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Impact Evaluation of Louisville Gas & Electric Company's Energy Partners Program

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Executive Summary

Energy Partners is a weatherization program designed to reduce the energy consumption of Louisville Gas and Electric Company's low income and payment-troubled customers. The program began in 1994 with a target of treating 1500 high use households over the life of a three year pilot effort. The main goals of the program include saving 15-20% of the participants' energy usage; reducing bills and therefore service disconnections, arrearage levels, and collection actions; and improving the health, safety, comfort, and quality of life of the participants. The main program treatments include air sealing, attic insulation, heating system safety repairs, and energy education. Proctor Engineering Group (PEG) was hired by the LG&E Collaborative to perform an impact evaluation of the program. This report describes the methods employed in the evaluation and the findings including: estimates of the gas and electricity savings achieved by the program; descriptions of the participants, housing stock, and treatments; and an assessment of some of the non-energy benefits. Cost-effectiveness analyses are also provided from a number of perspectives.

Data Collection

As part of the evaluation, PEG had to create a program tracking system from a combination of various existing electronic data sources and from manual data entry on more than 1300 case files. Some of the difficulties encountered while performing this task are described in the report. PEG acquired historical monthly gas and electric usage data from LG&E billing records. Data on arrearages could not be obtained, but some information was obtained on collection problems and service disconnections.

Analysis Methods

Gas savings were evaluated using a standard pre/post comparison of weather-normalized energy consumption based on billing data. The participant group for this analysis included all participants treated by the end of 1995. A comparison group was created from later participants. Net savings were calculated as the average change in the participants' weather-normalized usage minus the average change in the comparison group's weather-normalized usage (which was very small). Electricity savings were evaluated in a similar manner, but difficulties in weather-normalizing the cooling loads led PEG to pursue an alternative statistical approach (a pooled time-series cross-sectional regression analysis). The results from the two methods were comparable, but the alternative approach provided several advantages and was used as the primary source of electricity savings estimates. The program's impacts on payment problems and service disconnections were assessed using a standardized rate approach which compares the observed frequencies for the treated and treated houses each month, controlling for month-specific effects.

Findings

The gas and electric usage and savings analysis found that participants in Energy Partners saved an average of 186 ccf of gas and 783 kWh of electricity annually due to program treatments. The gas savings equal about 12% of total usage and 16% of heating usage. The electricity savings equal about 8% of a very high total annual usage level of more than 11,000 kWh. These energy savings are worth about $128 in bill reductions at current rates, or about $61 in marginal costs for LG&E. Savings from individual measures were difficult to estimate due to certain aspects of the program design and field data collection problems. However, it appears that insulation saved as much as expected while air sealing may not have performed as well, particularly for houses which received a very large amount of air sealing work. Participant education was likely responsible for some of the electricity savings, but no evidence was found to indicate that heating season thermostat settings were affected.

The frequency of service disconnections dropped by 22% after treatment as did the frequency of "brown" bills (termination notices). These reductions are equivalent to avoiding approximately 76 disconnections and 980 brown bills annually per 1000 participants. The frequencies of late and missed payments also declined. Changes in arrearage levels could not be quantified due to a lack of data. Numerous gas leaks and safety hazards were identified and repaired through the program with approximately three quarters of all participants receiving safety-related repairs to their heating or water heating equipment. A number of other potential non-energy benefits in areas ranging from participant health and housing affordability to economic and environmental benefits were also identified, but mostly remained unquantified.

Cost-Effectiveness

Program costs averaged $1062 per house for direct weatherization treatments, including $122 for heater safety repairs. Overall pilot costs averaged about $1600 per house when including all start-up and evaluation costs. The cost for a continuing version of Energy Partners is estimated at $1355 per unit including some on-going training and evaluation costs. The present value of the energy savings is $1434 when these savings are valued from the participants' perspective, making Energy Partners cost effective as a continuing program. LG&E's low avoided costs make the net present value of energy savings worth just $691 on an avoided cost basis. From this perspective, Energy Partners is not currently cost effective unless non-energy benefits are valued at more than $600 per participant.

Comparison to Goals

In comparison to the program goals, Energy Partners fell a little short on overall percent energy savings, but did have significant impacts on participants' bills and service disconnections, and identified and repaired many health and safety problems. Relative to other low income weatherization programs, Energy Partners compares favorably by providing more savings per dollar invested than many other programs including the national WAP study (WAP cost more and saved slightly less than Energy Partners). The high gas and electric usage levels of Energy Partners' participants contributed to the fairly high ccf and kWh savings, but also played a role in the relatively modest percent savings.

Recommendations

Overall, Energy Partners has provided a sound foundation for assessing future low-income weatherization efforts. Although PEG is hesitant to make specific recommendations without direct in-field observation of the program housing stock and treatments, the evaluation results and PEG's experience point to several issues which may be worth exploring.

The targeting of high gas use households is a key element in helping Energy Partners achieve a fairly high level of savings per dollar invested. This targeting could be refined. Among program participants, the 24% of households who used more than 1800 ccf/yr before treatment saved nearly twice the average while the 27% who used less than 1200 ccf/yr saved only about half the average. It appears that cost-effectiveness could be improved by devoting a smaller fraction of program resources to low-use households. In addition, measures such as dense-pack wall insulation and targeted heating system replacements should be explored for their potential to cost-effectively increase savings among high gas use households.

Electricity savings may also provide opportunities for improved cost-effectiveness, particularly if savings are valued from the participants' perspective. Targeted cooling system efficiency upgrades (through advanced tune-ups of central systems or replacements of older window units) and refrigerator replacements can reduce bills considerably, but may not be cost effective on an avoided cost basis unless targeted narrowly. Enhanced energy education focusing on more efficient or reduced use of air conditioning, space heaters, and large appliances such as freezers may be particularly worthwhile given the high electric usage levels found.

1.0 Introduction

Energy Partners is a weatherization program designed to reduce the energy consumption of Louisville Gas and Electric Company's low income and payment-troubled customers. The program was designed by the Louisville Gas and Electric Collaborative -- a group of stakeholders including LG&E, low-income advocates and service providers, and government and business representatives. The program design called for weatherizing approximately 1500 households over the three year period from 1994 through 1996 with a budget of $3 million. The program was targeted to LG&E customers with incomes below 125% of the federal poverty level and high gas and/or electric usage. The main program treatments included attic insulation, blower-door guided air sealing, heating system safety tests and repairs, duct sealing, in-home energy education, and compact fluorescent light bulbs.

Energy Partners has been operated by Project Warm, a local non-profit agency. LG&E staff and a management panel of the Collaborative have overseen the implementation of the program. The program began operation in the Spring of 1994 and has performed work on approximately 1100 houses as of the end of June 1996. Prior formal evaluation efforts have focused on the "process" evaluation issues concerning the start up and implementation of the program[1]. In order to quantify the impacts of Energy Partners, assess its performance, and provide the Collaborative and regulators with information needed to plan potential future efforts, the Collaborative issued a Request For Proposals for Impact Evaluation services in May, 1996. Proctor Engineering Group (PEG) was selected and awarded a contract in July. This report describes the approach and findings of the impact evaluation.

1.1 Program Goals and Impact Evaluation Objectives

The RFP issued by the Collaborative identified 4 general goals of Energy Partners:

1. achieve overall energy reduction of 15-20%
2. save money for low income households and improve their quality of life
3. reduce utility shut offs and arrearages
4. make participation in DSM possible for low income customers

[1] see Early Process Evaluation of the Energy Partners Low Income Weatherization Program, M. Sherman of EDS Management Consulting Services, April 25, 1995 ; and Early Process Review Update of the Energy Partners Program, M. Sherman of Sherman Energy Associates, May 17, 1996.

The RFP also identified as an implied goal to "Make the program cost effective." The Collaborative had also previously produced a list of program objectives and weights for assessing Energy Partners. These objectives and specific areas of interest were:

- Energy usage reduction (weight=50%): overall goal to surpass national WAP performance, targets of 40% gas heating usage reduction and 9% overall electricity usage reduction;
- Quality of Life improvement (weight=20%): address health and safety concerns (weight=10%), reduce the number of shutoffs (7%), and improve community relations (3%);
- Program Administration (weight=20%): maintain strict cost control (5%), test the management panel process (5%), and maximize the percentage of the program budget spent on the homes (10%); and,
- Program Design (weight=10%): identify factors/measures that drive cost-effectiveness (4%), learn the balance between spending more on each home vs. treating more homes (4%), and evaluate the cost-effectiveness of sidewall insulation (2%).

PEG developed a set of 16 research questions for this impact evaluation based on a combination of these identified goals and objectives, a list of questions included within the RFP, interviews with individual Collaborative members, and discussions at the evaluation kick-off meeting. These questions are:

1. What are the overall gas and electricity savings achieved by the program in terms of energy units and dollar reductions in bills?
2. What is the distribution of savings across households?
3. What are the demographic and housing characteristics of the participants?
4. What building or demographic characteristics, treatments, or usage levels are identified with high or low savings levels?
5. What are the savings for each major type of measure?
6. What is the impact of energy education on behavior?
7. How do savings differ for households treated by both WAP and Energy Partners vs. Energy Partners only?
8. Has the program affected household mobility?
9. What are the health and safety impacts of the program?

10. What is the impact of the program on shut offs, brown bills, and arrearages?
11. How many Energy Partners participants also participated in other LG&E DSM programs?
12. How much did the program cost? How much of the program costs went into treating houses? How much of these costs were for energy saving measures vs. health and safety? How much of the total program costs were associated with start-up and the pilot nature of the project? What level of costs could be expected for an on-going version of this program?
13. What are the benefits of the program? What is the value of the gas and electric savings to the participants? To LG&E? What are the cost savings and other benefits from reduced shut offs, brown bills, and arrearage levels? What are the benefits from health and safety work? What other benefits occur and how can they be quantified?
14. Is the program cost effective? How cost effective is the program from multiple perspectives (participant, utility, ratepayers, etc.)?
15. How do the costs and impacts of Energy Partners compare to other low income weatherization efforts such as the national Weatherization Assistance Program and weatherization efforts of other utilities?
16. How could the program be made more cost-effective? Should the program add or remove any measures? Should the program be targeted to a more specific group of households? Should resources be allocated differently among households?

The impact evaluation was able to address nearly all of the identified research questions. However, a lack of data on arrearages, the absence of a program tracking system, often incomplete hard-copy records, and certain program design issues have left some questions unanswered. Nevertheless, the overall goal of assessing program impacts has not been materially affected by these difficulties.

2.0 Program Description

Energy Partners was designed to reduce gas and electricity usage in the homes of high-use low-income customers of Louisville Gas and Electric Company. The program was developed in response to the high energy cost burdens faced by many LG&E low income customers, the low likelihood that these customers would participate in other LG&E DSM efforts, and the inadequate funding levels of the local Weatherization Assistance Program to serve this population. The program design, developed by the LG&E Collaborative, included measures to reduce space heating and water heating usage of the predominantly gas heated target population while also reducing baseload electricity consumption. The program has been operated by Project Warm, a local non-profit agency. Program operations began in the Spring of 1994 and are scheduled to complete work on all 1500 houses in the pilot by the end of 1996. From program inception through March of 1995, LG&E paid Project Warm on a reimbursement basis which required an extremely detailed and complex invoicing process. A unit pricing approach for each major aspect of the work was instituted starting in April 1995. A total of 1082 customers had participated in the program through the end of June, 1996. All specified program treatments had been completed on 942 of these customers (referred to as a "Q" final by program implementors).

2.1 Population Served

The target population of the program has been LG&E customers whose income is below 125% of the Federal poverty level and have either gas usage greater than 1200 ccf/year, electricity usage greater than 7000 kWh/year, or an equalized monthly payment plan amount of more than $100 per month. The program is open to both renters and owners. The total size of the target population is not known, but has been estimated at 10,000 households (see reference in footnote 1). Census figures from 1990 show 25,000 households in Louisville (and 37,000 total in Jefferson county) below 100% of the poverty level.

Sources for program participants have included LG&E-supplied customer lists of potential leads, referrals from the local WAP agency, a pool of participants from a special pilot payment program (ASAP) which ended in 1994, LIHEAP lists, WinterHelp lists, Project Warm energy management workshops, and referrals from other community-based organizations. The process evaluations of the program noted that not all participants met the high usage thresholds established in the program design.

PEG developed descriptive data on the participants actually served by the program through early July, 1996 as part of this evaluation. Table 1 summarizes a number of characteristics of the population served.

TABLE 1. ENERGY PARTNERS PARTICIPANT CHARACTERISTICS	
Characteristic	**Average or %**
Number of occupants	3.0
Households with seniors	34%
Households with handicapped	29%
Renters	16%
Female-headed household	80%
Household Annual Income	$9312
Average % of poverty level	78%
LG&E Annual Bill (1995 rates)	$1374
Energy Burden (% of income)	18.5%

The participant group is quite similar to many other low income weatherization programs. About 80% of participant households are female-headed and half are seniors and/or have household members with handicaps. Energy Partners participants devote a high percentage of their income to cover electric and gas bills. It is worth noting that the electric portion of the bill is nearly half of the average annual cost ($670/yr., 49% of the total), even though 99% of participants have gas heat. As a point of comparison, national data indicate that households with incomes below 100% of the poverty level spend an average of 16% of their income on energy bills, 2.5 percentage points less than Energy Partners households even though LG&E rates are considerably lower than national averages.

The table also shows that only 16% of the participants are renters. This finding may point to the need to consider ways for increasing participation among this segment of the population, particularly because they are not served by the local WAP agency due to program restrictions (According to Project Warm, much higher renter participation rates have been achieved recently by targeting landlords of Section 8 properties).

