programs. The major goals of the evaluation procedures are to document the fuel savings and cost effectiveness of (1) the programs implemented by the states and (2) the four retrofit types installed.

The major tasks involved in the evaluation include identification of program-eligible households, screening for data quality, assignment of eligible households to treatment or control groups, assembling cost data, collecting pre- and postretrofit consumption data, obtaining pre- and postretrofit weather data, checking for data quality, and analyzing the data. Data analysis relies on the calculation of weather-adjusted normalized annual consumption (NAC) figures for pre- and postretrofit years for treatment and control groups. The differences between the treatment and control groups' NACs for the pre- and postretrofit years are the measure of the program's impact.

Cost effectiveness analysis will combine the NAC results with cost data and with a variety of assumptions concerning future fuel prices, retrofit lifetimes, and discount rates to produce benefit/cost indicators.

Completion of all the evaluation tasks will require slightly over two years from the time of program startup.

The total cost of an evaluation of a state program will be about \$45,000--69,000. This cost is divided as follows: \$10,000--15,000 for data collection and preparation, \$15,000--30,000 for data analysis, and \$15,000--19,000 for report preparation and publication.

1. EVALUATION OBJECTIVES

The Department of Energy (DOE) Weatherization Assistance Program (WAP) was established in 1976 to provide funds to install insulation, storm windows, caulking, weatherstripping, and other improvements to the building shell in low-income households. The program was expanded on January 27, 1984 to allow for the inclusion of various energy-conserving mechanical options such as repairs, modifications/efficiency improvements, and tune-up efficiency improvements for heating and cooling systems. The new measures are designed to give the states additional options to the standard weatherization measures which would provide a more balanced approach to reducing fuel consumption in low-income households.

The Alliance to Save Energy (ASE) and the Institute for Human Development (IHD) have designed a gas heating system retrofit pilot program for low-income households that can be incorporated in state weatherization programs under the new weatherization program regulations. The ASE/IHD gas retrofit program has been adopted or is in the process of being adopted in several states. The gas retrofit program is patterned after the ASE/IHD oil heating system retrofit program* which has been implemented in 13 states.

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*Two evaluations of the oil retrofit program are available (U.S. Department of Energy, 1981; Kensill, 1984). For a review of these evaluations, see Vineyard (1984).

The major goals of state evaluations of their gas retrofit pilot programs are to document the fuel savings and the cost effectiveness of the programs implemented and of the four retrofit types installed. The purpose of this evaluation plan is to present a standard set of methods for achieving these goals.

Other evaluation issues that could be considered include analysis of the variation across homes and of the variation across local community action agencies (and for the U.S. Department of Energy, variation across states) in the savings achieved. Such analyses would focus on understanding the household and program characteristics that cause variations in fuel savings results.

To accurately measure the fuel savings from a gas heating system retrofit, one must control other factors influencing household energy consumption. Changes in weather patterns, fuel prices, and occupant behavior are especially important short-run influences on consumption. Weather effects can be controlled with analytic techniques that produce weather-normalized measures of fuel use (Appendix A). The influences of occupant behavior and price changes on consumption are most effectively controlled by comparing the fuel use of two <u>equivalent</u> groups of households--one of which receives heating system retrofits (the treatment group) and one of which does not (the control group). If the treatment and control groups are initially equivalent, any post-treatment differences in their weather-normalized fuel consumption can then be validly attributed to the program's influence. Surveys of occupant behavior (Appendix D) are a useful additional tool for analyzing behavioral effects (e.g., changes in temperature settings or sizes of heated area) on consumption.

Sections 2 and 3 discuss sample design and selection procedures and the data collection efforts needed to determine program impacts. After data collection is complete, program savings and cost effectiveness can be estimated with the techniques described in Section 4. Section 5 reviews additional issues that could be addressed by more comprehensive evaluation efforts than the one recommended in this standard plan. Section 6 summarizes the tasks, schedule, and costs of the standard evaluation plan.

2. SAMPLE DESIGN AND SELECTION

2.1 RATIONALE

The major purpose of an impact or outcome evaluation is to determine the difference between the energy savings actually achieved by program participants and the savings that would have been realized had there been no program. The second term, savings without the program, cannot, of course, be measured. Instead, data from a comparable group of households that did not participate are used to infer the energy savings that participants would have achieved if they had not participated.

The validity of an outcome evaluation relies on the method of choosing the comparison group used as a basis for separating program effects from all other effects on consumption. If the choice or construction of the comparison group is poor, the results of the evaluation will be ambiguous or misleading. The best approach is to compare two equivalent groups (a treatment group and a control group). These equivalent groups should be obtained by randomly assigning households to treatment or control group status. The random assignment procedure ensures the initial equivalence of the two groups. Procedures for implementing this approach are explained in Sect. 2.2 and in Appendix F.

Obtaining two equivalent groups of households requires careful sample design and selection procedures. In many conservation programs, households that choose to request services are noticeably different from households that do not. If all households that request a service must receive it (e.g., as in the Residential Conservation Service Program), obtaining a truly equivalent control group will be very difficult. In the gas retrofit pilot program, the problem of selecting a control group with the same characteristics as the treatment group is easier to solve because all households eligible for the retrofit will not receive it. Funds for heating system retrofits are so limited that only a small fraction of the eligible* households will actually receive a retrofit treatment. As a result, a control group that is eligible for the retrofit but does not receive it can be easily identified. The before-and-after retrofit consumption patterns of the treatment and control groups can then be compared to measure the program's impact.

This type of comparison allows one to hold all factors constant except the retrofit treatment offered by the program. In this way, non-program influences on consumption are controlled, and the effect of the heating system retrofit program alone can be estimated. If, for example, prices decrease in the heating season following the installation of retrofits, a comparison of changes in treatment vs control group consumption would allow one to separate price effects from retrofit effects. Additionally, the issue of take-back behavior (i.e., the tendency for households receiving retrofit to take back some of the fuel savings by raising thermostat settings or by heating previously closed off rooms) can be partially addressed by using comparisons of engineer-

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*Criteria for eligibility will vary from state to state. While most states will offer the gas retrofit program to low-income households, there is no federal requirement that income be a criterion for eligibility. Criteria will be dependent upon program funding sources.

ing predictions of savings with actual savings along with data on treatment and control group consumption changes.*

2.2 PROCEDURES

Two acceptable procedures for obtaining equivalent treatment and control groups in a basic pretest, posttest design are presented in this section. Applicable procedures for the Gas Retrofit Program include (1) a waiting list procedure and (2) a no-treatment control group procedure. To obtain more information on the effects of background factors, either of these procedures can be combined with matched sampling and/or stratified random sampling. Both procedures are explained later in this section. First, three prior steps (identifying eligible households, determining sample sizes, and screening for data quality) are discussed below.

2.2.1 Identification of Eligible Households and Sample Sizes

For each of the group assignment procedures, the first step is to identify a group of program eligible households. The criteria for eligibility will vary from state to state. Most states will use home ownership, income, steady-state efficiency level, and heating system life expectancy to determine eligibility. In Minnesota, for example,

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*Comparisons of treatment/control and predicted/actual savings provide only suggestive information on the take-back issue. A definitive study of take-back behavior (or the rebound effect) would require close monitoring of the energy-related behaviors of a panel of households for a year before and after retrofit. Instrumentation would also be required to provide reliable data on behaviors such as thermostat settings or window and door management practices. Such a careful study of behavioral effects would be expensive and beyond the scope of the gas retrofit program evaluation.

eligible households would have to (1) live in single-family homes that they own, (2) have incomes below 60% of the median for the state or 150% of the federal poverty level, and (3) have heating system efficiencies < 70% and a heating system lifetime of at least 5 years.* In this case, therefore, a list of eligibles would be constructed by identifying households with all of these characteristics.

To obtain an estimate of overall program savings, the list of eligibles should include enough households to allow for the selection of a treatment and a control group of about 160 to 190 households each. The required size of the treatment and control groups depends on the mean, range, and variability in energy savings that one assumes to be characteristic of the retrofits to be studied (Appendix C). The size of the sample that should be selected also depends on assumptions about what proportion of the selected household will have complete data.

In Appendix C the assumptions used about the mean, range, and variability in fuel savings expected for each retrofit type are presented. Given these assumptions, Appendix C also contains calculations of what sample sizes are needed when complete data are available on all households. <u>Since the sample sizes given in Appendix C assume that complete</u>

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*The energy savings and cost effectiveness of the retrofits is highest for heating systems that have low initial efficiencies but are otherwise in good condition and likely to last for a number of years. Thus, the program is targeted to households with the most to gain from the retrofits and the savings results cannot be generalized to all heating systems that could be retrofitted. Because retrofits will be installed only for a select group of households, the control group must meet the same selection criteria if a valid estimate of program effects is to be obtained. If the control group's heating systems had higher average efficiencies than the treatment group's, the effect of the retrofits installed would be underestimated.

<u>data are available on all cases, the sample sizes reflect the number of cases needed for the analysis of savings. A larger sample size should be selected than is needed for the analysis to allow for the loss of cases due to incomplete data.</u> That is, more households should be selected for the treatment and control groups than are statistically required for the analysis. By selecting more households, cases with incomplete data can be dropped without affecting the significance of the results. Some problems with incomplete data are inevitable. Our previous experience with billing data, for example, suggests that approximately 15% of households will have unusable records (Hirst et al., 1983a).

The range of 160 to 190 households given above includes intentional oversampling to allow for the loss of cases (thus, the figures are higher than those shown in Appendix C). The choice of a sample size to select within the 160 to 190 range will depend upon how much incomplete data one expects to find (Table 1). The expected amount of incomplete data will depend, in turn, on how much screening is conducted before selecting the sample and how much is done afterwards. If most of the screening is done before the selection is made, a sample size at the

Table 1. Initial sample sizes needed with various attrition rates

Initial sample size	Attrition rate due to incomplete data (%)	Final sample size required for analysis (all cases have complete data)
160	10	140
175	20	140
190	25	140

lower end of the range should be large enough. If most of the screening is done afterwards, sample sizes at the upper end should be selected. The relationship between screening procedures and sample selection is discussed further in Sect. 2.2.2.

Obtaining estimates by retrofit type (Appendix E) requires slightly smaller sample sizes than obtaining overall program estimates because stratification by type reduces the expected variability in savings (Appendix C). The same considerations about the amount of incomplete data expected apply as were discussed above. To have enough cases with complete data for the analysis, samples of 40 to 45 households for both the treatment and control group should be selected for Type I (heat extractor), Type III (electric vent damper and electronic ignition), and Type IV (two thermally actuated vent dampers) retrofits. For Type II (power gas burner) retrofits, which have a smaller expected variability in savings, samples of 15 to 20 should be selected.

2.2.2 Data Quality Screening

To ensure the completeness and quality of data, screening on several variables that are not part of the formal eligibility requirements should be conducted. Thus, those households that (1) do not have at least one year of preprogram fuel consumption records, (2) use supplemental heating fuels (e.g., wood stoves, kerosene or electric heaters), (3) have installed other weatherization measures during the 12 months before the retrofit, (4) have had a change in occupancy (i.e., a new family moved in), or (5) have had a change in the number of household members should be dropped from the sampling frame.*

To the extent possible, screening for data quality should take place before inclusion in the sample. Screening for supplemental fuel use, installation of weatherization measures, and changes in occupancy can be done at the time that steady-state efficiency is checked. The survey questions to be used for screening on these factors are given in Appendix D.

It is more difficult to screen for the completeness of fuel consumption records than it is for the other factors because utility cooperation is required. To minimize the need to drop households with incomplete consumption data in the analysis stage and to be sure of having enough households with complete data left in the sample, it would be desirable to know that a household had complete fuel records before assigning it to either the treatment or the control group. Checking for completeness before this assignment process, however, would require repeated requests to utilities for data on small numbers of households. Most utilities are probably not willing to respond to so many small requests. To reduce the burden on the utilities, as well as the cost of handling the data, consumption records can be obtained after the

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*Applying these criteria for inclusion in the sampling frame can be expected to result in a loss of 30 to 40% of the households on the original list of eligibles. Most of this screening should take place before constructing the initial sample. Possible additional losses have been corrected for in the suggested ranges for sample selection given in Sect. 2.2.1.

retrofits are installed. This simpler procedure will, of course, result in greater attrition in the analysis stage because of poor records. If consumption data are requested after the retrofits are installed, larger numbers of households must be assigned to the treatment and control groups to allow for attrition due to incomplete data.

Another way of simplifying fuel consumption data collection is to collect data from as small a number of natural gas utilities as possible. The sample should be selected from those areas of the state with the largest number of program households served by the same utility or utilities. This procedure minimizes the number of requests to utilities and the amount of data reformatting. Collection of weather data should also be limited to as small a number of weather stations as possible to simplify data handling.

A final important consideration in collecting fuel consumption data is the length of time utilities keep records. Many utilities keep billing records for only a 12-month period. Program staff should check with the utilities to determine how long records are kept. If a 12-month bill record keeping period is used, consumption data must be collected twice. In this case, data are collected once for the preprogram year (e.g., in July 1985) and once for the postprogram year (e.g., in July 1986). If records are kept for two years or more, only one request for data on sample households is required.

2.2.3 Treatment and Control Group Selection

After the sampling frame consisting of a list of eligible households with adequate data quality and no major behavioral changes is defined, the next step is to construct the treatment and control groups. Two general appproaches to treatment/control group selection are discussed in Sects. 2.2.3.1 and 2.2.3.2.

To obtain separate estimates of savings by retrofit type, the procedures are simply conducted separately for each retrofit type. That is, a treatment group and a control group are constructed for each retrofit type so that eight groups are formed (i.e., treatment and control for Type I, treatment and control for Type II, etc.). In other words, the sampling frame is separated, or stratified, by retrofit type and then a large enough sample is selected from each stratum to allow for the calculation of a savings figure for that stratum. Section 2.2.1 and Appendix C give the required sample sizes by retrofit type.

In most states, the large majority of retrofits will be Type I or Type II. It may be difficult, therefore, to obtain a large enough sample to estimate Type III and IV savings separately. If not enough Type III and IV retrofits are completed, separate estimates can still be obtained for Types I and II and an overall program figure calculated by combining and weighting the data on all the retrofit types to reflect the proportions installed. It also may be possible to combine Types III and IV to obtain one estimate for damper retrofits. For each retrofit type studied, assignment to treatment or control groups should follow the procedures presented below.

2.2.3.1 Waiting List Procedure. In a waiting list design, the control group eventually receives a retrofit but at a later time than the treatment group. Differences in weather-adjusted consumption in the time period _after_ the treatment group receives retrofits and _before_ the control group receives retrofits are the measure of program impact. In this procedure, households are randomly assigned (Appendix F), after their eligibility has been established, to a group that receives a retrofit immediately or to a group that is placed on a waiting list (Table 2).

The assignment is done by selecting approximately 50% of the households on the list of eligibles for the control group. The rest of the households receive retrofits immediately. To ensure the equivalence

Table 2. Waiting list design[a]

	T1		T2		T3
Treatment group	O_e O_s	X	O_e O_s		
Control (waiting list) group	O_e O_s		O_e O_s	X	O_e O_s

[a]T1-3 = heating seasons each one year apart; O_e = energy consumption record; O_s = survey of demographic/behavioral factors; and X = retrofit received.

of the groups, it is very important to make _no exceptions_ for households that have an especially great need for services. The procedures for assignment are described in Appendix F.

A waiting list procedure is already being used by the Colorado Gas Retrofit Pilot Program. The Colorado Office of Energy Conservation is randomly assigning 125 of the 500 households identified as eligible by local agencies to a control group. Members of this control group have been placed on a waiting list until June 1985. At that time (i.e., after consumption data for the 1984-85 heating season are obtained), the control group will receive priority service.

