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An Impact Evaluation of the Missouri Gas Energy Low-Income Weatherization Pilot Program

A Final Report Prepared for
Missouri Gas Energy Company

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Executive Summary

This report presents the result of an impact evaluation of Missouri Gas Energy's Low-Income Weatherization Assistance Pilot Program. The evaluation is the second phase of a multi-year process and impact evaluation. In 1998 a process and early feed-back impact evaluation was conducted. The 1998 study documented program processes and operational effectiveness. In addition, the early feedback impact documented energy savings in less than a year following program participation. In 1999 the impact evaluation was repeated. This allowed the program to experience a longer post-program consumption history and increased the reliability of the energy savings estimates.

The 1999 impact evaluation documents increased savings and an improved benefit cost ratio for the program. Between its inception and March of 1999, the Missouri Gas Energy Low-Income Weatherization Assistance Pilot Program served 343 clients providing an estimated savings to Missouri citizens of $61,720 a year in 1997 dollars or $1,167,540 over the 20 year life of the installed measures.

On average, the consumption of space heating fuel for units heated with natural gas was reduced by 34.4 million BTUs annually, or 20.9 percent of total gas consumption, for a program-wide savings 296 billion BTUs over the 20 year life of the installed measures. This gas savings is provided through a 28.2 percent reduction in heating related gas consumption and an 8.5 percent increase in baseload consumption and provides each customer with an annual savings of $155 dollars.

In addition, the program is providing an electric savings of 500 kWh per year per customer, or about $35.00 a year off the average bill. The benefit-to-cost ratio for the program is 1.62 to 1. On the basis of this, we conclude that the Missouri Weatherization Program is cost effectively providing weatherization services to the residents of Missouri.

Chapter 1. Introduction

TecMRKT Works is pleased to present this report describing the impacts of the Missouri Gas Energy (MGE) Low-Income Weatherization Pilot Program. The evaluation examines program impacts and the benefits associated with those impacts, including those provided to the customer and to the State of Missouri. This study repeats an earlier short-term impact analysis performed at the end of 1997. The short-term analysis provided an early indicator of program impacts using less than a year of customer consumption records for of the participants. The short-term analysis indicated that the program was producing cost-effective energy savings, but because of the short-term nature of the data used in the analysis a more rigorous impact analysis was needed to confirm the estimated savings. This report presents the results from the longer-term analysis and is based on between 1.5 and 2 years of consumption data following participation.

This report is based on an analysis of information provided by Missouri Gas Energy, the Kansas City Weatherization Assistance Program, Kansas City Power and Light the State of Missouri and the University of Dayton. Gas consumption data was provided by Missouri Gas Energy. The Kansas City Weatherization Assistance Program identified program participants, a comparison group and cost data. Kansas City Power and Light provided electric consumption data. Daily weather data was obtained from the State of Missouri and by the national weather tracking data base maintained by the University of Dayton.

Program Background

The Low-Income Weatherization Pilot Program is sponsored by Missouri Gas Energy Company which contracts the delivery of service to the Kansas City Weatherization Assistance Program. The primary objective of the program is to improve the energy efficiency of eligible low-income households. In addition to providing energy efficiency and health and safety benefits, the program also provides financial benefits to participants by reducing the amount of money needed to pay energy bills and by increasing participant's ability to control their consumption.

The Kansas City Weatherization Assistance Program has program implementation staff responsible for identifying and enrolling participants, conducting energy audits, installing measures, inspecting completed work and for educating participants about how to control energy costs.

Chapter 2. The Impact Evaluation Design and Methodology

The basic design for this impact study is a comparison group design in which the pre- and post-retrofit weather adjusted energy consumption for buildings with a single heating source are compared for a retrofit and a comparison group using time-series weather and participant consumption data. In this design, the weather normalized energy consumption of a retrofit and the comparison group is determined before and after weatherization measures are installed. For each group, the average change in energy consumption per unit between the before and after period is determined. The net savings are obtained by adding the per unit change in energy consumption for the two groups. In addition, electricity consumption before and after the retrofit for non-space heating uses was compared in order to estimate savings from non-space heating related changes.

Data Collection Techniques

The participation and energy consumption data collected in this analysis were obtained from five sources: the State of Missouri, the KCWAP, MGE, Kansas City Power and Light and the University of Dayton's national weather data archives. The specific data and the sources are described below.

Weatherization Program Data

TecMRKT Works requested program data from the Kansas City Weatherization Assistance Program for participants in the MGE program who have had measures installed and who were awaiting the installation of measures. The requested data included the Weatherization Program tracking number; account numbers for electric and gas service; personal identification information such as name, address, and telephone; a date when measures were inspected (a proxy for installation date); the installation costs associated with each of the nine measure categories such as infiltration, attic and wall insulation; and the total installation costs.

These data were contained in the KCWAP program database management system. This system tracks dollars expended per category of measure installed rather than the number and amount of measures on a measure by measure basis. For instance, the category for "infiltration" contains the cost of installing an array of measures such as window and door caulk, sill box insulation, etc. The costs include labor and material. This means that the part of the evaluation aimed at analyzing measure specific savings focuses on savings from categories of measures rather than measure specific results.

