DOCKETED

Docket Number:	17-BSTD-02
Project Title:	2019 Title 24, Part 6, Building Energy Efficiency Standards Rulemaking
TN #:	222349
Document Title:	Unique Multifamily Buildings Proposed Energy Code Measures
Description:	Document relied upon (indoor air quality).
Filer:	Adrian Ownby
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	1/23/2018 4:18:32 PM
Docketed Date:	1/23/2018

Energy Research and Development Division
FINAL PROJECT REPORT

UNIQUE MULTIFAMILY BUILDINGS PROPOSED ENERGY CODE MEASURES

Prepared for: California Energy Commission
Prepared by: Benningfield Group, Inc.

MARCH 2014
CEC-500-2015-045

PREPARED BY:

Primary Author(s):
Garth Torvestad
Nehemiah Stone

Benningfield Group, Inc.
400 Plaza Drive, Suite 120
Folsom, CA 95630
Phone: 916-221-3110 | Fax: 916-404-0422
http://www.benningfieldgroup.com)

Contract Number: 500-10-019

Prepared for:

California Energy Commission

David Weightman
Contract Manager

Virginia Lew
Office Manager
Energy XXXXXXXX Research Office

Laurie ten Hope
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Robert P. Oglesby
Executive Director

ACKNOWLEDGEMENTS

The primary authors would like to thank the following individuals for their direct and substantial contributions to this report:

- David Weightman (California Energy Commission)
- Judy Roberson, Lynn Benningfield, Bruce Benningfield, Alex Benningfield, Brian Selby, Robin Wells, Marci Vistro (Benningfield Group)
- Curtis Harrington, John Markley (WCEC)
- Ken Nittler (Enercomp)
- Thomas E. McClure, Christine Kohn (IN Communications)

Additionally, we would like to thank the following project partners and subcontractors for their immeasurable contributions to the project:

- Vikki Wood, Bobbie Harris (SMUD)
- Andy Brooks (AEA)
- Mary Sutter, Seth Wayland (Opinion Dynamics)
- Mark Modera, Jim Rix (WCEC)
- Barry Brooks, Robert Brown (Robert Thomas Brown, Inc.)
- Karen Herter (Herter Energy Research Solutions)

PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The Energy Research and Development Division strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

Energy Research and Development Division funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Unique Multifamily Proposed Energy Code Measures is the final report for the Unique Multifamily Code-Relevant Measures project (contract number 500-10-019 conducted by Benningfield Group. The information from this project contributes to Energy Research and Development Division's Building End-Use Energy Efficiency Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at http://www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

The Unique Multifamily Energy Code Measures research project investigated energy-related attributes of multifamily buildings and determined if the California Energy Code should be adjusted to better suit these attributes. Three specific technical research tracks included ventilation, fenestration (windows or doors), and smart thermostats and energy information displays. The research comprised site visits, surveys, computer modeling and field deployment and monitoring of technologies in retrofit solutions.

Ventilation research found that central exhaust systems provide uneven and often inadequate airflow. Self-balancing dampers and duct sealing can address this problem. The study also found that air infiltration and its transfer between apartments is particularly problematic in high-rise buildings. This can be addressed through sealing interior and exterior apartment walls. In addition to codifying these measures, the study recommends extending low-rise multifamily ventilation requirements to high-rise buildings.

Fenestration research identified that multifamily buildings use a lower ratio of glazing to floor area than single-family homes, and recommends that the energy code reflect this difference. The study also found that reducing the prescriptive maximum U-factor in all California Climate Zones, and the prescriptive maximum solar heat gain coefficient in all Climate Zones except 1, 3, and 5 are cost effective measures.

The smart thermostats research demonstrated a 29-percent peak load demand reduction from multifamily tenants when coupled with time-dependent rates. Researchers recommend that smart thermostats be a mandatory requirement for multifamily new construction. In-home energy information displays provided minimal savings, however customers reported satisfaction with receiving real-time energy and price information, a feature recommended to be required for smart thermostats. The research also found that these wireless technologies did not maintain reliable connectivity because of the distance between apartments and smart meters. Further study is necessary to overcome the transmission range issue and determine the appropriate code measures to address multifamily connectivity.

Keywords: Energy Code, multifamily, ventilation, fenestration, smart-thermostats, exhaust systems, U-factor.

Please use the following citation for this report:

Torvestad, Garth; Stone, Nehemiah. (Benningfield Group). 2014. ***Unique Multifamily BuildingsProposed Energy Code Measures, Final Project Report.*** California Energy Commission. Publication number: CEC-500-2015-045.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Introduction

In each of the past three years, multifamily unit construction in California has exceeded single-family home construction . With more multifamily buildings being constructed, the sections of the state's energy code dealing with this type of construction requires examination and refinement.

Because single-family home construction dominated the new housing market in California for much of the last two decades, most of the research on residential energy efficiency, especially to code development, has been on single-family homes.

Since multifamily buildings now represent such a large portion of new construction in the state, it is important that the construction industry and regulatory agencies be equipped with the technical knowledge and regulatory tools to ensure these buildings are as efficient as possible. In addition, California is faced with the challenge of developing standards for all newly constructed residential buildings to be zero-net energy by 2020. The challenge is more difficult because each code measure is mandated to be cost effective. To best assess which measures will be cost effective, specifically in multifamily buildings, it is critical to understand current construction practices and the most promising measures for improving energy efficiency. Currently, low rise multifamily buildings, i.e. those that are 3 stories high or less are regulated by the residential building code. Multifamily buildings 4 or more stories high are regulated as commercial buildings.

Project Purpose

This project investigated the unique attributes of multifamily buildings, used these findings to improve the understanding of how to make these buildings more efficient, and helped determine if specific Title 24 requirements of the state building energy efficiency code should be revised to better address issues unique to multifamily building construction.

The study also determined if current building energy efficiency codes adequately address the conditions of multifamily construction, and whether a new code section is necessary to address these requirements..

Project Results

The data gathered in the three technical projects yielded recommendations for energy code changes and other building performance improvements. It also concludes that California should develop a section of the energy code dedicated specifically to multifamily construction.

Ventilation

This research yielded one proposed code change report and four specific changes. Results of surveys, field data collection, and computer modeling provide evidence that the following changes are appropriate.

1. Require sealing the central exhaust shafts and installing self-balancing dampers in each apartment served by a central shaft.

Although central shaft sealing and self-balancing dampers each provide energy and indoor air quality benefits, the two work best when combined. Research teams monitored a tightly sealed exhaust shaft with self-balancing dampers in an eight-story multifamily building, as well as two other reference shafts. The data showed that the sealed shaft combined with self-balancing dampers saved fan energy and provided more consistent apartment-level exhaust. Simulation indicates significant space conditioning energy savings as well.

2. Require compartmentalizing (sealing the exterior walls and walls adjoining other interior spaces) in high-rise residential buildings.

   Energy and airflow modeling show that compartmentalization can reduce conditioning costs by reducing infiltration from outdoors. Compartmentalization can also significantly mitigate "stack effect", a phenomenon most pronounced in high-rise buildings. Stack effect is when, during cold weather, less dense warm air inside buildings travels upward through any available pathway. This creates pressure imbalances that disrupt the function of central ventilation systems, transfer potentially contaminated air between apartments, and create issues with infiltrtion of unconditioned air. Sealing the interior walls of units prevents this movement, while sealing exterior walls prevents the infiltration and exfiltration that drives this process. Combined with self-balancing dampers, compartmentalization can improve indoor air quality and reduce energy consumption in high-rise multifamily buildings.

3. Require mechanical ventilation of high-rise multifamily buildings.

   Current Title 24 minimum ventilation rates are high enough that compliance would be difficult through any means other than mechanical ventilation. However, mechanical ventilation is not required in high-rise multifamily buildings. By contrast, low-rise multifamily code calls for mechanical ventilation, despite specifying a lower minimum ventilation rate than high-rise. Requiring mechanical ventilation in high-rise buildings will make it clear that this is the only way to provide consistent and reliable fresh air to residents of all multifamily buildings.

4. Extend the low-rise multifamily ventilation rate requirement to high-rise multifamily buildings.

   At present, high-rise multifamily ventilation requirements are calculated using a different equation than used for low-rise. The calculation results in higher ventialtion requirements in high-rise buildings. In addition to creating confusion, this wastes fan and space-conditioning energy in most California climates. There is no fundamental difference between three-story buildings and those taller that would justify a different ventilation rate. The low-rise rate requirement was adjusted upward during the 2013 Code cycle, has had thorough vetting through the American Society of Heating and Refrigeration and Air Conditioning Engineers (ASHRAE), and should be applied consistently to all multifamily buildings.

Fenestration (Windows or Doors)

The research findings from this project produced three code change recommendations.

1. Reduce the penalty threshold in the performance compliance method for low-rise multifamily buildings from 20 percent to 15 percent of glazing area to conditioned floor area.

   Multifamily buildings that were surveyed had fenestration area well below the maximum of 20 percent, averaging 13.7 percent in one survey of utility program buildings. The few multifamily buildings that propose to use more than 15 percent glazing should be required to undertake extra efficiency measure s to compensate for the unwanted thermal losses.

2. Reduce the maximum U-factor for low-rise multifamily window and door design from 0.32 to 0.30 in all California Climate Zones.

   Manufacturer surveys show that different styles of windows at or below U-factor of 0.30 are commercially available. Computers models showed that the cost associated with lowering the U-factor by .02 is lower than the dollar value of savings estimates, when viewed as a statewide average.

3. Reduce the maximum solar heat gain coefficient from 0.25 to 0.23 in all Climate Zones, with the exception of zones 1, 3, and 5. In zones 1, 3 and 5, no solar heat gain coefficient should apply.

   Manufacturer surveys also indicate solar heat gain coefficient can cost-effectively be lowered by 0.02 using available technology. Computer models show savings in every Climate Zone except 1, 3, and 5. Although not analyzed in buildings of four or more stories, these recommendations also are appropriate for window and door design in high-rise multifamily buildings.

Multifamily resident energy-related information and smart thermostats

The findings from this reearch support energy code improvements that will ensure delivery of smart meter data into multifamily homes and encourage using technology that can deliver information to manage peak energy consumption.

1. Require systems for the reliable delivery of energy data into reliable signals between smart meters and apartments.

   The research showed energy savings can be achieved by using smart thermostats in multifamily buildings during peak periods. Another benefit is that the delivery of real-time energy information into the home increases awareness of energy use. The research showed that wireless communication between smart meters and in-home devices was not as reliable as it must be for widespread deployment. Whether through smart meters or another channel, such as the internet, the necessary infrastructure for energy data communication should be part of each newly constructed multifamily building. More research is necessary to determine the appropriate requirements for the energy code.

2. Expand the requirements for smart thermostats in multifamily homes.

   Although obligated under many construction scenarios, smart thermostats are not required in all cases in California's energy code. Because of the potential savings during peak periods and the increased customer satisfaction observed during this study, it is recommended that smart thermostats be required in all new multifamily construction and major renovations. Although this study data does not directly support savings from energy information displays alone, customers found value in the data and reported a better understanding of their energy use. The researchers recommend that specifications for smart thermostats be expanded to include real-time energy and price information assuming improvements in wireless technology that will ensure reliable interface between the meters and individual units in apartment buildings.

Benefits to California Ratepayers

Based on the current growth in new multifamily buildings construction in California, the research team estimated the following savings from each of the measures:

- Fenestration code change: The change could yield 280,000 therms and 33.14 megawatt hour (Mwh) in annual energy savings and reduce GHG emissions by 2,786 tons.
- Ventilation code changes: The change could result in annual savings of 1.66 million therms and 7,800 megawatt hours. If these targets were reached, ventilation-related GHG emissions would be reduced by 2,686 tons annually.
- Smart control code change: Assuming a 3 percent savings from smart controls and rate information displays for thermostats, this code change could yield 0.48 megawatts of energy load reduction annually. The benefit of the smart control code measure would be 6,766 megawatt hours when calculated on a time-dependent valuation basis which considers the societal value of energy based on time of day during each day of the year.

CHAPTER 1: Introduction

In the last 35 years, California has advanced the energy efficiency of new construction — most notably by iterative improvements to the California Code of Regulations, Title 24, Part 6, and Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24). These advances have put the state ahead of the rest of the nation specific to lowering per-capita energy use, and serve as an example for other states to improve energy efficiency in the building sector. However, California's energy efficiency advances, excluding non-residential commercial buildings, are based almost entirely on analysis of single-family homes within the residential sector.

Recent research suggests the California housing market is changing quickly. Currently, one in three California families lives in multifamily homes. Multifamily building construction has increased steadily in the last 20 years, topped by nearly 40,000 multifamily residences constructed in 2013, a figure that represents almost 55 percent of all new home construction in the state (Table 1.)

Table 1: Construction of Dwelling Units by Year

Year	Single-Family		Multifamily		Total
	Number	% of Total	Number	% of Total	Number
2009	25,454	**69.9%**	10,967	**30.1%**	36,421
2010	25,526	**57.0%**	19,236	**43.0%**	44,762
2011	21,538	**45.7%**	25,554	**54.3%**	47,092
2012	27,406	**47.3%**	30,555	**52.7%**	57,961
2013*	32,721	**45.1%**	39,876	**54.9%**	72,597

Source: California Department of Finance data, December 2013.

With those statistics in mind, this project focused exclusively on identifying potential energy efficiency opportunities in multifamily buildings, and suggests these improvements be included in future upgrades to the energy code.

A multifamily building is defined by the energy efficiency building standards as a classification of housing where multiple separate dwelling units for residential inhabitants are contained within one building or several buildings within one complex. A common form is an apartment building. A condominium is also considered a multifamily residence.

This project highlighted specific opportunities for energy code improvements under the current code structure, discusses the differences between high-rise and low-rise multifamily residential energy code requirements, and proposes the possibility for a unified multifamily code section within the residential building energy code.

State Energy Efficiency Goals

California has two policy initiatives that highlight the importance of constructing highly efficient multifamily buildings—buildings which currently account for about 24 percent of greenhouse gas emissions in the residential sector.

The first from the California Public Utilities Commission's long-term energy efficiency strategic plan is that all new residential construction be zero-net energy by 2020. The second mandate from the Global Warming Solutions Act of 2006 (AB 32) is a 20 percent reduction of greenhouse gas emissions from 1990 emissions. To meet the state's energy efficiency and climate action goals, a better understanding is necessary to how energy is used and where savings opportunities exist in multifamily buildings.

1.1 Project Goals and Objectives

This project provided research data demonstrating ways to reduce energy in multifamily dwellings, advance the science of building performance in the multifamily sector (via new energy code proposals) so that design teams can maximize efficiency, and increase the knowledge base around multifamily energy efficiency so program managers, design firms and codes and stanThe contractordards consultants can do their jobs more effectively.

Within that framework, research focused on cost-effective energy efficiency improvements in three areas: ventilation air in multifamily structures, fenestration products (windows or doors), and smart thermostats and energy information displays within individual dwelling units.

Improving ventilation in multifamily buildings was a very important component of the research because it includes considerations of public health in addition to energy use. The findings lead to a proposed code change ensuring that adequate fresh air is delivered within multifamily dwelling units. It also provides evidence that multifamily building construction should be reviewed for unique attributes under the code. Currently, standards for multifamily buildings of three or fewer stories are different from the standards that dictate how multifamily buildings of four or more stories are constructed. The study conclusions question that designation.

The research components for the three projects included a secondary information and data review, desktop and field data collection, performance monitoring of some "treated" sites, and resulted in recommendations for changes to Title 24.

The contractor managed the overall project with a number of subcontractors and a utility partner, Sacramento Municipal Utility District (SMUD). SMUD provided customers, infrastructure, knowledge and funding to help research the impact of real-time information and smart thermostats in relation to energy use, and energy demand during peak periods.

A subcontractor assisted with the experimental framework for the energy information and smart thermostat research, and performed the impact analysis on post-treatment data in the controlled experiment noted in Chapter 4. They also assisted with surveys for participants in the pilot study, and conducted follow-up phone surveys with non-respondents.

The Western Cooling Efficiency Center conducted the multifamily ventilation research. They were assisted with study design, reporting and field data collection by the Association for Energy Affordability, and received field data collection support from the Robert Thomas Brown Company, a Disabled Veterans Business Enterprise (DVBE) subcontractor.

IN Communications, also a DVBE subcontractor, provided professional editing of several documents, including a scoping paper used to orient the project advisory committee.

Ken Nittler, an independent consultant with expertise in testing and evaluating window products, gathered performance and cost data from window manufacturers and suppliers, conducted hundreds of building simulation runs, and developed the final cost-effectiveness analysis for the proposed changes to multifamily fenestration code requirements in Title 24.

1.1.1 Time Dependent Valuation

Since this project was focused on code improvements in multifamily buildings, the primary metric used to evaluate savings potential was the same metric that has been used for Title 24 updates and measure evaluation since the 2005 standards: Time Dependent Valuation (TDV). The following text from the California Energy Commission Reference Appendices for the 2013 Building Energy Efficiency Standards defines time dependent valuation and provides a link to the TDV data that was used in the analysis:

> “Time dependent valuation (TDV) is the currency used to compare energy performance when the performance compliance method is used. TDV is also used to evaluate the cost effectiveness of measures and to perform other codes analysis. TDV replaces source energy, which was used to compare performance prior to the 2005 Standards. TDV consists of large data sets that convert electricity, gas or propane to TDV energy. The rate of conversion varies for each hour of the year, for each climate zone and for each energy type (electricity, natural gas or propane). The conversion factors also vary by building type: low-rise residential and other building types, including nonresidential, hotel/motel and high-rise residential. There are a total of 144 hourly data sets (16 climate zones x 3 fuel types x 3 building types) where the 3 building types are residential 30 year, nonresidential 15 year, nonresidential 30 year. ” The actual TDV data may be downloaded from: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/2011_TDV_v3_110112.xlsx.

CHAPTER 2:
Multifamily Ventilation

2.1 Introduction

This project improved current understanding of prevailing construction practices related to ventilation in multifamily buildings, researched and analyzed the benefits of modifying those practices, and proposed energy code changes that reflect those improved practices.

The research comprised five technical tasks:

- Reviewing current multifamily ventilation standards
- Characterizing multifamily building ventilation practices used in design and constuction using market surveys
- Modeling ventilation performance in an existing high rise
- Conducting field tests, measurements, and monitoring of energy use and ventilation rates based on alterations to existing buildings intended to improve building performance, and
- Preparing a synthesis and summary of findings

The first task helped the research team understand the intricacies of California's ventilation code, including the differences between high- and low-rise buildings and how this code relates to the current American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) standards. Information from this secondary research is presented as "background" in the following chapter.

The methods and findings from research tasks 2, 3, and 4 follow the background section, and in the fifth task recommendations suitable for a California code change proposal are identified.

2.2 Background

Unlike most requirements of the California Building Energy Efficiency Standards, mechanical ventilation is not an energy efficiency measure. It is a way to provide good indoor air quality, necessary for public health.

Building codes have long required mechanical outdoor air ventilation in most nonresidential buildings, to dilute and remove primarily occupant-generated pollutants from indoor spaces. Beginning with the 2008 Standards, California code also requires mechanical ventilation in new low-rise residential buildings. This requirement is driven by the reality that home envelopes are tighter than they used to be such that indoor spaces can retain volatile organic compounds (e.g. solvent-based paints and coatings) from many sources, and most people do not open windows as often as necessary to insure adequate ventilation. Since whole-house ventilation causes additional energy use in homes, it is important to optimize the energy efficiency and ventilation effectiveness of these systems.

In California, ventilation requirements in buildings of three stories or less is covered by the Low-Rise Residential section of the Energy Efficiency Standards, and ventilation of buildings of four stories or more is covered by the Nonresidential section of the Energy Efficiency Standards. The two sets of standards have significant differences in ventilation regulations.

As noted, Title 24 part 6 requires new low-rise apartments to be continuously and mechanically ventilated, but there is no requirement for mechanical ventilation for high-rise apartments. Ironically, the required minimum ventilation rate for high-rise apartments is significantly higher than the required minimum ventilation rate for low-rise apartments.

The historical basis for the differences is described in detail below, however there is no scientific basis for claiming that high-rise apartments need more ventilation than low-rise apartments. In practice, the higher high-rise ventilation rate specified in the energy code has the positive effect of causing most multifamily builders to install mechanical ventilation systems in new construction projects. However, the downside to meeting the higher ventilation rate is increased fan and space conditioning energy use and considered an unnecessary waste of energy.

Historially, developing multifamily ventilation standards for low-rise residential buildings has received more attention than those for high-rise buildings in previous code development cycles. One element of the 2013 Standards requires low-rise building apartments to be "compartmentalized" or air sealed to minimize transfer of air between adjacent units. It is noted that this not a requirement for high-rise residential buildings.

In any building, envelope air tightness is essential for energy efficiency and the mechanical ventilation system must be able to control indoor-outdoor air exchange. Unlike single-family homes where a high percentage of enclosing walls face the outdoors, apartments share walls with other apartments, creating a risk that contaminated air is transferred from one apartment to another. The new compartmentalization standard is designed to reduce this risk in low-rise apartment buildings. However, because the natural driving force of stack effect increases with building height, it is even more important to seal interior and exterior leaks in high-rise multifamily buildings. Sealing interior leaks eliminates pathways for air to move vertically, and sealing exterior leaks reduces the amount of air drawn in through lower floors as replacement air for the warm air moving vertically through the stack.

Another impact of stack effect is on the function of central shaft exhaust systems. Central exhaust shafts provide ventilation through a rooftop fan that depressurizes a large ventilation shaft running the length of the building. The shaft typically connects to one apartment on each floor through a short horizontal duct and exhaust grille.

Stack effect creates pressure imbalances between floors — apartments on the top of the building can have positive pressure relative to the outdoors, while bottom floor apartments have negative pressure relative to the outdoors. As a result, central shaft exhaust systems often have significant differences between the exhaust rates delivered to different floors of the building. An exhaust register pulling against a negative pressure has a much more difficult time moving air than one pulling against a positive pressure. These problems increase with the height of the building, and are aggravated by leaky central exhaust ducts. Title 24 currently has no regulations to combat these known issues, which occur almost exclusively in high-rise multifamily buildings.

In our experience, the ventilation regulations for high-rise multifamily buildings in the code are not well documented, are poorly understood by many, and finding the appropriate reference to the ventilation rate calculation is a challenge. High-rise residential ventilation requirements in California's Title 24 Energy Code (Part 6) refer the reader to the Building Code (Part 2), which in turn refers to the Mechanical Code (Part 4). It is in the Mechanical Code that the designer finds the minimum ventilation rates for high-rise residential dwellings and requirements for local exhaust (kitchens and bathrooms), which are drawn directly from ASHRAE Standard 62.1– Ventilation for Acceptable Indoor Air Quality.

The 2010 version of ASHRAE Standard 62.1 recommends the following minimum ventilation rate for high-rise residences, but does not require that it be provided by mechanical means:

- High-rise multifamily homes: ventilation $CFM = 5(N_{br}+1)+0.06A$

Where CFM is the cubic feet per minute of air moved through the dwelling, Nbr is the number of bedrooms (which is never less than one), and A is the floor area. High-rise requirements also include a ventilation rate of 0.06 CFM/ft2 for common corridors.

The 2013 Title 24 requirements for ventilation of low-rise residential buildings, including multifamily, correspond to ASHRAE Standard 62.2, which was developed to address the specific needs of residential occupancies. Title 24, 2008 references Standard 62.2-2007, while Title 24, 2013 references an Energy Commission version of Standard 62.2-2010 that was in effect at the time commission staff prepared the 2013 Standards.

The Energy Commission version of Standard 62.2-2010, which is effective with the 2013 Title 24 Standards, includes a new Section 8 devoted to low-rise multifamily buildings, and requires that:

- Corridors and other common areas within the conditioned space be ventilated at the rate of 0.06 CFM per ft2 of floor area;
- Nonresidential areas within mixed-use buildings meet Standard 62.1 requirements
- Air movement across envelope components separating dwelling units be minimized (compartmentalized). One method to demonstrate compliance with this requirement is using a blower door to verify a maximum leakage rate of 0.02CFM 50 per ft2 of total envelope area.

The Energy Commission version of Standard 62.2-2010 also specifies higher minimum whole-home ventilation rates for low-rise apartments than for low-rise single-family homes:

- Low-rise multifamily homes: $Q_{fan}=0.03A_{floor}+7.5(N_{br}+1)$
- Low-rise single-family homes: $Q_{fan}=0.01A_{floor}+7.5(N_{br}+1)$

Where Qfan is minimum fan flow in cubic feet per minute; Afloor is floor area in ft2, and Nbr is number of bedrooms.

The difference between the two equations is the amount of infiltration that Standard 62.2 previously assumed all low-rise homes received regardless of their tightness, climate, wind exposure, or height. Eliminating the infiltration assumption and adding it to the mechanical ventilation rate functionally increases the minimum required ventilation rate for low-rise apartments, although it is still lower than the high-rise requirement.

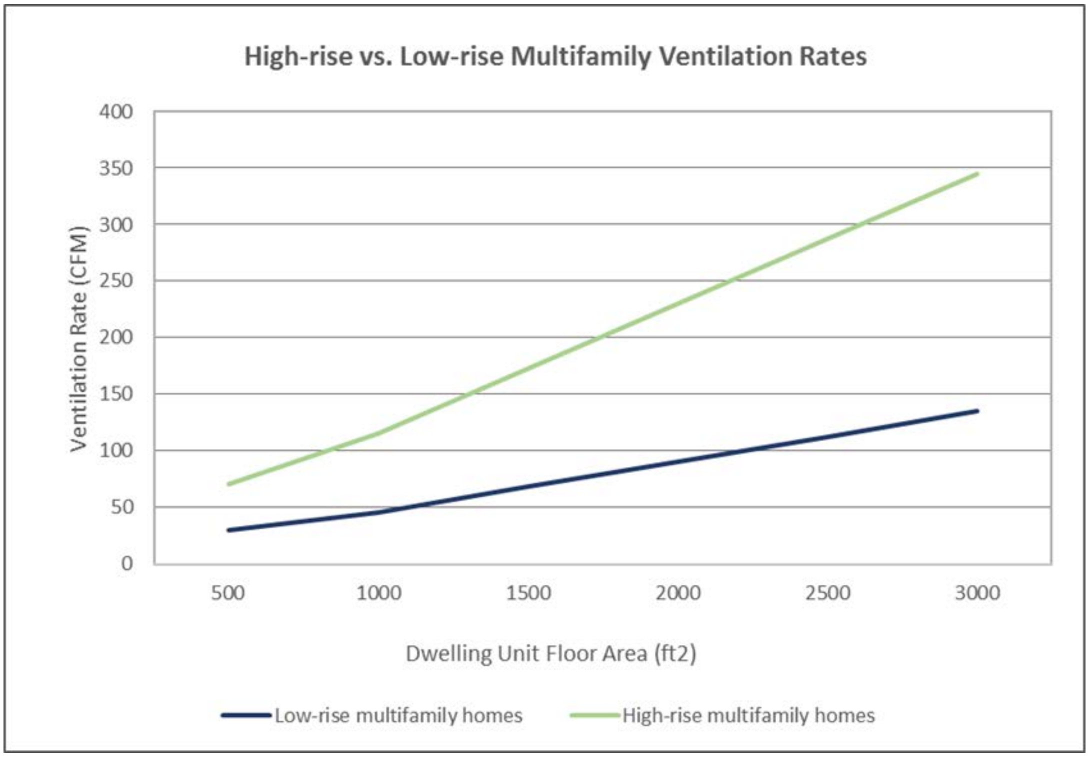
Table 2 shows a few examples of the ventilation rate requirements for various sizes of apartments.

Table 2: 2013 Title 24 Minimum Low- and High-Rise Residential Ventilation Rates

Floor Area (ft2), A	# of bedrooms, N_{br}	Low-rise multifamily home ventilation rate: $= 0.03A + 7.5(N_{br} + 1)$ CFM	High-rise multifamily home ventilation rate: $= 5(N_{br} + 1) + 0.06A$ CFM	Ratio of High-rise to Low-rise rates
500	1	30	40	1.33
1000	1	45	70	1.56
1500	2	68	105	1.54
2000	3	90	140	1.56
2500	4	112	175	1.56
3000	5	135	210	1.56

Source: Adapted from Summary and Analysis of California Codes and Standards Pertaining to Multifamily Building Ventilation, PIER 500-10-019, Report on Task 1.1.1, March 27, 2012

Figure 1: 2013 Title 24 Minimum Ventilation Rates for Multifamily Dwellings



Source: Adapted from Summary and Analysis of California Codes and Standards Pertaining to Multifamily Building Ventilation, PIER 500-10-019, Report on Task 1.1.1, March 27, 2012.

2.3 Primary Research – Methods and Findings

The three primary research tasks included market surveys, computer simulation of various building ventilation arrangements in high rise residential buildings in several climate zones and field testing of modifications to existing ventilation configuration to determine the energy and indoor air ventilation rate differences over preretrofit conditions.

Surveys were conducted to document the types of HVAC equipment that were installed in post 2005 multifamily buildings in California and gather data on how energy professionals view the effectiveness of the energy code in relation to ventilation in these buildings. The qualitative surveys were designed to help us understand attitudes about the code and ventilation in general. The quantitative surveys were designed to help us better understand the frequency of ventilation systems and design type distributions. Surveys were conducted for building locations in all climates in California.

Qualitative data was gathered from 29 mechanical engineers/contractors, HVAC system designers, and energy consultants and from eight leading ventilation researchers, practitioners, multifamily program managers, and contributors or technical experts to Title 24 or ASHRAE ventilation standards.

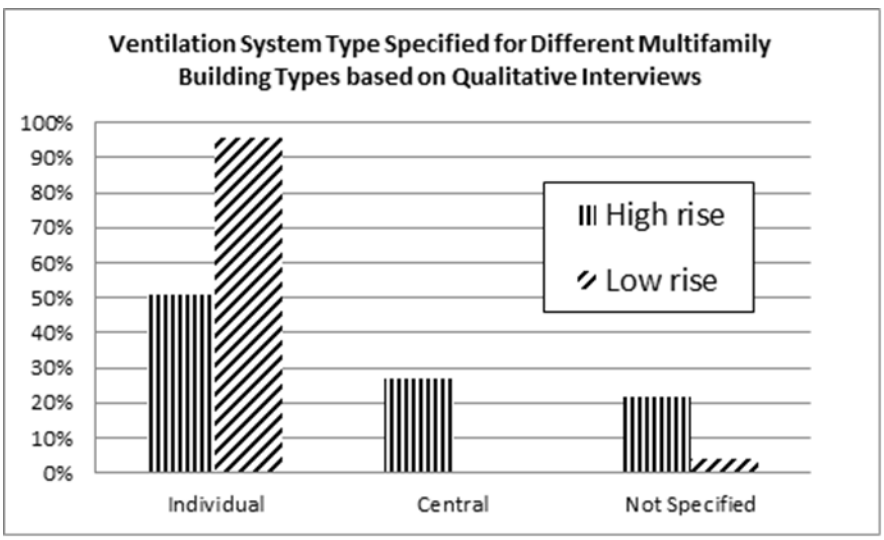
The professionals interviewed had design or construction experience in both low and high-rise residential buildings that included California Climate Zones 3, 6, 8, 9, and 12.[1]

The survey of mechanical engineers, HVAC system designers and energy consultants ask questions regarding the ventilation systems they typically specify, and how their interpretation of current regulations influences their decision-making process. Interviews with technical experts ascertained how current codes and standards affect ventilation performance in multifamily buildings, and how these regulations address the challenges present in multifamily buildings.

The survey of ventilation system designers showed that nearly all low-rise buildings use individual-unit ventilation systems, whereas high-rise buildings sometimes use shared central exhaust ventilation systems (Figure 2).

There is no specific number of floors at which designs transition from individual unit ventilation to shared central shaft exhaust. It does not appear to coincide with the traditional low-rise and high-rise distinction of three or fewer stories. No central shaft systems were found in buildings of fewer than six stories.

Figure 2: Characterization of Low- and High-Rise Multifamily Ventilation Systems



Source: Market Characterization of HVAC Practices in California Multifamily Buildings Based on Qualitative Surveys of Engineers, PIER 500-10-019, Report on Task 1.2.4, January 24, 2013.

Survey results from engineers, designers and consultants indicate that the primary reasons for specifying individual unit ventilation systems were cost, ease of installation, lower maintenance, and the ability to pass fan operating costs to the tenants. Central ventilation systems, which are only present in the taller buildings in the survey, were typically installed to accommodate architectural concerns and appear to have been used only when all other options had been eliminated. For example, if exterior wall penetrations are prohibited or horizontal

[1] For a map of California Climate Zones, visit: http://www.energy.ca.gov/maps/renewable/building_climate_zones.html

ducting within the building is not possible, vertical central shaft systems are the only viable solution for providing ventilation to each home.

Technical experts were asked about the three- and four-story split between ventilation standards for multifamily buildings. The general belief was that the split was based more on convenience than technical rationale. Interviewees said that when ASHRAE 62.2 was developed, and split from 62.1, the reference point of three and four stories was carried over from ASHRAE Standards, 90.1 and 90.2.

Experts were asked how ventilation of multifamily buildings could be improved. Many responses supported a greater focus in two specific areas: (1) home compartmentalization, and (2) supply ventilation. Compartmentalization means that each dwelling unit in a multifamily building is well isolated not just from the exterior, but from surrounding units and common areas, to reduce inter-apartment airflows (called "transfer air" in ASHRAE 62.2).

Supply ventilation is an alternative to exhaust ventilation where, instead of removing stale air from a home that is then replaced through infiltration, outdoor air is drawn from a selected location, usually filtered, and delivered directly to where it is needed.

Some experts pointed out multifamily buildings were not directly considered during developing ventilation codes and standards. Developing Standard 62.1 addressed commercial spaces where people have no direct control of ventilation or windows, and developing Standard 62.2 focused on mechanical ventilation of single-family homes. However, recent changes to ASHRAE Standard 62.2 have begun to address multifamily buildings, and could be the basis for resolving compartmentalization and other ventilation issues.

2.3.1 Quantitative survey

Data was gathered for specific multifamily buildings by either visiting the sites or reviewing building plans. This survey comprised 33 high-rise and 9 low-rise multifamily buildings with a combined total of more than 4,500 apartments. Surveyed buildings were in State Climate Zones 3, 4, 5, 6, 7, 8, 9, 10, 12 and 13. More high-rise buildings were studied within the quantitative survey because the results of our qualitative survey indicated high-rise buildings have more variation in the HVAC systems that were installed.

A primary goal was to determine the rationale, if any, between the differences in the low- and high-rise sections of the code. Survey results indicate there is more variation in ventilation systems in buildings of four stories or more, but it is not clear whether building height is a factor in ventilation system selection.

Table 3 summarizes the results of the quantitative surveys of multifamily buildings in the state.

Table 3: Findings from Survey of California Multifamily Building HVAC Equipment

	High-rise	Low-rise
Number of buildings in survey	33	9
Total number of dwelling units	3,950	615
Percent of buildings with central shaft ventilation systems	18%	0%
Percent of buildings with individual unit ventilation systems	88%	100%
Percent of buildings with packaged units	0%	22%
Percent of buildings with split systems	85%	56%
Percent of buildings with central heating & cooling systems	6%	11%
Percent of buildings with enclosed corridors	61%	33%

Source: Adapted from Western Cooling Efficiency Center (WCEC) file Quantitative Survey Results Summary.docx

Based on the survey sample, 6 of 33, or 18 percent of high-rise buildings had a central shaft exhaust system while none of the low-rise buildings did. Twentynine (29) of 33, or 88 percent of high-rise buildings and all of the low-rise buildings had individual unit ventilation. Two high-rise buildings had individual unit ventilation systems exhausting to a central shaft operating at a low pressure. Those buildings had individual unit and central shaft exhaust systems. This data confirms the qualitative survey that shows central shaft systems are rarely used in low-rise buildings.

There was a low incidence of central heating and cooling in both types of buildings, but it was not substantially different between buildings types. Not surprisingly, a greater number of high-rise buildings had enclosed corridors, but it is far from a uniform construction practice across either building type.

2.3.1.1 Performance Modeling Methods

Early in the project several potential improvements to the Title 24 energy code were identified including:

- Unifying multifamily ventilation requirements by extending ASHRAE Standard 62.2 to high-rise. This includes:
  - Requiring continuous mechanical ventilation of high-rise apartments;
  - Applying low-rise multifamily ventilation rates to high-rise apartments; and
  - Extending the requirement for compartmentalization to high-rise apartments.
- For central (shared) ventilation shaft construction:
  - Limiting central ventilation shaft leakage to 5 percent of total fan flow; and

- Requiring self-balancing dampers [2] at each home's ventilation grill.

The research team used computer simulations and field experiments to test the savings and indoor air quality potential of each potential improvement measure.

EnergyPlus (E+) software was used to simulate reasonable combinations of these potential code changes in three of California's most populous Climate Zones. EnergyPlus is a whole-building simulation program that can simulate natural ventilation and HVAC systems, but its ability to simulate both at the same time is limited. When simulating natural ventilation, which is driven by wind pressure and stack effect, EnergyPlus cannot also model any ducted forced-air systems. Therefore, heating and cooling equipment in the models to radiant systems were limited.

A model of a six-story apartment building was developed in EnergyPlus. The model was designed to help investigate the effects of various ventilation-related technologies and construction practices on energy use and ventilation airflows. Researchers modeled it in State Climate Zones 3 (San Francisco), 8 (Los Angeles), and 12 (Sacramento), to account for variations in climate. Building materials primarily from the National Renewable Energy Laboratory's (NREL) Building Component Library were selected. The building envelope includes steel framing and a 20 percent window-to-wall ratio, and is Title 24 compliant.

Because EnergyPlus could not model the individual forced-air heating and cooling systems commonly used to condition multifamily homes, our model used a radiant hydronic system fed by a central plant providing hot and cold water. Conditioning of each apartment was individually controlled by a thermostat; its schedule configured using a temperature profile specified by the Energy Commission's Residential Alternative Calculation Method (ACM) Manual. Building internal mass and internal gains were also set according to the ACM manual.

Because wind- and stack-driven pressures vary with building height, the locations of building envelope leaks affect airflow rates for both infiltration and exfiltration. Under some conditions, air can flow in opposite directions through leaks at different heights in the same wall. To capture the effects of distributed leak heights on airflow, researchers modeled the exterior walls of each apartment with three leaks evenly spaced along the wall height. Interior walls, which are not directly impacted by wind or stack effect, were modeled with a single leak each. Researchers also modeled ceilings or floors with a single leak each, as height is not a factor in horizontal surfaces.

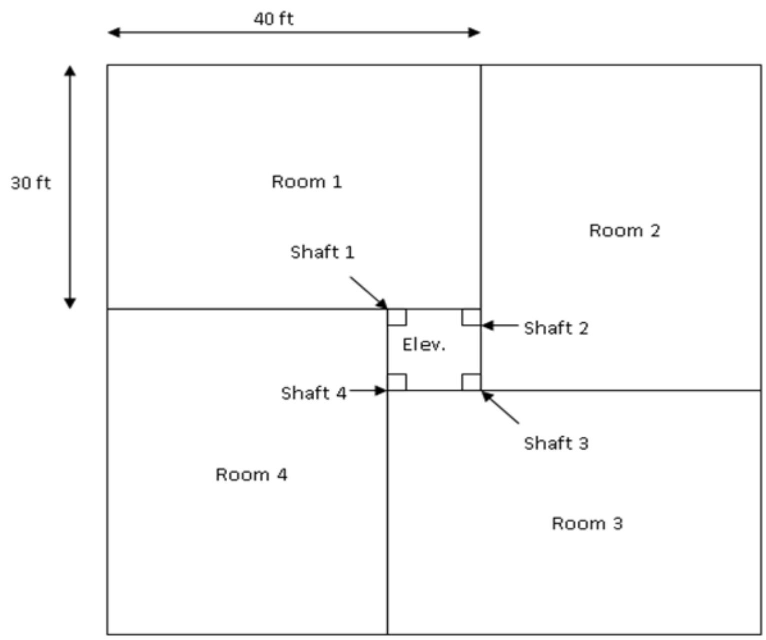
Figure 3 illustrates the floor plan developed for this study, which is symmetrical to minimize the effects that building orientation can have on results. For example, the magnitude of wind or solar effect on a symmetrical building is independent from the direction of the wind or sun.

---

[2] "Self-balancing damper" is a generic term that describes a short section of round ductwork that includes a proprietary damper that allows a specified amount of air to flow through the duct regardless of the difference in pressure across the duct (within a specific range). They are used to maintain consistent airflows in response to building pressures that vary as a result of stack effect, fan operation, wind pressures and air filter conditions. Proprietary names include Constant Airflow Regulators (CAR) and Volume Flow Limiters

A focus of the research was on stack effect (vertical air movement), and a primary path for vertical air movement in a building is through vertical shafts that run the entire height of the building. These can include elevator shafts, exhaust ducts, plumbing chases, and garbage chutes. To account for such vertical air movement, the model includes an elevator shaft in the common space between apartments. Each apartment was modeled with a leak in the apartment door, and a corresponding leak through the elevator door to the elevator shaft.

Figure 3: Floor Plan of Multifamily Building Model



Source: Multifamily Ventilation Modeling Discussion and Results. PIER 500-10-019, Report on Task 1.3, Dec 16, 2013

Several different metrics are used for describing the amount of leakage within an apartment. The two metrics used in this report are CFM50/ft2, which is a measure of the cubic feet of air that leaks through one square foot of envelope every minute, at a pressure of 50 Pascals. The other metric is ACH50, which is a measure of how many times the volume of air within a space would be replaced over the course of an hour, also at a pressure of 50 Pascals. The effect of compartmentalization was modeled by "sealing" exterior and interior leaks from a baseline of 0.40 CFM50/ft2 to 0.20 CFM50/ft2 of total envelope area, which is the target specified by the Energy Commission version of Standard 62.2-2010. It was determined the distribution of floor/ceiling leakage based on typical leakage for floors of commercial buildings since high-rise multifamily buildings have similar floor construction to commercial buildings. Remaining leakage was evenly distributed among exterior walls and interior partition walls.

Three types of mechanical exhaust ventilation systems were modeled:

1. Individual unit exhaust fans
2. Central shaft exhaust with a rooftop fan and unbalanced dampers at each apartment
3. Central shaft exhaust with a rooftop fan and self-balancing dampers in each home

Individual unit exhaust fans deliver roughly the same amount of airflow regardless of the interior and exterior pressure of an apartment, within normal operating ranges. An individual unit fan sized to deliver 60 cubic feet per minute will generally deliver 60 cubic feet per minute. However, the amount of air exhausted by central shaft systems that serve multiple floors can vary widely, depending on the pressure inside the duct and the variation in pressures between apartments on different floors of the building. The proposed code change to require self-balancing dampers is aimed at alleviating this issue, but to test the effectiveness of self-balancing dampers, a baseline for current code was established. Because of the challenges with unbalanced central shaft systems, there are two different versions of what might be considered "code compliant" — systems that meet the intended requirements of the code, and those that would meet the performance expectations or "intent" of the code.

The 2008 Standards do not require testing of apartment level exhaust flows. Rather, compliance with code involves sizing the rooftop fan such that the total exhaust from the fan equals the sum of the minimum ventilation rates for all apartments served by the shaft. For example, if a shaft served eight apartments, and each apartment had an exhaust requirement of 100 cubic feet per minute, the fan would need to provide 800 cubic feet per minute. There are two problems with this approach to code compliance:

1. The pressures in each apartment served by the shaft are quite variable, leading to variation in the exhaust flows — some apartments are over ventilated and some are under ventilated.
2. Leaks in the exhaust shaft may not be pulling air from the apartments served by the shaft.

Complying with Title 24 through the prescriptive path (sizing the fan as described above) only meets the letter of the code, but not the intent (that each apartment receive a minimum rate of exhaust flow). Therefore, models were designed to simulate two different approaches to Title 24 compliance:

1. A building that complies with the letter of the code but does not control for ventilation levels in individual apartments.
2. A building that complies with the intent of the code, where all apartments receive at least the minimum required exhaust. To ensure that the apartment with the lowest flow rate still meets the minimum, the fan was upsized resulting in over-ventilation of many of the individual apartments.

The second approach accounts for the variable, unbalanced apartment-level airflows known to exist in many multifamily buildings.

The central shaft models have an exhaust fan at the top of each of four shafts. These fans operate continuously. Airflow for these models was attributed to two different sources: flow through the exhaust grilles in each apartment, and flow through leaks in the central shaft.

Central ventilation shafts were modeled in EnergyPlus as a series of vertical indoor zones connected by “leaks.” Flow resistance was modeled by creating discrete flow resistances within the shaft at each story of the building. Two central shaft leakage scenarios were modeled: 5 percent and 25 percent leakage, including the horizontal ducts connecting each apartment to the central shaft.

The self-balancing dampers in each apartment were modeled to deliver a known, constant airflow throughout the year. Fan power was determined for the self-balancing damper scenario by post-process identification of a fan pressure that corresponds to the high pressure required to achieve constant air flow through the registers. Using fan pressure, fan air flow rate, and fan efficiency, a realistic power draw was determined for the rooftop exhaust fans in each of the ventilation scenarios.

For the individual unit ventilation models, each apartment was ventilated by an exhaust fan mounted in an exterior wall. Since these systems were ductless, rooftop fans and central exhaust shaft leaks used in the central system models were removed. The geometry of the central exhaust shafts was not changed, but were made airtight so the ventilation system was not affected. Fan power for this model was determined post-process by applying an appropriate back pressure to the unit exhaust fans to account for actual flow resistance.

For the 1,200 ft2 three-bedroom apartments, two different ventilation rates were modeled:

- 92 CFM = 0.06(1,200)+5(3+1), Title 24 rate for high-rise apartments
- 66 CFM = 0.03(1,200)+7.5(3+1), Title 24, 2013 rate for low-rise apartments

The following list explains the nomenclature for our multifamily building modeling scenarios.

- Ventilation system type:
  - Individual unit — Each apartment has its own exhaust ventilation system
  - Central shaft — Each apartment connects to a central ventilation shaft
- Ventilation rate:
  - High-rise — Required by Title 24 nonresidential code
  - Low-rise — Required by Title 24 residential code
- Envelope leakage:
  - Leaky envelope — 0.40 CFM50 per ft2 total envelope area

- Tight envelope — 0.20 CFM50 per ft2 total envelope area
- Central shaft duct leakage:
  - Leaky duct — Duct leakage is 25 percent of ventilation fan flow
  - Tight duct — Duct leakage is 5 percent of ventilation fan flow
- Rooftop fan sizing:
  - Prescriptive — Fan is nominally sized based on ventilation requirements
  - Compliant — Fan is upsized so each home receives minimum ventilation
- Apartment exhaust dampers:
  - Manual balancing — Damper in each home is manually adjusted once a year
  - Automatic balancing — All homes have self-balancing dampers

Modeling Results

After running the models, an analysis of the results was conducted focusing on two primary metrics:

- HVAC energy use, including heating, cooling, and ventilation fan energy; and
- Consistency of ventilation rates within each apartment over time, and among apartments at different locations in the building.

All graphics represent models for Climate Zone12.

Ventilation rate

To isolate the savings potential for each measure, 36 different scenarios were modeled. The first variable that was adjusted was the ventilation flow rate. Eighteen of the models used the current Title 24 rate for high-rise, and another 18 used the low-rise rate. Comparing the energy use for the model with each of these two ventilation rates shows the savings potential from lowering the high-rise rate in Title 24 to match the low-rise rate.

Reducing the ventilation rate from the Title 24 high-rise rate to the Title 24 low-rise rate had the largest singular impact on energy use in the building. In the modeling, the lower ventilation rate reduced annual heating energy use. Total HVAC energy use for the building was reduced in each case.