2.2.3.2. No-Treatment Control Group Procedure. In a no-treatment control group design, the procedure is essentially the same as the first part of a waiting list design. That is, one first obtains a list of eligible households with adequate data quality and then randomly assigns them to the treatment group or to the control group. The difference, of course, is that the control group does not receive a retrofit at a later time (Table 3). Since this procedure requires program retrofit activity during only one spring and summer instead of two, it is somewhat easier to implement than the waiting list design. Thus, if there is no objection to not providing the control group with the retrofits, the no-treatment design is preferable.

Table 3. No-treatment control group design[a]

	T1		T2
Treatment group	O_e O_s	X	O_e O_s
Control group	O_e O_s		O_e O_s

[a]T1-2 = heating season one year apart; O_e = energy consumption record; O_s = survey of demographic/behavioral factors; and X = retrofit received.

2.2.3.3 Matched Sampling. In a matched sample design, the first step is to construct a set of matched pairs of households. The second step is to randomly assign one member of each pair to the treatment group and the other to the control group. In the statistical literature this procedure is known as "blocking." Two major advantages of blocking are (1) it improves the statistical precision of estimates of outcomes (thus reducing the necessary sample size requiring complete data collection) and (2) it allows one to study the effects of background or matching variables on outcomes.

The most easily accessible and useful matching variable is pre-program steady-state efficiency. Household or dwelling characteristics such as family composition and square footage would also be good blocking variables. A matched design requires more effort by program staff than the unmatched waiting list or no-treatment control group designs; therefore, we expect that matching will be done only in a more comprehensive evaluation (Sect. 5) and not as part of the standard plan.

2.2.3.4 Stratified Random Sampling. An alternative to pairwise matching is stratified random sampling. In this approach, one selects a few key variables thought to be important determinants of natural gas use (e.g., house size, family size) and creates a few (2-4) classes or strata for each (e.g., homes less than 800 sq. ft., 800-1200 sq. ft., 1200-1600 sq. ft., 1600 sq. ft. and over). Households receiving retrofits are classified appropriately, and a random sample is drawn from each cell. Control households are classified into the same categories, and a sample is drawn in the same proportions as for the treatment homes. Like pairwise matching, stratified random sampling reduces variances and permits the use of smaller sample sizes. We have already recommended stratification by retrofit type so that type-specific fuel savings estimates can be obtained. Stratification on additional variables would make it possible to explore patterns of variation in savings by household type as well. Such additional stratification will probably only be done in more comprehensive evaluations, however. It would require larger numbers of households receiving retrofits than most pilot programs will include.

3. DATA COLLECTION

3.1. ENERGY CONSUMPTION DATA

For the gas retrofit program, billing histories from gas utilities are the source of energy consumption data. Although billing data are the best source of information on consumption, there are some important complicating factors that must be considered in their use. First, the time periods separating meter readings are of variable length; thus, different households will have different beginning and ending dates for a meter-reading (billing) cycle. Since calendar months rarely correspond to the cycle months, no monthly summary data can be used. Instead, daily weather data must be matched to the days in the consumption data and each household's weather-adjusted estimates of consumption must be computed separately (Appendix A).

A second problem is that different utilities keep records in different formats. Households receiving heating system retrofits may be geographically dispersed across the state and served by different utilities and local agencies. Thus, fuel consumption records are likely to be in a variety of formats (some hard copy and some computerized), and the records will have to be reformatted by the analyst into a standard system. To minimize these reformatting problems, the evaluation should focus on areas where the largest numbers of program households are served by the same utility.

Inaccurate or missing billing data may result from meters not being read when scheduled, from estimated readings, or from changes in occupancy or utility accounting procedures. Errors of this type are best handled by eliminating households with inadequate billing histories from the data base.*

3.2. PROGRAM AND MEASURE COSTS

The heating contractor who performs the retrofit installations will receive fixed fees for his work. The fees may vary slightly from state to state, but the ASE recommends that $650 be paid for a Type I (heat extractor) retrofit and $500 for a Type II (power gas burner) retrofit. The recommended fees for a Type III (electric vent damper and electronic ignition) retrofit and a Type IV (two thermally actuated vent dampers) are $400 and $175, respectively. (Appendix E defines the four retrofit types in more detail.) The fee for each retrofit type is based upon current market pricing standards for parts and labor.

Administrative costs associated with retrofit installation include the costs of inspecting and testing preretrofit and postretrofit equipment, and of issuing work orders, as well as the costs associated with contract bidding, bookkeeping and the accounting cost of paying a contractor, etc. These costs also vary from state to state. The Minnesota Department of Economic Security is now experiencing administrative costs of approximately 13% of the retrofit cost (i.e., of the fixed fee paid for each retrofit type) for its gas retrofit program. Typically, then, administrative costs per retrofit can be expected to range from about $20--85 depending on the retrofit type. Since Types I and II are the most common, average costs would probably be in the $50--70 range.

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*There is a possibility of sample bias if missing bills are nonrandom. Little can be done to remedy this problem, but the analyst may wish to consider the issue in interpreting results. Tests for bias can be conducted by comparing the characteristics of households without records to the characteristics of households with billing records.

Records of program costs are routinely maintained by state agencies responsible for pilot programs. Invoices for contractor services will probably be collected on a monthly basis by the agency. Thus, no additional data collection on program costs is required for evaluation purposes. In the analysis stage, data on both installation and administrative costs are, of course, integrated with fuel savings measurements to produce estimates of program cost effectiveness (See Sect. 4.2).

3.3. HOUSEHOLD AND DWELLING CHARACTERISTICS

A survey form (Appendix D) is the probable source of information on household and dwelling characteristics. In some states, other data sources, (such as the Energy Assistance Program (EAP) or WAP) may provide some of the same information (e.g., number of household members and their ages, square footage of the dwelling, weatherization status).

Basic survey information should be obtained at the time that the preretrofit measurements of furnace efficiencies are taken in the home. These survey data are used to remove households from the sample that have important confounding factors (i.e., supplemental fuel use, installation of weatherization measures in the 12 months before the furnace retrofit, change in occupancy or household composition). They also provide a baseline measure that can be compared to later measures of household dwelling and behavioral characteristics. If resources allow, it would be desirable to collect information on basic household characteristics again about 8-12 months postretrofit. This second survey would provide another check on important confounding factors and make analysis of household changes possible.

Data on household and dwelling characteristics can also be used to help explain variations in actual fuel savings among different household and dwelling types and among states. Since different states will serve a different mix of household and dwelling types, analysis of the relationship between these types and actual fuel savings will be especially useful for comparing results from one state to another and for predicting savings for future programs.

If a program serves mainly elderly, low-income households, it may be extremely difficult to obtain valid survey information from occupants.* In Kentucky, efforts by the Department for Social Insurance to obtain survey information from elderly, low-income recipients of EAP funds produced largely unusable data. Response rates of less than 50% were typical, and many questions produced "I don't know" or obviously incorrect responses. As a result, most states will probably wish to collect only a few basic data items on household characteristics (the essential items are identified in Appendix D). As explained in Sect. 5, extensive survey data are not required to answer basic fuel savings and cost-effectiveness questions.

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*Obtaining valid survey information on certain energy-related behaviors is problematic for households of all incomes and ages. Self-reports of thermostat settings and of conservation actions are often very inaccurate (Geller, 1981). The problem of inaccurate self-reports seems to be even more severe for low-income, elderly households, however.

3.4 WEATHER DATA

The National Oceanic and Atmospheric Administration (NOAA) compiles data from each weather station in the country. A report (local climatological data) is published each month for each station. The reports contain information at 3-hour intervals with daily, monthly, and average summaries. These reports, which cost $1.50 each, can be ordered directly from NOAA at the National Climatic Data Center, Federal Building, Asheville, NC 28801. NOAA data tapes also are available (Appendix B).

Generally, one would obtain data from the weather station that is geographically closest to an area for weather adjustment purposes. However, under special circumstances (e.g., high mountain ranges or other distinctive weather patterns), a station that is farther away may be more appropriate. Usually, temperature data are available from a number of stations in each county in the state (Fig. 1). First order stations generally have the most accurate data. Utilities will often be able to identify the weather station most appropriate for the areas they serve. It is also possible that utilities, agricultural experiment stations, or state universities will have weather data that have already been put in usable formats. It is worthwhile to check with such organizations before obtaining and processing the NOAA weather data oneself.

3.5 HEATING EQUIPMENT CHARACTERISTICS

Program recordkeeping forms (Appendix G) contain information about heating equipment characteristics. The heating system data collected on these forms include the manufacturer, model, capacity, component dimensions, and the results of the preretrofit flue gas analysis. The flue

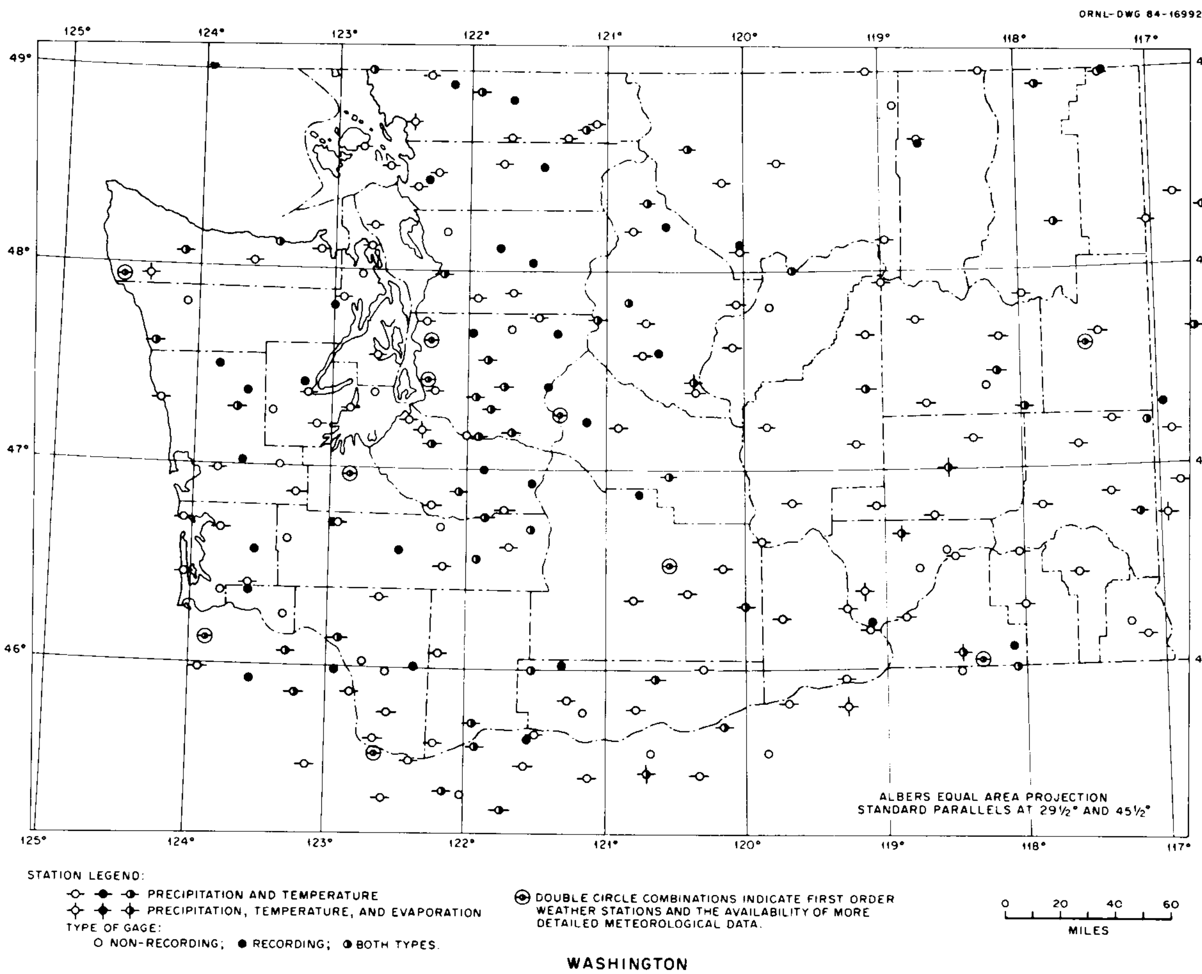

Fig. 1. Distribution of weather stations by county for the state of Washington.

gas analysis provides a measure of the thermal performance of the heating system during continuous or steady-state operation. This analysis technique approximates the percentage of the energy in the fuel that actually heats the house by identifying the amount of heat lost up the flue. This steady-state efficiency measurement is used to determine the eligibility of the heating system for retrofit.

After the retrofit is installed the contractor provides information on the work order about the equipment installed (Appendix G). The installer must certify that the retrofit meets the performance requirements. In a Type I retrofit, a heat extractor, the steady-state efficiency cannot be determined using the Bacharach combustion tester used in the preretrofit flue gas analysis because the exhaust stack temperature is below 100°F, the temperature below which the test results become unreliable. Therefore, a steady-state efficiency equivalent is calculated by measuring the temperature rise between the supply air at the top of the plenum and the return air before the extractor coil, with the extractor on and off and using the following relationship:

$$\text{steady-state efficiency equivalent} = \frac{\text{temperature rise with extractor}}{\text{temperature rise without extractor}} \times \text{pre-retrofit steady-state efficiency.}$$

The ASE/IHD training course explains in detail how to determine steady-state efficiency for each retrofit type. In a Type II retrofit, the Bacharach Combustion Tester is used to determine the steady-state efficiency. Type III and IV retrofits do not require a flue gas analysis but the contractor's work must meet the requirements shown on the work order (Appendix G). A trained auditor will inspect the contractor's work, duplicate the testing described above, and report the results on the work order.

The data collected on the heating equipment should be useful in explaining variations in energy savings among the households. For example, a power gas burner may achieve larger saving in a boiler than in a hot air furnace. Collecting data on the heating equipment allows energy savings to be quantified for various types of gas heating equipment. In addition, collecting data from the flue gas analysis and the postretrofit auditor inspection provides useful information about the pre- and postretrofit condition of the heating equipment. Finally, much of this data is required by the program as a quality assurance check on the contractor's work.

4. ANALYSIS PLAN

Most states will probably wish to address only two major questions:

1. What fuel savings are due to the program and to each retrofit type?*

2. How cost effective is the program and each retrofit type?

Methods for analyzing these questions are discussed below.

4.1. FUEL SAVINGS

To determine what fuel savings are due to the program and to each retrofit type average (NAC) figures in MBtu/year are computed for both the treatment and control groups with the methods described in Appendix A. The difference between the treatment and control group NACs for the preheating and postheating seasons are the measure of the program's impact [Eq. (1)].

$$S = (NAC_1 - NAC_2) - (NAC_{C_1} - NAC_{C_2}), \tag{1}$$

where

S = annual energy savings,

NAC_1 = normalized annual consumption for the treatment group in year one (preretrofit),

NAC_2 = normalized annual consumption for the treatment group in year two (postretrofit).

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*This plan addresses the gas savings due to the heating system modification and does not consider the effect on other fuel usage of the household. However, the heat extractor, Type I retrofit, uses a 400-W pump, which will affect the household's electricity consumption. If the heating unit operates 150 days per year, and during this time period, the pump operates one-third of the time with the price of electricity being $0.07/kWh, the pump will cost about $34.00 per year to operate. We do not recommend analysis of electricity consumption data because it would nearly double the analysis effort without having much effect on the results.

NAC_{C_1} = normalized annual consumption for the control group in year one (preretrofit),

NAC_{C_2} = normalized annual consumption for the control group in year two (postretrofit),

Fuel consumption and weather data are the only inputs required for developing the NAC estimates (Fig. 2).

A more complete analysis of the reasons for the measured fuel savings would also include an examination of behavioral data and other background factors. The predicted technical potential for savings from a given retrofit typically will not be equal to the savings realized in actual homes. The technical potential for savings measured in laboratories or in specially designed test houses is unlikely to be realized in field settings for several reasons, including imperfect installation and use, interactions with specific dwelling or occupant characteristics, and changes in occupant behavior.

