AMERICAN ELECTRIC POWER - KENTUCKY

AMERICAN ELECTRIC POWER

COMMENTS:

The Mobile Home High Efficiency Heat Pump program provides incentives to customers, encouraging them to install the highest efficiency equipment practical.

The projected participant and budgetary level for 2006 has been revised to reflect what the Collaborative believes to be reasonably achievable goals. The projected participant and budgetary level is 100 and $50,000 respectively.

AMERICAN ELECTRIC POWER - KENTUCKY

AMERICAN ELECTRIC POWER

PROGRAM INFORMATION

PROGRAM:	Mobile Home New Construction
PARTICIPANT DEFINITION:	Number of Units Installed
CUSTOMER SECTOR:	Residential
REPORTING PERIOD:	January - June, 2005

2005

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YTD	PTD
Heat Pump	17	7	9	12	10	12							67	1,057
Air Conditioner	0	0	0	0	0	0							0	2

Impacts

Estimated in Place Energy (kWh) Savings		Anticipated Peak Demand (kW) Reduction			
YTD	PTD	YTD		PTD	
		Summer	Winter	Summer	Winter
76,776	22,001,294	9	181	137	2,861

AMERICAN ELECTRIC POWER - KENTUCKY

AMERICAN ELECTRIC POWER

Mobile Home New Construction	
Reporting Period:	January - June, 2005

Costs

Description	Year-To-Date	Retroactive Adjustment	Program-To-Date
Total Evaluation	4,195.00	0.00	29.414.00
Equipment/Vendor:	3,300.00	0.00	67,213.00
Promotional:	0.00	0.00	3,939.00
Customer Incentives:	33,500.00	0.00	537,150.00
Other Costs:	200.00	0.00	3,416.00
Total Program Costs:	41,195.00	0.00	641,132.00
Lost Revenues:	20,871.00	0.00	284,252.00
Efficiency Incentive:	8,372.00	0.00	36,110.00
Maximizing Incentive:	0.00	0.00	2,580.00
Total Costs:	70,438.00	0.00	964,074.00

AMERICAN ELECTRIC POWER - KENTUCKY

AEP
AMERICAN ELECTRIC POWER

COMMENTS:

The Collaborative has devised and implemented a plan working in conjunction with trade allies to offer a financial incentive to new mobile home buyers and trade allies to encourage the installation of high efficiency heat pumps and upgraded insulation packages in new mobile homes.

The Collaborative is requesting Commission approval to discontinue the incentive for the installation of high efficiency air-conditioning at the end of the 2005 calendar year due to lower than expected participation levels and the revised federal energy efficiency standards that are scheduled to go into effect on January 23, 2006.

On April 14, 2005, the Department of Energy's Office of Hearing and Appeals (OHA) granted Nordyne's application for exception relief from the 2006 13.0 SEER requirement for split system air-conditioners of the 3 to 5 ton capacity. The OHA granted Nordyne's application which in effect would permit a 12.0 SEER air-conditioning system to be installed in HUD-Code homes until January 1, 2010. Only Nordyne 12.0 air-conditioning systems will be allowed to be installed in HUD-Code homes. Since 70% of the manufactured housing dealers use Nordyne equipment, this exception eliminates any possibility of upgrading air-conditioning systems next year. Therefore, the Collaborative is recommending the measure for high efficiency air-conditioning be discontinued December 31, 2005.

The projected participant and budgetary level for 2006 has been revised to reflect what the Collaborative believes to be reasonably achievable goals. The projected participant and budgetary level is 150 heat pumps and $ 87,500 respectively.

AMERICAN ELECTRIC POWER - KENTUCKY

AEP AMERICAN ELECTRIC POWER

PROGRAM INFORMATION

PROGRAM:	Modified Energy Fitness
PARTICIPANT DEFINITION:	Number of Households
CUSTOMER SECTOR:	Residential
REPORTING PERIOD:	January - June, 2005

2005														
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YTD	PTD
New Participants	84	94	11	84	87	11							371	1,638

Impacts

Estimated in Place Energy (kWh) Savings		Anticipated Peak Demand (kW) Reduction			
YTD	PTD	YTD		PTD	
		Summer	Winter	Summer	Winter[i]
159,398	3,557,407	49	223	218	984

AMERICAN ELECTRIC POWER - KENTUCKY

Modified Energy Fitness	
Reporting Period:	January - June, 2005

Costs

Description	Year-To-Date	Retroactive Adjustment	Program-To-Date
Total Evaluation	22,747.00	0.00	25,750.00
Equipment/Vendor:	125,976.00	0.00	602,937.00
Promotional:	0.00	0.00	0.00
Customer Incentives:	0.00	0.00	0.00
Other Costs:	0.00	0.00	0.00
Total Program Costs:	148,723.00	0.00	628,687.00
Lost Revenues:	28,250.00	0.00	108,315.00
Efficiency Incentive:	15,612.00	0.00	42,294.00
Maximizing Incentive:	0.00	0.00	0.00
Total Costs:	192,585.00	0.00	779,296.00

AEP AMERICAN ELECTRIC POWER

COMMENTS:

The Modified Energy Fitness Program provides energy audits, blower door testing, duct sealing and direct installation of low cost conservation measures to residential customers with electric space heating and electric water heating.

The equipment/vendor cost category includes the cost of labor and materials of measures installed, the cost of promotion by the vendor and vendor administration costs.

The Collaborative is requesting Commission approval to increase annual participation levels to 1,000 per year due to the customer's overwhelming endorsement of the program.With the current backlog of customers, the Company and the implementation contractor (Honeywell, DMC Services) both agree that the annual achievement of 1,000 energy audits is feasible.

The projected participant and budgetary levels for 2006 have been revised to reflect what the Collaborative believes to be reasonable achievable goals. The projected participant and budgetary level is 1,000 and $405,000 respectively.

AMERICAN ELECTRIC POWER - KENTUCKY

AMERICAN ELECTRIC POWER

PROGRAM INFORMATION	
PROGRAM:	Smart Audit - Commercial
PARTICIPANT DEFINITION:	Number of Audits
CUSTOMER SECTOR:	Commercial
REPORTING PERIOD:	January - June, 2005

2005														
Participant	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YTD	PTD
Class I	0	0	0	0	0	0							0	1,952
Class II	0	0	0	0	0	0							0	194

Impacts					
Estimated in Place Energy (kWh) Savings		Anticipated Peak Demand (kW) Reduction			
YTD	PTD	YTD		PTD	
		Summer	Winter	Summer	Winter
n/a	n/a	n/a	n/a	n/a	n/a

AMERICAN ELECTRIC POWER - KENTUCKY

AMERICAN ELECTRIC POWER

Smart Audit - Commercial	
Reporting Period:	January - June, 2005

Costs

Description	Year-To-Date	Retroactive Adjustment	Program-To-Date
Total Evaluation	0.00	0.00	30,661.00
Equipment/Vendor:	0.00	0.00	1,268,176.00
Promotional:	0.00	0.00	0.00
Customer Incentives:	0.00	0.00	0.00
Other Costs:	0.00	0.00	(8,156.00)
Total Program Costs:	0.00	0.00	1,290,681.00
Lost Revenues:	0.00	0.00	0.00
Efficiency Incentive:	0.00	0.00	0.00
Maximizing Incentive:	0.00	0.00	64,533.00
Total Costs:	0.00	0.00	1,355,214.00

AMERICAN ELECTRIC POWER - KENTUCKY

AMERICAN ELECTRIC POWER

COMMENTS:

This program was discontinued December 31, 2002.

AMERICAN ELECTRIC POWER

PROGRAM INFORMATION

PROGRAM:	Smart Incentive - Commercial
PARTICIPANT DEFINITION:	Number of Incentives
CUSTOMER SECTOR:	Commercial
REPORTING PERIOD:	January - June, 2005

2005														
Participant	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YTD	PTD
Existing Building	0	0	0	0	0	0							0	182
New Building	0	0	0	0	0	0							0	69

Impacts

Estimated in Place Energy (kWh) Savings		Anticipated Peak Demand (kW) Reduction			
YTD	PTD	YTD		PTD	
		Summer	Winter	Summer	Winter
0	61,757,956	0	0	1,519	2,640

AMERICAN ELECTRIC POWER - KENTUCKY

Smart Incentive - Commercial	
Reporting Period:	January - June, 2005

Costs

Description	Year-To-Date	Retroactive Adjustment	Program-To-Date
Total Evaluation	0.00	0.00	144,039.00
Equipment/Vendor:	0.00	0.00	21,504.00
Promotional:	0.00	0.00	0.00
Customer Incentives:	0.00	0.00	399,592.00
Other Costs:	0.00	0.00	691.00
Total Program Costs:	0.00	0.00	565,826.00
Lost Revenues:	27,168.00	442.00	873,573.00
Efficiency Incentive:	0.00	1,078.00	88,039.00
Maximizing Incentive:	0.00	0.00	281.00
Total Costs:	27,168.00	1,520.00	1,527,719.00

COMMENTS:

This program was discontinued December 31, 2002.

AMERICAN ELECTRIC POWER

PROGRAM INFORMATION

PROGRAM:	Smart Audit - Industrial
PARTICIPANT DEFINITION:	Number of Audits
CUSTOMER SECTOR:	Industrial
REPORTING PERIOD:	January - June, 2005

2005

Participant	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YTD	PTD
Class I	0	0	0	0	0	0							0	60
Class II	0	0	0	0	0	0							0	4

Impacts

Estimated in Place Energy (kWh) Savings		Anticipated Peak Demand (kW) Reduction			
YTD	PTD	YTD		PTD	
		Summer	Winter	Summer	Winter
n/a	n/a	n/a	n/a	n/a	n/a

AMERICAN ELECTRIC POWER - KENTUCKY

AMERICAN ELECTRIC POWER

Smart Audit - Industrial	
Reporting Period:	January - June, 2005

Costs

Description	Year-To-Date	Retroactive Adjustment	Program-To-Date
Total Evaluation	0.00	0.00	5,741.00
Equipment/Vendor:	0.00	0.00	37,786.00
Promotional:	0.00	0.00	0.00
Customer Incentives:	0.00	0.00	0.00
Other Costs:	0.00	0.00	161.00
Total Program Costs:	0.00	0.00	43,688.00
Lost Revenues:	0.00	0.00	0.00
Efficiency Incentive:	0.00	0.00	0.00
Maximizing Incentive:	0.00	0.00	2,186.00
Total Costs:	0.00	0.00	45,874.00

AMERICAN ELECTRIC POWER - KENTUCKY

AMERICAN ELECTRIC POWER

COMMENTS:

This program was discontinued December 31, 1998.

AEP AMERICAN ELECTRIC POWER

PROGRAM INFORMATION

PROGRAM:	Smart Incentive - Industrial
PARTICIPANT DEFINITION:	Number of Incentives
CUSTOMER SECTOR:	Industrial
REPORTING PERIOD:	January - June, 2005

2005

Participant	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YTD	PTD
General	0	0	0	0	0	0							0	1
Compressed Air	0	0	0	0	0	0							0	0

Impacts

Estimated in Place Energy (kWh) Savings		Anticipated Peak Demand (kW) Reduction			
YTD	PTD	YTD		PTD	
		Summer	Winter	Summer	Winter
0	96,715	0	0	6	6

AMERICAN ELECTRIC POWER - KENTUCKY

AEP AMERICAN ELECTRIC POWER

Smart Incentive - Industrial	
Reporting Period:	January - June, 2005

Costs

Description	Year-To-Date	Retroactive Adjustment	Program-To-Date
Total Evaluation	0.00	0.00	28,385.00
Equipment/Vendor:	0.00	0.00	3,288.00
Promotional:	0.00	0.00	0.00
Customer Incentives:	0.00	0.00	441.00
Other Costs:	0.00	0.00	0.00
Total Program Costs:	0.00	0.00	32,114.00
Lost Revenues:	0.00	0.00	0.00
Efficiency Incentive:	0.00	0.00	383.00
Maximizing Incentive:	0.00	0.00	655.00
Total Costs:	0.00	0.00	33,152.00

AMERICAN ELECTRIC POWER - KENTUCKY

AMERICAN ELECTRIC POWER

COMMENTS:

This program was discontinued December 31, 1998.