Figure 4 illustrates the average energy use from all 18 models that used the high-rise rate as compared to the energy use for all models using the low-rise ventilation rates in Climate Zone 12. It is clear that lowering the minimum rate requirement will save energy regardless of the other variables at play.

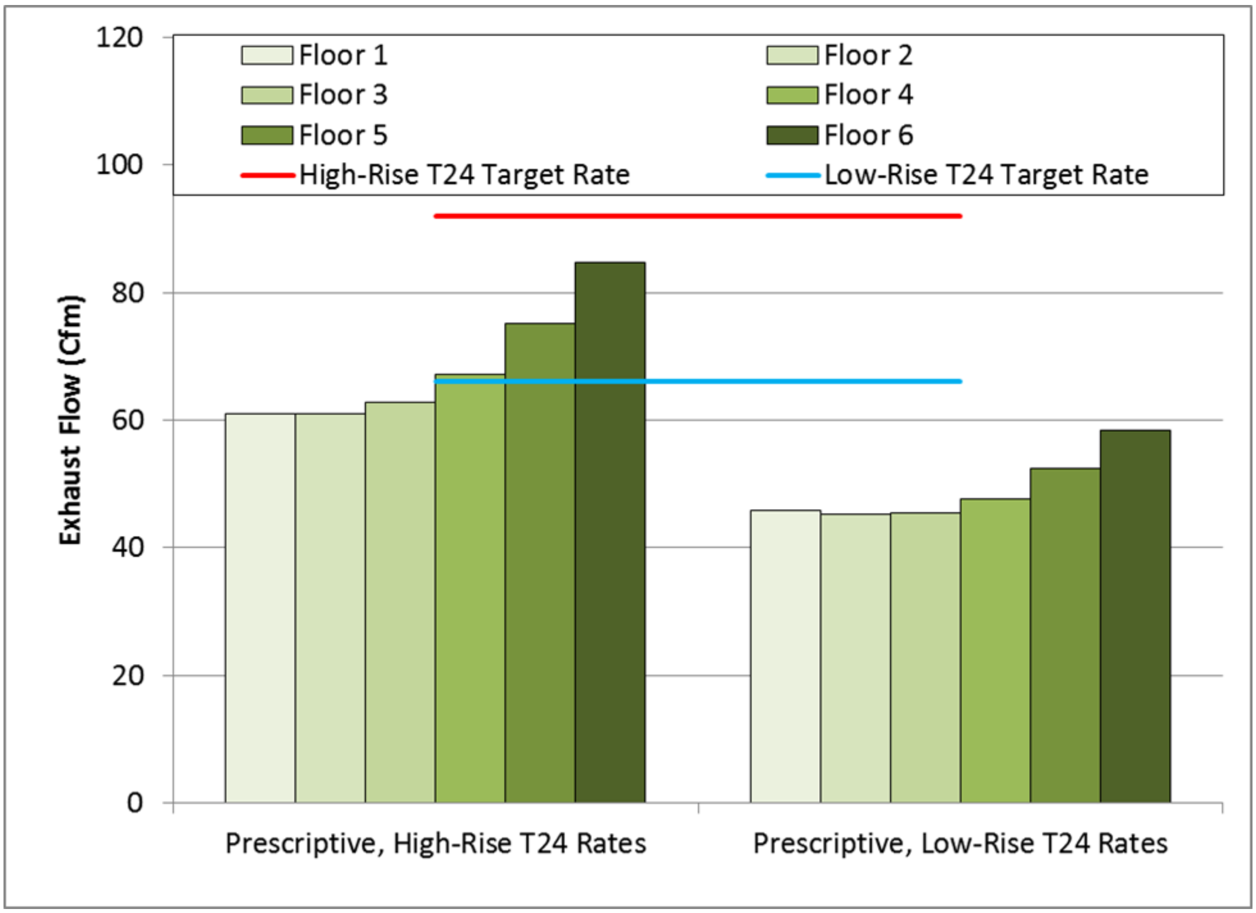
Fan sizing and exhaust balancing

The next variable that was changed was the size of the fan. "Upsized" systems reflect the scenario whereby minimum rates are maintained in each individual apartment by increasing the fan flow to account for leakage and system imbalances.

The models were then assigned to one of three categories — no balancing, manual balancing dampers, or self-balancing dampers. Balancing does not apply to individual unit systems since the models assumed little-to-no variability in the flow rates for individual systems.

Manual balancing dampers can be helpful in reducing the variation in flow between apartments, but have a major limitation in that they do not automatically adjust to changes in pressures. Self-balancing dampers make this adjustment automatically.

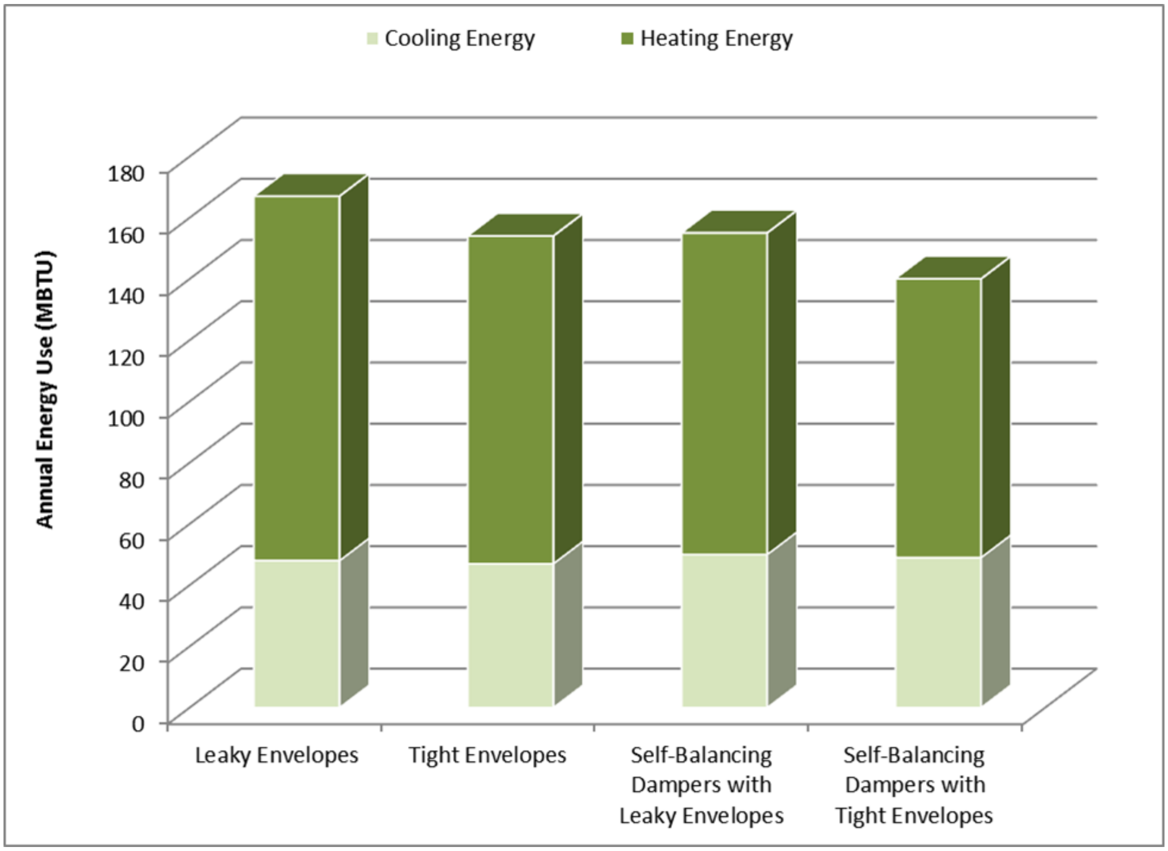
Figure 4: Exhaust Airflow Rates by Floor, as Compared to Code Requirements



Source: WCEC

Figure 4 illustrates the variation in airflow within a system designed to meet prescriptive code. Because of central shaft leakage and system imbalances, none of the floors get the ventilation the code says they should, however the system designed to meet high-rise rate requirements does meet the lower low-rise requirements on three of the six floors.

Figure 5: Energy Impact of Tightening Envelope and Self-Balancing Dampers



Models with Fans Sized to Provide Minimum Required Airflow to Every Unit

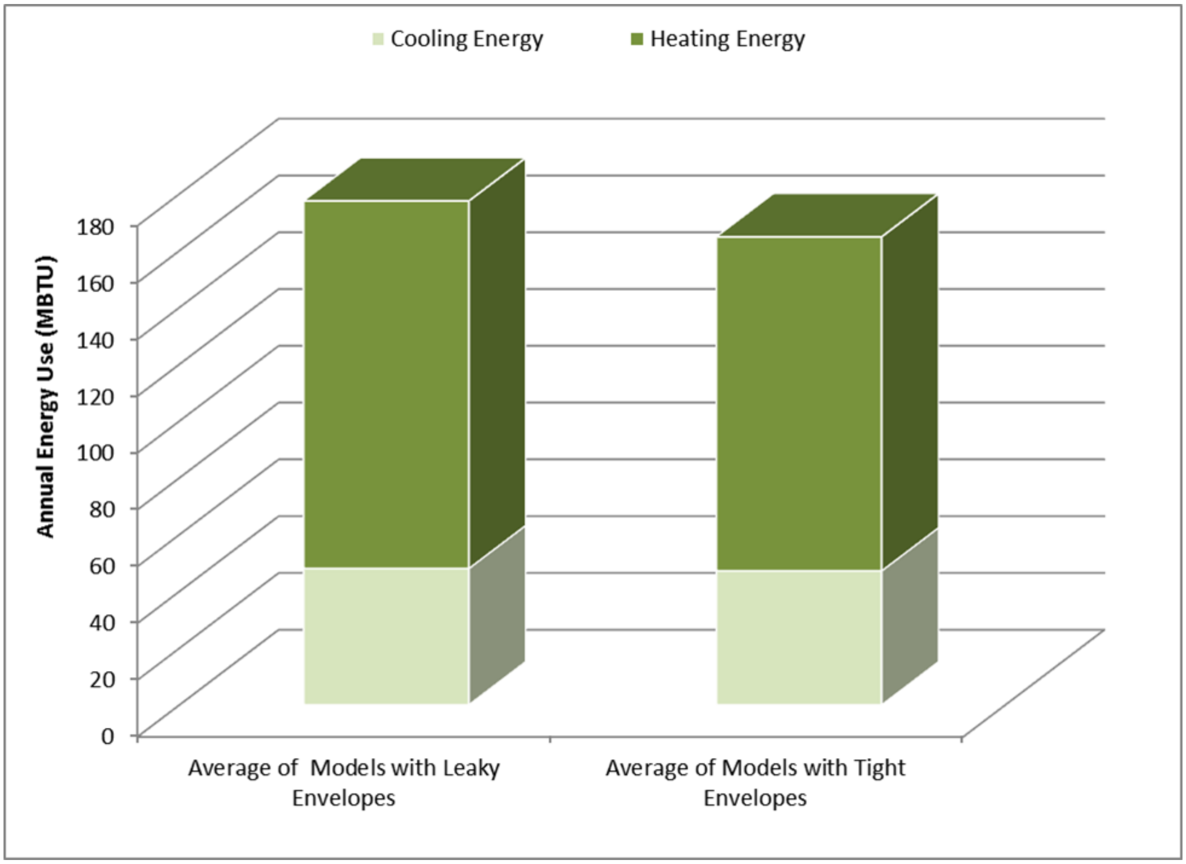
Source: WCEC

Compartmentalization

Figure 5 shows the energy savings attributable to compartmentalization for buildings with two different ventilation schemes. "Envelope" refers to the air barrier around each apartment, not the entire building. A model of an apartment building with "tight envelopes" is one that has been compartmentalized, or each apartment has been sealed from other apartments and the outdoors. Self-balancing dampers mitigate the issues created by stack effect, which is largely attributable to leaky envelopes and interior airflow. However, a tighter envelope leads to energy savings regardless of whether the central exhaust system is in balance.

Another way of looking at the effect of compartmentalization is by looking at average energy savings of the eight models with leaky envelopes versus the eight models with tight envelopes, shown in Figure 6, below. All sixteen models had the fan sized to provide at least the minimum required airflow to each unit.

Figure 6: Energy Savings Attributable to Compartmentalization



Models with Fans Sized to Provide Minimum Required Airflow to Every Unit

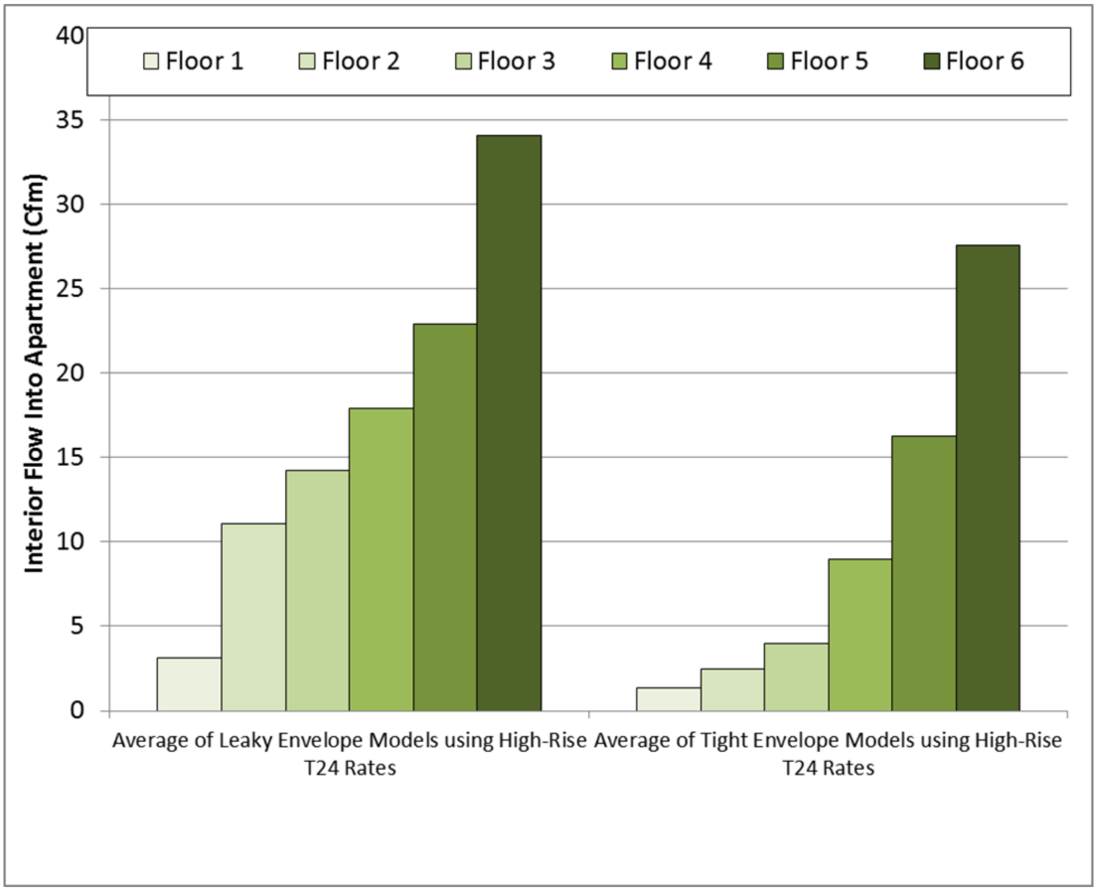
Source: WCEC.

More importantly, in addition to saving energy, compartmentalizing apartments results in reduced air transfer between units.

Figure 7 shows the effect of compartmentalizing as represented by the amount of air moving into each apartment from other apartments. Although top-floor apartments still receive a lot of transfer air from other apartments, compartmentalization reduces transfer air for apartments on all floors of the building.

When air is exhausted from a space, it is replaced by makeup air. Ideally, 100 percent of the makeup air, or "ventilation air," infiltrates from outside through exterior walls into the occupied space, but this often is not the case. Because of wind pressure, the stack effect, and uneven distribution of ventilation flow, a large portion of makeup air often is drawn from adjacent occupied spaces. The transfer air being drawn from one occupied space into another occupied space should not be considered fresh air and cannot be relied on to improve the air quality, which is the intent of a ventilation system. In fact, the air drawn from neighboring apartments can contain higher levels of contaminants, such as cigarette smoke, that can reduce indoor air quality and increase tenant complaints

Figure 7: Reduction in Transfer Air due to Compartmentalization



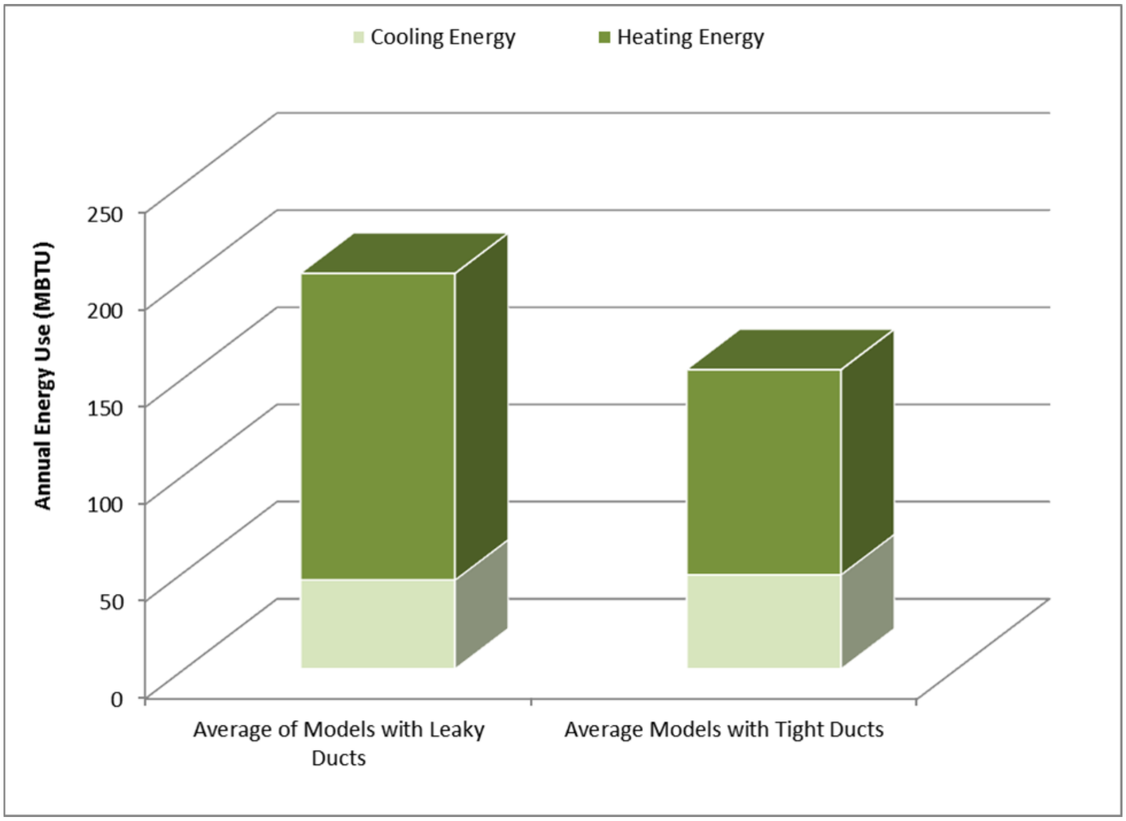
Source: WCEC

In general, the annual cooling energy required for the building increases slightly with each new performance improvement, while both heating and total space conditioning energy use decreases for all cases relative to the baseline model. The reason for the increase in overall cooling energy use is that the baseline model has significantly higher ventilation flow rates than do the other cases, which in Climate Zone 12 results in "free cooling" for the building, since outdoor air temperature is lower than the indoor set point for many hours of the year. What the model is not able to capture is the occupant use of operable windows during times when the outdoor air is favorable. This suggests that these results could slightly overstate the added cooling energy use for buildings with lower ventilation flow rates, and that occupant use of operable windows could erase these cooling load increases in real-world applications.

Duct sealing

The objective of a central ventilation system is to provide equal rates to all of the apartments it serves. Reducing duct leakage in the central shaft not only helps create consistent ventilation among apartments, but also allows the fan speed to be lowered, reducing fan energy consumption. Figure 8 shows that, on average, sealing ducts can provide significant energy savings.

Figure 8: Average Energy Use of Models with Leaky Ducts vs. Tight Ducts



Models with Fans Sized to Provide the Minimum Required Airflow to Each Unit

Source: WCEC

The key results from the computer modeling portion of the research are as follows:

- Tightening the building envelope according to the multifamily requirements of the 2013 Title 24 Low-Rise Ventilation Standard reduced the combined energy use for heating, cooling and ventilation of the six-story building model in all three Climate zones . The impact of tightening the envelope was greater for models with lower ventilation rates and tighter ducts, resulting in a 6 to 12 percent reduction in combined heating, cooling, and ventilation energy use.

- Tightening the building envelope according to the multifamily requirements of the 2013 Title 24 Low-Rise Ventilation Standard also reduced the amount of indoor air transfer between apartments by half. Reducing transfer air improves indoor air quality.

- Among all of the variables modeled, reducing the ventilation rate from the Title 24 high-rise residential rate to the 2013 Title 24 low-rise ventilation rate had the largest single impact on energy use.

- Designing with individual unit ventilation or with central shafts that utilize self-balancing dampers yields the most stable ventilation rates. The annual fluctuation in ventilation rates for these models is less than one percent from the mean, indicating they provide consistent, compliant ventilation without excess energy use.

Field Testing

Two types of field research were conducted in this project. They included:

1. Single-point measurements of envelope and shaft leakage in seven multifamily buildings.
2. Ongoing (60-day) monitoring of energy and ventilation characteristics of retrofitted central shaft and baseline/comparison central exhaust shafts in a single high-rise building.

The first task characterized typical high-rise multifamily envelope leakage and central shaft leakage rates, and investigated the types and distribution of ventilation systems. The second task, field testing, evaluated the performance of strategies for improving central shaft ventilation systems.

Because low-rise buildings rarely have central shafts, buildings with at least four stories were selected for site visits. Field measurements included 24 apartments in seven multifamily buildings that had a construction range from 1960 to 2010. Building samples ranged from four residential stories to 18 residential stories above a commercial ground floor. The apartments tested were generally smaller than most newly constructed multifamily buildings, averaging just 285 square feet. It is also important to note that the buildings do not represent current construction practice so findings cannot be directly transferrable for purposes of code change affecting new construction.

Envelope and shaft leakage testing

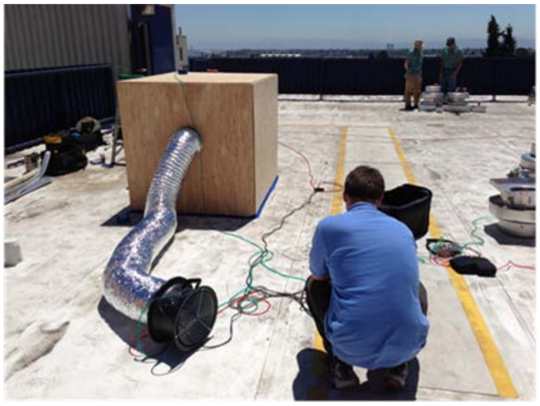
The team conducted blower door tests to determine the envelope leakage of each apartment. Prior to each test, exhaust registers were sealed. However, since the HVAC ducts are a contained system within each apartment, they were not sealed before the test; the leakage was included in the total apartment leakage calculations.

Figure 9: Blower Door Testing of a Multifamily Apartment

Source: Benningfield Group, Folsom CA

Exhaust flows were measured at every apartment's exhaust grille by using a combination of an anemometer [3] and flow hood. The total exhaust flow was measured by installing a calibrated duct-blaster fan in a large capture flow hood at the top of the central ventilation shaft. Total leakage of the central shaft system (shaft plus connecting ducts) was determined by subtracting the sum of the airflow from all apartments from the total flow at the top of the shaft

Figure 10: Rooftop Exhaust Fan Flow Capture Hood and Duct Blaster



Source: WCEC.

[3]Testo 417 large vane anemometer.

The CFM50 value that is the result of each test was converted to air changes per hour at 50 Pascals (ACH50) and CFM50 per ft2 of total envelope area. Both values are shown in Table 4

Table 4: High-Rise Multifamily Apartments Tested

No.	Year Built	# of Stories (residential)	Floor Area (ft2)	ACH50	CFM50 / ft2 envelope area
1	2010	4	165	7.53	0.23
2	2010	4	165	9.24	0.28
3	2010	4	165	6.53	0.21
4	2010	4	165	6.49	0.20
5	2010	4	165	7.39	0.24
6	2010	4	165	7.15	0.22
7	2005	4	200	4.99	0.17
8	2005	4	200	3.67	0.13
9	2005	4	200	4.29	0.15
10	2005	4	200	3.88	0.13
11	1960	5 (4)	142	8.10	0.24
12	1960	5 (4)	142	18.68	0.56
13	1960	5 (4)	142	13.12	0.39
14	1960	5 (4)	142	9.26	0.28
15	1960	5 (4)	142	11.43	0.34
16	1960	5 (4)	142	6.88	0.21
17	1963	5 (4)	142	15.34	0.46
18	1963	5 (4)	142	7.88	0.24
19	1964	18 (17)	744	3.60	0.06
20	2003	4	1,244	5.12	0.27
21	1972	8 (7)	484	7.00	0.27
22	1972	8 (7)	484	5.67	0.22
23	1972	8 (7)	484	4.31	0.17
24	1972	8 (7)	484	5.38	0.21

Source: Adapted from WCEC Summary and Analysis of Field Measurements.

This limited sample of results suggests that apartment tightness has improved over time. Seven apartments meet the “⩽ 0.2 CFM50 per ft2 envelope area” metric that complies with

Standard 62.2-2013's low-rise multifamily ventilation requirements. Those values are shaded in Table 4.

Using methods described above, the leakage of seven central ventilation shafts in the eight-story 1972 apartment building was measured. Shaft leakage averaged 19.4 percent and ranged from 8.7 to 40.0 percent (Table 5).

Table 5: Central Shaft Leakage Results

Ventilation Shaft ID	Sum of Apartment Flows (CFM)	Rooftop Capture Hood Flow (CFM)	Flow Difference (CFM)	Shaft System Leakage (% of total flow)
3	212	273	61	22.4%
4	193	222	29	12.9%
5	188	220	32	14.6%
6	281	320	39	12.2%
7	222	297	75	25.4%
12	265	290	25	8.7%
13	175	290	115	39.7%

Source: Adapted from WCEC Summary and Analysis of Field Measurements
Field testing of proposed code measures

Following the tests, one of the buildings considered to be the most suitable for evaluating retrofit options was selected, an eight-story building with seven floors of apartments over a ground-floor commercial space. The retrofit as a monitoring exercise tested hypothesis about the effectiveness of three strategies aimed at improving the performance of central shaft systems. Those three strategies are:

1. Reducing the leakage of a central exhaust shaft by one of two means:
    A. Manual sealing using mastic tape
    B. Aerosol sealing with a product called AeroSeal
2. Using manually adjustable dampers to regulate the exhaust flow from each apartment.
3. Using a self-balancing damper to regulate the exhaust flow from each apartment.

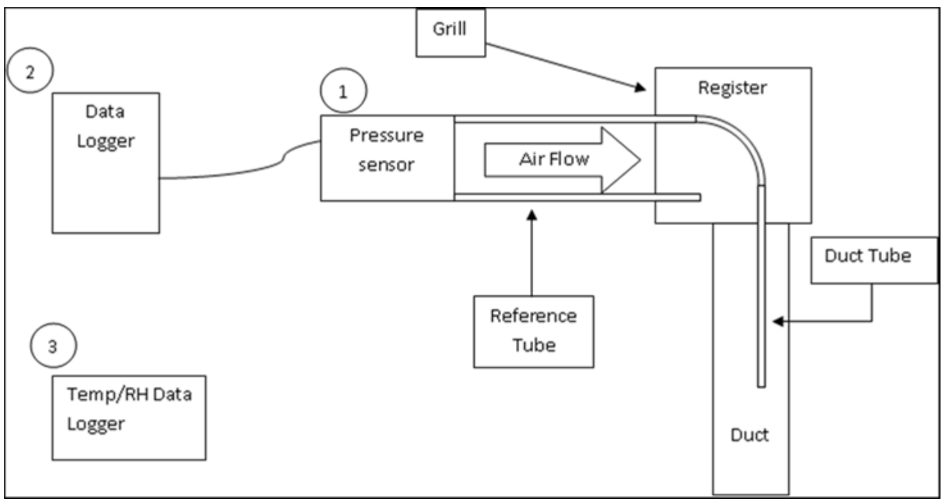
To perform the tests, three of the most accessible shafts for installation and evaluation of retrofit strategies were selected. One central shaft system and its rooftop fan served as a "common practice" baseline, representing a configuration that would meet current code requirements, but had the potential for performance improvement. This system had a total leakage of about 20 percent of exhaust fan flow, which corresponds to the typical conditions. This shaft did not have any type of flow regulator.

The second shaft represented a mid-level performance case. It was manually sealed with mastic. The measured leakage of this shaft was about 16 percent of exhaust fan flow. On this shaft, manually adjustable airflow dampers were used at each apartment's exhaust grille. The manually adjustable dampers were set to deliver a consistent airflow rate to all apartments.

The third shaft system was sealed using the patented AeroSeal sealing system. Using this process, shaft system leakage was reduced to 0.5 percent of fan flow. Also, instead of manually adjusted airflow dampers, the team installed self-balancing dampers at each exhaust grill. These ensure that 30 cubic feet per minute is consistently exhausted from each apartment when appropriate duct pressure is maintained.

A schematic of the equipment and its location is shown in Figure 11.

Figure 11: Schematic of Pressure Monitoring Equipment in Each Apartment

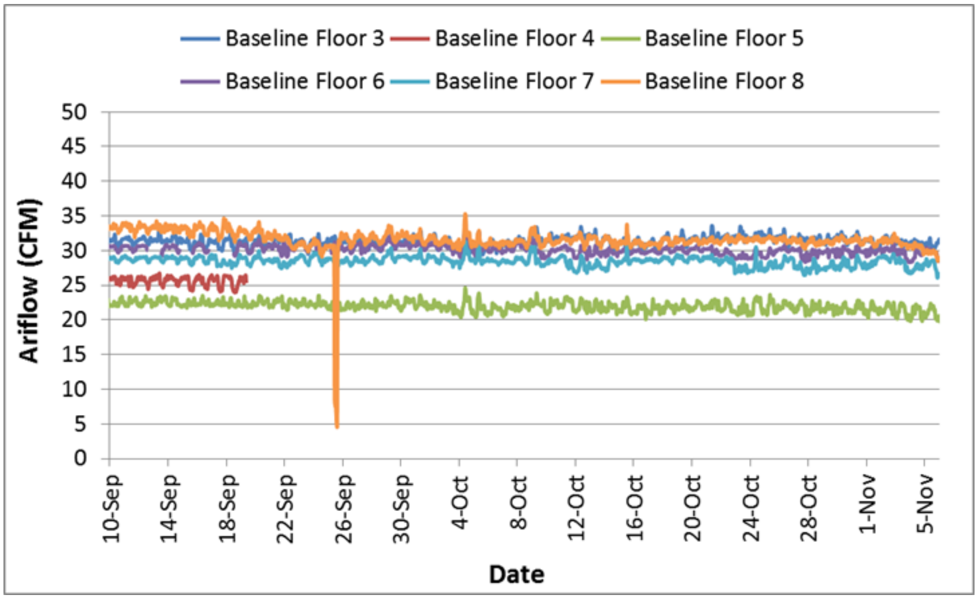


Source: WCEC Summary and Analysis of Ventilation Retrofit Monitoring

Of the 21 apartments (seven per shaft) served by the three central exhaust ventilation shafts in this study, data from 14 were usable in the analysis. Data from the other seven had to be discarded because there were periods of lapsed monitoring or other issues that invalidated the data.

Results of the monitoring effort demonstrated that shafts sealed by AeroSeal combined with self-balancing ventilation dampers in each apartment can consistently improve ventilation in high-rise multifamily buildings.

Figure 12: Hourly Average Exhaust Flows for Baseline Condition

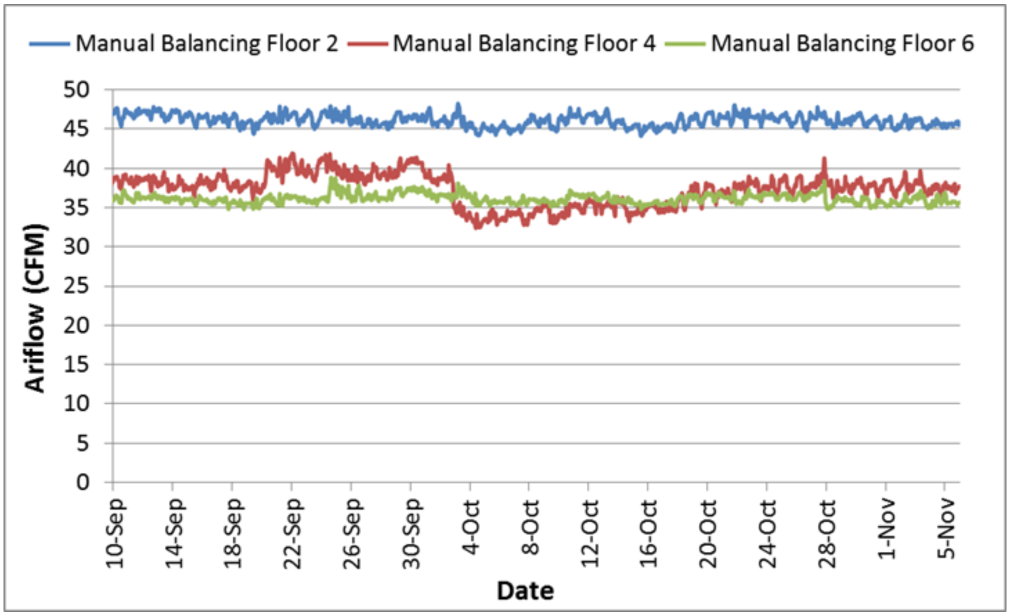


Source: WCEC

Figure 12 shows the exhaust airflow for the baseline condition. Exhaust flows were fairly consistent for each apartment over the monitoring period. However, there is a substantial difference between the flow rates in the different apartments. Average flow for the 5th floor apartment is about 30 percent lower than that for the 8th floor apartment.

Figure 13 shows exhaust airflows for three of the seven apartments attached to the shaft treated with manual sealing and manual balancing dampers. The results show less consistency in each apartment, and higher flow rates overall compared to the baseline scenario shown in Figure 12

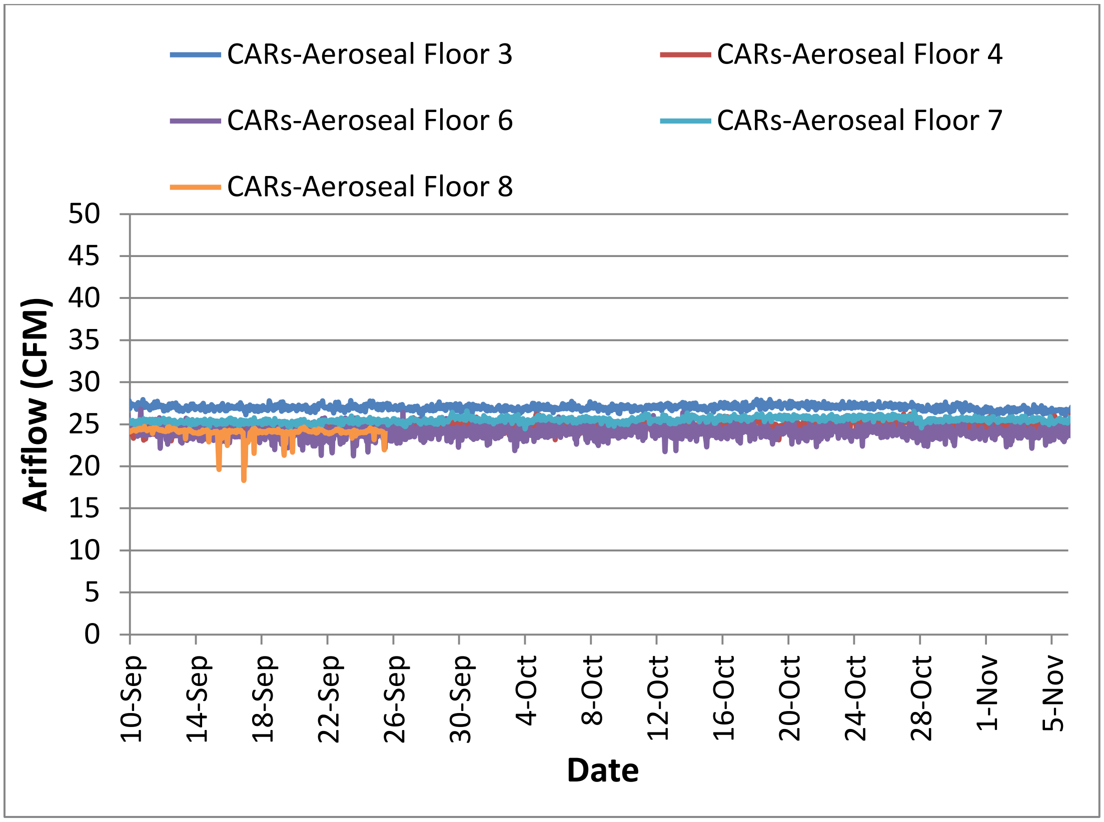
Figure 13: Hourly Average Exhaust Flows for Manual Sealing and Balancing Condition



Source: WCEC

Figure 14 shows exhaust flows for five of the seven apartments on the shaft sealed with AeroSeal and retrofitted with self-balancing dampers. These flow rates were very consistent throughout the monitoring period and showed less variation diurnally than the other two shafts monitored.

Figure 14: Hourly Average Exhaust Flows for Aeroseal Sealing and Self-Balancing Dampers



Source: WCEC

The shaft retrofitted with AeroSeal and self-balancing dampers had the smallest standard deviation, due to the dampers' ability to continuously regulate the exhaust airflow. This shaft had a standard deviation of 0.5 cubic feet per minute, compared to a standard deviation of 3.1 CFM for the baseline shaft and 5.0 CFM for the manually balanced and sealed shaft. The higher flow rates and variability displayed by the manually sealed and dampered shaft could not be explained.

This field experiment confirms that self-balancing dampers combined with tightly sealed central shafts results in consistent exhaust air flow rates, both within each apartment over time, and between floors in the same high-rise building. The fluctuation in exhaust fan flow of this retrofitted shaft was about 3 percent of the total fan flow, compared to 17 percent for the baseline shaft, and 46 percent for the manually sealed and dampered shaft.

The self-balancing dampers not only reduced fluctuations in airflow to each apartment but also improved the distribution of ventilation in the building. The largest difference between any two apartments that were served by the exhaust shaft retrofitted with AeroSeal and self-balancing dampers was 3 cubic feet per minute on average, or about 10 percent of the target exhaust flow for an apartment. Apartments on the manually sealed shaft with manual balancing dampers showed 10 cubic feet per minute difference between two apartments on the shaft which was about 33 percent of the target exhaust flow. Similarly, the baseline shaft showed 10 cubic feet per minute difference between two apartments on the shaft.

2.4 Recommendations and Conclusions

Our recommendations for improving Title 24 requirements for multifamily ventilation fall into two categories: Those that apply to all multifamily buildings and those that apply only to multifamily buildings with central ventilation shafts.

Unify Low-Rise and High-Rise Multifamily Ventilation Requirements

It is recommended that the Energy Commission extend 2013 Title 24 low-rise residential ventilation requirements to high-rise residential buildings. Aligning the Title 24 ventilation requirements for high-rise multifamily construction with the low-rise residential requirements will reduce the amount of conditioned air that is exhausted, provide more consistent ventilation throughout, and put new multifamily construction on a path to become zero-net energy compliant by 2020.

Applying ASHRAE 62.2 to all multifamily buildings accomplishes several major improvements:

1. Ensuring continuous mechanical ventilation of homes in new high-rise buildings
2. Saving energy by reducing high-rise ventilation rates to low-rise multifamily ventilation rates
3. Improving air quality by reducing indoor air transfer between adjacent homes within a multifamily building
4. Reducing infiltration and pressure-related system imbalances by combating stack effect

These changes will improve the energy efficiency of high-rise residential buildings by reducing over-ventilation, thereby reducing the ventilation-related space conditioning and fan energy. Additionally, compartmentalizing apartments and sealing each dwelling unit so that it is well isolated not just from the exterior, but from surrounding units and common areas, will reduce inter-apartment airflows.

The co-benefits of making the high-rise multifamily ventilation requirements consistent with the low-rise requirements are also significant. Building designers, developers and contractors will no longer be frustrated by the substantial but arbitrary differences between ventilation requirements for low-rise and high-rise multifamily buildings in the same project. They will have clear multifamily-specific requirements for home air tightness and mechanical ventilation rates. Saving occupants on their utility bills and providing a higher level of comfort may result in lower turnover and higher retention rates, benefiting occupants, building owners, and managers.

2.4.1 Improve Central Shaft Ventilation Systems

Changing the high-rise code to require self-balancing dampers and sealing of central shafts will provide substantial reductions in the exhaust rate variation between apartments on different floors or different sides of buildings, ensuring that everyone served by the system will receive the minimum required airflow without over-ventilating. For multifamily buildings with central shaft ventilation systems, it is recommended:

- Limiting central shaft leakage to 5 percent of total ventilation fan flow
- Requiring self-balancing dampers at each apartment's ventilation grille

These requirements will improve multifamily building energy efficiency by reducing total ventilation fan flow and minimizing over-ventilation of homes on higher floors. They will improve indoor air quality in multifamily buildings by eliminating under-ventilation of homes on lower floors, reducing the amount of make-up air that comes from unintended locations, and providing a consistent ventilation rate throughout the year for all homes.

2.4.1.1 Summary of Energy Benefits

Based on our modeling of a six-story multifamily building in the three Climate Zones, the proposed changes to multifamily ventilation requirements result in significant energy savings. Table 6 shows annual savings estimates based on the EnergyPlus model described above, as well as Time Dependent Valuation (TDV) values for each Climate Zone. TDV values weight the value of energy for each hour of the year that the energy is used, based on several factors including electrical system demand.

Table 6: Estimated Savings for Proposed Code Improvements

		Electricity Savings, kWh/year	Electricity Savings, %	Natural Gas Savings, therms/year	Natural Gas Savings, %	TDV Electricity Savings	TDV Gas Savings	Net TDV Savings
CZ 3 San Francisco	Per prototype building	-689	(39%)	1,749	69%	-31,981	88,881	**56,900**
	Per square foot floor area	-0.024	(39%)	0.061	69%	-1.110	3.086	**1.976**
CZ 8 Los Angeles	Per prototype building	-1,050	(26%)	816	77%	-30,263	42,944	**12,681**
	Per square foot floor area	-0.036	(26%)	0.028	77%	-1.051	1.491	**0.440**
CZ12 Sacramento	Per prototype building	-114	(3%)	2,048	82%	1,568	106,608	**108,176**
	Per square foot floor area	-0.004	(3%)	0.071	82%	0.054	3.702	**3.756**

Source: Western Cooling Efficiency Center (WCEC) Multifamily Ventilation Code Change Proposal_012814.docx.

Compliance with Compartmentalization Requirement

The Standard 62.2-2010 requirement for compartmentalization of multifamily homes specifies that one way of demonstrating compliance is to conduct a blower door test on individual homes and verify that the leakage area does not exceed 0.20 CFM50 per ft2 of total envelope area.

Verifying compliance with this compartmentalization requirement presents a challenge. Visual inspection is typically inadequate because it is difficult to access building assemblies that need to be inspected, and even if they are accessible, visual assessments are qualitative. Blower door testing yields a quantitative measurement of envelope leakage, but due to their larger size and complexity, it is more difficult to measure multifamily than single-family buildings. For example, in high-rise homes with no door to outside, it can be difficult to determine the reference pressure, which should be "outdoors."

Currently there is no standard ASTM method for blower door testing multifamily buildings. However, it is easier to blower door test individual apartments in a multifamily building than it is to blower door test the multifamily building as a whole. There are several methods for blower door testing individual apartments. In practice, testing of apartments might be done on a sampling basis, but interactions with adjacent apartments complicate that approach.

Indoor Air Quality and Public Health Implications

Mechanical ventilation is not an energy efficiency measure itself, but rather a means to an even more important end, which is human health. Mechanical ventilation provides a reliable supply of outdoor air, but it cannot control indoor-outdoor airflow unless homes are also tight. In other words, uncontrolled infiltration is the enemy of controlled ventilation and energy efficiency. Compartmentalizing apartments has the potential to improve indoor air quality by minimizing transfer of indoor air pollutants between attached homes. Of particular concern are second hand tobacco smoke, volatile organic compounds, and excess moisture.

ASHRAE's new compartmentalization standard, now part of Title 24 for low-rise multifamily buildings, will reduce the amount of air transferred between apartments, and it is recommended extending it to high-rise multifamily buildings.

Finally, due to the pressure imbalances due to upward air movement (stack) and wind, central exhaust systems do not always deliver the amount of ventilation they were designed to. Changing the high-rise code to require self-balancing dampers and sealing of central shafts will provide substantial reductions in the exhaust rate variation between apartments on different floors or different sides of buildings, ensuring that everyone served by the system will receive at least the minimum required airflow. In addition to reducing transfer of pollutants between apartments, requiring compartmentalization will mitigate the pressure imbalances often seen in tall buildings, further helping to stabilize ventilation flow rates.

Tech Transfer Activities

Three ventilation-related white papers were produced: a guide to understanding multifamily ventilation, an early preview of the code changes that were to come later in the project, and a paper advocating a unified multifamily code.

In an effort to address ventilation issues specific to multifamily buildings, a guide was developed entitled "Multifamily Ventilation: Practices and Principles for High Performance Ventilation in California's Multifamily Buildings." The impetus for developing the guide was contact from a staff person at the Energy Commission Standards Office who reported a high volume of questions from developers and engineers. He said that many were confused regarding not only code requirements, but also best practice and building science related to multifamily ventilation.

Our team designed the guide to help fill this knowledge gap by highlighting the issues related to multifamily ventilation system design, and offering guidance on how to address these issues while complying with or exceeding code.

The final product is a document that provides the reader with a strong foundation in understanding why mechanical ventilation is important, how multifamily ventilation is unique, and what ventilation strategies are available to the designer. The guide includes recommendations based on the primary research performed in this study, as well as a summary of best practices sourced from interviews and secondary research. In addition to engineers and designers, the audience for the guide includes building departments struggling with understanding how and why multifamily ventilation systems differ from single-family and commercial systems, and what kind of code compliance and enforcement efforts are appropriate.

The project also produced two white papers, entitled "The Case for a Multifamily Energy Code" and "California Energy Commission PIER Brief — Multifamily-Specific Code Change Proposals for 2016". The first paper outlined the reasons and necessary steps to develop a multifamily specific section of the energy code, while the second paper provided a preview of the code changes that eventually came from this research.

Future Research Needs

During the course of this research project, the project team identified two technologies requiring further research in multifamily settings: passive vents and supply ventilation systems. Both have potential to improve the effectiveness and energy efficiency of multifamily ventilation, but both are poorly understood and can be detrimental if used incorrectly.