Since it is very expensive to measure the influences of occupant behavior, installation or use problems, etc. a standard program evaluation will not be able to eliminate, or separate out, these effects on estimates of program fuel savings. It would be useful, however, to conduct a few more comprehensive studies that explore the magnitude and distribution of such effects so that the probable fuel savings due to expanded program efforts can be forecast more accurately. Accordingly, information on changes in occupant behavior should be collected in a few evaluations so that the magnitude of behavioral effects on consumption can be estimated. Further discussion of issues beyond the basic fuel savings and cost effectiveness questions is presented in Sect. 5.

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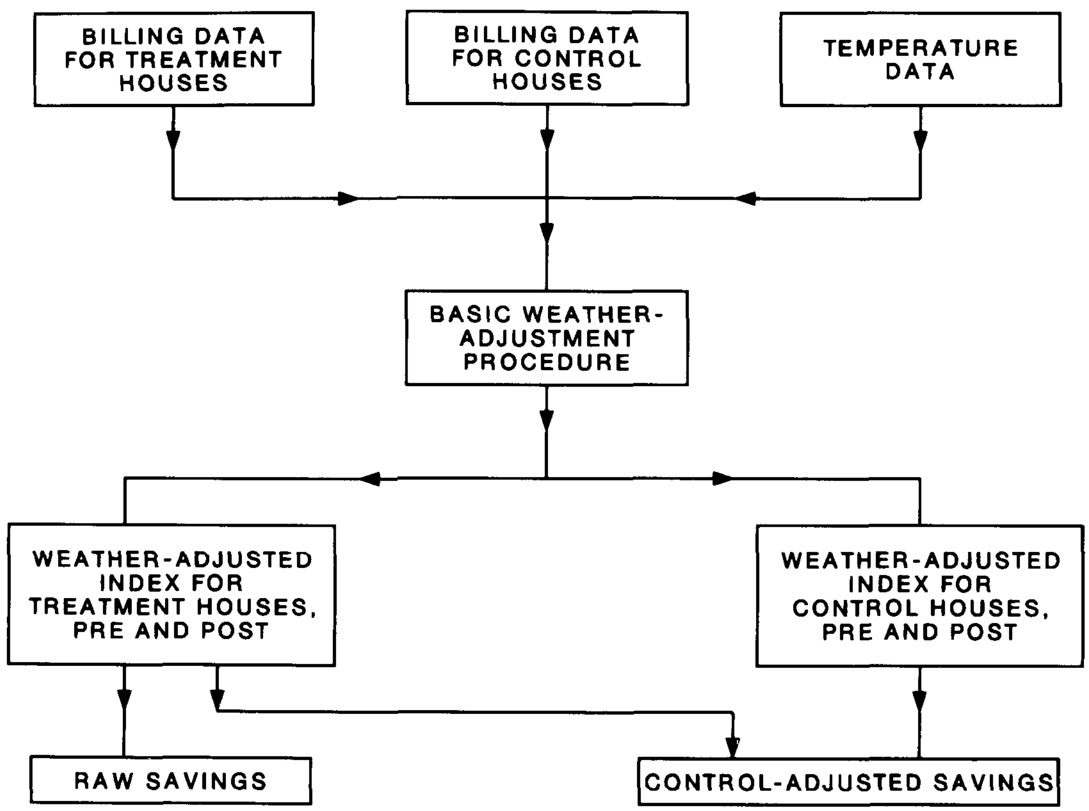

Fig. 2. Simple schematic of fuel savings analysis procedure.

4.1.1 Estimating Annual Fuel Savings from Combustion Efficiency

The change in steady-state efficiency after the retrofit provides an indication about the effectiveness of that retrofit. The steady-state efficiency gives a measure of the thermal performance of a home heating system during continuous operation. However, improved steady-state efficiency cannot be directly translated into fuel savings because the off-cycle losses are not accounted for in a steady-state efficiency measurement. Therefore, the steady-state efficiency is a useful measure of the performance of a heating system when it is operating, but the annual fuel use depends on seasonal efficiency, which takes into account the losses that occur when the system is not operating. These losses include heat lost to an unheated basement, heat lost through the unit during its off-cycle, and losses in efficiency when the unit is on but is not warmed up. Unfortunately, seasonal efficiency is very difficult to measure in the field, and laboratory tests are required for an accurate estimation of a system's seasonal efficiency.

An alternative to determining the seasonal efficiency is to try to derive a factor representing the (possible) relationship between improvement in steady-state efficiency and NAC. One would expect the percentage of fuel saved to be greater than the percentage of steady-state efficiency improvement since the reduction of off-cycle losses as a result of the retrofit are not considered in the improvement in steady-state efficiency. If a relationship between steady-state efficiency and fuel savings can be developed, the fuel savings associated with one of the retrofit types can be approximated in the future from the improvement in steady-state efficiency without analyzing preretrofit and postretrofit fuel bills. This factor, however, could only be applied for households with (1) similar heating equipment, (2) similar characteristics, and (3) similar climates as the households from which data were used to derive the factor. Regression analysis can be used to try to establish the relationship between change in steady-state efficiency and change in fuel consumption.

4.2. COST EFFECTIVENESS*

The cost effectiveness of a retrofit investment can be determined with a variety of approaches. Although a basic comparison of measured energy savings to the costs of achieving them is always involved, a number of other inputs is usually needed as well. Key assumptions include the expected lifetime of the retrofit measures, a discount rate that reflects the time value of money, and estimated fuel price escalation rates. Since there is significant uncertainty in these key assumptions, sensitivity analysis is often used to estimate a range of cost effectiveness under varying conditions.

The expected range of lifetimes for gas heating system retrofits is 15 to 20 years. This range is dependent, of course, on the overall lifetime of the heating system. Since systems with expected lifetimes of less than 5 years are ineligible for program services, a lower bound of 5 years applies to all households. Average expected lifetimes of 10, 15, and 20 years are probably an appropriate range for cost-effectiveness calculations.

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*Most of the material in this section is taken directly from Goldman (1983).

To evaluate energy conservation options, one must weigh the future benefits against present costs. The weight given to benefits and costs at different time periods is determined by the discount rate. The higher the discount rate, the lower the future benefits and costs are valued compared with present benefits and costs. In other words, a discount rate reduces the nominal dollar value of these future savings and costs to their present value. A <u>real</u> discount rate is expressed in constant dollar values; that is, current dollar values are corrected for reduced purchasing power due to inflation. Unfortunately, there is no consensus on the question of the appropriate rate of discount for use in evaluating government energy projects. Determining of the appropriate social rate of discount is a complex problem and continues to be the subject of controversy among professional economists (Lind, 1982).

When trying to arrive at the appropriate discount rate, it is important to note that benefits derived from retrofit investments are not taxable. Thus, after-tax rates of return for alternative investments should be used to determine appropriate discount rates. In addition, the alternative investments must be of the same time span as the lifetime of the retrofit.

A range of real discount rates has been used in previous evaluations of federal programs. A real discount rate of 3% was used in the analyses of the Building Energy Performance Standards, whereas the National Bureau of Standards used a 6% discount rate in its study of low-income weatherization (Berman and Cooper, 1981). The Office of Management and Budget recommends a 10% discount rate for all federal projects (Lind, 1982). For a sensitivity analysis we recommend discount rates of 3, 6, and 10%. In addition, each state could use the current rate (net of inflation) at which the state borrows money as the discount rate.

Obtaining reasonable estimates of future fuel prices is a highly uncertain process. Yet, some assumption must be made to calculate most indicators of cost effectiveness. The American Gas Association (AGA) estimates real fuel price escalation rates of 4 and 8% for natural gas. The Energy Information Administration (EIA) also publishes fuel price forecasts which are widely used in the evaluation of energy policies and programs. The most current forecast will be available in January 1985. In addition, fuel price projections can be obtained from the state's supplier or public utility commission. Thus, the sensitivity analysis could include AGA, EIA, and local projections.

To summarize, reasonable assumptions for estimating the cost effectiveness of gas furnace retrofits include a range of retrofit lifetimes of 10, 15, and 20 years; discount rates of 3, 6, and 10%; and fuel price escalation rates of 4 and 8%. We believe that an assumed lifetime of 15 years, a discount rate of 6%, and a real fuel price escalation rate of 4% represent the best guesses, but it would be worthwhile to calculate cost effectiveness under the full range of assumptions (Table 4).

Once the key assumptions about retrofit lifetimes, discount rates, and future fuel price escalation rates are selected, a variety of cost-effectiveness indicators can be calculated with standard formulas. The net present value (NPV), the cost of conserved energy (CCE), the internal rate of return (IRR), and simple payback calculations are described below. The advantages, disadvantages, and underlying assumptions of each indicator are also briefly discussed.

Table 4. Recommended economic parameters for cost-effectiveness calculations

	Retrofit lifetime (Yrs.)	Discount rate (%)	Fuel price escalation factor (%)
Range	10, 15, 20	3, 6, 10, and state cost of money	4, 8, EIA forecasts, and local supplier forecast
Best guess	15	6	4

4.2.1 Net Present Value

Net present value (NPV) analysis calculates the difference between a retrofit measure's discounted benefits and costs. The energy saved and the cost of obtaining those savings are valued over the lifetime of the measure. An investment with a net benefit greater than zero is considered worthwhile. Measures with the highest NPV are the best investments. The general formula for NPV is

$$NPV = \sum_{j=1}^{n} \frac{S \cdot P_j - C_j}{(1 + d)^j} , \qquad (2)$$

where

n = lifetime of measure,

S = annual energy savings (equal to first-year savings),

P_j = real energy price in year j,

C_j = annual cost of measure (in constant dollars). (Note: For the gas retrofit program, this will be the initial cost of the retrofit since maintenance costs are not being considered. Thus, the total cost will appear in year one and costs in subsequent years will be equal to zero),

d = real discount rate.

This formula sums the difference between the discounted benefits and costs each year over the lifetime of the measure. In practice, the present value of future energy savings is traded off against the total (usually initial) investment cost.

The NPV technique is well suited for situations where the present investments are large in proportion to other disbursements. This is often the case in a comparison of immediate and deferred investments (Grant, Ireson, and Leavenworth, 1976). The limitation of NPV is that the calculation requires an appropriate discount rate that is difficult and complex to determine.

4.2.2 Cost of Conserved Energy

The cost of conserved energy (CCE) is found by dividing the annualized cost of the retrofit by the annual energy savings due to the investment. The CCE is particularly useful if one wants to compare conservation investments to purchases of fuel. CCE can be expressed as

$$CCE = \frac{I}{S} \left[\frac{d}{1 - (1 + d)^{-n}} \right] , \qquad (3)$$

where

I = total investment,

S = annual energy savings (equal to first-year savings),

d = real discount rate,

n = lifetime of measure.

CCE provides an effective means of rank-ordering conservation investments by cost effectiveness. Calculating the cost per unit of energy saved makes direct comparison to supply costs per unit of energy produced possible. Thus, for policy purposes, a CCE approach clarifies the issue of where federal energy dollars can be most effectively spent (Berman and Cooper, 1981). Another advantage of the CCE indicator is that a good deal of analysis of the DOE Weatherization Assistance Program, based on CCE, has already been completed (Berman and Cooper, 1981).

4.2.3 Internal Rate of Return

The internal rate of return (IRR) can be used to find the economic return on an investment. Typically, IRR is solved through an iterative process that finds the interest rate for which the net value of the investment is equal or close to zero. The IRR is then compared to the investor's minimum acceptable rate of return to determine the quality of the investment. The IRR requires an estimate of future energy prices and a measure's expected lifetime but no specification of a discount rate. The internal rate of return is i in the following equation:

$$I(1 - TI) = \sum_{j=1}^{n} \frac{S \cdot P_j}{(1+i)^j} \qquad (4)$$

where

I = total investment,

TI = tax incentive,

S = annual energy savings (equal to first year savings),

P_j = real energy price in year j,

n = lifetime of measure.

This indicator is capable of reflecting the relative economic efficiencies of alternative investments and can be used to rank competing projects. Thus, it would probably be most useful to individuals making choices among competing investments. In addition, it can be compared to the rate at which money can be borrowed. The IRR has the disadvantage of being cumbersome to calculate.

4.2.4 Simple Payback

Simple payback time (SPT) is a measure of the length of time required for the cumulative savings from an investment to pay back the initial cost.

It can be expressed as

$$SPT = \frac{I}{S \cdot P} \tag{4}$$

where

I = initial investment,

S = annual energy savings (equal to first-year savings),

P = local energy price.

Although SPT is easily understood and widely used, it neglects temporal changes in energy prices, the expected life of the investment, differential operating and maintenance costs, and the time value of money. The indicator's failure to account for key economic variables means that simple payback often gives biased and misleading investment signals. For example, SPT ignores any changes in conditions after the payback has been achieved. Two retrofit measures with the same payback may have very different physical lifetimes; hence, one measure produces additional energy and dollar savings while the other requires replacement.

Because of the purposes and limitations of IRR and SPT calculations, we believe that NPV and CCE calculations are the most suitable for determining the cost effectiveness of gas heating system retrofit programs. Once energy savings data, cost data, and key assumptions are available, however, any of the calculations can be done at little additional expense. In the process of determining cost effectiveness (Fig. 3), a great deal more effort is required for determining inputs and assumptions than is required for doing the calculations. Thus, if one wishes to compare the results of more calculations, there is no reason not to do so.

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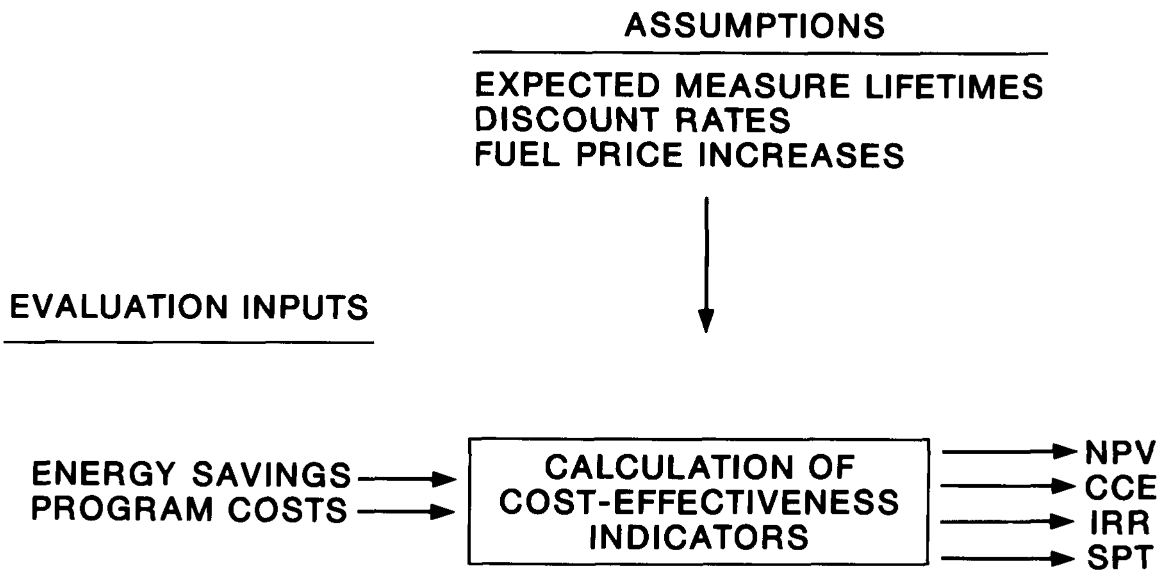

Fig. 3. Cost-effectiveness analysis process.

5. COMPREHENSIVE EVALUATION EFFORTS

In the preceding sections we have assumed that state-level evaluations will address only two basic questions:

1. What fuel savings are due to the program and to each retrofit type?
2. How cost effective is the program and each retrofit type?

Answering these two questions provides basic measurements of the impact of the pilot programs as implemented by each state.

Measurement of program impacts is, of course, only part of a comprehensive evaluation strategy. Issues related to the process of program implementation and to the generalizability of measured program impacts to broader target populations or to larger-scale programs are also part of a complete evaluation effort. Not every evaluation study can or should address a full range of issues, however. Considering more issues naturally requires more costly and complex evaluation research.