Housing and appliance holding characteristics, where available, were also tabulated for the participant population. Figure 1 shows the distribution of house construction styles for participants. Three quarters of all houses treated were either shotgun, cape, or ranch construction. Housing types were fairly uniform within neighborhoods and therefore the relative frequencies in the figure are most

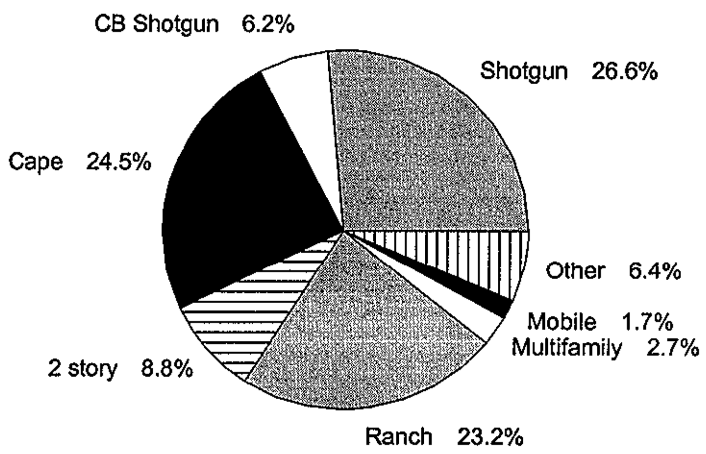

Figure 1. Participant Housing Types

representative of the geographic distribution of the participants. The shotgun houses were rated to be in the worst condition according to the program field auditors.

Table 2 summarizes other housing characteristics and appliance holding information. The average house was fairly small with 1344 square feet of living space. Shotgun houses were the smallest at just 1105 square feet on average. The electric appliance saturation rates appear quite high for a gas-heated low-income population and most likely reflect the targeting of the program to households with high electric usage. These saturation rates were undoubtedly increased further from one of the program marketing lists used by Project Warm which identified low income customers with extremely high annual electric usage levels of more than 14,000 kWh.

TABLE 2. ENERGY PARTNERS HOUSING CHARACTERISTICS AND APPLIANCES

Characteristic	Average or %
Years of current occupancy -median	9
Total Living Area (sq. ft.)	1344
Electric central heat	0.6%
Electric hot water	1.7%
Central Air Conditioning	35%
Window Air Conditioners	57%
No air conditioning	11%
Electric Space Heaters	21%
Electric Dryer	45%
Electric Stove	24%
Freezer	47%
2nd refrigerator	11%
Water bed(s)	14%

The large proportion of houses with central air conditioning (35%) is particularly surprising for a low-income program because the low-income housing stock is typically older and less likely to have this amenity. PEG examined saturation rates by house construction style and found that central air conditioner are much more common in ranch houses (55%) and much less common in shotgun houses (18%) than this average value.

Other major electric end uses identified include freezers and electric dryers present in nearly half of all houses and the fairly common use of electric space heaters. Electric stoves were also found in greater frequency than expected.

2.2 Program Treatments

The Energy Partners program includes a wide array of treatments designed to reduce gas and electric consumption. The program was delivered by Project Warm and typically involved six steps:

1. initial home energy audit and heating equipment inspection;
2. heating system safety-related repair work and re-inspection;
3. blower-door guided air sealing, duct sealing, and home repairs;

4. attic and/or crawlspace insulation;
5. in-home energy education and installation of miscellaneous measures; and,
6. a final inspection.

The energy audit was designed to collect basic information about the house and assess the opportunities for air sealing, attic and crawlspace insulation, duct sealing, home repairs, and the installation of some other miscellaneous measures. The audit included a blower door test, a combustion equipment safety inspection, and a general home safety inspection. The combustion equipment safety inspection checked for the proper operation of the heater and water heater and their safety devices and controls; checked the integrity and design of venting systems; looked for cracked heat exchangers; and measured for carbon monoxide production. Gas ranges were also tested for carbon monoxide.

If combustion equipment safety problems were found and they could be fixed for $350 or less, then a heating system contractor was hired to perform the work. Project Warm personnel then re-inspected the equipment before any further weatherization occurred at the house. If repair costs were too great, then the customer was usually referred to the local WAP program, the landlord, or other resources for making the repairs. Combustion equipment repairs were performed in approximately 73% of all houses which completed treatments at an average cost of $181. In about 8% of the heater repair cases, budget caps were extended above $350. Much of the repair work involved fixing gas leaks, problems with venting systems, and faulty safety controls. This work was not performed to improve equipment efficiency and save energy, but to enhance the health and safety of program participants and avoid exacerbating existing problems with weatherization work. In fact, some of the work may slightly reduce overall system efficiency by properly venting hot combustion gasses out of the home.

The blower-door guided air sealing, duct sealing and home repair work was usually performed by a 3 person Project Warm crew. The work focused on eliminating attic bypass and ensuring the integrity of the building envelope and distribution system. If estimated home repair costs were excessive, the customer was referred to other local resources for accomplishing the work (excessive was redefined over time). The work typically required a full day, although in some cases two, three, or more crew-days of time were spent to complete the work. In order to meet production goals, air sealing work was sometimes contracted out (approx. 15% of cases). Air sealing was performed in 94% of all completed homes and required an average of 23.2 person-hours of work when performed by Project Warm crews. The average pre-treatment leakage rate was 4989 cfm50 for the 75% of the homes where it was recorded. This high level of leakage is estimated to be responsible for about 350 ccf/yr. of gas heating usage based on standard infiltration algorithms. Leakage reductions averaged 31% of pre-treatment leakage (equal to 1679 cfm50) for the one third of all homes where reduction information was recorded. The total cost of this work averaged $450/house (which was the average cost prior to April 1995 and was thereafter established as a unit price reimbursement rate).

If attic or crawlspace insulation upgrades were needed and feasible, Project Warm specified the work, issued work orders for attic insulation to local contractors, and then inspected the work. Attics were generally brought up to R-30 and crawlspaces to R-19 (with vapor barriers installed). Approximately 80% of all completed jobs included insulation work and about 35% had no existing attic insulation. Only about 1% of all jobs included crawlspace insulation. The average cost of insulation work was $463, with $81 of this cost going to adding attic ventilation.

Energy Education was provided to nearly all program participants (97%) using an in-home visit. The original program design had this visit coincide with the energy audit, but competition for the participant's attention led to a separate visit approach. In addition to educating participants about ways to save energy and developing an "action plan" with them, the educator would also install compact fluorescent light bulbs in high use fixtures, low flow showerheads if needed and acceptable, and provide mattress covers for electrically-heated water beds. The educator also collected data about appliance holdings and provided some subjective ratings about participant behavior and responsiveness. The average in-home visit took three hours for one Project Warm educator. Compact fluorescent bulbs were installed in virtually every home with an average of 2.5 bulbs per home. Mattress pad covers were installed in about 50 houses; half of all houses with water beds. In addition to the measures described above, a few miscellaneous measures were installed in a small percentage of homes including setback thermostats.

After all work was completed on a home, Project Warm made a final inspection and either specified corrections which were needed or declared the job complete. In some cases, not all specified work could be completed because the customer moved, died, did not want further work, or other logistical problems prevented the work from being finished. Because these jobs involved expending program resources, they are still included within this evaluation, although the fully completed jobs (referred to as Q finals) are examined separately in some analyses.

2.3 Production

Energy Partners started in the Spring of 1994 and, like most new weatherization programs, began slowly. A gradual ramp-up of program operations is often desirable in order to make early adjustments and corrections to the program design, specifications, paperwork and logistics. Fewer than 100 jobs were fully completed (Q finals) by the end of 1994. Production increased significantly by early 1995 and a total of 580 jobs were completed by the end of that year. Production in 1996 is at an even greater pace with an average of more than 60 completions per month. A total of 942 jobs were fully completed and classified as Q finals through the end of June, 1996. The monthly production rate is shown in Figure 2 (the completion rates shown in figure may lag slightly the rates reported elsewhere due to PEG counting a job as complete at the date of last contact, even if after the final inspection).

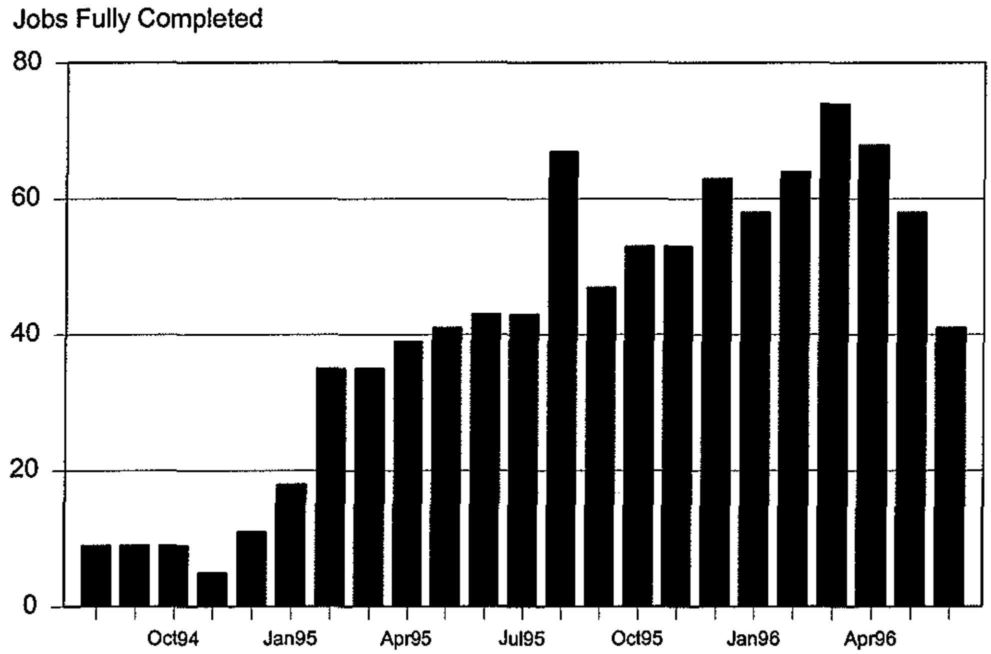

Figure 2. Monthly Production of Energy Partners (fully completed jobs - "Q" finals)

An additional 140 participants have been involved in the program, but treatments could not be completed on 56 houses due to logistic problems and were not performed on 84 houses due to program restrictions (too much heating system repair or home repair work required for program budget). Most of these cases received an energy audit and energy education, about 30% received heating system repairs, 20% received air sealing, and 10% received insulation.

3.0 Evaluation Approach

The basic impact evaluation approach for assessing energy savings involved a classic pre/post treatment/comparison group design. This evaluation approach examines changes between the pre- and post-treatment periods for a group of participants and compares these changes with a group of similar non-participants. The purpose of the comparison group is to reflect what would have happened to participants if they hadn't participated. The impacts of the program are estimated as the net difference in savings between the two groups.

Because of the on-going nature of the program and the need for post-treatment winter weather to assess heating energy impacts, PEG defined the treatment group as participants with all treatments completed prior to 1996. The comparison group was formed from the 1996 group of participants with pseudo-treatment dates assigned as a year before actual treatment. Energy usage data were first analyzed and adjusted to a long-term average weather year using the industry-standard Princeton Scorekeeping Method (PRISM).

The impact evaluation involved four primary tasks for estimating the main program impacts:

1. Data collection and cleaning to develop a database of information on program participants, treatments, energy usage, and payment behavior, and other information needed for the evaluation;
2. Sample characterization and selection to define analysis groups and time periods and establish that the samples are representative of the population served;
3. First stage data analysis to develop reliable estimates of overall gross and net program impacts through PRISM analysis and other statistical summaries of the data; and,
4. Second stage data analysis to examine factors associated with high or low impacts and estimate impacts for key groups defined by program measures, housing characteristics, or demographic factors.

The energy savings and bill payment impact estimates, combined with information on program costs, provide the foundation for assessing the success and cost-effectiveness of the program. However, in addition to these direct impacts, low income weatherization programs may provide a number of other benefits to participants, ratepayers, the utility company, and/or society at large. The Collaborative expressed interest in providing as complete a picture as possible of the program's impacts and cost-effectiveness. Therefore, the results of the primary impact analysis needed to be supplemented with information on other impacts in order to provide multiple perspectives on the relative success and cost-effectiveness of Energy Partners. Two additional tasks related to providing this assessment were also included within the scope of work and are described in greater detail in section 5:

5. An assessment of other potential program impacts such as service disconnections, health and safety effects, and other non-energy benefits;
6. Cost effectiveness analysis including a variety of economic tests to assess the relative costs and benefits of the program from multiple perspectives.

The basic steps in the evaluation process are described below.

3.1 Data Collection

Evaluating the impacts of Energy Partners required collecting data on participants and their houses, program treatments, monthly gas and electricity usage and payment-related data, weather data, program cost information, program procedures and policies, and LG&E rates and avoided costs. This task was the most time consuming aspect of the evaluation.

3.1.1 Program Tracking System

The Energy Partners program had no program tracking system database to provide the basis for the impact evaluation. Most weatherization programs the size of Energy Partners have a relational database system which contains information on the participants, their houses, program treatments, costs, etc.. This unified repository of information typically serves a valuable role in tracking the progress of the program, serving the customers efficiently, maintaining certain financial information, and providing a basis for developing a program impact evaluation. The prior process evaluations strongly recommended developing such a system, but it was not put in place prior to this evaluation. Instead, ad-hoc databases and spreadsheets on multiple computers and covering various and sometimes overlapping information had been put together by Project Warm to help them manage the program. LG&E also had developed an internal job cost-tracking system.

The lack of a tracking system created the first major task of the impact evaluation. PEG developed a tracking system for the program based upon a combination of existing electronic data sources and hard copy case files. PEG utilized Project Warm staff to copy all relevant paperwork from all program case files and ship it to PEG's Boston office. PEG developed a database structure and data entry application and then populated the database with existing electronic information developed from a variety of sources. A team of data entry personnel then manually entered and/or corrected all of the needed data from the 1335 hard copy case files records into the database.