When used correctly, passive vents can help control the source and quality of makeup air. Exhaust ventilation introduces outdoor air to a home by removing indoor air, which creates some level of negative indoor pressure, inducing infiltration through the paths of least resistance in the envelope. When homes are reasonably tight (≤ 2.0 ACH50), installing " passive vents," trickle vents or other manufactured holes in exterior walls are possible to control the source of outdoor air. Being able to control the source of outdoor air is a definite advantage because only then it is known that the outdoor air is not coming from a neighboring smoker's apartment, an adjacent garage, garbage chute, laundry room, or other polluted space. Passive vents that include air filters offer the additional advantage of removing particulates from outdoor air as it is pulled into the building.

Passive vents work well in homes that are tight enough, small enough, and open enough for a small continuously operating exhaust ventilation fan to depressurize the space. However, if the exhaust fan does not continuously or adequately depressurize a home, the vent will not function as designed. Under those conditions, passive vents are just expensive holes that compromise building air tightness.

Passive vents have various different specifications, including the amount of negative indoor air pressure required for operation. Some include air filters, which can improve indoor air quality, but increase the resistance and negative indoor pressure required to admit outdoor air. Most passive vents do not have a backdraft damper to ensure one-way airflow, because that also adds to the resistance and negative indoor pressure required for it to admit outdoor air.

Research is needed to apply a combination of building airflow modeling and lab or field measurements to characterize the performance of passive vents in multifamily homes, to determine the range of conditions under which they perform as intended. The results of this research would enable the Energy Commission to develop guidelines for how they should be selected and used, and if they should become a code requirement.

Supply ventilation is often integrated with the central heating and cooling system, which is usually a worst-case scenario for energy efficiency, and is seldom capable of providing the minimum amount of outdoor air required. However, supply ventilation can also be independent of the central forced-air system, in which case it can operate continuously. This is an advantage over intermittent operation for several reasons, including improved energy efficiency, pollutant control (filtering) and occupant satisfaction. Our research found no example of a building design that had incorporated standalone supply ventilation in California. However, standalone systems appropriate for multifamily buildings are available from several manufacturers.

Research is needed to determine what barriers are currently preventing the widespread use of independent supply systems, to measure the IAQ and energy effects of using standalone supply, and to evaluate the way the code handles supply ventilation.

CHAPTER 3
Fenestration

3.1 Introduction

Fenestration is the design and placement of windows and doors in a building. This project included four separate research components focused on fenestration: (1) a review of existing research, which provided background information, (2) a market characterization, which involved using plan review data to better understand construction practice, (3) field data collection, which included site visits to verify the type and amount of fenestration being installed in newly constructed multifamily buildings, and (4) an evaluation of the costs and energy savings for different fenestration performance levels.

Research focused on finding answers to these questions:

a. What is the typical amount of fenestration in a multifamily building?
b. What fenestration type and performance specification is used in multifamily new construction?
c. What are the cost effective U-factor and SHGC values for multifamily buildings?
d. Is there new technology that is appropriate for multifamily buildings?
e. Is there good reason to maintain separate performance requirements for high- and low-rise multifamily building fenestration?

Key findings were:

- Multifamily buildings have significantly less glazing area (~14 percent of conditioned floor area) than allowed by the residential prescriptive standards.
- For multifamily buildings:
  - Fenestration with a U-factor of 0.30 is cost effective.
  - SHGC of 0.23 is cost effective in all Climate Zones except 1, 3, and 5.
- In general, the increased structural strength required to meet wind loads on upper stories of tall buildings requires reinforcing with materials that either reduce thermal performance or increase window cost.
- Other types of glazing, such as electrochromic glazing, are becoming more affordable and available from U.S. manufacturers and show promise for incorporation into multifamily buildings.
- Windows in both high-rise and low-rise multifamily buildings tend to have higher average U-factors (less insulating) than those in single-family homes.

- Vinyl frames are more common than metal frame windows in both low-rise and high-rise multifamily buildings, but are less common than in single-family homes.
- Metal frame windows are more common in high-rise than in low-rise multifamily buildings.
- High-rise buildings tend to have greater solar heat gain than low-rise buildings because of unshaded surfaces, but quantitative data about SHGC values of fenestration in multifamily buildings are lacking.

3.1.1 Background

To assess prior research on multifamily fenestration, a literature review was conducted that included research papers addressing multifamily energy efficiency, technical fenestration performance studies, white papers on industry trends, and market research reports.

Data was sparse. Few studies or reports focused specifically on multifamily fenestration, but some sources with a broader focus provided relevant information, which was categorized as quantitative studies and qualitative reports.

Quantitative studies indicate:

- Multifamily buildings typically used significantly less fenestration as a percentage of conditioned floor area than did single-family homes.
- Multifamily buildings had metal framed windows more often than did single-family homes.
- High-rise multifamily buildings had metal framed windows more often than did low-rise multifamily buildings.
- Multifamily buildings used windows with higher U-factors than those in single-family homes.
- Quantitative data about solar heat gain coefficient values of multifamily building fenestration is lacking.
- Qualitative reports indicate:
- High-rise multifamily buildings need windows with greater structural strength than low-rise buildings and single-family homes.
- High-rise multifamily buildings have greater wind loads which may account for a greater amount of air leakage.
- High-rise buildings may have greater issues with solar heat gain than low-rise or single-family buildings because of unshaded apartments on upper stories.

The primary source of quantitative information was four new construction characterization reports from Regional Economic Research, which were published for four consecutive years beginning in 2000. The first report focused on low-rise multifamily construction, the second and third reports on single-family and low-rise multifamily construction, and the fourth report on low-rise and high-rise multifamily construction.

The 2000 study reported fenestration data separately for buildings located in municipalities where the energy code imposed a 16 percent or 20 percent window-to-floor ratio limit on total glazing. In both cases, multifamily buildings used substantially less than the prescriptive limit.

The 2001 and 2002 studies collected data on both single-family and multifamily fenestration, and found that multifamily buildings typically have a lower window-to-floor ratio than single-family homes. In both years, the average installed window-to-floor ratio of both low- and high-rise multifamily buildings was below that of single-family buildings. The two reports also show that single-family homes had an average glazing percentage much closer to the prescribed values than did multifamily projects.

Average U-factors for multifamily buildings across all years of the studies were at least twice the amount allowed in the 2013 Standards. Even the most thermally efficient windows, which were found in the single-family homes, had U-factors that were higher than allowed in current standards. It illustrates the progress in production of high performance windows that has occurred over the last decade.

Table 7: Findings from Previous Studies

	Low-Rise Single Family			Low-Rise Multifamily				High-Rise Multifamily		
	Glazing Installed, average WFR	U-factor Installed, average	Percent with Metal Frames, average	Prescriptive Glazing Allowed, maximum WFR	Glazing Installed, average WFR	U-factor Installed, average	Percent with Metal Frames, average	Glazing Installed, average WFR (WWR)	U-factor Installed, average	Percent with Metal Frames, average
RER 2000				16.0%	12.9%	0.73				
				20.0%	14.7%	0.86				
RER 2001	17.0%	0.59	2.0%		9.0%	0.66	15.2%			
RER 2002	17.4%	0.60	16.2%		9.0%	0.65	23.0%			
RER 2003					12.7%	0.83	77.0%	13.8% (22.0%)	0.64	66.0%

Source: Benningfield Group Synthesis of Existing Research

Table 7 summarizes some of the fenestration data collected from the RER reports. The 2003 study reports that about two-thirds of high-rise buildings had metal-framed windows, and that only half of those had low E glazing. The high-rise window-to-wall-ratio (WWR) was 22 percent, which, after dividing the reported glazing area by the reported floor area, translates to a window-to-floor ratio of about 13.8 percent. That was slightly more glazing than was observed in low-rise multifamily (12.7 percent) in the same report.

3.2 Market Characterization

Next, the team collected primary fenestration data on recently constructed multifamily buildings in California. Data was collected from plan check compliance forms used for utility program participation, and site visits were conducted to buildings that were under construction or had recently been completed.

3.2.1 Incentive Program Plan Review

Data was taken from reviews of projects that were participating in utility incentive programs. These projects typically strive to exceed code by 15 percent or more, so building components typically exceed code minimums. Data from 130 plan check forms from 54 multifamily projects built in PG&E and SDG&E territories were compiled. The buildings were in ten different California Climate Zones, with Climate Zones 3, 4, 12, and 13 having the greatest representation.

Data was sorted by Climate Zone, building type, Title 24 version, and modeling technique used. The data was compared to 2008 and 2013 Title 24 prescriptive requirements to determine whether the fenestration of participating buildings exceeded the prescriptive requirements, and if so, by what percentage. The information helped to evaluate whether the U-factors and SHGC values of installed windows were an asset or liability to achieving energy code compliance.

Plan sets obtained from the utility programs showed window performance was better than the prescriptive SHGC and U-factor requirements. Few plans showed window-to-floor ratios that exceeded the prescriptive limit; most were substantially below. In cooling-dominated Climate Zones where window-shading devices can gain compliance credit, those devices were commonly found. Window-shading devices also were present on several plan sets for buildings in Climate Zone1 and other heating-dominated zones, although less common. The presence of these devices in heating-dominated climates was unexpected, since the addition of such devices does not add to the compliance margin in the performance model.

The data shows fenestration products with performance substantially better than the minimum requirements are widely available and are generally specified for buildings participating in utility programs. It does not reveal whether installation was partly or wholly driven by the incentive reimbursement.

On average, the buildings were 2.5 stories high, and the average floor area of residential units was roughly 1,100 square feet. The average window-to-floor-ratio was 14 percent, and 40 percent of plans showed some type of exterior shading device. The average U-factor was 0.36, and the average SHGC was 0.33.

3.2.1.1 Field Data Collection

Site surveys were conducted to learn more about window-to-floor ratio, and the orientation and performance of fenestration installed in new multifamily construction.

Figure 15: Low-Rise Multifamily in Final Phases of Construction

NFRC temporary labels still intact

Photo source: Barry Brooks.

A worksheet was developed to record and transcribe data gathered in the field (Appendix E). Potential sites for data collection were identified through records at building departments or by previous contact with building owners and developers. Permission was granted at numerous sites after cold-call contact with on-site management staff.

Data was collected from 21 buildings on five multifamily properties. The size of the properties ranged from one to 13 buildings per property. The 21 buildings were comprised of three high-rise and 18 low-rise buildings. Of the three high-rise buildings, one was eight stories, one was five stories and one was four stories. All 18 of the low-rise buildings were three stories.

The most practical way to determine U-factor and SHGC of installed windows was to gather data from National Fenestration Rating Council (NFRC) temporary labels, so construction sites where temporary labels were still in place were sought.

Site visits took place in 2012 and 2013, and all buildings were either under construction or recently completed. Assumptions were made that all were built under the 2008 version of Title 24. SHGCs were lower than 2008 prescriptive requirements in every building than observed.

Table 8: Average SHGC for all Sites, as Compared to Title 24 Standards

Average SHGC	T-24 2008 SHGC CZ 12	% Better than T-24 2008	T-24 2013 SHGC CZ 12	% Better than T-24 2013
0.26	0.40	36.05%	0.25	-2.32%

Negative percentages indicate worse than prescriptive

Table 8 compares the average SHGCs found in the field to 2008 and 2013 Title 24 prescriptive maximum values for the Climate Zones in which the field research took place. On average, the SHGC from the sites was 0.26, which is 36 percent better than the low-rise prescriptive standard for 2008. The average SHGCs also were nearly equal to the SHGC requirement from the 2013 Standards that will take effect July 1, 2014. In the three high-rise buildings in our survey, SHGCs averaged 0.25, 0.27, and 0.25 for the four-, five-, and eight-story buildings, respectively

Table 9: Average U-factor for Surveyed Sites

	U-factor (Average)	T-24 2008 U-factor CZ 12	% Better than T-24 2008	T-24 2013 U-factor CZ 12	% Better than T-24 2013
All Buildings	0.36	0.40	10%	0.32	-12.5%
Excluding 8-Story HR	0.30	0.40	25%	0.32	6.3%

Negative percentages indicate worse than prescriptive

Table 9 compares average U-factors from the site surveys to the prescriptive maximum values used for all Climate Zones, since U-factor maximums are applied uniformly across the State. After excluding the eight-story building with metal frame windows, average U-factors also were considerably lower than required by the Title 24 Standards under which these buildings were constructed. The average U-factor was 25 percent better than required for low-rise buildings in 2008, but only 3 percent better than required under the 2013 Standards. In the three high-rise buildings, the average U-factors were 0.30, 0.30, and 0.54 for the four-, five-, and eight-story buildings, respectively.

The eight-story building had metal-frame windows, while all of the other buildings had vinyl frame windows. This is consistent with previous findings that indicate taller buildings need enhanced structural strength to meet wind loads.

Among the low-rise buildings, the greatest number of windows were on the North orientation and the lowest number on the West orientation, which is consistent with energy conservation principles. The architectural firm that designed the eight-story high rise was interviewed, reporting their design included placement of high solar gain windows with high visible transmittance on the North side of the building. This design strategy allows residents on the north side greater access to daylight, since there would be no energy benefit to using low solar gain windows. However, the architect reported great difficulty in implementing the strategy on site, as it is difficult to distinguish the two types of windows with the naked eye. As a result, they reported that they would not use this approach in a construction project again.

The window-to-wall ratio is the most precise measure that can be collected in the field from the exterior view. As Table 10 illustrates, builders used less total glazing on the West orientation than on other orientations

Table 10: Fenestration Characteristics by Orientation.

Attribute	North	East	South	West
SHGC	0.26	0.26	0.25	0.26
U-factor	0.31	0.25	0.32	0.32
Window to Wall Ratio	0.21	0.20	0.21	0.17
Window to Floor Area Ratio	0.04	0.03	0.04	0.03

3.3 Manufacturer Survey and Cost Analysis (Modeling)

To assess the cost differential between multifamily fenestration with different energy performance levels, manufacturers and suppliers were provided with a window schedule from a typical multifamily project (see Table 11) and a list of four different performance bins. Each performance bin was defined as a combination of one SHGC and one U-factor. The current low-rise requirements represented the lowest performance bin. The other three bins included improved performance values for SHGC, U-factor, or both. Price data was gathered for several performance levels so the cost of fenestration that complies with the current code could be compared to the cost of higher performing products. Researchers requested price information on the highest volume products in the design. In a supplementary survey, researchers also requested:

- Frame, spacer and glazing characteristics associated with each U-factor/SHGC combination
- State and regional availability of windows meeting the performance specifications
- Relative sales volume for single-family, high-rise multifamily, and low-rise multifamily buildings
- Cost variance for products meeting a higher structural (wind load) criteria
- Industry trends that manufacturers and dealers believe would affect the incremental cost of high-performance windows

Table 11: Portion of the Window Schedule Used in the Study

ID				TYPE		OPENING						GLAZING	Quantity Untempered	Quantity Tempered
						Width			Height					
W	0	1		A	Single Hung	3	-	0	5	-	0	Dual Pane Low e	**107**	**10**
W	0	2		A	Single Hung	2	-	0	5	-	0	Dual Pane Low e	**1**	
W	0	3		A	Single Hung	4	-	0	5	-	0	Dual Pane Low e	**13**	
W	0	4		A	Single Hung	3	-	0	3	-	0	Dual Pane Low e	**2**	
W	0	5		A	Single Hung	3	-	0	5	-	6	Dual Pane Low e	**6**	**1**
W	0	6		A	Single Hung	2	-	0	5	-	6	Dual Pane Low e	**1**	
W	0	7		A	Single Hung	4	-	0	5	-	6	Dual Pane Low e	**1**	
W	0	8		A	Single Hung	2	-	6	5	-	6	Dual Pane Low e	**0**	**1**
W	0	9		A	Single Hung	2	-	6	3	-	0	Dual Pane Low e	**2**	
W		0		A	Single Hung	3	-	0	3	-	6	Dual Pane Low e	**4**	
W		1		C	2-Wide SH	6	-	0	5	-	6	Dual Pane Low e	**1**	
W		2		B	Horiz. Slider	3	-	0	2	-	0	Dual Pane Low e	**16**	
W		3		B	Horiz. Slider	6	-	0	3	-	0	Dual Pane Low e	**2**	
W		4		B	Horiz. Slider	6	-	0	4	-	0	Dual Pane Low e	**1**	
W		5		B	Horiz. Slider	4	-	0	1	-	6	Dual Pane Low e	**4**	
W		6	a	D	Fixed	2	-	6	2	-	6	Dual Pane Low e	**12**	
W		7		C	2-Wide SH	6	-	0	6	-	0	Dual Pane Low e	**72**	
W		8		A	Single Hung	2	-	6	4	-	6	Dual Pane Low e	**10**	
W		9		A	Single Hung	4	-	0	6	-	0	Dual Pane Low e	**32**	
W		0		A	Single Hung	3	-	0	6	-	0	Dual Pane Low e	**72**	**10**
W		1		C	2-Wide SH	5	-	0	6	-	0	Dual Pane Low e	**22**	**10**
W		2		C	2-Wide SH	7	-	0	6	-	0	Dual Pane Low e	**10**	

Source: Benningfield Group and Enercomp

The original study was designed to acquire a total project price for all windows shown on the window schedule, to most accurately portray fenestration costs that would be incurred by a builder or developer. However, most manufacturers and distributors were unwilling to devote that much time. Instead, the project team requested pricing information for just two representative products: a single hung 3’0” x 5’0” window and an 8’0” x 6’0” sliding glass door, and used this information as the basis of the cost analysis.

A building model was created to analyze the energy use by performance specifications and to generate savings estimates for higher performance glazing. The research version of the 2013 Low-Rise Residential Compliance software, CBECC-Res , was used. The project team modeled the eight-unit, 6,960 ft2 baseline prototype used in developing the 2013 Standards for savings estimates.

To examine the impact of lower U-factors, a series of models were run that held the SHGC constant at 0.25 (the 2013 prescriptive SHGC for most Climate Zones), and varied U-factors from 0.32 to 0.24. Then, with the U-factor constant at 0.32, SHGCs were modeled from 0.20 to 0.50. Each simulation was compared to the 2013 prescriptive requirements for each particular Climate Zone. There was no change to any of the other building features. Energy use was then compared in the prescriptive model to each performance improvement.

The difference between modeled energy use from the prescriptive run and the proposed run equals first-year energy savings. The energy savings are provided in kTDV/ft2 of floor area, the metric used in the Standards. TDV is a unit measure for the time-dependent value of energy sources on an hourly basis. TDV heavily values electricity use during summer peak periods when demand for air conditioning is high. kTDV represents 1000 TDV units, and kTDV/ft2 is thousands of TDV per square foot of conditioned floor area in the building.

Energy savings were converted to the net present value of 30 years of energy savings by multiplying the first-year energy savings (kTDV/ft2) by the floor area of the modeled buildings, and then multiplying by a factor of $0.173. This factor converts the kTDV to a 30-year net present value in 2011 dollars. It was developed and used during the 2013 Standards development process and was the most current conversion factor available. To make the figures easier to understand and easier to compare to incremental cost, the 30-year net present value savings was divided by total window area to yield $/ft2 of window area. The result is the value of the square foot of more efficient fenestration given the savings expected over the next 30 years. The calculation is represented by the following equation:

$$\frac{1st\ Year\ TDV\,\frac{Savings}{ft^2} \times ft^2\ floor\ area\ of\ prototype \times\ NPV\ conversion\ factor}{ft^2\ of\ windows\ in\ prototype}$$

$$= \frac{\$}{ft^2}\,window\ area$$

3.3.1 Manufacturer Survey Results

The manufacturer/supplier survey resulted in a database of 69 individual products. A portion of the database is shown in Figure 16.

Figure 16: Window Product Cost Database Sample

Window	Base	U-factor	SHGC	VT	List	Discount	Cost	CostPerFt2	Diff	DiffPerFt2	DiffDescription
1	1	0.33	0.35	0.61	$254.62	0.52	$122.22	$8.15	$0.00	$0.00	
2	1	0.30	0.35	0.61	$266.46	0.52	$127.90	$8.53	$5.68	$0.38	Air to Arg
3	2	0.29	0.23	0.54	$290.15	0.52	$139.27	$9.28	$11.37	$0.76	MSLE#2 to ELSLE#2
4	3	0.28	0.23	0.54	$303.12	0.52	$145.50	$9.70	$6.23	$0.42	StdSpc to UpgSpc
5											
6	6	0.33	0.35	0.60	$820.22	0.52	$393.71	$9.84	$0.00	$0.00	
7	6	0.29	0.35	0.60	$852.09	0.52	$409.00	$10.23	$15.30	$0.38	Air to Arg
8	7	0.28	0.23	0.54	$915.82	0.52	$439.59	$10.99	$30.59	$0.76	MSLE#2 to ELSLE#2
9											
10	10	0.33	0.33	0.57	$349.30	0.52	$167.66	$11.18	$0.00	$0.00	
11	10	0.29	0.33	0.57	$361.14	0.52	$173.35	$11.56	$5.68	$0.38	Air to Arg
12	11	0.29	0.22	0.51	$384.83	0.52	$184.72	$12.31	$11.37	$0.76	MSLE#2 to ELSLE#2
13	12	0.28	0.22	0.51	$397.80	0.52	$190.94	$12.73	$6.23	$0.42	StdSpc to UpgSpc
14	11	0.25	0.28	0.45	$484.31	0.52	$232.47	$15.50	$59.12	$3.94	Dbl to Tri MSLE#2 to MSLE#2MSLE#5
15	14	0.24	0.19	0.36	$515.42	0.52	$247.40	$16.49	$14.93	$1.00	MSLE#2MSLE#5 to ELSLE#2ELSLE#5
16	14	0.21	0.28	0.45	$705.38	0.52	$338.58	$22.57	$106.11	$7.07	Arg to Kry
17	16	0.20	0.19	0.36	$736.49	0.52	$353.52	$23.57	$14.93	$1.00	MSLE#2MSLE#5 to ELSLE#2ELSLE#5
18											
19	19	0.33	0.33	0.57	$1,192.10	0.52	$572.21	$14.31	$0.00	$0.00	
20	19	0.29	0.33	0.57	$1,223.97	0.52	$587.51	$14.69	$15.30	$0.38	Air to Arg
21	20	0.29	0.22	0.52	$1,287.70	0.52	$618.10	$15.45	$30.59	$0.76	MSLE#2 to ELSLE#2
22	20	0.24	0.28	0.46	$1,794.29	0.52	$861.26	$21.53	$273.75	$6.84	Dbl to Tri MSLE#2 to MSLE#2MSLE#5 Te
23	22	0.24	0.19	0.36	$1,877.99	0.52	$901.44	$22.54	$40.18	$1.00	MSLE#2MSLE#5 to ELSLE#2ELSLE#5
24	22	0.20	0.28	0.46	$2,389.09	0.52	$1,146.76	$28.67	$285.50	$7.14	Arg to Kry
25	24	0.20	0.19	0.37	$2,472.79	0.52	$1,186.94	$29.67	$40.18	$1.00	MSLE#2MSLE#5 to ELSLE#2ELSLE#5

Source: Enercomp.

Ideally, window suppliers would be able to specify a price for a performance upgrade. However, most distributors and manufacturers do not price products in that manner. Instead, prices are based on component features. The components can be tied to performance upgrades, thereby connecting performance to price.

To draw this connection, the properties of the window products were coded so that the spreadsheet could be filtered to isolate the incremental cost of a single product upgrade, such as changing to a low emissivity coating or adding argon. This enabled direct comparison to the savings estimates. Filtering the database in this manner reveals that:

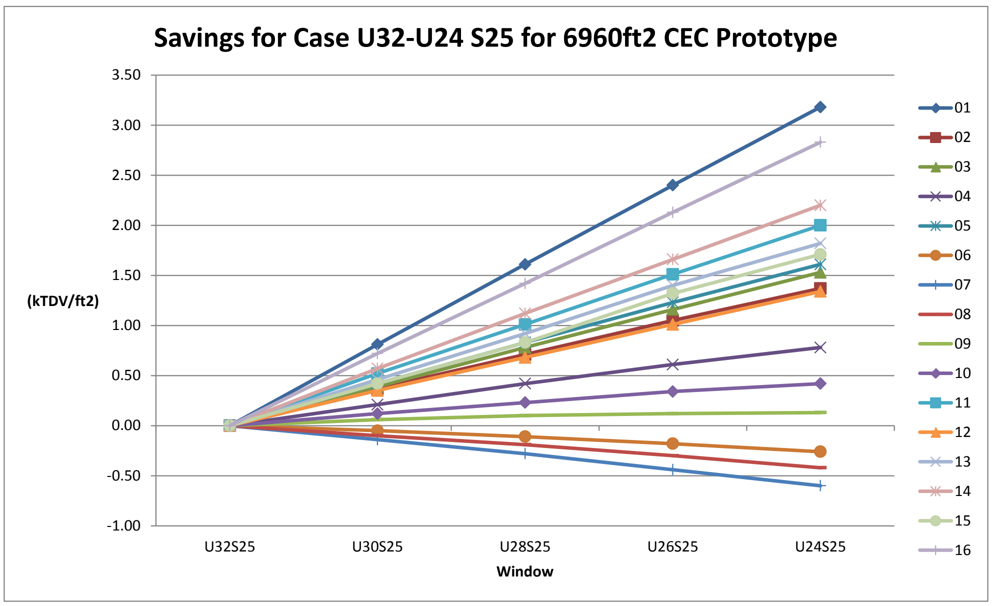
- Replacing an existing low emissivity coating with an extra low solar gain low emissivity coating averages $0.64/ft2 and lowers the U-factor by 0.01 and the SHGC by 0.10. The average U-factor is 0.29 and SHGC is 0.22.
- Adding a low emissivity coating averages $1.59/ft2 and lowers the U-factor by 0.18. The impact on the SHGC depends on which coating is used.
- Adding argon averages $0.49/ft2 and lowers the U-factor by 0.04.
- Replacing double glazing with triple glazing averages $4.99/ft2 and lowers the U-factor by 0.03 and the SHGC by 0.04.
- Adding a low emissivity coating facing inside averages $2.29/ft2 and lowers the U-factor by 0.04 and the SHGC by 0.02.
- Adding dynamic glazing with controls averages $88.81/ft2 and lowers SHGC by 0.40.

3.3.1. *Modeling Results*

Our modeling showed that lowering the U-factor reduces energy use in most Climate Zones. Figure 17 illustrates the energy impacts for five levels of U-factor ranging from 0.32 down to 0.24, while holding the SHGC constant at 0.25. The largest savings are in heating dominated climates like Climate Zone1, with negative savings showing in the mild Climate Zones of 6, 7, and 8. Negative savings are likely due to the fact that better insulating windows retain more heat, increasing cooling load.

In Figure 17 and Figure 18 the horizontal axis shows values for five different windows, which are denoted with the shorthand of “U(xx)S(yy)”, where the digits following the “U” represent the U-factor (shown without the decimal point) and the digits following “S” represent the SHGC (also shown without the decimal point). The 16 California Climate Zones are color coded and shown on the right hand side of each chart.

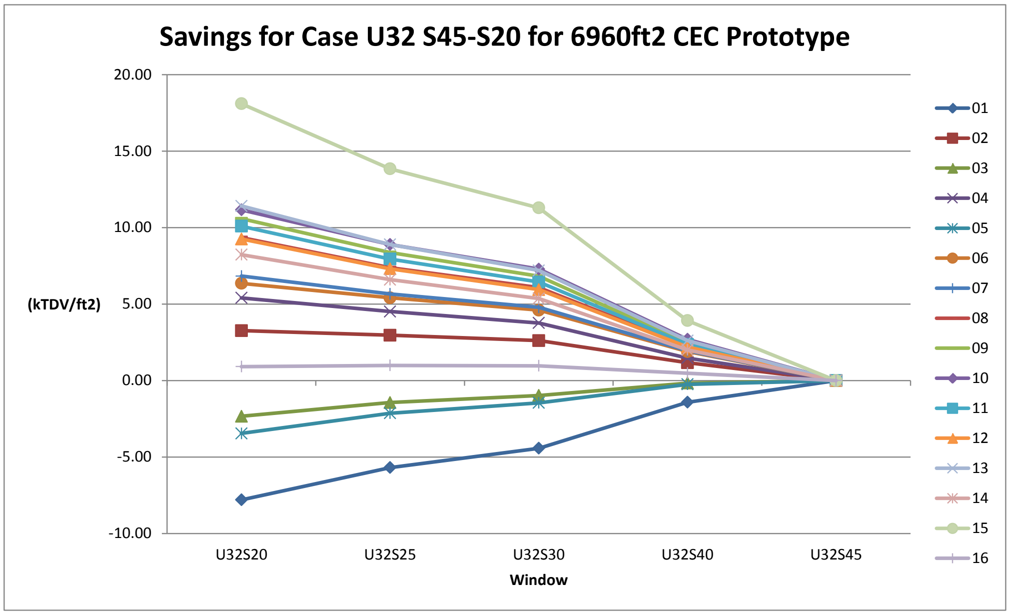
Figure 17: Energy Impact of Lowering Fenestration U-factor in all 16 Climate Zones



Source: Enercomp

Modeling results show that lowering the SHGC reduces energy use in many, but not all Climate Zones. Figure 18 shows the impacts for five levels of SHGC starting from 0.20 up to 0.45. This model holds the U-factor constant at 0.32.

Figure 18: Energy Impact of Lowering Fenestration SHGC in all 16 Climate Zones



Source: Enercomp.

There are several noteworthy results:

- In Climate Zones 8 through 15 (those with the most cooling) lowering SHGC results in the largest energy savings. These zones all have a 0.25 prescriptive value in the 2013 Standards.
- In Climate Zones 4, 6 and 7, lowering the SHGC increases energy savings, but the incremental value of each lower SHGC declines progressively. This is evident for the 0.20 SHGC through the 0.30 SHGC cases where the savings is positive, but the curve is flattened. These zones all have a 0.25 prescriptive value in the 2013 Standards.
- Results for Climate Zones 1, 3 and 5 show that lowering the SHGC increases energy use. These are Climate Zones that already have no requirement for SHGC.
- Results for Climate Zones 2 and 16 show that the energy savings decreases with lower SHGC values. Both of these zones currently have a 0.25 prescriptive SHGC. This prescriptive requirement should be studied more.

The study found that requiring 0.30 U-factors for all Climate Zones and 0.23 SHGC for all Climate Zones except for 1, 3, and 5, brings the standard closer to the actual performance of products sold in the marketplace.

The 2013 Prescriptive Standard references products with extra low solar gain glass in all Climate Zones except 1, 3 and 5. Windows used under the 2013 Standards already incorporate the cost of a lower conductance frame and a low emissivity coating. The use of these technologies means that many of the windows designed to meet the current standards have U-factors and SHGC that would also meet or exceed the standards proposed in this report. So, in most cases, changing the standard to a lower U-factor and SHGC will not increase costs; it simply aligns the code requirement with the type of windows already being installed in many multifamily buildings. In a few cases, adding argon gas fill between the panes will be needed to meet the new criteria.

The energy savings analysis completed for this study shows the average net present value of energy savings from requiring 0.30 U-factors and 0.23 SHGC windows in cooling dominated climates is $1.14 per ft2 of windows. In Climate Zones 1, 3 and 5 (those with minimal cooling), the lower U-factor was modeled with an SHGC of 0.50, consistent with software modeling rules. The average NPV of the energy savings for 0.30 U-factor and 0.50 SHGC windows in these mild non-cooling climates is $0.42 per ft2 of windows. In the cases where argon gas may need to be added, it would still be cost effective, as adding argon fill costs $.49/per ft2. On a statewide basis, the added cost is much less than the NPV of the savings, making the lower U-factor and SHGC values cost effective.

3.4 Conclusions and Recommendations

We recommend the following:

- Because both low-rise and high-rise multifamily buildings have significantly less fenestration as a percent of conditioned floor area than single-family homes, the performance penalty threshold area should be reduced from 20 percent to 15 percent for low-rise multifamily buildings. If the high-rise and low-rise multifamily requirements are unified, the 15 percent threshold should be applied to high-rise buildings, too.
- Create a code change proposal to set a multifamily prescriptive maximum U-factor of 0.30 for all Climate Zones. For Climate Zones with significant cooling (zones 2, 4 and 6 through 16) a prescriptive maximum SHGC of 0.23 is recommended. There should be no maximum SHGC for Climate Zones 1,3, and 5. If possible, this requirement should be separate from the single-family standards.
- Requirements should be driven by design factors such as the specification of site-built, site manufactured or manufactured windows, not by whether the building is less than four stories.
- Fenestration code requirements for buildings currently defined as “low-rise” or “high-rise” residential could be unified into one section for all multifamily buildings, and differences between the requirements for buildings of three or fewer and four or more stories should be removed.
    a. High-rise and low-rise multifamily buildings are more like each other than they are like nonresidential and single-family buildings.
    b. The factors that should change requirements between short and tall multifamily buildings are not whether they are three stories or four stories. For example, wind loads, which almost always govern structural concerns in very tall buildings, can also be concerns in certain locations in low-rise buildings.

Likewise, a four- or five-story building in another location may require little wind load concerns.

c. A common configuration for a multifamily project with several buildings is to use essentially the same design for three- and four-story buildings. Having requirements that require design teams to significantly change the design for the one additional story is problematic.

3.4.1 Recommended Changes for the 2016 Code Cycle

Adjust the penalty threshold for glazing in multifamily buildings from 20 percent to 15 percent

Prior to 2005, the Performance Approach saw glazing areas less than 20 percent of conditioned floor area as an energy efficiency measure. In practice, nearly every multifamily building got credit for a normal amount of fenestration. The 2005 Residential Energy Standards eliminated this compliance credit. The code now sets the glazing area in the "standard" run equal to the glazing area in the "proposed" run, as long as the fenestration area is not in excess of the prescriptive 20 percent of conditioned floor area.

Based on the data collected in this project, the average multifamily building has less than 14 percent glazing. Single-family homes often exceed 20 percent glazing and must upgrade fenestration performance or other components to offset the penalty associated with the large amount of fenestration installed. Based on our survey and other research, glazing in multifamily buildings rarely exceeds 15 percent or 16 percent of conditioned floor area. This proposed change aligns the penalty threshold with the glazing percentages typical of multifamily construction.

Eventually, the compliance software should treat all multifamily buildings similarly, regardless of whether a building is over three stories. Meanwhile, the team recommended lowering the allowable glazing area for low-rise multifamily buildings from 20 percent to 15 percent of conditioned floor area.

Reduce the prescriptive maximum U-factor to 0.30 for all Climate Zones, and the prescriptive maximum SHGC to 0.23 for all Climate Zones except 1, 3, and 5

Analysis shows that many of the fenestration products sold and installed in California multifamily new construction already meet these proposed standards. For those few products that meet the current standards but not the proposed standards, an argon fill at the approximate cost of $0.49/ft2 could provide the necessary improvement. When compared to the net present value of the savings from lowering the U-factor, $1.14/ft2, the improvement is still cost effective.

Builders who specify U-0.30/SHGC-0.23 windows to meet the current code receive an energy credit in the performance model, allowing them to lower the efficiency of other components or systems. Aligning the code will eliminate this compliance credit and improve overall energy efficiency.

3.4.1. Long-Term Recommendations and Considerations

Consider wind-loads/structural ratings when establishing U-factor requirements

Manufacturers state that increased wind and structural loading for fenestration in tall multifamily buildings means an increase in the U-factor for an otherwise similar window used near the ground. Vinyl frames do not have the necessary structural strength without metal reinforcing, and reinforcement increases the frame conductivity. Aluminum frames are stronger, but are significantly more conductive. Fiberglass provides high strength and low conductivity, but at a higher cost.

The nonresidential/high-rise residential standards have much higher prescriptive U-factors than the low-rise residential standards: 0.36, 0.46, and 0.41 for fixed windows, operable windows, and curtain walls, respectively, compared to 0.32 for low-rise residential buildings. Since three- and four-story buildings can be part of the same project, subject to essentially the same seismic and wind conditions, this disparity is striking. It may make more sense to (a) have a lower U-factor for fenestration that is not subject to wind loading, regardless of how many stories the building has, and (b) maintain the distinction between fixed windows, operable windows, and curtain walls, but reexamine what is cost effective in the absence of wind-loading. More research is needed to determine the precise relationship between structural strength, thermal performance and dollar cost.

Structurally reinforced vinyl windows and fiberglass-frame structural windows show promise as cost-effective ways to provide both structural strength and thermal performance. The 2013 High-Rise Residential Standards have a prescriptive U-factor of 0.41 for site-built fenestration, which is generally a thermally broken aluminum framed product capable of providing the structural strength necessary for high wind loads. Manufacturers and fabricators have attested to the affordability of many of these products, and thermally broken aluminum was found to be cost effective during a 2013 Code analysis. However, a detailed cost analysis is still needed before it becomes clear how to handle other types of structural windows, and the energy impacts from wind loads, within the code.

Require/enforce permanent NFRC labels

An unexpected finding from this research is that once a builder or owner removes the temporary NFRC label from installed fenestration, it is virtually impossible to determine the U-factor and SHGC. Title 24 and NFRC require that manufacturers install both temporary labels and permanent labels. Discussions with NFRC confirmed that as of 2013 there still was no reliable way to trace the exact make and model or original performance parameters of a window once the temporary label had been removed.

Since NFRC has been unable to address the issue of permanent labeling, the Energy Commission should consider how to make window manufacturers provide permanent labels on fenestration products as required by the Standards. This could be the same information included on the temporary label, or a reference number that links to a product-specific database. It is recommend that the Energy Commission either enforce the requirement or remove it from the Standards (Section 110.6(a) 5.B).

Encourage the use of electrochromic glazing by improving Performance method modeling

According to the designers of EnergyPro compliance software, the energy performance of electrochromic glazing can be approximated by combining the output from two EnergyPro models: a heating season model using a high SHGC that represents the glazing in its most transparent state, and a cooling season model with a low SHGC representing the glazing in its most opaque state. While better than a fixed-SHGC model, this method does not accurately represent the savings from an electrochromic system that constantly responds to temperature and solar intensity. To capture these nuances, the software needs to approximate the optimal state of glazing for each hour of the year. Updates to compliance software for both low-rise and high-rise multifamily (CBECC-Res, and CBECC-Com, respectively) should include the ability to effectively model electrochromics or other dynamic glazing systems. This means capturing the impact of the dynamic glazing as it changes from hour to hour and requires a detailed model of the operation of the automatic control.

Study options for unifying the method of calculating the Prescriptive maximum fenestration area

There is a distinct difference in how the low-rise and high-rise standards determine allowable fenestration area. The low-rise standards use the ratio of fenestration to conditioned floor area, while high-rise standards use the window-to-wall (WWR) area ratio. There are no upper limits on allowable fenestration area when using the Performance Approach, but there are penalties for exceeding the values set by the Standards for each building type that must be reconciled by improving other design aspects of the building.

The WWR method can allow high-rise multifamily buildings to have a larger fenestration allowance than a low-rise multifamily building. For example, the average apartment in California (960 square feet) can have dimensions of less than 50 feet by less than 20 feet. If one long wall faces the exterior, a 40 WWR would equal 157 square feet of glazing. But for a corner apartment, the same WWR would yield a limit of 220 square feet. If the fenestration equaled 15 percent of conditioned floor area (CFA), that would be 144 square feet. Even the current 20 percent CFA threshold only yields 192 square feet for a 960 square foot apartment. This is one reason that unifying the requirements for multifamily buildings should be based on the window-to-floor area ratio.

There are some situations where the WWR method may be more suitable for determining fenestration area. For example, tower-style multifamily buildings that use curtain wall window construction typically have a much greater fenestration area than a four-story apartment complex, as well as different fenestration performance limitations. In this case, the style of construction and area of glazing is consistent with other nonresidential high-rise buildings.

High-rise residential standards use the window-to-wall ratio (WWR) method for determining the fenestration area allowance, while the low-rise residential standards use a measure of window to conditioned floor area (CFA). In some buildings the WWR may be more appropriate because the building design has enclosed (interior) hallways. If window-to-CFA ratio was used, the conditioned hallway would contribute to total conditioned floor area of the building, allowing the designer to increase glazing area on the apartments. However, the fact that a building is four stories in height does not necessarily mean that the hallways are enclosed. Again, a multifamily-specific code could trigger the use of WWR when enclosed hallways or other thresholds were met, but standardize around Window-to-CFA the rest of the time.

3.5 Future Research Needs

The gains in efficiency from the incremental cost-effective code improvements identified in this report will increase efficiency of newly constructed buildings. But those gains could be just a small step toward zero-net energy buildings. Further research will be needed to identify what contribution fenestration can play in reaching the zero-net-energy goal in multifamily buildings.

The relationship between structural and thermal performance needs additional research in to help develop appropriate standards for tall buildings. In buildings above a certain height, it is necessary to install structural windows. To maintain thermal performance consistent with windows on lower stories, there is likely to be added cost. If this cost is significant, it may be appropriate to allow leniency in the code for the portion of a building above a certain height.

CHAPTER 4
Multifamily Resident Information and Hvac Control

4.1 Introduction

The focus of this project was to identify and understand the savings potential from smart energy devices in multifamily buildings, and to explore opportunities to codify the technologies. The contractor's research outcomes were focused on potential connections to energy code, while our project partner, SMUD, hoped to better understand and assess programmatic solutions for improving energy efficiency for customers residing in multifamily housing.

The research objectives were to:

- Quantify the energy and demand savings potential of in-home energy displays and smart thermostats in multifamily buildings.
- Determine whether the Energy Commission should consider requiring smart thermostats or information displays as part of the building energy efficiency standards for multifamily buildings, or if they should be considered as a compliance option.
- Identify practical, technical and building code barriers to adoption of smart controls for multifamily energy code.

SMUD and other California utilities have made investments and upgrades to their electricity grids over the past decade. These investments are supporting the creation of the "smart grid," which includes networked communications between power supply, distribution, transmission, and end users. However, consumer-facing extensions of the smart grid — including smart thermostats and in-home energy displays — still are being refined.

The study was designed to assess the market readiness and savings potential for these devices by getting them in front of SMUD customers, and then assessing the impact on energy use and peak demand. The formation of code requirement recommendations for multifamily buildings was a goal.

Although TOU/CPP pricing was not widely offered by California utilities at the time of the study, the technology is likely to become commonplace within the next decade. To study the possible benefits of the technology, SMUD agreed to offer customers TOU/CPP rates for the duration of the study. This pricing structure allows consumers to better understand the time-dependent cost of electricity and how they can shift energy demands to periods of greater availability and lower costs.

Before getting started, in-home energy displays and smart thermostats were selected, wireless communication options were evaluated and customer participants were recruited. As the devices were being installed, customers were prepped on how to read and use them.

SMUD and The contractor representatives monitored device connectivity during the data collection period and intervened as needed. At the conclusion of the study, customers were asked to participate in a survey.

4.2 Device Selection

The process for identifying and purchasing the devices involved several steps, including internet research, interviews with vendors and discussions with SMUD.

A decision was made to leverage recently deployed, advanced metering infrastructure and go "through the meter", since this approach is far more scalable and therefore more representative of the future of smart energy management in the State. SMUD's smart meters use a wireless communications protocol called ZigBee, so the study was limited to devices that adhered to ZigBee Smart Energy protocols.

Figure 19: Landis + Gyr Smart Meters with ZigBee Wireless Radios

Source: SMUD.org

Bringing devices onto SMUD's AMI meant the devices would undergo additional scrutiny related to security and functionality. Although the project team investigated many different ZigBee certified devices, SMUD's security and testing requirements ultimately limited our selection to one in-home device and one thermostat. The devices used for the study were the Energate Pioneer Z 100 smart thermostat and the EnergyAware PowerTab in-home device, show below in Figure 20.

Figure 20: EnergyAware PowerTab IHD and Energate Pioneer Smart Thermostat

Source: www.energy-aware.com.

Source: Energate

SMUD installed ZigBee receivers in all residential smart meter deployments. Since ZigBee is a low-energy wireless protocol, the range of the wireless signal is limited. The risk associated with range limitations was acknowledged, but accepted as a necessary. Plans were formulated to acquire a stock of wireless repeaters, which, when plugged into an AC outlet, receive and repeat the ZigBee wireless signal to shorten the effective distance between devices. To gain further understanding of these limitations, data on signal interruptions between the devices and the meter was collected. The repeater that was used was the DIGI Xbee wireless range extender, shown below in Figure 21.

Figure 21: DIGI Xbee Wireless ZigBee Repeater

Source: www.digi.com.

4.3 Study Design

The study design underwent a revision before it started.

There were multiple goals for the revisions: (1) create a study design and comparison scheme that would answer the most cogent research questions; (2) increase the number of participants per group, therefore increasing the likelihood that results would be significant; (3) deploy technologies that consumers would understand and use, and that represent state-of-the-art home energy management; and (4) deploy technologies that could be securely and reliably integrated with SMUD's advanced metering infrastructure.

A power analysis conducted by subcontractor Opinion Dynamics indicated the size of the four treatment groups in the original study design likely were too small to reveal significant impacts, but increasing the size of each of the treatment groups was not practical because of technical and budgetary limitations.

Further, the original treatment groups did not include a rate-only treatment group. It was critical to add a TOU/CPP "rate-only" group to assess the incremental value of the technologies. The study design was revised to reduce the number of treatment and comparison groups, thereby increasing the number of participants in each group .

A review of related research showed that more than 100 demand response studies had tested the impacts of time-dependent rates, both with and without enabling technologies. The results of these studies indicated that while both information and automation increase load savings, automation has far greater impact. Few studies, however, were designed to separate the savings attributed to the rate from those attributed to technologies.

The final study design included 300 customers that would need to be recruited to three groups, and another 100 customers that would not be directly recruited, but would be part of a control group. The control group, which received no equipment or rate, was created out of participants who volunteered for the study and were qualified to participate, but were unable to because of practical issues such as over enrollment. The four groups are shown below in Table 12.

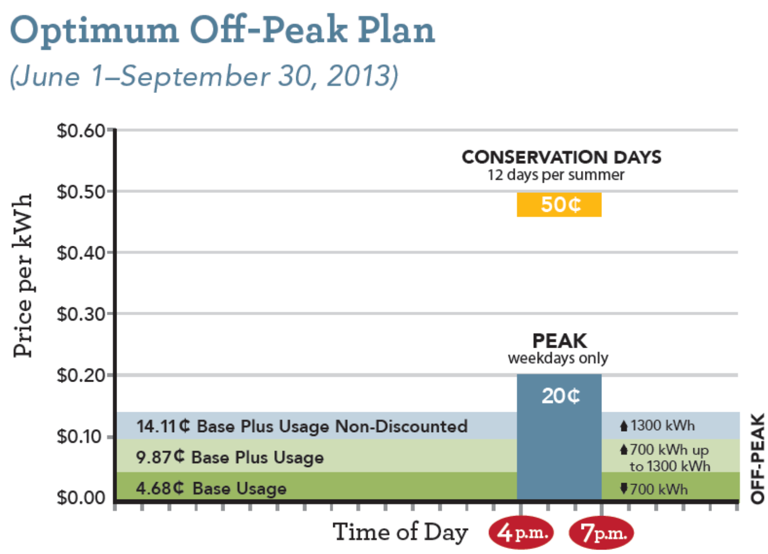
Table 12: Planned Sample Points (Recruited Households)

Treatment Number	Treatment	Expected Treatment Group (n)	Control Group (n)
1	**TOU/CPP rate only.** No equipment supplied by research team. The tenant will use whatever thermostat is currently installed in the unit, most likely a programmable thermostat.	100	100 (Populated by customers who enrolled after the close of recruitment or those who were too far from the meter to receive the wireless signal. No TOU/CPP rate or equipment provided.)
2	**TOU/CPP rate + in-home display.** The tenant will use whatever thermostat is currently installed in the unit, most likely a programmable thermostat.	100	
3	**TOU/CPP rate + in-home display + Smart Thermostat.** In addition to an IHD, the tenant will receive a thermostat capable of receiving price signals from the utility and adjusting set points in response to price and user preferences.	100	
	Total	**300**	**100**

Source: Opinion Dynamics.