Since the states have limited evaluation resources, a focus on program impact issues seems appropriate. This focus is also desirable in a standard evaluation plan because most state agencies need such information to document the value of and/or justify the expansion of their heating system retrofit programs. In addition, we believe that it is much better to study only two issues well with some assurance of obtaining useful and reliable information about them, than it would be to study many issues superficially with the risk of obtaining no useful information on any of them. Although some states may wish to go beyond the two basic impact evaluation questions addressed in this plan, truly comprehensive evaluation efforts are more likely to be funded by organizations such as the ASE or the DOE.

Some process evaluation has already been completed under ASE/DOE sponsorship. The basic elements of the pilot heating system retrofit programs (i.e., training procedures for contractors, fixed fees contingent on performance standards, 100% preretrofit and postretrofit inspections, etc.) are the result of a good deal of careful development, pretesting, and refinement. The states, therefore, will be implementing an already well-defined program, not developing a new one on their own.

Even though the gas retrofit program has a standard and well-defined structure, there will inevitably be differences between the standard program plan and the actual program process. A well-managed state program will have activity-monitoring feedback loops (such as reviews of installation and inspection records to identify problem areas) and quality-control checks built into its structure. This program monitoring effort need not take the form of a formal process evaluation, however.

The issue of the generalizability of pilot program results to broader target populations and to larger-scale program efforts is more difficult to deal with. Because states are not required to target a specific population, different states will serve a different mix of household types. Variations among states in the amount of savings achieved are likely to result, in part, from the differences in the mix of household types served. Retrofits of low-income, elderly households are likely to produce different impacts, for example, than retrofits of households drawn from all age and income groups. Differences in the condition of the housing stock served by the program, the pre-retrofit efficiency of heating systems, and the distribution of retrofit types (Types I-IV as defined in Appendix E) installed can also be expected to strongly affect the amount of savings achieved.

Two strategies could be used to achieve a greater ability to generalize than that provided by the standard impact evaluation. First, a systematic study of the influence of background factors (such as housing characteristics and demographic/behavioral variables) on the savings achieved could be implemented in one state. Conducting such a study would require a much larger sample size and survey effort than is present in this standard evaluation plan. Developing a more comprehensive data set would allow analysis by household and retrofit types so that predictions about future program impacts under various assumptions could be made.

Alternatively, the analysis of savings by household and retrofit types might be accomplished by combining data from a number of state program evaluations. The states providing data for the larger evaluation would have to collect more survey data on background factors than in a standard impact evaluation, however.

With either strategy, the influence of background factors on savings could be analyzed by using NAC results as the dependent variable in cross-sectional models of energy use. In these models, variations in NAC are explained by factors such as household demographics, dwelling characteristics, and dummy variables to capture program participation effects. To construct a data set for these models, NAC values for each household for each year analyzed are used as dependent variables; the explanatory variables are obtained from surveys. Examples of this type of analysis can be found in Hirst et al. (1983a) and Hirst et al. (1983b).

6. EVALUATION SCHEDULE AND COSTS

The specific tasks required to address the standard issues of program fuel savings and cost effectiveness are summarized in Table 5*. Note that tasks 1--3 are conducted simultaneously and continuously for about 6 months from the time of program startup (February of the first year). For tasks 1 and 2, households are checked by local agency staff for eligibility and data quality on a week-by-week basis.

After certifying a household's eligibility and data quality, heating system inspectors randomly assign the identified household to a treatment or a control group (Appendix F). Retrofits are then installed for the treatment group to complete task 3. Since installation of retrofits must be completed in the spring, summer, or early fall months (before the start of the second heating season), all of tasks 1--3 must be completed between February and September of the first program year. Task 4, assembling cost data, can begin as soon as retrofit installations are completed.

Tasks 5 and 6, obtaining postprogram consumption and weather data, cannot be completed until June of the second year. Data analysis can begin as soon as collection of weather and consumption data is completed. Report preparation should be completed by the following

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*The allocation of tasks shown in Table 5 assumes that state agency staff will conduct the data collection but not the data analysis tasks. In some states, agency staff may include experienced evaluation researchers who will wish to conduct parts of the data analysis themselves. In such cases, the allocation of tasks may be changed to suit the skills and interests of those involved.

Table 5. Summary of tasks for standard outcome evaluation

Tasks	Procedures	Months to complete from start of project	Costs ($ thousands)
1. Identify eligible households The process of identifying eligible households continues until enough total households or enough of each retrofit type are selected.	Local agencies make retrofit offers to households meeting basic eligibility criteria (e.g., single-family, owner occupied, natural gas sole heating source, low-income, etc.). The state agency may be able to supply a list of potential eligibles identified from Energy Assistance Program records, or the local agencies may have to use their own records to begin the identification process.	2 - 5 (Feb. - May) 1st year	
	Local staff inspects the heating systems of households expressing an interest in receiving retrofits to see if they meet eligibility criteria.	3 - 8 (Mar. - Aug.) 1st year	2[a]
2. Screen for data quality	If heating system has appropriate efficiency rating and expected lifetime, inspectors screen for recent changes in occupancy, household size, weatherization status, etc. If not already available, inspector obtains fuel consumption record waiver form from the household. If all criteria are met, household is identified as eligible.	3 - 9 (Mar. - Sept.) 1st year	2
3. Assign eligibles to treatment or control group and complete retrofit installations	After identifying a household as eligible, staff randomly assigns the household to either a treatment or control group. For whole program estimates of savings one treatment and one control group are constructed. For estimates by retrofit type, eight groups are constructed--one treatment and one control group for each retrofit type. No further contact is made with control households. Retrofits are installed for treatment households.	3 - 9 (Mar. - Sept.) 1st year	1
4. Assemble program cost data	Cost data can be assembled as soon as all retrofit installations are complete.	12 - 13 (Dec. - Jan.) 1st year	1
5. Obtain preretrofit and postretrofit consumption data	Consumption data are obtained from gas utilities by either local or state agency staff.	19 - 21 (July - Sept.) 2nd year	2
6. Obtain weather data for both preprogram and postprogram heating seasons	Evaluation research contractor obtains this data from NOAA or, if available, from other orgainzations.	19 - 21 (July - Sept.) 2nd year	2
7. Check reliability and completeness of data	Evaluation research contractor completes this task.	19 - 21 (July - Sept.) 2nd year	2-5
8. Merge data sets Prepare computer tapes with complete fuel consumption data and cost data for all households	Evaluation research contractor completes this task.	22 - 23 (Oct. - Nov.) 2nd year	3-5
9. Analyze data relative to evaluation issues	Evaluation research contractor completes this task.	23 - 24 (Nov. - Dec.) 2nd year	15-30
10. Prepare draft report	Evaluation research contractor completes this task.	25 (Jan.) 2nd year	8
11. Review draft report	State agency staff and other qualified reviewers complete this task.	26 (Feb.) 2nd year	3
12. Publish final report	Evaluation research contractor completes this task.	27 (Mar.) 2nd year	4-8
	Total	27 months	45-69

[a]The process of determining eligibility must take place whether or not an evaluation is conducted. Thus, the costs of most of this activity are not evaluation costs. Since a somewhat larger number of inspections must be made to identify a control group, however, this figure represents the assumed incremental cost of locating the control group.

March. Thus, completion of the evaluation will require slightly over two years from the time of program startup. The overall timing of the evaluation tasks is summarized in Fig. 4. The essential data elements and their sources are listed in Table 6.

The total cost of a standard evaluation of a state program will be about $45,000-$69,000. This cost is divided as follows: $10,000-$15,000 for data collection and preparation, $15,000-$30,000 for data analysis, and $15,000-$19,000 for report preparation and publication.

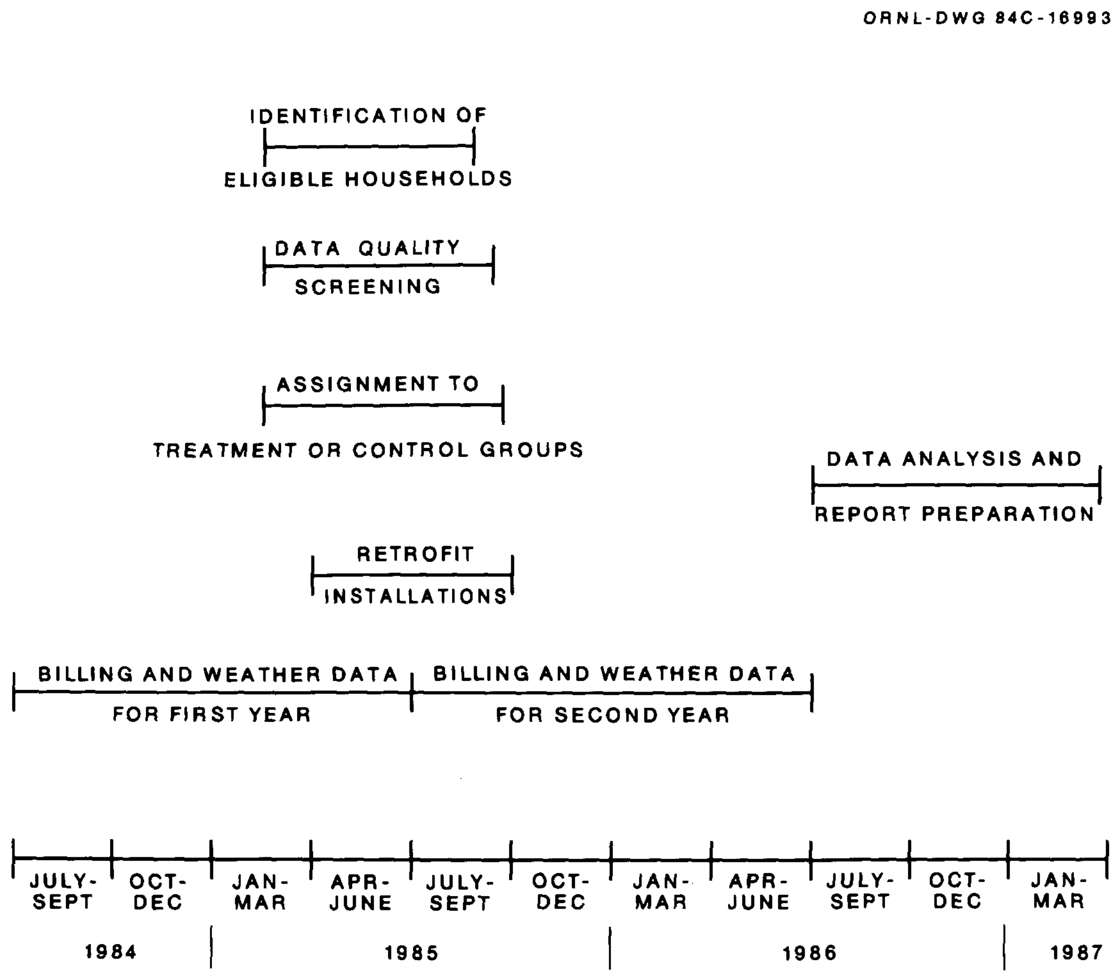

Fig. 4. Timing of evaluation tasks.

Table 6. Summary of essential data elements and their sources

Variable	Source
Type of Retrofit and Heating System	
Retrofit Type I--IV	Program recordkeeping forms (Appendix G)
Heating system type:	
Furnace or boiler Steam or hot water Forced air or gravity	Program recordkeeping forms (Appendix G)
Number of inspections done per retrofit installed	Program recordkeeping forms (Appendix G)
Pre- and post-steady-state efficiency measurements	Program recordkeeping forms (Appendix G)
Eligibility and screening variables	
Home ownership	Occupant questionnaire (Appendix D)
No supplemental fuels	Occupant questionnaire (Appendix D)
No change in fuel type	Occupant questionnaire (Appendix D)
No weatherization measure installed in last 12 months	Occupant questionnaire (Appendix D)
No change in occupancy	Occupant questionnaire (Appendix D)
No change in number of household members	Occupant questionnaire (Appendix D)
Complete (12 months preretrofit and postretrofit) fuel consumption data available	Gas utilities
Fuel savings	
Daily minimum and maximum temperatures	NOAA weather data
Monthly household fuel consumption records (12 months preretrofit and postretrofit)	Utilities
Costs	
Costs (labor and materials) of retrofit installations	Program managers' budget records and invoices
Administrative costs	Program managers' budget records and invoices

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Appendix A

FUEL SAVINGS CALCULATION METHODS

Two methods of calculating fuel savings are presented in this Appendix. The first, the Princeton Scorekeeping Method (PRISM) treats the house's reference temperature (which corresponds to the outside temperature above which no heating fuel is required) as a variable. In PRISM the reference temperature is estimated separately for each individual house. The second approach, which is a useful, easy to compute shortcut when the desired output is aggregate savings, treats the house's reference temperature as a fixed value (e.g., 60°F).

Although the PRISM method is based on a more precise, and in an engineering sense a more correct, model of household energy consumption, the shortcut method may be preferable for many state evaluation efforts. Implementation of PRISM would require obtaining help from its Princeton developers, or from other experienced users. PRISM cannot be done by simply applying standard statistical package programs (e.g., SAS). The fixed reference temperature method, in contrast, can be implemented with standard package programs and does not require contact with experienced users. Thus, the shortcut method is readily available to almost all analysts and can be implemented by those without much previous experience.

In addition, estimates of aggregate savings are not sensitive to the reference temperature used. Estimates of the components of fuel use (i.e., base level consumption for appliances, etc., which is independent of outside temperature; and heating consumption, which is dependent on outside temperature), on the other hand, are sensitive to the reference temperature used. Information on the components of fuel use is certainly interesting and useful, but the greater cost and difficulty of obtaining it may not be justified. If aggregate measures of fuel savings are sufficient, the shortcut method is all that is required.

The description of PRISM presented below is taken directly from Fels (1984). Even if the analyst decides to use the simpler fixed reference temperature method, this description of PRISM provides valuable background information for interpreting results. The description of the fixed reference temperature method is written so that it can be implemented with standard statistical package regression procedures.

Princeton Scorekeeping Method

The Princeton scorekeeping method uses utility bills from before and after retrofit installation, together with average daily temperatures from a nearby weather station for the same periods, to determine a weather-adjusted index of consumption, normalized annual consumption (NAC), for each year. Analogous to the EPA miles-per-gallon rating based on a standard driving cycle, the NAC index provides a measure of what energy consumption would be under typical weather conditions. The total energy savings are then derived from the difference between the NAC in the pre-and post-periods. A conservation effect is thus neither masked by a cold winter nor exaggerated by a warm one.

To isolate the savings due to the program from savings that would otherwise have occurred, the same method should be applied to a control group of houses, or to the aggregate of houses in the utility region. The analysis is easily updated for succeeding years to follow the durability of the savings.

PRISM differs from other weather-normalization procedures in that the house's breakeven temperature is treated as a variable, rather than a constant such as 65°F. Three physical parameters result from the variable-temperature model applied to an individual house: <u>base level consumption</u>, corresponding to the amount of fuel used (for appliances, etc.) independent of outside temperature; the <u>heating slope</u>, representing the amount of fuel required per degree drop in outside temperature; and the <u>breakeven or reference temperature</u> corresponding to the outside temperature above which no heating fuel is required.

It turns out that the standard errors of NAC are, in almost all cases, extremely small (about 3-4% of the estimate), so that savings of 6% or more may generally be considered statistically significant. Furthermore, NAC is quite insensitive to which periods of time are included, or their length.

<u>The Physical Basis for the Model</u>

We start by describing the method developed for fuels used for heating but not cooling. Generally, whether for natural gas, oil or electricity, a house's heating system is first required when the outside temperature (T) drops below a certain level (the heating reference temperature T_{ref}), and for each additional degree drop in temperature a constant amount of heating fuel (b) is required. Thus, the required heating fuel is linearly proportional to T_{ref} - T, and the proportional constant b represents the house's effective heat-loss rate. In addition, the house may use a fixed amount of fuel (the base level a) which is independent of outside temperature T. Formally, the expected fuel consumption, f, as illustrated in Fig. A-1 for an idealized house, is given by

$$f = a + b \ (T_{ref} - T)_{+} \qquad \text{(A-1)}$$

where the term in parentheses is the heating degree-days to base T_{ref} and the "+" indicates zero if the term is negative.