The KCWAP program provided two files, one for homes in which measures had already been installed (411 locations, 282 of which were in the previous analysis) and one for homes awaiting installations (63 locations) Many of the homes awaiting in the previous study are now among the 411 for which we have participation data. Homes which were awaiting installations were assigned to the comparison group. The homes which had had installations were largely assigned to the retrofit group although those whose retrofits were too recent to have sufficient post-retrofit data to make a pre and post analysis possible were assigned to the comparison group.

Gas Consumption Data

Based on the program data provided by KCWAP, TecMRKT Works made a data request to MGE for six years of monthly energy consumption data (four years of data were requested for the previous study), monthly bill reading dates, and data flags associated with each reading, as well as personal identification data for the 411 participants and the 63 homes awaiting installations. TecMRKT Works provided files with account numbers to MGE. MGE provided 399 participant cases, (346 of which were usable cases of data for participants), and 94 for non-participants, (93 of which were usable cases).

Electric Consumption Data

TecMRKT Works made a similar request to KCPL for monthly electric consumption data, monthly bill reading dates, and data quality flags associated with each reading and personal identification data for the same participant group and for those awaiting installations. KCPL provided 390 usable cases of data for participants and 124 for non participants. In the previous study, KCPL provided 258 cases of data for participants and 75 for non-participants.

Fuel Use Data

After reviewing the relevant gas data provided by MGE, TecMRKT Works identified 399 building units with sufficient fuel data to warrant inclusion in the study. Of these, 346 had sufficient pre- and post-retrofit data for possible inclusion in the energy savings analysis (Table 1). Of these 346 buildings, 255 had data of sufficient quality to pass the reliability checks for the analysis (see below).

In impact evaluations records with estimated data reduce the overall reliability of the analysis. This is especially the case when estimates are made following a retrofit and the formulas for estimating consumption have not been updated to reflect the retrofit. Also, when there are a small number of post retrofit records, a small number of highly variable readings may reduce the reliability of the data. These variations in fuel use can be influenced by changes in family size, energy related behaviors, and the social and economic conditions of the household. Together, these conditions often make energy consumption data unusable for estimating weatherization program impacts. Typically, in low-income programs as many as 50% of the units do not pass the reliability checks. MGE's rate of 74% passing this test indicates that most reads are actual meter reads and the number of estimated meter reads is low.

Weather Data

In order to conduct an energy savings analysis using the PRISM™ software (see below), approximately twelve years of average daily temperature data are needed in addition to the weather data for the pre- and post-program years. These data were obtained from the University of Dayton Department of Engineering Web site (http://www.engr.udayton.edu/weather/source.htm) which maintains a national weather data base for weather stations throughout the U.S. In addition, weather data from the Kansas City International Airport was obtained from the State of Missouri. These data were provided to TecMRKT Works. After reviewing data for the various weather stations in the Kansas City area, TecMRKT Works decided that the temperature data from the Kansas City International Airport most represented the program implementation area. This was the weather data used for comparing participant and non-participant energy consumption in this evaluation.

PRISM™

Program impacts were examined using PRISM™ Advanced Version 1.0 software for Windows developed at Princeton University's Center for Energy and Environmental Studies.

PRISM™ is a commercially available analysis software package designed to estimate energy savings for heating and/or cooling loads in residential and small commercial buildings. The current Advanced Version permits users to enter and edit data from a variety of sources, to carry out sophisticated reliability checks, to eliminate cases that do not meet standards, and to display results in graphical and textual forms.

PRISM™ allows the user to estimate the change in energy consumption per heating or cooling degree day for the periods before and after measures are installed in homes by combining energy consumption and weather data. By subtracting the estimate of energy use per degree day after the measures are installed from the value before the measures are installed and multiplying by an appropriate annual degree day value, total annual normalized energy savings can be estimated.

Degree days vary from year to year, which potentially presents a problem for deciding on a value for annual degree days. This is especially problematic if one is trying to determine paybacks. For example, one could normalize the savings to the period preceding the installation of measures or the period after. If one selects a warm period, then savings may be too low and paybacks too long. If one selects a cool period for normalization, then the estimate of paybacks may be too high.

PRISM™ mitigates this problem by effectively averaging temperatures over a twelve year period and providing an estimate of degree days that is typical for the region of the study, although not one that necessarily matches the specific weather conditions in any given year. The user can select a twelve year period or use the PRISM™ recommended period of January 1, 1980 to December 31, 1991. The advantage of normalizing to the PRISM™ recommended period is that the results will be consistent from study to study over a period of time. The same end can be achieved by consistently using the same user selected time frame. For this study we chose the period from January 1, 1982 through December 31, 1998. In the previous study we selected the period from July 1, 1982 through June 30, 1997.