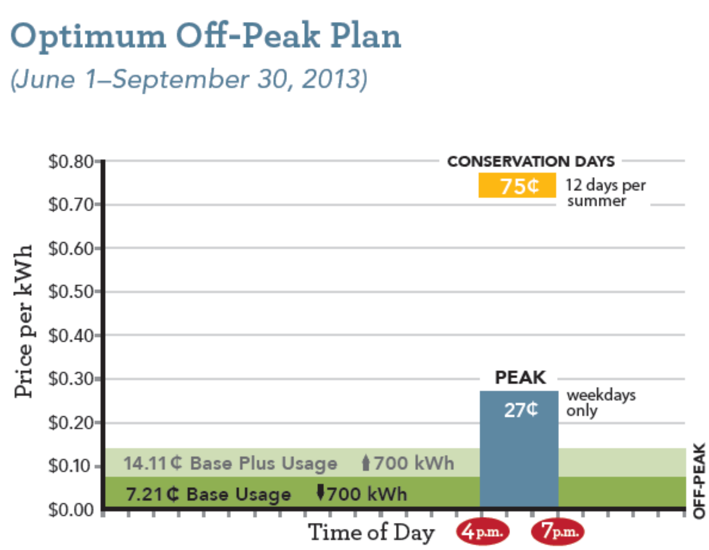
To include as many multifamily customers as possible, SMUD made two TOU/CPP rate schedules available; a TOU/CPP rate for standard rate customers, and a TOU/CPP rate for Energy Assistance Program Rate (EAPR) customers. In addition to the base (off peak) rate, the weekday peak rate and the event peak rate, SMUD retained tiered pricing. In the case of EAPR customers, this meant a total of three off-peak rates. Standard rate customers had two off-peak rates. The rate schedules are shown in Figure 22 and Figure 23.

Figure 22: TOU/CPP Rates for EAPR Customers



Source: SMUD marketing collateral for PIER Smart Thermostat Pilot.

Figure 23: TOU/CPP Rates for Standard Rate Customers



Source: SMUD marketing collateral for PIER Smart Thermostat Pilot

The price responsive thermostat used, the Energate Pioneer, must be programmed by the vendor to respond to price signals. The settings are defined within a price matrix, as shown in Figure 24 and Figure 25. The customer does not see this matrix, although a simplified version was provided in the "welcome kit" each customer received. The user only sees a screen from which they can choose one of five settings ranging from maximum comfort to maximum savings.

Figure 24: Standard Price Matrix

Standard Conservation Setting and Temperature Change Impact

LED Color	Price Signal	MAXIMUM SAVE	SAVE	BALANCE	COMFORT	MAXIUM COMFORT
NONE	Off-Peak Base Usage	0°	0°	0°	0°	0°
YELLOW	Off-Peak Base Plus Usage	+1°	+1°	+1°	0°	0°
ORANGE	Peak hours, 4:00 p.m. to 7:00 p.m., weekdays	+4°	+3°	+2°	+1°	0°
RED	Peak hours, 4:00 p.m. to 7:00 p.m., Conservation Day	+6°	+5°	+4°	+2°	0°

Figure 25: EAPR Price Matrix

EAPR Customer
Conservation Setting and Temperature Change Impact

LED Color	Price Signal	MAXIMUM SAVE	SAVE	BALANCE	COMFORT	MAXIUM COMFORT
NONE	Off-Peak Base Usage	0°	0°	0°	0°	0°
YELLOW	Off-Peak Base Plus Usage	+2°	+1°	+1°	0°	0°
ORANGE	Off-Peak Base Plus Usage (no discount)	+3°	+2°	+1°	+1°	0°
ORANGE	Peak hours, 4:00 p.m. to 7:00 p.m., weekdays	+5°	+3°	+2°	+1°	0°
RED	Peak hours, 4:00 p.m. to 7:00 p.m., Conservation Day	+6°	+5°	+4°	+2°	0°

Customers were alerted when energy rates rose above Tier 1 Off Peak by colored LED lights on the thermostat. The customers could always choose to modify their thermostat setting selection.

4.4 Recruitment

Prior to recruitment, a sampling frame of 50,563 multifamily customers in complexes of greater than 50 units was identified, and customers were randomly assigned to one of the three treatment groups. Because the study involved the installing PCTs in dwelling units, the project team was not able to contact tenants directly, but first had to gain permission from property managers. Property managers and owners of apartments with 50 or more units were recruited. Next, all tenants residing in those properties were recruited. Finally, owner-occupants of condominiums and townhomes were recruited directly.

There were 465 apartment complexes with greater than 50 units included in the sampling frame, managed by 323 property managers or owners. Letters were sent to all these property managers offering a $100 gift card for participation in the study, and informing them that the installed smart thermostats would become property of the building owner at the close of the study.

Follow-up phone calls were made to 304 of these property managers for whom the team had phone numbers. Seventeen property managers/owners accounting for 63 properties and 7,557 apartment units agreed to participate. Letters and other recruitment materials were sent to residents of all these apartment units as well as 4,302 randomly selected residents of condominiums and townhomes. When the treatment quota in each treatment group was met, the remaining respondents who agreed to participate in the study were assigned to the comparison group. The team further extended the comparison group by adding in those participants who initially agreed to participate but later declined.

Participants received substantial education and educational materials. Installers provided guidance on using the IHDs and PCTs, and participants were left with treatment-customized welcome booklets, with information about peak hours and Conservation Days, notifications, energy saving tips, the TOU-CPP rate, frequently asked questions and contact information. The PCT group received a SMUD-developed simplified Thermostat User’s Guide educating customers on how to set up automated temperature adjustments based on their needs and how the thermostat displayed real-time price changes through different light signals. Finally, customer support was provided by a dedicated team via phone, email, and site visits if necessary. Email, text and phone notifications were sent the day before each of the 12 Conservation Days.

Because of the different rate offerings for low-income customers and the different agreement language necessary for customers who owned homes, the three treatment groups became 12 different recruitment groups, each with slightly different marketing collateral and agreement language. SMUD produced the agreements and marketing materials for each of the 12 different groups.

4.4.1 Recruitment and Participant Outcomes

Below are tables showing recruitment and response rates, and final installed samples.

Table 13: Recruitment, Response, and Enrollment Rates

Treatment Group	Recruitment				Comparison Group					Participant Group			
	Recruited	Responded	Response Rate	Desired Sample Sizes	Ineligible	Dropped	Declined	Exceeded Quota	Final Comparison	Dropped	No Hourly Data	Final Participants	% of Goal
Rate Only	6,270	190	3.0%	100	1	3	7	76	83	5	4	94	94%
Rate Standard	4,007	82	2.0%		0	1	2	36	38	2	2	39	
Rate EAPR	2,263	108	4.8%		1	2	5	40	45	3	2	55	
Rate and IHD	2,794	193	6.9%	100	2	2	51	40	91	9	1	88	88%
IHD Standard	1,808	85	4.7%		1	1	24	16	40	3	1	39	
IHD EAPR	986	108	11.0%		1	1	27	24	51	6	0	49	
Rate, IHD and PCT	2,795	165	5.9%	100	5	1	60	12	72	10	2	75	75%
PCT Standard	1,789	78	4.4%		3	0	27	5	32	1	1	41	
PCT EAPR	1,006	87	8.6%		2	1	33	7	40	9	1	34	
Total	**11,859**	**548**	**4.6%**	**300**	**8**	**6**	**118**	**128**	**246**	**24**	**7**	**257**	

Source: SMUD Energy R&D

The response rate for the three groups was close to what was expected; however, the number of participants in the "dropped" column was surprisingly high. Customers were dropped if there was a physical limitation, such as range, to installation of a device in an apartment. The majority of customers classified as dropped were customers that signed up, but later changed their minds either when the installing contractor called to schedule an appointment or when the contractor arrived for the installation. Possible explanations include:

- Language barriers: many did not speak or read English well, and may have signed up without fully realizing the requirements, or
- Relationship with SMUD: although the installing contractor identified themselves as working for SMUD, the customer may have been more willing to go through with the installation if they had received a call and/or a visit from SMUD directly.

4.5 Energy and Demand Savings — Methods and Findings

Once the summer data collection period was complete, SMUD provided Opinion Dynamics with hourly load data for each customer in the study. Opinion Dynamics estimated the impacts for weekday peak-period kW demand, event-period kW demand and overall kWh savings using fixed-effects panel models.

The analysis accounted for factors such as outside variables unique to some participants, and also were corrected for influences that affect everyone in the population. This was done using linear regression models.

When a study randomly chooses the participants and comparison groups from the entire population of interest, analysts may, in theory, be able to extrapolate the model results to the full population of interest. In this pilot however, a convenience sample was chosen and sample size limitations were imposed. This classifies the study as a pilot. While much can be learned from pilot studies, their results typically cannot support population-wide claims with the required level of confidence. This study provided information that can be used in a number of ways: to learn more about kWh and KW savings, to better understand how customers use the devices in the home, to begin to investigate signal reliability issues and to look at factors that influence the energy code.

4.5.1 Hypotheses

The two sets of hypotheses below cover the overall energy savings and peak energy savings, which includes both daily and event peak impacts.

4.5.1.1 Energy Savings

H1a: The treatment groups on a TOU/CPP rate, with and without in-home displays and price-responsive thermostats, will show significant savings between the summers of 2012 and 2013 compared to an equivalent group of customers on a conventional rate.

H1b: The treatment group on a TOU/CPP rate, with an in-home display, will show significant savings between the summers of 2012 and 2013 compared to a group on a TOU/CPP rate and compared to a group on a conventional rate.

H1c: The treatment group on a TOU/CPP rate, with a price-responsive thermostat and an in-home display, will show significant savings between the summers of 2012 and 2013 compared to a group with an in-home display on a TOU/CPP rate, a group on a TOU/CPP rate, and a group on a conventional rate.

Demand Reduction

H2a: The treatment groups on a TOU/CPP rate, with and without in-home displays and price-responsive thermostats, will show significant reductions in daily and event peak energy between the summers of 2012 and 2013 compared to an equivalent group of customers on a conventional rate.

H2b: The treatment group on a TOU/CPP rate, with an in-home display, will show significant reductions in daily and event peak energy between the summers of 2012 and 2013 compared to a group on a TOU/CPP rate and compared to a group on a conventional rate.

H2c: The treatment group on a TOU/CPP rate, with a price-responsive thermostat and an in-home display, will show significant reductions in daily and event peak energy between the summers of 2012 and 2013 compared to a group with an in-home display on a TOU/CPP rate, a group on a TOU/CPP rate, and a group on a conventional rate.

4.6 Results

The study indicates a peak-demand savings potential of 29 percent from smart thermostats in multifamily residences, when used with a TOU/CPP rate. Nine percent of this reduction is estimated to be attributable to the rate, the other 20 percent is estimated to be incremental saving from the technology. The IHDs provided a 16 percent peak-demand savings potential, most of which is likely attributable to the rate. Customers reported satisfaction in receiving the information provided by the devices, and felt more informed about energy use issues. The study also found there is signal strength and device connectivity issues in multifamily buildings that present a barrier to widespread deployment of these devices, and require further research.

4.6.1 Energy Savings

The analysis of study data showed the following results:

- Peak demand savings (KW) accrue for all treatment groups ranging from 8 percent to 28 percent of overall demand. The rate-only group showed an 8 percent savings, the in-home display alone group showed 16 percent savings, and the in-home display and thermostat group showed 29 percent savings. The difference between rate-only and in-home display groups is not statistically significant, however, the incremental savings for the in-home display plus thermostat group was deemed to be statistically significant. The study showed that the price-responsive thermostat group saved peak demand and that the amount of savings was larger than the group with only the in-home display.
- The evaluation team expected overall energy savings (kWh) to be minimal. Analysis supported that expectation with savings of 3.2 percent for customers with treatment group 3 (rate, in-home display and thermostat) and 0.5 percent savings for the remaining groups.

All tests of significance in the model-based sections of this report are Wald chi-square tests of significance of one or more model parameters. This test examines the hypothesis that one or more model parameters are jointly different from zero. In the case of the peak load impact of the in-home display treatment group versus the rate-only treatment group, the project team does not have confidence that the peak load impacts are actually different.

4.6.1.1 Peak Demand Savings

The results show a substantial peak-period demand reduction for all treated groups. The two technology groups were compared against the rate-only group to determine the savings that can be attributed to the devices, but only the thermostat showed incremental savings during event days.

Table 14 shows the peak savings for the in-home display treatment group is the same as the peak savings for the rate-only group, while the peak savings for the thermostat treatment group is almost double that of the other two treatment groups.

Table 14: Peak-Period Demand Savings by Treatment Group (kWh/hr.)

Treatment Group	N[4]	Weekday Time Period	Savings (kWh/hr.)	SE Hourly	95% Confidence Interval		Reference Load	Percentage Peak Savings	Treatment Incremental Savings
Rate-only	85	Peak	0.10	0.04	0.03	0.17	1.14	8%	-
Rate + IHD	81	Peak	0.18	0.03	0.11	0.25	1.14	16%	7% – but not statistically different from Rate-Only
Rate + IHD + Thermostat	74	Peak	0.33	0.04	0.23	0.42	1.14	29%	20%

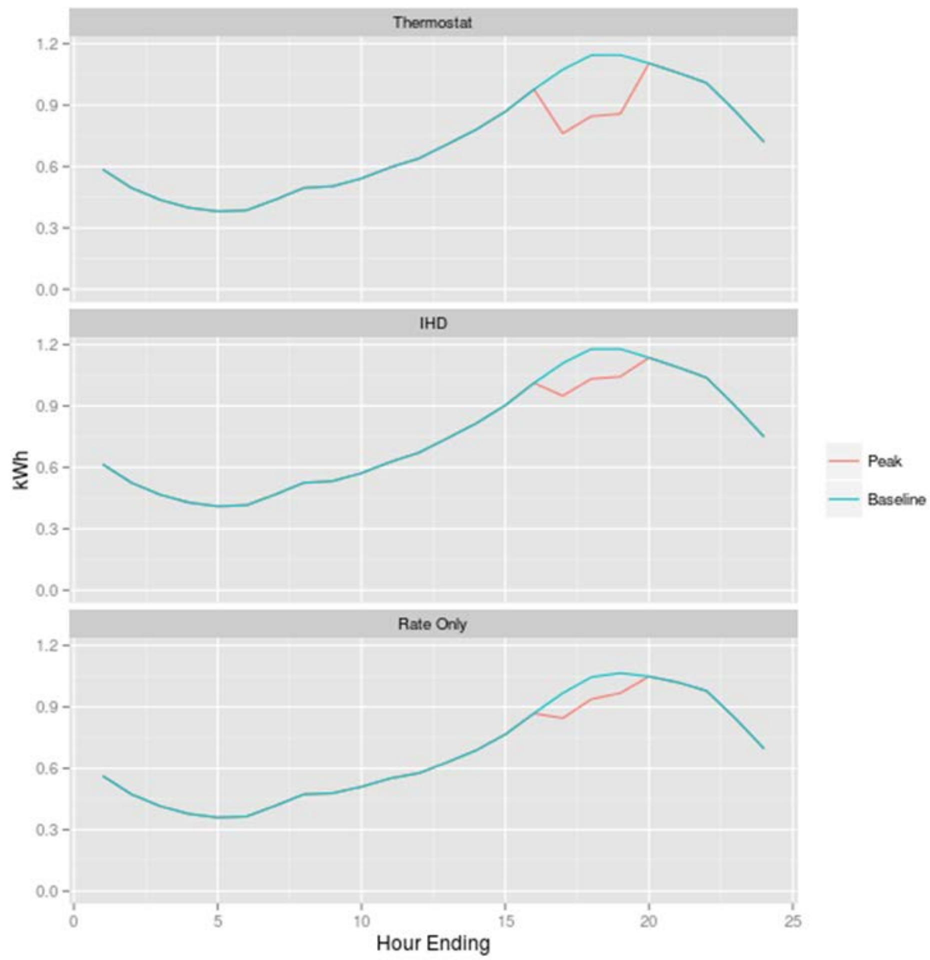
Source: Opinion Dynamics Final Analysis Report.

Note: Peak period covers hours ending 4 PM to 7 PM on non-holiday weekdays in June, July, August, and September. The savings includes non-CPP event days only.

Figure 26 shows the 2013 (treatment period) weekday mean kWh/h demand for the three treatment groups as compared to 2012 (pre-treatment period). The baseline on this graph represents the hourly 2013 weather-corrected treatment group baseline usage, while the peak line represents the load for the treatment groups with their treatments applied on non-event days. There is a clear peak demand reduction in the thermostat treatment group, while demand reductions are lower for the in-home display and rate-only treatment groups.

[4] Due to ommission of participants with less than full summer study perid data, the numbers (N) for each group in the final analysis were different from the final participant counts shown in Table 13.

Figure 26: 2013 Weekday Mean kWh Demand for Treatment Groups Over a 24 Hour Period



Source: Opinion Dynamics Final Analysis Report

Event Savings

During the study, SMUD called twelve 'events'. Events are defined as utility-driven 'super peaks', when temperature patterns are most likely to cause stress on the reliability of the utility system because of high demand for power.

Table 15 shows the event-period demand savings that occurred in addition to treatment group peak-period savings when SMUD called an event. For the rate-only and in-home display groups, there was no significant additional event period reduction in demand, when compared to the usual peak-period usage for the group..

Table 15: Event-Period Additional Demand Savings by Treatment Group (kWh/hr.)

Treatment Group	N	Weekday Time Period	Savings (kWh/hr.)	SE Hourly	95% Confidence Interval		Reference Load	Peak + Event Savings	Treatment Incremental Savings
Rate-only	85	Event	0.17	0.04	0.08	0.25	1.14	15%	-
Rate + IHD	81	Event	0.24	0.04	0.16	0.31	1.14	21%	6% – but not statistically different from Rate-Only
Rate + IHD + Thermostat	74	Event	0.40	0.05	0.28	0.52	1.14	35%	21%

Source: Opinion Dynamics Final Analysis Report

The per-household overall electricity savings from the program is small, ranging from 0.08 kWh per day for the rate-only treatment group to 0.59 kWh per day for the thermostat treatment group. The difference between the energy savings of the rate-only treatment group and that of the in-home display treatment group is not statistically significant. The savings of the thermostat treatment group is significantly higher than that of both of the other groups. Energy usage was estimated through regression modeling. It is compared to an estimate of what the same customers would have used without the interventions to develop the percent savings estimate. The estimate of the incremental savings is the difference between the savings attributable to the rate (0.5 percent) and the specific intervention.

Therefore, our analysis shows that three of the six research hypotheses are true, while three are false. There is not a statistically significant difference between the in-home display and rate-only treatment groups in either the overall energy savings or the peak demand savings.

Table 16: Answers to Research Hypotheses

Research Hypotheses			Results
Energy Impacts	H1a:	The treatment groups on a TOU/CPP rate (with and without IHDs and Price-Responsive Thermostats) will show significant savings between the summers of 2012 and 2013 compared to an equivalent group of customers on a conventional rate.	True
	H1b:	The treatment group on a TOU/CPP rate with an IHD will show significant savings between the summers of 2012 and 2013 compared to a group on a TOU/CPP rate and compared to a group on a conventional rate.	False
	H1c:	The treatment group on a TOU/CPP rate with a Price-Responsive Thermostat and an IHD will show significant savings between the summers of 2012 and 2013 compared to a group with an IHD on a TOU/CPP rate, a group on a TOU/CPP rate, and a group on a conventional rate.	False
Demand Impacts	H2a:	The treatment groups on a TOU/CPP rate (with and without IHDs and Price-Responsive Thermostats) will show significant reductions in daily and event peak energy between the summers of 2012 and 2013 compared to an equivalent group of customers on a conventional rate.	True
	H2b:	The treatment group on a TOU/CPP rate with an IHD will show significant reductions in daily and event peak energy between the summers of 2012 and 2013 compared to a group on a TOU/CPP rate and compared to a group on a conventional rate.	False
	H2c:	The treatment group on a TOU/CPP rate with Price-Responsive Thermostat and an IHD will show significant reductions in daily and event peak energy between the summers of 2012 and 2013 compared to a group with an IHD on a TOU/CPP rate, a group on a TOU/CPP rate, and a group on a conventional rate.	True

Source: Opinion Dynamics Final Analysis Report.

Connectivity Assessment

Although not a stated goal of the original research plan, it became apparent that wireless signal strength and range issues were likely to be a significant problem in multifamily buildings. To better understand the extent of the range issues, the Received Signal Strength Indicator (RSSI) level during installations was recorded. For customers with connectivity issues, they were supplied with a wireless repeater, a display that improves signal reception. RSSI levels were recorded after the repeaters were installed to compare and test signal strength improvements.

Assessing device connectivity was important for two reasons:

1. It provided a better understanding of the challenges of deploying wireless smart energy devices in multifamily settings, and the related code and market readiness.

2. It showed how poor connectivity can directly impact the customer experience and customer bill, and likewise the savings estimates from the program.

Although not realistic to expect utilities to consistently monitor and repair connectivity for customers, it was beneficial to be able to monitor connectivity during the data collection period. Customers with persistent problems were identified and contacted, which helped to maintain a level of functionality believed more closely represents technology that will be available in the near future. Once the data collection was complete, the connectivity data was included as a variable in the energy model to see if it had a measureable impact.

Survey Administration

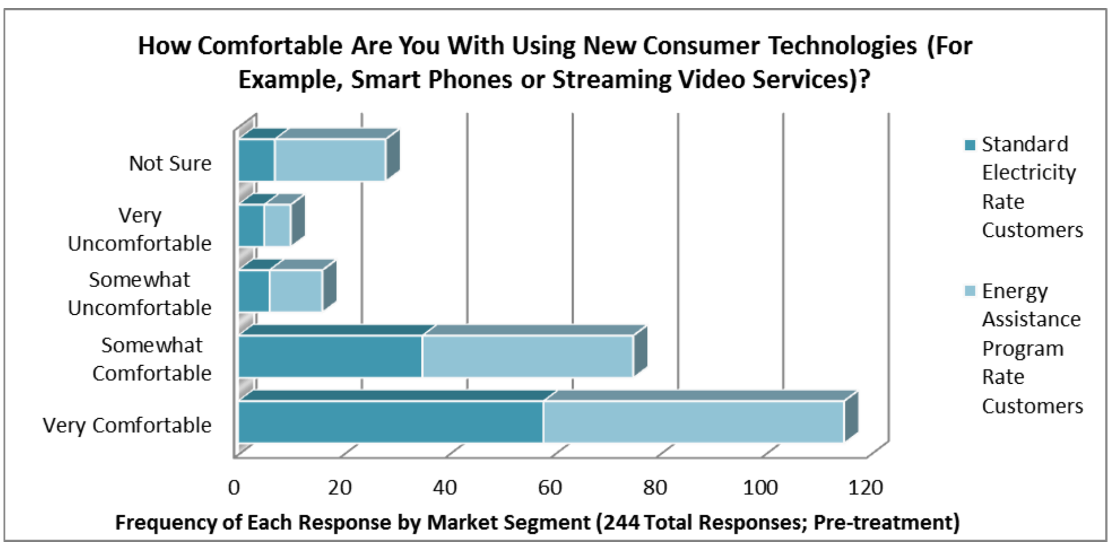
Participants were asked to complete two surveys — one was completed in the spring, prior to participation in the program, and the other in the fall after the close of the program. The two groups that received installed devices were provided with the pre-survey at the time of install, and asked to complete it while the technician set up the device or devices.

After the survey data was collected, Opinion Dynamics ran a correlation analysis with the savings data to determine if there was a detectable relationship between answers to survey questions and energy use behaviors/savings.

Tenant/customer Sentiment (Survey Sesults)

As a whole, participants were a tech-savvy group, with 78 percent of respondents reporting that they were either somewhat comfortable or very comfortable with new consumer technologies like smartphones and video streaming services. This is important because it indicates customers should be able to understand and operate the devices provided to them.

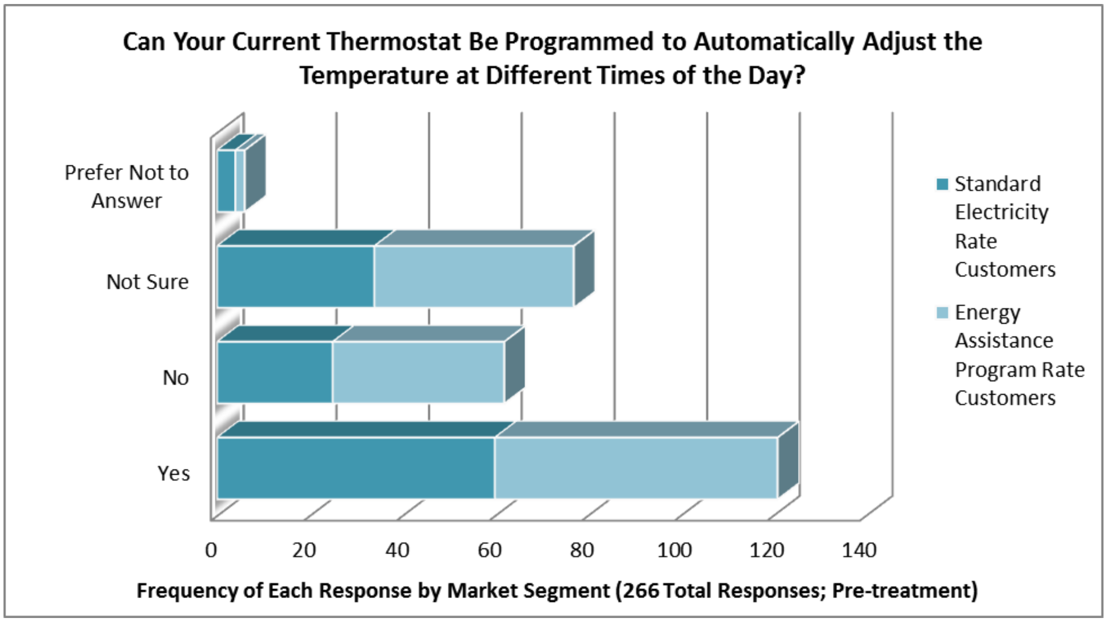
Figure 27: Participant Comfort with Technology



Source: Benningfield Group Summary of Survey Results

Participants improved their knowledge of peak hours after participating in the study, which was expected because the TOU/CPP rate was designed to increase their awareness of peak times and signal them to reduce energy consumption. Those selecting the correct answer to a question about when residential electricity use is greatest (4 to 7 p.m.), improved from 63 percent before the pilot to 81 percent after the pilot. Pre-treatment responses about participants' thermostats support the assumption of many energy professionals — the basic understanding and utilization of programmable thermostats is limited. Seventy-five respondents didn't even know if their thermostat was capable of being programmed.

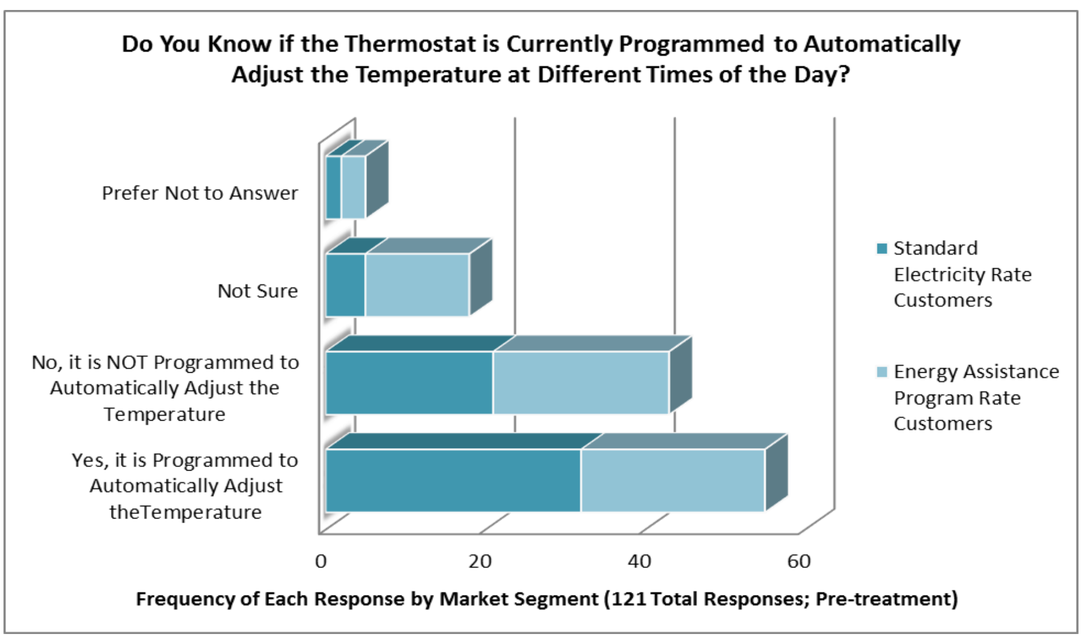
Figure 28: Participant Knowledge of Thermostat Operation



Source: Benningfield Group Summary of Survey Results.

For those participants that reported having a programmable thermostat, many of them are not using the available features.

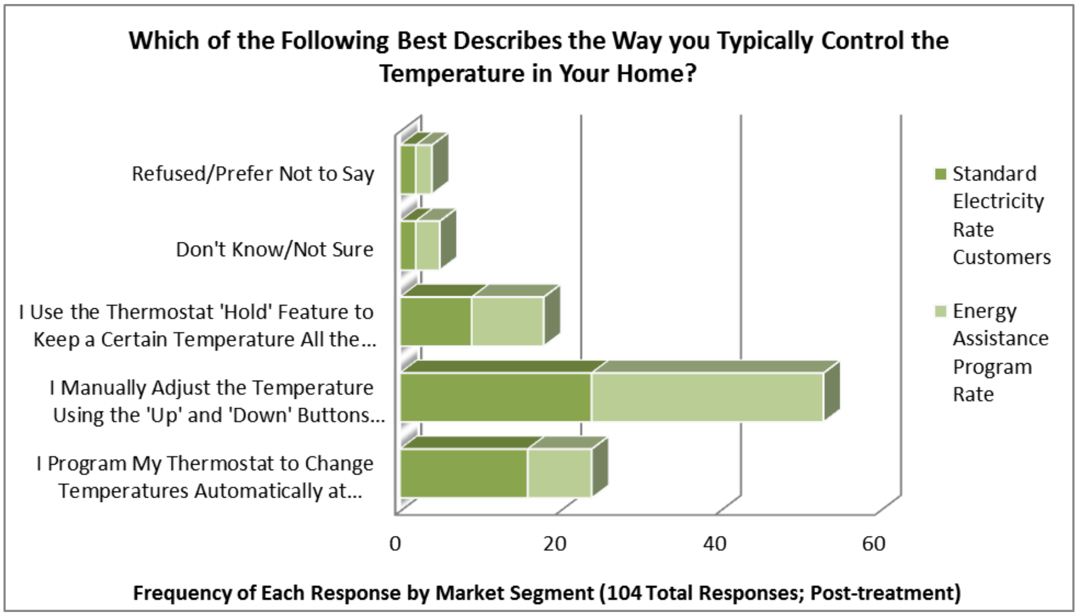
Figure 29: Participant Use of Programmable Thermostat



Source: Benningfield Group Summary of Survey Results

Thermostats supplied during the study were programmed with temperature set points so that occupants need only choose one of five available savings choices (maximum savings to maximum comfort) rather than programming a number directly. The option to select these settings simplifies the customer interface. This thermostat also provides a greater level of manual adjustment, a feature shown to be preferred in pre- and post-treatment groups.

Figure 30: Temperature Control



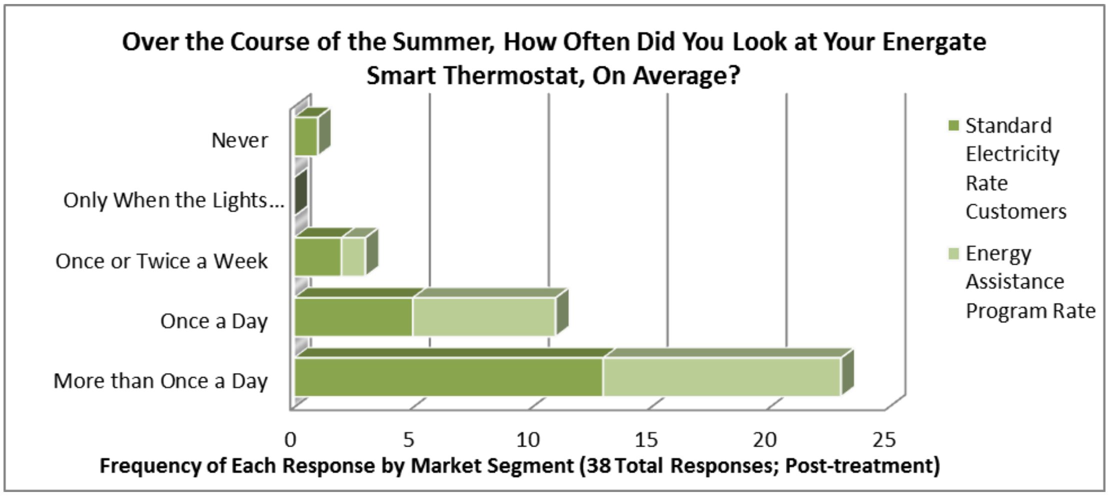
Source: Benningfield Group Summary of Survey Results.

Customers were generally happy with their in-home display, with the majority of them saying it required little or no effort to learn to use the display, and nearly all respondents reporting good or excellent overall performance and ease of use. Seventy-five percent of participants said that they looked at the in-home display once a day or more than once a day on average over the course of the study. Fifty-five percent of customers said the in-home display made them "a lot" more aware of their energy use, and 42 percent said the in-home display motivated them to change their energy use habits "a lot". However, the small level of savings data in this treatment group does not appear to support these responses.

Corroborating the connectivity data, 35 percent of participants responded that the in-home display did a very poor, poor, or fair job of maintaining connectivity to the meter — which was the same number that the study observed as having consistent connection problems, as viewed through SMUD's portal.

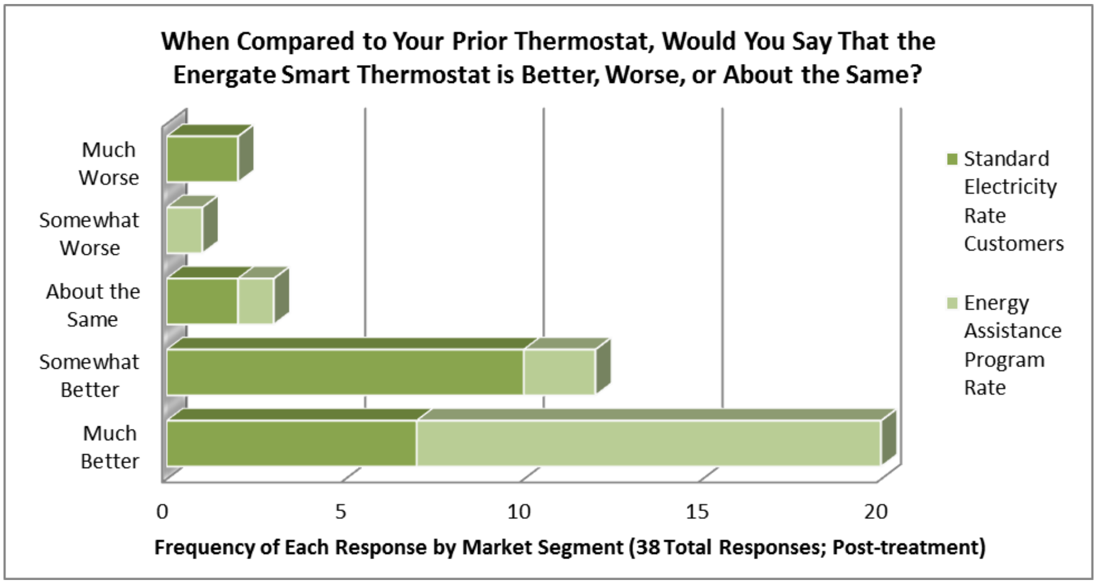
According to responses, customers were generally very engaged with their smart thermostat, with 60 percent reporting that they looked at it more than once a day (on average) and 54 percent saying that they used the price signal indicators to change their energy use some or all of the time.

Figure 31: Participant Engagement with Smart Thermostat



Source: Benningfield Group Summary of Survey Results.

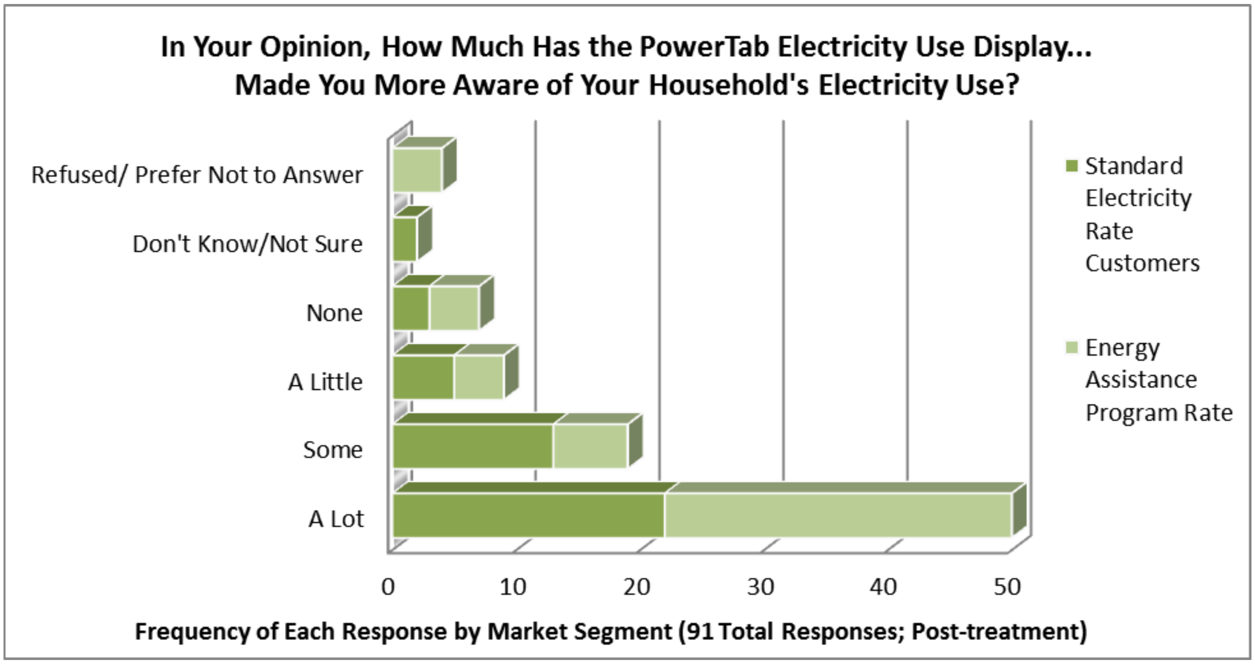
Figure 32: Participant Satisfaction with Smart Thermostat



Source: Benningfield Group Summary of Survey Results

Perhaps most importantly, more than half of customers felt the in-home display made them "a lot" more aware of their energy use, and 62 of 91 respondents (68 percent) said the in-home display motivated them to change their energy use habits.

Figure 33: Participant Awareness Due to IHD



Source: Benningfield Group Summary of Survey Results.

These responses are important because they support a recommendation that code-compliant smart thermostats be required to provide real-time energy use and cost information, much like in-home displays, but without the need for an additional display. Since the analysis showed no significant savings from the in-home displays, a recommendation cannot be made that they be required as a standalone device in code.

4.7 Conclusions and Recommendations

Study results indicate there is substantial peak savings potential from time-of-use rates, and smart thermostats in multifamily buildings. Research shows a peak load reduction savings of 29 percent was achieved with that particular treatment group. Connectivity issues in multifamily buildings need to be studied more to achieve an understanding of possible solutions.

In-home devices provide multifamily residents better visibility and understanding of their usage patterns and the cost implications, especially under a TOU/CPP rate structure. Thermostats with these types of displays appear to provide the best of both worlds (information plus automation). Two code improvements are recommended for consideration in the 2016 Standards. Further research is also needed to ensure that newly constructed buildings have the infrastructure necessary to relay data reliably and securely.

4.7.1 Code Improvements

Study findings support development of code change proposals in two areas:

1. Require systems for delivering reliable signals.

Research shows that smart thermostats and energy information displays can help residents understand and manage their energy use, leading to savings. However, for communicating thermostats and information displays to function properly, they must receive a reliable signal from the smart meter or other source. Two features make smart meter communications more problematic in multifamily buildings: (1) the typical architectural features and geometry of multifamily — elongated buildings with multiple stories and partition walls, creates physical obstructions, and (2) the placement of meters in centralized banks increases the average distance between the device in a dwelling unit and that dwelling unit's meter.

This code change requires further research into increasing signal reliability within multifamily buildings. Several market-ready solutions show potential to improve reliability of the ZigBee-based systems. However, alternative systems may serve the same function. It is critical that there be a reliable system for usage and price data transfer between the utility and residents, but there may be several ways to provide that reliability. The viability of these solutions to meet the level of rigor required by code change proposals needs further research and testing.

2. Expand requirements for occupant-controlled price/demand response enabled thermostats in multifamily homes.

The study showed a high degree of consumer satisfaction with thermostats that allow the user to view the cost of their bill and automate thermostat temperature offsets based upon personal preference. The Joint Appendices of the 2013 Code provide the specifications for communication thermostats, including a requirement that the thermostats must be capable of responding to real-time price signals from the utility. Such thermostats are required under many construction scenarios in the 2013 building code. For 2016, smart thermostats are recommended to be a mandatory measure for all multifamily new construction and major renovations. Additionally, it is recommended that adding real-time cost information (current price, multiplied by current usage) to the list of features required in the Joint Appendices.

4.7.1.1 Tech Transfer Activities

This portion of the project helped audiences to understand the complexity of energy information communication systems and protocols.

The contractor and SMUD co-hosted an informal session at the 2012 American Council for an Energy Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Buildings, which took place from August 12-17, 2012.

With SMUD as lead author, an abstract was submitted, which was accepted, for the August 2014 Summer Study, and results of the study will be shared during the session.

During the Utility Energy Forum, an annual conference held near Lake Tahoe that brings together municipal utilities from throughout California and neighboring states, Garth Torvestad participated in a "lightning round" to present a poster describing the project.

The poster illustrated the ways that wireless communication of energy information could potentially be shared within a building, and the technical and practical reasons why the particular approach used was selected. This format allowed us to provide information directly to utilities interested in deploying multifamily information and control programs, and helped them to understand the complexities involved with this type of effort.

The team delivered a 30-minute presentation during a California Multi-Family New Homes (CMFNH) webinar on our PIER research to more than 50 attendees in October of 2013. Since the target audience for CMFNH is multifamily builders, developers and energy consultants, the information presented was focused on how our research could help to exceed Title 24 requirements, with a secondary purpose of highlighting potential code changes that could eventually come out of our work.

Other Tech Transfer activities included submitting a "Code Change Brief" to the Energy Commission and Investor Owned Utility Codes and Standards teams. The brief included a snapshot preview of our proposed code changes, which was intended to make sure that the changes were included in discussions about which code changes would receive funding for CASE initiatives.

Research Needs

Energy data and automation companies are aware of the limitations of using today's wireless devices in multifamily settings and several of them are working toward solutions. However, it is difficult for companies to make the necessary investments to develop new technologies when they are not receiving a clear message from regulators and the utilities regarding the importance of energy information in multifamily buildings. Public policy that supports development of the required products and infrastructure will help provide the confidence necessary for the private sector to make the necessary investment.

As a follow-up to this study, field studies designed to test the effectiveness of energy data transmission solutions in multifamily buildings are recommended. Technologies to be studied could range from web-based solutions, solutions that utilize Ethernet cables but do not require web access, power line based solutions, cellular data solutions, or any other technology that shows promise. A better understanding of costs, limitations, reliability and durability of products, and infrastructure would support those products.

Additionally, more research is needed on the potential for more sophisticated controls to enter the home market. Systems that can automate and help manage other appliances and plug loads in multifamily buildings could also provide a source of substantial savings. Home Area Networks are still maturing and need further research and involvement from regulators before they can become an ordinary part of multifamily homes.

CHAPTER 5
Conclusions

The researchers found that there are energy-saving opportunities and challenges that are unique to the multifamily sector. In some ways, multifamily buildings behave like single-family residences. In other ways, they behave like commercial buildings. But in most ways, multifamily buildings behave in their own individual way, and require individualized treatment in the energy code. This study recommends specific changes that will alleviate some of the issues with how the code addresses multifamily buildings, but a continued focus on multifamily is the only way to ensure that all energy code issues are eventually resolved.

The research showed that ventilation and air tightness (compartmentalization) requirements for high-rise multifamily buildings should align with 2013 Low-Rise Residential Standards. This conclusion mirrors a recent move by ASHRAE towards unifying multifamily ventilation requirements around the national 62.2 standard.

In cases where exhaust shafts are shared with other residential units, pressure differentials create airflow imbalances leading to inadequate ventilation, wasted energy, or both. These effects can be mitigated by self-balancing dampers and duct sealing. The study proposes that these two measures be required in new residential buildings with central exhaust ventilation.

Fenestration features in multifamily buildings vary depending on the building configuration. The structural design and architectural components drive the type of glazing specified which, in turn, drives the performance options for windows. In multifamily buildings that use manufactured products, performance levels could be cost-effectively lowered below 2013 Code levels.

Because shared walls are common in multifamily buildings, there is less surface area on which to install windows. Data analysis indicates that multifamily buildings do, in fact, use far less glazing than allowed by the prescriptive standard. This research supports a recommendation to lower the performance penalty threshold for glass-to-floor area ratios.

The study also recommends looking more closely at the basic metrics by which window area is calculated and, to the extent possible, aligning them for all multifamily buildings. In high-rise, a window-to-wall ratio is referenced, whereas in low-rise, a window-to-floor ratio is utilized. The study recommends using the window-to-floor metric in more cases and limiting the use of window-to-wall to exceptional buildings. For example, tower-style multifamily buildings with ten or more stories could still use window-to-wall area and should also reference standards that align with curtain wall and site-built or site-assembled products.

The smart meter pilot showed that savings were consistent with prior studies on single-family residents. Occupants in the pilot, as in the prior single-family pilot, appreciate the information delivered via passive in-home displays. The treatment group that received IHDs did save substantially more energy than the comparison groups, but the savings were not significantly greater than those attributable to the TOU/CPP rate only. Smart thermostats which automate control while preserving some choice for the homeowner showed substantial potential to save peak energy—above and beyond the group with a TOU/CPP rate only.

Typical multifamily architecture introduces a new dimension to the problem of transmitting a wireless signal from the meter to the control device. The sheer distance from a typical multifamily meter bank, and the number of walls in between the meter bank and the control device, prevent clear and reliable signals. This problem requires further study and may require new code measures to ensure reliable energy data communication in all new construction.