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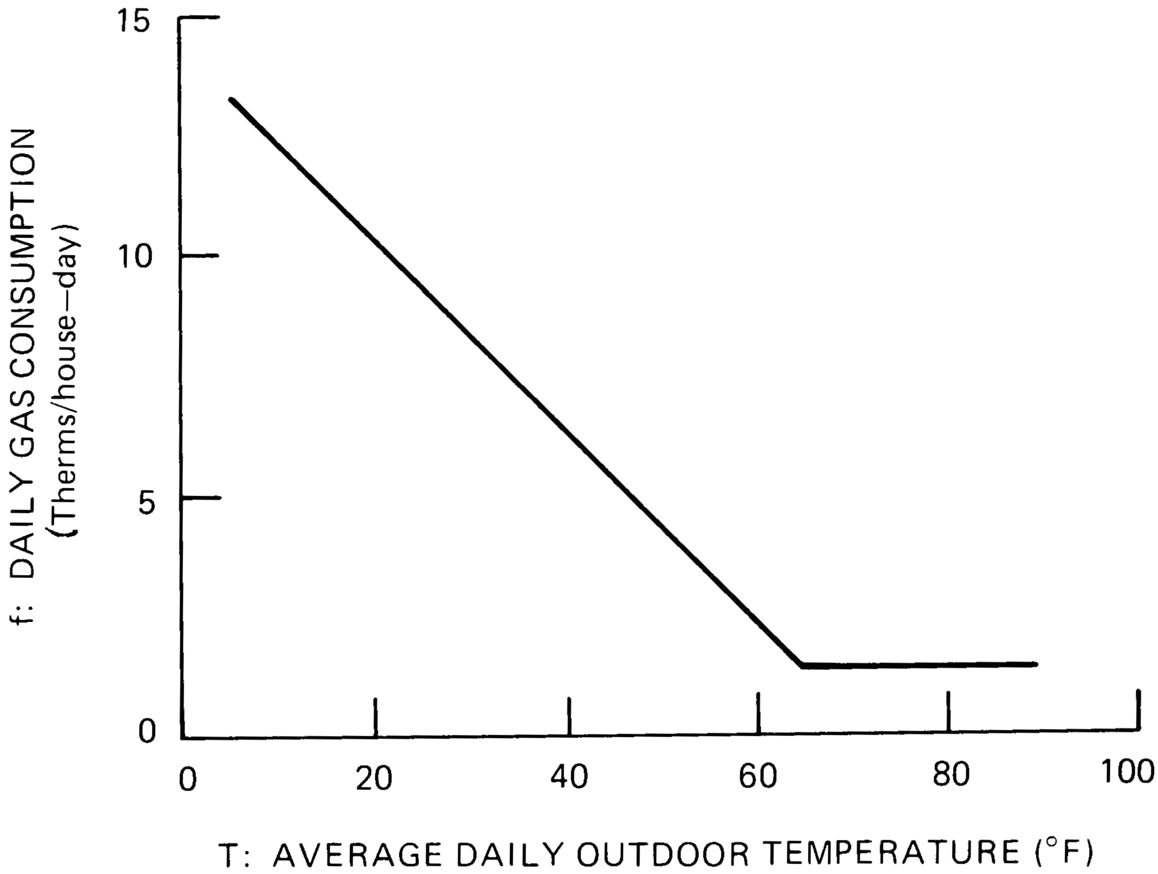

Fig. A-1. Daily gas consumption (f) as a function of outside temperature (T) for a single idealized house.

Source: Fels (1984)

Individual House Analysis

Based on this physical interpretation, the two data requirements for the analysis are actual meter readings, from which consumption is calculated, and daily average temperatures, from which heating degree-days to different reference temperatures are computed in exact correspondence to the consumption periods. The input to the procedure is then F_i and HDD_i where

F_i = average daily consumption (e.g., in MBtu/day) in time interval i

HDD_i (T_{ref}) = average heating degree days per day to reference temperature T_{ref} in time interval i.

Here HDD_i (T_{ref}) is computed from average daily temperatures T_{ij} for the N_i days in interval i, i.e.,

$$HDD_i\ (T_{ref}) = \sum_{j=1}^{N_i} (T_{ref}-T_{ij})^{+}/N_i \ , \qquad \text{(A-2)}$$

where "+" indicates that the term in parentheses is set to zero if T_{ij} is above T_{ref}. Figure A-2 shows a plot of F_i against HDD_i for a sample house. A straight-line relationship is clearly suggested.

The set of data points [F_i] and [HDD_i] for an approximately year-long period are then fit to a linear model:

$$F_i = a + b\ HDD_i\ (T_{ref}). \qquad \text{(A-3)}$$

For a guessed value of reference temperature T_{ref}, the base level and heating slope parameters a and b are found by standard statistical techniques (ordinary least-squares linear regression). The parameters a and b are calculated in this way for several different values of T_{ref}. "Best T_{ref}" is the one for which a plot of F_i vs HDD_i (T_{ref}), such as the one shown in Fig. A-2, is most nearly a straight line. Formally, T_{ref} is determined as the value for which the mean squared error is minimized, or equivalently for which the R^2 statistic is highest. The corresponding values of a and b are the best estimates of base level and heating slope.

The parameters a, b, and T_{ref} resulting from the model are used to calculate normalized annual consumption. The NAC index represents consumption that would occur in a year with typical weather conditions, and is calculated as follows:

$$NAC = 365\ a + b\ HDD_0\ (T_{ref})\ , \qquad \text{(A-4)}$$

where $HDD_0(T_{ref})$ is the heating degree-days (base T_{ref}) in a "typical" year.

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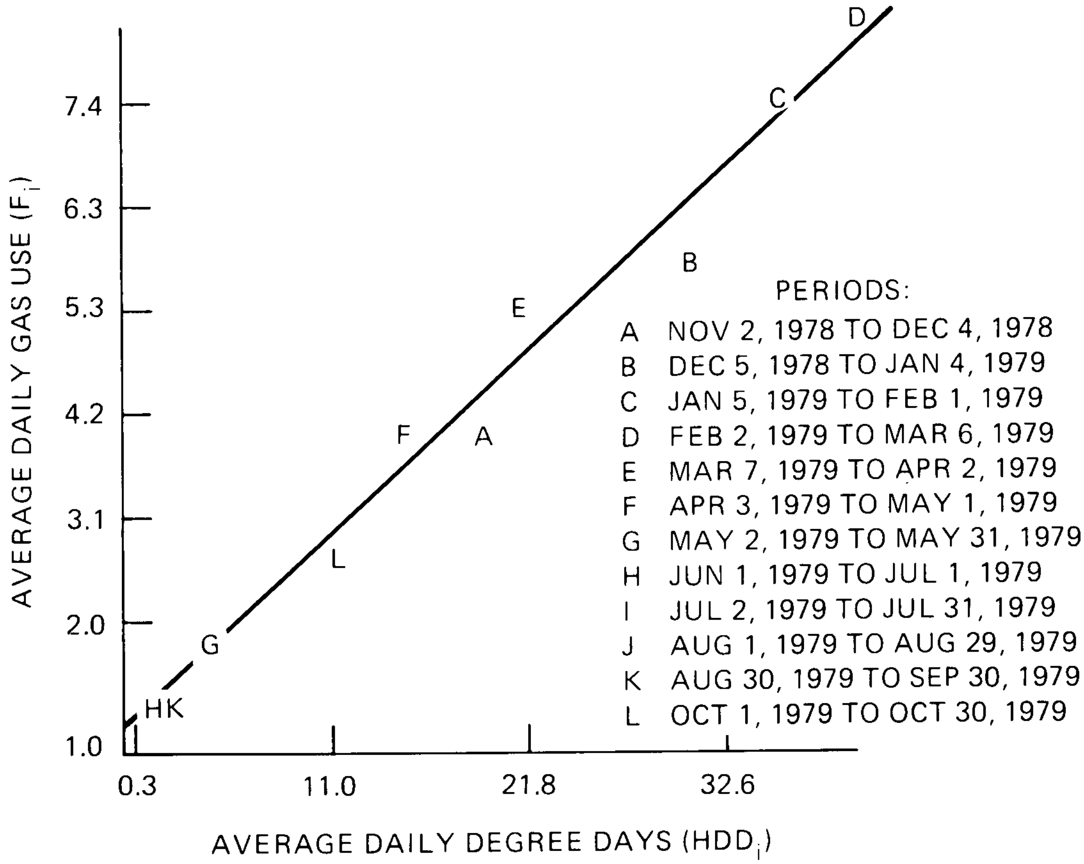

Fig. A-2. Plot of F_1 vs H_1 for a sample gas-heated home.

Source: Fels (1984)

In general we feel that the three parameters a , b, and T_{ref} provide physically meaningful indicators, whose changes may not be statistically significant but whose behavior can often suggest the reason for a consumption change. It appears that a and b are considerably more meaningful when estimated for best T_{ref} than when estimated at a more usual value such as 65°F. The NAC result provides a reliable conservation index from which energy savings and conservation trends may be accurately estimated.

Use of the Methodology to Measure Savings

The NAC index provides the basic parameters for monitoring energy savings resulting from retrofit programs. Using billing and weather data for approximately year-long periods before and after the period during which the retrofits are performed, NAC_1 and NAC_2 are calculated as averages (means or medians) over houses in the treatment group for the pre- and post-periods respectively. The weather-adjusted change in energy consumption between the two periods is then given by

$$S_1 = NAC_1 - NAC_2 \ . \tag{A-5}$$

Analogous indices NAC_{C1} and NAC_{C2} for the same pre- and post-periods are calculated for a control group. The savings can then be adjusted as follows:

$$S_2 = NAC_1 \left(NAC_{C2} \ / \ NAC_{C1} \right) - NAC_2 \tag{A-6}$$

or

$$S_2 = (NAC_1 - NAC_2) - (NAC_{C1} - NAC_{C2}) \tag{A-7}$$

to represent an estimate of the savings attributable to the retrofit program. The total change in the household's consumption Eq. (A-5), the control savings and the savings adjusted by the control are the quantities of interest in scorekeeping.

If the treatment and control groups have about the same initial consumption (within 20% of each other), the results from Eqs. (A-6) and (A-7) will be about the same (within 4%). The two formulas do, however, make different assumptions about how the change in consumption is measured. Formula (A-6) measures the precentage change in consumption relative to first-year consumption. Formula (A-7) measures the absolute amount of reduction in consumption and this measurement is not proportional to first-year consumption. It is not clear which formula is superior, since consumption reductions for some retrofit measures may be proportional to baseline consumption levels and some may not. If the control group is selected to be as similar as possible to the treatment group, which it should be, the two formulas will give equivalent results.

Fixed Reference Temperature Method

As indicated earlier in this Appendix, it is possible to obtain most of the benefits of the Princeton Scorekeeping Method without the analytical and computational burdens of implementing the full method. We discuss here a modified NAC model in which the reference temperature is fixed a priori by the analyst for all houses in the data set. ORNL's experience, with natural gas-heated homes in Minnesota and electrically heated homes in the Pacific Northwest, suggests that a fixed reference temperature of 60°F is a good choice.* Assuming a fixed reference temperature for all household-years in the data set greatly simplifies estimation of the two remaining parameters, the heating and baseload coefficients, and the overall NAC. Further, estimates of NAC obtained with the fixed reference temperature method are very close to those obtained with the full method. However, estimates of the heating and baseload components are less accurate with this simpler method, especially if a house's reference temperature is far from the fixed value.

As with PRISM, the simpler method requires natural gas meter readings for a 12-month period and daily temperature data for the same time period for the closest (or most appropriate) NOAA weather station to the home. The gas consumption data for each billing period are normalized by the number of days in the billing period (usually about 30) to yield estimates of average daily gas use (e.g., MBtu/day) for each of the 12 billing periods.

The daily temperature data are used to derive values of daily heating degree days (HDD) to the preselected reference temperature: maximum (0, T_{ref} - T_{ave}) where Tref is the assumed reference temperature and T_{ave} is the average outdoor temperature for that day. As shown in Eq. (A-2), daily HDD values are summed over the appropriate days to obtain the HDD figure for that billing cycle. This "monthly" HDD is then normalized by dividing by the number of days in the billing cycle (to yield a weather variable consistent with the energy use variable).

The combined data set (MBtu/day, HDD/day) for the 12 billing cycles is then input to a standard regression package that estimates ordinary least squares equations. For example, the SAS (1982) procedures GLM, SYSREG, and REG can all be used to implement this method. We use REG at ORNL to estimate the simplified scorekeeping models because it is an easy to use general purpose procedure to fit ordinary least-squares estimates to linear regression models.

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*It is possible, that elderly households maintain higher than average indoor temperatures resulting in a higher than average reference temperature. If a program is serving only the elderly, the analyst may wish to try calculations with a higher reference temperature to see if better results can be obtained.

The 12 observations (MBtu/day, HDD/day) are input to the regression procedures to statistically estimate the baseload and heating slope coefficients in the following regression model:

$$F_i = a + b*HDD_i \ , \qquad \text{(A-8)}$$

where F_i is household natural gas use for billing period i, HDD_i is the number of heating degree days (at the fixed reference temperature) during the same billing period, and a and b are coefficients determined by the regression model.

The coefficients (a,b) are estimated for each household-year of data used in the analysis. The coefficients are then used to define NAC, as discussed above:

$$NAC = 365a + bHDD_o \ , \qquad \text{(A-9)}$$

where NAC is normalized (weather-adjusted) annual natural gas use and HDD_o is the long-run normal HDD at the fixed reference temperature for the NOAA weather station closest to that household. This NAC formula corrects household natural gas use for year-to-year changes in winter severity and for temporal misalignment across households in fuel bills (e.g., some records begin on July 1 and others on July 23; some histories are for 330 days and others for 375 days).

The National Oceanic and Atmospheric Administration publishes values of the 30-year normals for HDD for their weather stations. These long-run HDD values are computed at a reference temperature of 65°F. We suggest conversion of these long-run HDD values from 65°F to the appropriate reference temperature as follows:

$$HDD_o(T_{ref}) = \left[\sum_i^j HDD_{T_{ref}} / \sum_i^j HDD_{65}\right] \times \text{NOAA } \overline{HDD}_{65}, \qquad \text{(A-10)}$$

where i is the first day of the first analysis year and j is the last day of the last analysis year (i.e., use the largest multiple of 12 months possible with the data on file). This equation seems to yield reasonably accurate approximations at reference temperatures close to 65°F.

The NAC estimates are then used to determine total energy savings, with or without adjustment for a control group, as explained earlier in our discussion of PRISM.

Appendix B

DATA QUALITY ISSUES

The preceding Appendix discussed methods to analyze natural gas billing data and daily temperature data to develop credible estimates of the energy savings attributable to gas heating system retrofits. This Appendix offers suggestions on ways to examine the data prior to analysis. We think that analysts too often manipulate data using high-speed computers and sophisticated statistical software packages without taking sufficient time to carefully examine the data beforehand. The old adage - garbage in, garbage out - applies here.

In order to obtain reliable normalized annual consumption (NAC) results, it is important to have reliable inputs. This requires a commitment to data quality and an investment of the resources necessary to achieve it. The reward for this effort is confidence in the results and a strengthening of the overall evaluation investment.

Three input data files are necessary for NAC model implementation: utility meter readings, daily average temperatures, and long-run heating degree days (HDD). Data quality issues for each of these inputs are discussed below.