KENTUCKY POWER COMPANY
TARGETED ENERGY EFFICIENCY PROGRAM
2003-2004 LOAD IMPACT EVALUATION REPORT

Final Report

July 7, 2005

Prepared for:

American Electric Power
1701 Central Avenue
P.O. Box 1428
Ashland, KY 41105-1428

Prepared By:

RLW Analytics, Inc.
2 Hyde Road
Clark Lake, MI 49234
(517) 529-6277

KENTUCKY POWER COMPANY TARGETED ENERGY EFFICIENCY PROGRAM 2003-2004 LOAD IMPACT EVALUATION REPORT

Table of Contents

List Of Tables

List Of Figures

List Of Equations

KENTUCKY POWER COMPANY
TARGETED ENERGY EFFICIENCY PROGRAM
2003-2004 LOAD IMPACT EVALUATION REPORT

E Executive Summary

This report presents the Kentucky Power Company ('KPCo') Targeted Energy Efficiency Program ('TEE Program'). The TEE Program is designed to perform energy audits, provide energy education to all households, perform blower door tests and install extensive weatherization and energy conservation measures to low income customers living within the KPCo service territory. The TEE Program is a "piggyback" program leveraging the resources of five not-for-profit agencies that provide weatherization services to low-income customers via the existing Weatherization Assistance Program. This program is offered to electric heat and non-electric heat customers. The load impact evaluation method examined the changes in customer bills to determine the program's impact.

The primary objective of this evaluation was to quantify the savings for the 2003-2004 program years. Two critical components to the success of meeting the evaluation objective are the research design and the evaluation methodology. The research design allows the results from the evaluation to meet its evaluation objectives i.e., allowing the results of the program to be determined and applicable to the improvement of the TEE Program. The evaluation methodology operationalizes the research design. The research design contributes to the development of valid conclusions. In turn, the results may be generalized for use in other applications.

This evaluation quantified the change in electric consumption that is a result of the program. In the case of heating system replacements, it was found that some participant's energy consumption actually increased for those participants where the existing heating system was inoperative or its operation was severely restricted. When this condition exists, customers often turn to alternative fuels (i.e., kerosene, space heaters, wood, etc.) to maintain comfort, these alternative fuels can sometimes pose a safety hazard. When a heating system was not in operation or not economically feasible to repair, that heating system was replaced. Accordingly, this replacement would cause an increase in electric consumption, while increasing the participant's comfort and safety. To illustrate this effect, an additional analysis was performed to quantify the savings of customers that did not have their heating system replaced.

Based on this analysis **it can be concluded that the TEE program significantly reduced electric consumption.** The best estimates of savings, by program component, are:

- For the all-electric participants, the average savings were 1,792 kWh/year per participant. This is an 8% reduction from the pre-installation NAC.

- For the all-electric participants who had their heating system replaced, the average savings was 2,372 kWh/year per participant. This is a 10% reduction from the pre-installation NAC.
- For the all-electric participants who did not have their heating system replaced, the average savings were 1,605 kWh/year per participant. This is a 8% reduction from the pre-installation NAC.
- For the base load participants, the average savings were 553 kWh/year per participant. This is a 3% reduction from the pre-installation NAC.

The total program annual energy savings, based on 488 participants, was estimated to be 678 MWH.

KENTUCKY POWER COMPANY TARGETED ENERGY EFFICIENCY PROGRAM 2003-2004 LOAD IMPACT EVALUATION REPORT

1 Introduction

This report presents the Kentucky Power Company ('KPCo') Targeted Energy Efficiency Program ('TEE Program'). The TEE Program is designed to perform energy audits, provide energy education to all households, perform blower door tests and install extensive weatherization and energy conservation measures to low income customers living within the KPCo service territory. The TEE Program is a "piggyback" program leveraging the resources of five not-for-profit agencies that provide weatherization services to low-income customers via the existing Weatherization Assistance Program. This program is offered to electric heat and non-electric heat customers. The load impact evaluation method examined the changes in customer bills to determine the program's impact.

The primary objective of this evaluation was to quantify the savings for the 2003-2004 program year. Two critical components to the success of meeting the evaluation objective are the research design and the evaluation methodology. The research design allows the results from the evaluation to meet its evaluation objectives i.e., allowing the results of the program to be determined and applicable to the improvement of the TEE Program. The evaluation methodology operationalizes the research design. The research design contributes to the development of valid conclusions. In turn, the results may be generalized for use in other applications.

1.1 Research Design

The evaluation's research design was chosen to serve as a foundation for the continued monitoring of the program. In addition to quantifying program impacts, the initial research design enables KPCo to continue to build the capability to perform evaluations, and establish baseline information for future program designs.

The research design chosen for the TEE Program is a time-series comparison/cross sectional design. This research design essentially determines the program impacts by examining the change in participant's usage patterns over time. Comparing a representative control group's change in usage over a similar time period further refines the impact estimate. This experimental design helps to reduce any potential bias in the results.

The time series/cross sectional design achieves internal and external validity. Internal validity means the evaluation is conducted in a manner such that the results isolate the impact of the activity being studied. When other factors are not recognized, the changes attributed to the program may be the result of other phenomena. For example, if the experiment does not recognize the effect of a participant's demographic or end-use characteristics, the change in usage could be explained by the impact of the implementation of the program or, alternatively, by the change in lifestyle of the participant. A research design can help achieve external validity by ensuring that the results are representative of a larger population of interest, allowing for the findings to be generalized. For example, for the TEE Program, the information determined by the 2003-2004 participants and the corresponding control group permits the evaluation to represent the total program impacts.

1.2 Evaluation Methodology

The evaluation methodology used billing data to determine the impact of the program using the maximum number of 2003-2004 participants and a representative group of non-participants. This initial analysis determines energy impacts, while minimizing the uncertainty associated with the estimate.

A systematic and comprehensive approach using billing analysis was used to determine the program energy impacts. The approach consists of a variety of methods ranging from a simplistic comparison approach to more complex regression techniques.

Specifically, the evaluation consisted of the following four steps:

1) Development of the participant billing information,
2) Development of a representative control group,
3) Temperature normalization of billing information, and
4) The quantification of the energy impacts.

In each of the subsequent sections of this report, the approach and the results of the analysis are presented.

2 The Participants

Billing analysis requires that sufficient billing information is available to establish consumption trends in both the pre-installation and post-installation periods. This section presents the development of the participant group consumption analysis. For a discussion of the methodology to develop the participant group, see Appendix A.

From program tracking records (i.e., the WX Data Collection Forms), it was determined that there were 488 participants. Using these accounts, KPCo gathered the appropriate billing data from the Marketing and Customer Service System (MACSS). As noted above, billing information from MACSS was available for 215 customers of the 488 participants from the tracking system information.

The initial step in developing the participant information was to examine every individual read for each of the participants with billing records. When the information from a particular billing record appeared to be incongruent, that record was edited or eliminated from the analysis.

After the individual reads were examined, the participant data was split into pre- and post-installation periods. The next editing step checked the participant accounts to verify that there was enough data in each period to be accurately analyzed. At the end of the editing of the participant billing data a total of 207[1] customers were available for the billing analysis.

Number of Participants	488	
Pre Annualized Usage (kWh)	19,980	
	Pct	**Number**
House Type		
Combination (Mobile/Modular/Site)	2%	9
Mobile	60%	291
Site-Built	39%	188
Electric Primary Heat	67%	327
Heating System Replaced		
Yes:	16%	80
		-
Electric Furnace	86%	69
Heat Pump	9%	7
Wall Unit	5%	4

Table 1 - Particpant Information

Table 1 presents information about the participant population. As this table shows, the participant group consists of more customers that live in mobile homes, and have electric heat.

3 The Control Group

The primary purpose of the TEE Program billing analysis is to determine the program's effects on electricity consumption. One of the challenges in the analysis is that residential energy consumption can be significantly affected by a variety of variables such as changes in weather, activity, demographics, building shell, etc. One of the most efficient methods for controlling these confounding effects is the establishment of a representative "control" group of non-program participants.

For the TEE Program evaluation, a systematic method for determining a representative control group was used. A detailed presentation of the methodology used to develop the control group is presented in Appendix A. This section presents the results of the development of the control group.

For the TEE Program KPCo provided a file with billing information for 12,805 customers. These customers were designated the "Control Group Pool". From this pool, all known participants were eliminated.

Next, the participant group was examined to establish matching criteria. The criteria that was determined to partition the participant group into homogeneous groups was based on

[1] The majority of customers eliminated from the analysis were a result of insufficient post-program data.

annualized usage, pseudo-January load Factor, and pseudo-July load factor. Seven strata were defined. Table 2 shows the definition of the seven strata, and some descriptive population statistics for each stratum. This table shows that over half of the participants are in the more than 50 kWh/day, less than 80% January load factor strata.

Strata Definition			Participants			
Average usage Per Day (kWh)	Jan Load Factor	Jul Load Factor	Distribution	Average usage Per Day (kWh)	Average Pseudo Jan Load Factor	Average Pseudo Jul Load Factor
Less than 50	Less than 80%	Less Than 130%	13%	41.08	67%	105%
More Than 50	Less than 80%	Less Than 130%	24%	67.45	64%	106%
Less than 50	More Than 80%	Less Than 130%	19%	35.64	111%	83%
More Than 50	More Than 80%	Less Than 130%	9%	63.51	104%	88%
Less than 50	Less than 80%	More Than 130%	11%	40.82	57%	187%
More Than 50	Less than 80%	More Than 130%	22%	66.72	58%	168%
More Than 50	More Than 80%	More Than 130%	2%	62.78	173%	316%

Table 2 - Strata Definitions For Control Group Matching

The control group pool customers were compared to the TEE Program participants based on annual usage within the strata. Based on the above methodology, up to three control group members were selected for each participant.

Table 3 shows the control group for each program. At the end of the selection and editing process, the control group consisted of 621 customers. Table 4 shows a comparison of the pre-installation period annualized usage between the participants and the control group. This table demonstrates how well the control group selection process worked. Based on average usage per day within the load factor strata, the control group closely matches the participant group. Based on this comparison, the control group was accepted and promoted to the later stages of the analysis.

Strata Definition			Control Group			
Average usage Per Day (kWh)	Jan Load Factor	Jul Load Factor	Distribution	Average usage Per Day (kWh)	Average Pseudo Jan Load Factor	Average Pseudo Jul Load Factor
Less than 50	Less than 80%	Less Than 130%	12%	41.51	66%	106%
More Than 50	Less than 80%	Less Than 130%	24%	67.62	66%	107%
Less than 50	More Than 80%	Less Than 130%	19%	35.60	156%	82%
More Than 50	More Than 80%	Less Than 130%	9%	63.18	102%	90%
Less than 50	Less than 80%	More Than 130%	12%	41.03	56%	204%
More Than 50	Less than 80%	More Than 130%	22%	66.51	58%	176%
More Than 50	More Than 80%	More Than 130%	2%	63.52	112%	164%

Table 3 - Selected Control Group, By Selection Strata

Statistic	Participants	Control Group
N	215	621
Minimum	18.42	18.16
25th Percentile	41.65	41.64
Median	52.72	52.90
Mean	54.74	55.59
75th Percentile	66.01	65.85
Maximum	103.82	103.91

Table 4 - Comparison of Pre-Installation Period Average Daily Usage

4 Temperature Normalization of Billing Information

One of the most important steps in the assessment of the effect of the TEE Program is the pre-installation to the post-installation comparison of energy usage. By controlling for other non-program influences, such as weather, the program's effects can be isolated and quantified. This normalization methodology is presented in Appendix A. This section presents the results of the temperature normalization procedure.