GLOSSARY

Term	Definition
Advanced Metering Infrastructure (AMI)	Advanced Metering Infrastructure (AMI) is a two-way communications system between utilities and customer meters. It allows for the transmission, collection, and analysis of real-time energy use and price data, and is part of the larger "Smart Grid", which also includes generation, transmission, and distribution communications.
American Council for an Energy- Efficient Economy (ACEEE)	American Council for an Energy- Efficient Economy (ACEEE) is a nonprofit 501(c)(3) organization that acts as a catalyst to advance energy efficiency policies, programs, technologies, investments, and behaviors.
Anemometer	An Anemometer is an instrument for measuring and indicating the force or speed of airflow or wind.
Ashrae Standard 62.2	Ashrae Standard is the American Society of Heating, Refrigerating and Air-Conditioning Engineers document titled "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings." ASHRAE continuously maintains this Standard and publishes updates every three years. The 2013 Title 24 energy code references a CEC version of Standard 62.2-2010 that was in effect when the 2013 Title 24 Standards were being developed.
Conditioned Floor Area (CFA)	Conditioned Floor Area (CFA) is the floor area in square feet of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces of exterior walls enclosing the conditioned space.
Constant Airflow Regulators (CARs)	Constant Airflow Regulators (CARs) are specialized in-line sections of duct with factory-calibrated dampers that maintain a constant, specified airflow through the ductwork, whenever the pressures across the damper vary within a known, specified range.
Contam	Contam is a multi-zone indoor air quality and ventilation analysis computer program from the National Institute of Standards and Technology (NIST) that is designed to model building airflows, contaminant concentrations, and potential for occupant exposure.

Critical Peak Pricing (CPP)	Critical Peak Pricing (CPP)) is a rate used by utilities to signal a period of particularly high demand to customers. CPP events are called at least 24 in advance, allowing customers to make adjustments to their energy use. The CPP rate in this study was about ten times higher than the off-peak rate, and about three times higher than the daily-peak rate.
Cubic Feet Per Minute (CFM)	Cubic Feet Per Minute (CFM) is the rate (unit volume per unit time) of air that flows in response to any mechanical or natural driving force.
Dynamic Glazing Systems	Dynamic Glazing Systems are glazing systems that have the ability to reversibly change their performance properties, including U-factor, Solar Heat Gain Coefficient (SHGC), and/or Visible Transmittance (VT) between well-defined end points. These may include, but are not limited to chromogenic glazing systems, electrochromic glazing systems and integrated shading systems. Dynamic Glazing systems do not include internally mounted or externally mounted shading devices that attach to the window framing/glazing that may or may not be removable.
Energyplus	Energyplus is a whole building energy simulation program that engineers, architects, and researchers use to model energy and water use in buildings. It is free to download and use and is published by the US Department of Energy.
Energypro	Energypro is a Windows-based building energy software certified for compliance with both the residential and nonresidential Title 24 Standards. It must be purchased and is published by EnergySoft Corporation.
Energy Assistance Programrate (EAPR)	Energy Assistance Programrate (EAPR) is a discounted rate available for SMUD customers with an annual income below $22,980 for a one-person household, ranging to $63,180 for a six-person household. Standard rates are discounted by 38 percent, up to a maximum monthly discount amount.
Event Days	Event Days are utility-driven 'super peaks' when temperature patterns are most likely to cause stress on the reliability of the utility system because of high demand for power.
Fenestration	Fenestration is the arrangement, proportioning, and design of windows and doors in a building, but refers only to glass doors and windows and their frames for the purposes of building energy efficiency and code.

High-Rise Residential Building	High-rise Residential Building is a building, other than a hotel/motel, of Occupancy Group R, Group R-2 or R-4 with four or more stories.
Indoor Air Quality (IAQ)	Indoor Air Quality (IAQ) is a way of describing the presence or lack of contamination of the air in an indoor environment. The purpose of building ventilation is to remove contaminants to maintain good IAQ.
International Code Council (ICC)	International Code Council (ICC) is an organization that develops building codes and standards for structural, fire, energy, and other aspects of construction. The IECC code is the energy standard. ICC codes are used as the official building codes by many US States.
Joint Appendices (JA)	Joint Appendices (JA) is a reference document for the Title 24, Part 6 energy standards. The JA includes a glossary, weather data used for energy modeling, and specific technical information and details to support the energy efficiency standards.
Low-E Glazing	Low-E Glazing is glass that emits low levels of radiant thermal (heat) energy. The lower the emissivity, the less heat is radiated from the glazing.
Low-Rise Residential Building	Low-Rise Residential Building is a building, other than a hotel/motel that is Occupancy Group R-2, multi-family, with three stories or less; or R-3, single-family.
National Fenestration Rating Council (NFRC)	National Fenestration Rating Council (NFRC) is a non-profit organization that administers the uniform, independent rating and labeling system for the energy performance of windows, doors, skylights, and attachment products.
Net-Present Value (NPV)	Net-Present Value (NPV) is the value of future cash flows in today's dollars. Net present value uses discounting to account for the time value of money, which means that future cash flows are deemed to be worth less than present day cash, and discounted accordingly. The sum of future discounted cash flows over a given period is the NPV.
Public Interest Energy Research (PIER)	Public Interest Energy Research (PIER) is a program administered by the California Energy Commission to fund research and development on energy technologies and innovations, including generation, transmission, transportation, and building efficiency.
Self-Balancing Dampers	Self-Balancing Dampers— see Constant Airflow Regulators (CARs)
Smart Grid	Smart Grid — see Advanced Metering Infastructure (AMI)

Smart Thermostat	Smart Thermostat is a thermostat capable of wireless communication. Some smart thermostats are designed to communicate with, and respond to, signals from the utility, while others are designed to optimize energy or temperature settings either internally or through Wi-Fi communications with cloud-based services.
Solar Heat Gain Coefficient (SHGC)	Solar Heat Gain Coefficient (SHGC)) is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's SHGC, the less solar heat it allows to enter a building.
Tiered Pricing	Tiered Pricing is a utility fee structure in which customers pay a different price for each unit of energy based on the volume of energy they use.
Time of Use (TOU)	Time of Use (TOU) refers to electricity rates that are set well in advance and vary between two or more periods during the day. The daily peak rates used in this study are an example of time of use.
Title 24	Title 24 is all of the building standards and associated administrative regulations published in Title 24 of the California Code of Regulations. The Building Energy Efficiency Standards are contained in Part 6. Part 1 contains the administrative regulations for the building standards.
U-Factor	U-Factor is the overall coefficient of thermal transmittance of a fenestration, wall, floor, roof or ceiling component, in Btu/(hr. x ft.^{2} x °F), including air film resistance at both surfaces.
Window-to-Floor-Ratio (WFR)	Window-to-Floor-Ratio (WFR) or Window-to-floor area ratio is the comparison of the total amount of glazing on the exterior of a building to the total conditioned floor area of the same building.
Window-to-Wall-Ratio (WWR)	Window-to-Wall-Ratio (WWR) is the ratio of total window area of a building to the total gross exterior wall area of the same building.
Zigbee	Zigbee is a specification for a suite of communication protocols used to create personal area networks built from small, low-power digital radios. ZigBee Smart Energy is the protocol used for communication between many of the smart meters in California and in home devices such as smart thermostats and in-home energy displays.
Zero-Net Energy (ZNE)	Zero-Net Energy (ZNE) buildings are structures that consume the same amount of energy as they produce on an annual basis.

ACRONYMS

Term	Definition
AFLOOR	Floor Area
ACEEE	American Council for an Energy Efficient Economy
ACH50	Air Changes per Hour at 50 Pascals
ACM	Alternative Calculation Method
AMI	Advanced Metering Infrastructure
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
CAR	Constant Airflow Regulator(s)
CBECC	California Building Energy Code Compliance (software)
CEC	California Energy Commission
CFA	Conditioned Floor Area
CFM	Cubic Feet per Minute
CFM50	Cubic Feet per Minute at 50 Pascals
CMFNH	California Multi Family New Homes (program)
Com	Commercial
CPP	Critical Peak Pricing
CZ	Climate Zone
DVBE	Disabled Veterans Business Enterprise
E+	EnergyPlus (software)
EAPR	Energy Assistance Program Rate
Ft2	Square Feet
HR	High Rise
HVAC	Heating, Ventilating and Air-Conditioning
IAQ	Indoor Air Quality

ICC	International Code Council
IHD	In-Home Display
kTDV	Kilo-TDV (time dependent valued energy)
kW	Kilowatts
kWh	Kilowatt Hours
LED	Light Emitting Diode
Nbr	Number of bedrooms
NFRC	National Fenestration Rating Council
NPV	Net Present Value
NREL	National Renewable Energy Lab
Pa	Pascal(s)
PG&E	Pacific Gas & Electric
PIER	Public Interest Energy Research
Qfan	Fan flow (in cfm)
RD&D	Research and Development Division (of the California Energy Commission)
RER	Regional Economic Research (now part of Itron)
Res	Residential
RSSI	Received Signal Strength Indicator
SDG&E	San Diego Gas & Electric
SH	Single Hung (window)
SHGC	Solar Heat Gain Coefficient
SMUD	Sacramento Municipal Utility District
T24	Title 24
TDV	Time Dependent Valuation
TOU	Time of Use
WCEC	Western Cooling Efficiency Center
WFR	Window-to- Floor Ratio

WWR	Window-to-Wall Ratio
ZNE	Zero Net Energy

APPENDIX A: Smart Controls Owner/Manager Recruitment Collateral

Powering forward. Together.

SMUD™

Help your residents be more energy efficient,
and you'll get a $100 VISA gift card!

Dear Property Owner or Manager,

We recently sent you a letter about this special offer, and included the incorrect phone number. We apologize for any inconvenience. The corrected phone number is below.

Your properties in Sacramento County with 70 or more units and your residents have been randomly selected to participate in a special study, called Multifamily Summer Solutions, to evaluate new time-of-use electricity rates and in-home devices that help your residents track and manage their electricity use. This pilot program is being conducted by SMUD and Benningfield Group, a local research firm.

You can help by allowing us to install smart thermostats in selected residential units of your properties, all at no cost to you. And just for participating, our partner will send you a $100 VISA gift card! We're offering **property owners or managers** gift cards on a first-come, first-served basis. We will be installing a total of 100 smart thermostats in various complexes throughout SMUD's service territory, as well as providing multifamily residents in those complexes the opportunity to try out a new rate and to use energy information displays.

Your residents will know you worked with SMUD to help them be more energy efficient and save money on their energy bills. Plus, the new thermostats – valued at $350 each - will remain in each participating unit after the study's conclusion, unless you request otherwise.

If you choose to participate, we'll mail your residents an invitation to participate, and an application for them to sign and return if they are interested. Enrollment is limited, and space will be filled on a first-come, first-served basis.

All equipment and installation costs will be covered by SMUD and our contractors. We'll also give your residents special training and technical support for the devices throughout the study. On the next page you'll find additional information about this project.

If you're interested in having one or more of your properties in Sacramento County participate, please contact Garth Torvestad from Benningfield Group at (916) 221-3110 ext. 16, or email garth@benningfieldgroup.com, or simply fill out the enclosed agreement form and return it in the postage-paid envelope provided.

We're looking forward to working with you.

Bobbie Harris
SMUD Program Manager

The Multifamily Summer Solutions Pilot Program is being conducted by Benningfield Group, Inc, and SMUD. It's funded by the California Energy Commission Public Interest Energy Research (PIER) Program and SMUD.

SMUD HQ | 6201 S Street | P.O. Box 15830 | Sacramento, CA 95852-0830 | smud.org

Printed on Recycled Paper

Powering forward. Together.

SMUD™

About Multifamily Summer Solutions

SMUD is interested in learning more about the energy savings potential from In-Home Energy Displays and Smart Thermostats in multifamily buildings. To conduct this research, we have partnered with Benningfield Group, Inc., and the California Energy Commission.

This study involves the installation by Benningfield's contractor of a total of 100 Smart Thermostats and 200 In-Home Energy Displays in randomly selected customers' apartments, townhomes and condominiums in various complexes throughout SMUD's service territory. During the summer of 2013, we will be monitoring the energy use patterns of customers who have received these devices to determine if they use less electricity than they did without the benefit of the devices. SMUD will use this information to help design energy efficiency programs, while our partner, Benningfield Group, will be evaluating the potential for these technologies to become part of California's building code.

A key component of the project is that all customers who elect to participate will be placed on a special SMUD electricity rate, which discounts the cost of electricity when demand is low, and increases the cost when demand is high—summer afternoons. In similar studies, SMUD has found that most customers are able to save electricity and money while on this rate—especially when they have a device that tells them the current cost of the electricity, and how much they are using in real-time.

Residents in complexes that are part of the study will be solicited and randomly placed in one of three treatment groups: 1) a group that receives the new rate only, 2) a group that receives the rate and an in-home display, and 3) a group that receives the rate, an in-home display and a smart thermostat. Once the study is complete and the data have been analyzed, we will share aggregated results with participating residents and property managers or owners.

Why Saving During Peak Hours Is Important

All energy is not created equally. SMUD works hard to develop a reliable and environmentally clean stream of energy sources to supply you with electricity. These sources include hydroelectric, natural gas, geothermal, wind and solar. During the summer months, and especially during late afternoon and early evening weekday hours, the demand for electricity soars. To meet this higher demand, we often have to buy energy from very expensive and less environmentally-friendly sources. By reducing electricity use during peak periods, we can avoid purchasing less-desirable forms of energy. As your community-owned electric service, we want to work with customers to find solutions that help reduce electricity costs and build a cleaner, healthier environment.

SMUD™ BenningfieldGroupinc pier

SMUD HQ | 6201 S Street | P.O. Box 15830 | Sacramento, CA 95852-0830 | smud.org

APPENDIX B: Smart Controls Household Recruitment Collateral

Summer Solutions Customer Recruitment Letter Key

Rate Only

SS-R

SS-R-E

SS-C

SS-C-E

IHD

SS-I

SS-I-E

SS-C-I

SS-C-I-E

IHD + Smart Therm

SS-I-T

SS-I-T-E

IHD + Smart Therm Condo/HOA

SS-C-I-T

SS-C-I-T-E

[contract]

Summer Solutions Study - Application

Am I eligible?

Although we encourage you to apply to be part of this study, not all who are interested will be able to take part. To be included, you'll need to meet these conditions:

- You live in an apartment, condominium or townhome
- Your name is on the SMUD account and you live at the service address printed below
- Your home has a central heating and cooling system (a wall air conditioner does not qualify)
- You don't plan to move before December 31, 2013
- You are not a SMUD employee
- You do not operate a childcare or convalescent care facility in your home
- You're willing to be surveyed online, by mail and/or by telephone throughout the study period

If you participate, you will be placed on SMUD's Optimum Off-Peak Plan. You'll receive a discount off the standard price on the amount you pay for your electricity during off-peak hours this summer from June 1 through September 30, 2013. Off-peak hours are before 4 p.m. and after 7 p.m. Monday through Friday, and all day on weekends, July 4th and Labor Day. During peak hours, from 4 p.m. through 7 p.m. Monday through Friday, the price you pay will be higher than the standard price. On 12 weekdays during the summer—called Conservation Days—the peak price you pay will be higher than your usual peak price. We'll notify you the day before a Conservation Day. More information regarding the Optimum Off-Peak Rate Plan can be found in the enclosed brochure.

If you meet these conditions and wish to participate, please fill out this Application and the Participation Agreement and return them in the postage-paid envelope. Applications will be processed on a first-come, first-served basis, and you'll be notified by mail if your home is selected.

Please fill out the information below:

[fulname] Name 1	Complex Name
The following address is eligible: [saddress1] Street Address, Unit	Best Phone Number
[saddress2] City, State, Zip	Alternate Phone Number
Email address *(Your email address will be used only to send you the required research surveys and other important information regarding the study).*	

Please check (✓) how you would like to be notified of Conservation Days. You may choose all three methods below:

❑ Telephone: (________) __________ - ____________

❑ SMS text message: (_________)__________ - ____________

❑ Email: ________________________________

➨ Review and Sign Participation Agreement

SMUD™

Here's how it works

The **Optimum Off-Peak Plan** will be in effect from June 1 through September 30, 2013.

- You'll receive a discount on the standard price you pay for your electricity during off-peak hours. Off-peak hours are before 4:00 p.m. and after 7:00 p.m. on weekdays, and all day on weekends, July 4th and Labor Day.

- Peak hours are the hours when electricity use is typically highest—4:00 p.m. to 7:00 p.m., Monday through Friday. During these hours only, the amount you pay will be higher than the standard price. This means that **90% of the time, you get a discount**!
- On 12 weekdays during the summer—called Conservation Days—the amount you pay during peak hours will be higher than your usual peak price. That's just 1% of the time, or 36 hours all summer! We'll notify you the day before a Conservation Day.
- After September 30, 2013, you'll return to your standard price.

Use less electricity during peak hours by shifting when you use it (such as doing laundry before 4:00 p.m. or after 7:00 p.m.) or by reducing your use overall (such as turning off your TV when you're not watching). If you shift your electricity use to off-peak hours or reduce your use overall, you can save on your electric bill.

Sign up today

All you need to do now is let us know that you want to participate in the study. Signing up is simple.

- Fill out and sign the enclosed Application and Participation Agreement.
- Return the Application and Participation Agreement to SMUD in the postage-paid envelope provided.

To learn more about this study, please call Customer Solutions at **916-732-7000**.

Enrollment is limited. Qualified customers will be enrolled on a first-come, first-served basis, so send in your signed Application and Participation Agreement today. If you decide not to participate, you don't need to do anything; nothing about your service will change.

For more information, call SMUD at **916-732-7000.**

SMUD™

 Printed on Recycled Paper | SS-R

Summer Solutions Study

Sign up today and you could save on this summer's electric bills. Reward yourself and help the environment, too!

SMUD™
Powering forward. Together.

Conserve and save

Sign up for the Summer Solutions Study and you'll be enrolled in the **Optimum Off-Peak Plan,** where the price you pay for electricity is **based on when you use it.** You can take control of your summer electricity bills, manage your energy use and help the environment.

This study is being offered to a small group of randomly selected SMUD customers and runs from June 1 to December 31, 2013.

Save energy and money with the Optimum Off-Peak Plan

(June 1–September 30, 2013)

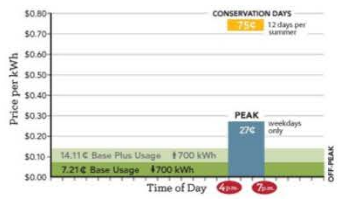
Typical Usage Appliances & Watt Usage	Cost for 1 Hour of Peak Usage	Cost for 1 Hour of Conservation Day Usage	Make A Shift >	Shifting Your Usage Appliances & Watt Usage	Cost for 1 Hour of Off-Peak Usage
A/C (5 ton) – 9000 watts	$2.43	$6.75		A/C (5 ton) – 9000 watts	$1.27
Stove – 2200 watts	$0.59	$1.65		Stove – 2200 watts	$0.31
8x60 watt lights	$0.13	$0.36	Shift Your Time of Use >	8x60 watt lights	$0.07
Clothes Washer – 400 watts	$0.11	$0.30		Clothes Washer – 400 watts	$0.06
Dryer – 3000 watts	$0.81	$2.25		Dryer – 3000 watts	$0.42
LCD TV – 110 watts	$0.03	$0.08		LCD TV – 110 watts	$0.02
Dishwasher – 1200 watts	$0.32	$0.90		Dishwasher – 1200 watts	$0.17

As a participant in the Summer Solutions Study, your benefits include:

- A special pricing plan that makes it possible to save money based on when you use energy.
- A voice in helping to shape future energy savings programs.

Optimum Off-Peak Plan

(June 1–September 30, 2013)



For most customers, the current price is 9.89 cents/kWh for the first 700 kWh (Base Usage[2]) used in a billing period, and 18.03 cents/kWh for any use above 700 kWh (Base Plus Usage[2]) in a billing period.

If you are on our Energy Assistance Program Rate (EAPR), this chart does not include the discount you'll receive on the price you pay for electricity.

This chart does not reflect service charges or other fees that are included in your bill.

Why saving during peak hours is important

Not all energy is created equally. It takes a lot of work to develop a reliable and environmentally clean stream of energy sources. These sources include hydroelectric, natural gas, geothermal, wind and solar. During the summer months, and especially during late afternoon and early evening weekday hours, the demand for electricity soars. To meet this higher demand, we often have to buy energy from very expensive and less environmentally friendly sources. By reducing electricity use during peak periods, we can avoid purchasing less desirable forms of energy. As your community-owned electric service, we want to work with you to find solutions that help reduce your electricity costs and build a cleaner, healthier environment.

Sign up today

All you need to do now is let us know that you want to participate in the study. Signing up is simple.

- Fill out and sign the enclosed Application and Participation Agreement.
- Return the Application and Participation Agreement to SMUD in the postage-paid envelope provided.

Once your enrollment is confirmed, SMUD partner Benningfield Group, Inc., will contact you to schedule the set up and overview of your electricity use display.

To learn more about this study, please call Customer Solutions at **916-732-7000.** The sooner you enroll, the sooner you can take advantage of this opportunity to try new energy-conserving and money-saving tools.

Enrollment is limited. Qualified customers will be enrolled on a first-come, first-served basis, so send in your signed Application today. If you decide not to participate, you don't need to do anything; nothing about your service will change.

For more information, call SMUD at **916-732-7000.**

SMUD™

Summer Solutions Study

Sign up today and you could save on this summer's electric bills. Reward yourself and help the environment, too!

You may be eligible to receive a FREE electricity use display.

Powering forward. Together.

SMUD™

Conserve and save

Sign up for the Summer Solutions Study and you'll be enrolled in the **Optimum Off-Peak Plan,** where the price you pay for electricity is **based on when you use it.** You can take control of your summer electricity bills, manage your energy use and help the environment. You'll also receive a FREE electricity use display.

This study is being offered to a small group of randomly selected SMUD customers. It begins with the set up of your new electricity use display and runs from June 1 to December 31, 2013.

About the EnergyAware PowerTab™ electricity use display

The PowerTab™ electricity use display will help you monitor and manage your real-time electricity use.

- It estimates what electricity use is costing you right now and recalculates costs every 15 seconds when the display is plugged in, or every 60 seconds when using the battery.
- It shows your estimated accumulated costs for the current hour, or the running total for a longer period of time.

You can turn appliances on and off to see your change in costs and electricity use within seconds.

Here's how it works

Once your enrollment is confirmed, your participation in the Summer Solutions Study will begin when SMUD partner Benningfield Group, Inc., sets up your electricity use display, at no cost to you.

The Optimum Off-Peak Plan will be in effect from June 1 through September 30, 2013.

- You'll receive a discount on the standard price you pay for your electricity during off-peak hours. Off-peak hours are before 4:00 p.m. and after 7:00 p.m. on weekdays, and all day on weekends, July 4th and Labor Day.
- Peak hours are the hours when electricity use is typically highest—4:00 p.m. to 7:00 p.m., Monday through Friday. During these hours only, the amount you pay will be higher than the standard price. This means that **90% of the time, you get a discount!**
- On 12 weekdays during the summer—called Conservation Days—the amount you pay during peak hours will be higher than your usual peak price. That's just 1% of the time, or 36 hours all summer! We'll notify you the day before a Conservation Day.
- After September 30, 2013, you'll return to your standard price.

Optimum Off-Peak Plan

(June 1–September 30, 2013)

For EAPR customers, the current price is 6.43 cents/kWh for the first 700 kWh (Base Usage[2]) used in a billing period, 12.62 cents/kWh for any use above 700 kWh and up to 1300 kWh (Base Plus Usage[3]) in a billing period, and 18.03 cents/kWh for use above 1300 kWh (Base Plus Usage Non-Discounted[4]).

As an Energy Assistance Program Rate (EAPR) customer, this chart includes the discount you'll receive on the price you pay for electricity.

This chart does not reflect service charges or other fees that are included in your bill.

Use less electricity during peak hours by shifting when you use it (such as doing laundry before 4:00 p.m. or after 7:00 p.m.) or by reducing your use overall (such as turning off your TV when you're not watching). If you shift your electricity use to off-peak hours or reduce your use overall, you can save on your electric bill.

As a participant in the Summer Solutions Study, your benefits include:

- A special pricing plan that makes it possible to save money based on when you use electricity.
- A convenient, real-time PowerTab™ electricity use display, at no cost to you.
- An opportunity to conserve energy and save money on your electricity bills by trying new technology for free.
- A voice in helping to shape future energy savings programs.

Save energy and money with the Optimum Off-Peak Plan

(June 1–September 30, 2013)

Typical Usage Appliances & Watt Usage	Cost for 1 Hour of Peak Usage	Cost for 1 Hour of Conservation Day Usage	Make A Shift ›	Shifting Your Usage Appliances & Watt Usage	Cost for 1 Hour of Off-Peak Usage
A/C (5 ton) – 9000 watts	$1.80	$4.50	Shift Your Time of Use ›	A/C (5 ton) – 9000 watts	$0.89
Stove – 2200 watts	$0.44	$1.10		Stove – 2200 watts	$0.22
8x60 watt lights	$0.08	$0.24		8x60 watt lights	$0.05
Clothes Washer – 400 watts	$0.08	$0.20		Clothes Washer – 400 watts	$0.04
Dryer – 3000 watts	$0.60	$1.50		Dryer – 3000 watts	$0.30
LCD TV – 110 watts	$0.02	$0.06		LCD TV – 110 watts	$0.01
Dishwasher – 1200 watts	$0.24	$0.60		Dishwasher – 1200 watts	$0.12

Why saving during peak hours is important

Not all energy is created equally. It takes a lot of work to develop a reliable and environmentally clean stream of energy sources. These sources include hydroelectric, natural gas, geothermal, wind and solar. During the summer months, and especially during late afternoon and early evening weekday hours, the demand for electricity soars.

To meet this higher demand, we often have to buy energy from very expensive and less environmentally friendly sources. By reducing electricity use during peak periods, we can avoid purchasing these less desirable forms of energy. As your community-owned electric service, we want to work with you to find solutions that help reduce your electricity costs and build a cleaner, healthier environment.

Sign up today

All you need to do now is let us know that you want to participate in the study. Signing up is simple.

- Fill out and sign the enclosed Application and Participation Agreement.
- Return the Application and Participation Agreement to SMUD in the postage-paid envelope provided.

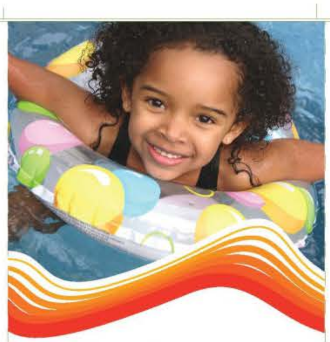
Once your enrollment is confirmed, SMUD partner Benningfield Group, Inc., will contact you to schedule the installation and overview of the technology.

To learn more about this study, please call Customer Solutions at **916-732-7000.** The sooner you enroll, the sooner you can take advantage of this opportunity to try new energy-conserving and money-saving tools.

Enrollment is limited. Qualified customers will be enrolled on a first-come, first-served basis, so send in your signed Application today. If you decide not to participate, you don't need to do anything; nothing about your service will change.

For more information, call SMUD at **916-732-7000.**

SMUD™



Summer Solutions Study

Sign up today and you could save on this summer's electric bills. Reward yourself and help the environment, too!

You may be eligible to receive a FREE electricity use display and a FREE smart thermostat.

Powering forward. Together.

SMUD™

Conserve and save

Sign up for the Summer Solutions Study and you'll be enrolled in the **Optimum Off-Peak Plan,** where the price you pay for electricity is **based on when you use it.** You can take control of your summer electricity bills, manage your energy use and help the environment. You'll also receive a FREE electricity use display and smart thermostat.

This study is being offered to a small group of randomly selected SMUD customers. It begins with the set up of your new electricity use display and installation of a smart thermostat and runs from June 1 to December 31, 2013.

The EnergyAware PowerTab™ electricity use display shows you how much electricity you're using in real time and estimates what it's costing you. The Energate Pioneer Z100 smart thermostat automates energy savings based on the comfort setting you select. It also provides information and options that help you manage your electricity use more efficiently.

About the Energate Pioneer Z100 smart thermostat

The Energate smart thermostat features advanced climate controls that make temperature adjustments based on what's important to you. You can choose from five comfort settings that each respond differently to peak hours. Then, the thermostat takes over, maintaining your home's temperature to keep you at that chosen comfort level. The easy-to-read help screens and indicator lights ensure that you're always aware of what the system's doing and what price you're paying for the electricity you're using.

About the EnergyAware PowerTab™ electricity use display

The PowerTab™ electricity use display will help you monitor and manage your real-time electricity use.

- It estimates what electricity use is costing you right now and recalculates costs every 15 seconds when the display is plugged in, or every 60 seconds when using the battery.
- It shows your estimated accumulated costs for the current hour, or the running total for a longer period of time.

You can turn appliances on and off to see your change in costs and electricity use within seconds.

Here's how it works

Once your enrollment is confirmed, your participation in the Summer Solutions Study will begin when SMUD partner Benningfield Group, Inc., sets up your electricity use display and installs the smart thermostat, at no cost to you.

The Optimum Off-Peak Plan will be in effect from June 1 through September 30, 2013.

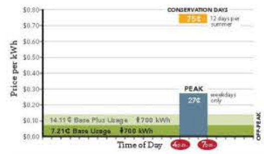
- You'll receive a discount on the standard price you pay for your electricity during off-peak hours. Off-peak hours are before 4:00 p.m. and after 7:00 p.m. on weekdays, and all day on weekends, July 4th and Labor Day.

- Peak hours are the hours when electricity use is typically highest—4:00 p.m. to 7:00 p.m., Monday through Friday. During these hours only, the amount you pay will be higher than the standard price. This means that **90% of the time, you get a discount!**
- On 12 weekdays during the summer—called Conservation Days—the amount you pay during peak hours will be higher than your usual peak price. That's just 1% of the time, or 36 hours all summer! We'll notify you the day before a Conservation Day.
- After September 30, 2013, you'll return to your standard price.

Use less electricity during peak hours by shifting when you use it (such as doing laundry before 4:00 p.m. or after 7:00 p.m.) or by reducing your use overall (such as turning off your TV when you're not watching). If you shift your electricity use to off-peak hours or reduce your use overall, you can save on your electric bill.

Optimum Off-Peak Plan

(June 1–September 30, 2013)



For most customers, the current price is 9.89 cents/kWh for the first 700 kWh (Base Usage[2]) used in a billing period, and 18.03 cents/kWh for any use above 700 kWh (Base Plus Usage[3]) in a billing period.

If you are on our Energy Assistance Program Rate (EAPR), this chart does not include the discount you'll receive on the price you pay for electricity.

This chart does not reflect service charges or other fees that are included in your bill.

As a participant in the Summer Solutions Study, your benefits include:

- A special pricing plan that makes it possible to save money based on when you use electricity.
- A convenient, real-time PowerTab™ electricity use display and an Energate smart thermostat.
- No-cost set up and installation of all new technology.
- An easy way to automate energy savings while keeping your home comfortable.
- An opportunity to conserve energy and save money on your electricity bills by trying new technology for free.
- A voice in helping to shape future energy savings programs.

Save energy and money with the Optimum Off-Peak Plan

(June 1–September 30, 2013)

Typical Usage Appliances & Watt Usage	Cost for 1 Hour of Peak Usage	Cost for 1 Hour of Conservation Day Usage	Make A Shift >	Shifting Your Usage Appliances & Watt Usage	Cost for 1 Hour of Off-Peak Usage
A/C (5 ton) – 9000 watts	$2.43	$6.75	Shift Your Time of Use >	A/C (5 ton) – 9000 watts	$1.27
Stove – 2200 watts	$0.59	$1.65		Stove – 2200 watts	$0.31
8x60 watt lights	$0.13	$0.36		8x60 watt lights	$0.07
Clothes Washer – 400 watts	$0.11	$0.30		Clothes Washer – 400 watts	$0.06
Dryer – 3000 watts	$0.81	$2.25		Dryer – 3000 watts	$0.42
LCD TV – 110 watts	$0.03	$0.08		LCD TV – 110 watts	$0.02
Dishwasher – 1200 watts	$0.32	$0.90		Dishwasher – 1200 watts	$0.17

Why saving during peak hours is important

Not all energy is created equally. It takes a lot of work to develop a reliable and environmentally clean stream of energy sources. These sources include hydroelectric, natural gas, geothermal, wind and solar. During the summer months, and especially during late afternoon and early evening weekday hours, the demand for electricity soars.

To meet this higher demand, we often have to buy energy from very expensive and less environmentally friendly sources. By reducing electricity use during peak periods, we can avoid purchasing these less desirable forms of energy. As your community-owned electric service, we want to work with you to find solutions that help reduce your electricity costs and build a cleaner, healthier environment.

Here's how it works

The **Optimum Off-Peak Plan** will be in effect from June 1 through September 30, 2013.

- You'll receive a discount on the standard price you pay for your electricity during off-peak hours. Off-peak hours are before 4:00 p.m. and after 7:00 p.m. on weekdays, and all day on weekends, July 4th and Labor Day.

- Peak hours are the hours when electricity use is typically highest—4:00 p.m. to 7:00 p.m., Monday through Friday. During these hours only, the amount you pay will be higher than the standard price. This means that **90% of the time, you get a discount!**
- On 12 weekdays during the summer—called Conservation Days—the amount you pay during peak hours will be higher than your usual peak price. That's just 1% of the time, or 36 hours all summer! We'll notify you the day before a Conservation Day.
- After September 30, 2013, you'll return to your standard price.

Use less electricity during peak hours by shifting when you use it (such as doing laundry before 4:00 p.m. or after 7:00 p.m.) or by reducing your use overall (such as turning off your TV when you're not watching). If you shift your electricity use to off-peak hours or reduce your use overall, you can save on your electric bill.

Sign up today

All you need to do now is let us know that you want to participate in the study. Signing up is simple.

- Fill out and sign the enclosed Application and Participation Agreement.
- Return the Application and Participation Agreement to SMUD in the postage-paid envelope provided.

To learn more about this study, please call Customer Solutions at **916-732-7000**.

Enrollment is limited. Qualified customers will be enrolled on a first-come, first-served basis, so send in your signed Application and Participation Agreement today. If you decide not to participate, you don't need to do anything; nothing about your service will change.

For more information,
call SMUD at **916-732-7000.**

SMUD™

Printed on Recycled Paper | SS-R

Summer Solutions Study

Sign up today and you could save on this summer's electric bills. Reward yourself and help the environment, too!

SMUD™
Powering forward. Together.

Conserve and save

Sign up for the Summer Solutions Study and you'll be enrolled in the **Optimum Off-Peak Plan,** where the price you pay for electricity is **based on when you use it.** You can take control of your summer electricity bills, manage your energy use and help the environment.

This study is being offered to a small group of randomly selected SMUD customers and runs from June 1 to December 31, 2013.

Save energy and money with the Optimum Off-Peak Plan

(June 1–September 30, 2013)

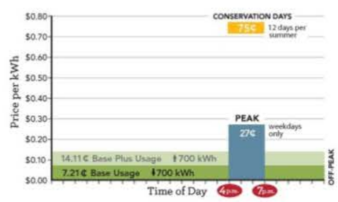
Typical Usage Appliances & Watt Usage	Cost for 1 Hour of Peak Usage	Cost for 1 Hour of Conservation Day Usage	Make A Shift ›	Shifting Your Usage Appliances & Watt Usage	Cost for 1 Hour of Off-Peak Usage
A/C (5 ton) – 9000 watts	$2.43	$6.75	Shift Your Time of Use ›	A/C (5 ton) – 9000 watts	$1.27
Stove – 2200 watts	$0.59	$1.65		Stove – 2200 watts	$0.31
8x60 watt lights	$0.13	$0.36		8x60 watt lights	$0.07
Clothes Washer – 400 watts	$0.11	$0.30		Clothes Washer – 400 watts	$0.06
Dryer – 3000 watts	$0.81	$2.25		Dryer – 3000 watts	$0.42
LCD TV – 110 watts	$0.03	$0.08		LCD TV – 110 watts	$0.02
Dishwasher – 1200 watts	$0.32	$0.90		Dishwasher – 1200 watts	$0.17

As a participant in the Summer Solutions Study, your benefits include:

- A special pricing plan that makes it possible to save money based on when you use energy.
- A voice in helping to shape future energy savings programs.

Optimum Off-Peak Plan

(June 1–September 30, 2013)



For most customers, the current price is 9.89 cents/kWh for the first 700 kWh (Base Usage[2]) used in a billing period, and 18.03 cents/kWh for any use above 700 kWh (Base Plus Usage[2]) in a billing period.

If you are on our Energy Assistance Program Rate (EAPR), this chart does not include the discount you'll receive on the price you pay for electricity.

This chart does not reflect service charges or other fees that are included in your bill.

Why saving during peak hours is important

Not all energy is created equally. It takes a lot of work to develop a reliable and environmentally clean stream of energy sources. These sources include hydroelectric, natural gas, geothermal, wind and solar. During the summer months, and especially during late afternoon and early evening weekday hours, the demand for electricity soars. To meet this higher demand, we often have to buy energy from very expensive and less environmentally friendly sources. By reducing electricity use during peak periods, we can avoid purchasing less desirable forms of energy. As your community-owned electric service, we want to work with you to find solutions that help reduce your electricity costs and build a cleaner, healthier environment.

Here's how it works

The **Optimum Off-Peak Plan** will be in effect from June 1 through September 30, 2013.

- You'll receive a discount on the standard price you pay for your electricity during off-peak hours. Off-peak hours are before 4:00 p.m. and after 7:00 p.m. on weekdays, and all day on weekends, July 4th and Labor Day.
- Peak hours are the hours when electricity use is typically highest—4:00 p.m. to 7:00 p.m., Monday through Friday. During these hours only, the amount you pay will be higher than the standard price. This means that **90% of the time, you get a discount**!
- On 12 weekdays during the summer—called Conservation Days—the amount you pay during peak hours will be higher than your usual peak price. That's just 1% of the time, or 36 hours all summer! We'll notify you the day before a Conservation Day.
- After September 30, 2013, you'll return to your standard price.

Use less electricity during peak hours by shifting when you use it (such as doing laundry before 4:00 p.m. or after 7:00 p.m.) or by reducing your use overall (such as turning off your TV when you're not watching). If you shift your electricity use to off-peak hours or reduce your use overall, you can save on your electric bill.

Sign up today

All you need to do now is let us know that you want to participate in the study. Signing up is simple.

- Fill out and sign the enclosed Application and Participation Agreement.
- Return the Application and Participation Agreement to SMUD in the postage-paid envelope provided.

To learn more about this study, please call Customer Solutions at **916-732-7000**.

Enrollment is limited. Qualified customers will be enrolled on a first-come, first-served basis, so send in your signed Application and Participation Agreement today. If you decide not to participate, you don't need to do anything; nothing about your service will change.

For more information, call SMUD at **916-732-7000.**

SMUD™

Summer Solutions Study

Sign up today and you could save on this summer's electric bills. Reward yourself and help the environment, too!

SMUD™
Powering forward. Together.

Conserve and save

Sign up for the Summer Solutions Study and you'll be enrolled in the **Optimum Off-Peak Plan,** where the price you pay for electricity is **based on when you use it.** You can take control of your summer electricity bills, manage your energy use and help the environment.

This study is being offered to a small group of randomly selected SMUD customers and runs from June 1 to December 31, 2013.

Save energy and money with the Optimum Off-Peak Plan

(June 1–September 30, 2013)

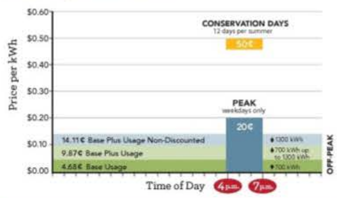
Typical Usage Appliances & Watt Usage	Cost for 1 Hour of Peak Usage	Cost for 1 Hour of Conservation Day Usage	Make A Shift >	Shifting Your Usage Appliances & Watt Usage	Cost for 1 Hour of Off-Peak Usage
A/C (5 ton) – 9000 watts	$1.80	$4.50	Shift Your Time of Use >	A/C (5 ton) – 9000 watts	$0.89
Stove – 2200 watts	$0.44	$1.10		Stove – 2200 watts	$0.22
8x60 watt lights	$0.08	$0.24		8x60 watt lights	$0.05
Clothes Washer – 400 watts	$0.08	$0.20		Clothes Washer – 400 watts	$0.04
Dryer – 3000 watts	$0.60	$1.50		Dryer – 3000 watts	$0.30
LCD TV – 110 watts	$0.02	$0.06		LCD TV – 110 watts	$0.01
Dishwasher – 1200 watts	$0.24	$0.60		Dishwasher – 1200 watts	$0.12

As a participant in the Summer Solutions Study, your benefits include:

- A special pricing plan that makes it possible to save money based on when you use energy.
- A voice in helping to shape future energy savings programs.

Optimum Off-Peak Plan

(June 1–September 30, 2013)



For EAPR customers, the current price is 6.43 cents/kWh for the first 700 kWh (Base Usage[2]) used in a billing period, 12.62 cents/kWh for any use above 700 kWh and up to 1300 kWh (Base Plus Usage[3]) in a billing period, and 18.03 cents/kWh for use above 1300 kWh (Base Plus Usage Non-Discounted[4]).

As an Energy Assistance Program Rate (EAPR) customer, this chart includes the discount you'll receive on the price you pay for electricity.

This chart does not reflect service charges or other fees that are included in your bill.

Why saving during peak hours is important

Not all energy is created equally. It takes a lot of work to develop a reliable and environmentally clean stream of energy sources. These sources include hydroelectric, natural gas, geothermal, wind and solar. During the summer months, and especially during late afternoon and early evening weekday hours, the demand for electricity soars. To meet this higher demand, we often have to buy energy from very expensive and less environmentally friendly sources. By reducing electricity use during peak periods, we can avoid purchasing less desirable forms of energy. As your community-owned electric service, we want to work with you to find solutions that help reduce your electricity costs and build a cleaner, healthier environment.