The quality and accuracy of the final program database developed from this process is somewhat less than desired because the data sources occasionally contained conflicting information, typographical errors, and/or had missing data. However, extensive data cleaning resolved many of the problems and the vast majority (95+%) of the data on key variables such as treatments performed, job costs, and dates are believed to be accurate. In contrast, the data quality for many secondary variables of interest such as household income and demographic factors is much worse. Some variables, such as number of children in the household, could not be used at all because the spaces on the forms were often left blank. Other variables, such as household income, were available and reasonable in only about half the cases (income was not recorded or verified if LIHEAP eligibility was shown). These data quality problems limited the scope of the impact analysis and restricted many of the analyses to only the proportion of cases where the information was believed to be reliable.

The final tracking system contained data on 1455 total participants/ work orders through the first week of July, 1996 -- 1103 had a status of final (947 were Q final) and the remaining 352 were either in progress, on hold, of unknown status, or were "orphan" workorders with data from only one source and no corroborating information (likely not to represent an actual additional job, but caused by an error in entering the work order number into one of the original spreadsheets or databases).

3.1.2 Energy Usage and Payment Data

PEG prepared a request for usage and payment data on all 1390 customers in the tracking system which had names and addresses recorded (the remaining 65 records were either orphan workorders or duplicates). LG&E account numbers were included in the request for the 1362 cases where available. LG&E was able to find matches for 1387 customers, a remarkably high success rate.

LG&E provided PEG with monthly gas and electric usage data from early 1993 though mid-July of 1996. PEG carefully cleaned this data to create as complete and accurate usage histories as possible for all customers. This task involved properly combining estimated readings into the following actual usage periods, identifying service interruptions, and flagging meter reading problems or errors (LG&E uses 129 different meter reading codes).

In addition to usage data, LG&E was able to provide payment and shut-off codes for the previous 12 bills. Unfortunately, detailed information on billed amounts, payments, and arrearage levels were not available. In addition, the shut-off and payment code data were limited in detail and covered a short and ill-defined time period. However, the impact of the program on payment behavior and shut offs could still be assessed by using a combination of these payment codes and an analysis of the special meter reading code signifying shut off due to lack of payment which was contained in the usage data. Service terminations often involved shutting off only the electricity and therefore required combining the gas and electric meter reading code profiles to properly identify terminations. Meter reading codes were also used to assess customer mobility by noting "New Party" read codes.

3.1.3 Other Data

Additional data needed for the evaluation included weather data, LG&E rate and avoided cost data, program cost information, local WAP program data, and general information concerning program design and operations. LG&E and weather service data were used to develop a database of daily average temperature data for Louisville spanning from the beginning of 1978 through the end of July 1996. This database was used to account for the effects of weather on energy usage and to establish long-term averages to provide weather-normalized savings results. LG&E also provided PEG with detailed program cost information; 20 year projections of avoided costs for gas commodity, gas demand, electricity production, and electricity demand; and discount rates to be used for cost-benefit analysis. Project Warm and LG&E both provided information on the program design and implementation. Because Energy Partners received referrals from and made referrals to the local WAP agency, PEG obtained information on joint participation from the local WAP agency.

3.2 Sample Selection and Characterization

The tracking system database was used to characterize the progress of the program and the composition of the participant population. PEG defined the participant group as all 672 jobs in which work was finished by the end of 1995. This definition provided a compromise between maximizing sample size while maintaining winter usage data in the post-treatment period. Participants completed near the end of 1995 would have only about half a year of post-treatment usage data and so would need to be examined closely for any potential problems caused by the short analysis period. PEG planned to use two alternatives to PRISM analysis if problems were found. The comparison group was selected as all 637 jobs where some or all of the treatments occurred in 1996. Of the total tracking system database of 1455 cases, 1309 were in either the participant or comparison group, 107 jobs had no work in 1996 but were not listed as final, and 39 jobs had no information on dates of treatment (orphan work orders).

The comparison and participant groups should be fairly similar because they all applied for and were qualified for the same program and only differed in the timing of their participation. However, the population served by a program may vary over time due to changes in program rules, marketing and referral mechanisms, or early adopter phenomena. PEG examined available information on both groups to assess their comparability and the potential need for adjustments to avoid biased results. This analysis revealed that the two groups differed in several respects. With respect to the comparison group, the participant group had:

- a greater proportion of homeowners (89% vs. 80%);
- more seniors (38% vs. 29%);
- lower incomes by about 10% ($8867 vs. $9829, 74% vs. 82% of poverty);
- greater participation in the local Weatherization Assistance Program (16% vs. 3%)
- slightly tighter homes (4940 vs. 5086 cfm50), smaller reductions in air leakage (1576 vs. 1954 average cfm50 leakage reduction), yet more time spent on air sealing (23 hours vs. 18.9 hours);
- fewer houses receiving insulation (76% vs. 85% among "Q" finals); and,
- less money invested in program treatments ($1155 vs. $1220 among "Q" finals).

These differences have two primary implications: any comparison group adjustment to net savings needs to be carefully scrutinized, and results may not be generalizable to the impacts of the whole program population -- but instead only to participants prior to 1996. The demographic differences found may affect the impact estimates in either direction or may have little or no net effect on the analysis. These factors need to be explored (i.e., do owners save more than renters?, seniors more than non-seniors? do energy savings relate to income?) and may require an adjustment in the analysis. The differences in WAP participation can be controlled for by analyzing cases separately based on whether they were treated by both programs. The differences in the frequency of insulation work and average air leakage reductions both point toward expecting the participant group to understate overall program savings. These differences between the groups are examined further in section 4.

3.3 Analysis Methods

The primary evaluation issues and research questions concern the energy savings impacts of Energy Partners. PEG employed a two stage analysis approach involving the use of PRISM® to weather normalize usage data and calculate savings by house in the first stage, and further statistical analysis to assess patterns in savings in the second stage. For electric usage data, PEG performed both the PRISM analysis and a pooled time-series cross-sectional analysis to provide alternative estimates of program impacts. The results from the energy usage impact analysis were also used to estimate gas and electric demand impacts.

In addition to the energy savings analysis, PEG assessed the impact of Energy Partners on payment behavior, service disconnections, and customer mobility by calculating the frequencies of these events before and after treatment, adjusting for temporal changes. PEG also tabulated the frequencies of health and safety problems identified and corrected through Energy Partners.

3.3.1 Gas Usage Analysis

PEG utilized the industry-standard Princeton Scorekeeping Method (PRISM®) as the primary tool for analyzing gas usage and savings. PRISM is a software package developed at Princeton University which analyzes monthly energy usage data and daily average temperatures to develop a weather-normalized estimate of annual gas usage based on an iterative non-linear regression technique. PRISM estimates a balance point temperature, baseload usage rate, heating usage rate and, by applying long-term average weather data, a total Normalized Annual Consumption (NAC) for each house in each analysis period (i.e., pre- and post- treatment). PRISM also has a cooling-only model and a combined heating/cooling model. The PRISM output includes statistical indicators of the reliability of the analysis results for each house. Individual house savings are calculated as the difference in NAC between the pre- and post-treatment periods.

The usage data were assigned to treatment periods based on dates of program interventions and job status codes. For the participant group, the pre-period included all data within the 425 days preceding the first program intervention and the post-period included all data within 425 days after the last program intervention. For the comparison group, the pre-period was defined as all data between 820 and 395 days before treatment, and the post-period was all data within the 395 days preceding treatment. Once treatment phases were assigned to cases, the dataset was formatted for PRISM analysis.

A PRISM analysis requires usage data which encompass a range of weather conditions and preferably span approximately one year. In order to maximize sample sizes, PRISM analysis was performed on all cases possible, including a significant number of houses treated in late 1995 with less than a year of post-treatment data. PEG examined the potential for problems from this shortened analysis period by assessing PRISM's statistical output and looking for differences between the savings for these cases compared to cases with a full year of data. If problems were found, then an alternative short-term variation on PRISM would be used.

It is common practice for evaluators to exclude houses with "unreliable" PRISM results from a savings analysis. However, if a significant fraction of cases are deemed unreliable then the remaining sample may not be representative and the results may be biased[2]. PEG employed relatively lenient screening criteria in an effort to maintain a representative sample. The impact of different screening criteria on the conclusions was also assessed.

3.3.2 Electricity Usage Analysis

Although very few participants heated primarily with electricity, Energy Partners could affect electricity usage in several ways:

- reductions in baseload usage from compact fluorescent bulbs and energy education efforts;
- reductions in winter seasonal usage from water bed mattress pads, reduced furnace fan power draw from gas heating savings, and reduced use of electric space heaters; and,
- reductions in summer seasonal usage from reduced cooling loads due to program measures.

In order to quantify these impacts, electricity usage data were analyzed in two ways. The first approach involved assessing usage patterns, classifying cases by their seasonality, and then performing PRISM analysis. The size of winter and summer usage increases were calculated for each house and analysis period by subtracting out a baseload estimate, calculated as the average of the two lowest months' average daily usage. A case was classified as heating if the average usage in the winter was at least 50% and 8 kWh/day higher than the baseload. The same criteria were applied to summer data to classify whether cooling loads were large enough to require weather normalization. PEG then ran the appropriate PRISM model for each case based on these classifications (either heating-only, cooling only, or heating-cooling). For cases classified as having no heating or cooling, usage was normalized to a full year based on the number of days. In addition to the PRISM analysis, PEG also developed a time-series cross-sectional regression analysis of the monthly usage data. This alternative approach was employed due to concerns about the reliability of the PRISM results, particularly given the short post-treatment period for some cases and difficulties in normalizing cooling loads (behavioral factors and humidity can have large effects on cooling usage which may not be adequately captured by PRISM's variable-base cooling degree day approach).

3.3.3 Analysis of Other Impacts

The impact of Energy Partners on payment behavior was also identified as an important evaluation issue. Research questions focused on rates of "brown" bills (termination notices), disconnections for non-

[2] A bias toward lower usage, lower saving houses from applying stringent PRISM screening criteria was documented in *Attrition Bias in Fuel Savings Evaluations of Low-Income Energy Conservation Programs*, M. Blasnik, in proceedings of Energy Program Evaluation: Conservation and Resource Management, Argonne National Laboratory, Chicago, 1989.

payment, and arrearage levels. There are no standard payment behavior analysis methods, but experience has shown that a full 12 months of pre- and post-treatment data is most desirable because of strong seasonal patterns in bill amounts, payments, and disconnection rates caused by weather, availability of fuel assistance, and regulatory or policy mandates. LG&E was only able to supply payment and shut-off code data for the past 12 bills, not for the full analysis periods desired. In addition, historical arrearage level data were not available. Service disconnection data were available over a long timeframe through the meter reading histories. PEG examined several analysis approaches to develop reliable estimates of program impacts. The preferred approach involved calculating rates of brown bill, disconnection and other payment problem occurrences, adjusted for month-specific time period effects, and comparing these rates between the pre- and post-treatment periods. For shorter-term data, the true pre- and post-periods were used instead of using a comparison group and assigning pseudo-treatment dates. This approach maximizes the use of available information and provides the largest samples of both pre- and post-treatment data for analysis. For the longer term disconnection data, the same approach was followed and was supplemented with the full year pre/post comparison group method. The mobility impact of Energy Partners was assessed similarly. The impact of Energy Partners on customer health and safety was assessed by tabulating the frequencies of certain types of safety problems identified.

4.0 Findings

PEG performed the analyses of gas, electricity, payment, and other impacts using the approaches outlined in section 3.

4.1 Gas Savings

LG&E provided gas usage data to PEG on 1387 accounts. PRISM runs were completed on 1151 of these accounts -- 99 accounts were not in the participant or comparison groups and 137 accounts had insufficient data in either the pre- or post-periods for the analysis. A total of 84 cases had PRISM estimates which PEG considered unreliable (a standard error of NAC greater than 20%, r^2 less than 0.6, negative usage components, or a change in usage of more than 67%). The remaining 1067 cases included 557 in the participant group and 510 in the comparison group. Table 3 summarizes the usage and savings for these cases and for two sub-groups of interest: those receiving Energy Partners Only (no local WAP treatment), and those participants which were fully treated (Q finals) and received Energy Partners Only.

TABLE 3. GAS USAGE & SAVINGS RESULTS (ccf/yr.)						
Group	#cases	Pre	Post	Savings (± 90% c.i.)	%Total	%Heat
All Cases (reliable)						
Participants	557	1524	1314	210	13.8%	17.6%
Comparison Group	510	1494	1492	2	0.1%	0.2%
Net Savings - All Cases	**1067**			**208 (±27)**	**13.7%**	**17.4%**
Energy Partners Only (No WAP)						
Participants	457	1514	1325	189	12.5%	16.1%
Comparison Group	499	1496	1493	3	0.2%	0.3%
Net Savings- E.P. only	**956**			**186 (±28)**	**12.3%**	**15.8%**
Energy Partners Only -- Full Treatment (Q final)						
Participants (comparison group same as above)	397	1485	1291	194	13.1%	16.8%
Net Savings - E.P. only, Q final	**896**			**191 (±27)**	**12.9%**	**16.5%**

The figures in the table show that participants in Energy Partners experienced substantial energy savings while the comparison groups usage remained stable. The average annual gas savings of 186 ccf for Energy Partners represents about 16% of heating usage and 12% of total usage, somewhat below the program goal of a 15%-20% energy reduction. However, these savings do meet the program goal of surpassing the national WAP results, which were 173 ccf/year overall and 182 ccf/year for moderate climate states[3]. The pre-treatment usage rates averaged about 50% greater than the average LG&E residential customer's usage of 974 ccf in 1995..

Savings for the 100 houses which received both Energy Partners and WAP averaged 304 ccf equal to 19.4% of total usage. These savings should not be interpreted as the combined savings of the two programs (and are not shown in the table) because of substantial variations in the timing of the programs' treatments. WAP work occurred both before and after Energy Partners and sometimes many months apart. Therefore, this figure is likely to understate the net effect of the two programs working together.