The temperature normalization procedure described in Appendix A presented an enormous computing challenge. For the electric consumption models, heating degree-days based on reference temperatures from 50^{0}F to 75^{0}F, and cooling degree-days based on reference temperatures from 60^{0}F to 75^{0}F were examined. The wide variety of reference temperatures meant that thousands of models were considered for each customer to determine the optimal models.

To capture accurate temperatures, information from the Ashland, Hazard, and Pikeville, Kentucky weather stations were used. The daily mean of these stations were chosen to be representative of the average daily temperature for the TEE Program participants.

Table 5 shows the distribution of the actual to model predicted usage for the most recent 12 months of data in each period. The participants predicted mean usage is usually within 0.2% of the actual mean. This supports the conclusion that the models are performing well within each period. The comparison of annualized usage between groups for each period also supports the conclusion that the control group is well matched to the participant group.

	Participants		Control Group	
	Pre	Post	Pre	Post
Actual Average Annualized Usage	20,293	18,351	20,203	19,008
Predicted Average Annualized Usage	20,271	18,354	20,187	18,972
Actual Median Annualized Usage	19,946	17,439	19,488	18,570
Predicted Median Annualized Usage	19,930	17,434	19,616	18,516

Table 5 - Distribution of Actual and Predicted Electric Usage

The normal temperatures used in this analysis are 18-year average daily temperatures. The average normal temperatures are presented in Table 6.

Month	Ashland	Hazard	Pikeville	Average
Jan	33	36	35	34
Feb	37	40	39	38
Mar	43	45	44	44
Apr	53	55	54	54
May	63	64	63	63
Jun	72	71	71	71
Jul	76	75	75	75
Aug	74	74	73	73
Sep	66	67	66	66
Oct	55	56	55	55
Nov	44	45	45	45
Dec	36	38	37	37

Table 6 - Average Normal Daily Temperatures

Using normal temperatures the Normalized Annual Consumption (NAC) was calculated for each period for each group. Table 7 shows the NAC for each period. The mean and median consumption is decreased for the participant group from the pre-installation to the post installation period. The Control group shows a modest increase in the mean and median consumption for the pre to post period. The comparison of the NAC between groups, for each period does however demonstrate that the control group is well matched to the participant group.

	Participants		Control Group	
	Pre	Post	Pre	Post
Mean	19,123	18,813	18,967	19,473
Median	18,473	18,147	18,588	18,817

Table 7 - Distribution of Electric NACs

5 The Energy Impacts

To fully investigate the effects of the program, several different analytical methods were used. These methods ranged from a simplistic comparison approach to a more complex regression technique. As expected, the estimates of savings should remain relatively stable from method to method. The more complex methods were expected to produce "better" estimates. This section presents the methodology to estimate the energy savings for the TEE Program.

In the evaluation of the TEE Program, the following two different methods were used. First, the energy impact was determined using an Augmented Comparison Method (PRISM). The second approach was a Regression Approach. Appendix A contains a detailed discussion of the methodology used to quantify the energy impacts. This section presents the results of that analysis.

One of KPCo's objectives was to establish savings estimates for subsets of the participant population, the electric heat participants and the base load participants. Accordingly, the analysis will be presented for these groups.

Participant Type	Number of Customers	Percent Of Population	Annualized Pre-Installation Usage (kWh)
Electric	330	77%	22,086
Base Load	158	37%	16,619

Table 8 - Participant Distribution

Table 8 shows the distribution of participants. As this table shows, the program was dominated by electric heating customers.

5.1 The Augmented Comparison Approach Results

For the net savings, the average control group pre- and post installation usage were used. Table 9 shows the mean savings by program component.

	Electric Heat	Electric Heat	Electric Heat Total	Base Load	Program Total
Heating System	Replaced	Not Replaced			
Pre Installation NAC (kWh)	20,091	20,900	20,703	15,891	19,142
Mean Savings (kWh)	(369)	1,575	1,102	375	866
Pct Savings	-2%	8%	5%	2%	5%

Table 9 - Comparison of the Net Savings, By Component

Table 9 shows a mean savings for the electric heat customers of 1,102 kWh/year. This is a 5% reduction from the pre-installation NAC. This table also shows that the base load customers had a mean savings of 375 kWh/year. This is a 2% reduction from the pre-installation NAC. The tables also illustrate the unique impacts of electric heat customers that had a heating system replacement as compared to electric heating customers that did not have a heating system replacement.

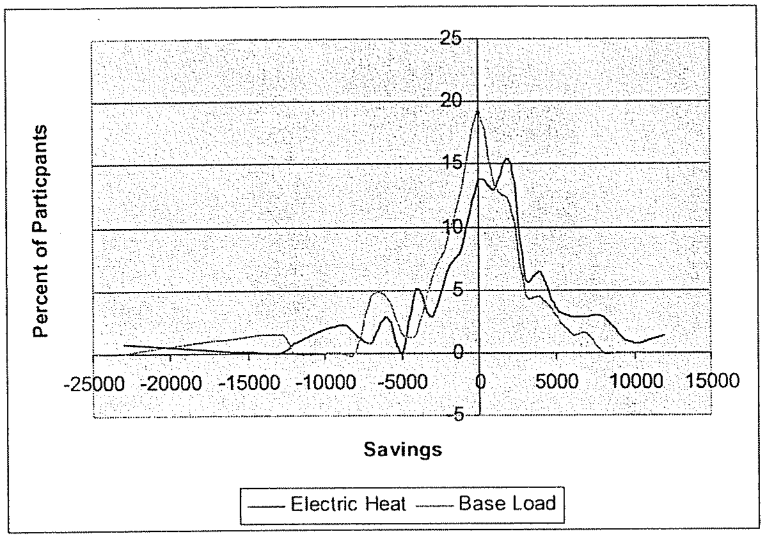


Figure 1 - Distribution of PRISM Savings

Figure 1 shows a comparison of the distribution of the PRISM savings estimates, for each participant type. This is typical of the distribution of savings generated by PRISM analysis. The distribution is essentially a *normal* (i.e., bell-shaped) curve, with most of the estimates falling around the center point or mean. The tails of the distribution are symmetrical. The large confidence intervals are exemplified by the large spread in values shown in this figure. Interestingly, about 43% of the participants showed a predicted *increase* in usage from the pre-installation to the post-installation period. This may be due in part to the heating system replacement[2] feature of the program.

Some conclusions can be drawn from the augmented comparison approach. Although the results can be refined, it is clear from this initial analysis that the TEE Program has effected the electric consumption of the participants. In addition, the initial estimates can be considered a substantial amount of energy savings.

The variability of the savings estimates produced by this method is quite large. To produce a more precise estimate of savings, the regression approach was implemented.

5.2 The Regression Approach Analysis Results

The regression analysis was implemented using the four-step approach described in Appendix A. Unfortunately, there was not engineering estimates of savings available for the individual customers to incorporate into the model.

[2] It was determined that the inclusion of heating system replacements and heating repair work does not necessarily increase the program's electric energy savings benefits. The justification for this is that a repaired heating system would lead to increased reliance as the primary heating source. Similarly, the installation of a new heating system can also lead to higher customer consumption, if alternative heating fuels were used or if the customer chose to increase their comfort level.

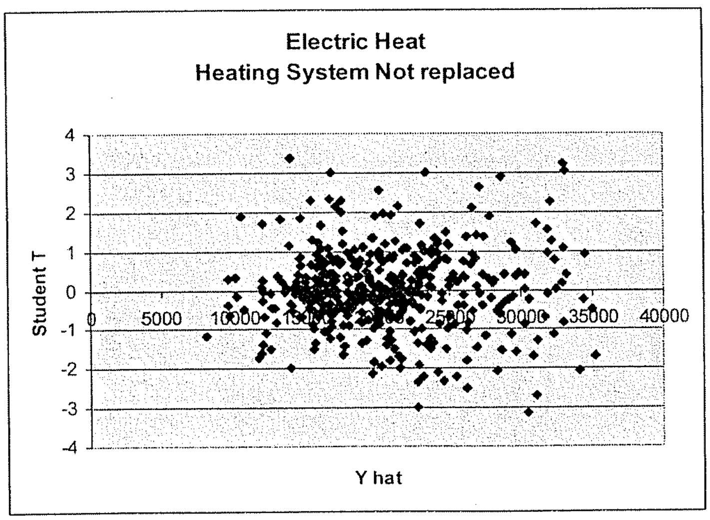
The initial analysis step was to build a simple regression model. As noted above, no engineering estimates of savings were available to this analysis. Accordingly, the analysis was performed using a participation indicator variable.

	Electric Heat	Electric Heat	Electric Heat Total	Base Load	Program Total
Heating System	Replaced	Not Replaced			
Pre Installation NAC (kWh)	20,091	20,900	20,703	15,891	19,142
Mean Savings (kWh)	(506)	1,802	1,241	228	912
Pct Savings	-3%	9%	6%	1%	5%

Table 10 - Average Savings Estimates From Simple Model

Table 10 shows the average savings estimates from the simple model. The savings estimates shown in this table are not statistically different from the PRISM results. However, the estimates are much less variable. The savings for the average electric heat participant were 1,241 kWh/year. This is a 6% reduction from the pre-installation NAC. The savings estimate for the base load participants 228 kWh/year. This is a 1% reduction from the pre-installation NAC.

One of the fundamental regression assumptions is that the standard error of the error terms (or residuals) has a constant variance across the range of predicted values. When the residuals are related to the predicted values, the model is said to be *heteroscedastic*. Heteroscedasticity is a violation of the basic regression assumptions that could lead to mis-specification of the mathematical relationships. Specifically, as a result of the residual standard error being related to the size of a customer's usage, heteroscedasticity will mis-estimate the confidence interval around the estimates. Heteroscedasticity is common in cross sectional models such as the Simple Model discussed above.



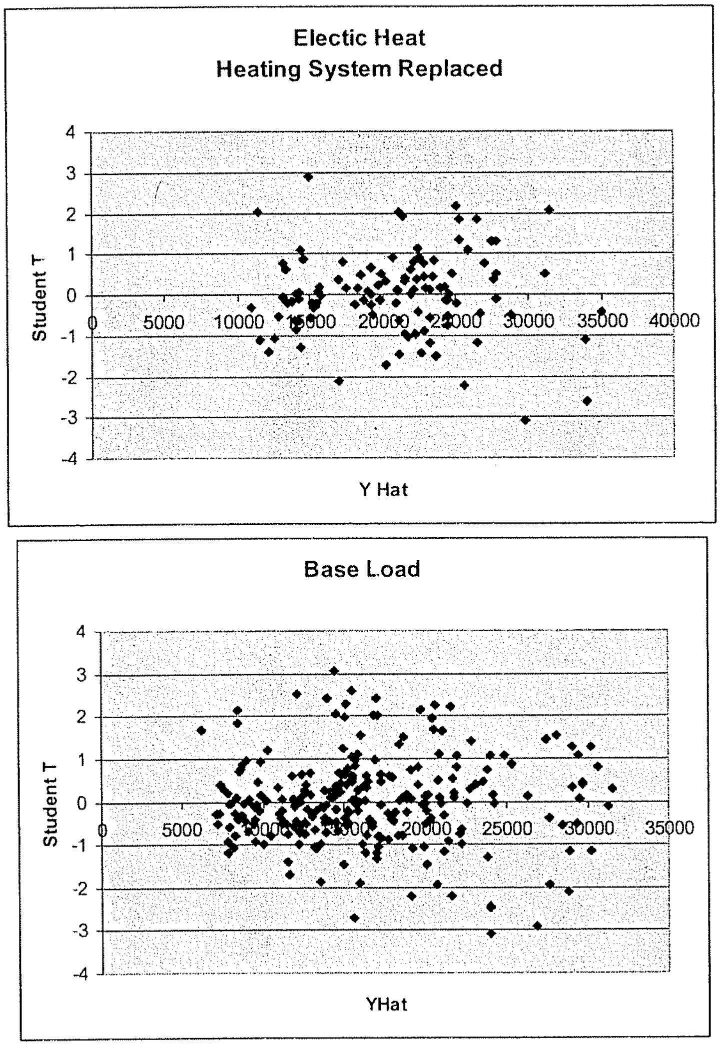


Figure 2 - Residual Plots

Figure 2 shows the residual plots of the error terms to the pre-installation NAC. In these figures, the residual for each participant and control group member is plotted on the vertical axis and that customer's pre-installation NAC is plotted on the horizontal axis. These figures do not strongly suggest that as the pre-installation NAC increases as does the variance (i.e., the spread) of the residuals, which would be typical of a heteroscedastic relationship.