APPENDIX C: Savings from Ventilation Measures

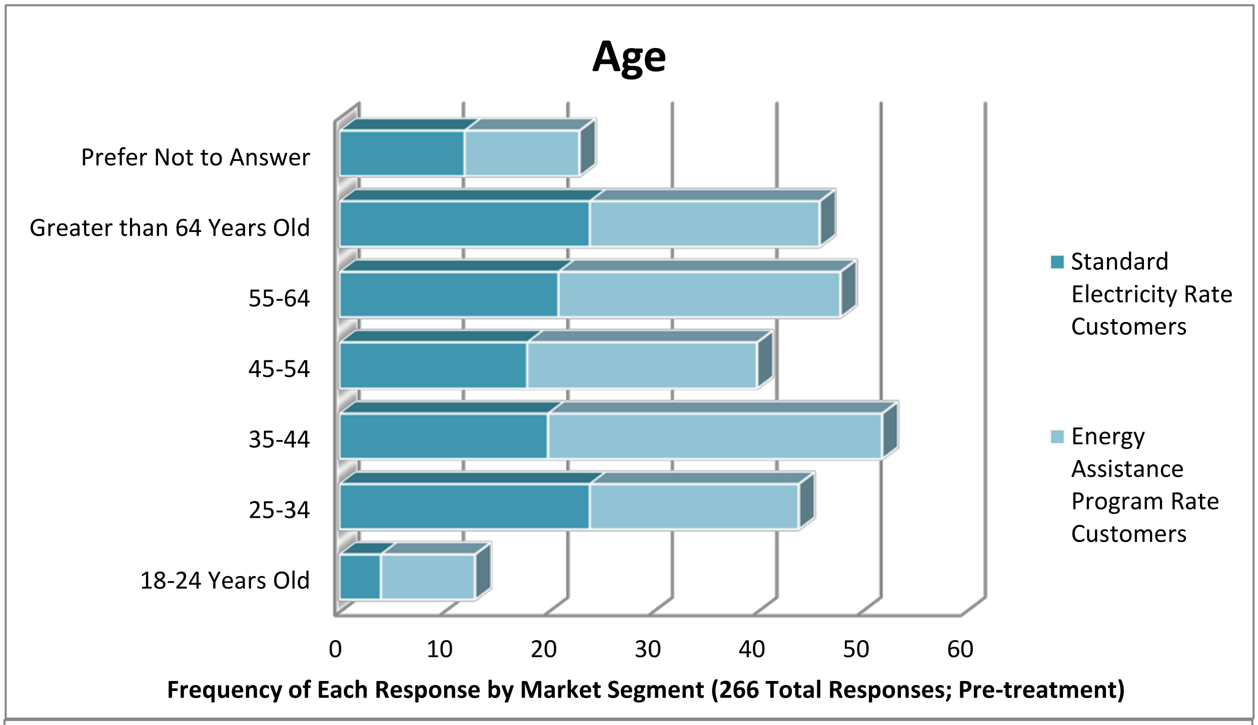
Ventilation Rate Reduction Savings

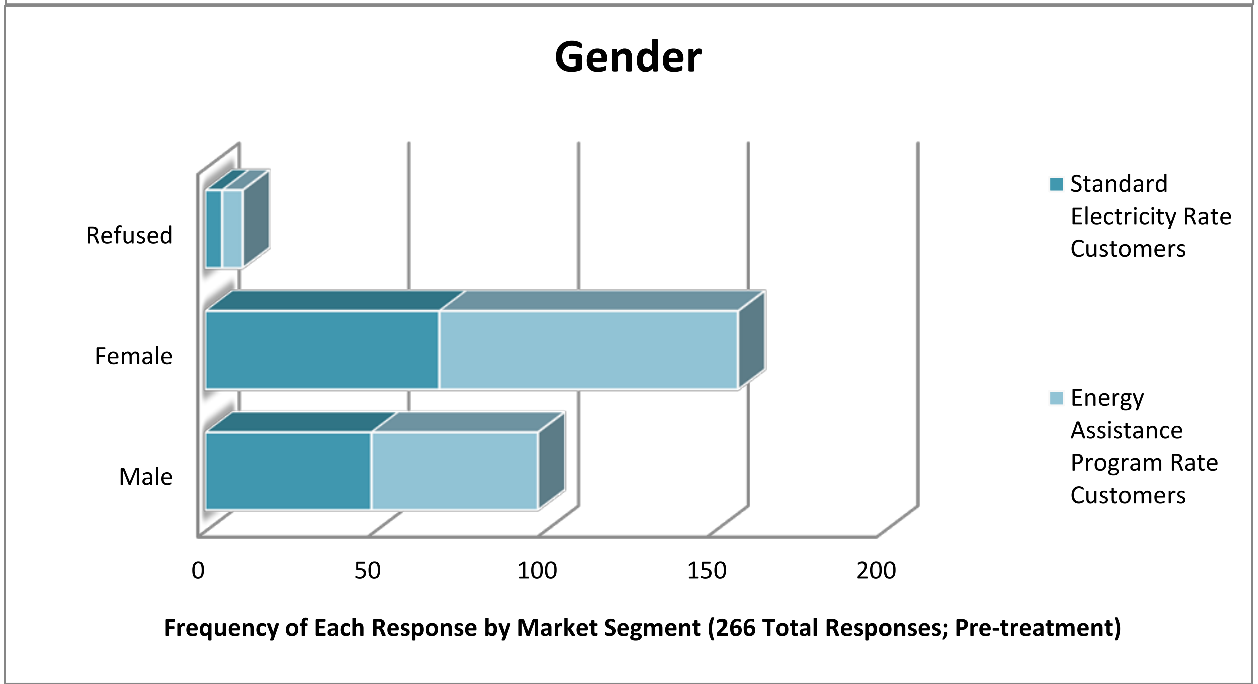
California Climate Zone	3 (San Francisco)	8 (Los Angeles)	12 (Sacramento)
Heating energy	46%	50%	38%
Cooling energy	(62%)	(22%)	(7%)
Total heating, cooling, and fan energy	37%	19%	29%

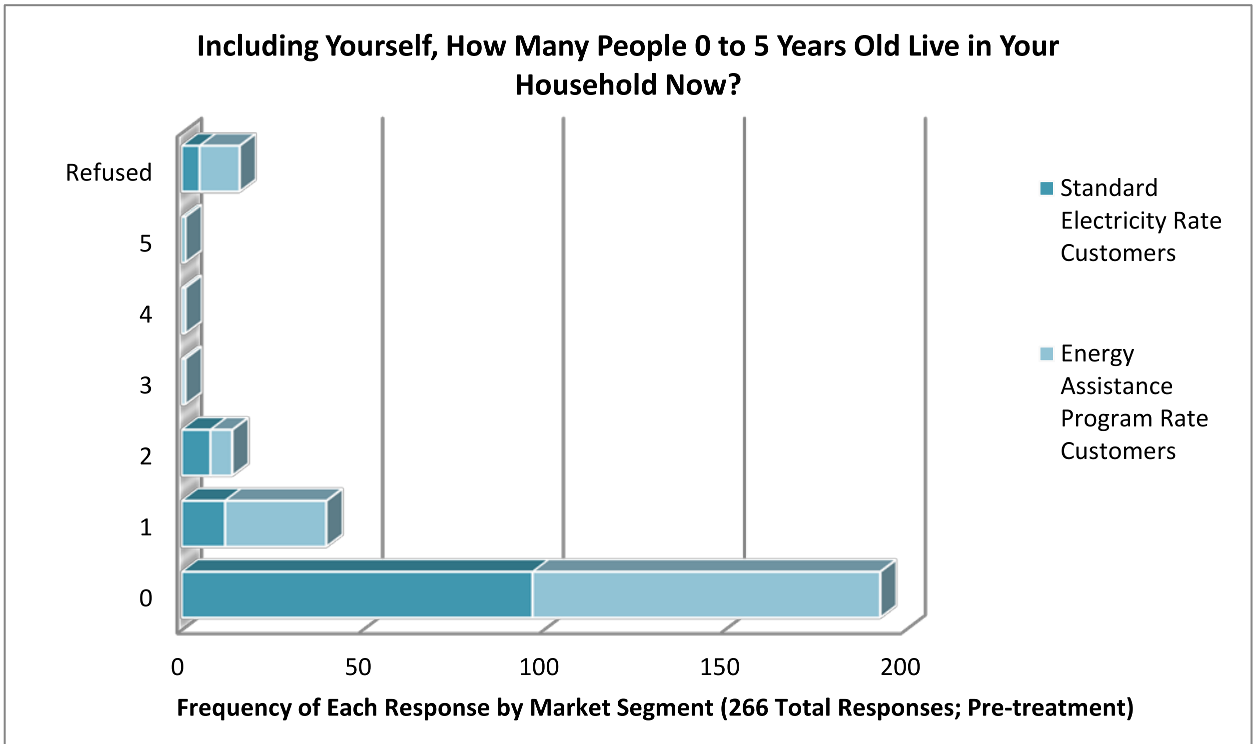
Envelope Tightening Savings

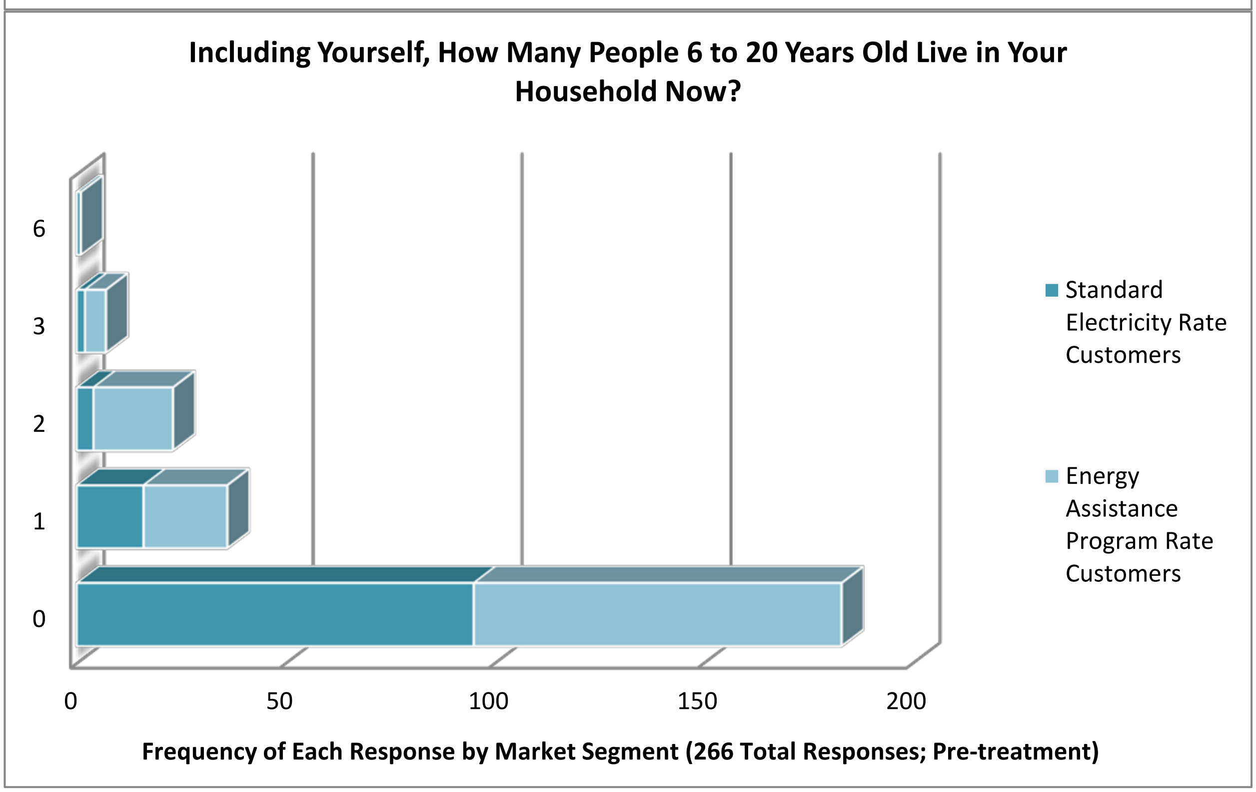
California Climate Zone	3 (San Francisco)	8 (Los Angeles)	12 (Sacramento)
Heating energy	11%	14%	9%
Cooling energy	(1%)	1%	2%
Total heating, cooling, and fan energy	11%	6%	7%

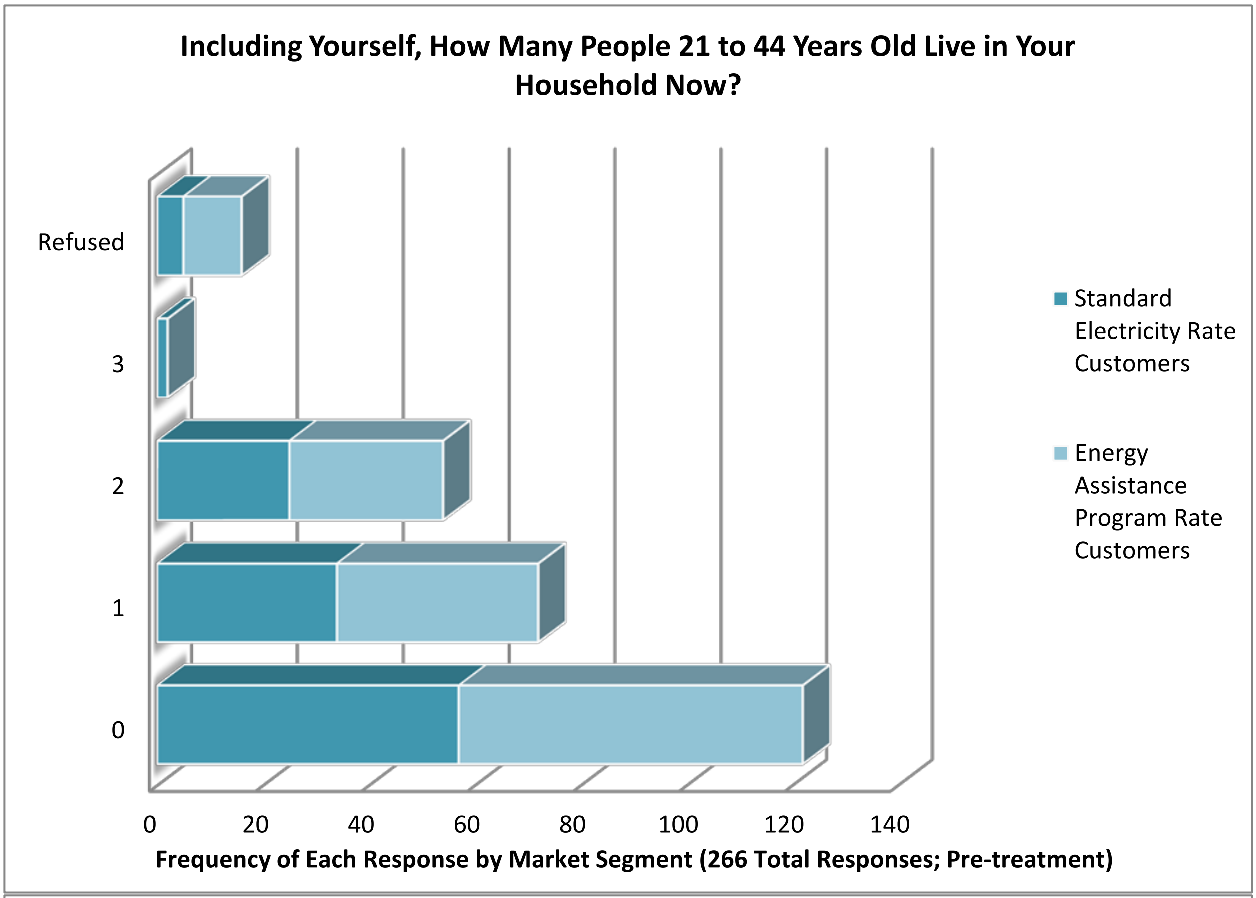
APPENDIX D: Pre- and Post-Treatment Survey Results—SMUD Smart Controls Study

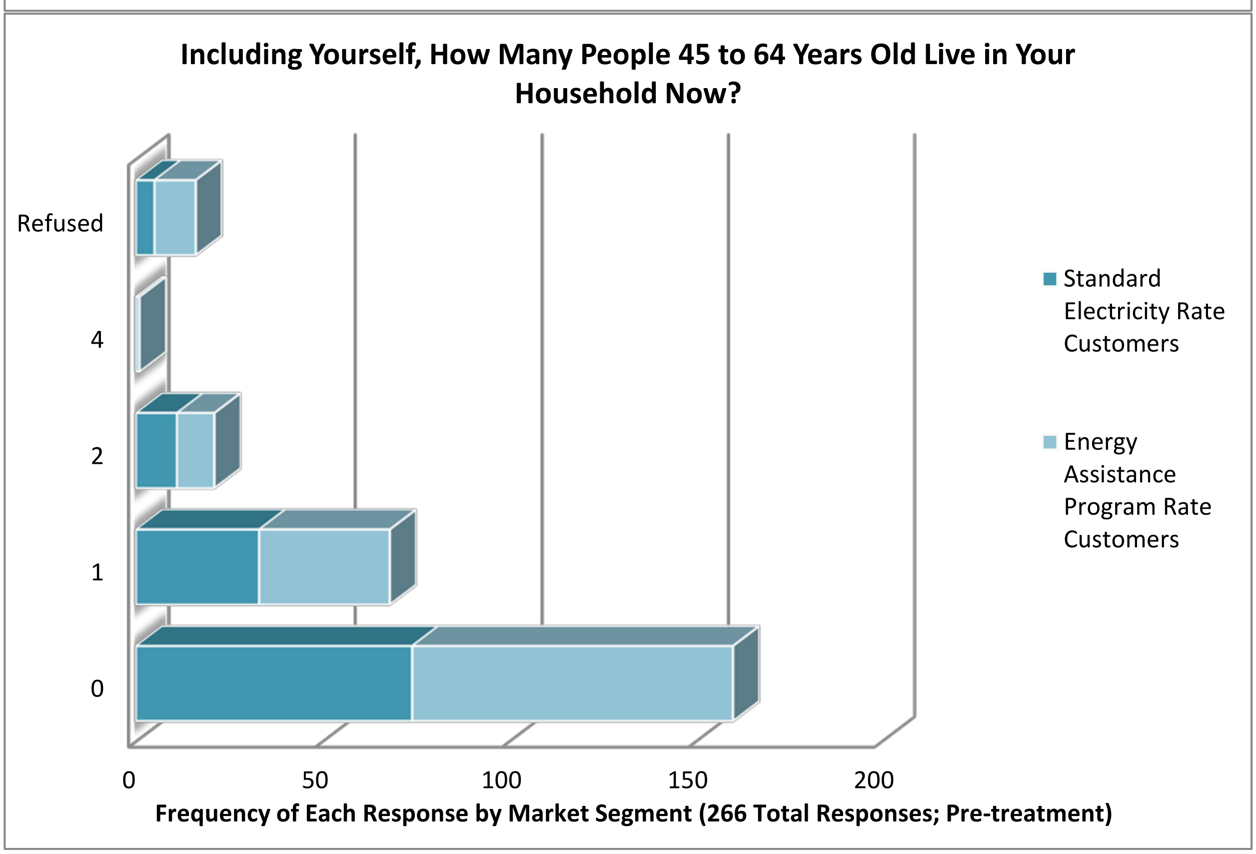


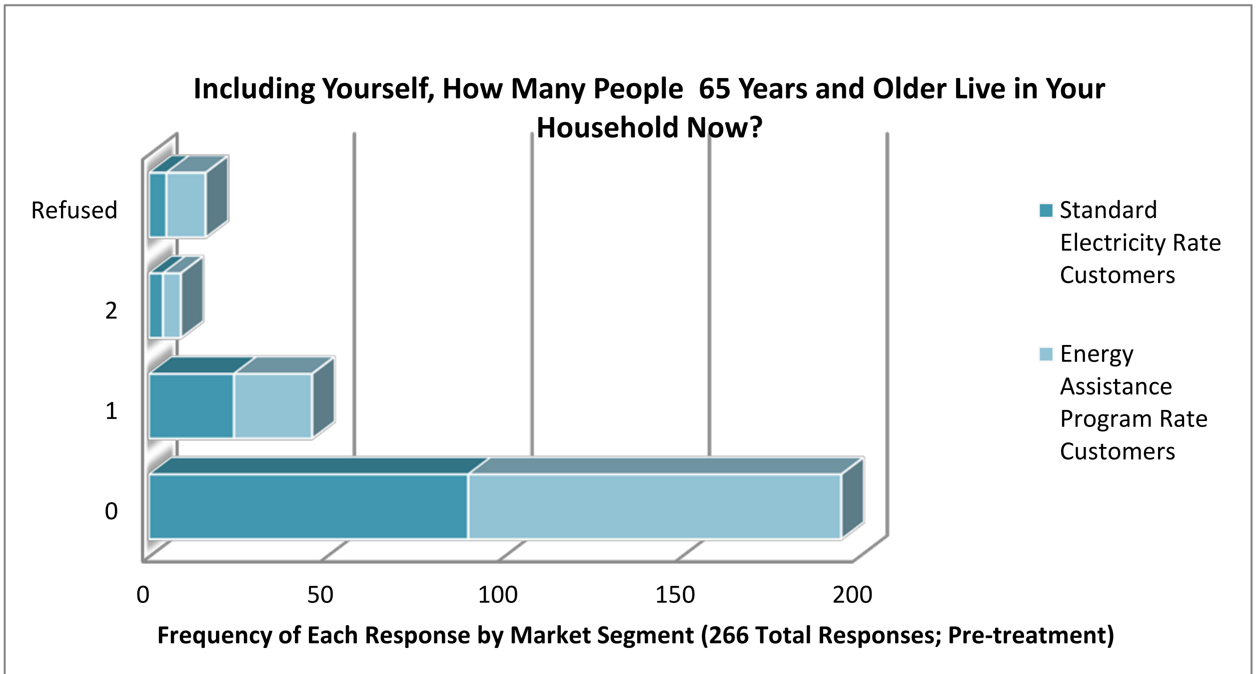


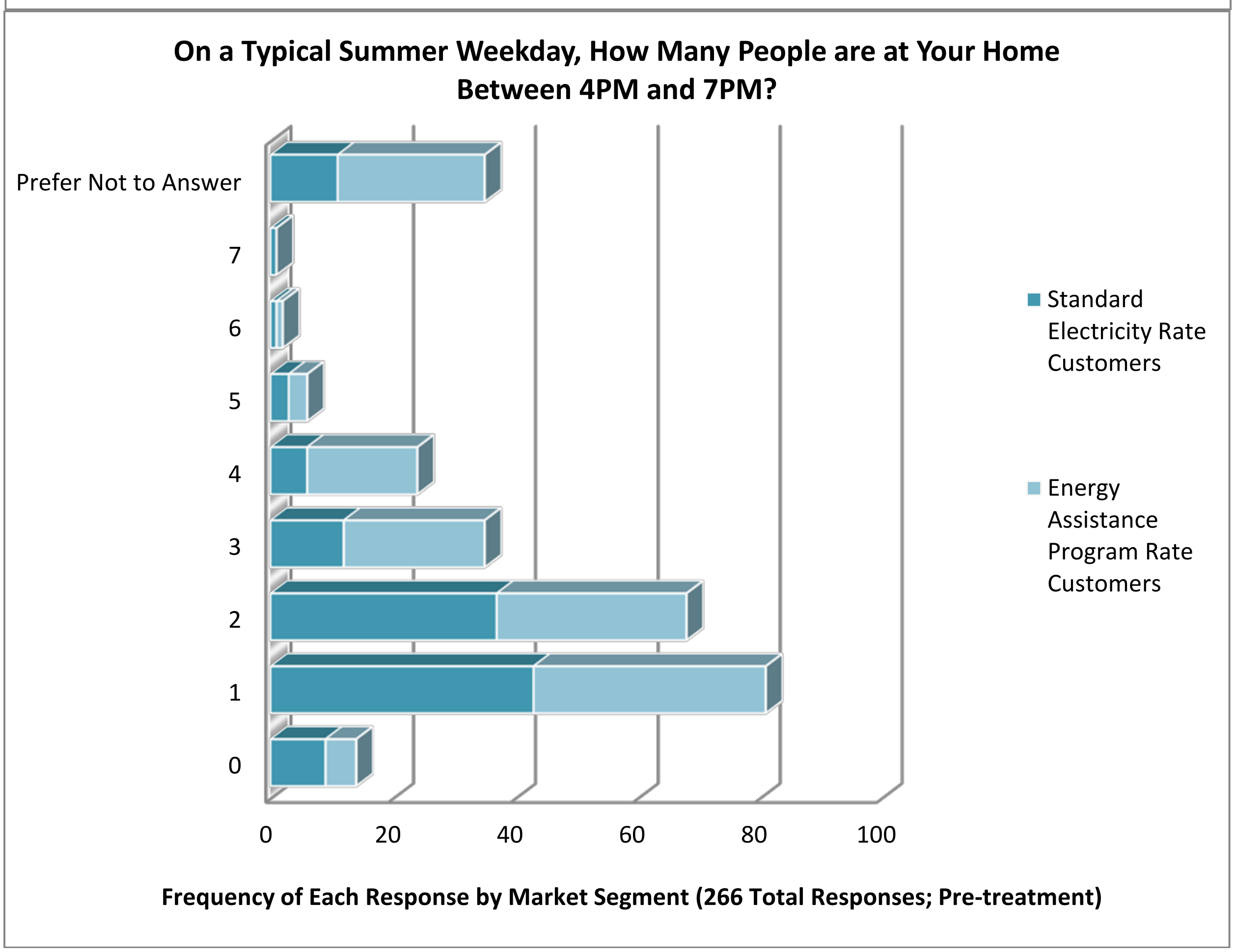

Including Yourself, How Many People 0 to 5 Years Old Live in Your Household Now?
Refused
5
4
3
2
1
0
0
50
100
150
200
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

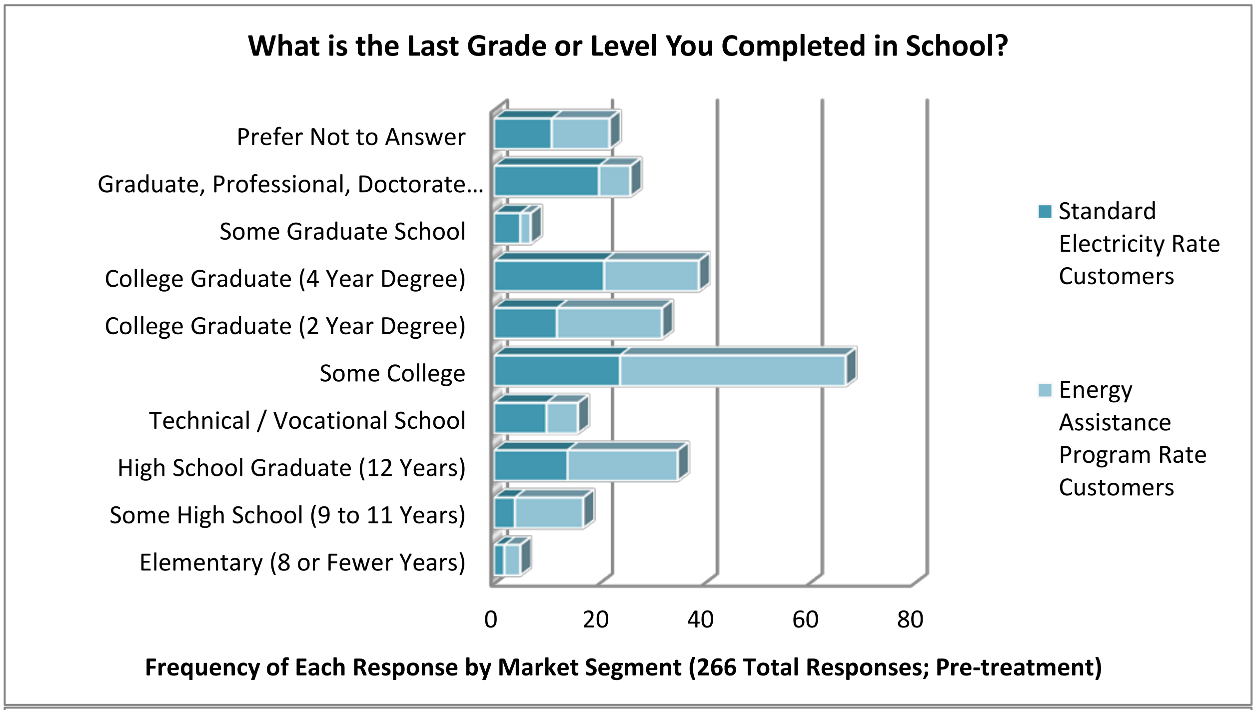

Including Yourself, How Many People 6 to 20 Years Old Live in Your Household Now?
6
3
2
1
0
0
50
100
150
200
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

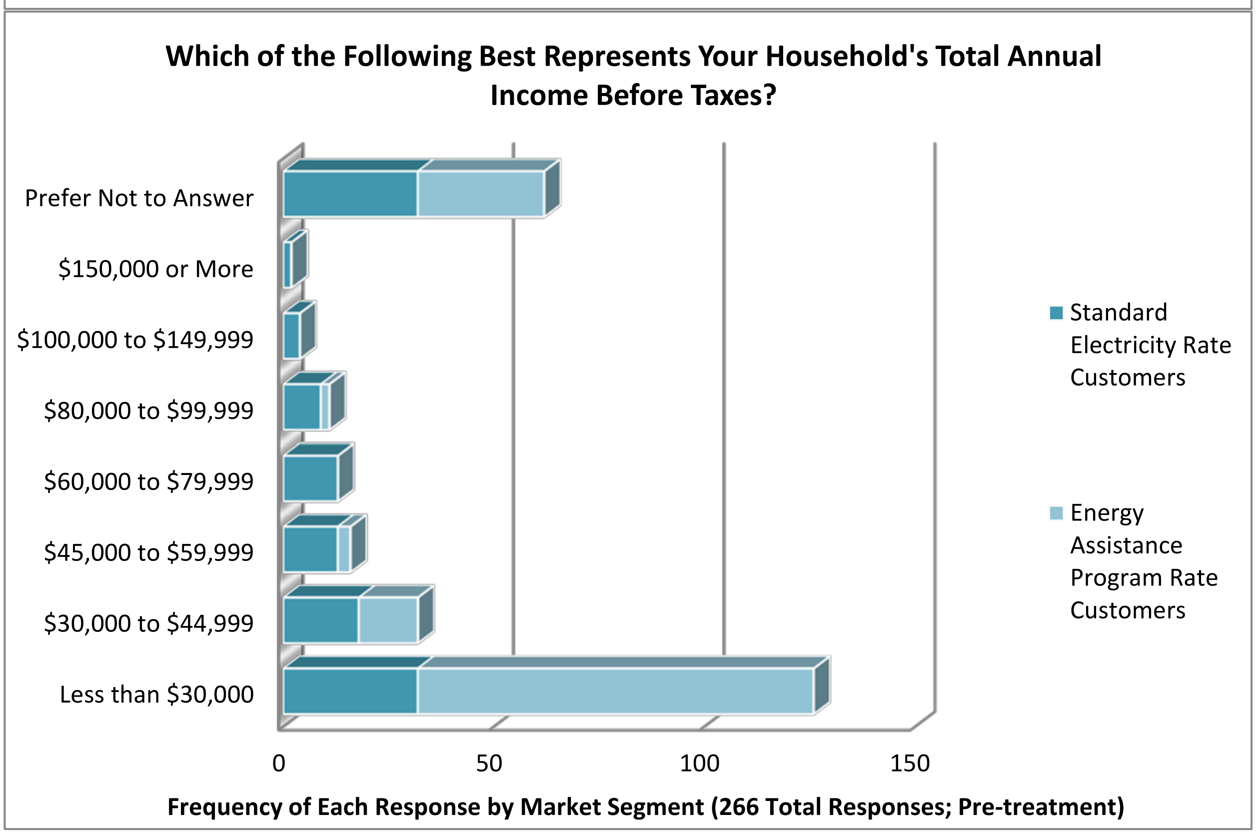

Including Yourself, How Many People 21 to 44 Years Old Live in Your Household Now?
Refused
3
2
1
0
0
20
40
60
80
100
120
140
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

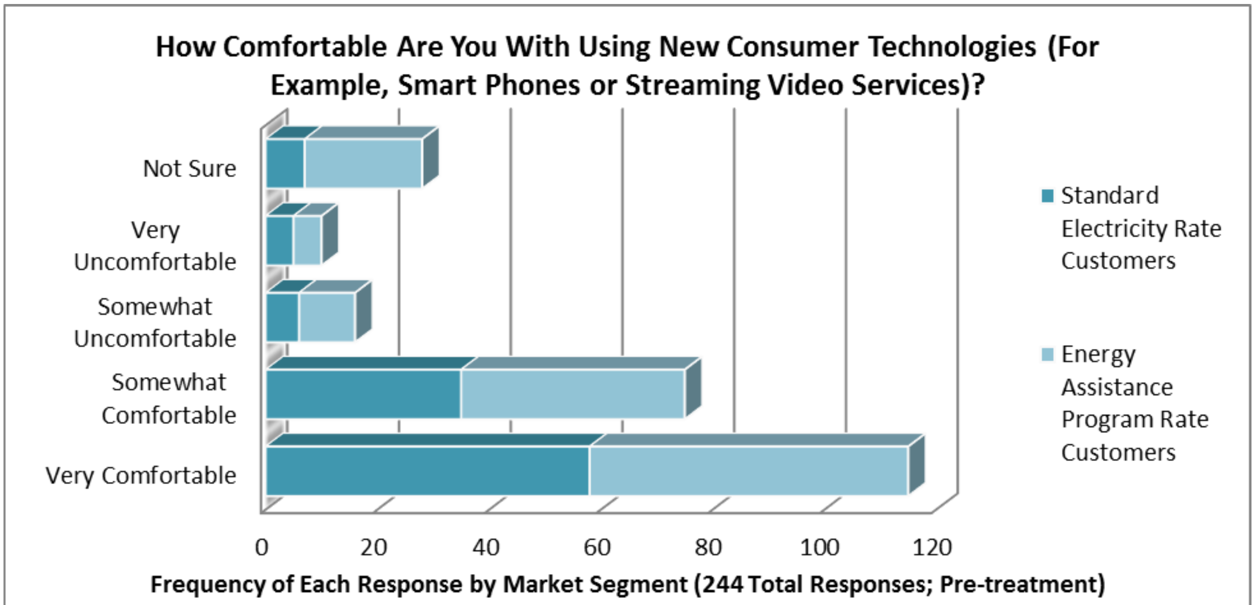

Including Yourself, How Many People 45 to 64 Years Old Live in Your Household Now?
Refused
4
2
1
0
0
50
100
150
200
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

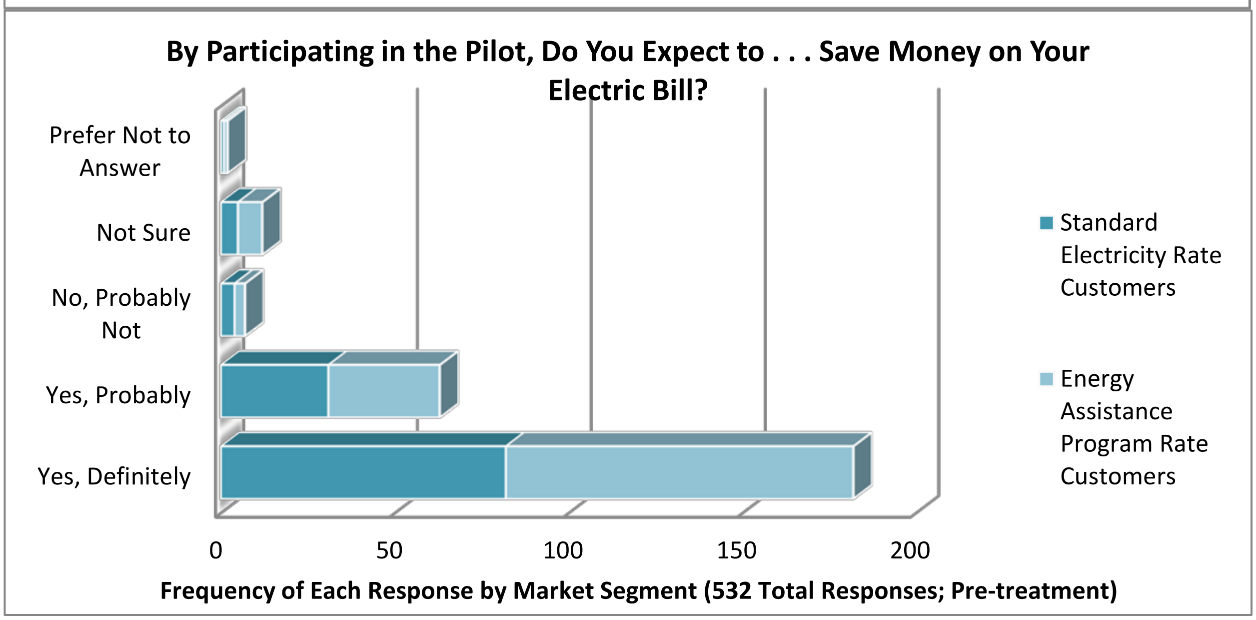

Including Yourself, How Many People 65 Years and Older Live in Your Household Now?
Refused
2
1
0
0
50
100
150
200
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

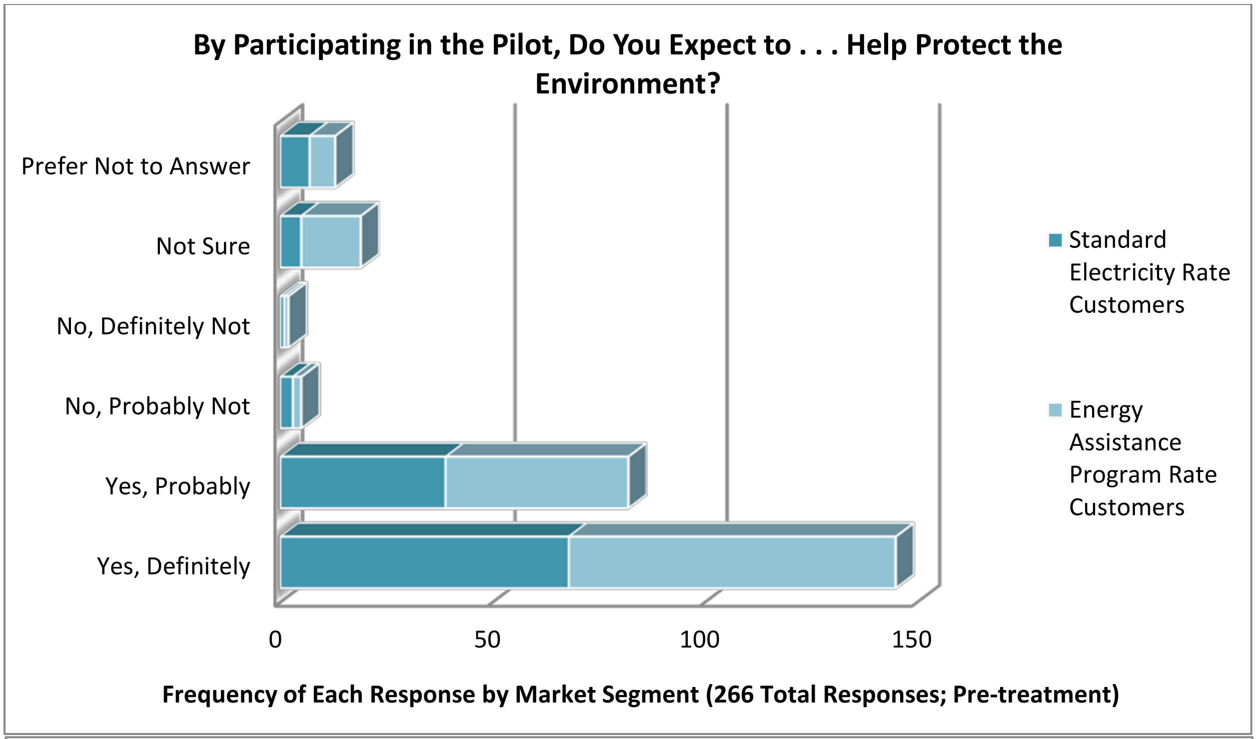

On a Typical Summer Weekday, How Many People are at Your Home Between 4PM and 7PM?
Prefer Not to Answer
7
6
5
4
3
2
1
0
0
20
40
60
80
100
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

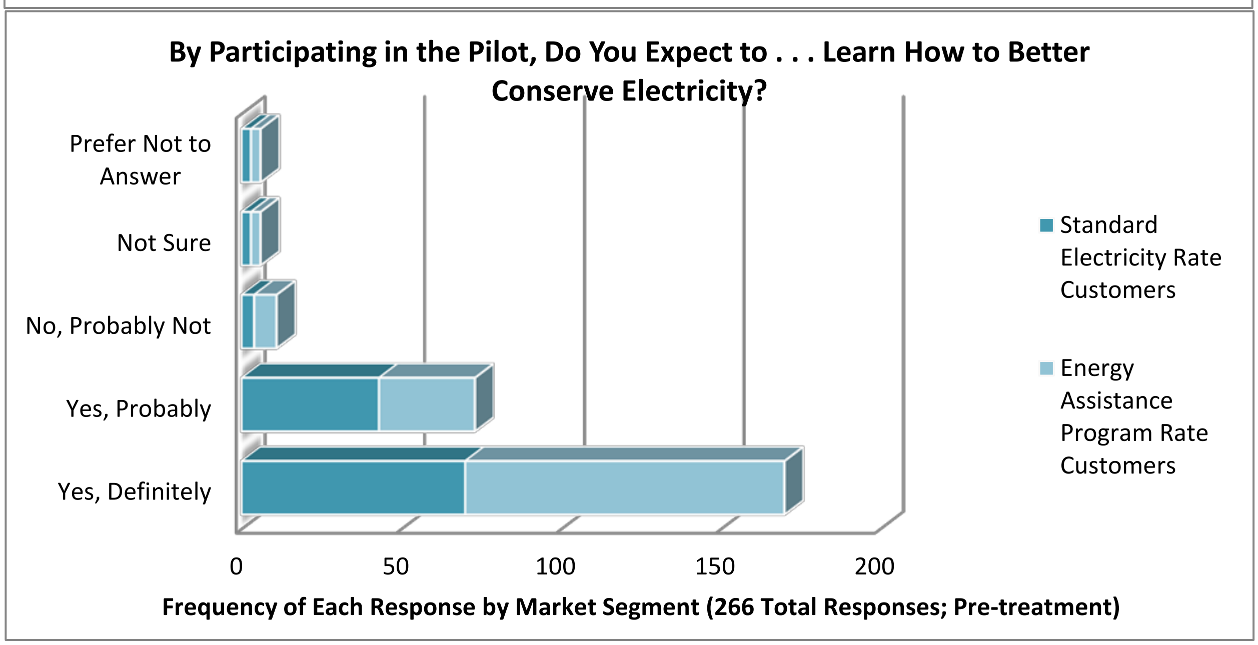

What is the Last Grade or Level You Completed in School?
Prefer Not to Answer
Graduate, Professional, Doctorate...
Some Graduate School
College Graduate (4 Year Degree)
College Graduate (2 Year Degree)
Some College
Technical / Vocational School
High School Graduate (12 Years)
Some High School (9 to 11 Years)
Elementary (8 or Fewer Years)
0
20
40
60
80
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

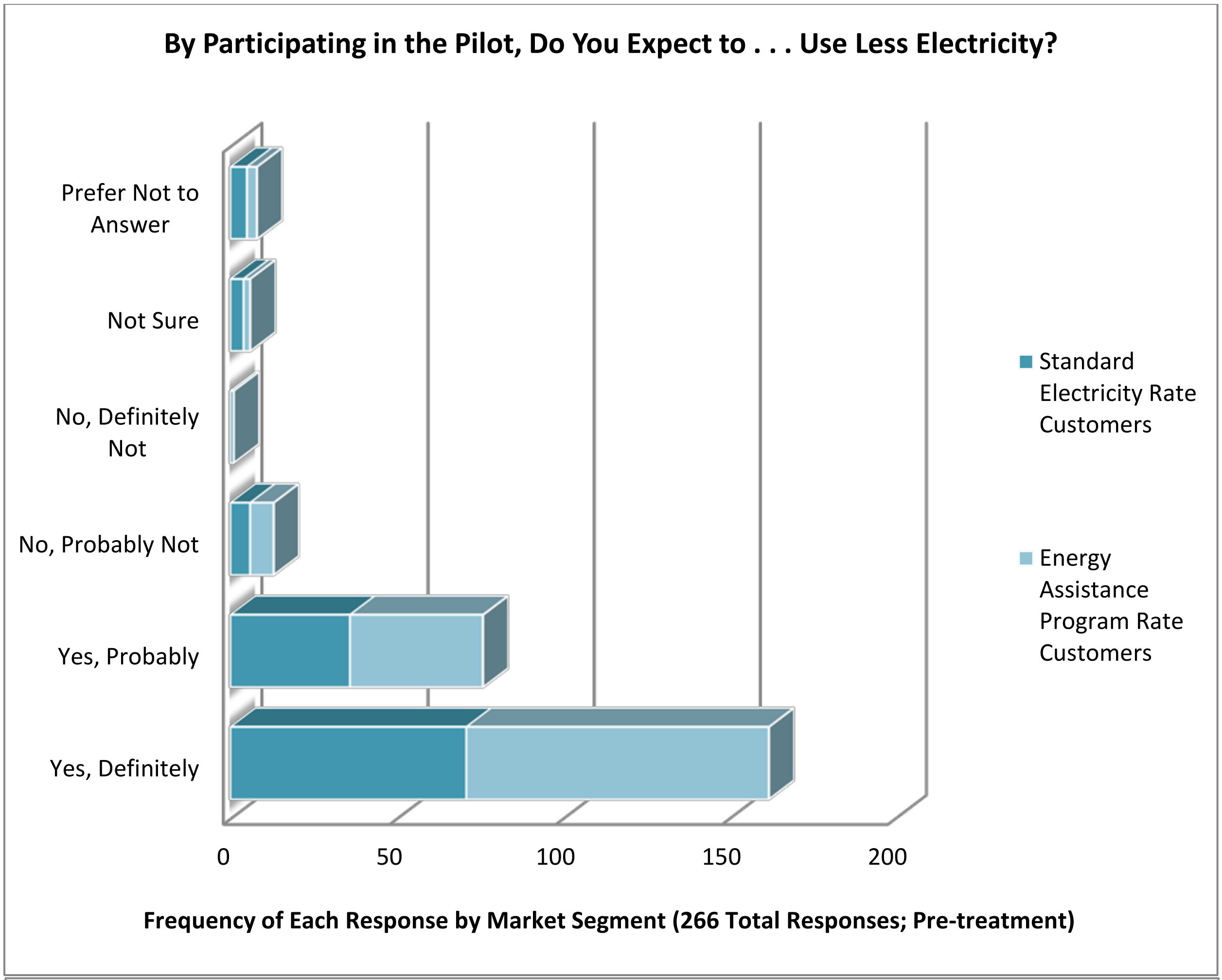

Which of the Following Best Represents Your Household's Total Annual Income Before Taxes?
Prefer Not to Answer
$150,000 or More
$100,000 to $149,999
$80,000 to $99,999
$60,000 to $79,999
$45,000 to $59,999
$30,000 to $44,999
Less than $30,000
0
50
100
150
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

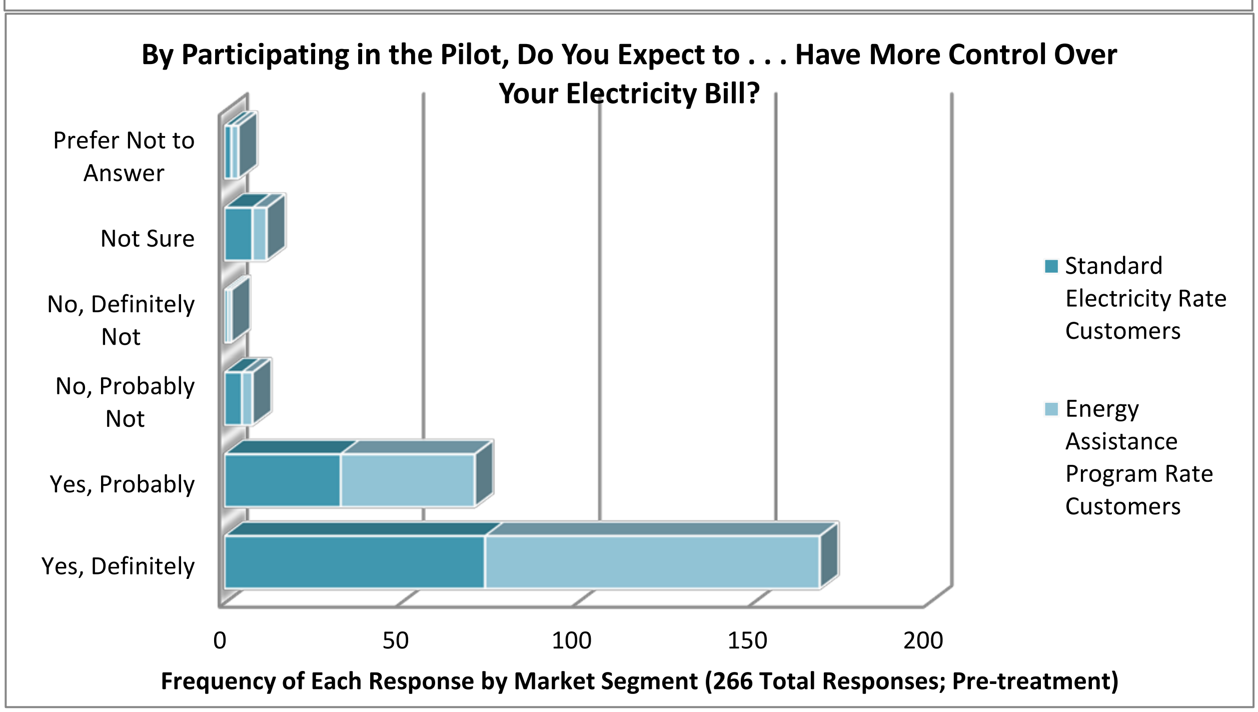

How Comfortable Are You With Using New Consumer Technologies (For Example, Smart Phones or Streaming Video Services)?
Not Sure
Very Uncomfortable
Somewhat Uncomfortable
Somewhat Comfortable
Very Comfortable
0
20
40
60
80
100
120
Frequency of Each Response by Market Segment (244 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

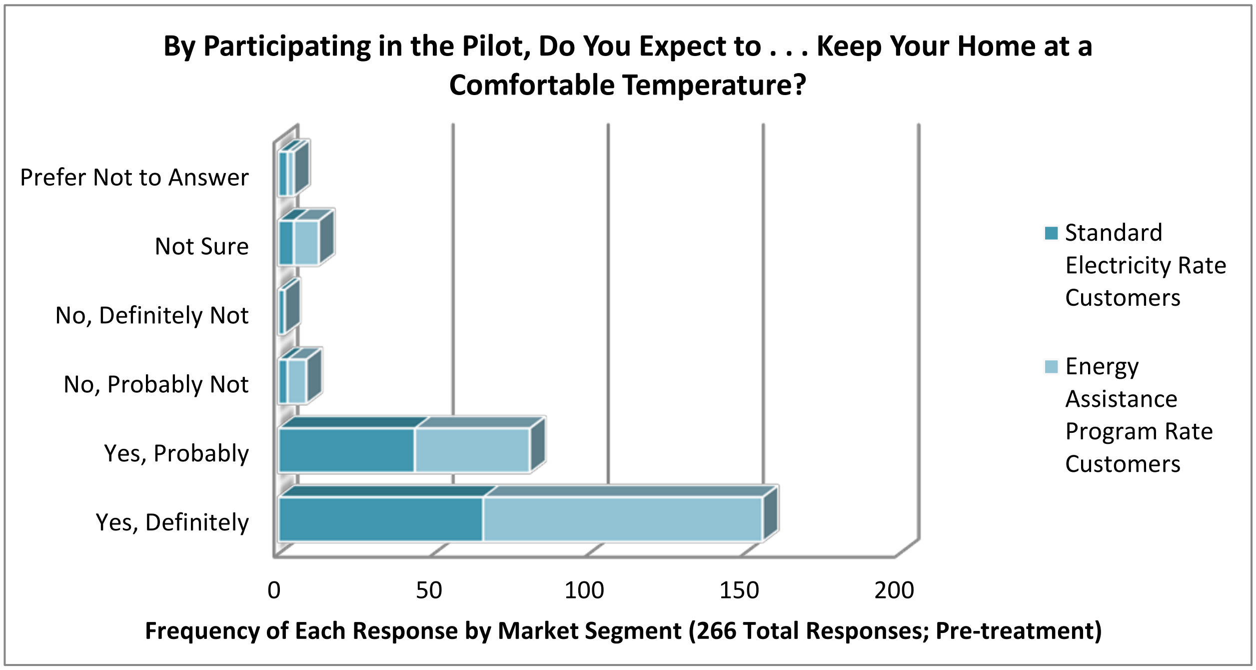

By Participating in the Pilot, Do You Expect to . . . Save Money on Your Electric Bill?
Prefer Not to Answer
Not Sure
No, Probably Not
Yes, Probably
Yes, Definitely
0
50
100
150
200
Frequency of Each Response by Market Segment (532 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