A major feature of PRISM™ is the ability to evaluate cases against reliability criteria. The first criterion is the R^2 value (explained variance), a measure of the fit of the degree day and energy consumption data, or in statistical lingo, the amount of variance in energy consumption explained by changes in degree days. Energy consumption is assumed to be a linear function of degree days. R^2 varies from 0 to 1. If R^2 is close to zero, it means that factors other than outdoor temperature are driving heating fuel consumption. If the R^2 is close to 1 it means that outdoor temperature is almost entirely responsible for heating fuel consumption. Outdoor temperature is usually the overriding factor in heating fuel use and the goal of the weatherization program is to improve the thermal characteristics of the building shell and the fuel use rate of the heating system to reduce fuel use related to outdoor temperature. The PRISM™ default for R^2 is at .7. This means that at least seventy percent of heating fuel use is temperature related. If less than 70 percent of the fuel use in a building is temperature related, then it becomes difficult to understand the effects of the weatherization measures and the case is dropped from the analysis. We used .7 in this study although most all of the R^2 values in this study were .85 or higher. In other words, 85 percent or more of heating fuel use in this study is temperature driven. Very few cases were dropped because of the R^2 criterion.

PRISM™ has a second measure of reliability which is the coefficient of variation for the normalized annual consumption (CV_{NAC}). Normalized annual consumption is the amount of fuel consumed by a unit for a typical weather year. When estimating normalized annual consumption some estimates may have a very tight error band while others may have a band that is quite wide. In estimating the average consumption we want estimates of unit consumption that are very close to the actual and we want to eliminate values that may not be very close because they may cause the estimates of the average consumption for all units to vary significantly from the actual. Because the variation in the estimates of normalized annual consumption generally will be higher in homes with higher consumption, the estimate of the variation in normalized annual consumption is divided by the estimate of normalized consumption to obtain CV_{NAC}. This provides a standardized measure of the variability of the normalized consumption that is comparable across homes. The PRISM default for CV_{NAC} is 7 percent and that is the value used in this study. Housing units that failed the PRISM™ criteria most often failed this test.

Data Editing

We examined and cleaned data for natural gas as the predominant space heating fuel type. Because electricity consumption may decrease when the use of heating fuel is reduced, we examined household electricity consumption for all participants for whom we calculated savings for natural gas. Theoretically, improved efficiency would reduce furnace / boiler run times. In addition, increased electricity consumption (non-space heating) due to air conditioning use during summer months was also examined. However, for these households electricity consumption did not pass the PRISM™

reliability criteria because the R^2s were particularly low. We concluded that a temperature related component of electricity use could not be reliably extracted for the retrofitted buildings with non-electric primary space heating.

We examined the energy data for duplicates, estimated data, and out-of-range data, and for data comprehensiveness and established pre- and post-program participation dates for each home consistent with the Kansas City Weatherization Assistance Program inspection dates. We then formatted the data into files for import into the PRISM™ software. We subsequently ran the first PRISM™ analysis and examined raw data and PRISM™ results for each home.

We evaluated each home's R^2 and CV_{NAC} values to identify "problem" homes to be singled out for more careful inspection. We also examined the pre- and post-retrofit energy consumption information and read dates. We confirmed that the retrofit dates used to assign energy consumption values to the pre- and post-program periods were correct. For homes where the dates were problematic, we examined the PRISM™ results by placing the values in question in both the pre- and post-program periods and identified in which period the best R^2 and CV_{NAC} values were determined. If neither the pre- or post-program period provided an improved run, a reading which could not be clearly placed in either the pre or post retrofit periods was excluded from the analysis for the home. In some instances, PRISM™ runs were improved by merging consumption data from two or more periods into one period.

Chapter 3. Energy Impacts

Introduction

The Missouri Gas Energy Low-Income Weatherization Pilot Program saved an average of 34.4 million BTUs of natural gas and 500 kWh of electricity per home per year for the housing units examined in the savings analysis. This is an 11% increase in natural gas savings over the estimated savings identified in the short-term analysis conducted earlier and supports the need to conduct longer-term evaluations of these programs. This saving is provided by an average 28.2 percent savings in space heating fuel per unit, an 8.5 percent increase in household baseload consumption and a 1.3 percent net reduction in electric consumption. During the program an estimated 411 housing units were weatherized, achieving a total annual energy savings of 14.1 billion BTUs or approximately 104,000 gallons of oil equivalent or 141,000 therms and 205,500 kWh of electricity. Over the 20-year lifetime of the installed measures the energy savings are expected to equal 296 billion BTUs or about 2.2 million gallons of oil equivalent or 2,960,000 therms.

The Units Being Analyzed

According to the tracking information, the program served 411 single unit buildings between January 1995 and January 1998. The primary fuel examined in this analysis was natural gas. Table 1 presents the details of the inclusion of units in the PRISM™ savings analysis.

Table 1. Population of Units In Study

Fuel Type	Units originally identified by KCWAP	Units in gas or electric files received from the utilities	Units with Pre- and Post-Program Energy Records	Units with Pre- and Post- records for weatherization savings analysis[1]	Units meeting reliability criteria to be included in savings analysis[2]
Natural gas 1999 study (retrofit)	411	399	379	346	255
Natural gas 1999 study (comparison)	96	94	94	93	84
Electric cooling 1999 study (retrofit)	411	408	390	232	174
Electric cooling 1999 study (comparison)	126	126	126	124	100
Totals 1999 study			989	795	613

[1] Energy consumption analysis includes participants with data from January 1, 1992 through December 31, 1998.
[2] These units met the reliability criteria with PRISM R^2 levels of .7 or better and NAC of seven percent or less.