When heteroscedasticity is present, the ordinary least squares (OLS) regression approach to establishing the relationship between the dependent variable, and the independent variables may be inappropriate. Accordingly, a WLS approach was applied to see what, if any effect that heteroscedastic was influencing the analysis. The initial WLS analysis was performed using the Simple Model described above. Families of weights based on the standardized geometric mean, raised to the gamma power were developed. In order to determine the optimal gamma, the Simple model was calculated for each of the weights. The model that minimized the mean squared error was chosen as the optimal model.

	Electric Heat	Electric Heat	Electric Heat Total	Base Load	Program Total
Heating System	**Replaced**	**Not Replaced**			
Pre Installation NAC (kWh)	20,091	20,900	20,703	15,891	19,142
Mean Savings (kWh)	(467)	1,605	1,101	553	923
Pct Savings	-2%	8%	5%	3%	5%

Table 11 - WLS Savings Estimates

Based on the WLS regression technique, the average savings were estimated. Table 11 shows the average savings estimates from the WLS model. Again, the savings estimates shown in this table are not statistically different from the PRISM results. However, the estimates are much less variable. The savings for the electric heating participants were 1,101 kWh/year per customer. This is a 5% reduction from the pre-installation NAC. The savings estimate for the base load customers was 553 kWh/year. This is 3% reduction from the pre-installation NAC.

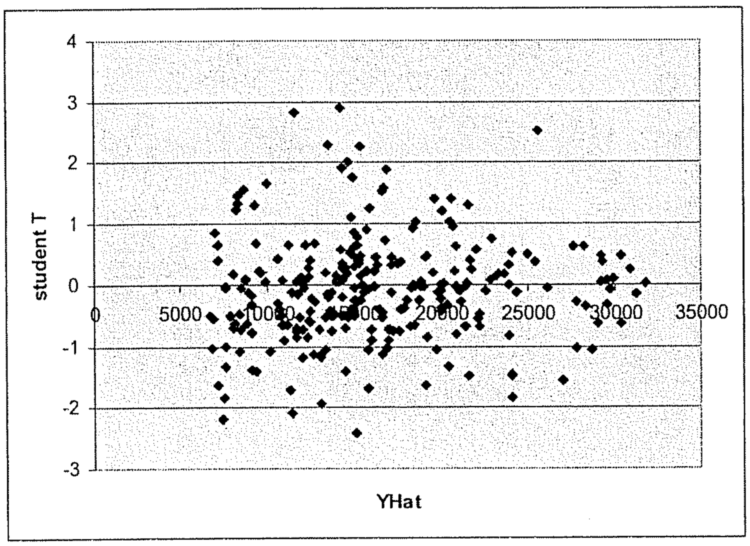


Figure 3 - Residual Plot-Weighted Least Squares Results

Figure 3 shows the residual plots for the WLS model. These plots show that the WLS approach has addressed the heteroscedasticity inherent in the data. Accordingly, it is appropriate to use WLS.

5.3 Analysis of the Effects of Heating System Replacement Measure

The inclusion of heating system replacements and heating repair work does not necessarily increase the program's electric energy savings benefits. The justification for this is that a repaired heating system would lead to increased reliance as the primary heating source. Similarly, the installation of a new heating system, may lead to higher customer consumption when alternative heating fuels were used, or the customer chose to increase their comfort level.

To investigate these hypotheses, the analysis of the 2003 program specifically was designed to determine the savings estimates for the electric heat customers that had a heating system replacement, and for the electric heat customers that did not have a heating replacement.

Twenty four (80) of the 2003 electric heat participants had a heat pump installed as their heating system replacement. Table 11 shows that the normalized savings reduction in bills for heating replacement customers was -467 kWh. However, the average reduction in bills for the non-heating replacement customers was 1,605 kWh. Accordingly, this suggests that the heating system replacement component of the program may decrease electric savings for the average participant receiving this measure.

Intuitively, the replacement of a heating system with a high efficiency heat pump would reduce the post-installation bills. However, the program implementers did report that many of the systems that were being replaced were inoperable. Accordingly, this would lead to an increase in post-installation bills and would not allow billing analysis to accurately determine the savings.

Accordingly, in 2002 an engineering analysis was performed to determine the expected savings of the installation of a heat pump, rather than a standard efficiency electric furnace. The methodology to estimate the savings can be found in Appendix A. The estimate assumed a heat pump installed in a 944 square foot home use 1,902 kWh annually less than a home with a standard efficiency furnace.

To leverage the engineering estimates of savings into the analysis, individual estimates of non-heating system replacement savings were made for each of the sites that had heat pump replacement engineering estimates of savings. This model estimate and the engineering estimate of savings were added together to determine an estimate of saving for each of these sites. For the heat pump replacement participants the average site total savings was 2,372 kWh/year.

To estimate the savings for all heating replacement customers, an assumption was made that the effect that was estimated for the heat pump participants was applicable to the other heating replacement customers. Accordingly, an adjustment factor was developed based on the heat pump participants to adjust the pre-NAC for all heating replacement customers.

	Electric Heat	Electric Heat	Electric Heat Total	Base Load	Program Total
Heating System	Replaced	Not Replaced			
Pre Installation NAC (kWh)	22,930	20,900	21,393	15,891	19,608
Mean Savings (kWh)	2,372	1,605	1,792	553	1,390
Pct Savings	10%	8%	8%	3%	7%

Table 12 - Restated Savings Estimates Incorporating Engineering Estimates

Table 12 presents the savings estimates incorporating the engineering estimate of the installation of a heat pump, plus the estimate of all other measures. This table shows that the estimate of savings for electric heat customers would be 1,792 kWh/Year. The average program participant savings is estimated at 1,390 kWh/year.

5.4 Summary of Analysis Results

Figure 4 shows a comparison of the savings estimates. Among the estimates based on billing analysis alone, the various procedures produced a range of point estimates of savings. However, the differences cannot be considered statistically significant. Among these estimates, the choice of the estimate that produces the most accurate estimate of program impact can be analytically determined. This "best" estimate of savings was determined by a review of the process to develop the estimates. The Augmented Comparison Approach (PRISM) produces unnecessarily large confidence intervals. The Simple Regression Approach produces valid estimates of savings, but violates some fundamental regression assumptions. The WLS regression model does not violate the basic regression assumptions, and contains only statistically significant variables. Therefore, the results based on this latter approach are used to define the most accurate estimate of savings.

However, as discussed in Section 5.3, the analysis of billing data alone obfuscates the full program impacts of customers that had non-functional or poorly functioning space conditioning systems. Accordingly, it is appropriate to incorporate additional information to obtain a more accurate estimate of program impacts.

Incorporating engineering estimates of savings with estimates of savings generated by the regression analysis provides the most accurate indication of program impact. The average program participant savings is estimated at 1,390 kWh/year.

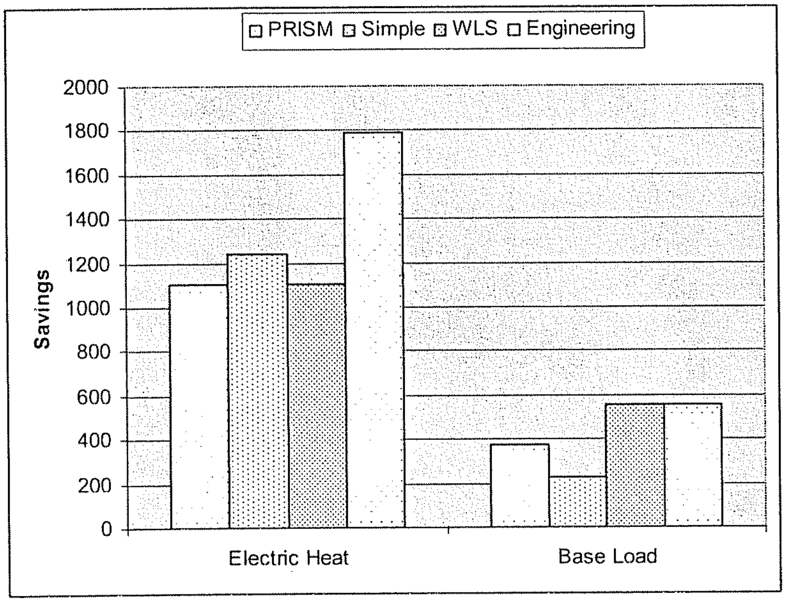


Figure 4 - Comparison of Savings Estimates

To determine the total annual impact of the program, the average per customer savings for each group (i.e., electric heat and base load) were multiplied by the number of customers in that group. Based on this analysis shows that, in total, the 2003-2004 TEE Program will save 678 MWH/year.

Appendix A Methodology

Methodology to Develop the Participant Analysis Group

The first step in the analysis of the TEE Program was to identify all participants that could contribute to the analysis. To this end, KPCo constructed a data set of all known participants' electric usage history. This data set contained information for 488 participants.

Once the billing data set was constructed it was examined, consisting of the following three steps:

- Merge billing data with site specific information.
- The first step eliminated records with unusually long or short number of days, bills with large or zero consumption, or any bill that was not within two years of the completion date.
- The next step limited the analysis to customers that had sufficient information during the pre and post installation periods. This included at least 275 days in each period, which consisted of at least 9 billing periods of information, having a minimum of 2 summer billing periods and 2 winter billing periods.

Methodology to Develop the Control Group

The Control Group for the TEE Program was developed following a four-step algorithm:

1. An appropriate pool of potential control group customers was established,
2. Criterion was developed to match control group pool customers to participants,
3. Known participants were eliminated from the control group pool, and
4. The control group pool customers were compared to each participant. Based on the established criteria, the best Control Group pool matches were selected.

Each of these steps is explained in detail below.

Step 1: The Establishment of a Control Group Pool

In order to develop a control group for the TEE Program, KPCo selected a large sample of LIHEAP customers. The customers in the Control Group Pool were examined, and if necessary, edited. This examination was consistent with the editing procedure applied to the participants.

Step 2: The Establishment of Control Group Matching Criteria

Based on the available information, criteria to match Control Group customers to specific participants were established. These criteria were based on annualized 2003 usage, as defined by Equation 1, pseudo summer load factor[3] and pseudo winter load factor, as defined by Equation 2.

[3] Typically a 'load factor' will describe a peak demand in relationship to an average demand for a period. Since demand information was not available, a proxy variable, the pseudo load factor, was used. The pseudo load factor describes the relationship between the average annual daily use and the average daily usage during the peak month.

$$AU = \frac{(\sum U_i)*365}{(\sum D_i)}$$

Where;

AU = Annualized Usage
U_i = Monthly Billed Consumption
D_i = Monthly Days in the Cycle

Equation 1 - The Calculation of Annualized Usage

$$LF = \frac{kWh_a}{(kWh_m)*12}$$

Where:

kWh_a = Annualized kWh
kWh_m = Peak Month Usage.

The pseudo summer load factor was based on the July bill. For the pseudo winter load factor, the monthly peak month usage was based on the January bill.

Equation 2 - The Calculation of Pseudo Load Factor

Step 3: Eliminating Known Participants

After the initial edits, any known current TEE Program participants were eliminated from the control group pool. This was done by matching the current participants against the Control Group Pool database.

Step 4: The Establishment of the Control Group

During this step, each control group pool customer was compared to each participant. For each control group pool customer within a given strata, the relative deviation in annualized usage was calculated using Equation 3.

$$ARD = \left(\frac{|U_c - U_p|}{U_p} \right) * 100$$

Where;
ARD = Absolute Relative Deviation
U_c = Annualized Usage for Potential Control Group Member
U_p = Annualized Usage for Participant

Equation 3 - The Determination of the Absolute Relative Deviation

For each participant, the ten control group pool customers with the smallest absolute relative deviation in the annualized usage was chosen for each participant. These ten control group matches were then examined further.