Billing Data

In utility consumption data or "billing data," three fields of information are of interest: household and location identifier, date meter was read, and quantity of fuel consumption since the last reading (ID, DATE, and Q). To study changes in heating fuel consumption, the analysis year should be from one summer to the next. The analysis year boundaries can be defined in one of two ways: hard or soft. Hard analysis year boundaries could be July 1 through June 30. A bill is assigned to an analysis year if the reading date falls within the boundaries. Soft analysis year boundaries can be defined as "the next 12 (if monthly) cycles" if the billing schedules are regular. With either definition, it is important to collect an additional bill at the beginning of each history to supply a starting date for the first bill in the first analysis year. Choosing analysis year boundaries that start late (e.g., August or September) may cause an unnecessary delay in the completion of the evaluation. July 1 to June 30 are better boundaries to use.

Usually, the NAC software will require the input bills to be a "stack" of records with ID, DATE, and QUANTITY (Q); sorted by ID and

DATE.* As the stack of records is created, estimated bills must be removed by adding the estimated Q to the next observed Q and then removing the estimated record.

It is recommended that a computer program be developed to perform a quality control scan of the bills. A number of tests are useful. If one is dealing with monthly bills, for example, one can check to see that all analysis years are fully represented with at least 11 and not more than 13 bills. The number of days spanned in an analysis year should be at least 325 and not more than 425. These are important tests as NAC calculations with less than a full year of data can be misleading. For monthly readings the number of days spanned should be at least 20 and not more than 40. A data item that falls out of range is not necessarily deleted. Instead, the purpose of the tests is to identify problem households that merit further checks. Similar tests, with appropriate ranges, could be performed on bimonthly bills.

The most important data quality issue associated with the gas billing data concerns assurance that the data are for the correct household/house combination. Because households frequently move from one residence to another, it is important to be sure that the natural gas data being analyzed are for the appropriate household. A change in occupancy can sometimes be detected by a change in the utility's account number or by the presence of one or more months of zero (or very low) gas use. A phone call to the utility may yield additional information on households that have moved. This issue of occupant change is particularly critical for rental units: tenants move much more frequently than do homeowners, and the gas bill might be sent to the dwelling unit's owner rather than the tenant (making it difficult to identify the change in occupancy from the account number).

It is also important to examine the individual (monthly) bills for each household-year to identify anomalously high or low bills. A convenient way to do this is to plot monthly gas use (MBtu/day) as a function of HDD per day and to examine the graph relative to the expected linear relationship. If an unusually high (or low) bill is identified, this outlier could be dropped from the household-year data set; NAC model estimates with and without this outlier can be compared and the better model used in subsequent analysis.

An even more common occurrence is the appearance of two outlier bills, of opposite sign and temporally adjacent. This can occur if the first bill is an estimate (which occurs if the meter is not read that

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*A stack of records consists of one observation for each billing date and has the following form:

Customer ID, DATE, MBtu
Customer ID, DATE, MBtu
. . .
. . .
. . .

month). The subsequent outlier of opposite sign, the reading for the following month, then corrected whatever error occurred in estimating the initial bill. In this case, we suggest combining the two outlier bills to yield one (bimonthly) bill and then estimating the NAC model.

It is also important to examine the NAC model outputs, as well as inputs, to identify possible anomalies. We suggest close examination of the NAC model R^2, heating, and baseload values and the ratio of heating use to total use. It might be useful to report NAC results and energy-saving estimates for different subsets of households based, for example, on the intensity with which natural gas is used for heating. Such a disaggregation of results may provide additional insight into the energy-saving effects of the gas heating system retrofit options. More information on these procedures can be found in Hirst, Goeltz and White (1984).

Daily Average Temperatures

The best source of temperature data is the National Oceanic and Atmospheric Administration (NOAA). NOAA can provide data in two forms: computer tape and monthly publications from which data must be keypunched. If tapes are used, data quality flags that indicate questionable data items are provided by NOAA. If the data are keypunched, monthly averages can be used as a check field.

Copies of NOAA reports can be obtained by writing to the National Climatic Data Center, Federal Building, Asheville, NC 28801 or by calling 704-672-0682. Assistance from professional climatologists is also available at this number.

Our experience suggests that the daily temperature data obtained from NOAA are generally of very high quality, especially if they are from the First Order weather stations. The only problem we have encountered with NOAA data is missing values. Frequently, temperatures will be missing for one or two days; rarely, data will be missing for several weeks or a month. In the former case, we suggest imputation of missing values using the average of temperatures for the day before and the day after the day with the missing values. In other words, we assume that the average temperature on the "missing" day was equal to the average of the preceding and succeeding days.

In the rare case that data are missing for more than a few days, we suggest two alternative approaches. One is to use a different weather station that has little or no missing data and that is reasonably close to the households that had been assigned to the original weather station. The second approach is to develop a simple regression model to "predict" daily temperatures at the missing station using data from a nearby station. In this approach, daily average temperatures for the month before the missing period and for the month after are used to estimate the following equation:

$$T_{ave_o} = a + b*T_{ave_n}, \tag{B-1}$$

where T_{ave} is the average daily temperature, o refers to the original weather station (the one with missing data), and n refers to the nearby weather station (the one with no missing data). The coefficients (a,b) are estimated using daily data for periods before and after the missing dates. The formula is then used to estimate daily temperatures at the original station during the missing period based on daily temperatures at the nearby station.

The daily temperature data can be organized into a stack with each record containing: station ID, date, and average temperature [0.5* (MAX + MIN)] sorted by station and date. Or, one record per month may be easier for some software. A quality control program could report, for each station, the station ID, starting date of history, ending date, missing or extra days (in a stack), and missing temperature data.

Long-run Heating Degree Days

The file of long-run HDD contains one record for each station with station ID and annual long-run HDD at each temperature reference base needed (e.g., 60 and 65°F). There are at least two ways to calculate long-run HDD. One is to collect at least 10 years of temperature data for each station and calculate directly. A second method, a shortcut, is to apply a multiplier to the NOAA base 65° figure as explained in Appendix A. The shortcut method seems to be reasonably accurate for bases close to 65°F.

Appendix C

SAMPLE SIZE CALCULATIONS

The appropriate sample size must be determined early in the design of a program evaluation. The sample needs to be large enough so that the estimate is accurate but not so large that the estimate is more accurate than is required. The cost of the program evaluation increases with the size of the sample. While a large sample will usually provide more supportable results, the size of the sample does not have a direct linear relationship to the accuracy of the findings. That is, there tends to be a "ceiling effect" whereby, after a certain percentage of respondents have been surveyed, doubling the sample does not cut the potential error in half but rather by one-tenth (Marsh, 1983).

The parameter to be estimated for our sample of households is the change in energy savings between the treatment and control groups. This can be represented mathematically as follows:

$$D_i = \overline{X}_i - \overline{X}_o \tag{C-1}$$

where D_i represents the difference in the change in energy savings between the treatment and control groups,

$\overline{X}_i$ is the mean energy savings for the treatment group i (i = 1, 2, 3, 4 represents the four retrofit types),

$\overline{X}_o$ is the mean energy savings for the control group corresponding to the treatment group i.

From the households eligible for retrofit type i, N_i units $X_{i1}, X_{i2}, \ldots, X_{in_i}$ will be sampled from the households receiving retrofit type i, and N_o units $X_{o1}, X_{o2}, \ldots, X_{on_o}$ will be sampled from the households qualifying for but not receiving retrofit type i. The estimate for D_i is the statistic:

$$\overline{d}_i = \overline{x}_i - \overline{x}_o \tag{C-2}$$

where $$\overline{x}_i = \sum_{j=1}^{n_i} \frac{x_{ij}}{n_i} \quad \text{and} \quad \overline{x}_o = \sum_{j=1}^{n_o} \frac{x_{oj}}{n_o} \quad .$$

Sample Size Analysis for the Treatment Group

The sample size for the treatment group can be determined from the following relationship:

$$n_i = \frac{1}{\left(\frac{e\,|\overline{X}_i|}{S_i\, Z_{t/2}}\right)^2 + \frac{1}{N_i}} \qquad \text{(C-3)}$$

such that

$$\text{Prob}\left(\frac{|\overline{x}_i - \overline{X}_i|}{|\overline{X}_i|}\right) \geq e \;\leq t \qquad \text{(C-4)}$$

where, n_i is the sample size for the treatment group i;
N_i is the total population of households eligible for retrofit type i;
t is the level of confidence specified by the analyst;
$Z_{t/2}$ is the number associated with the 1-t/2 percentile point of the standard normal distribution;
S_i is the standard deviation, $S_i = \sqrt{\frac{X_{ij} - \overline{X}_i}{N_i - 1}}$;

e is the tolerable error specified by the analyst and defined in Eq. (C-4).

Computations of the estimated mean energy savings, $\overline{x}_i$, and the standard deviation, S_i

The standard deviation of the savings associated with the four gas retrofit types, S_i, is not well known at this time. However, the standard deviation is bounded by

$$S_i \leq \sqrt{\frac{R_i^2}{4}}\ , \qquad \text{(C-5)}$$

where R_i is the difference (range) between the largest and smallest estimated savings associated with retrofit type i.

The estimated range of savings for each retrofit type is based upon the observed steady-state efficiency improvements for gas retrofits installed under Minnesota's Pilot Gas Retrofit Project and engineering judgment based on past studies. The Alliance to Save Energy is anticipating the savings associated with the heat extractor to be in the

20-30% range. However, Minnesota is tentatively reporting a steady-state efficiency measurement improvement of 20-32% for the furnaces which they have retrofit with a heat extractor and expect to translate this steady-state measurement into a 16-24% fuel savings. The Minnesota Program anticipates the savings for the power gas burner to be in the 18-23% range. Once again, this range is based on measured steady-state efficiency improvement exhibited by the retrofits which were installed in the summer and fall of 1984. The Alliance to Save Energy expects a gas savings of approximately 20% as a result of the installation of a power gas burner. Type III and IV retrofits involve the installation of both an electric vent damper and electronic ignition and the installation of two thermally actuated vent dampers. A range of savings has been reported in the literature from various studies (Lee, 1983). Values vary from a negative 16% to a plus 36% reduction in energy use (Jung, 1983). Many studies do not specify the type of vent damper installed in the heating system, that is, thermal vs electric dampers. Vent dampers have different specifications, and each performs uniquely. Therefore, they cannot be classified in a single group with an average savings associated with the group. The Space Heating Efficiency Improvement Program (SHEIP) reports a mean gas savings of 11.1% for a Type III retrofit with a standard deviation of 1.4 (Macriss, 1980). However, the savings were based upon a fixed thermal balance technique. R. N. Caron of A. D. Little, Inc. presents a convincing argument that a fixed balance point does not correctly describe the physics involved and thereby produces erroneous results (Lee, 1983). Consequently, the range of savings and the estimated mean value for Type III and IV retrofits are only guesses. At a later date it is possible that data from the Minnesota Gas Program can be used to better specify a standard deviation for the four retrofit types. However, the sample size calculation involves the ratio of the estimated mean fuel savings and the standard deviation. This is probably a more stable term than either the mean savings or standard deviation alone; that is, the calculation of sample size may be less affected by incorrect values of the standard deviation and mean savings because the ratio of these two quantities is used to determine the sample size. The values of standard deviation and mean fuel savings used to determine sample size are presented in Table C-1.

Determination of the Allowable Error and Sample Size

The allowable error is determined somewhat arbitrarily. Since the standard deviation and mean fuel savings for each retrofit type (Table C-1) are estimates rather than known quantities, the sample size for the treatment group is calculated for two error values, a 5% and 10% error; two population sizes, $N = 1000$ and $N = \infty$; and a 90% confidence limit. The results are tabulated in Table C-2. The values in the bottom two rows in Table C-2 are, in our judgement, the only feasible choices for the gas retrofit program evaluation because of the limited number of retrofits the programs will install. Thus, while a 5% error might be more desirable only a 10% error can be achieved due to the greater number of homes required for a 5% tolerable error.

Table C-2. Treatment Group Sample Size Estimates

		n_i				
		Type I	Type II	Type III	Type IV	Combined Group
e = 0.05	N = 1000	111	41	105	88	359
	N = ∞	125	43	118	97	561
e = 0.10	N = 1000	30	11	29	24	123
	N = ∞	31[a]	11[a]	29[a]	24[a]	140[a]

[a]Recommended sample size for treatment group assuming complete data for all households.

Sample Size Analysis for the Control Group

Suppose that for a tolerable error (r), which is the difference between the true value of the change in energy savings between the treatment and control groups and the estimated value, one would expect

$$\text{Prob} \quad |\bar{d_i} - D_i| \geq r \leq t . \tag{C-6}$$

The relationship between n_i and n_o is described by the variance of $\bar{d}_i$:

$$\text{Var}\ (\bar{d}_i) = \left[\frac{S_i\sqrt{1-\frac{n_i}{N_i}}}{\sqrt{n_i}}\right]^2 + \left[\frac{S_o\sqrt{1-\frac{n_o}{N_o}}}{\sqrt{n_o}}\right]^2 \tag{C-7}$$

By assuming $\frac{n_i}{N_i}$ and $\frac{n_o}{N_o}$ are zero, an approximate equation for computing n_o is

$$n_o = \frac{S_o^2}{\left[\frac{r^2}{Z_{t/2}^2} - \frac{S_i^2}{n_i}\right]} \tag{C-8}$$

The value for r is chosen somewhat arbitrarily. However, one must consider the intended use of the estimated program effect and the consequences of a sizable difference between the true program effect and the estimated effect. Also, the standard deviations for the fuel savings of the control group is not well known at this time. A conservative assumption is that the standard deviation for the control group and the treatment group are the same. The difference term, r, is influenced by the error term, e, because the tolerance limit for the difference in fuel saving between the treatment and control groups cannot be more stringent than for the fuel savings of either group. Therefore, the value for r must always be greater than the quantity $e \cdot |\overline{X}_i|$. Therefore, the difference term will vary for each retrofit type based on mean fuel savings. Table C-3 presents the sample sizes for the control group by retrofit type assuming the treatment sample sizes are based on an error value of 10% and a population size of infinity.

The size of the treatment group and the size of control groups are approximately equivalent for the values of r equal to 3.0 for Type I, 2.75 for Type II, 1.25 for Type III, and 0.7 for Type IV.

Table C-3. Treatment and Control Group Sample Sizes

	r	N_i	N_0	N_{total}
Type I retrofit	2.5	31	113	144
	2.75	31	57	88
(S_i = 7.5; $Z_{0.05}$ = 1.645)	3.0	31[a]	37[a]	68[a]
Type II retrofit	2.25	11	50	61
	2.5	11	19	30
(S_i = 4.0; $Z_{0.05}$ = 1.645)	2.75	11[a]	12[a]	32[a]
Type III retrofit	1.0	29	152	181
	1.2	29	41	70
(S_i = 3.0; $Z_{0.05}$ = 1.645)	1.25	29[a]	34[a]	63[a]
Type IV retrofit	0.6	24	57	81
	0.65	24	36	60
(S_i = 1.5; $Z_{0.05}$ = 1.645)	0.70	24[a]	25[a]	49[a]
Combined sample of	2.5	140	351	491
all retrofit types	2.75	140	175	315
(S = 13; $Z_{0.05}$ = 1.645)	3.0	140[a]	113[a]	253[a]

[a]Recommended sample sizes for treatment (N_i) and control (N_0) groups assuming complete data for all households

Table C-1: Parameters Used in Sample Size Calculation

	Type I	Type II	Type III	Type IV	Combined Sample of All Retrofit Types
Estimated range of fuel savings (%)	15-30	16-24	6-12	4-7	4-30
Estimated mean fuel savings, $\bar{y}$ (%)	22	20	9	5	18
S_i	7.5	4.0	3.0	1.5	13.0

Appendix D

OCCUPANT SURVEY DATA

Essential Screening Questions to be administered at the time of the pretest visit to measure furnace efficiency and expected lifetime.