In order to estimate the energy savings from program efforts, it is necessary to make assumptions pertaining to the measures installed and how these measures are used in the average home. For this evaluation it is assumed that the savings calculated for the average unit in the impact analysis reflect the savings in the average participant's unit and that the measures installed in homes last 20 years or more.

Program Energy Savings for Natural Gas

Table 2 presents the basic data from the energy savings analysis. The rows in Table 2 represent the base load consumption, the heating portion of total consumption, total consumption and the calculated reference temperature. Columns 2 and 3 are the pre- and post-average dwelling unit normalized energy consumption estimates for natural gas for the retrofit group as determined by the use of PRISM™. Column 4 presents the gross estimate of savings for the retrofit group.

The retrofits resulted in a total average gross savings of 303 therms of natural gas per year or approximately an 18.4 percent gross reduction in total usage (not just space heating usage). When we take the energy consumption of the control group into account the net savings from the retrofits increases to 20.9 percent for all consumption and 28.2 percent savings (374 therms) in space heating related natural gas consumption.

For the average dwelling, approximately 81 percent of the usage (1338 of 1644 therms) is heating related and 19 percent is used for base loads such as water heating, pilot lights, etc. This is almost exactly the same ratio as the 1998 study where approximately 80 percent of the usage was heating related and 20 percent was used for base loads. Retrofit measures affect the heating portion of the load more than the base load. As we can see, the gross base load reduction for the retrofit was about 44 therms or 14.4 percent of the estimated base load and the heating load reduction was 259 or about 19.4 percent of the heating load. In the previous study, the gross base load reduction for the retrofit was about 50 therms or 14.7 percent of the estimated base load and the heating load reduction about 270 or about 19.3 percent of the heating load.

Columns 6 - 9 provide the same information for the comparison group. There was a slight increase in gross consumption for this group. Total base load consumption increased 115 therms but the heating portion of consumption decreased by 75 therms for an average increase in usage of 40 therms per household. For the comparison group, the percentage gross changes in base load, space heating and total consumption were 22.9 percent, -9 percent and –2.5 percent, respectively. The negative sign indicates an increase in consumption. If we subtract the gross savings for the comparison group from those of the retrofit group, we find the net savings due to the program are -31 therms of base load (44 therms – 75 therms) and 374 therms of heating load (259 therms - (-115 therms)) for a combined net savings of 344 therms. The percentage net savings in base load, space heating and total consumption are –8.5 percent, 28.2 percent, and 20.9

percent respectively. The 344 therms of net savings in this study is quite in line with savings in other localities with significant heating loads.

There are a couple additional points to be made in reference to the baseload data in this table. First, the net savings for the base load was –30 therms indicating a net increase in baseload consumption for the average participant home. However if we look at the data we see that the increase in baseload consumption is a net increase and not a gross increase. That is, both the participant group and the comparison group decreased their baseload consumption over the study period, however, the comparison group decreased their consumption at a rate faster than the participant group and that difference is 31 therms or 8.5 percent. What is interesting is that while the baseload consumption for the participant group decreased by 14.4 percent the comparison group's baseload consumption decreased by 22.9 percent. The participant group decreased consumption at a rate that was about 60 percent less than the decrease for the comparison group.

Second, we conclude that there is absolutely no indication of take-back effects with this program. The reference temperatures for pre and post consumption retrofit groups (row 4) are almost identical and they are almost identical to the reference temperatures for the comparison group. If there were a take back affect, we would expect to see these temperatures increase.

Finally, we should observe that the overall consumption of the comparison group is very similar to the retrofit group. The comparison group used about 44 therms less energy in their hypothetical "before" period. This suggests that the average size of homes were about the same in both the retrofit and comparison groups.

Program Savings from Electricity

A similar analysis was completed for electricity savings. The program was not designed to save electricity and therefore electric measures, such as compact fluorescent lamps, were not installed during the program. Electricity savings from the program would largely result from the reduced furnace run times due to weatherization measures and reduction in air conditioning energy savings. Consumption records indicate that the proportion of homes with air conditioning and which use the air conditioning for a significant number of hours during the summer does not appear to be very high.

For each home in the PRISM™ space heating analysis, we conducted a PRISM™ analysis of electricity consumption. We let PRISM auto-select the best model. During this run, 174 participant cases passed the reliability checks but the savings were actually negative, meaning this group of households used more energy rather than less. The mean savings for these 174 cases was –456 kWh or about a $3.00 per month increase. For the comparison group, 100 cases passed the reliability checks. However, the mean savings for these cases was –950 kWh or about a $6.00 a month increase, providing an almost 500 kWh or $3.00 dollars per month net decrease in electric consumption for program participants. This net reduction in electric savings is about 5 times what we would expect to see if we only consider the furnace run-time savings and provides an indication that there are electric savings from this program beyond the savings from increased heating efficiencies. These savings are most likely as a result of the educational training provided by the program or through air conditioning savings.