Based on the matching of the program participants, each selected control group member was assigned an installation date. This information was used to split the customers in the control group into pre- and post installation periods that are consistent with that of their matched participant.

Next, each member of the control group was checked to confirm that they had enough pre-installation and post installation billing data to be analyzed. This editing process was consistent with that applied to the participant group.

The best control group match was always chosen, and up to two others were chosen if the annual usage relative deviation was less than 10%. These customers were designated the Control Group.

The Control Group was chosen *with replacement*. Selecting a sample with replacement allows a customer to have the potential of being designated a Control Group member for more than one participant.

Temperature Normalization Methodology

The temperature normalization procedure used for this analysis is the *Princeton Scorekeeping Model* (PRISM) algorithm. Through years of experience, RLW has taken the fundamental concept of the PRISM methodology and refined it to produce more accurate estimates of normalized annual consumption (NAC).

The PRISM algorithm develops a mathematical model that represents the temperature to energy consumption relationship. The standard, Heating-Only version of this model is shown in Equation 4.

$$U_i = \alpha + \beta * DD_i(\tau) + e_i$$

Where;

U_i = average daily consumption in interval i.
$DD_i(\tau)$ = average degree days in interval i, based on reference temperature τ.
α,β = parameters to be estimated to minimize e.
e = a random error term.

Equation 4 - The PRISM Heating Only Model

The PRISM model reflects that a customer's energy usage is equal to some base level α, and a linear function between a reference temperature τ, and the outside temperature. The constant proportionality, β, represents a customer's effective heat-loss or heat-gain rate.

PRISM recognizes that each customer has unique space conditioning operating characteristics. To capture these unique space-conditioning characteristics, PRISM examines a range of heating and cooling reference temperatures. The model chosen to represent a customer's energy use is the model that best linearizes the relationship between usage and degree-days. For each customer, an optimal model based on a unique reference temperature (τ) is identified by the minimum mean squared error (MSE) of the regression.

Once the optimal parameters have been established, normalized annual consumption is estimated using Equation 5.

$$NAC=365*\alpha+\beta*DD_o(\tau)$$

Where:

DD_o is the number of degree days expected in a typical year.

Equation 5 - Determination of Normalized Annual Consumption (NAC) [4]

When this model is applied to a home's heating characteristics, it is referred to as the *heating only model* (HOM). When this model is applied to a home's cooling characteristics, it is referred to as the *cooling only model* (COM).

For the analysis of electric consumption data, it was not known whether or not the participants or control group members had significant space conditioning load. Therefore, the first adaptation of the PRISM methodology was to consider a *heating and cooling model* (HCM), along with the standard PRISM *heating only* or *cooling only models*. The expansion of the standard PRISM approach to consider heating and cooling loads is calculated using Equation 6.

[4] For a more comprehensive technical discussion of PRISM, see Impact Evaluation of Demand-Side Management Programs, Volume 1: A Guide to Current Practice, EPRI Report CU-7178,V1, pages 5-6.

$$U_i = \beta_0 + \beta_1 * HDD_i(\tau_1) + \beta_2 * CDD_i(\tau_2) + e_i$$

Where:

U_i	=	The electric usage during cycle i.
$HDD_i(\tau_1)$	=	The heating degree days based on reference temperature τ_1, during cycle i.
$CDD_i(\tau_2)$	=	The cooling degree days based on reference temperature τ_2, during cycle i.
β_i	=	The coefficients to be estimated to minimize the error term.
e_i	=	The error in predicting U.

Equation 6 - PRISM Heating and Cooling Model

As with the standard PRISM procedure, the optimal heating and cooling model is determined by calculating the regression models assuming various reference temperature values (τ_1 and τ_2). Expected annual degree-days are applied to the optimal model to calculate a normalized annual consumption (NAC). The results of the model can be interpreted as:

- β_o is an estimate of the average base load for a cycle;
- β_1 represents the heating slope, or the increase in electric usage for each incremental increase in heating degree days; and,
- β_2 represent the cooling slope, or the increase in electric usage for each incremental increase in cooling degree-days.

The standard PRISM approach uses usage and degree-day data on a billing cycle basis. However, the data has an inherent variability associated with the varying lengths of billing cycles. For the estimation of the heating and cooling slopes (β_1, and β_2) the effects of the varying lengths of the billing cycle are mitigated. This is a result of the number of degree-days being directly correlated to the number of days in the cycle. However, the estimates of base load (β_o) reflects the average base load per cycle and does not account for the days in the cycle. In effect, this estimate infers the base load will be β_o, regardless of the length of the cycle. Since base load usage is a function of time, this result may introduce a slight bias into the calculation. To eliminate this bias, the augmented PRISM approach uses usage per day as the dependent variable, and expresses the degree days on a per day basis.

The PRISM methodology assumes that there is a linear relationship between usage and temperature. However, if the assumption is not valid, it could lead to a violation of a basic regression assumption (i.e., the error terms are uncorrelated). To avoid any bias, two additional terms was considered in developing individual customer electric models. These terms are heating degree-days squared, and cooling degree-days squared. The incorporation of these variables result in Equation 7.

$$U_i = \beta_0 + \beta_1 * HDD_i(\tau_1) + \beta_2 * (HDD_i(\tau_1))^2 + \beta_3 * CDD_i(\tau_2) + \beta_4 * (CDD_i(\tau_2))^2 + e_i$$

Equation 7 - Electric PRISM Model, with Second Order Terms Incorporated

Alternative models, with different numbers of independent variables, introduce a challenge to choosing an optimal model. The standard PRISM approach relies on the maximization of R^2 to indicate the optimal model. However, in building mathematical regression models, the R^2 statistic has a tendency to increase as the number of independent variables increases. Therefore, when comparing models with different numbers of regressors, the maximum R^2 criteria may not lead to choosing the optimal model between alternative models. To avoid this possibility, an alternative method to determine the optimal model was used. The minimization of the mean squared error of the residuals (MS_E) is a good alternative. The MS_E accounts for the decrease in the degrees of freedom when an additional regressor is added to the equation. Therefore, the model that minimized the MS_E was chosen as the optimal model to represent the temperature versus usage relationship.

Lastly, in an effort to obtain the most accurate models possible, a system of re-analyzing poor performing models was developed. A "poor performing model" is defined as one that produced a low R^2 statistic.

The determination of the optimal model used a four-step approach. These steps are:

1) The optimal models are determined using all available data.
2) If the optimal model produced in Step 1 has a poor R^2, the usage data point with the largest prediction error was omitted. Using this trimmed and edited data set the models were re-estimated.
3) Choosing the optimal model for each customer from the first two steps, the customers with poor R^2 are again identified. For these customers, the usage data was limited to the most recent year of information. Using this trimmed data set, the models were re-estimated.
4) The models developed for each customer in each of the first three steps are compared. The optimal model (i.e., the model that minimizes RMSE) was chosen.

Normal temperatures were applied to the optimal models generated by this algorithm. The estimates produced are the Normalized Annual Consumption (NAC) for each period.

Energy Impact Analysis Methodology

In the evaluation of the TEE Program, the following two different methods were used. First, the energy impact was determined using an Augmented Comparison Method (PRISM). The second approach was a Regression Approach. This section discusses the methodology used to determine the energy impacts of the TEE Program.

The Augmented Comparison Approach

An augmented comparison approach controls for weather and other factors using a representative control group and simple equations. After the normalization of the participant and control group bills (see Temperature Normalization Methodology), the difference between the pre-program and post-program NACs were used to determine the raw energy savings that can be attributed to the program. The determination of energy savings is calculated using Equation 8.

$$S_{raw} = NAC_{Pre\text{-}Program} - NAC_{Post\text{-}Program}$$

Equation 8 - The Augmented Comparison Approach Determination of Gross Savings

To account for exogenous influences, the raw savings expressed in can be adjusted by using a representative control group. If it is assumed that the same outside influences are affecting both the control and participant groups, then the adjustment will yield an estimate of energy savings that are isolated from all other influences. Determining the pre- and post-program NACs for both the participant and control groups makes this adjustment. The estimated savings are calculated by adjusting the participant results by the Control Group results. This adjustment is shown in Equation 9.

$$S_{adjusted} = NAC_{pre-program}(P_i) * \frac{NAC_{Post-Program}(C_i)}{NAC_{Pre-Program}(C_i)} - NAC_{post\,Program}(P_i)$$

Where:

C_i = The average of control group members associated with participant *i*.
P_i = Participant *i*.

Equation 9 - The Augmented Comparison Approach, Determination of Net Savings

While this method is simple, it can obscure real program effects and usually produces a high variability around the estimate.

The Regression Approach

The regression approach was performed using a comprehensive and systematic approach. This approach, presented below, has been applied with great success to the analysis of conservation programs.

The regression approach consisted of four steps that result in the selection of an optimal model that accurately quantifies the program impact. This sub-section describes the four steps of the regression approach.

Step 1: The Simple Model

During this step an initial regression model is developed using ordinary least squares ("OLS"). This simple model determined the effect of *one* important change variable (i.e., the participation indicator variable status, or the participants engineering estimate of savings) on energy savings *while controlling for all other changes*. The basic form of this model is shown in Equation 10.

$$NAC_{post,i} = \beta_0 + \beta_1 NAC_{Pre,i} + \beta_2 P_i + \varepsilon_i$$

Where:

$NAC_{post,i}$ = Post Installation Normalized Annualized Consumption for customer i
$NAC_{pre,i}$ = Pre Installation Normalized Annualized Consumption for customer i
P_i = Participation Indicator Variable or Engineering Estimate of Savings
ε_i = Prediction error

Equation 10 - The Simple Regression Model

Step 2: Regression Diagnostics

As a result of the residual standard deviation related to the size of the customer's energy usage, one regression assumption most often violated is that the standard deviation of the error terms, (or "residuals") is not constant across the range of predicted values. When the standard deviation residuals are related to the predicted values, the model is said to be "heteroscedastic." Heteroscedasticity can often be detected in cross sectional models used to analyze program impacts. During this step, verification that the regression assumptions are valid is performed. If the initial regression model is found to be "heteroscedastic" further regression analyses are performed. These analyses are performed using a weighted least squares ("WLS") approach.

Step 3: Weighted Least Squares

As discussed above, one of the fundamental regression assumptions is that the standard deviation of the error terms (or residuals) has a constant variance across the range of predicted values. When the residuals are related to the predicted values, the model is said to be heteroscedastic. Heteroscedasticity is a violation of one of the basic regression assumptions and could result in the miss-specification of mathematical relationships. As a result of the residual standard deviation being related to the size of the customer's energy usage, heteroscedasticity is often detected in cross sectional models used to analyze program impact.

When heteroscedasticity is present, an ordinary least squares (OLS) approach to establishing the relationship between the dependent and independent variables may be inappropriate. An OLS approach that does not correct for the heteroscedastic relationship of its residuals will yield confidence intervals[5] that are misleading. More specifically, when heteroscedasticity is present, the

[5] Even though it is the best possible estimate given the data, it is unlikely that the point estimate will exactly equal the true, unknown parameter being estimated. Accordingly, instead of using a single value to

OLS regression coefficients are unbiased estimates of the true parameters, but they are subject to greater statistical variation than the appropriate estimates. Moreover, the standard errors produced by the OLS regression analysis are biased estimates of the true standard deviations of the regression coefficients.

Weighted least squares (WLS) is one approach to correct for heteroscedasticity in regression analysis. According to econometric theory, the advantages of WLS are:

a) Under a properly specified heteroscedastic model, WLS yields the best linear unbiased estimates of the true parameters and,
b) WLS gives an unbiased estimate of the variance of the estimators, providing appropriate confidence intervals and p-values.