PEG assessed the reliability and precision of the results in table 3 using several approaches. The analysis was repeated using a wide range of data quality screening criteria and the results were quite stable under all scenarios -- net savings varied by no more than 13 ccf from the average with the most and least stringent screening employed. In terms of statistical precision, the net savings results are all fairly precise with about 15% relative uncertainty at 90% confidence. Median savings were also calculated and, as expected, were somewhat lower at 154 ccf/year net, equal to 10.8% of median total usage. Lower median savings are commonly found in weatherization program evaluations because of the skewed distribution of savings -- there tend to be more houses which save a lot than houses whose usage increases substantially. A more detailed array of statistics on the usage and savings levels are provided in Appendix A.

PEG examined the results for potential problems from the short post-treatment period for participants treated near the end of 1995. The savings levels were practically and statistically indistinguishable from earlier participants, just 7 ccf lower. The similarity of the results and the high quality of most PRISM model fits led PEG to conclude that alternative analysis approaches for the short post period were not needed.

Figure 3 shows the distribution of savings as a percentage of total usage for Energy Partners only participants. About a quarter of the participants saved 0-10%, another quarter saved 10-20%, one in six saved 20-30%, one in nine saved more than 30%, while one in five had negative savings (i.e., increased usage after treatment).

[3] Weatherization Works: Final Report of the National Weatherization Evaluation, Marilyn A. Brown, L.G. Berry, and L.F. Kinney, Oak Ridge National Laboratory, September, 1994.

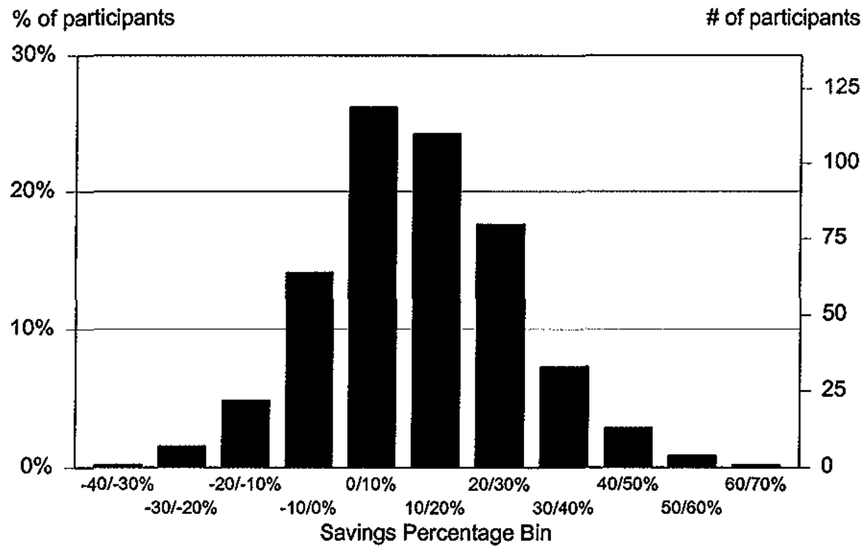

Figure 3. Distribution of Percent Savings - Energy Partners only

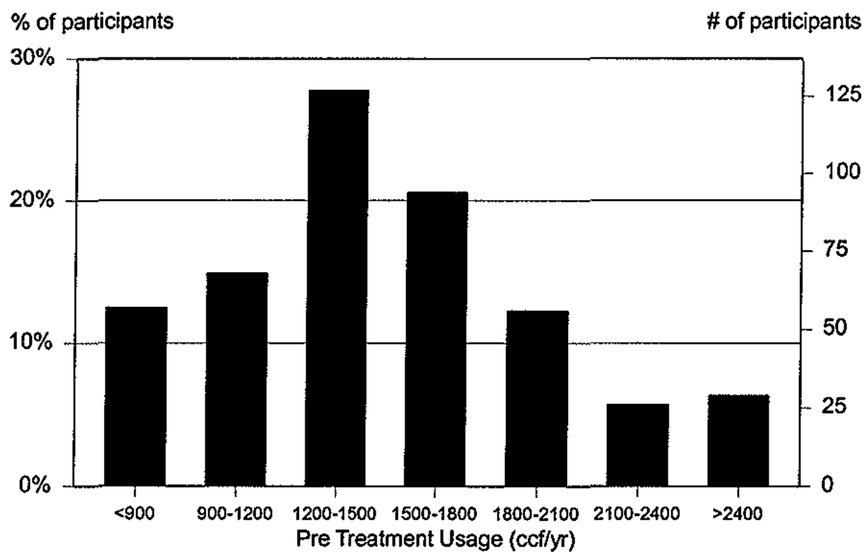

Figure 4. Distribution of Pre-Treatment Usage - Energy Partners Only

Figure 4 shows the distribution of pre-treatment gas usage for the participant group. A significant fraction of cases (27%) have usage levels below 1200 ccf/year. These participants most likely qualified for the program due to high electric usage, although their moderate gas usage limits gas savings opportunities.

The evaluation objectives and research questions include estimating the differences in savings for certain sub-groups of the population based on demographics, housing characteristics, and program treatments. In addition, section 3.2 noted that there are differences between the participant and comparison groups on several demographic and treatment factors which may affect the results. As a first step in addressing these research questions and concerns, PEG calculated average savings levels for a number of key sub-groups within the Energy Partners only participant group. Table 4 provides the results of these group savings calculations along with the percentage of cases with available data which belong to each group and an assessment of whether the observed differences are statistically significant at the 90% confidence level (i.e., is there less than a 1 in 10 probability that the observed differences in the samples would occur due to chance if indeed there were no true differences in the population).

TABLE 4. AVERAGE GAS SAVINGS FOR KEY SUB-GROUPS

		Average Savings		Statistically
Characteristic	% Yes	Yes	No	Significant?
Homeowners	89%	183	212	no
Seniors	37%	175	195	no
Above 75% poverty	45%	198	158	no
4+ occupants	32%	203	186	no
Shotgun House	27%	260	171	yes
Job Cost>$1000	56%	240	126	yes
Insulated Empty Attic	25%	250	167	yes
Air Seal & Insulate	64%	226	124	yes
PreUsage>1800	24%	336	142	yes
PreUsage<1200	27%	98	224	yes

The values in the table show that the program achieved the greatest savings in houses which had high pre-treatment usage (>1800 ccf per year) and also tended to save more in houses which had insulation added to an uninsulated attic, received air sealing and insulation, had large program expenditures, or were shotgun style construction. Savings were low in houses which used less than the program target minimum of 1200 ccf. The fairly large number of low-use houses reduced overall savings. If spending on these houses were much lower than average, then their inclusion may not adversely affect cost-effectiveness. However, spending was only 16% lower in low-use houses than the program average, while spending on the high use high saving houses was only 7% higher than the program average.

The relationship between pre-treatment usage and savings is shown in greater detail in Figures 5 and 6.

Figure 5 shows the expected relationship -- savings are much higher in high-use households and lower in low-use households. This relationship appears fairly strong over the range of usage rates. Figure 6 shows an even stronger relationship by accounting for house size through re-expressing the usage level as an energy intensity rate in Btus per square foot of heated space per heating degree day (the average pre-treatment energy intensity was 38.2 Btu/sq.ft./hdd62). The figures indicate that cost-effectiveness may be

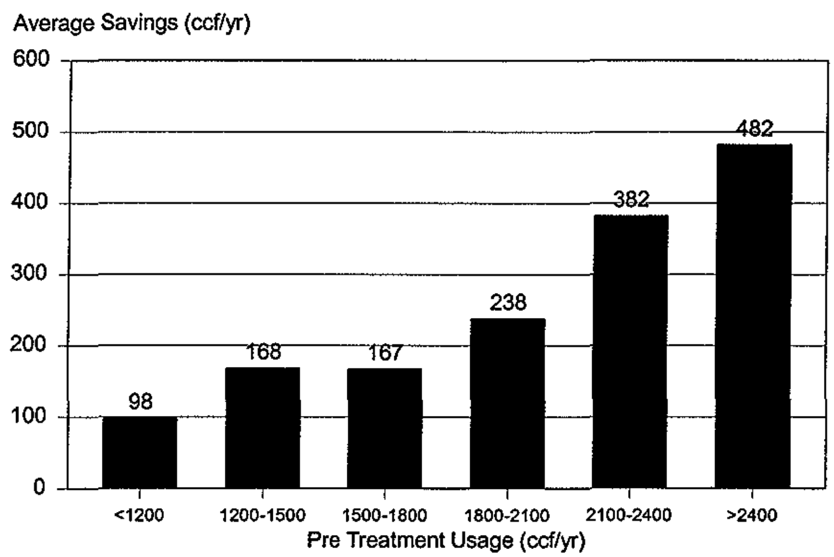

Figure 5. Average Savings by Pre-Treatment Usage Bin

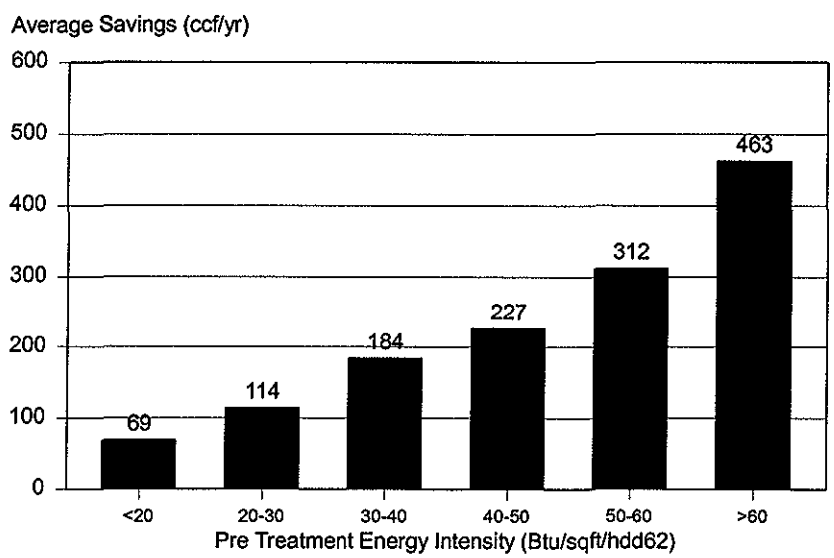

Figure 6. Average Savings by Pre-Treatment Energy Intensity Bin

significantly improved if a smaller proportion of program resources were devoted to low-use households.

In terms of demographic characteristics, none of the savings differences shown in Table 4 are statistically significant. However, the savings levels associated with these categories are of interest because, as noted in section 3.2, the participant sample included a greater proportion of homeowners and seniors and tended to have lower incomes than the overall program population. The results in the table indicate that all three of these differences would be associated with the sample savings being lower than the full program population savings.

The savings comparisons in Table 4 provide useful information concerning program performance. However, regardless of statistical significance, the differences in savings should not be interpreted as indicating cause and effect, but only associations. The observed differences may be due to differences in some true underlying causal factors which vary between the groups. A more sophisticated analysis is needed in order to assess the many influences on energy savings and develop estimates of the impacts of specific measures or factors of interest.

4.1.1 Gas Savings - Further Analysis

PEG examined the relationships between gas savings, usage, treatments, housing characteristics, and demographics using multiple regression analysis and related statistical techniques. Regression analysis is a statistical technique which seeks to "explain" the variations in a variable of interest (e.g., gas savings) based on a set of "explanatory" variables (e.g., treatments performed, prior usage, demographic factors). Regression models attempt to sort out the multiple relationships between factors of interest and estimate the separate impacts of each. The goals in this application included estimating savings from individual measures and identifying characteristics associated with savings.

There are three main program measures expected to affect gas usage: insulation, air sealing, and energy education. Potential savings from safety-related repairs to heating equipment were also identified as an area of interest. In order to estimate the impacts of a program measure, there must be some information about the measure's installation or expected performance which varies significantly between houses. If all participants receive a measure and are expected to save the same amount of energy from the measure, then there is little information available for discerning its impact. PEG sought to develop useful indicators for each major program measure.

Insulation work was performed on about three quarters of the houses. In the simplest approach, the impact of insulation could be estimated by including a variable in the regression model which indicates whether the treatment was performed. A potentially better way to estimate the impact is to develop sitespecific insulation savings estimates based on installed areas and existing and added effective R-values and then use this predicted savings in the regression analysis. PEG used information entered from the hard copy case files to develop such savings estimates. However, the accuracy of these savings calculations depends strongly on the initial r-value, which was not recorded by Project Warm and had to be estimated based on the amount insulation added. In addition, these savings estimates were, by necessity, based on nominal r-values, although the actual field performance of insulation often varies greatly due to installation quality and thermal bypasses. Nevertheless, to the extent that measured savings are related to these predictions, this approach may provide a better estimate of insulation savings than the simple indicator variable approach.

PEG planned to estimate the savings from air sealing using a procedure similar to that used for insulation. Unfortunately, problems with the field data hampered this approach. Although blower-door guided air sealing work was performed in the vast majority of homes, pre- and post-treatment blower door readings which are needed to predict savings were available in fewer than a third of the case files. Air sealing costs could not be used as a proxy because fixed pricing per house started in April of 1995 and so did not vary for most houses treated. The only information widely available about the amount of air sealing performed was a tally of person-hours of air sealing performed by Project Warm crews in each house.

The energy education element of Energy Partners offered little opportunity for analyzing its savings. Education was provided to virtually every household. In addition, no participant-specific information is available to help estimate how education impacts might vary between houses (Project Warm started to collect some subjective ratings by educators, but this information wasn't collected when most of the participant group was treated). Because of these factors, the savings from energy education can not be estimated statistically. If a random group of participants had not been given education, then the savings could be estimated. Some insight into education impacts may be gained by examining changes in PRISM-estimated balance point temperatures as a proxy for changes in thermostat setting behavior. PEG found a 1.2°F decline in the participant groups' average balance point temperature (from 64.3 to 63.1°F) and no change in the comparison group. However, this change in balance point temperature is consistent with improving the efficiency of the building shell by about 15%, without any change in thermostat setting. Therefore, this analysis does not indicate any likely reduction in thermostat setting after treatment.