Table 2. Energy use and savings calculations

	Retrofit Group				Comparison group					
	Pre-retrofit usage	Post retrofit usage	Gross change in usage	Gross percent change	Pre-retrofit usage	Post retrofit usage	Gross Change in usage	Gross percent change	Net change	Net change percent
1999 Study										
Base load portion 1999 study (therms)	306	262	44	14.4	328	253	75	22.9	-31	-8.5
Heating portion 1999 study (therms)	1338	1079	259	19.4	1272	1387	-115	-9.0	374	28.2
Total 1999 study (therms)	1644	1341	303	18.4	1600	1640	-40	-2.5	343	20.9
Reference temperature (°F)	63.4	61.2	2.3		63.1	63.5	-.4			

Chapter 4. Program Costs

The Installed Measures

Figure 1 shows the percentages of eight measures installed as they were recorded in the KCWAP tracking system. Ninety-nine percent of all homes received infiltration and general heat waste installation measures and 95 percent received door, window, and / or plaster repairs. Examples of air infiltration measures are caulking around windows and doors and applying weather stripping.

Furnace repair and tune-up was done for health and safety reasons and for energy savings reasons. Eighty-eight percent of households were identified as having heating related measures installed for health and safety reasons and 71 percent for energy savings reasons. Many homes received heating related measures that were split between the two categories. Eighty-three percent of the homes had measures related to ducts, vapor problems and sealing electrical outlets. Almost half of the sites received attic insulation (52 percent) and wall insulation (51 percent). Forty-five percent installed foundation and / or floor insulation.

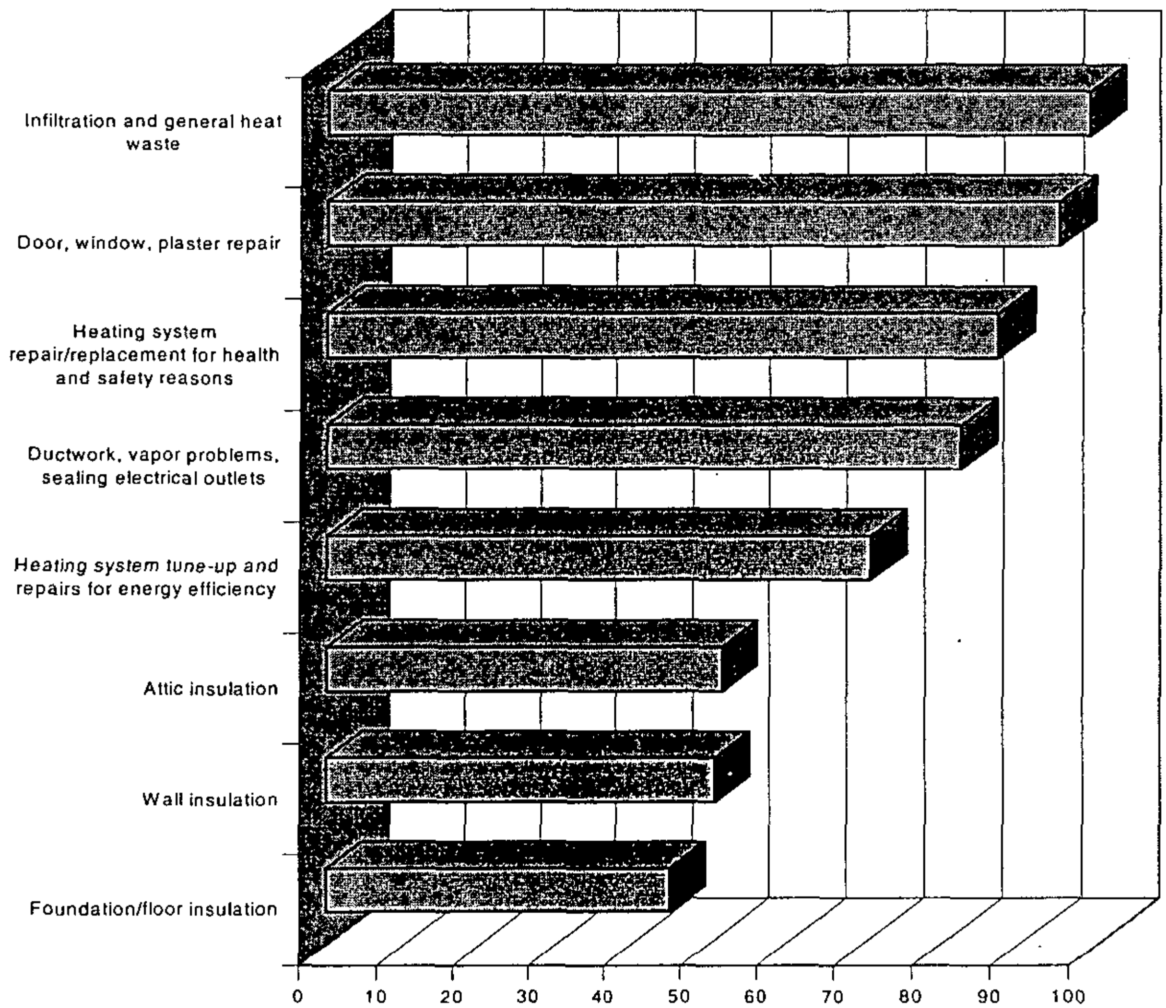

Figure 1. Percentages of measures installed

Measure Specific Installation Costs

Table 3 reflects the different average costs for installing measures. The data have been presented in three ways. Column 2 is the cost to install a measure averaged over the 343 homes (excluding mobile homes) in the program. However, not all homes had each measure installed. Accordingly, column 3 is the average measure cost for just those homes that received the specific measure. Column 5 is the average measure cost of installing the specific measure in homes that were included in the savings analysis.