In other words, WLS provides the most reliable estimate of savings and an accurate measure of the resulting reliability. The theory of WLS depends on a correct specification of the heteroscedasticity. The theory assumes that a positive-valued variable can be specified, say z, such that the residual standard deviation is proportional to z. Usually, z is taken to be some measure of size (for example, the pre-retrofit NAC consumption).

The benefits of WLS depend on the correct choice of z. Therefore, it is useful to have a way of comparing alternative candidates for z. If it can be confirmed that heteroscedasticity is present, the following procedure[6] is employed:

1. Postulate a family of possible candidates for z. In the following analysis, the regression has been estimated assuming that the residual standard deviation is proportional to pre-retrofit NAC dampened by raising this variable to some power between 0 and 1. This variable will be termed $(NAC_{Pre})^{\gamma}$, where $\gamma \geq 0$. Here the exponent, gamma, is an unknown parameter that creates a family of candidate choices of z.

2. For each candidate of z, geometrically standardize z by dividing each value of z by the geometric mean of the n sample values of z. The geometric mean is the n^{th} root of the product of the n values of z.

3. Fit the regression model using WLS with each geometrically standardized z, and calculate the root mean square error (RMSE) of each regression model.

estimate the true, unknown value, it is common to use a set of values or a *confidence interval*. A confidence interval is a range of values between which we can define a statistical probability, based on the estimate variability that the true value will fall. Generally, the higher the probability, the wider the confidence interval. Usually, the confidence interval is stated in terms of the probability that the true value will fall within plus or minus the interval around the point estimate. For example, given a 90% confidence level (the probability), the true mean will fall within ± 5% of the estimated mean.

[6] The justification for this approach is from the statistical theory of maximum likelihood estimation. Although the WLS is different, the mathematical derivation of the methodology is the same as used by Box and Cox in their paper An Analysis of Transformations, (Journal of the Royal Statistical Society, Series B, 1964). A good summary of the approach is given in the text *Econometrics,* by G.S. Maddala, McGraw-Hill, 1977, pp. 315-317. J. Kmenta gives a similar methodology in Elements of Econometrics, to deal with autoregression in time series analysis.

4. Minimize the RMSE to find the best choice of z and use this particular WLS regression to obtain the best estimate of savings.

During this step, a residual analysis is performed. If heteroscedasticity is suspected, the models are estimated using WLS.

Step 4: Calculation of Energy Savings

The final step in the analysis estimates the energy savings by using the resultant models.

Engineering Estimate of Heating Replacement Methodology

For electric furnace to heat pump conversions, the engineering estimate of savings is based on the ASHRAE simplified energy formula method[7].

First the heat loss is calculated using the following formula:

$$HL = UA(T_i - T_o)$$

Where:

HL	= the component heat loss, Btu/hr
U	= the overall heat transfer coefficient, Btu/(hr-ft^2-^{0}F)
A	= the area of the component, ft^2
T_i	= the indoor temperature, ^{0}F
T_o	= the outdoor temperature, ^{0}F

The building heat loss (HL) is then input into the following formulas:

$$\text{Annual Electric Furnace}_{kWh} = \frac{(24 \text{ X HL X HDD X } C_d)}{(Ti\text{-}To) \text{ X } 3{,}413}$$

$$\text{Annual Heat Pump}_{kWh} = \frac{(24 \text{ X HL X HDD})}{((Ti\text{-}To) \text{ X } 1000 \text{ X HSPF})}$$

Where:

HDD	= 4,555 (mean average of Ashland and Williamsburg)
C_d	= 0.65
(Ti-To)	= 70 ^{0}F (assumption)
HSPF	= Heating Seasonal Performance Factor (@47 ^{0}F)

Savings for the heat pump retrofit is determined by the following formula:

$$\text{Savings}_{kWh} = \text{Electric Furnace}_{kWh} - \text{Heat Pump}_{kWh}$$

[7] ASHRAE Handbook, 1993 Fundamentals, Chapter 22, Table 10.

Appendix B Temperature Normalization Results Details

The original simple model approach (i.e., Step 1, all available data) was the most accurate for each group and used for this evaluation. None of the periods were improved by the alternative methods listed in (Steps 2 and 3).

As detailed in Appendix A Temperature Normalization Methodology, four variables were considered for the electric models. Heating and cooling degree-days were considered. Figure 5 shows that for the participants, models that featured the heating and cooling PRISM models were chosen nearly 70% of the time. The distribution of the type of models is fairly consistent from period to period and within customer groups. This suggests the models are stable across time and that the control group is well matched to the participant group.

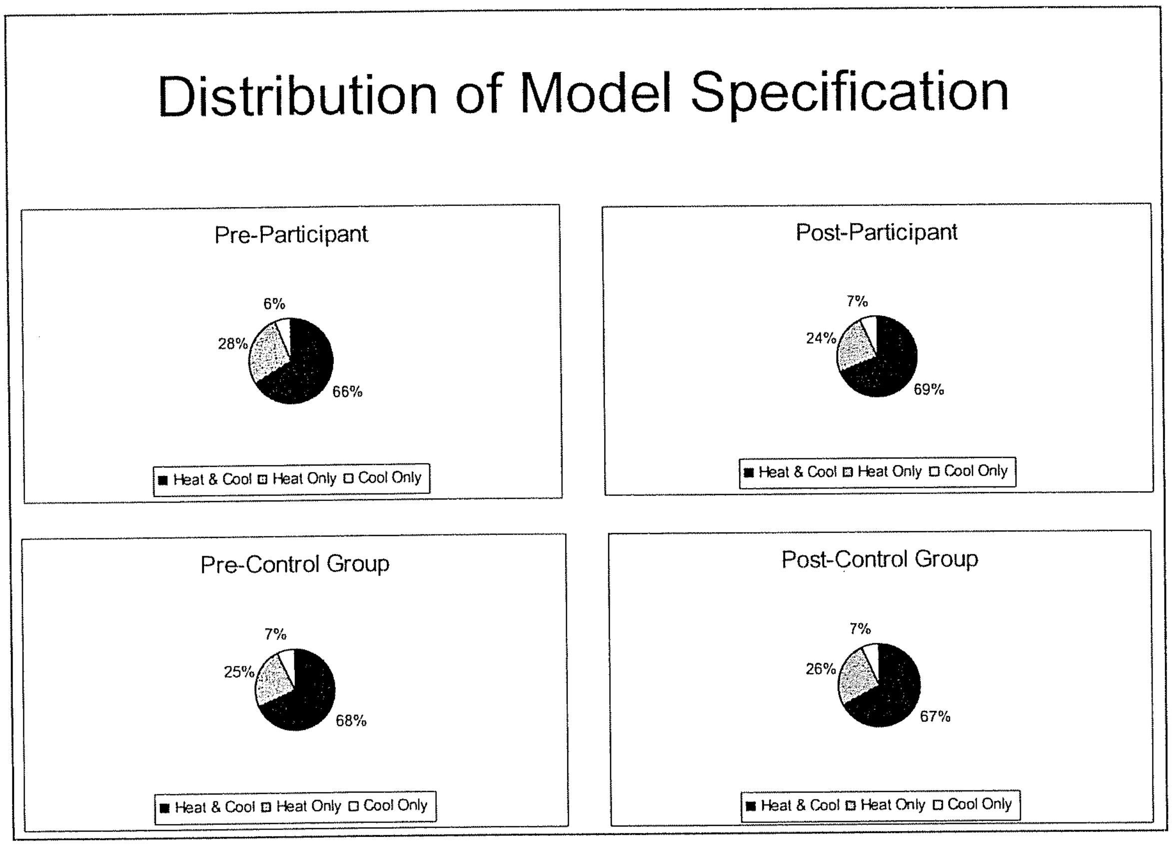


Figure 5 – Distribution of Model Specification

Table 13 compares the distribution of set points for the degree-day variables. For the participants, the median heating degree-day reference point was 61°F in the pre- and 60°F in the post-installation periods. For the control group, the median heating degree-day reference point was 60°F in the pre-and 60°F in the post-installation period. For the participants, the median cooling degree-day reference point was 68°F in the pre- and 67°F in the post-installation periods. For the control group, the median cooling degree-day reference point was 67°F in the pre-and 67°F in the post-installation period. The distribution points of both groups are strikingly similar. This reinforces the conclusion that the models are stable across time and that the control group is well matched to the participant group.

	Heating Degree Day Reference Temperatures			
	Pre-Installation		Post-Installation	
Statistics	Participant	Control Group	Participant	Control Group
Maximum	74	74	74	74
75th Percentile	65	64	64	64
Median	61	60	60	60
Mean	60	60	60	59
25th Percentile	54	54	55	54
Minimum	50	50	50	50
	Cooling Degree Day Reference Temperatures			
	Pre-Installation		Post-Installation	
Statistics	Participant	Control Group	Participant	Control Group
Maximum	75	75	75	75
75th Percentile	71	71	73	71
Median	68	67	67	67
Mean	67	67	68	67
25th Percentile	64	63	64	62
Minimum	60	60	60	60

Table 13 – Distribution of Degree-Day Set Points

Table 14 shows the distribution of the R^2 statistics. For the participants and the control group, about half the models had R^2 over 90%. Again, the distribution of R^2 for each group in each period is very similar, supporting the conclusion that the models are stable across time and that the control group is well matched to the participant group.

	Pre-Installation		Post-Installation	
Statistics	Participant	Control Group	Participant	Control Group
Maximum	100%	100%	100%	100%
75th Percentile	95%	96%	98%	97%
Median	88%	90%	91%	93%
Mean	76%	80%	79%	87%
25th Percentile	61%	73%	69%	84%
Minimum	2%	0%	1%	0%

Table 14 – Distribution of R-Squared Statistics for the Electric Models

KENTUCKY POWER COMPANY
2004 TARGETED ENERGY EFFICIENCY PROGRAM

2004 ENGINEERING ESTIMATION

Final Report

June 28, 2005

Prepared for:

American Electric Power
1701 Central Avenue
P.O. Box 1428
Ashland, KY 41105-1428

Prepared By:

RLW Analytics, Inc.
2 Hyde Road
Clark Lake, MI 49234
(517) 529-6277

KENTUCKY POWER COMPANY
TARGETED ENERGY EFFICIENCY PROGRAM
2004 ENGINEERING EVALUATION

Table of Contents

List of Tables

1 Introduction

This report presents the 2004 Engineering Evaluation of Kentucky Power Company ('KPCo') Targeted Energy Efficiency Program ('TEE Program'). The TEE Program is designed to perform energy audits, provide energy education to all households, perform blower door tests and install extensive weatherization and energy conservation measures to low income customers living within the KPCo service territory. The TEE Program is a "piggyback" program leveraging the resources of five not-for-profit agencies including:

1. Big Sandy Community Action Agency
2. Gateway Community Action Council
3. LKLP Community Action Council
4. Middle Kentucky River Area Development Council
5. Northeast Kentucky Area Development Council

These five agencies provide weatherization services to low-income customers via the existing Weatherization Assistance Program. This program is offered to electric heat and non-electric heat customers.

The primary objective of this evaluation was to quantify the savings for the 2004 program year. For this evaluation, engineering estimation was used to estimate 2004 program impacts. Engineering calculations provide energy savings estimates at the measure, project, and program levels.

Simple accounting of program activity from a tracking system typically represents the first level of impact evaluation for DSM programs. To enhance the accounting approach, engineering estimates can be developed through using the information contained in the program's tracking information. Engineering analyses offer reliable means for estimating program impacts at very low costs.

For the engineering analysis component of the evaluation, individual estimates were developed based on the information contained in the data collection forms recorded at the time of measure installation.

The engineering analysis was performed by major end-use measure category. These categories included:

1. Lighting measures
    - CFL Light bulbs
2. Air infiltration measures,
3. Insulation measures
    - Attic Insulation
    - Wall Insulation
    - Floor Insulation
4. Heating system replacements,
5. Domestic hot water measures
    - Low-flow showerhead installation
    - Hot water heater tank wrap installation
    - Hot water heater temperature reduction

- Hot water pipe insulation

6. Water bed covers.

The following sections discuss the engineering estimation approach for each measure and provide estimates of savings based on information contained in the data collection forms. It is important to note that no interactive savings effects are calculated.