Health and safety-related heating equipment repairs were performed in 67% of participant group houses. Because the impact of these repairs on energy usage is not expected to be related to the repair cost, PEG used an indicator variable to represent the impact of these repairs.

In addition to variables designed to estimate measure-specific savings, PEG also examined a number of demographic and housing characteristics contained in the program database. For many of the variables of interest, the quality of the available data was lacking due to extensive missing, inconsistent, or questionable information on the forms. These data problems created a situation where the size of the analysis sample varied dramatically depending on which variables were included in the model, limiting the scope of the analysis. Just 65 of the 457 participants in the Energy Partners only analysis sample have complete data on all variables of interest. The results from such small sample models may be unreliable due to both small sample size and potential sample bias (cases with data may differ from those without data). These considerations had a significant impact on the modeling efforts.

PEG developed regression models of gas usage and savings based on data availability, the research questions, engineering and evaluation experience, and theoretical and statistical considerations. The potential factors considered for use in the model included variables representing: insulation (yes/no, predicted savings), air sealing (yes/no, predicted savings, hours spent), heater repairs (yes/no), pre-treatment usage, heated floor area of the house, number of occupants, measure costs, house type, homeownership, senior household, and household income.

PEG examined a large number of models and employed a combination of graphical diagnostics, formal statistical tests, weighted analysis, and robust regression techniques to develop the most reliable insights into program performance. Data quality problems and the typical high level of unexplained variability in savings found in residential weatherization evaluations make firm conclusions difficult and therefore only modeling results which appear statistically reliable and theoretically sound are reported.

The regression analysis revealed that the level of savings was most strongly influenced by the pre-treatment usage rate and the predicted savings from insulation. Insulation savings were close to predicted on average. The 62% of the houses receiving insulation in the regression model (of the 220 treated cases with full data) had average predicted insulation savings of 81 ccf with a per unit cost of $441. The regression analysis indicated that 77 ccf were saved from insulation in these houses on average. A closer examination revealed that the savings predictions were too high by about 20% for previously uninsulated attics and too low by about 37% for attics where there was some existing insulation. Lower than predicted savings in uninsulated attics could be accounted for by a higher effective R-value for an uninsulated attic (R-5 instead of R-4 as was assumed in the prediction). Higher than predicted savings in attics with existing insulation may be due to lower than nominal r-value performance of the existing insulation due to bypasses or poor insulation quality, both of which were addressed by the added insulation combined with air sealing of bypasses. Further analysis indicated that houses which received insulation tended to save more than those that didn't, even after accounting for the predicted savings of the insulation. This finding may represent additional insulation savings beyond those cited above (perhaps due to a problem in the savings prediction method) or could represent savings from other measures which save more in houses receiving insulation (perhaps air sealing).

Air sealing variables were not very strong predictors of savings, particularly blower door leakage reductions which were only available for a small number of treated houses. The analysis did indicate that higher savings are associated with houses which had more person-hours of air sealing work, but only up to a point. Houses which received more than 24 person-hours of air sealing tended to save less than otherwise expected. The 85% of houses in the analysis sample which were air sealed received an average of 22 person-hours of air sealing. The regression analysis estimated the average savings associated with this air sealing effort at 41 ccf/yr. Based on the limited number of houses with blower door readings, the predicted savings were approximately 100 ccf, implying that less than half the expected savings were realized. The regression estimate of air sealing savings has considerable uncertainty and may understate the true savings due to a high correlation between air sealing work, pre-treatment usage levels, and insulation savings. Air sealing hours do not provide a very good indication of air sealing savings and therefore other correlated variables in the model, such as pre-treatment usage, may absorb some of these savings. If air sealing savings were as low as indicated, then slightly more than half of the program savings remain unaccounted for after air sealing and insulation savings. It is highly unlikely that energy education and a few miscellaneous measures can account for these remaining savings, implying that air sealing savings are understated by the regression analysis.

The problem with estimating air sealing savings does not appear to be some fundamental limitation of the blower door readings, but most likely a combination of missing and/or erroneous field data. PEG performed a regression analysis of pre-treatment usage levels and found that pre-treatment blower door reading (which was available for most houses) was the strongest predictor of energy usage, even stronger than house size or type. This finding reinforces the belief that a more reliable and worthwhile analysis of air sealing impacts may have been possible if more blower door readings had been recorded fully and accurately.

Health and safety-related repairs were not associated with any change in usage. This results is consistent with expectations given that most repairs aren't expected to save energy while some may save energy and others may actually increase usage.

Demographic factors such as homeownership, number of occupants, and income levels were generally not significant in the analysis. Several of the differences in savings by sub-group shown in Table 4 completely disappeared or even reversed sign after accounting for pre-treatment usage levels and insulation work. For example, Table 4 shows that homeowners saved less than renters. However, the regression analysis found that these differences are fully accounted for by differences in pre-treatment usage levels and insulation work. Similarly, shotgun houses saved much more than other house types. However, the regression analysis showed that, after accounting for pre-treatment usage level and energy intensity, shotgun houses saved no more than other types of houses. After also accounting for expected insulation savings, shotgun houses actually appear to save somewhat less than other houses. Therefore, the higher savings among shotgun houses were due to the greater opportunity for savings from having high usage and less existing insulation, not from any specific characteristic of the housing type. Only one demographic factor appeared to be related to savings -- senior households tended to save about 20% less energy than others after accounting for pre-treatment usage levels and insulation and air sealing work. The lower savings were not statistically significant, but appeared consistently throughout the analysis.

Overall, the regression analysis of gas savings found that:

- pre-treatment usage levels are the largest determinant of savings;
- savings from insulation were generally consistent with expectations;
- savings from air sealing are unclear but may be lower than expected;
- homes which received a lot of air sealing tended not to get a comparable boost in savings;
- health and safety-related heating equipment repairs did not produce any savings on average;
- most differences in savings associated with demographic or housing type characteristics are due to differences in pre-treatment usage rates and insulation opportunities.

4.2 Electricity Savings

PEG examined and classified electricity usage patterns to identify potential heating and cooling usage as described in section 3.3.2. A total of 1260 accounts in the participant and comparison groups had sufficient data for classifying the pre- and post-treatment periods. For the pre-treatment period, this process identified 62% of the accounts as cooling only, 11% as heating and cooling, 6% as heating only, and the remaining 21% as neither heating nor cooling. The classification method was designed to detect seasonal loads which were large enough that weather normalization may be both needed and reliable. PEG ran the appropriate PRISM models for each of the three groups with seasonal loads. The PRISM results indicated that the balance point temperature estimates often had considerable uncertainty, so the analysis was repeated with constraints placed on the balance point temperature selection (70-80°F for cooling, 50-65°F for heating). In addition to the PRISM runs, usage data for the 21% of the cases without strong seasonal loads were normalized to a full year based on daily average usage if at least 10 months of data were available.

The usage normalization process resulted in a data set with pre- and post-normalized usage estimates for of 1045 of the 1260 cases. A significant fraction of the PRISM models had indications of low reliability, particularly concerning cooling loads. PEG employed the same PRISM model screening criteria to identify potentially unreliable usage/savings estimates as was used for the gas analysis. These screens resulted in removing 239 cases from the analysis. In contrast to the loss of only 8% of the gas sample, this attrition represents 23% of the electric usage sample. This result was not unexpected given the greater influence of behavior on electric cooling loads compared to gas heating loads, but still raises concern about potential bias in the remaining sample. PEG compared the two groups and found that the group which survived the data screens tended to be the more stable households -- more homeowners, more seniors, fewer changes in occupancy, and fewer service disconnections. These same households also tended to have lower pre-treatment gas usage and lower gas savings than the attrition group, implying that electric savings may be under-stated.

An initial analysis of the savings results for the 806 reliable cases found that houses treated in the later part of 1995, with shortened post-treatment periods, had much lower apparent savings than houses with a full year of pre- and post-treatment data. Most of these cases relied on just one actual summer usage period in the post-treatment period (mid-June to mid-July 1996). This problem led PEG to screen out all houses with fewer than 330 days of pre- or post-treatment data from the analysis, eliminating an additional 147 houses from the participant group and 44 houses from the comparison group. Table 5 provides the results of the usage normalization analysis for the remaining reliable cases with summaries of net savings for the Energy Partners only (no WAP) and fully treated (Q final) sub-groups.

TABLE 5. ELECTRICITY USAGE & SAVINGS RESULTS (KWH/yr.) NORMALIZATION APPROACH					
Group	#cases	Pre	Post	Savings (± 90% c.i.)	%Total
All Reliable Cases					
Participants	247	11109	10438	671	6.0%
Comparison Group	368	11389	11583	-194	-1.7%
Net Savings - All Cases	615			865 (±333)	7.7%
Net Savings - E.P. Only	549	11275		758 (±362)	6.7%
Net Savings - E.P. only, Q final	517	10816		758 (±380)	6.9%

The table shows that Energy Partners participants had very high electric usage levels given that nearly every home had gas heat and hot water. A typical usage level for lights, refrigeration, and basic appliances should be about half the usage found. The average pre-treatment cooling load estimate from PRISM was 3318 kWh/yr for the 77% of cases with cooling detected, or 2541 kWh/yr on average for all 615 houses shown. The remaining usage of approximately 3500 kWh/yr. is likely due to the relatively high saturation of major appliances such as freezers, electric dryers, water beds, and electric stoves.

The average electricity savings are fairly large in absolute terms for a program primarily designed to reduce gas heating usage, but are fairly small on a percentage basis due to the high usage rates. The average savings from the 2.5 compact fluorescent bulbs given to each home should be about 300 kWh/yr if they were each used for 6 hours per day. The remaining savings could be due to reduced furnace fan run-time in the winter (which should average about 80 kWh/yr), reduced cooling loads from insulation and air sealing, savings from some other miscellaneous measures, and energy education. While this rough breakout of the sources for the observed savings may seem reasonable, a closer examination of the results revealed a large level of uncertainty in the average savings (about 40-50%), potential sample attrition problems, and some counter-intuitive PRISM results.

4.2.1 Electricity Savings - concerns with PRISM results

The final electric savings participant sample includes only 247 of the 672 cases in the full participant group. Data requirements resulted in this sample having a large proportion of early program participants, which may differ from the overall program population. PEG compared this final sample with the comparison sample, the initial participant sample, and the full program population. While all groups had similar pre-treatment electric usage levels, the final participant sample includes more homeowners and seniors, fewer occupants, lower household incomes, more houses with freezers and electric dryers, and more room air conditioners per house than the program population or the comparison group. Many of these differences were also found when comparing the final and original participant samples. The impact of these differences on the observed savings is unclear but is cause for some concern.

PEG developed additional concerns about the reliability of the electric savings results when examining the cooling component of the savings. The PRISM results indicated that both the comparison and participant groups had 8% cooling savings, yielding no net cooling savings from the program -- a questionable finding given the high cooling loads, fairly large saturation of central air conditioning, and the high frequency of attic insulation treatments.

In an effort to further understand the usage and savings patterns, PEG calculated some summaries of the raw monthly usage and usage changes over time. First, average daily usage rates by month were calculated for the pre- and post-treatment periods for all houses, providing a summary of raw seasonal usage patterns. The pre-treatment usage rates for May 95 through May 96 are shown in Figure 7.

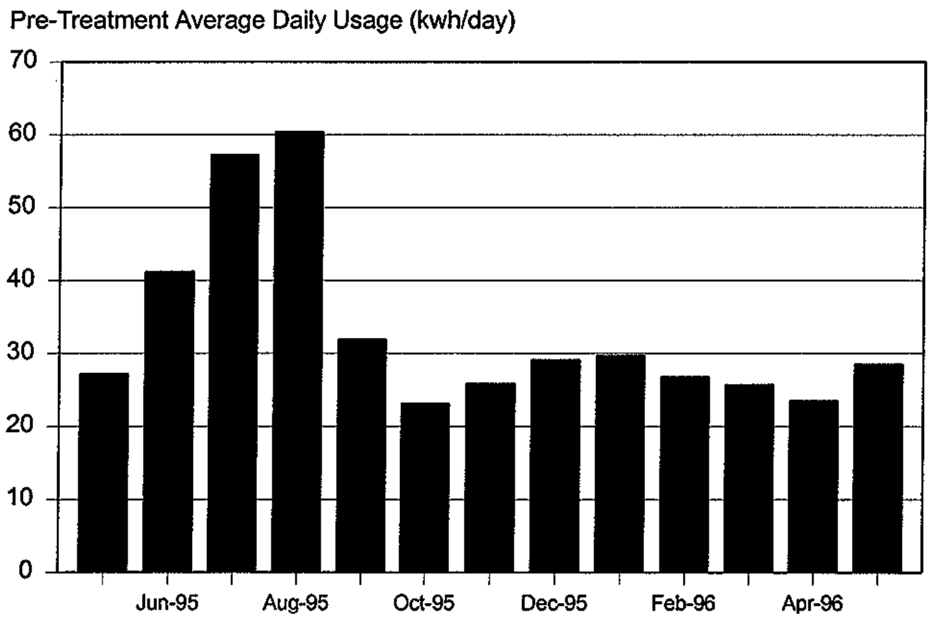

Figure 7. Average Daily Electricity Usage Rates, pre-treatment

The figure shows a very large cooling load, a fairly high baseload usage, and a noticeable increase in usage during the winter. To directly assess savings patterns over the year, PEG calculated the net change in usage for each month compared to the same month one year earlier for each house with data available in both months. These figures were summarized separately for all houses which were treated in the intervening year and all houses which had no treatment during that year (creating moving treatment and comparison groups). The net difference in the average change in usage for each month provides a rough estimate of net savings over the year. Figure 8 shows these raw net savings estimates for the period May 95 though May 96.