These data suggest that the homes in our energy savings analysis had slightly more heating system work than did the average home.

Table 3. Average Cost Per Weatherization Measure

Measure	Average cost per unit for all housing units	Average measure cost per unit for units with measure	Number of units	Average measure cost per unit for units with measure included in savings analysis	Number of units
1999 Study (n = 343)					
Infiltration and general heat waste	$416.49	$428.99	333	$443.14	265
General repair needed to weatherize doors, windows, ceilings, etc.	$224.03	$245.50	313	$256.46	251
Foundation and floor insulation including repair	$56.12	$121.06	159	$114.63	121
Heating system repair/replacement for health and safety reasons	$503.03	$565.70	305	$583.34	234
Wall insulation	$236.34	$479.68	169	$501.63	139
Attic insulation	$197.81	$411.21	165	$418.59	135
Heating system tune-up and repair for savings reasons	$169.92	$237.88	245	$241.89	187
Ductwork, vapor problems, electrical outlets and miscellaneous items	$67.76	$84.82	274	$87.40	217
Total	$1871.50	$2574.84	343		268

Considering the average measure cost per unit (Column 3), we see that the most costly measure was the heating system replacement done for health and safety reasons at $566, followed by wall insulation ($480), infiltration and general heat waste ($429), attic insulation ($411),general repair needed to weatherize doors, windows, ceilings, etc. ($246), heating system tune-ups ($238), foundation / flooring insulation ($121), and miscellaneous items ($85).

The preceding estimates for the cost of the work do not include program administration costs. Program costs include the costs associated with a site visit, conducting an audit, developing a set of specifications, placing the specifications for bid, awarding a contract, and providing technical assistance. Based on data supplied by the KCWAP, TecMRKT Works estimated program costs to be 12 percent of installation costs. Using the average installation costs per unit weatherized ($1,871.50) and adding the 12 percent for program costs, the total cost to weatherize a unit is $2,096.08.

Table 4 summarizes the total program costs for the units that were weatherized.

Table 4. Total Program Costs

Description	Units Weatherized January 1995 to December 1998 [2]
1999 Study (n = 343)	
Weatherization measure installation cost	$641,965.66
Kansas City Weatherization Assistance Program fixed and indirect costs	$77,034.37
Total costs	$719,000.03

[2] The totals are the number of units times the average cost per unit.

Chapter 5. Program Cost Effectiveness

To determine the benefit-to-cost ratio for the program we compared the program delivery costs to the value of energy savings. The benefits were calculated based on an assumed life of the measures of 20 years. The annual savings in each of the 20 years were adjusted for the projected change in fuel prices and the change in the value of the dollar and then summed for the 20 years.

The changes in fuel prices are based on changes in the projected prices of natural gas and electricity using data from the Department of Energy's, Energy Information Administration (EIA). Each year the EIA makes 20 year discounted fuel price projections and reports these projections in the Annual Energy Outlook. The discounted price projections used in this report are contained in the 1999 Annual Energy Outlook. This report is available on the world wide web and can be accessed via an Acrobat reader at http://www.eia.doe.gov/oiaf/aeo99/pdf/0383(99).pdf. However, regional prices of fuel can vary quite substantially from average national energy prices. Although EIA reports regional prices, it does not make similar regional projections of prices. Thus, regional price trend projections are available but not Kansas City area prices.

To overcome this problem, we assumed that Kansas City energy prices will follow national trends. By taking the local price of energy from MGE and from KCP&L and applying the national projections of price we arrived at a reasonable projection of fuel prices in Kansas City over the next 20 years. Column 1 of Table 5 shows the number of the year from 0 to 20. Column 2 provides the year from 1998 to 2018. Column 3 shows the EIA projected prices for natural gas in 1997 dollars using current MGE residential prices. Column 4 is the projected prices for electricity using current residential prices from KCP&L. Fixed customer charges are not included in these rates. Column 5 is the number of therms saved per participant. Column 6 is the present value, discounted price of the projected gas savings. Column 7 is the electric savings per participant in kWh. Column 8 is the present value, discounted price of the projected electric savings. Over the 20 year lifetime of the measures, the customer can expect to save $2,789 in natural gas costs and $614 in electric cost in 1997 dollars for a total savings of $3,403.

If the $3,403 in benefits to customers are compared to the levelized cost of the program, of $2,096, the benefit cost ratio the program is 1.62 to 1. In other words, the program returns a $1.62 in benefits to the customers for every dollar spent on the program.

The cost-effectiveness of measures

As part of the analysis, TecMRKT Works attempted to analyze the cost effectiveness of the various measures. A typical approach to this problem is to regress the presence or absence of the measures installed in homes on the savings for the homes. The resulting regression coefficients represent the average savings attributable to the measures. This approach works as long as there is sufficient variation in the measures installed between homes. If nearly every home has a particularly measure installed or almost none of the homes have a measure installed, then there is unlikely to be sufficient variation to accurately apportion the savings.