Do you own or rent your dwelling?	________
Have you lived in this dwelling since March 198_ (year before the program starts)?	________
Do you use any fuel for heating other than your gas furnace?	YES NO
If yes,	
Wood stoves?	YES NO
Electric heaters?	YES NO
Kerosene heaters?	YES NO
Cooking stove?	YES NO
Have you had any insulation installed since last winter?	YES NO
When was it put in?	____________
Have you had any storm windows installed since last winter?	YES - ________ storm windows were put in. NO
Have there been any other changes that make your home easier or harder to heat? What are they?	________________________ ________________________ ________________________
How many people live here?	________
How many people lived here last winter?	________

Type of housing unit:

_____ Mobile home or trailer
_____ One family detached
_____ One family semidetached (townhouse)
_____ Unit in 2-4 unit building detached
_____ Unit in 2-4 unit building semidetached
_____ Unit in 2-4 unit building attached
_____ Unit in building with 5 or more units
_____ Other ____________________

How old is your residence? __________

1 less than 10 years
2 10 - 19 years
3 20 - 29 years
4 30 - 39 years
5 40 - 49 years
6 50 years or older
10 Don't know

What type of fuel is used by your hot water heater? (INT: if 2 fuels used, ASK FOR MAIN WATER HEATER)

1 Electricity
2 Natural Gas
3 Propane or LPG
4 Other (What?) _____
12 Don't know

How many people living in your household are in each of the following age categories?

	Number in Household					
Infant - 5 years old	0	1	2	3	4	5 or more
6 - 11 years old	0	1	2	3	4	5 or more
12 - 17 years old	0	1	2	3	4	5 or more
18 - 24 years old	0	1	2	3	4	5 or more
25 - 34 years old	0	1	2	3	4	5 or more
35 - 44 years old	0	1	2	3	4	5 or more
45 - 54 years old	0	1	2	3	4	5 or more
55 - 64 years old	0	1	2	3	4	5 or more
65 or older	0	1	2	3	4	5 or more

Is occupant an Energy Assistance Program recipient?

YES
NO

Interviewer, please note any special characteristics that could significantly affect energy usage (e.g., siting of house has important effect on usage, physical condition of unit is such that significant amounts of energy are wasted)	____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________

Suggested additional postretrofit questions (Note that administration of these postretrofit questions is not part of the standard evaluation plan. For a more comprehensive study, it would be best to ask these questions at a time near the end of the second heating season being examined).

Behavior/Dwelling Changes

Are there any rooms in the house you do not heat?	YES - I do not heat _____ rooms. NO
Did you do the same last winter?	YES - I did not heat ____ rooms. NO
Do you use any electric heaters?	YES - I use _____ heaters. NO
Did you use any electric heaters last winter?	YES - I used _____ heaters. NO
Do you use kerosene portable heaters?	YES - I use _____ heaters. NO
Did you use kerosene heaters last year?	YES - I used _____ heaters. NO
Do you use your cooking stove to heat your home?	YES NO
Did you use it last year?	YES NO
Do you use a wood stove?	YES NO
Did you use it last year?	YES NO

At what temperature do you now set the thermostat?	________
Did you set the thermostat at the same temperature last winter?	YES NO - I set it at ________
Do you <u>regularly</u> lower the thermostat at night or while you are away during the day?	YES NO
How many hours is it at the lower temperature? (Total of both day and night hours).	________
Did you lower it the same amount last winter?	YES NO - I lowered it ________ hours per day.
Have you had any insulation installed since last winter?	YES NO
When was it put in?	________________
Have you had any storm windows installed since last winter?	YES - ________ storm windows were put in. NO
When were they put in?	________________
Have there been any other changes that make your home easier or harder to heat?	________________________ ________________________ ________________________
Interviewer, please note any special characteristics that could significantly affect energy usage (e.g., siting of house has important effect on usage, physical condition of unit is such that significant amounts of energy are wasted)	________________________ ________________________ ________________________ ________________________ ________________________ ________________________ ________________________ ________________________

Dwelling Characteristics

Number of stories in house or unit (not including basement)?

_____ 1
_____ 2
_____ 3
_____ 4
_____ 5 or more

How many rooms are in the house not including bathrooms? (A basement is not a room.) __________

Is your basement heated or unheated?

Heated
Unheated

In terms of square feet, what is the approximate total heated living space in your home? Please include basement only if heated. (Just your best estimate)

__________ square feet

12 Don't Know

Type of fuel mostly used for cooking:

_____ Electricity
_____ Gas from underground pipes
_____ Bottled or tank gas
_____ Other ____________

Demographics

How many people living in your household are in each of the following age categories?

	Number in Household					
Infant - 5 years old	0	1	2	3	4	5 or more
6 - 11 years old	0	1	2	3	4	5 or more
12 - 17 years old	0	1	2	3	4	5 or more
18 - 24 years old	0	1	2	3	4	5 or more
25 - 34 years old	0	1	2	3	4	5 or more
35 - 44 years old	0	1	2	3	4	5 or more
45 - 54 years old	0	1	2	3	4	5 or more
55 - 64 years old	0	1	2	3	4	5 or more
65 or older	0	1	2	3	4	5 or more

What is your age category? _______
I have listed (people above). Have I missed .....

Any lodgers or boarders who live here?

_____ YES (ADD TO LISTING)
_____ NO

Any one who usually lives here but is away traveling or in the hospital?

_____ YES (ADD TO LISTING)
_____ NO

Anyone else staying here who does not have a regular residence elsewhere?

_____ YES (ADD TO LISTING)
_____ NO

Does another family share your home with you?

_____ YES
_____ NO

How many persons in your household are usually home during the day? __________

What is the highest level of education you have completed? __________

Appendix E

RETROFIT TYPES

TYPE I GAS RETROFIT - HEAT EXTRACTOR

I. Applicable Heating Systems

1. Forced warm air furnaces whose steady-state efficiency is 81% or less.

2. All units must have life expectancy of 5 years or more.

II. Materials in Package

1. Heat extractor

2. Four-inch PVC vent pipe

3. Applicable flue fittings

4. Miscellaneous hardware and wiring materials for hook-up

5. Where required - sheet metal housing for heat extractor coil

III. Price Paid Under Gas Retrofit Program

$650

IV. Performance Standard

1. Either 90% steady-state efficiency equivalent* or 20% savings based on the following formula:

$$\frac{S_2 - S_1}{S_2} \times 1.4 = \text{Savings}$$

AND

2. Trace to 50 parts per million CO

AND

3. No more than 10% of flue gases may bypass the heat extractor, i.e., no more than 1°F temperature change between operation with chimney blocked and open.

---

*Steady-State Efficiency Equivalent is defined as measured initial steady-state efficiency $\times \frac{\text{temperature rise with Extractor on}}{\text{temperature rise with Extractor off}}$.

TYPE II GAS RETROFIT - POWER GAS BURNER

I. Applicable Heating Systems

1. Boilers whose steady-state efficiency is 75% or less and which will accept a power burner.

2. Gravity warm air furnaces whose steady-state efficiency is 75% or less and which will accept a power burner.

3. All units must have a life expectancy of 5 years or more.

II. Materials in Package

1. Power gas burner

2. Combustion chamber where needed

3. Adaptor plate where needed

4. Necessary wiring materials to supply 110 V to the burner

5. Miscellaneous hardware

6. Double-acting flue draft regulator and mounting fee

III. Price Paid Under Gas Retrofit Program

$500

IV. Performance Standard

1. Steady-state efficiency of 80% or more

AND

2. Trace to 50 parts per million CO

AND

3. Oxygen level of 4% or less or corresponding CO_2 level depending on the fuel used.

TYPE III GAS RETROFIT - ELECTRIC VENT DAMPER AND ELECTRONIC IGNITION

I. Applicable Heating Systems

1. Atmospheric hot water or steam boilers on which:

   a. A power burner cannot be installed;

   b. A heat extractor cannot be installed;

   c. The steady-state efficiency is less than 82%.

2. The unit must have a life expectancy of at least 5 years.

3. The unit must be connected to the chimney in such a way that no other space heating device such as an add-on wood burning stove is sharing the flue from breech to chimney.

II. Materials in Package

1. Automatic vent damper

2. Intermittent ignition kit

3. Miscellaneous hardware and wiring materials where needed

III. Price Paid Under Gas Retrofit Program

$400

IV. Performance Standard

1. The vent damper shall close off at least 96% of the flue area.

2. Installer must test the vent damper to verify that it prevents the burner from firing if it fails to open.

TYPE IV GAS RETROFIT - TWO THERMALLY ACTUATED VENT DAMPERS

I. Applicable Heating Systems

1. Atmospheric warm air furnaces on which

   a. a heat extractor cannot be installed,

   b. a power gas burner cannot be installed,

   c. the steady-state efficiency is less than 82%.

2. The unit must have a life expectancy of at least 3 years.

II. Materials in Package

1. Thermally actuated vent damper for heating systems

2. If applicable - thermally actuated vent damper for hot water heater

III. Price Paid Under Gas Retrofit Program

$175

IV. Performance Standard

None

Appendix F

RANDOM ASSIGNMENT OF HOUSEHOLDS TO TREATMENT OR CONTROL GROUPS

A random assignment is conducted in such a way that every member of the sample has an equal and independent chance of being placed into either the treatment or control group. A reliable randomization procedure is to number each member of the sample sequentially and then to select the numbers that will be assigned to the treatment (or control) group from a random number table.

Numbers may be chosen from a table of random digits (Table F-1) in any manner so long as the procedure is systematic and determined in advance. For example, one could close their eyes, place a finger on a number in the table, and proceed in any direction across rows or up and down columns to select those members in the sample whose numbers appear in the table until the desired sample size is reached. Care must be exercised to use the right number of digits. If there are 500 members in the sample, three-digit numbers must be examined. A three-digit number may be obtained by reading across a line or by taking the first digit in each of three columns or by reading upward in a column. However, once a row or column has been examined, a new row or column must be used.

To illustrate the use of the Table of Random Digits, consider a list of households from which one wishes to select a control group of 200 cases. The households are numbered from 001 to 500 (or whatever the last number is). An extract of Table F-1 consisting of the first ten lines of the left-most column is presented in Table F-2. The first three digits in each line can be used to select members to be assigned to the control group as shown in Table F-2. If the first three digits in the table yield a number larger than the desired sample size of 200, that household is not placed in the control group. If the first three digits are 200 or less then the household is assigned to the control group.

Random numbers can also be obtained by a computer routine using a random number generator. This is frequently easier than use of a table of random digits, particularly if the sample size is large. For some computer applications, the random numbers generated by the computers are used internally to identify those elements of a computerized data bank which are selected for the sample, and only the descriptions of the sample elements are printed out. Some pocket calculators also can generate random numbers.

Table F-1. Table of Random Digits

Line	(1)-(5)	(6)-(10)	(11)-(15)	(16)-(20)	(21)-(25)	(26)-(30)	(31)-(35)
101	13284	16834	74151	92027	24670	36665	00770
102	21224	00370	30420	03883	94648	89428	41583
103	99052	47887	81085	64933	66279	80432	65793
104	00199	50993	98603	38452	87890	94624	69721
105	60578	06483	28733	37867	07936	98710	98539
106	91240	18312	17441	01929	18163	69201	31211
107	97458	14229	12063	59611	32249	90466	33216
108	35249	38646	34475	72417	60514	69257	12489
109	38980	46600	11759	11900	46743	27860	77940
110	10750	52745	38749	87365	58959	53731	89295
111	36247	27850	73958	20673	37800	63835	71051
112	70994	66986	99744	72438	01174	42159	11392
113	99638	94702	11463	18148	81386	80431	90628
114	72055	15774	43857	99805	10419	76939	25993
115	24038	65541	85788	55835	38835	59399	13790
116	74976	14631	35908	28221	39470	91548	12854
117	35553	71628	70189	26436	63407	91178	90348
118	35676	12797	51434	82976	42010	26344	92920
119	74815	67523	72985	23183	02446	63594	98924
120	45246	88048	65173	50989	91060	89894	36036
121	76509	47069	86378	41797	11910	49672	88575
122	19689	90332	04315	21358	97248	11188	39062
123	42751	35318	97513	61537	54955	08159	00337
124	11946	22681	45045	13964	57517	59419	58045
125	96518	48688	20996	11090	48396	57177	83867
126	35726	58643	76869	84622	39098	36083	72505
127	39737	42750	48968	70536	84864	64952	38404
128	97025	66492	56177	04049	80312	48028	26408
129	62814	08075	09788	56350	76787	51591	54509
130	25578	22950	15227	83291	41737	59599	96191
131	68763	69576	88991	49662	46704	63362	56625
132	17900	00813	64361	60725	88974	61005	99709
133	71944	60227	63551	71109	05624	43836	58254
134	54684	93691	85132	64399	29182	44324	14491
135	25946	27623	11258	65204	52832	50880	22273
136	01353	39318	44961	44972	91766	90262	56073
137	99083	88191	27662	99113	57174	35571	99884
138	52021	45406	37945	75234	24327	86978	22644
139	78755	47744	43776	83098	03225	14281	83637
140	25282	69106	59180	16257	22810	43609	12224
141	11959	94202	02743	86847	79725	51811	12998
142	11644	13792	98190	01424	30078	28197	55583
143	06307	97912	68110	59812	95448	43244	31262
144	76285	75714	89585	99296	52640	46518	55486
145	55322	07598	39600	60866	63007	20007	66819
146	78017	90928	90220	92503	83375	26986	74399
147	44768	43342	20696	26331	43140	69744	82928
148	25100	19336	14605	86603	51680	97678	24261
149	83612	46623	62876	85197	07824	91392	58317
150	41347	81666	82961	60413	71020	83658	02415

Table F-2. Use of Random Digit Table

Line	(1) - (5)	Household
101	13284	132 Control
102	21224	Not Control
103	99052	Not Control
104	00199	001 Control
105	60578	Not Control
106	91240	Not Control
107	97458	Not Control
108	35249	Not Control
109	38980	Not Control
110	10750	107 Control

We have completed a computer routine that generates random numbers and ensures equal numbers in the treatment and control groups for each retrofit type to produce Tables F-3.1 - F-3.4. Tables F-3.1 through F-3.4 should be used by each inspector of heating systems to assign households to treatment and control groups.

The treatment/control group assignment procedure (Figure F-1) has four steps: (1) determine if a household is eligible for the program; (2) determine which retrofit type is suitable for the household; (3) assign an entry number to the household. This assignment is done by sequentially numbering each household found to be qualified for each retrofit type. That is, the first household identified as eligible for a Type I retrofit is No. 1 for Type I, the second No. 2 for Type I, etc. the first household identified as eligible for a Type II is No. 1 for Type II, the second No. 2 for Type II, etc. A list of households by entry number for each retrofit type should be maintained by each inspector. As each additional household is identified as eligible for a given retrofit type, it is simply added to the list for that type and given the next consecutive number. The fourth and final step in assigning a household to a treatment or control group is to check the household's entry number in the appropriate table (F-3.1 to F-3.4) to determine if the household should be in the treatment or the control group. A "yes" means the household is in the treatment group; a "no" means it is in the control group. If a household is in the treatment group, a work order is issued. If it is in the control group, fuel consumption and survey data are collected, but no retrofit is installed.