2 Lighting Savings

The engineering estimation of annual lighting energy savings is as follows:

$$\text{Annual kWh savings} = (\Delta\text{Watts x Hours}) / 1000$$

This algorithm is a straightforward and simple calculation, with the proper inputs for the wattage reduction and hours of use taken from the data collection forms.

2.1 Tracking Estimate of Savings for Lighting

Lighting measures were installed in 81 base load and 161 electric heat participants. An additional bulb was installed in all of the base load and electric heat participants. The average wattage reduction was calculated to be 62.4 watts for the first bulb and 61.6 watts for the second bulb. The average hours of use for the first bulb was estimated to be 8.4 hours and 7.6 hours for the second bulb. This yields an average savings of 200 kWh for the first bulb and 176 kWh for the second bulb. In aggregate, the total annual savings associated with lighting measures were calculated to be 90,871 kWh. This yields overall average savings per participant of 376 kWh.

Table 1 shows the lighting tracking estimates of savings for installations done in 2004 through the TEE Program.

Customer Type	Average Wattage Reduction Bulb 1	Average Daily Hours of Use Bulb 1	Average Wattage Reduction Bulb 2	Average Daily Hours of Use Bulb 2	Total Savings for CFL Installations (kWh)	Average Savings Per Customer for CFL Installations (kWh)
Electric Heat	62.7	9.0	62.0	7.9	64,524	401
Non-Electric Heat	61.7	7.3	60.6	7.0	26,347	325
Combined	62.4	8.4	61.6	7.6	90,871	376

Table 1: Lighting Savings Estimates

3 Air Sealing

To develop the engineering savings associated with air sealing measures we calculate the reduction in heat loss, in BTU/hr, due to infiltration using the following equation:

$$H_L = V \times \Delta T \times C_P$$

In this equation, V is the volume of outdoor air entering the building in cubic feet per hour, ΔT is an assumed temperature difference of 70 °F between the inside and outside of the heated space, and C_p is the specific heat of air which is 0.018 BTU/ft^3-°F. The result is applied to the following equation to calculate the kWh savings per year:

Electric Resistance Heating Systems:

$$\text{Annual kWh} = \frac{H_L \text{ X HDD X } C_D \text{ X } 24}{3,413}$$

In this equation, HDD is the amount of heating degree-days, which varies by location. C_D is an empirical correction factor for the degree-day estimate, H_L is the building heat loss, and 24 hrs/day and 3413 BTU/kWh are conversion factors.

Assumptions:

HDD = 4,555 (Avg. mean of Ashland and Williamsburg)
C_D = 0.65 (from ASHRAE Handbook 1985 Fundamentals)

3.1 Tracking Estimate of Savings for Air Sealing

Infiltration measures were installed in 156 of the electric heat participant homes. In aggregate, the total annual energy savings associated with sealing measures were calculated to be 269,260 kWh. This yields overall average savings of 1,726 kWh per tracking system participant.

4 Insulation

To calculate the engineering estimate of savings associated with insulation measures we use the reduction of heat loss, in kWh per year, due to insulation:

Electric Resistance Heating Systems:

$$\text{Annual kWh} = \left(\frac{1}{R_{old}} - \frac{1}{R_{new}}\right) \text{X} \frac{\text{HDD X } C_D \text{ X A X } 24}{3413}.$$

In this equation, R_{old} and R_{new} are the total thermal resistance values, or R-values, for the surface in question both before and after the installation of the insulation. HDD is the amount of heating degree days, C_D is an empirical correction factor for the degree day estimate, A is the surface area, and 24 hrs/day and 3413 BTU/kWh are conversion factors.

Assumptions:

HDD = 4,555 (Avg. mean of Ashland and Williamsburg)
C_D = 0.65 (from ASHRAE Handbook 1985 Fundamentals)

4.1 Tracking Estimate of Savings for Insulation Measures

Approximately 170,838 ft^2 of insulation was installed in the electric participant homes, 81,840 ft^2 in the floor, 3,241 ft^2 in walls, and 85,757 ft^2 in the attic area. In aggregate, the total annual energy savings associated with insulation measures were calculated to be 481,591 kWh. Average savings per participant for attic areas were 1,973 kWh, walls were 1,924 kWh, and floors were 3,107 kWh.

Table 2 shows the insulated area square footage and savings estimates for the attic, wall and floor insulation measures that were installed in 2004 through the TEE program.

Area	Insulated Area (ft^2)	Total Savings (kWh)	Average Savings Per Home (kWh)
Attic	85,757	183,455	1,973
Walls	3,241	15,396	1,924
Floors	81,840	282,740	3,107
Total	170,838	481,591	3,391

Table 2: Insulation Savings Estimates

5 Domestic Hot Water

5.1 Water Heater Tank Wrap

Engineering estimates for the water heater tank wrap are based on the reduction of heat loss through the walls of the water heater. Standby losses are calculated using the heat transfer coefficient (U-value) of the tank before and after the installation of the insulating wrap, the outer surface area of the tank, and the temperature difference between the water and the outside of the tank. Also, water heater recovery efficiency is incorporated into the equation resulting in the following form:

$$TWSavings = \frac{(U_{pre} - U_{post}) \times (T_{hw} - T_{env}) \times tnkarea \times 8760}{EFF_r \times 3413}$$

Where:

TWSavings = annual energy savings due to tank wrap installation in kWh;
U_{pre} = U-value of tank wall prior to wrap (Btu / hr-ft^2-°F);
U_{post} = U-value of tank wall after installation of wrap (Btu / hr-ft^2-°F);
T_{hw} = measured hot water temperature in °F;
T_{env} = average annual temperature outside of the tank,
58 °F if in unconditioned space,
72°F if in conditioned space;
tnkarea = insulated surface area of tank in ft^2;
8760 = number of hours per year;
EFF_r = water heater recovery efficiency,
.98 for electric water heaters,
1.8 for heat pump water heaters;
3413 = conversion factor Btu/kWh.

5.1.1 Tracking Estimate Savings for Tank Wraps

An insulation tank wrap was installed on 30 base load and 111 electric heat participants'. In aggregate, the total annual energy savings associated with tank wrap installations were calculated to be 15,668 kWh. This yields overall average savings per tracking system participant of 111 kWh.

5.2 Hot Water Temperature Turndown

RLW estimates this measure's savings by combining two of the model elements previously described to estimate annual hot water usage in the home and annual standby losses from the hot water heater before and after temperature turndown. The difference between these two estimates provides the savings value from our analysis.

Annual hot water usage for each household is estimated using the LBL model described for the pipe insulation measure presented below. This method predicts average daily hot water usage by household, based on the number of occupants, the age distribution of the occupants, the hot water using appliances present in the home, and whether or not the occupants pay for their hot water usage. Since this model contained hot water temperature as a term in the equation, it is applied twice using the temperature before and after turndown to derive an estimate of daily (and annual) hot water usage in the household.

Annual energy use due to standby losses is calculated using the equation utilized to estimate savings for the water heater tank wrap measure, but using the difference in temperature values associated with the temperature turndown instead of the difference in U-value associated with the tank wrap.

The resulting equation used to estimate savings from the temperature turndown measure is as follows:

$$TTSavings = \frac{1}{EFF_r \times 3413} \times \left\{ \begin{matrix} \left\{ 365 \times M_w \times Cp_w \times \left[\begin{matrix} (HWUse_{bt} \times (T_{bt} - T_{cw})) \\ -(HWUse_{at} - (T_{at} - T_{cw})) \end{matrix} \right] \right\} \\ + \{ U_{tank} \times tnkarea \times 8760 \times (T_{bt} - T_{at}) \} \end{matrix} \right\}$$

Where:

TTSavings	= annual energy savings due to hot water temperature turndown in kWh;
EFFr	= water heater recovery efficiency, .98 for electric water heaters, 1.8 for heat pump water heaters;
3413	= conversion factor Btu/kWh;
365	= 365 days per year;
M_w	= mass of water, or 8.33 lbm/gallon;
Cp_w	= specific heat of water, or 1.0 Btu/lbm. °F;
$HWUse_{bt}$	= daily hot water use before temperature turndown in gallons;
$HWUse_{at}$	= daily hot water use after temperature turndown in gallons;
T_{bt}	= hot water temperature before turndown in °F;
T_{at}	= hot water temperature after turndown in °F;
T_{cw}	= average water heater inlet, or cold water temperature, (55 °F);
U_{tank}	= hot water tank U-value (Btu/hr. ft^2. °F);
tnkarea	= surface area of tank in ft^2.

5.2.1 Tracking Estimate of Savings for Hot Water Temperature Reduction

The hot water temperature was turned down in 17 base load and 56 electric heat participants. The average temperature reduction was 5.6°F. In aggregate, the total annual energy savings associated with hot water temperature reduction were calculated to be 39,969 kWh. This yields overall average savings per participant of 548 kWh.

5.3 Low-Flow Showerheads

RLW applies a formula that accounts for the number of showers per day, shower duration, flow reduction, and the temperature difference between the supply water temperature and the estimated shower temperature for the summer and winter periods. This formula is shown below:

$$SHSavings = \sum_{seas} \frac{Shwrd \times NShwrs \times Wk_{seas} \times 7 \times \Delta flow \times M_w \times Cp_w \times \Delta T \times HWPct_{seas}}{EFF_r \times 3413}$$

Where:

SHSavings	= annual Energy Savings due to low flow showerheads in kWh;
seas	= season of the year (summer and winter);
Shwrd	= shower duration in minutes per shower, or 7.4[1];
NShwrs	= number of showers per day, equal to the number of occupants above age 6;
Wk_{seas}	= number of weeks per season equal to 26 each for summer and winter;
7	= number of days per week;
Δflow	= change in flow due to showerhead installation in gallons/minute, or 0.7[1];
M_w	= mass of water, or 8.33 lbm/gallon;
Cp_w	= specific heat of water, or 1.0 Btu/lbm. °F;
ΔT	= temperature difference between hot water and cold water (T_{hw} – 55 °F) with T_{hw} as measured on site;
HWPct	= percentage of shower water which is hot water by season (shown below);
EFFr	= water Heater Recovery Efficiency, .98 for electric water heaters, 1.8 for heat pump water heaters;
3413	= conversion factor Btu/kWh.

$$HWPct_{seas} = \frac{T_{shower,seas} - T_{cw}}{T_{hw} - T_{cw}}$$

Where:

$T_{shower,seas}$	= shower temperature per season, 110 °F for the winter, 100 °F for the summer;
T_{cw}	= cold water temperature, or 55 °F;
T_{hw}	= hot water temperature (measured) °F.

If T_{hw} as measured < $_{Tshower}$, then HWPct = 1

[1] From ACEEE *1994 Summer Study on Energy Efficiency in Buildings*, p. 8.91

5.3.1 Tracking Estimate of Savings for Low-Flow Showerheads

Low-Flow showerheads were installed at a total of 57 base load and 156 electric heat participant households. In aggregate, the total annual energy savings associated with low-flow showerhead installations were estimated to be 191,815 kWh. This yields overall average savings per participant of 901 kWh.