Table 5. Changes in projected fuel prices for 20 years

	Year	Gas price	Electric price	Therms saved / home	Gas dollars saved / home	kWh saved / home	Electric Dollars saved / home
0	1998	$0.450	$0.068	0	0	0	0
1	1999	$0.428	$0.066	344	$147.06	500	$32.88
2	2000	$0.432	$0.065	344	$148.65	500	$32.39
3	2001	$0.432	$0.064	344	$148.65	500	$31.88
4	2002	$0.428	$0.063	344	$147.06	500	$31.43
5	2003	$0.422	$0.062	344	$145.24	500	$30.89
6	2004	$0.418	$0.062	344	$143.87	500	$31.13
7	2005	$0.413	$0.063	344	$142.05	500	$31.28
8	2006	$0.413	$0.062	344	$142.05	500	$31.14
9	2007	$0.412	$0.062	344	$141.60	500	$31.11
10	2008	$0.408	$0.062	344	$140.46	500	$31.00
11	2009	$0.404	$0.062	344	$138.86	500	$30.87
12	2010	$0.400	$0.062	344	$137.73	500	$30.80
13	2011	$0.397	$0.061	344	$136.59	500	$30.72
14	2012	$0.394	$0.061	344	$135.45	500	$30.29
15	2013	$0.389	$0.060	344	$133.86	500	$29.96
16	2014	$0.386	$0.059	344	$132.72	500	$29.73
17	2015	$0.384	$0.059	344	$132.04	500	$29.62
18	2016	$0.383	$0.059	344	$131.58	500	$29.42
19	2017	$0.383	$0.058	344	$131.81	500	$29.22
20	2018	$0.383	$0.058	344	$131.81	500	$29.02
	Totals				$2,789.13		$614.78

Source of price trend projections: USDOE 1999 Annual Energy Outlook
Source of current fuel price: Natural gas: MGE Electricity: KCP&L

The application of this approach to the current problem was made difficult by a number of factors. The data available to us was not organized by discreet measures. For instance, several infiltration measures, such as caulking and weather stripping, were combined in a single category. There was no way to separate caulking from weather stripping. Secondly, the measures were presented in terms of their cost and it was not possible to effectively relate cost to activity. Using several tubes of caulk may have had greater effect than weather stripping doors but the cost of the two measures may have been relatively the same or quite different.

After a preliminary review and analysis of the measures we made several determinations. Infiltration measures were applied to nearly every house. Therefore, it did not make sense to identify infiltration as separate variable to be entered into the regression analysis. Secondly, the repair measures were necessary in order to complete other weatherization measures but do not contribute to savings directly. Plastering the ceiling in order to install ceiling insulation only marginally contributes to additional savings beyond the value of installing the ceiling insulation. Therefore, it was determined that the repair variable should be dropped from the analysis. This does not diminish the importance of repairs to the overall project, it merely indicates that we do not expect them to contribute to the overall savings.

We were also confronted with the problem of having two variables relating to heating systems. One variable included costs assigned to improving health and safety and the second assigned cost to improving energy efficiency. The fact that these variables were highly correlated caused severe problems with the analysis when they were entered at the same time. In order to deal with this problem, we combined the two variables to obtain a total cost for dealing with the heating system and then created two new variables. If the total cost of heating system repair was $800 or more we assumed that a new furnace was installed and we coded a variable that we called "furnace replacement." If the amount was less than $799 but more than zero we assume that there was a heating system tune-up or repair. By coding the variables in this way we were able to distinguish between new units and system repairs and tune-up.

Finally, we discovered that the category of miscellaneous caused a fair bit of disturbance in the analysis. We concluded after a bit of exploration that this variable included duct work which was related to heating systems and thus was correlated with the heating variables. We removed this variable from the analysis.

Table 6 shows the model with five variables, wall insulation, foundation and floor insulation, attic insulation, heating system repair and furnace replacement. Instead of using the dollar amounts, we recoded the variable so that if money was expended the variable recorded the presence of the measure and if money was not expended the absence of the measure was recorded. Because we used presence or absence and these are the unstandardized coefficients, they can be interpreted directly as the therms of savings resulting from the measure.

The largest savings are associated with furnace replacement and the next largest wall insulation. The constant can be interpreted as the average savings from all other sources including infiltration measures, repairs, and miscellaneous. In this model foundation and floor insulation, attic insulation and heating repair make relatively small contributions to the overall savings. Note that the standard errors for heating repairs and the constant are unacceptably large.

Table 6. Preliminary linear regression model based on the presence or absence of the energy saving measures

Measures	Unstandardized Coefficients		t	Significance
	B (tens of therms)	Standard Error		
Constant	104.64	99.04	1.057	.292
Wall insulation	171.81	50.30	3.416	.001
Foundation and floor	9.05	50.69	.179	.858
Attic insulation	21.45	50.63	.426	.671
Heating system tune-up and repair	42.32	97.85	.433	.666
Furnace replacement	227.33	101.77	2.234	.027

An alternative model in which heating repair is removed is shown in Table 7. In this model, heating repair is now represented in the constant. The coefficient of the constant now increases by about 49 therms but the standard error is significantly reduced and the constant is now significantly different than zero. Furnace replacement provides the largest amount of savings, wall insulation the next most savings, and the measures summarized in the constant, most particularly infiltration measures provide the next largest amount of savings.