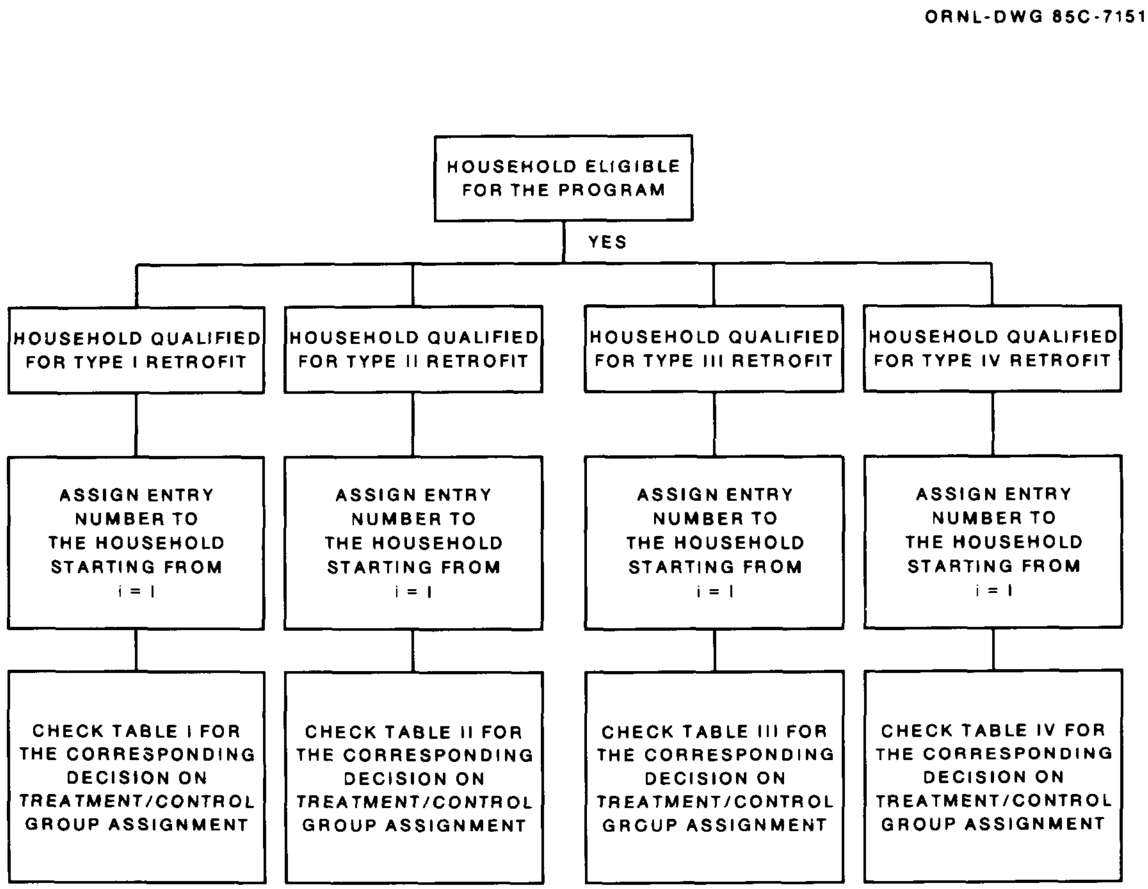

Fig. F-1. Procedure for treatment and control group assignment.

Table F-3.1. Decision table for households qualified to receive retrofit Type I

Entry Number	Program Offer (Yes/No)	Entry Number	Program Offer	Entry Number	Program Offer	Entry Number	Program Offer	Entry Number	Program Offer
1	Yes	21	No	41	No	61	Yes	81	No
2	Yes	22	No	42	No	62	Yes	82	Yes
3	No	23	Yes	43	No	63	No	83	No
4	Yes	24	Yes	44	Yes	64	Yes	84	Yes
5	No	25	No	45	No	65	No	85	Yes
6	No	26	Yes	46	Yes	66	Yes	86	No
7	No	27	No	47	Yes	67	No	87	Yes
8	Yes	28	Yes	48	Yes	68	Yes	88	No
9	No	29	Yes	49	Yes	69	No	89	Yes
10	Yes	30	No	50	No	70	No	90	No
11	Yes	31	No	51	No	71	No	91	Yes
12	No	32	No	52	Yes	72	Yes	92	No
13	Yes	33	Yes	53	No	73	Yes	93	Yes
14	Yes	34	No	54	No	74	Yes	94	No
15	Yes	35	No	55	Yes	75	No	95	Yes
16	No	36	Yes	56	Yes	76	No	96	No
17	No	37	Yes	57	Yes	77	Yes	97	No
18	No	38	Yes	58	No	78	Yes	98	Yes
19	No	39	No	59	No	79	No	99	No
20	Yes	40	Yes	60	Yes	80	No	100	Yes

Note: Entry number is the number assigned to a household when it is found to be qualified for the Type I retrofit. These numbers are assigned consecutively by the person inspecting the heating systems.

Table F-3.2. Decision table for households qualified to receive retrofit Type II

Entry Number	Program Offer (Yes/No)	Entry Number	Program Offer	Entry Number	Program Offer	Entry Number	Program Offer	Entry Number	Program Offer
1	Yes	21	Yes	41	No	61	Yes	81	No
2	Yes	22	No	42	No	62	No	82	Yes
3	No	23	No	43	Yes	63	No	83	Yes
4	Yes	24	No	44	No	64	Yes	84	No
5	No	25	Yes	45	Yes	65	Yes	85	Yes
6	No	26	Yes	46	No	66	Yes	86	Yes
7	No	27	Yes	47	Yes	67	No	87	No
8	No	28	Yes	48	No	68	Yes	88	No
9	Yes	29	No	49	Yes	69	No	89	No
10	Yes	30	No	50	Yes	70	No	90	Yes
11	Yes	31	No	51	No	71	No	91	No
12	Yes	32	Yes	52	Yes	72	Yes	92	No
13	Yes	33	No	53	Yes	73	No	93	Yes
14	Yes	34	Yes	54	No	74	No	94	No
15	No	35	Yes	55	Yes	75	Yes	95	No
16	No	36	Yes	56	Yes	76	Yes	96	Yes
17	No	37	No	57	Yes	77	No	97	Yes
18	No	38	Yes	58	No	78	Yes	98	Yes
19	No	39	No	59	No	79	No	99	Yes
20	Yes	40	No	60	No	80	Yes	100	No

Note: Entry number is the number assigned to a household when it is found to be qualified for the Type II retrofit. These numbers are assigned consecutively by the person inspecting the heating systems.

Table F-3.3. Decision table for households qualified to receive retrofit Type III

Entry Number	Program Offer (Yes/No)	Entry Number	Program Offer	Entry Number	Program Offer	Entry Number	Program Offer	Entry Number	Program Offer
1	No	21	No	41	Yes	61	Yes	81	Yes
2	No	22	No	42	No	62	No	82	No
3	Yes	23	Yes	43	No	63	Yes	83	No
4	No	24	No	44	Yes	64	Yes	84	Yes
5	No	25	Yes	45	Yes	65	No	85	No
6	Yes	26	No	46	No	66	Yes	86	Yes
7	Yes	27	Yes	47	No	67	No	87	No
8	No	28	Yes	48	No	68	No	88	Yes
9	Yes	29	Yes	49	Yes	69	Yes	89	Yes
10	Yes	30	No	50	Yes	70	No	90	No
11	Yes	31	No	51	No	71	No	91	No
12	No	32	Yes	52	No	72	Yes	92	Yes
13	Yes	33	Yes	53	Yes	73	No	93	Yes
14	Yes	34	No	54	Yes	74	No	94	Yes
15	Yes	35	Yes	55	No	75	Yes	95	Yes
16	No	36	Yes	56	Yes	76	Yes	96	No
17	No	37	No	57	No	77	Yes	97	No
18	No	38	No	58	Yes	78	No	98	No
19	No	39	No	59	No	79	Yes	99	Yes
20	Yes	40	Yes	60	Yes	80	No	100	No

Note: Entry number is the number assigned to a household when it is found to be qualified for the Type III retrofit. These numbers are assigned consecutively by the person inspecting the heating systems.

Table F-3.4. Decision table for households qualified to receive retrofit Type IV

Entry Number	Program Offer (Yes/No)	Entry Number	Program Offer	Entry Number	Program Offer	Entry Number	Program Offer	Entry Number	Program Offer
1	No	21	Yes	41	No	61	No	81	Yes
2	Yes	22	No	42	Yes	62	Yes	82	Yes
3	Yes	23	Yes	43	Yes	63	Yes	83	Yes
4	No	24	No	44	Yes	64	No	84	No
5	No	25	No	45	No	65	Yes	85	No
6	Yes	26	Yes	46	Yes	66	No	86	Yes
7	Yes	27	No	47	No	67	Yes	87	Yes
8	No	28	Yes	48	No	68	No	88	No
9	No	29	No	49	Yes	69	No	89	No
10	Yes	30	Yes	50	Yes	70	Yes	90	No
11	Yes	31	Yes	51	No	71	Yes	91	No
12	Yes	32	No	52	Yes	72	No	92	No
13	No	33	No	53	No	73	Yes	93	No
14	Yes	34	Yes	54	No	74	No	94	Yes
15	Yes	35	Yes	55	Yes	75	No	95	Yes
16	Yes	36	Yes	56	No	76	Yes	96	No
17	No	37	No	57	Yes	77	No	97	No
18	No	38	No	58	Yes	78	Yes	98	Yes
19	No	39	No	59	Yes	79	Yes	99	Yes
20	No	40	Yes	60	No	80	No	100	Yes

Note: Entry number is the number assigned to a household when it is found to be qualified for the Type IV retrofit. These numbers are assigned consecutively by the person inspecting the heating systems.

Appendix G

PROGRAM RECORDKEEPING FORMS

This appendix contains copies of program recordkeeping forms that were used by the state of Minnesota for the gas furnace retrofit program it conducted in 1984. Other states may wish to use these forms or, at least, be sure that their recordkeeping systems include the same information.

Three types of forms are included: (1) a "survey report" form which summarizes heating system characteristics and shows the results of the initial steady-state efficiency test that determines eligibility for the retrofit, (2) a "work order" form which authorizes a retrofit installation and certifies that it was completed at the required steady-state efficiency level, and (3) monthly reporting forms which record the numbers of completed retrofits of each type done that month and the number of heating systems inspected but found to be ineligible.

STATE OF MINNESOTA

GAS RETROFIT PROGRAM

SURVEY REPORT

1. Homeowner's Name, Address Phone Number	2. Energy Audit/Efficiency Test Appointment
	3. Job Number

4. I authorize representatives of ______________________________(agency) to enter my home to complete necessary testing and work on my heating system as prescribed on this form and to determine gas consumption. I understand that efficiency testing will not necessarily result in a retrofit. I also understand that any work completed will be done at no charge to myself or my family.

Signature of Homeowner Date

5. Gas Consumed Last Two Years___ CCF/MCF

☐ Natural Gas ☐ Propane

6. Heating System Working? ☐ Yes ☐ No

7. Major Problems: ☐ Gas Leak

☐ Flue Leak

☐ Boiler Leak

☐ Rust in Supply Plenum or Heat Exchanger

8. Emergency Switch: ☐ Working

☐ Not Working

9. Settings on High Limit at:

☐ 5 Pounds or Less on Steam

☐ 210° or Less on Hot Water

☐ 250° or Less on Hot Air

10. Heating System Data

Manufacturer ______________

Model ______________

Capacity ____________BTU/Hr.

Flue Size ____________Inches

Coal Conversion ☐ Yes ☐ No

If Yes

Burner Mounting ☐ Flange

☐ Pedestal

Airtube Length ________ Inches

Firebox Dimensions (LxWxH)

______" x ______" x ______"

Combustion Chamber Size (LxWxH)

____" x ____" x ____" ☐ Round

Condition of Combustion Chamber

____

Summer/Winter Hookup ☐ Yes ☐ No

Humidifier ☐ Yes ☐ No

Furnace Filter Size __" x __" x __"

Filter Condition ______________

11. Net Stack Temperature _____°F

12. CO Test _________PPM

13. CO_2 Test ______% or O_2 Test _____%

14. Draft in the Flue _____________

15. Pre-Retrofit Efficiency Rating _____%

16. If heating system is not eligible for retrofit, give reasons:

(a) efficiency rating too high

Yes ___ No ___

(b) life expectancy too short

Yes ___ No ___

(c) major repairs are required

Yes ___ No ___

cost of repairs $ ________

(d) replacement is recommended

yes ___ No ___

cost of replacement $ _____

other (please list):

____

____

17. Auditor's Name

Agency Name, Address, Phone Number

Homeowner's Gas Supplier	Retrofit Installer

WORK ORDER

______________________ is hereby authorized to complete gas retrofit work as described below:

☐ Type I Retrofit - Heat Extractor

☐ Type II Retrofit - Power Gas Burner

☐ Type III Retrofit - Electric Vent Damper & Electronic Ingition

☐ Type IV Retrofit - Thermally Actuated Vent Damper(s)

INSTALLER'S REPORT
Equipment Installed:

☐ Heat Extractor

☐ Power Gas Burner - Manufacturer and Model ______________

☐ Electric Vent Damper - Manufacturer and Model ______________

☐ Electronic Ignition - Manufacturer and Model ______________

☐ Thermally Actuated Vent Damper on ☐ Heater ☐ Water Heater

Manufacturer(s) and Model (s)______________

☐ Combustion Chamber ☐ Sheet Metal Housing for Heat Extractor Coil

☐ Barometric Damper ☐ Condensate Pump

☐ Other Equipment ______________

Comments ______________

INSTALLER'S CERTIFICATION
I certify that the work specified above (see items checked) has been completed and that all requirements have been met.

For a Type I Retrofit:
1. Steady-state efficiency equivalent = ____% or Savings = ________%
2. CO Concentration = ______PPM
3. The temperature rise across the Heat Extractor coil changed by ____°F when the flue was blocked.

For a Type II Retrofit:
1. Steaty-state efficiency = ____%
2. CO Contration = ______PPM
3. O_2 Concentration = ____% or CO_2 Concentration = ____%

For a Type III Retrofit:
1. The vent damper installed closes off at least 96% of the flue area.

   ☐ yes ☐ no

2. I have performed a test to verify that the vent damper prevents the burner from firing if the dampler fails to open.

   ☐ yes ☐ no

For a Type IV Retrofit:
1. The vent dampelr was installed in a workmanlike manner and according to manufacturer's instructions. ☐ yes ☐ no
2. The vent damper was installed so that three minutes after the main burner fires there is no spillage of flue gases at diverter or draft hood. ☐ yes ☐ no

______________________ ______________________
Signature of Installer Date

AUDITOR'S VERIFICATION
I inspected the retrofit equipment installed on this heating system on __________(date).
The results of my inspection are:

Type I Retrofit	Type II Retrofit	Type III Retrofit	Type IV Retrofit
1 = ____%	1 = ____%	1 ☐ yes ☐ no	1 ☐ yes ☐ no
2 = ____PPM CO	2 = ____PPM CO	2 ☐ yes ☐ no	2 ☐ yes ☐ no
3 = ____°F	3 = ____$\%O_2$ or	$\%CO_2$	

______________________ ______________________
Signature of Auditor Date

GAS RETROFIT PILOT PROJECT
MONTHLY REPORTING FORM

I. Agency ____________________ Reporting Period From ________ to ________

Compiled By ____________________ Phone No. ____________________

County ____________________

II. ____________ Number of heating systems retrofitted with Type I retrofit.

____________ Number of heating systems retrofitted with Type II retrofit.

____________ Number of heating systems retrofitted with Type III retrofit.

____________ Number of heating systems retrofitted with Type IV retrofit.

____________ Number of heating systems tested but did not qualify due to other repair problems (i.e., cracked heat exchanger).

____________ Number of heating systems tested that did not qualify due to high efficiency.

III.

	Job No.	Date Completed	Installer
A. Type I			
B. Type II			
C. Type III			
D. Type IV			

____
(STATE)

GAS HEAT RETROFIT PROGRAM

MONTHLY REPORT

Report for (month) ________

STATE OFFICE/ADDRESS:	PREPARED BY: ________ (name)
	________ (signature)
PHONE NUMBER: FUNDING SOURCE: TOTAL RETROFIT BUDGET:	________ (date)

CUMULATIVE DATA

Enter cumulative totals for all local agencies:

1. Survey Reports/Work orders completed. ________

2. Work orders accepted for retrofitting. ________

3. How many heating systems were not retrofitted because:
   a. life expectancy was too short; ________
   b. major repairs are required; ________
      average cost repairs $ ________
   c. replacement is recommended; ________
      average cost replacement $ ________
   d. steady-state efficiency was too high ________
      average rating ________ %

4. Total retrofits verified: ________
   a. TYPE I ________
   b. TYPE II ________
   c. TYPE III ________
   d. TYPE IV ________

5. Total payments made to installers. ________

COMMENTS

____

____

____

____

____

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