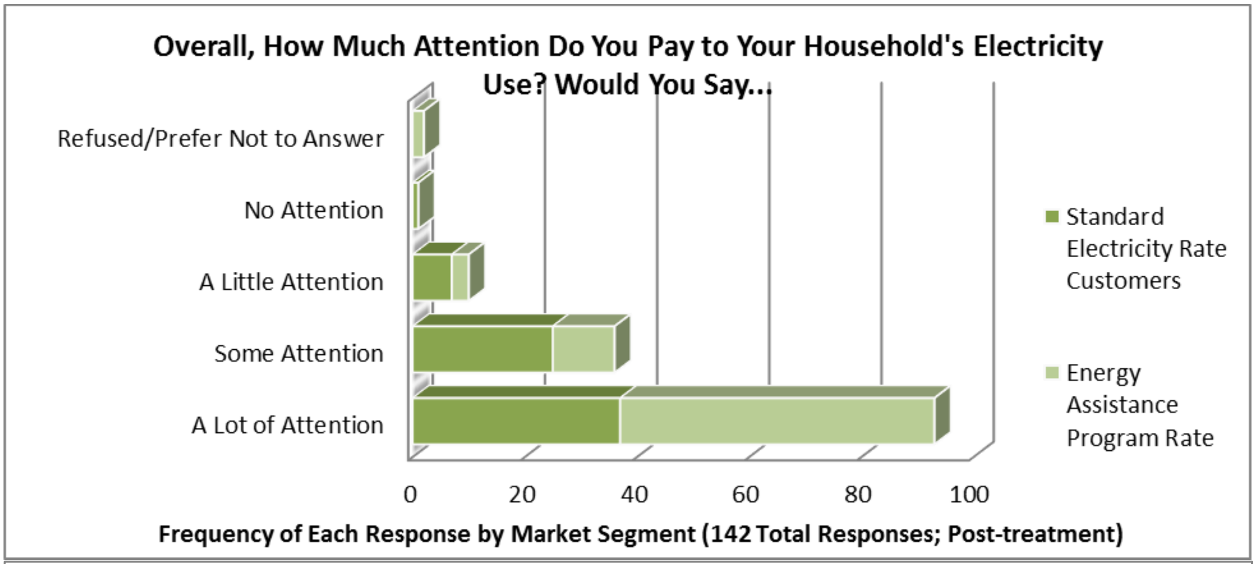

By Participating in the Pilot, Do You Expect to . . . Help Protect the Environment?
Prefer Not to Answer
Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely
0
50
100
150
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)

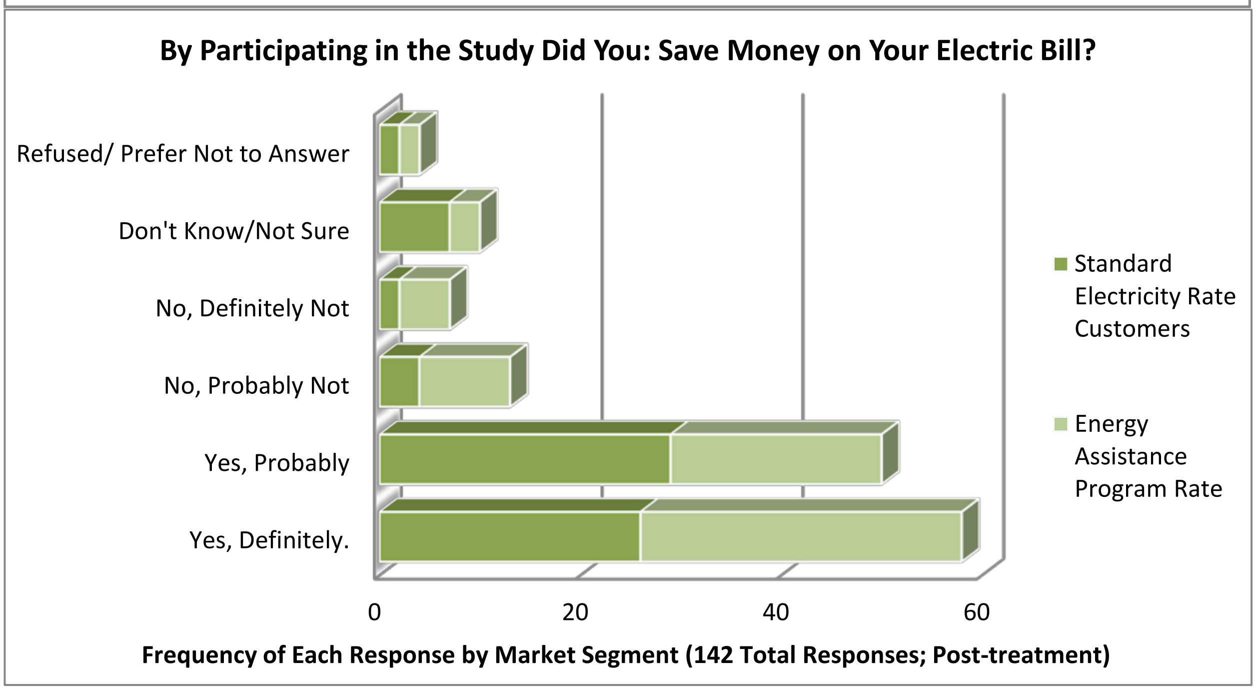

By Participating in the Pilot, Do You Expect to . . . Learn How to Better Conserve Electricity?
Prefer Not to Answer
Not Sure
No, Probably Not
Yes, Probably
Yes, Definitely
0
50
100
150
200
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)

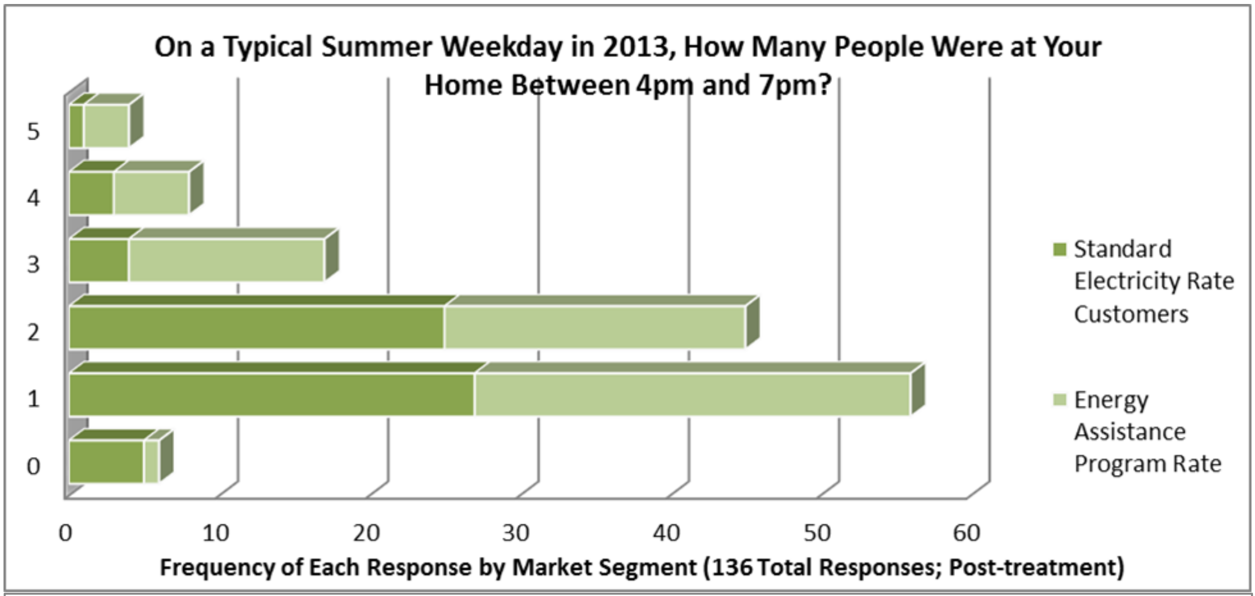

By Participating in the Pilot, Do You Expect to . . . Use Less Electricity?
Prefer Not to Answer
Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely
0
50
100
150
200
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)

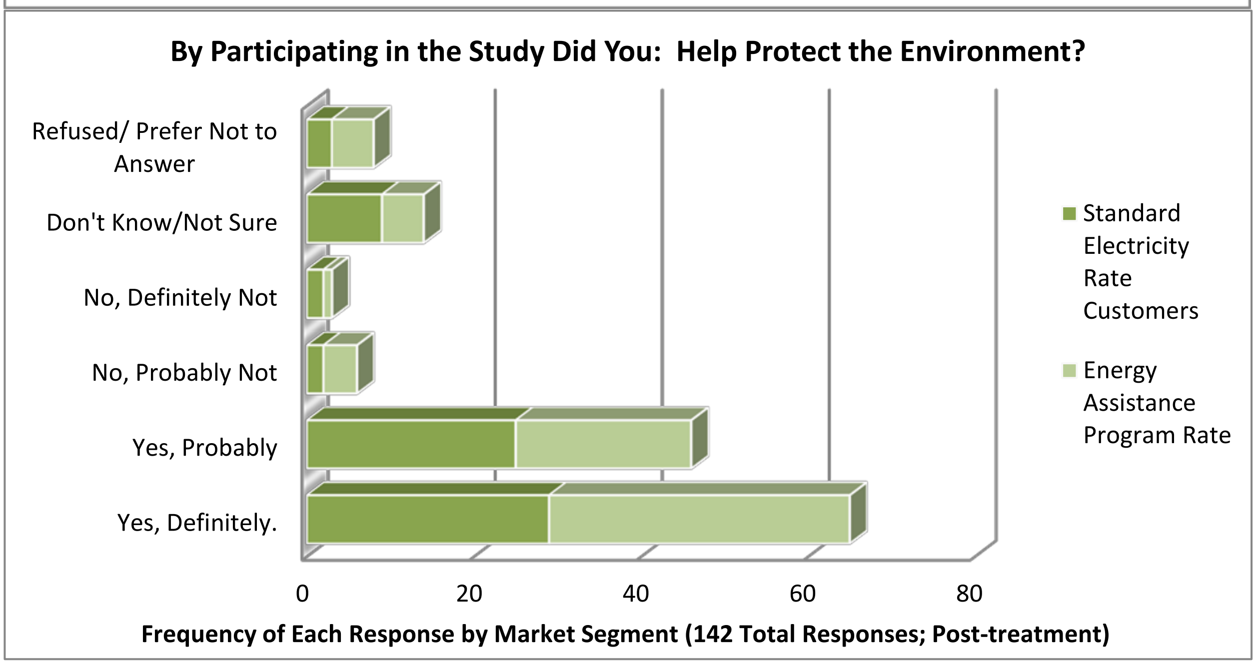

By Participating in the Pilot, Do You Expect to . . . Have More Control Over Your Electricity Bill?
Prefer Not to Answer
Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely
0
50
100
150
200
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)

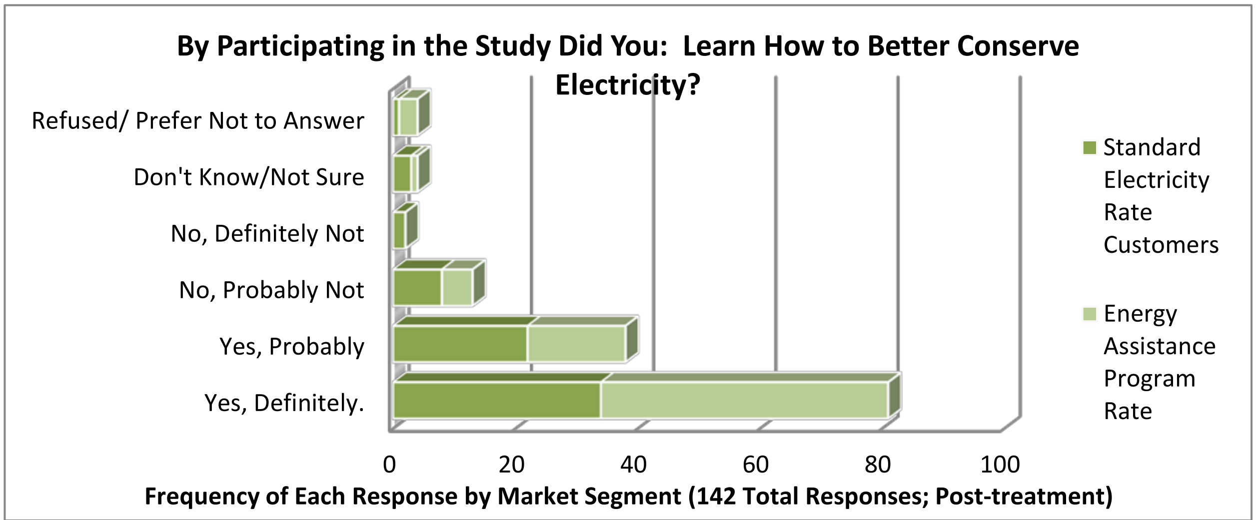

By Participating in the Pilot, Do You Expect to . . . Keep Your Home at a Comfortable Temperature?
Prefer Not to Answer
Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely
0
50
100
150
200
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

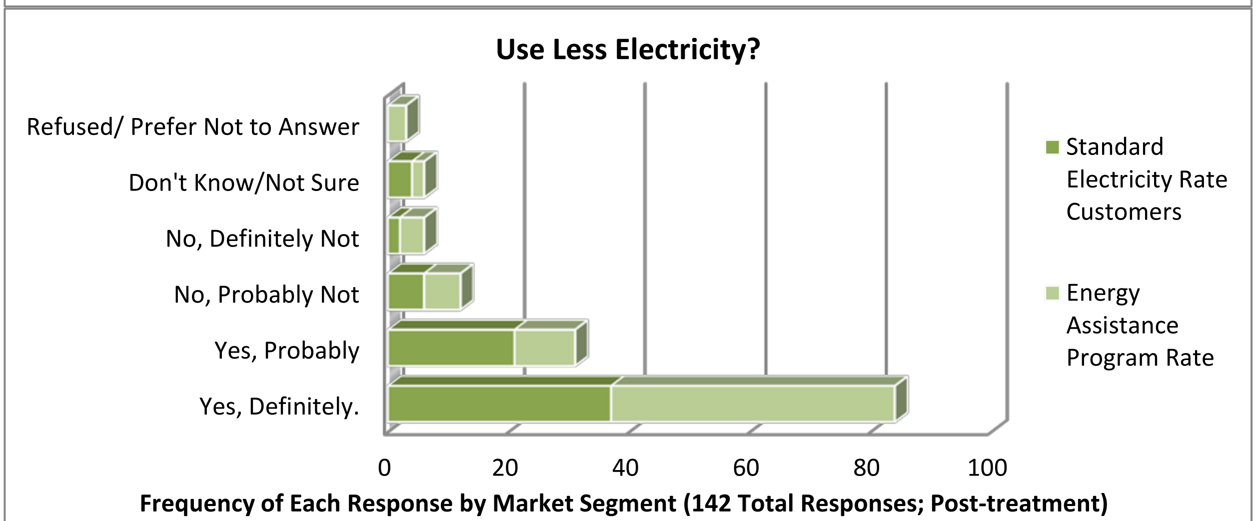

Overall, How Much Attention Do You Pay to Your Household's Electricity Use? Would You Say...
Refused/Prefer Not to Answer
No Attention
A Little Attention
Some Attention
A Lot of Attention
0
20
40
60
80
100
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

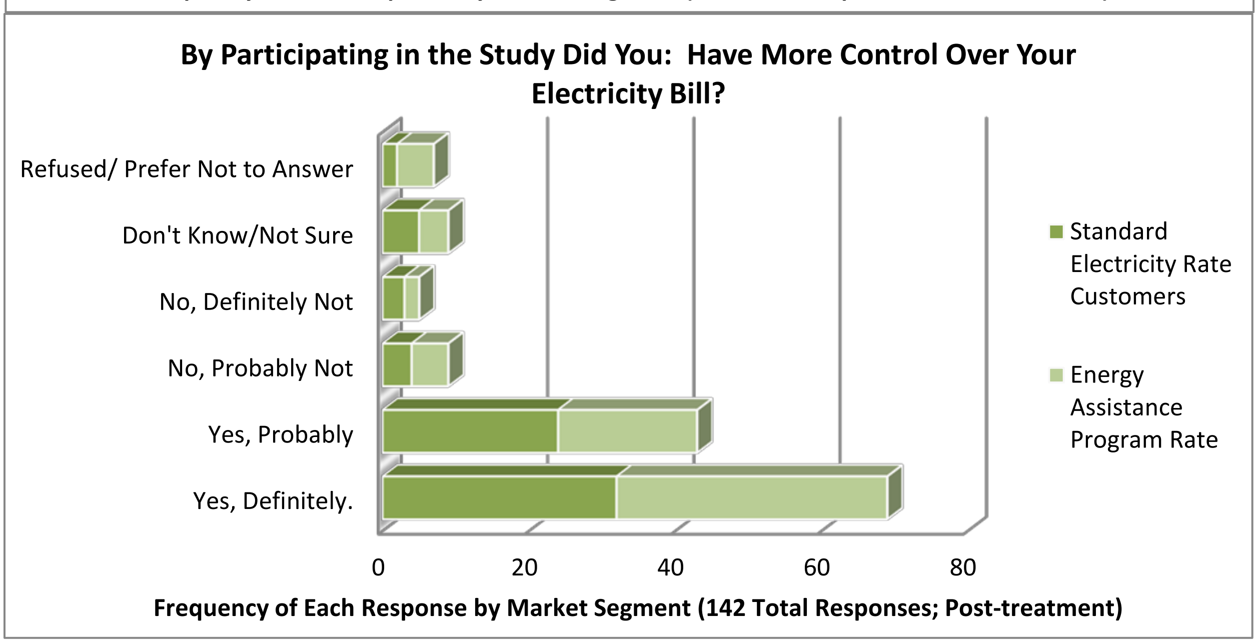

By Participating in the Study Did You: Save Money on Your Electric Bill?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely.
0
20
40
60
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

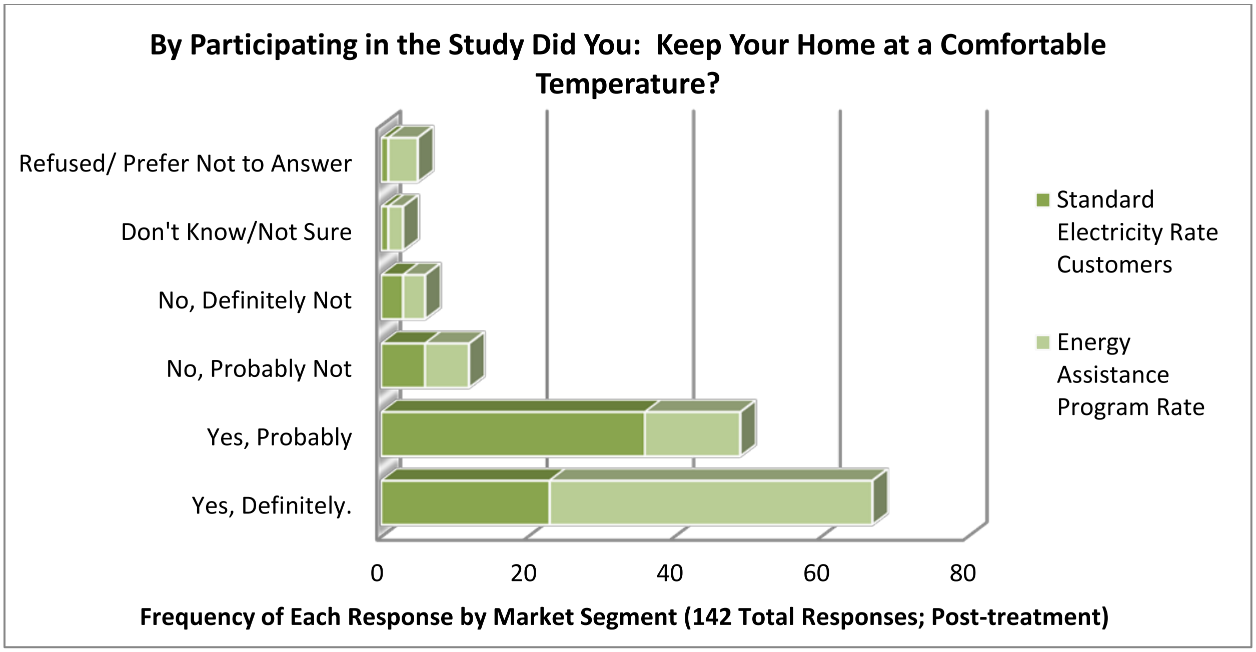

On a Typical Summer Weekday in 2013, How Many People Were at Your Home Between 4pm and 7pm?
5
4
3
2
1
0
0
10
20
30
40
50
60
Frequency of Each Response by Market Segment (136 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

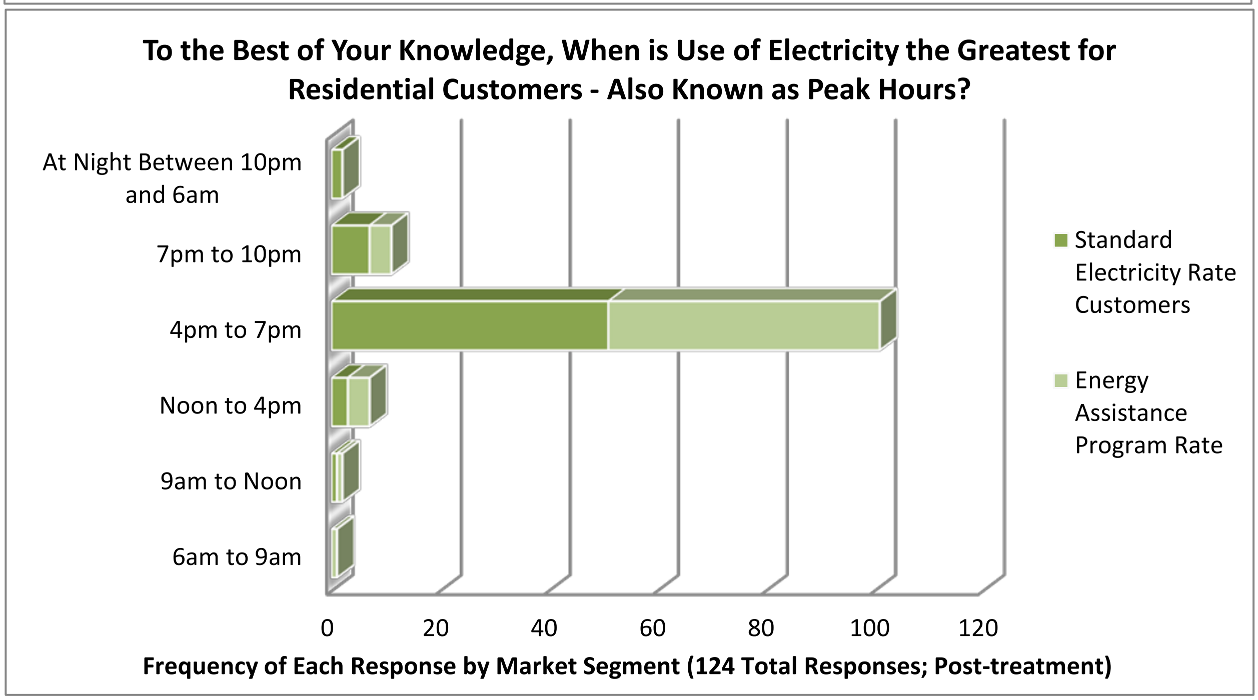

By Participating in the Study Did You: Help Protect the Environment?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely.
0
20
40
60
80
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

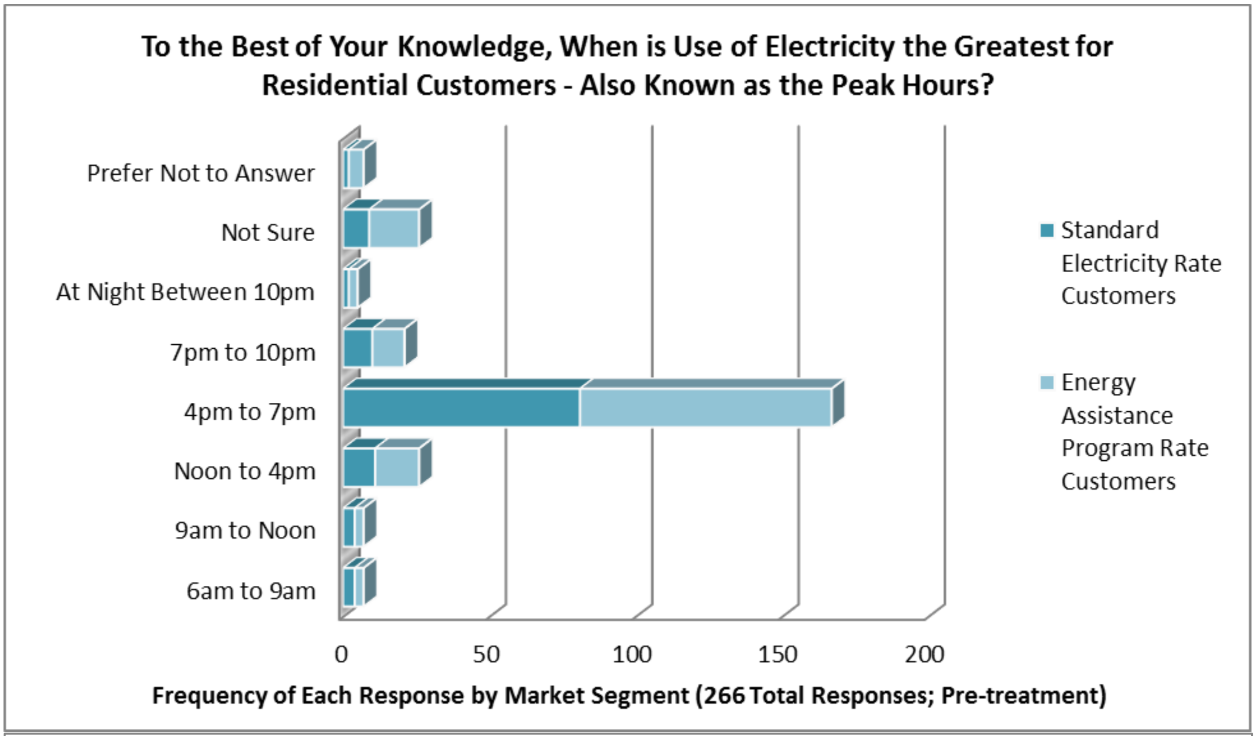

By Participating in the Study Did You: Learn How to Better Conserve Electricity?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely.
0
20
40
60
80
100
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

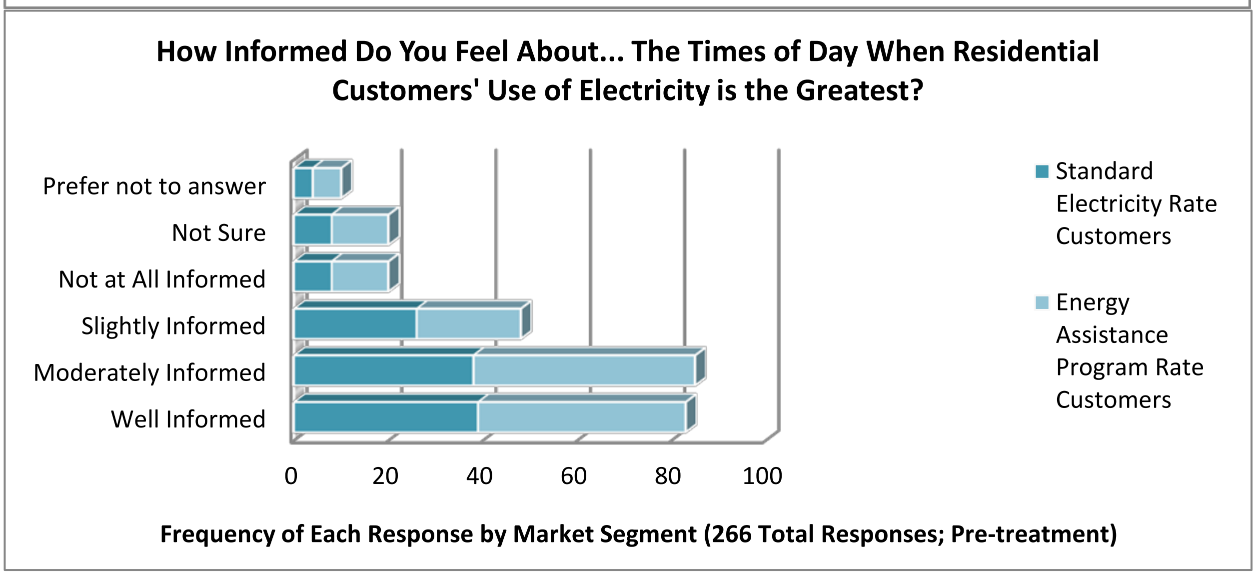

Use Less Electricity?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely.
0
20
40
60
80
100
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

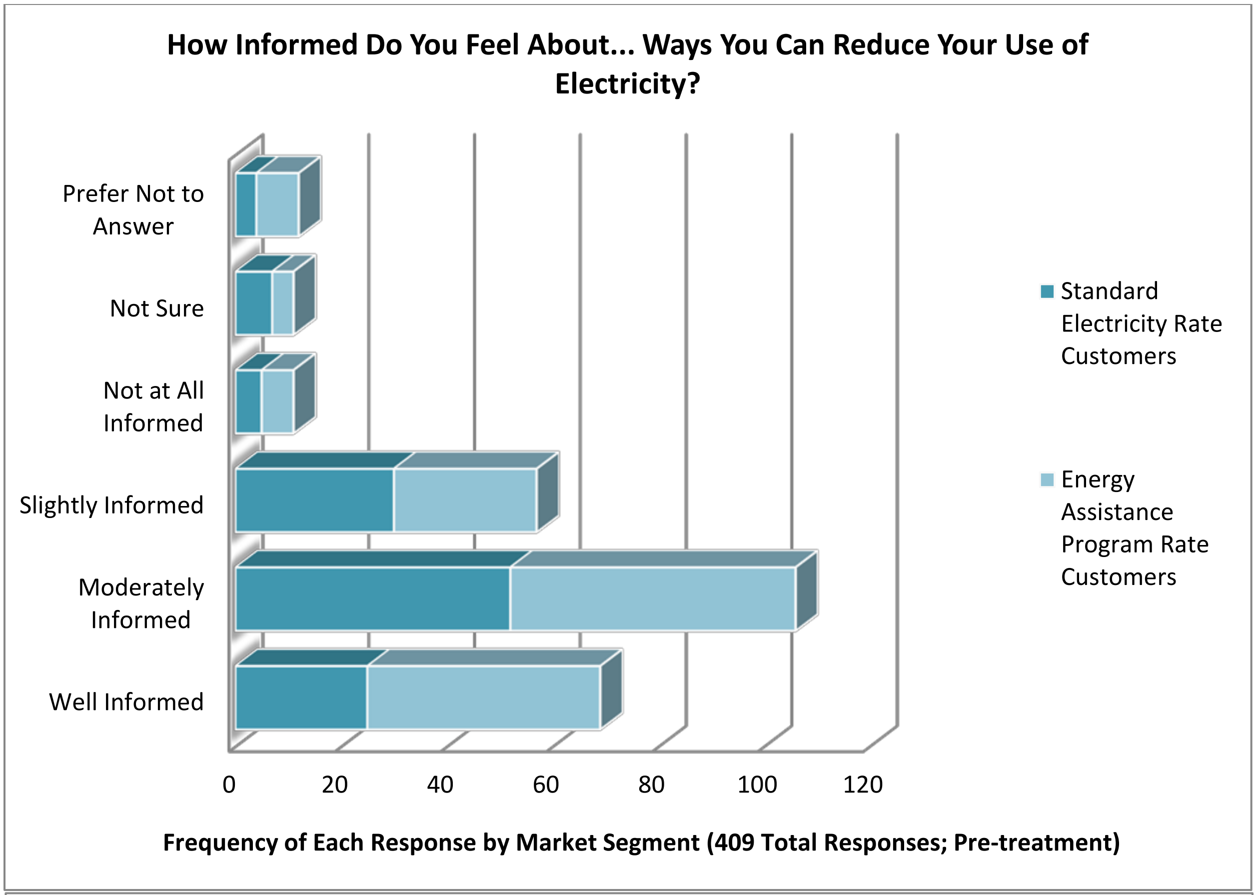

By Participating in the Study Did You: Have More Control Over Your Electricity Bill?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely.
0
20
40
60
80
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

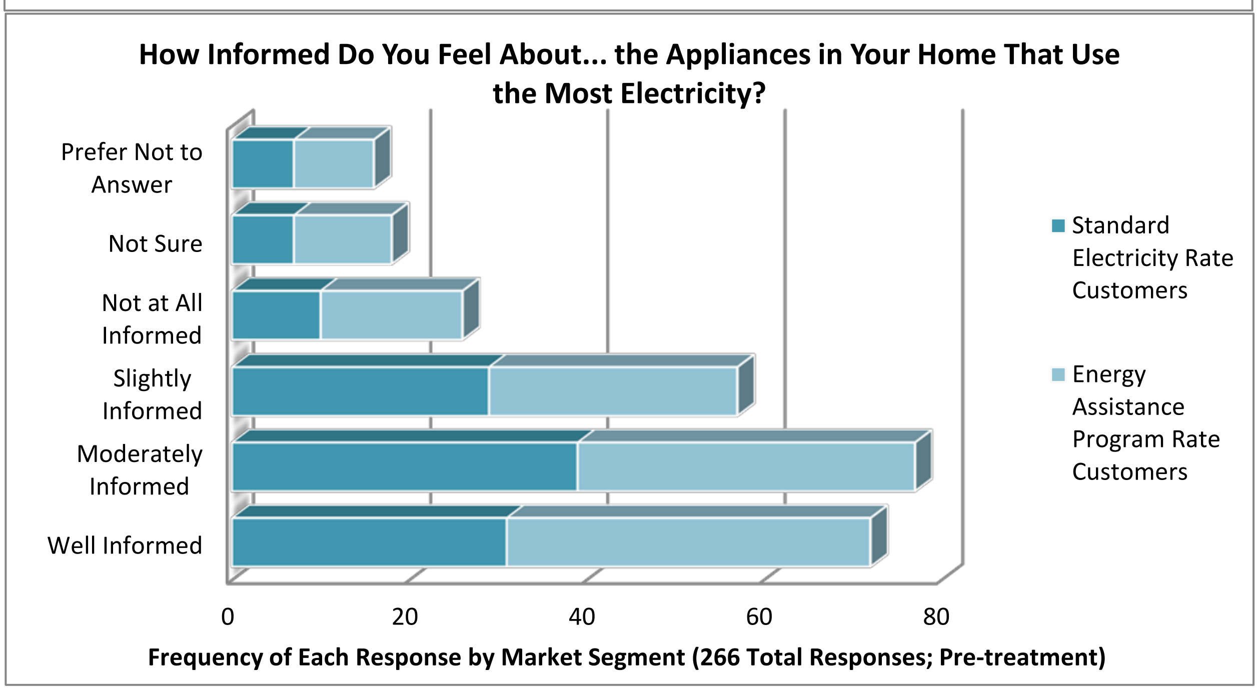

By Participating in the Study Did You: Keep Your Home at a Comfortable Temperature?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely.
0
20
40
60
80
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

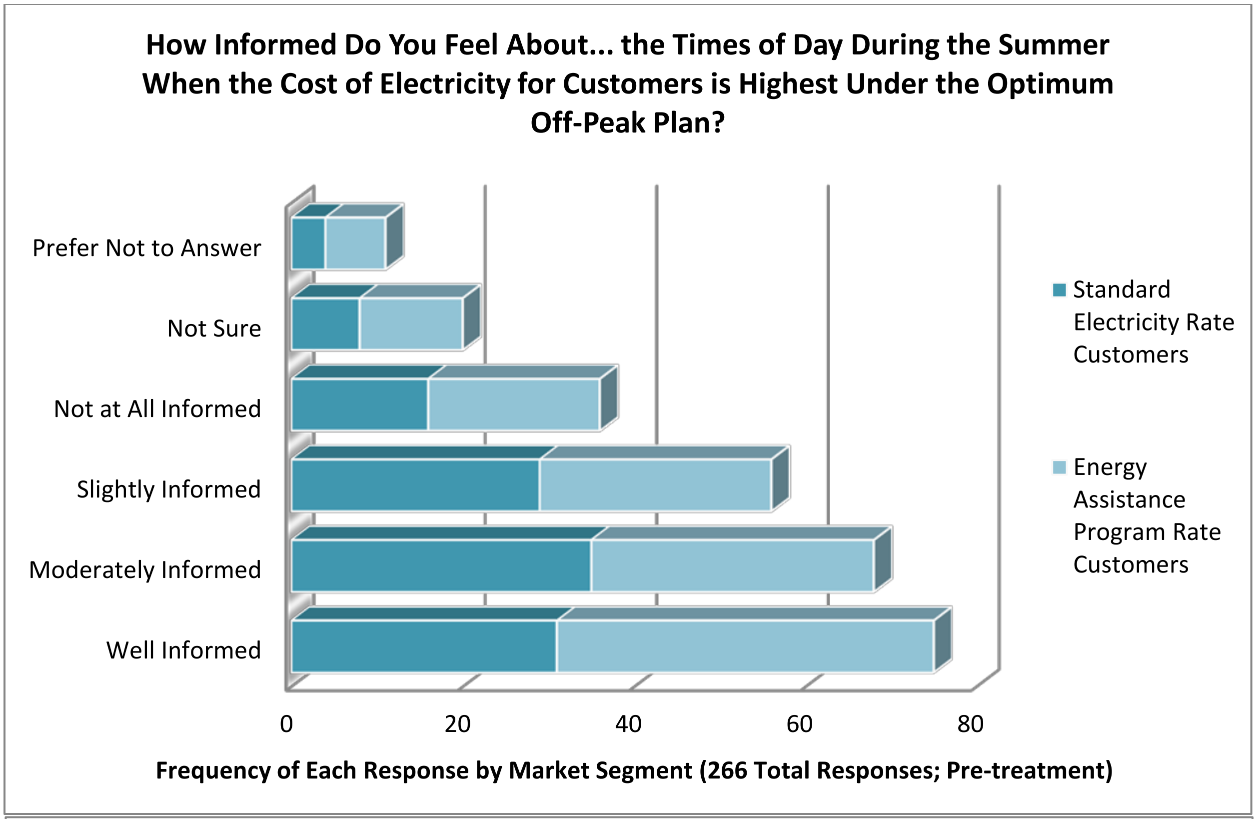

To the Best of Your Knowledge, When is Use of Electricity the Greatest for Residential Customers - Also Known as Peak Hours?
At Night Between 10pm and 6am
7pm to 10pm
4pm to 7pm
Noon to 4pm
9am to Noon
6am to 9am
0
20
40
60
80
100
120
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (124 Total Responses; Post-treatment)

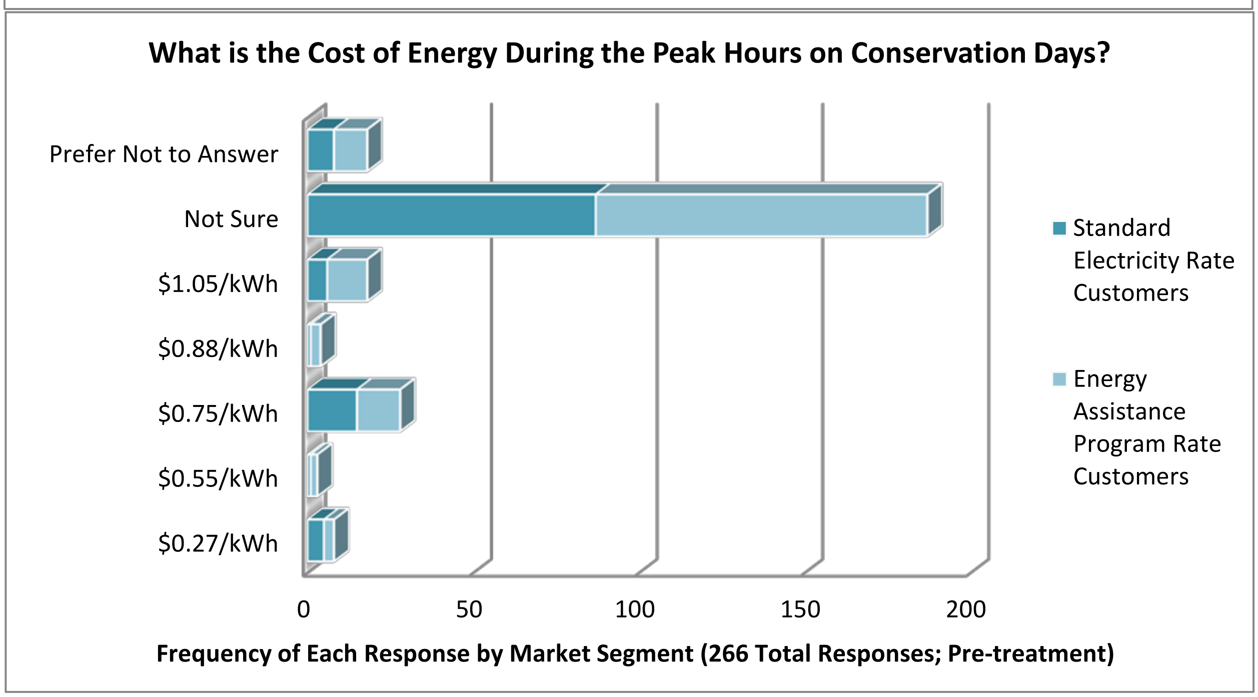

To the Best of Your Knowledge, When is Use of Electricity the Greatest for Residential Customers - Also Known as the Peak Hours?
Prefer Not to Answer
Not Sure
At Night Between 10pm
7pm to 10pm
4pm to 7pm
Noon to 4pm
9am to Noon
6am to 9am
0
50
100
150
200
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

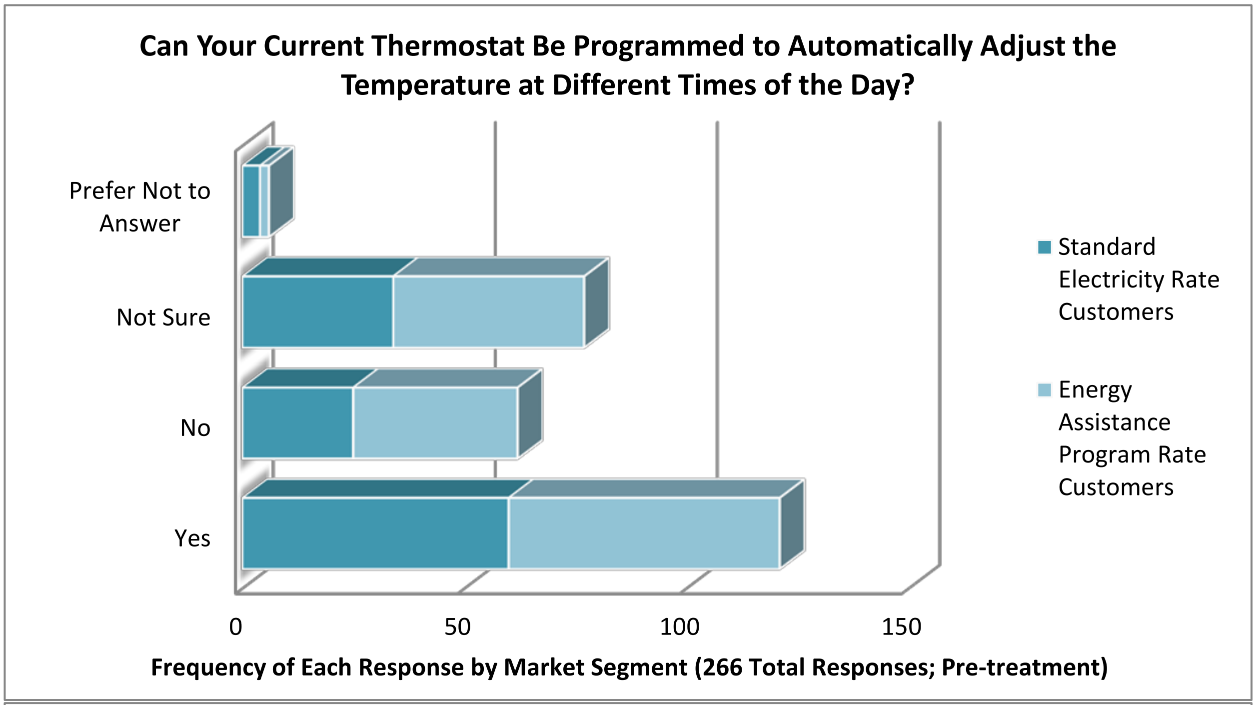

How Informed Do You Feel About... The Times of Day When Residential Customers' Use of Electricity is the Greatest?
Prefer not to answer
Not Sure
Not at All Informed
Slightly Informed
Moderately Informed
Well Informed
0
20
40
60
80
100
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

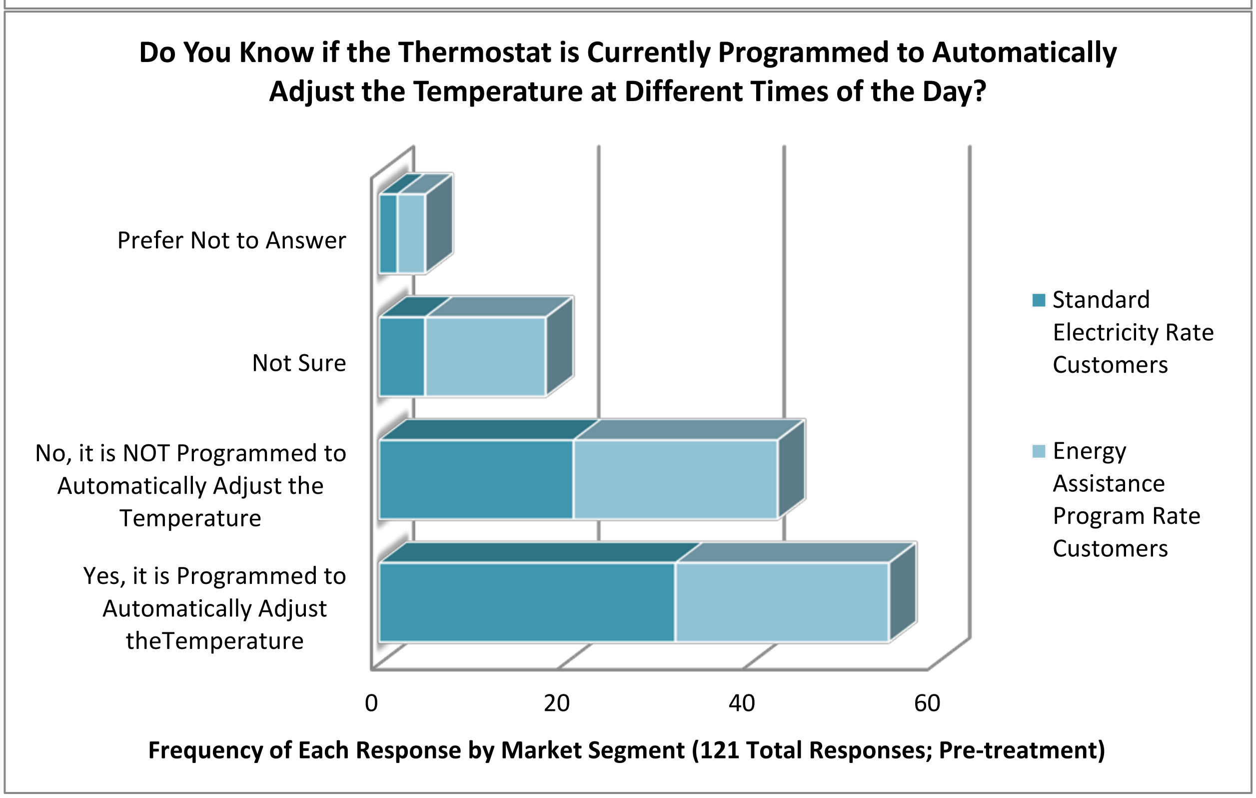

How Informed Do You Feel About... Ways You Can Reduce Your Use of Electricity?
Prefer Not to Answer
Not Sure
Not at All Informed
Slightly Informed
Moderately Informed
Well Informed
0
20
40
60
80
100
120
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
Frequency of Each Response by Market Segment (409 Total Responses; Pre-treatment)