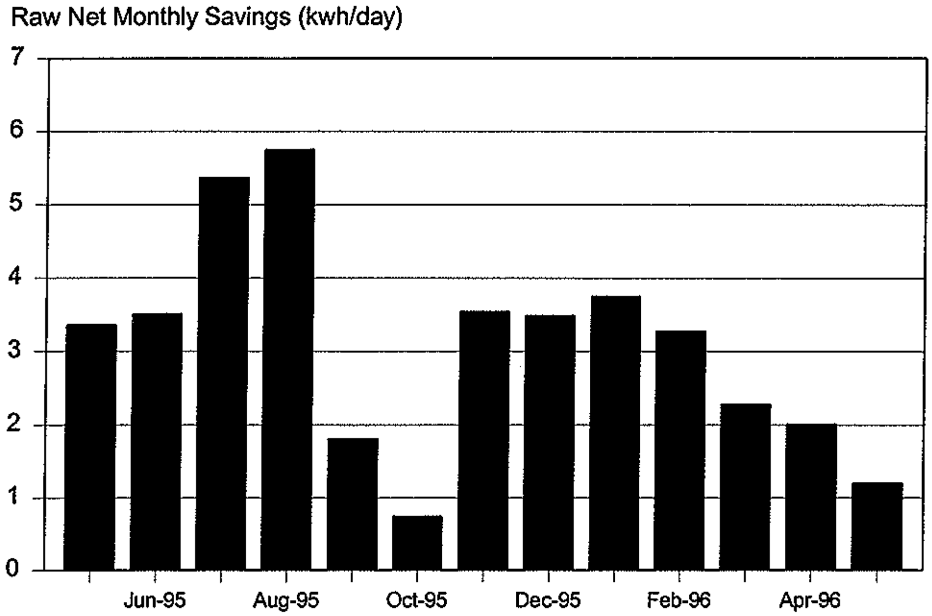

Figure 8. Raw Net Electricity Savings by month

The figure shows that savings are highest in the summer and are lowest during mild months such as October and May. These results differ from the PRISM estimates, indicating that the program produced significant cooling savings.

The simple calculation approach used to generate Figure 8 is best employed for assessing patterns in savings rather than directly estimating overall program savings because of the lack of explicit weather normalization, the shifting group membership over time, and considerable variability in individual monthly net savings figures. Nevertheless, the figure provides further evidence that the PRISM results are suspect. Because the primary PRISM analysis provided anomalous cooling savings, had relatively poor precision, and suffered from large scale sample attrition, PEG developed an alternative electricity savings analysis approach for comparative purposes.

4.2.1 Electricity Savings - Alternative Approach

PEG performed a pooled time-series cross-sectional (TSCS) regression analysis of the monthly electric usage data as an alternative to the standard house-by-house pre/post analysis. Instead of creating artificial pre- and post-treatment periods for 1996 participants to act as a comparison group, the TSCS analysis involved pooling all of the monthly usage data for all participants and estimating a single model which describes usage variations for the group as whole. This approach does not provide estimates of the savings for each house, but instead treats all of the houses as a single large group from which the average impact of different effects such as weather and program participation can be estimated. One of the advantages of the TSCS approach is that the participant group can act as their own control group if treatments occur over the full timeframe.

PEG developed a clean dataset of all electric usage data, calculated heating and cooling degree days for each meter reading period, and brought in data from the tracking system on appliance holdings, demographics, and housing characteristics. PEG then explored a number of different modeling approaches for estimating program impacts. The most reliable model involved performing a fixed-effects TSCS regression analysis of average daily usage as a function of heating degree days per day and cooling degree days per day with treatment effects estimated in three post-treatment variables: one for each degree day variable to capture heating and cooling savings and one indicator variable to capture baseload savings. The analysis sample was restricted to usage periods between 25 and 90 days long that occurred no earlier than 14 months before treatment and only included cases which had data in both the pre- and post-treatment periods. A total of 916 program participants contributed two or more data points to the overall analysis data set of 18,113 meter readings. The model coefficients were converted into weather-normalized annual consumption rates using long-term average weather data. The results of this analysis are shown in Table 6.

TABLE 6. ELECTRICITY USAGE & SAVINGS RESULTS (KWH/yr)
POOLED TIME SERIES CROSS SECTIONAL ANALYSIS

Usage Component	Pre	Post	Savings	%Savings
Cooling	2250	2058	192	8.5%
Heating	786	569	218	27.7%
Baseload	8099	7725	374	4.6%
Total	**11,135**	**10,352**	**783 (±113)**	**7.7%**
n=18,113 cases=916 model R-squared=0.40 (within) =0.21(overall)				

The total usage and savings figures in the table are quite similar to those from the PRISM approach (which showed savings of 865 out of 11,109 kWh/yr.). However, the precision of the TSCS savings estimate is considerably better (±14% instead of 38%). In addition, the TSCS method provides more reasonable estimates of the savings components:

- Instead of zero cooling savings found in the PRISM approach, the TSCS model finds 8.5% savings. This level of savings is reasonable given the 18% heating savings, the importance of solar gain on cooling loads (which is unaffected by program treatments), and the less thermostatically-controlled nature of cooling usage.
- The large relative reduction in the modest heating component is also reasonable given expected savings in furnace fan usage, seasonal savings from water bed covers, and some proportion of participants probably reducing or eliminating the use of electric space heaters after their home is made more comfortable from weatherization.
- The baseload savings level is also reasonable with perhaps half to two thirds of the observed savings coming from the lighting retrofits[4] and the remainder due to education and/or other miscellaneous measures.

PEG believes that the TSCS approach is superior to the normalization method because of the more reasonable component savings estimates, the greater estimated precision, and the larger sample of houses which could be included in the analysis. The similarity in total usage and savings levels for the two methods lends greater confidence to the overall results.

4.3 Payment / Service Disconnections

As described previously, limited data was available for assessing the impact of Energy Partners on payment behavior and service disconnections. There was no data on changes in arrearage levels and therefore the impact of the program on arrearages and associated tangible cost savings in terms of carrying costs and bad debt write-off could not be quantified. Data on late and missed payments and brown bills (termination notices) were available for the 12 most recent bills, preventing a full year pre/post analysis. Service disconnection information was available for a longer timeframe because it was contained within the meter reading histories. A strong seasonal pattern in bill amounts, payment assistance availability, and termination policies made controlling for time of year a key element in the analysis. Potential trends over time due to changes in fuel assistance levels or collection policies also needed to be examined and/or controlled for in the analysis.

[4] A variation on the TSCS model which included number of lights retrofitted provided an estimate of 162 kWh savings per bulb, although this estimate had considerable uncertainty.

PEG calculated the frequencies of brown bills, months with no payment, and months with late payment from the payment and shutoff code data supplied by LG&E (disconnection data were found to be unreliable). Frequencies were calculated separately for the true pre- and post-treatment periods for all cases which had a known final status or were on-going jobs and had the 12 monthly codes spanning the period July/August 1995 through June/July 1996. These criteria provided data on between 950 and 1150 cases each month of the analysis period, with about two thirds of the cases in the pre-treatment phase for the first month reducing down to about 9% of the cases in the pre-treatment phase for the final month. The frequencies were standardized by weighting each month for each group based on the total number of cases with data for the month in order to control for seasonal variations or trends which could bias the results. Table 7 shows the standardized rates for each of these factors of interest and also re-expresses the savings in terms of number of actions/problems avoided per unit per year.

TABLE 7. PAYMENT/COLLECTION PROBLEM IMPACTS
STANDARDIZED MONTHLY RATES FOR 7/95-6/96

Payment/Collection Issue	Pre	Post	Reduction	%Reduction	Reduction #/yr/unit
Brown Bills	36.4%	28.2%	8.2%	22.5%	0.984
Late Payments	20.7%	17.5%	3.2%	15.3%	0.384
No Payments	17.1%	15.8%	1.3%	7.6%	0.156

The table shows improvement for all payment factors after Energy Partners. Overall, Energy Partners led to annual reductions of about 984 brown bills, 384 late payments, and 156 missed payments per 1000 participants. The results appear to be somewhat inconsistent because the reductions in months without payments only declined by about 8% and the frequency of late payments declined by just 15% yet the reduction in brown bills was 22%.

PEG performed two types of analyses using the monthly meter reading codes indicating shut-off for lack of payment. In the first analysis, pre- and post-treatment periods for each participant and comparison group case were classified by whether or not a disconnection occurred. Annualized frequencies were tallied by accounting for the number of days in each period for each case. In the second analysis, the standardized rate approach was used with the full participant population. The analysis period was restricted to a 12 month period where there were a substantial number of pre and post cases in each month. Table 8 shows the results of these two analysis approaches.

TABLE 8. SERVICE DISCONNECTIONS						
Approach	# Cases	Pre	Post	Reduction	%Reduction	Reduction #/yr/unit
Annualized frequencies of disconnections pre/post						
Participants	586	11.9%	12.6%	-0.7%	-5.4%	
Comparison Group	532	11.7%	18.0%	-6.3%	-53.6%	
Net Reduction	1108			5.6%	48.2%	0.056
Monthly standardized disconnection rates 6/95-5/96 (% of months with disconnection)						
Standardized Rate -all	1040±	2.85%	2.22%	0.63%	22.0%	0.076

The figures in the table show extremely high disconnection rates, 5-10 times greater than found thus far in a study PEG is performing in Ohio. The overall disconnection rates and the estimated reductions in rates differ noticeably between the two approaches (rates can be compared by multiplying the monthly rate by 12). The differences in overall disconnection rates is partly due to the pre/post approach counting no more than one disconnection per case per period and the generally higher disconnection rates found in the more recent data which is represented in the standardized rate approach. LG&E sources reported that collection policies have become more aggressive over the course of the analysis period. The comparison group pre/post approach shows a large increase in the frequency of shut-offs for the comparison group and only a slight increase for the participant group, leading to a net comparison-adjusted reduction in shutoffs equal to 48% of the pre-treatment rate or 31% of the post-treatment comparison group rate (this latter figure should more closely follow the findings from the monthly approach). However, the annual pre/post approach does not explicitly control for seasonal fluctuations in disconnections and instead relies on an assumed similarity in the timing of the pre and post periods for the two groups. Unfortunately, the participants treated in the later part of 1995 have post periods which under-represent summer and fall months, potentially creating bias. Because of this concern with the annual pre/post approach, the explicit accounting for monthly effects in the standardized rate approach, the consistency with the brown bill reductions, and the more recent timeframe of this analysis, PEG believes that the standardized rate results showing a 22% reduction in service disconnections after treatment best represents the impact of Energy Partners. This impact can also be expressed, perhaps more intuitively, as avoiding 76 service disconnections per year for every 1000 participants in Energy Partners.

4.4 Other Program Impacts

In addition to gas and electricity savings and improved payment behavior, a program such as Energy Partners may provide other beneficial impacts. Reduced household transience and improved occupant health and safety are two areas in which the Collaborative specifically expressed interest. A wide array of other potential impacts have also been identified as worth considering.

4.4.1 Transience/Mobility Impacts

PEG assessed the impact of Energy Partners on customer transience similarly to the approach taken with payment data. Standardized frequencies of occupancy change as noted by the "New Party" meter reading code were calculated for all participants using true treatment dates over the period of June 1995 through May 1996. The results of this analysis are shown in Table 9.

TABLE 9. CUSTOMER TRANSIENCE
MONTHLY STANDARDIZED OCCUPANCY CHANGE RATES 6/95-5/96

	# Cases	Pre	Post	Reduction	%Reduction
Standardized Rate - all cases	1040±	0.96%	0.91%	0.05%	5.1%

The figures in the table indicate a 5.1% relative reduction in mobility after participation in Energy Partners, equal to avoiding 6 customer moves per year per 1000 participants. This relatively small impact should not be unexpected given that only 16% of participants were renters and that the participating homeowners had a median 13 years of occupancy at the same address. Larger mobility impacts may have occurred if more renters had participated in the program.

4.4.2 Health and Safety Impacts

Health and safety impacts of low income weatherization programs are difficult to assess, but can be quite real. The primary impacts are expected from the safety testing and repair of gas heaters and water heaters. As noted in section 2.2, 73% of all completed houses had safety problems identified and repaired by Energy Partners at an average cost of $181 each. Many low-income houses have old and poorly maintained heating and water heating equipment which may present potential health and safety problems to the occupants ranging from indoor air pollution due to inadequate venting of combustion gasses or cracked heat exchangers, to carbon monoxide poisoning, and fires or explosions from safety malfunctions or gas leaks. PEG tabulated the frequencies of some of the health and safety problems identified based on the inspection forms. The results of this analysis are provided in Table 10.

TABLE 10. SUMMARY OF HEALTH AND SAFETY PROBLEMS FOUND	
Health / Safety Problem	Percentage of Houses
Gas Leak	22.8%
No Draft for heater or water heater	26.2%
High Carbon Monoxide (CO 100-400 ppm)	8.5%
Very High CO (>400 ppm)	7.4%
Very High CO & No Draft on same appliance	1.3%
Other Equipment Safety problems (e.g., safety controls, venting, chimney, heat exchanger)	32.2%
Other housing-related safety problems	43.9%

The table shows very high frequencies for many potentially serious safety problems such as gas leaks and lack of draft in heaters and/or water heaters. High levels of carbon monoxide production were also found in a fairly high percentage of houses. The combination of a heater or water heater which produces high levels of carbon monoxide and also has no draft is one of the most potentially lethal safety problems and was found in 1.3% of the houses (14 out of 1043). The frequencies and types of problems found and addressed suggest that Energy Partners is providing significant health and safety benefits to the participants by reducing the likelihood of illness and/or death from combustion gasses entering the home and by reducing the likelihood of fires or explosions caused by gas leaks and other safety hazards. Although quantifying these benefits is extremely difficult and speculative, they need to be accounted for in some manner when assessing the overall value and cost-effectiveness of the program.