Attic insulation and foundation and floor insulation provided the least savings. Some may be surprised that attic insulation provides so few savings but this finding is consistent with observations that we are making in other jurisdictions where we have found that infiltration and wall insulation provide significantly more savings than attic insulation in leaky homes.

These savings estimates are quite reasonable. For example, given the average pre retrofit heating energy consumption of 1400 therms, a furnace replacement represents about a 15 percent reduction in energy use which is about what one would expect if furnace efficiency is improved from 65 percent to 80 percent. According to program staff, the furnaces that are being installed have efficiency ratings of about 80 percent.

Table 7. Final linear regression model based on the presence or absence of the energy saving measures for 1999 Study

Measures	Unstandardized Coefficients			
	B (tens of therms)	Standard Error	t	Significance
Constant	153.41	39.03	3.930	.008
Wall insulation	141.51	39.24	3.606	.815
Foundation and floor	85.43	39.23	2.178	.031
Attic insulation	23.55	39.46	1.777	.077
Furnace replacement	70.12	61.37	.234	.000

Table 8. Final linear regression model based on the presence or absence of the energy saving measures for 1998 Study

Measures	Unstandardized Coefficients			
	B (tens of therms)	Standard Error	t	Significance
Constant	133.73	49.56	2.698	.008
Wall insulation	175.48	49.79	3.524	.001
Foundation and floor	11.03	49.90	.221	.825
Attic insulation	23.55	50.22	.490	.625
Furnace replacement	213.50	53.06	4.023	.000

Based on these data, we can begin to make some assessments of the cost effectiveness of the different measures. Table 9 presents the costs of the measures, the dollar savings from the measures assuming that the cost of energy in constant dollars is about $0.41 per therm over a 20 year period and that the life of measures is about 20 years. Forty-one cents per therm is used because it is the present value of fuel savings at the half-way point in the measure's useful life.

Table 9. Estimated benefit cost ratio of selected measures

Measure	Cost	Annual savings (therms)	20 year savings (dollars)	Benefit to cost ratio
Water heater blanket[1]	$20	30	$246	12.30
Infiltration measures	$442	70	$574	1.30
Wall insulation	$497	175	$1,435	2.89
Attic insulation	$429	24	$197	0.46
Heating tune-up and repair	$366[2]	30	$246	0.67
Heating system replacement	$1,621[3]	213	$1,747	1.08

1 Cost of a water heater blanket and installation estimated by TecMRKT Works

2 Cost of the heating repair is the average of the repairs in all homes that had heating repairs less than 800 dollars but greater than zero.

3 Cost of heating replacement is the average for all households with heating system costs identified as being greater than $800.

Based on the preceding it is clearly cost effective to install water heater blankets, wall insulation, infiltration measures, and heating system replacements. The value of heating system tune-ups and repair is questionable on the basis of energy savings along and attic insulation appears not to be cost effective. It is important to keep in mind that heating system replacements are usually installed for health and safety reasons. We have not estimated the health and safety benefits of replacing heating systems but they may be substantial in terms of reducing illness and reducing the need for emergency and service visits to households. Likewise, there may be significant non energy benefits from heating system tune-ups including reduced services calls and health and safety related benefits.

Chapter 6. Summary and Conclusions

Between its inception and December 1998, the Missouri Gas Energy Low-Income Weatherization Assistance Pilot Program served 343 clients providing an estimated savings to Missouri citizens of $61,720 a year in current 1997 dollars or $1,167,540 over the 20 year life of the measures. On average, the consumption of space heating fuel for units heated with natural gas was reduced by 34.4 million BTUs annually, or 20.9 percent of total gas consumption, for a program-wide savings 296 billion BTUs over the 20 year life of the installed measures. This gas savings is provided through a 28.2 percent reduction in heating related fuel consumption and an 8.5 percent increase in baseload consumption. The benefit-to-cost ratio for the program is 1.62 to 1.

We also analyzed the benefit to cost ratios for the various types of measures installed. Water heater blankets pay for themselves in two years or less. Wall insulation, infiltration measures, and heating system replacement are also cost effective. Heating system replacement is usually done for health and safety reasons so the energy savings is a bonus benefit. Heating system tune-ups and repair do not appear to be cost effective until health and safety benefits are included. Attic insulation does not appear to be cost effective. From a policy standpoint, the program may want to consider the merits of replacing a furnace rather than tuning and repairing an existing system and insulating an attic, especially if the estimated combined cost of the last two measures exceeds the cost of a furnace replacement.

It should be kept in mind that this evaluation has focused entirely on the benefits and costs of weatherization. There are other health and safety benefits and costs associated with this program that have not been fully evaluated here. In particular, the replacement and repair of furnaces may significantly reduce service calls and emergency service calls, and reduce the number and consequences of health problems associated with a poorly functioning furnace.