5.4 Pipe Insulation

RLW employs a model which predicts average daily hot water usage by household, based on the number of occupants, the age distribution of the occupants, the hot water using appliances present in the home, and whether or not the occupants pay for their hot water usage. This model was obtained from recent work conducted at LBL[2] and can be applied using actual data for individual homes gathered from the program tracking data and from the on-site visits. The model used is the simplified equation presented in the LBL report and is employed as follows:

$$HWuse = F_{pay} \times F_{sr} \times \left\{ \begin{array}{l} -1.78 + .9744 \times Nocc + 6.3933 \times age1 + 10.5178 \times age2 \\ +15.3052 \times age3 - 0.1277 \times T_{hw} + 0.1437 \times tnkvol \\ -0.1794 \times T_{cw} + 0.5115 \times T_{oa} + 10.2191 \times Occd \\ -dwp\left(0.692 \times Nocc + 1.335 \times \sqrt{Nocc}\right) \\ -cwp\left(1.1688 \times Nocc + 4.7737 \times \sqrt{Nocc}\right) \end{array} \right\}$$

Where:

HWuse	= average daily hot water usage (gallons/day);
F_{pay}	= 1.0 if customer pays for their hot water, 1.3625 if not;
F_{sr}	= 0.3790 if senior only household (all occupants above age 65), 1.0 if not;
Nocc	= total number of occupants in the home;
age1	= number of preschool children (0-5 yrs);
age2	= number of primary and jr. high school age children (6-13 yrs);
age3	= number of high school age children and adults (14 yrs and over);
T_{hw}	= hot water temperature in °F;
tnkvol	= water heater tank size in gallons;
T_{cw}	= average water heater inlet, or cold water temperature, (55 °F);
T_{oa}	= average annual outdoor air temperature, (°F), average value of 58 °F used, based on typical year weather data for the KPCo service areas;
Occd	= presence of adults at home during the day, 1 if yes, 0 if no;
dwp	= presence of dishwasher in the home, 0 if yes, 1 if no;
cwp	= presence of clothes washer in the home, 0 if yes, 1 if no.

To estimate the savings due to the addition of pipe insulation, additional information is needed regarding the size and length of the insulated hot water piping and the flow rate in the pipe. The information on the pipe size and length can be obtained from the tracking and on-site data. The

[2] Modeling Patterns of Hot Water Use in Households, J. Lutz, et. al., Lawrence Berkeley Laboratory, LBL-37 05, November, 1996.

flow rate in the pipes is assumed to be 2.0 gallons per minute, which is then used to calculate the number of hours per year that the hot water is flowing in the pipes as follows:

$$Hours = \frac{HWuse \times 365}{gpm \times 60}$$

Where:

Hours	= hours per year that hot water flows in the pipe;
gpm	= hot water flow rate in the pipe, (2 gallons/minute);
365	= 365 days per year;
60	= 60 minutes per hour.

The number of hours is used in conjunction with the insulation properties and the difference in temperature between the hot water and the surroundings to calculate the annual savings, using the following formula:

$$PISavings = \frac{IPL \times Hours}{EFF_r \times 3413} \times \left(16 - \frac{k_{ins} \times OA_{ins} \times (T_{hw} - T_{env})}{OR_{ins} \times \ln\left(\frac{OR_{ins}}{IR_{ins}}\right)} \right)$$

Where:

PISavings	= annual energy savings due to pipe insulation in kWh;
IPL	= insulated pipe length in feet;
16	= typical heat loss per foot of un-insulated copper pipe, Btu/hr. ft;
K_{ins}	= thermal conductivity of rubber rigid foamed insulation used to insulate the pipe, (.215 Btu . in/hr . ft² . °F)[3];
OA_{ins}	= outside surface area of the pipe insulation per foot of pipe length in ft²;
T_{hw}	= measured hot water temperature in °F;
T_{env}	= annual average temperature outside of the pipe, 58 °F if in unconditioned space, 72°F if in conditioned space;
OR_{ins}	= outside radius of the insulation in inches;
IR_{ins}	= inside radius of the insulation (outside radius of the hot water pipe) in inches;
EFFr	= water heater recovery efficiency, .98 for electric water heaters, 1.8 for heat pump water heaters;
3413	= conversion factor Btu/kWh.

This number is then doubled to account for the standby losses.

5.4.1 Tracking Estimate of Savings for Pipe Insulation

The formula above was used to obtain pipe insulation savings estimates. Pipe insulation was installed on 404 linear feet for base load and 1,282 feet for electric heat participants. In aggregate, the total energy savings associated with pipe insulation installation for the tracking

[3] *ASHRAE Handbook, 1993 Fundamentals*, Chapter 22, Table 10.

system were calculated to be 1,494 kWh, or 0.9 kWh per linear foot of insulation. This yields overall average savings per participant of 8.6 kWh.

Table 3 shows the number of participants and savings estimates for the domestic hot water measures that were installed in 2004 through the TEE program.

Hot Water Measure	# of Baseload Participants	# Electric Heat Participants	Total Baseload Savings (kWh)	Average Baseload Savings (kWh)	Total Electric Heat Savings (kWh)	Average Electric Heat Savings (kWh)	Total Measure Savings (kWh)	Average Measure Savings (kWh)
Hot Water Tank Wrap	30	111	3,450	115	12,218	110	15,668	111
Temp. Reduction	17	56	11,219	660	28,749	513	39,969	548
Low-Flow Showerhead	57	156	51,331	901	140,484	901	191,815	901
Pipe Insulation	41	132	372	9	1,122	8	1,494	9
Total Water Savings			66,372	1,054	182,573	1,087	248,945	

Table 3: Water Savings Measures Estimates

6 Heat Pump Installations

For electric furnace to heat pump conversions, the engineering estimate of savings is based on the ASHRAE simplified energy formula method.

First the heat loss is calculated using the following formula:

$$HL = UA(T_i - T_o)$$

Where:

HL	= the component heat loss, Btu/hr
U	= the overall heat transfer coefficient, Btu/(hr-ft^2-^{0}F)
A	= the area of the component, ft^2
T_i	= the indoor temperature, ^{0}F
T_o	= the outdoor temperature, ^{0}F

The building heat loss (HL) is then input into the following formulas:

$$\text{Annual Electric Furnace}_{kWh} = \frac{(24 \times HL \times HDD \times C_d)}{(Ti\text{-}To) \times 3{,}413}$$

$$\text{Annual Heat Pump}_{kWh} = \frac{(24 \times HL \times HDD)}{((Ti\text{-}To) \times 1000 \times HSPF)}$$

Where:

HDD	= 4,555 (mean average of Ashland and Williamsburg)
C_d	= 0.65
(Ti-To)	= 70 ^{0}F (assumption)
HSPF	= Heating Seasonal Performance Factor (@47 ^{0}F)

Savings for the heat pump retrofit is determined by the following formula:

$$Savings_{kWh} = Electric\ Furnace_{kWh} - Heat\ Pump_{kWh}$$

6.1.1 Tracking Estimate of Savings for Heat Pump Installations

The formulas above were used to determine heat pump savings estimates. There were twenty-five 2004 participants that received a new heat pump unit. Based on the assumption that these heat pumps have taken the place of electric furnaces the total annual energy savings associated with heat pump installations was calculated to be 47,173 kWh, for an average of 1,887 kWh per installed heat pump.

7 Waterbed Covers

For waterbed covers, the engineering estimate can be based on a savings fraction of 65% of total waterbed heater energy use, using an average Unit Energy Consumption (UEC) based on the size of the water bed.[4,5] Estimates of savings per waterbed size category are shown in Table 4.

Waterbed Size	UEC w/o foam cover kWh/yr	Savings Fraction (%))	UEC w/ foam cover kWh/yr	Estimated Savings kWh/yr
Single-Small	700	65%	245	455
Queen-Medium	850	65%	298	553
King-Large	1,000	65%	350	650

Table 4: Waterbed Cover Savings Estimates

7.1 Tracking Estimate of Savings for Waterbed Covers

During 2004 no waterbed covers were installed.

8 Engineering Summary

Table 5 presents the total estimated annual kWh savings by measure type for the 2004 TEE Program participants. Table 6 shows that floor insulation had the single largest energy savings impact for the average home, followed by attic insulation, sidewall insulation, heat pump units, air sealing measures, domestic hot water measures, and compact fluorescent lamps.

[4] Waterbed Foam Mattresses: The Ultimate Payback, Jeff D. Newburn, Affordable Comfort Conference, Mar, 94.

[5] Waterbed Heating: Uncovering energy Savings in the Bedroom: Ted Rieger, Home Energy, Sep/Oct, 94.

Using the engineering algorithms mentioned in this report, the tracking system calculated estimated total yearly kWh reduction for the 2004 TEE program as 1,137,840 kWh. The impact for Electric Heat customers is estimated to be 1,045,121 kWh. The estimated impact for Non-Electric Heat customers is estimated to be 92,719 kWh.

The average estimated savings for tracking system Non-Electric Heat customers were estimated to be 1,145 kWh/year/household, and savings for Electric Heat participants were estimated to be 6,491 kWh/year/household.

It is important to remember that engineering estimates of savings are historically higher than billing energy estimates. The engineering formulas in many cases overestimate actual savings. Many factors can contribute to this phenomenon; higher reported water use by the customer, customer specific behavior patterns, absence of snapback and persistence effects, and the lack of interactive effects for multiple measure installations (which may significantly decrease savings).

Measure Type	Electric Heat Tracking Total Savings (kWh)	Non-Electric Heat Tracking Total Savings (kWh)
CFL	64,524	26,347
Air Sealing Measures	269,260	na
Attic insulation	183,455	na
Sidewall insulation	15,396	na
Floor insulation	282,740	na
Water Heater Tank Wrap	12,218	3,450
Hot Water Temperature Reduction	28,749	11,219
Low-Flow Showerheads	140,484	51,331
Pipe Insulation	1,122	372
Heat Pumps	47,173	na
Waterbed Covers	0	0
TOTAL	1,045,121	92,719
Average per Customer	6,491	1,145

Table 5: Estimated Total Annual kWh Savings by Measure Type

Table 6 presents the average kWh savings by measure estimates.

Measure Type	Electric Heat Tracking Savings/Measure (kWh)	Non-Electric Heat Tracking Savings/Measure (kWh)
CFL (per site)	401	325
Air Sealing Measures (per home)	1,726	na
Attic insulation (per home avg.)	1,973	na
Sidewall insulation (per home avg.)	1,924	na
Floor insulation (per home avg.)	3,107	na
Water Heater Tank Wrap (per wrap)	110	115
Hot Water Temperature Reduction	513	660
Low-Flow Showerhead	901	901
Pipe Insulation (per linear foot)	0.88	0.92
Heat Pumps	1,887	na
Waterbed Cover	na	na

Table 6: Estimated Average kWh Savings by Measure Type

9 Cost Effectiveness Estimates

RLW analyzed the distribution of TEE Program costs by measure and agency, based on electronic data. The average cost per home was $970.41 for all-electric homes and $62.79 for baseload (non all-electric) homes.

9.1 Simple Payback Period

One of the most commonly used cost analysis methodologies is the Simple Payback Period (SPP) analysis. The SPP determines the number of years required to recover an initial investment through project returns. The simple payback is determined by taking the initial cost and dividing it by the annual savings. The formula is:

SPP = (Initial cost) / (Annual savings)

For the 2004 TEE Program the following information was used for the SPP analysis:

<u>All-Electric Homes</u>

Customer cost per kWh	$0.0544
Average KPCo cost to weatherize an all-electric home	$970.41
Average annual kWh savings per all-electric home	6,491 kWh
Average annual cost savings per all-electric home	$353.11/year
Simple Payback Period (SPP) for all-electric home	2.75 years

<u>Baseload Homes</u>

Customer cost per kWh	$0.0544
Average KPCo cost to weatherize a baseload home	$62.79
Average annual kWh savings per baseload home	1,145 kWh
Average annual cost savings per baseload home	$62.29/year
Simple Payback Period (SPP) for baseload home	1.01 years

9.2 Benefit Cost Ratio

A benefit/cost ratio (BCR), also know as a savings investment ratio (SIR), calculates the present worth of all benefits, then calculates the present worth of all costs, and takes the ratio of the two sums.

The calculations required for the benefit cost ratio of the 2004 TEE Program are as follows:

*Assuming a measure life of 10 years.

<u>All-Electric Homes</u>

Present worth of annual savings	= $353.114($P/A_{10,10}$) = $353.11(6.1446) = $2,169.72
Total project cost per home	= $970.41
Benefit/cost ratio	= $2,169.72 / $970.41 = 2.24

Baseload Homes

Present worth of annual savings	= \$62.29($P/A_{10,10}$) = \$62.29(6.1446) = \$382.75
Total project cost per home	= \$62.79
Benefit/cost ratio	= \$382.75 / \$62.79 = 6.10