4.4.3 Other Unquantified Program Impacts

Beyond the impacts described and quantified previously, low income weatherization and energy efficiency programs can provide other benefits to the participants, the utility, ratepayers, and society at large. The scope and time constraints on this evaluation limited PEG's ability to identify and quantify some of these other impacts, but policy makers may wish to consider the full range of potential program benefits. PEG reviewed a number of published papers and low-income program evaluations which addressed the topic of non-energy benefits and developed the following list of potential impacts worth considering which could not be quantified in this study:

- reduction in write-off of utility bad debt;
- reduction in carrying cost of utility arrearages;
- lost utility profit margin on sales not made due to service termination;

- preservation and improvement of the low income housing stock;
- potential reduction in homelessness;
- improved comfort for participants and associated health benefits;
- reduction in gas emergency service calls;
- reduced risk of fires precipitated by lack of utility service or caused by unsafe gas heating and water heating equipment;
- reduction in potential utility liability from gas explosions;
- reduced risk of illness or death caused by low income households living without heat or air conditioning, particularly for the most susceptible groups such as seniors, small children, and the handicapped;
- other social benefits from reduced incidence of low income households living without utility service;
- direct job creation, often in low-income neighborhoods;
- indirect economic benefits from program-related local economic activity and reduced imports of fuel into the local economy;
- environmental benefits from reduced emissions at the houses and at power plants;
- community relations benefits for the utility.

This list of potential benefits from Energy Partners is undoubtedly incomplete but captures some of the factors which may otherwise be neglected in the assessment of program value. PEG has attempted to quantify a few of these factors in the cost benefit analysis provided in section 5.

5.0 Cost Effectiveness

The ultimate purpose of an impact evaluation is to assess whether the program was a worthwhile expenditure of resources and to suggest methods for improving its cost-effectiveness. However, standard cost-benefit analysis is inevitably limited by the relative ease of quantifying program costs, but the great difficulty in fully and accurately quantifying all benefits, particularly for low-income programs. To address this difficulty, PEG examined program costs and benefits from a number of perspectives and has refrained from putting forth a single best test of overall cost-effectiveness.

Most low-income weatherization program evaluations have valued energy savings from the participants' perspective, using retail rates. This approach is clearly appropriate for government-sponsored weatherization efforts. For utility-sponsored low-income weatherization, the best approach is not clear. Most DSM program evaluations value energy savings from an avoided cost perspective. Proponents of the avoided cost approach point out that one could consider using the same resources to provide an equivalent amount of free gas or electricity to the low-income participants and therefore energy savings should be valued at their avoided cost to the utility. This perspective is consistent with the DSM Total Resource Cost Test. Proponents of the participant perspective counter that a more accurate alternative use of weatherization funds would be to subsidize the participants' bills by an amount equivalent to the bill savings from weatherization and therefore retail rates should be used in valuing energy benefits. From either perspective, the quantification and monetization of non-energy benefits remains a major hurdle in performing a full accounting of program cost-effectiveness.

In addition to cost-effectiveness analysis, a program can also be assessed in terms of meeting its goals or in comparison to similar programs. In some jurisdictions, low-income programs are not held up to standard DSM cost-effectiveness tests, but are justified primarily on equity grounds since low income customers rarely participate in or benefit from standard DSM programs and many non-energy benefits from low-income programs are considered difficult to quantify.

In the case of Energy Partners, the development of the program was not guided by cost-benefit analysis and no specific measurement standard was put forth when the program was approved by the Collaborative and regulators. However, Collaborative members expressed interest in the results of a cost-benefit analysis as one method for measuring program performance, but perhaps not as the only method. All collaborative members were interested in assessing Energy Partners performance relative to expectations and to other similar low-income programs. Most members also agreed that the participant perspective provides a baseline approach which a worthwhile program should pass. Some members expressed an additional interest in examining cost-effectiveness from a more standard DSM perspective, with savings valued at avoided cost. The quantification and monetization of non-energy benefits was also identified as a key issue which should be explored, but would likely remain unresolved. PEG has assessed costs and benefits from several perspectives in an effort to reflect the varied interests of the Collaborative members and to provide as full a picture of Energy Partners' performance as feasible.

5.1 Program Costs

The costs of the Energy Partners program can be considered to have several components:

- the direct costs of treating the homes;
- the administrative and support costs of the program delivery agency;
- the administrative and support costs incurred internally by LG&E; and,
- program evaluation, training, and other miscellaneous costs.

Costs can be further differentiated within these categories. For example, direct costs can be allocated between energy saving measures and health and safety measures. For a pilot program such as Energy Partners, program start-up costs lead to much higher administrative and support costs than an on-going program would incur. Therefore, to assess the cost-effectiveness of continuing the program, the start-up costs need to be separated from the on-going costs. Certain evaluation and miscellaneous costs may also be considered start-up related. PEG examined program financial records in order to calculate each of these cost components for Energy Partners.

Program start-up costs were estimated by calculating the current (Jan-June 1996) on-going administrative and support costs of the program on a per-unit basis, multiplying this figure by the total number of units treated by the program to date, and then subtracting this product from the actual total program-to-date administrative and support costs. These start-up costs were then allocated on a per unit basis over the full 1500 houses expected to be completed by the program. Since many evaluation costs occur near the end of the program, the full budgeted evaluation costs were allocated over the 1500 houses as well. The resulting unit cost estimates are shown in Table 11.

TABLE 11. ENERGY PARTNERS PROGRAM COSTS AVG. $/UNIT		
Cost Category		$/House
Direct Cost - Energy Measures	911	
Direct Cost - Heater/WH Safety	126	
Total Direct Cost (avg. thru 12/95)		1037
Admin & Support- Project Warm	172	
Admin & Support- LG&E	71	
On-going Admin & Support		243
Allocated Start-up Costs		224
Evaluation (Process & Impact)		100
Total for Pilot		1604
Total for On-Going Program (1062direct+243admin+ 50eval&train)		1355

Average direct program costs per unit are shown for the 456 houses in the participant group who were treated through December 1995, had a final job status (not just Q finals), and were not treated by WAP. These costs are the most appropriate to use for this impact evaluation because they are the jobs which form the basis of the main impact estimate. The average direct costs of all 1090 jobs treated through June of 1996 were $25 per unit higher at $1062.

The on-going administrative and support costs are fairly low for a program of this type, averaging $243 per unit, equal to 23% of direct costs. However, the allocation of start-up and evaluation costs brings the total pilot costs to $1604 per unit. Based on this cost data, PEG estimates that an on-going version of Energy Partners would have a total cost of approximately $1355 per unit including the costs for regular evaluations (modest annual evaluations or larger scope every 2 years) and some training / skills development.

5.2 Program Benefits

Program benefits can be assessed from many perspectives. The primary quantifiable benefits are the gas and electricity savings. These benefits can be valued from the participants' perspective (at retail rates) or from a DSM avoided-cost perspective. LG&E provided PEG with rate schedules and 20 year avoided cost projections for quantifying the present value of benefits from each perspective. PEG examined LG&E's electric and gas rates from 1994 through the end of 1996 and found considerable variations in rates over time due to designed seasonal electric rate variations and large fluctuations in gas cost components. PEG applied the electric rate schedules to actual raw monthly electric usage data to develop average costs for the pre- and post-treatment periods and then calculated an effective marginal rate for the electric savings at 5.47¢/kwh. Gas rates have ranged from 36¢ to 44¢/ccf for the past three winters. However, current rates for the 1997 winter are slightly over 48¢/ccf. Future rates are unknown, but are of the greatest interest because program savings last over many years. PEG used 46¢/ccf as the "current" gas rate for valuing energy savings from the participant perspective.

In calculating the present value of program benefits, the longevity of program impacts must also be estimated and discount rates selected. PEG estimated the longevity of program impacts based on available literature and engineering judgment. For avoided cost calculations, PEG used LG&E's embedded cost of capital (9%) as the nominal discount rate. A real discount rate of 5% was used for calculating present values from the participants' perspective, with real retail rates assumed constant over time.

The benefits from improved payment-related factors, such as fewer brown bills and shut-offs, are more difficult to quantify and monetize than energy savings. At a minimum, these benefits should include marginal cost savings by LG&E for the specific collections activities avoided. LG&E has been unable to provide estimates for these cost savings. From the participants' perspective, direct monetary savings of $14 are provided by avoiding a reconnection fee following a disconnection. Some parties may suggest valuing the impact of avoiding a service disconnection at more than the avoided customer charge or the avoided cost savings of not having to send out service personnel to shut off and then later restore service. Similarly, many of the benefits described in section 4 are either unquantifiable or have a value which needs to be assessed from a policy perspective.

5.2.1 Value of Energy Savings

The average annual gas savings for Energy Partners participants, excluding those who also participated in WAP[5], are estimated at 186 ccf (see Section 3). From a participant's perspective, these savings are worth about $86 per year in reduced gas bills. From an avoided cost perspective, the gas commodity savings are currently worth about $40 per year. In addition to commodity savings, the gas savings will also reduce gas demand. PEG estimated gas demand savings by projecting gas usage rates during peak days (using the 1% winter design temperature) from the pre and post treatment PRISM models for each house. The net demand savings averaged 0.17 Mcf/day for the Energy Partners only participant group. These savings are worth $12 per year at current demand cost rates[6]. Therefore, the total gas commodity and demand savings are worth about $52 per year using LG&E avoided cost data.

[5] If the savings attributable to Energy Partners for WAP participants are equal to the savings from Energy Partners for non-WAP participants, then the use of the average savings and cost figures for the Energy Partners only group are appropriate.

[6] The best approach for valuing gas demand savings is a complex issue because of the way gas demand costs are incurred and LG&E's significant storage capacity. The approach taken here assumes demand reductions produce savings at marginal cost.

PEG calculated the present value of the gas savings from the participants' perspective and the avoided cost perspective using an estimated 20 year measure life (based on insulation providing the largest savings and having a very long measure life, and also to be consistent with the national WAP evaluation cited in footnote 3). The present value of the gas savings are $1066 for the participants and $633 from an avoided cost perspective.

The average electricity savings were estimated at 783 kWh/yr. in section 4.2.1. These savings are worth about $43 per year to the participants, but only about $9 per year from an avoided cost perspective. PEG assessed the potential impacts of Energy Partners on peak demand and concluded that demand savings are likely to be of negligible value. For measure life, PEG assumed that the baseload portion of the electric savings would last 5 years (since it is mostly from light bulbs) and the cooling and heating portions would last 20 years. Based on these assumptions, the present value of electricity savings is worth about $367 to participants and $58 on an avoided cost basis.

In total, the energy savings from Energy Partners provided the average participant with bill savings of $128 in the first year and reduced LG&E's marginal energy costs by $61. Over the life of the measures, the present value of these savings is $1434 to participants and $690 to LG&E.

5.2.2 Non-Energy Benefits

Energy Partners provides a number of other benefits beyond energy savings, such as those listed in section 4.3.3. A few of these non-energy benefits, such as brown bills and service disconnection reductions, have been quantified in this study on a frequency basis, but have not been monetized. Some other potential benefits were not quantified in this study due to a lack of data and/or limited evaluation resources, but have been addressed in other low-income studies. In addition, still other potential benefits have been identified by evaluators and program advocates but have not be quantified due to fundamental research limitations. In an effort to present a full picture of the non-energy benefits which may be provided by Energy Partners, PEG performed a brief literature review of studies addressing these issues[7]. Table 12 presents information and results from this literature review, combined with and/or adjusted to Energy Partners' specific data where possible[8], to provide a broad view of some actual and potential non-energy benefits from Energy Partners.

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[7] for an overview of many of these issues and studies, see *Finding Methods to Estimate Social Benefits of Low-Income Energy Efficiency Programs*, L.M. Megdal and M. Piper, in proceedings of 1994 ACEEE Summer Study on Energy Efficiency in Buildings, pp. 1.119-1.131, ACEEE, 1994.

[8] For valuing brown bills and service disconnections, PEG used a 10 year program impact life, a 5% real discount rate, and constant real costs.

Most of the potential benefits listed in the table have not been quantified and those that have been quantified entail considerable uncertainty in the methods and/or results. Even in an area with fairly solid data, such as avoided collection activities from improved payment behavior, the estimated value on an avoided cost basis ranges widely from $26-$130 per unit. However much non-energy benefits remain uncertain or difficult to quantify, excluding them from a cost-benefit analysis values them at zero, by default. This fact needs to be considered when examining cost-effectiveness results.

TABLE 12. NON-ENERGY BENEFITS

Program Benefit	#/EP house	Value ($/each)	N.P. Value ($/house)	Valuation Basis/Source
Payment-Related				
Avoided Brown Bills	0.98	0.30-2.00	2 - 15	guess
Avoided Disconnections	0.076	14 - 100	8 - 59	cust charge, cost guess
Avoided Late Payments	0.38			included in Bad Debt/Arrearage
Avoided Missed Payments	0.16			included in Bad Debt/Arrearage
Bad Debt/Arrearage Carrying Cost	?		16 - 56	low=50% of (1), high= (2)
Health & Safety				
Reduced gas emergency service calls	?	78	71	reduced from 27% to 7% in (2)
Reduced risk of fire (htr safety)			3	(1)
Reduced fires & illness from shutoffs			?	
Other illnesses/deaths avoided			?	
Reduced Liability from Explosions			?	
Environmental				
Carbon emissions (gas+elec)	1200 lbs./yr		285	(1) adj.to EP savings
Housing Improvement				
Improved Property Value			126	based on repair costs in (1)
Housing preservation / homelessness reduction	?		?	Phila. study found shut-offs related to homelessness
Reduced Mobility	.006/yr.		?	
Local Economic Benefits				
Job creation			?	63% more jobs than not spending ratepayer funds on program (3)
Indirect employment income			442	(1) adj. to EP costs
Net Value added to local economy			108	(3) adj. to EP costs
Total Net Other Benefits			????	(1) estimated total non-energy benefits at $976/unit

references:

(1) National Weatherization Assistance Program Evaluation, see footnote 3

(2) *Evaluation of Non-Energy Benefits from the Energy $avings Partners Program*, J. K. Magouirk, Public Service Company of Colorado, published in proceedings of 1995 Energy Program Evaluation Conference, Chicago, 1995.

(3) An Evaluation of Iowa's Low-Income Weatherization Efforts, by Wisconsin Energy Conservation Corporation, prepared for The Statewide Low-Income Collaborative Evaluation Committee, 1994.

5.3 Cost-Benefit Analysis

Because of the difficulty in assessing non-energy benefits and the subjective nature of monetizing them, PEG calculated conservative benefit-cost ratios based on the assumption that energy savings are the only benefit and using several cost perspectives. For scenarios where the avoided cost perspective is used to value energy benefits, PEG also calculated the value of non-energy benefits which would be needed for the program to be considered cost-effective overall. The results of this analysis are summarized in Table 13. Benefit-cost ratios above 1 indicate that the program is cost-effective from the perspective indicated.

TABLE 13. COST-BENEFIT ANALYSIS
ENERGY SAVINGS AS ONLY BENEFIT
AVG. $/UNIT

		Energy Benefit Perspective		
		Participant	Utility Avoided Cost	
Value of Energy Benefits Only ($/unit)		1434	690	
Cost Perspective	**Cost/unit**	**B/C Ratio**	**B/C Ratio**	**Non-Energy Benefits Needed**
Direct Energy Measure Costs	$911	1.57	0.76	221
On-going Total Costs (incl. admin & eval, excl. hlth/safety)	$1229	1.17	0.56	539
On-going Total Costs (All)	$1355	1.06	0.51	665
Total Pilot Costs (including start-up)	$1604	0.89	0.43	914

Note: Non-energy benefits Needed column is the value of non-energy benefits which would make the program appear cost-effective (B/C ratio=1) when energy benefits are valued on an avoided cost basis.

The figures in the table show that the program is cost-effective based on energy savings alone when the value of the energy savings are assessed from the participants' perspective and start-up costs are excluded. When all pilot costs are included in the analysis, the costs outweighed the energy benefits somewhat. However, when considering the expected costs of an on-going program, the energy savings benefits are about 6% greater than the full program costs.

Because expenditures on heating equipment repairs are made only for safety reasons and not to save energy, one could consider them cost-justified on a safety basis alone, otherwise they would not be provided as part of the program. If these costs are removed from the analysis, then the benefit-cost (b/c) ratio for an on-going program increases to 1.17.

From an avoided cost perspective, the current program can not be justified based on energy impacts alone. Even when the only costs considered are the $911 per unit of direct costs for delivering energy measures, the energy benefits of $690 are still 24% smaller than the costs. If non-energy benefits were valued at $665 per unit, then an on-going program could be considered cost-effective even with energy savings valued at avoided cost. This figure is less than the National WAP evaluation's estimate of $976 per unit for non-energy benefits from that program (although the $976 figure may not be accurate or applicable for this program). If health and safety expenditures are excluded from the analysis for reasons mentioned previously, then $539 per unit of non-energy benefits are needed to make the program cost-effective from an avoided cost perspective.

All of the cost-effectiveness measures provided thus far are based on the average costs and savings found for the Energy Partners pilot. However, changes in the program design or targeting could alter the cost-effectiveness. For example, among high gas use houses (>1800 ccf/yr.), the present value of the energy savings on an avoided cost basis is $1200 while program costs were only $70 per unit higher than the program average. For these houses, the avoided cost b/c ratio is 0.86 based on total on-going program costs and 0.92 if health and safety costs are excluded. The high savings in these houses requires a relatively modest valuation of non-energy benefits to be considered cost-effective ($99-$225/unit).

As this section indicates, the cost-effectiveness of Energy Partners depends upon the perspective used in assessing energy benefits and the valuation of non-energy benefits. The range of opinions on how to deal with these issues may lead to a benefit-cost ratio as low as one half or as high as two or three. However, based on the primary approach proposed by the Collaborative, the program has demonstrated cost-effectiveness.

5.4 Comparison to Program Goals and Other Low Income Weatherization Programs

In addition to cost-effectiveness, Energy Partners can be assessed in terms of meeting its goals and in comparison to the performance of similar programs. The primary goals of Energy Partners identified in the evaluation RFP were to achieve overall energy savings of 15%-20%, save money for low income households and improve their quality of life, reduce utility shutoffs and arrearages, and make participation in DSM possible for low-income customers. In terms of energy savings, gas savings averaged 12.3% of pre-treatment total usage and 15.8% of pre-treatment heating usage, while electricity savings averaged 7.7% of pre-treatment usage. These savings levels are somewhat below the goals set forth. The electricity savings were fairly large in absolute kWh terms, but the high usage levels made the percentage reduction small. In terms of saving money for low-income households, the program saved the average household $128 per year on their energy bills. Changes in quality of life are subjective and no surveys were performed, so success on this factor is speculative. In terms of reducing shutoffs and arrearages, the program reduced the likelihood of shutoffs by 22% and, based on available data, most likely reduced arrearages. In terms of making participation in DSM possible, the program certainly provided energy efficiency services to the participants. No data on participation in other LG&E DSM efforts were available. In addition to these four specific goals, the RFP also identified an implied goal of making the program cost-effective. If energy savings are valued from the participants' perspective, then the program succeeded in meeting this goal. Even from an avoided cost perspective, the program may be cost-effective depending upon how one values the non-energy benefits. Overall, Energy Partners performed fairly well in relation to the goals set forth.

Another goal of Energy Partners was to surpass the performance of the national Weatherization Assistance Program. In addition, Collaborative members expressed interest in how Energy Partners' performance compares to other weatherization programs. PEG reviewed several other low-income weatherization studies and generally found that the performance of Energy Partners compares favorably. Table 14 provides some comparisons between Energy Partners and other programs.

TABLE 14. ENERGY PARTNERS COMPARED TO OTHER LOW-INCOME PROGRAMS

Program	Savings (ccf/yr)	Cost ($/unit)	$ Cost per ccf/yr saved	%Savings
Energy Partners 1995	186	1355	7.28	12.3%
National WAP 1989	173	1550	8.96	13.0%
National WAP - mod. climate	182	1550	8.52	12.4%
Iowa WAP 1993	242	2119	8.76	17.9%
Ohio WAP 1994, prelim.	302	2000	6.62	24.0%
Colorado PSCo/WAP 1993/5	185	?		15.0%
Kansas WAP 1993/4	191	?		14.9%
Minnesota M200 Pilot 1988	243	1571	6.47	17.7%
Phila. Gas Works 1990	186	1200?	6.45	11.3%

Note: Program costs are provided in nominal dollars and would be considerably higher for programs evaluated earlier if adjusted for inflation.

Energy Partners produces more gas savings at a lower cost per unit than the National WAP evaluation found for WAP in 1989 overall or in the moderate climate region. The Ohio WAP and the Minnesota

M200 advanced pilot are generally considered high performance programs and do provide somewhat greater savings per dollar invested than Energy Partners (although an adjustment for inflation may change this conclusion for M200). The Iowa program is considered more typical and produces less savings per dollar invested than Energy Partners, but performs considerably more home repairs and safety-related heater replacement. Energy Partners saves somewhat less than many programs, but costs much less. The only less costly program (Phila. Gas Works) did not include heater safety testing or repairs in that program year, but added this feature in future years.

Advocates of WAP performance may point out that Energy Partners has an unfair advantage in targeting higher use households, which tend to provide greater savings. Most low-income programs shown in the table have pre-treatment usage rates ranging from about 1100-1350 ccf/yr, compared to 1514 ccf/yr for Energy Partners (the Phila. Gas Works program was an exception, with higher pre-treatment usage than Energy Partners). When savings are expressed as a percentage of pre-treatment usage, Energy Partners saves about the same as the moderate climate WAP program, but considerably less than many of the other programs. However, percentage savings have no fundamental value, it is actual ccf of gas and kWh of electricity that have value and reduce participants bills and utility costs.

Given the high gas usage rates and moderate percentage savings, it appears that there is a potential for greater savings from Energy Partners. PEG did not perform any field inspections as part of this evaluation, so the potential for higher savings from improved implementation of existing measures or missed opportunities is unknown. However, unless there were major problems with installation quality, it appears that bringing gas savings up to the 20% or greater level may require adding costly measures such as wall insulation (which was supposed to be tested in Energy Partners but was not) or targeted heating system replacement for houses with extremely high heating usage rates. The impact of these types of changes on overall program cost-effectiveness is difficult to estimate without more specific information on measure costs and data on wall insulation savings.

6.0 Conclusions

The Energy Partners Program has produced significant impacts:

- gas savings of 186 ccf/yr (12.3% of total usage, 15.8% of heating usage) worth $86/yr to participants;
- electricity savings of 783 kWh/yr (7.7% of total usage) worth $43/yr to participants;
- service disconnection reduced by 22%;
- brown bills reduced by 22%;
- reductions in late and missed payments;
- health and safety problems identified and repaired in three quarters of all houses; and,
- many other real or potential non-energy benefits such as arrearage reductions, housing preservation/improvement, environmental benefits, economic benefits, health and safety benefits from reduced disconnections and improved comfort, etc.

These impacts were produced by a program with on-going total costs estimated at $1355/unit and full pilot costs of about $1600/unit. The program performed comparably or better than many other low income weatherization efforts and produced more savings per dollar invested than the national Weatherization Assistance Program. Nevertheless, the program energy savings were somewhat below expectations.

In terms of cost-effectiveness, the value of the program energy savings to the participants is greater than the on-going costs of the program. On an avoided cost basis, the energy savings are worth about half of the program costs. Non-energy benefits would need to be valued at more than $600 per unit to make the program appear cost-effective from this perspective. The proper approach for assessing energy benefits and the true value of non-energy benefits are policy decisions outside the scope of this report.

Program cost-effectiveness may be improved by increasing savings relative to costs. The most powerful predictor of gas savings was the pre-treatment usage level. Gas savings were nearly twice the average in houses using more than 1800 ccf/yr and only about half the average in houses using less than 1200 ccf/yr. Cost effectiveness may be enhanced by devoting fewer resources to low-use households and more resources to high-use houses. Additional measures, such as dense-pack wall insulation or targeted heating system replacement, may be worth exploring as a means to bring savings over the 20% level for high use households. A more thorough analysis of potential ways to improve gas savings cost-effectively would require a combination of more and better data about the buildings, field visits to completed houses, and a modest-size pilot program to test some potential additional measures.

The very high electric usage levels among participants suggests that electricity savings may hold even greater opportunities than gas savings for reducing participants' bills and therefore improving affordability and payment behavior. LG&E's low avoided costs make these savings less likely to be cost-effective if savings are valued on an avoided cost basis. Hardware measures such as cooling system efficiency improvements (through enhanced tune-ups of central systems or replacements of inefficient window units) or refrigerator replacements are only likely to be cost effective if energy savings are valued from the participants' perspective or if they are targeted very carefully to only the best savings opportunities. Savings which are cost-effective from all perspectives may be achievable from energy education which focuses on ways to reduce cooling usage and the use or need for appliances such as freezers and electric space heaters.

Summary Statistics from PRISM analysis of gas usage
Energy Partners Only Group

Variable	N	Mean	Median	Min	5%	10%	25%	75%	90%	95%	Max	S.D.	IQR
Participant Group													
Pre-Treatment													
NAC	457	1514	1432	294	724	852	1166	1787	2213	2600	5096	590	621
Heat	457	1178	1094	83.7	442	563	823	1438	1844	2155	4666	551	615
Base	457	336	318	23.7	136	178	239	424	516	569	1355	148	186
T-reference	457	64.3	64.7	45.4	56.9	59.4	62	66.9	69.1	70.7	77.1	4.4	5
Post-Treat													
NAC	457	1325	1234	223	618	721	956	1620	2006	2202	3755	532	664
Heat	457	1001	946	112	357	447	626	1261	1638	1907	3276	494	635
Base	457	324	310	15.7	89.9	144	217	407	508	605	1547	165	189
T-reference	457	63.1	63.7	22.6	54	56.9	60.8	66.5	69.3	70.8	84	6.2	5.8
Savings													
NAC	457	189	154	-675	-174	-85.5	20	326	506	643	3041	298	306
Heat	457	177	153	-931	-171	-100	12.6	316	480	692	2888	297	304
Base	457	12.2	10.6	-1025	-214	-138	-53	78.5	155	255	1067	157	131
Comparison Group													
Pre-Treatment													
NAC	499	1496	1394	356	738	824	1091	1830	2254	2632	5044	611	738
Heat	499	1153	1069	169	441	518	746	1459	1869	2132	4472	567	713
Base	499	342	310	11.7	115	169	235	419	559	660	1091	164	184
T-reference	499	63.6	64.2	38.8	55.8	57.8	61.5	66.3	68.2	70	78.7	4.9	4.8
Post-Treatment													
NAC	499	1493	1403	267	706	825	1094	1777	2239	2605	4796	598	683
Heat	499	1167	1097	164	415	527	756	1462	1898	2183	4202	563	706
Base	499	326	311	3.7	121	164	233	393	511	579	1121	148	161
T-reference	499	63.6	64	34.4	55.5	58.5	61.2	66.8	68.7	70.7	77.9	5	5.6
Savings													
NAC	499	3	0.46	-778	-346	-235	-95.9	96.6	233	351	1846	224	192
Heat	499	-13.2	-4.87	-1007	-348	-257	-109	86	208	311	1876	225	195
Base	499	16.2	8.4	-721	-174	-106	-39.1	65.7	157	247	936	138	105