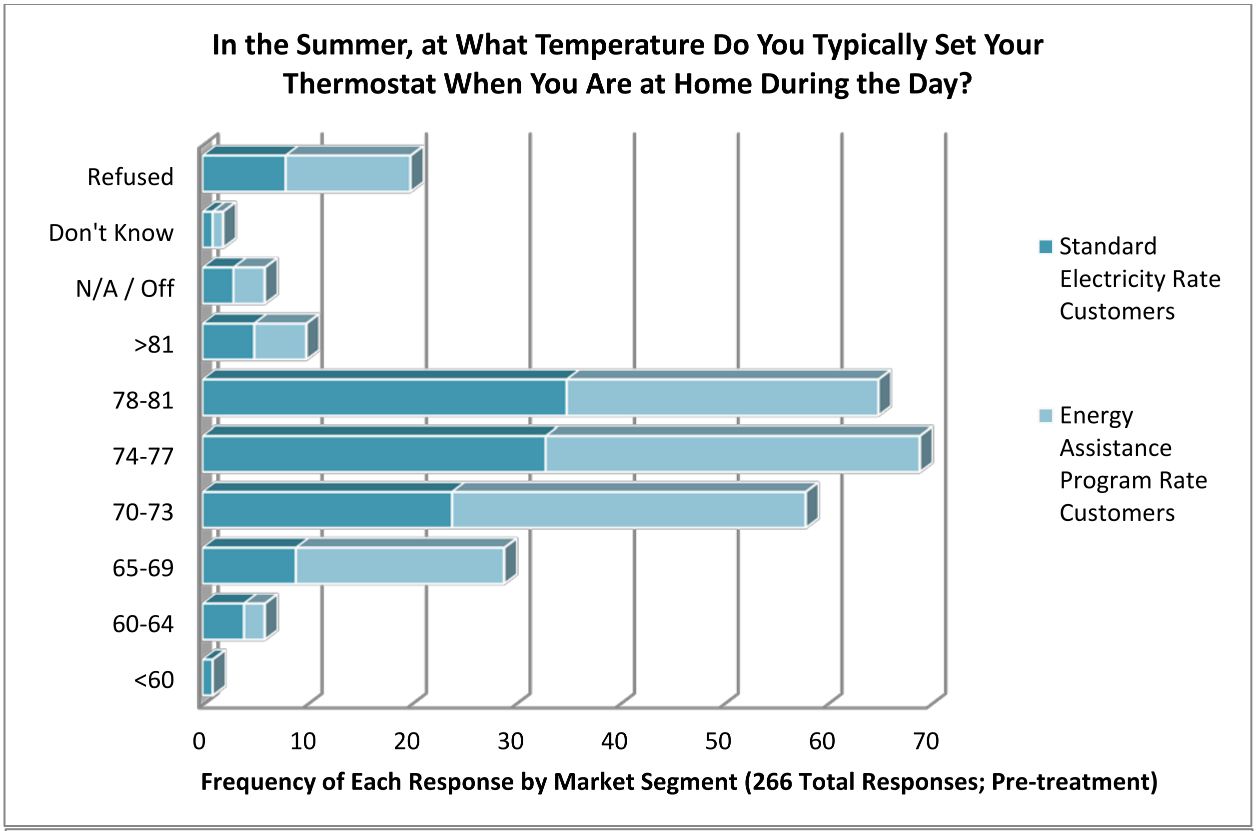

How Informed Do You Feel About... the Appliances in Your Home That Use the Most Electricity?
Prefer Not to Answer
Not Sure
Not at All Informed
Slightly Informed
Moderately Informed
Well Informed
0
20
40
60
80
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)

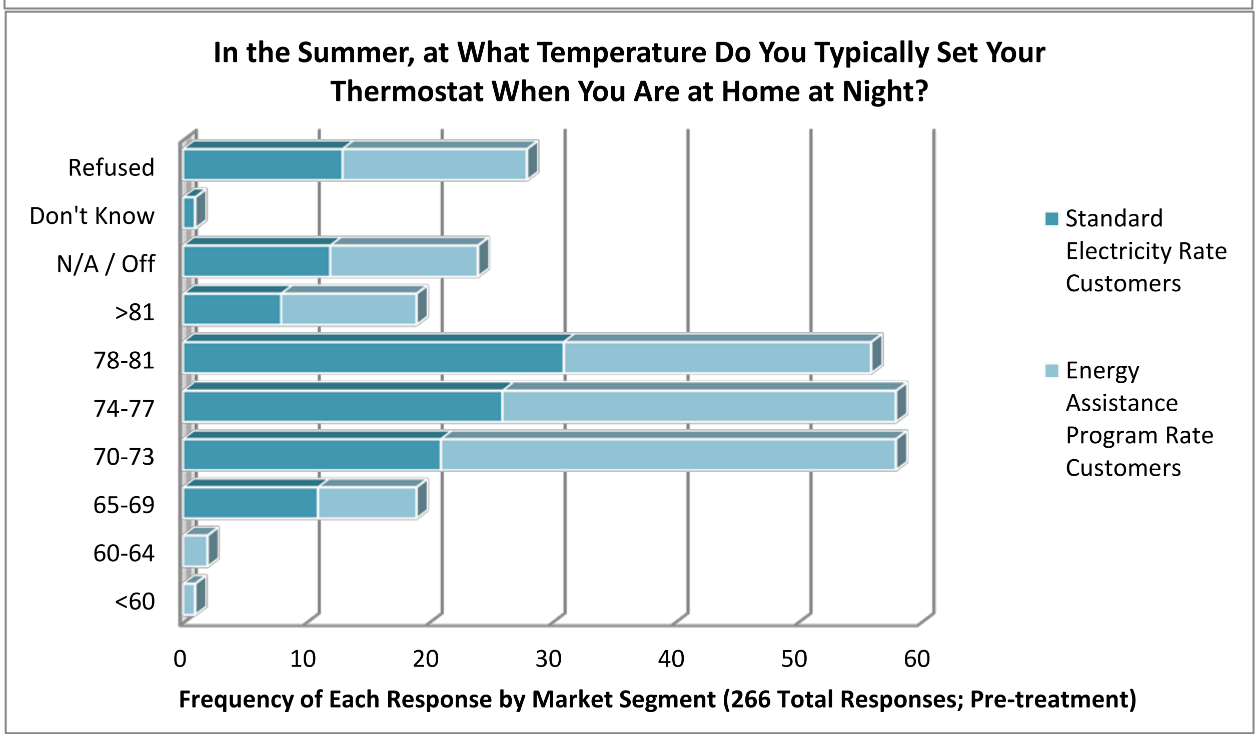

How Informed Do You Feel About... the Times of Day During the Summer When the Cost of Electricity for Customers is Highest Under the Optimum Off-Peak Plan?
Prefer Not to Answer
Not Sure
Not at All Informed
Slightly Informed
Moderately Informed
Well Informed
0
20
40
60
80
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

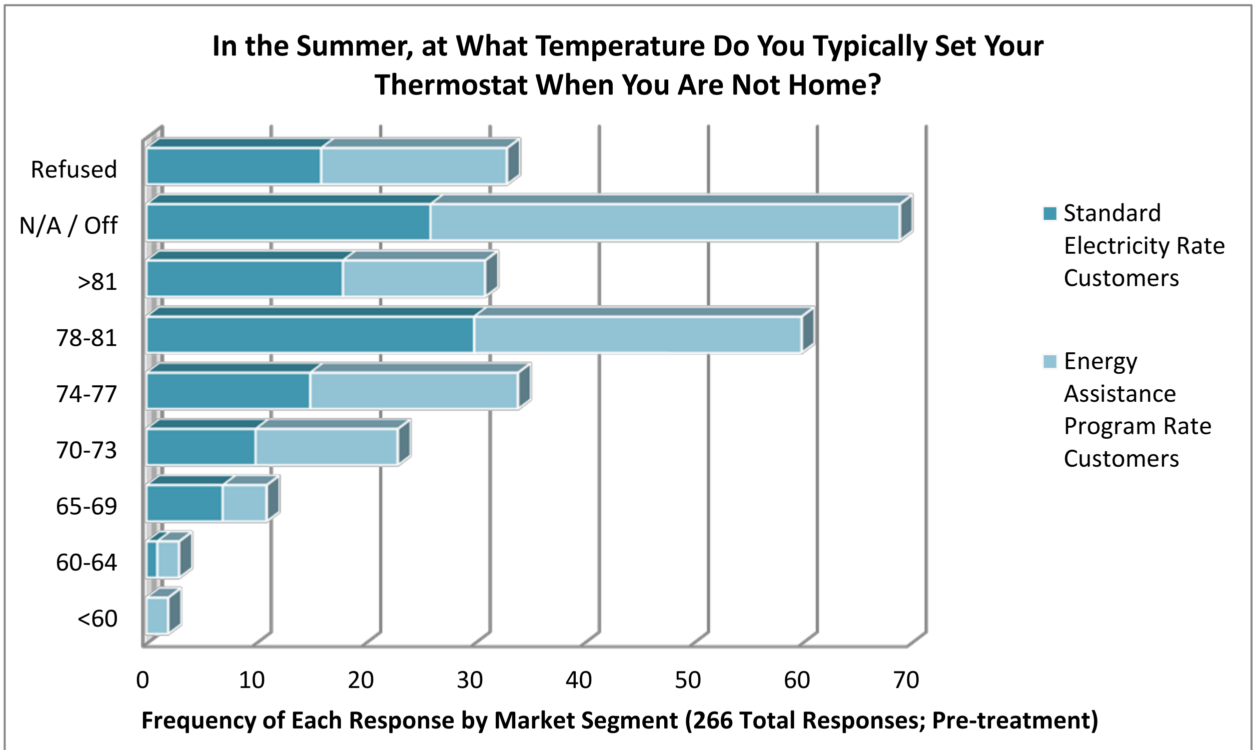

What is the Cost of Energy During the Peak Hours on Conservation Days?
Prefer Not to Answer
Not Sure
$1.05/kWh
$0.88/kWh
$0.75/kWh
$0.55/kWh
$0.27/kWh
0
50
100
150
200
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

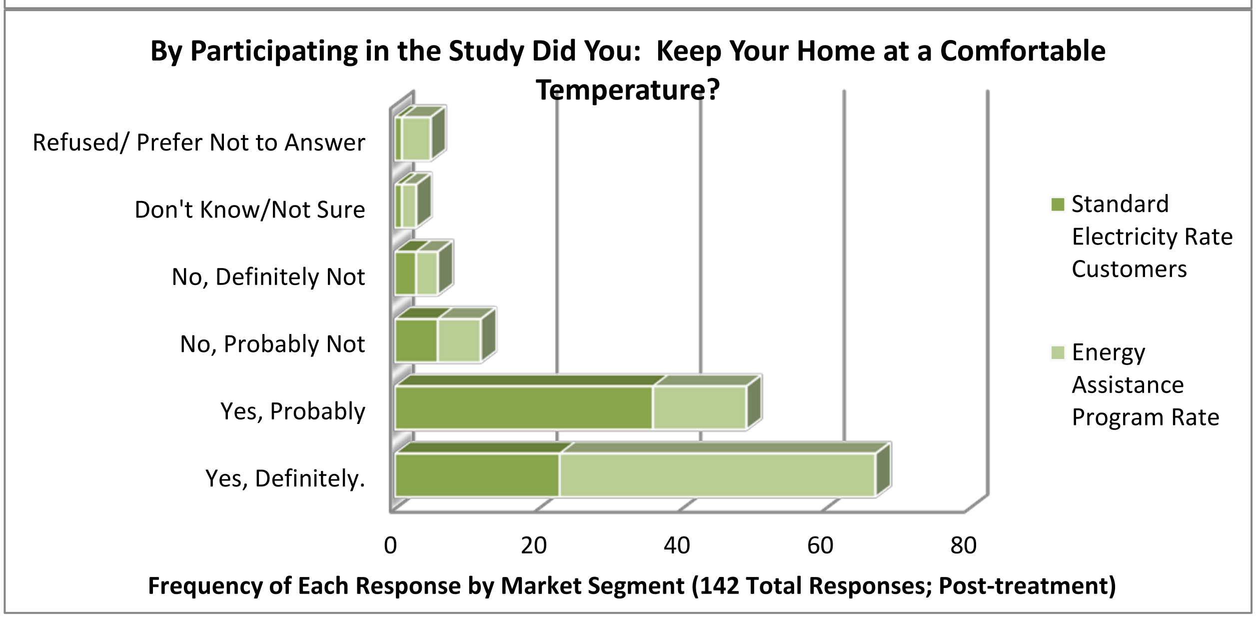

Can Your Current Thermostat Be Programmed to Automatically Adjust the Temperature at Different Times of the Day?
Prefer Not to Answer
Not Sure
No
Yes
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
0
50
100
150
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)

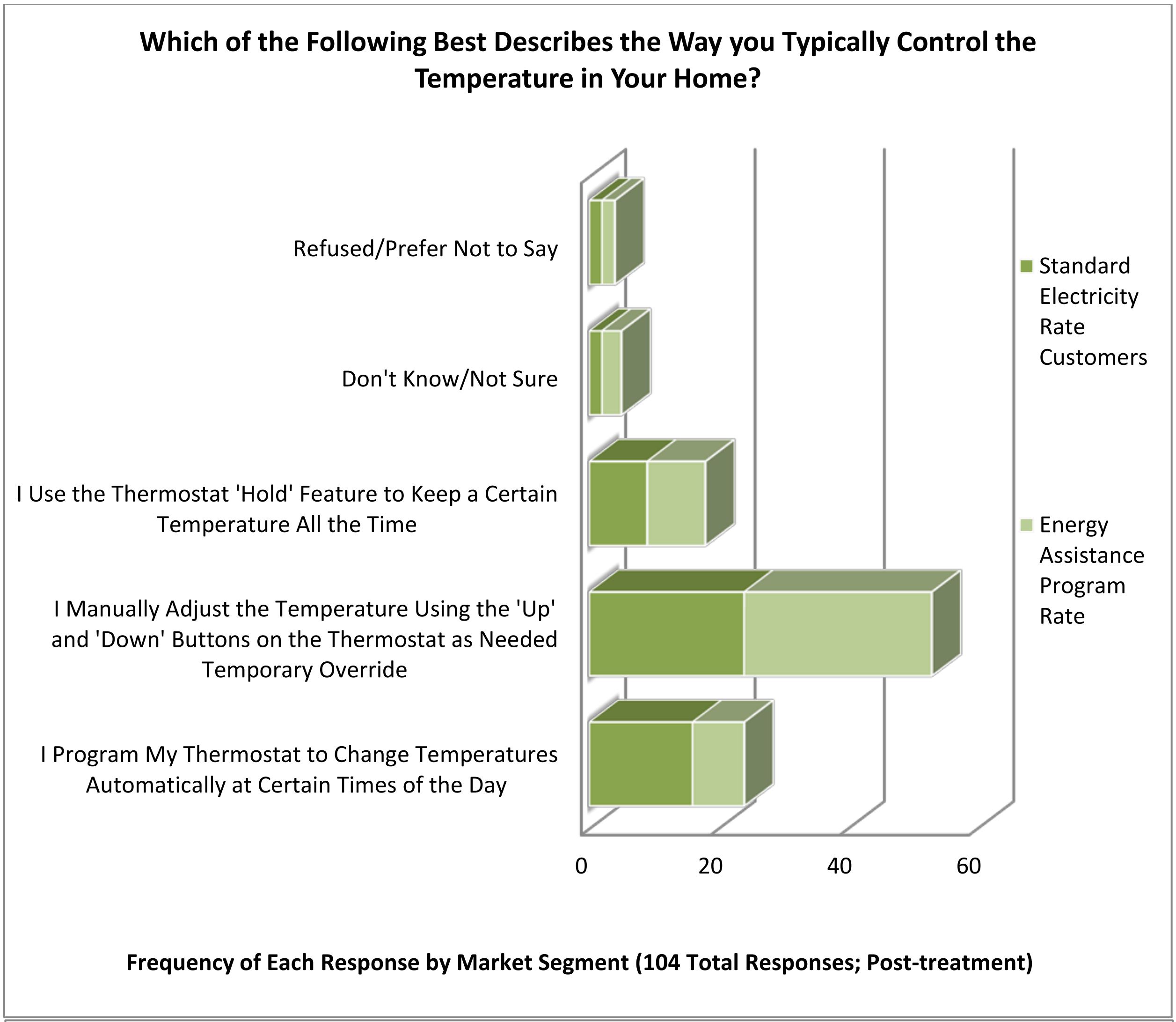

Do You Know if the Thermostat is Currently Programmed to Automatically Adjust the Temperature at Different Times of the Day?
Prefer Not to Answer
Not Sure
No, it is NOT Programmed to Automatically Adjust the Temperature
Yes, it is Programmed to Automatically Adjust theTemperature
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
0
20
40
60
Frequency of Each Response by Market Segment (121 Total Responses; Pre-treatment)

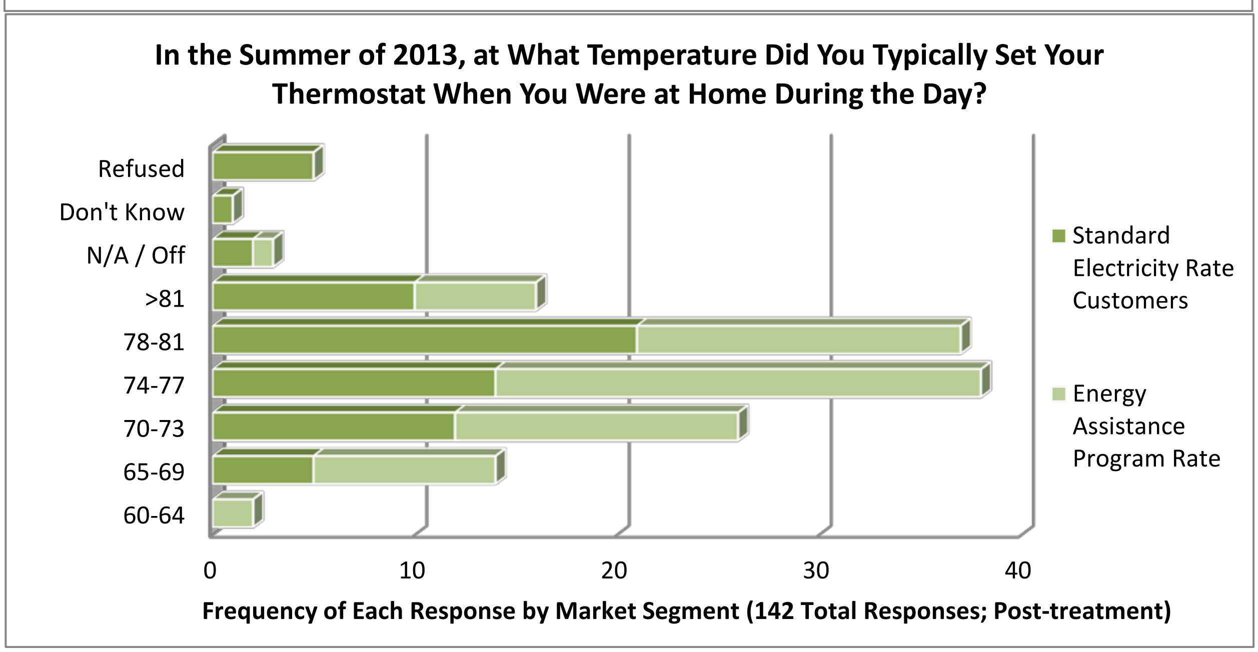

In the Summer, at What Temperature Do You Typically Set Your Thermostat When You Are at Home During the Day?
Refused
Don't Know
N/A / Off
>81
78-81
74-77
70-73
65-69
60-64
<60
0
10
20
30
40
50
60
70
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

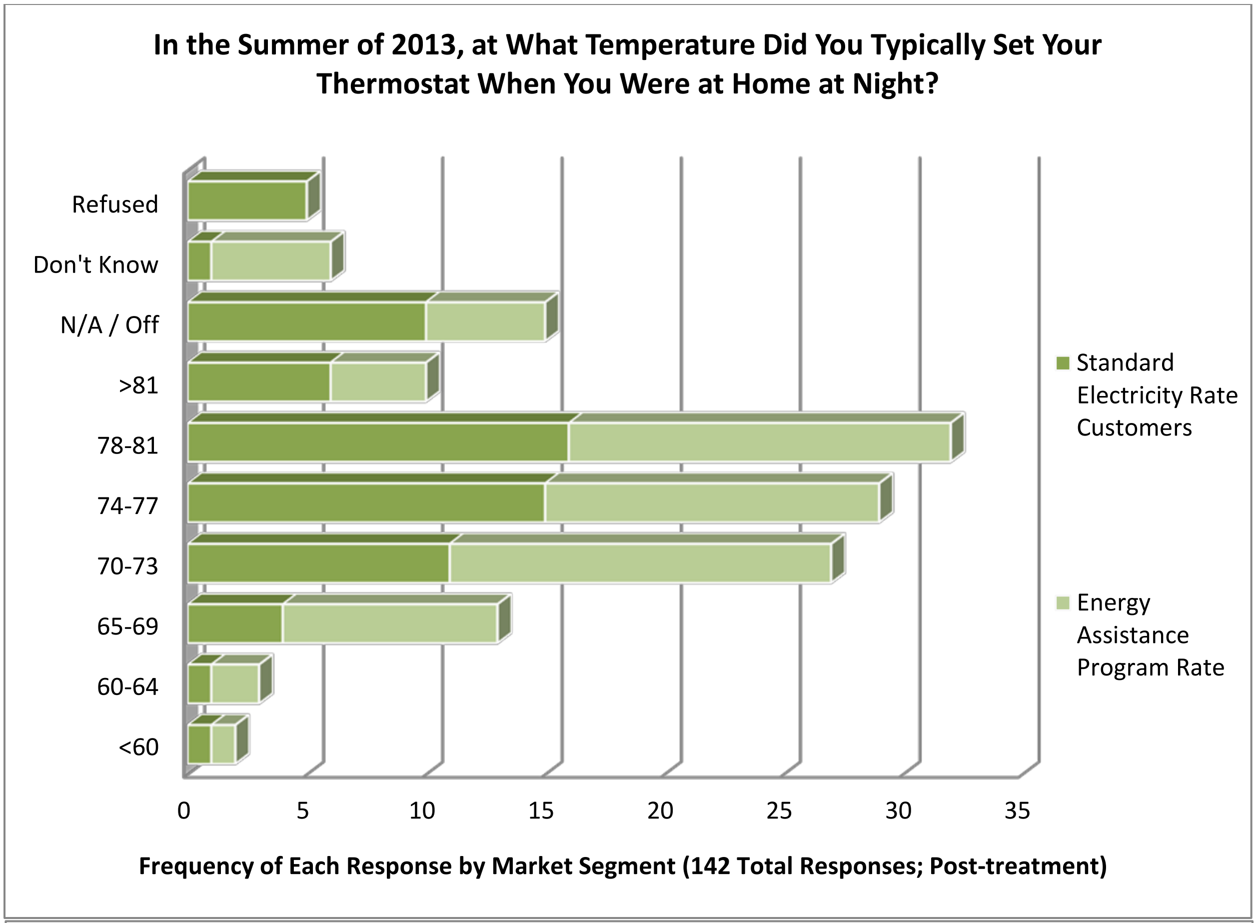

In the Summer, at What Temperature Do You Typically Set Your Thermostat When You Are at Home at Night?
Refused
Don't Know
N/A / Off
>81
78-81
74-77
70-73
65-69
60-64
<60
0
10
20
30
40
50
60
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

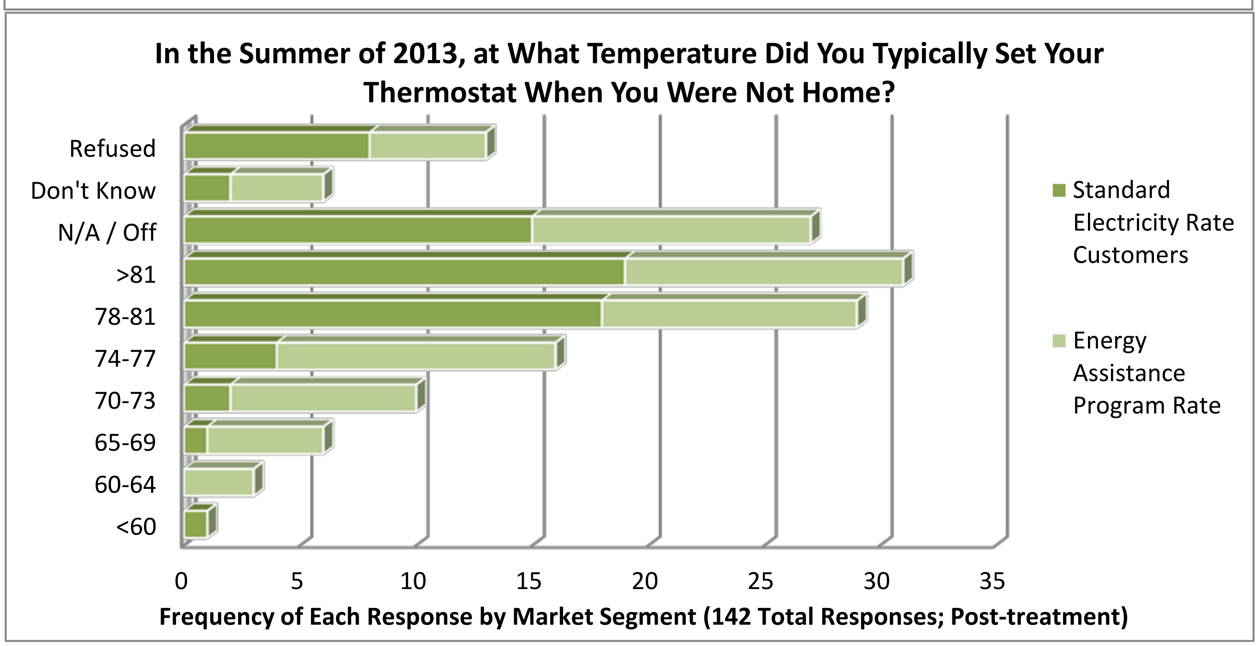

In the Summer, at What Temperature Do You Typically Set Your Thermostat When You Are Not Home?
Refused
N/A / Off
>81
78-81
74-77
70-73
65-69
60-64
<60
0
10
20
30
40
50
60
70
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

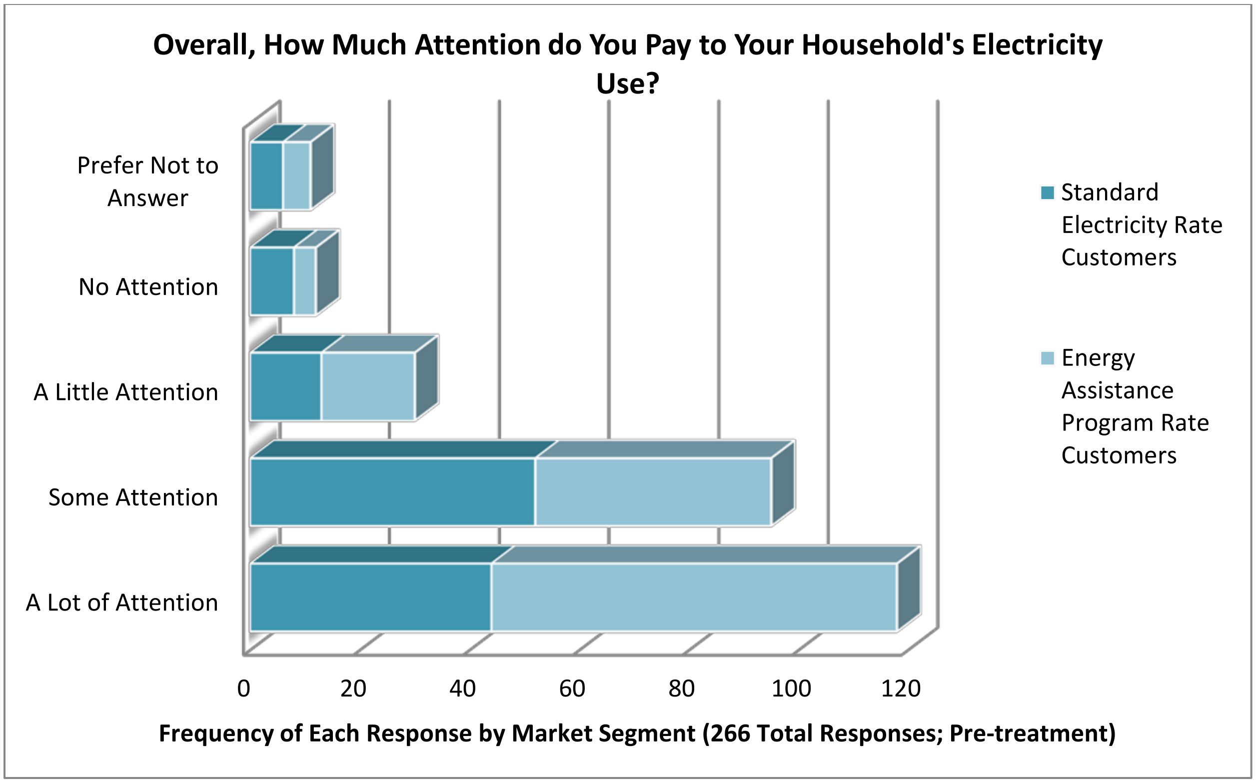

By Participating in the Study Did You: Keep Your Home at a Comfortable Temperature?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
No, Definitely Not
No, Probably Not
Yes, Probably
Yes, Definitely.
0
20
40
60
80
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate


Which of the Following Best Describes the Way you Typically Control the Temperature in Your Home?
Refused/Prefer Not to Say
Don't Know/Not Sure
I Use the Thermostat 'Hold' Feature to Keep a Certain Temperature All the Time
I Manually Adjust the Temperature Using the 'Up' and 'Down' Buttons on the Thermostat as Needed Temporary Override
I Program My Thermostat to Change Temperatures Automatically at Certain Times of the Day
0
20
40
60
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (104 Total Responses; Post-treatment)

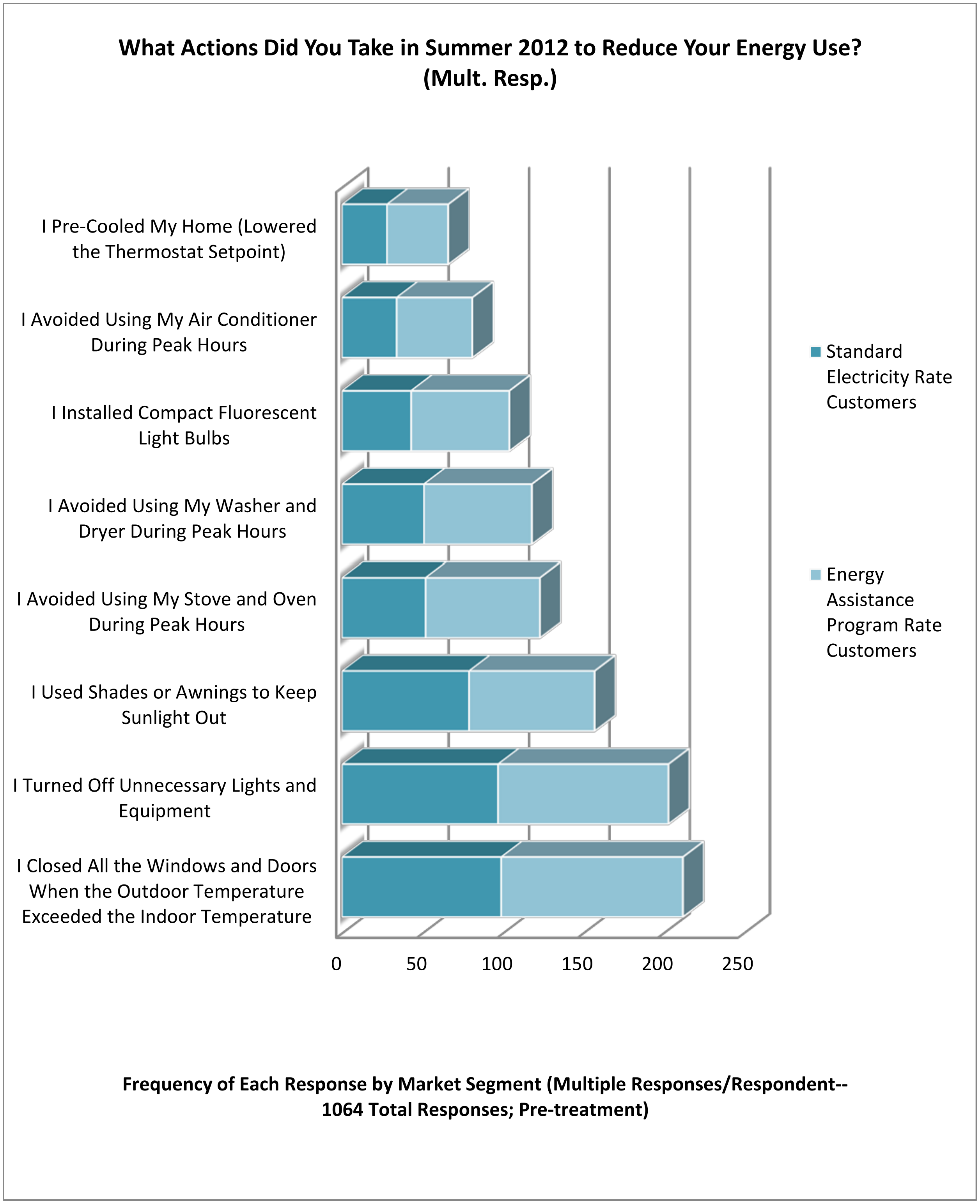

In the Summer of 2013, at What Temperature Did You Typically Set Your Thermostat When You Were at Home During the Day?
Refused
Don't Know
N/A / Off
>81
78-81
74-77
70-73
65-69
60-64
0
10
20
30
40
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

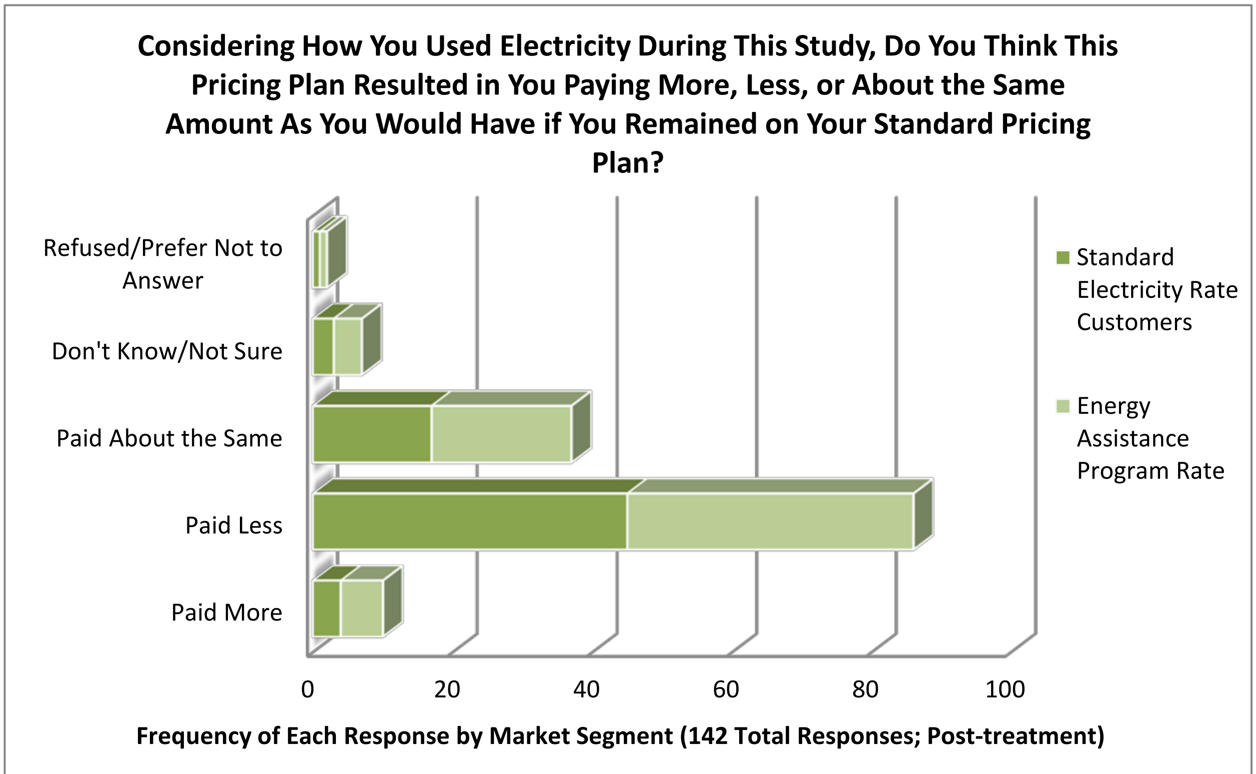

In the Summer of 2013, at What Temperature Did You Typically Set Your Thermostat When You Were at Home at Night?
Refused
Don't Know
N/A / Off
>81
78-81
74-77
70-73
65-69
60-64
<60
0
5
10
15
20
25
30
35
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

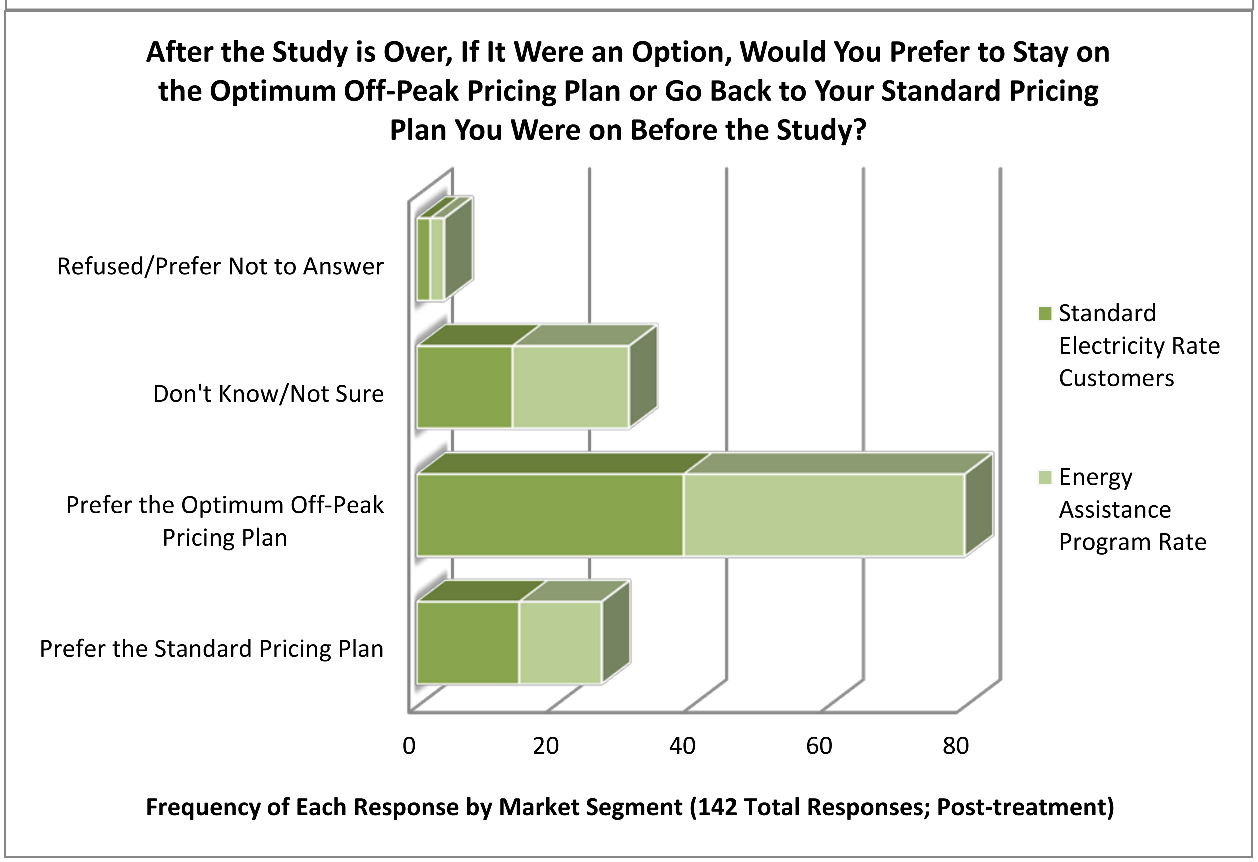

In the Summer of 2013, at What Temperature Did You Typically Set Your Thermostat When You Were Not Home?
Refused
Don't Know
N/A / Off
>81
78-81
74-77
70-73
65-69
60-64
<60
0
5
10
15
20
25
30
35
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

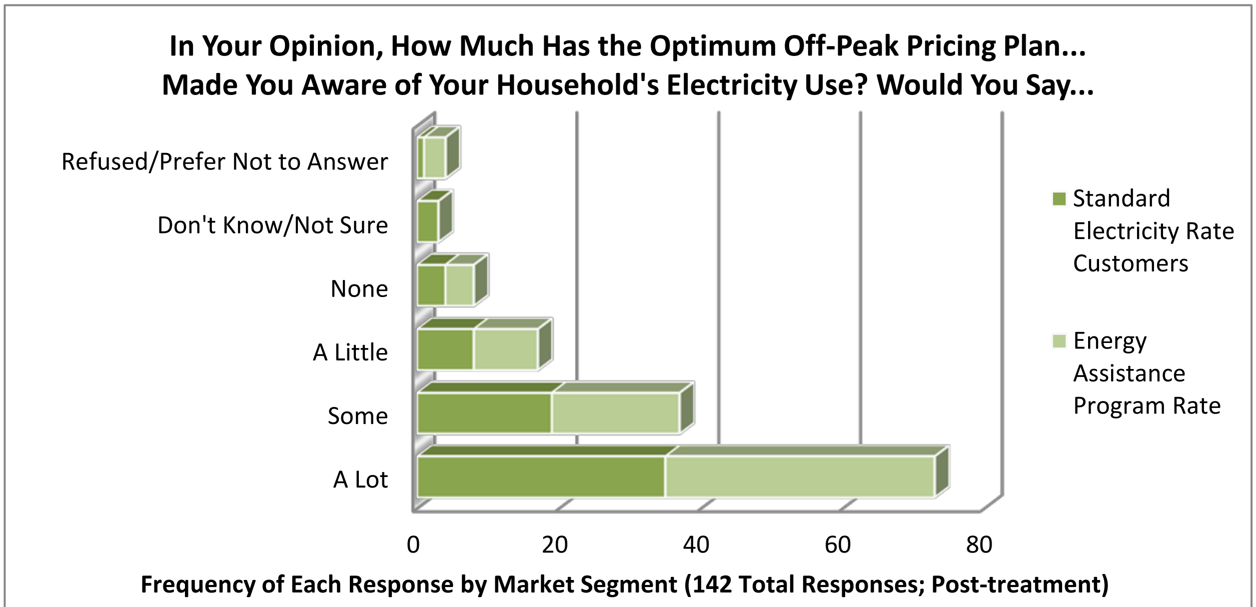


Overall, How Much Attention do You Pay to Your Household's Electricity Use?
Prefer Not to Answer
No Attention
A Little Attention
Some Attention
A Lot of Attention
0
20
40
60
80
100
120
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers

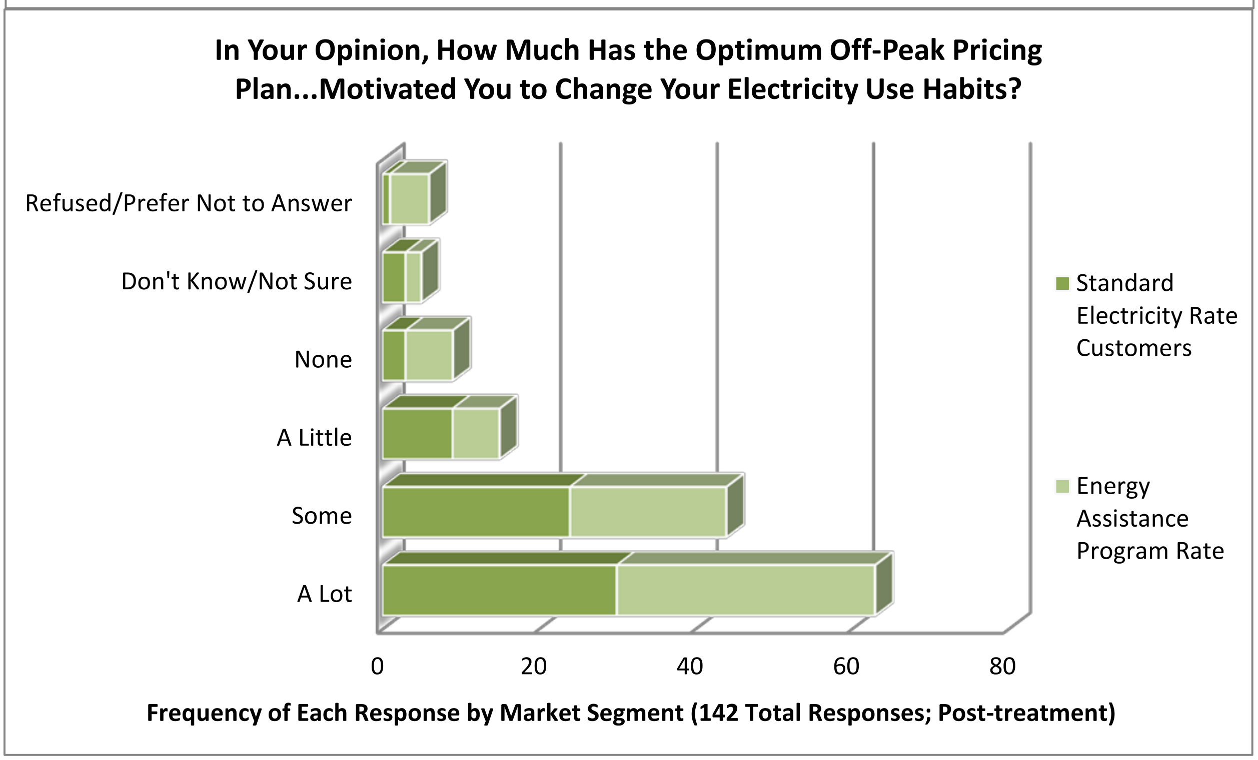

What Actions Did You Take in Summer 2012 to Reduce Your Energy Use?
(Mult. Resp.)
I Pre-Cooled My Home (Lowered the Thermostat Setpoint)
I Avoided Using My Air Conditioner During Peak Hours
I Installed Compact Fluorescent Light Bulbs
I Avoided Using My Washer and Dryer During Peak Hours
I Avoided Using My Stove and Oven During Peak Hours
I Used Shades or Awnings to Keep Sunlight Out
I Turned Off Unnecessary Lights and Equipment
I Closed All the Windows and Doors When the Outdoor Temperature Exceeded the Indoor Temperature
0
50
100
150
200
250
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
Frequency of Each Response by Market Segment (Multiple Responses/Respondent--
1064 Total Responses; Pre-treatment)


Considering How You Used Electricity During This Study, Do You Think This Pricing Plan Resulted in You Paying More, Less, or About the Same Amount As You Would Have if You Remained on Your Standard Pricing Plan?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Paid About the Same
Paid Less
Paid More
0
20
40
60
80
100
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

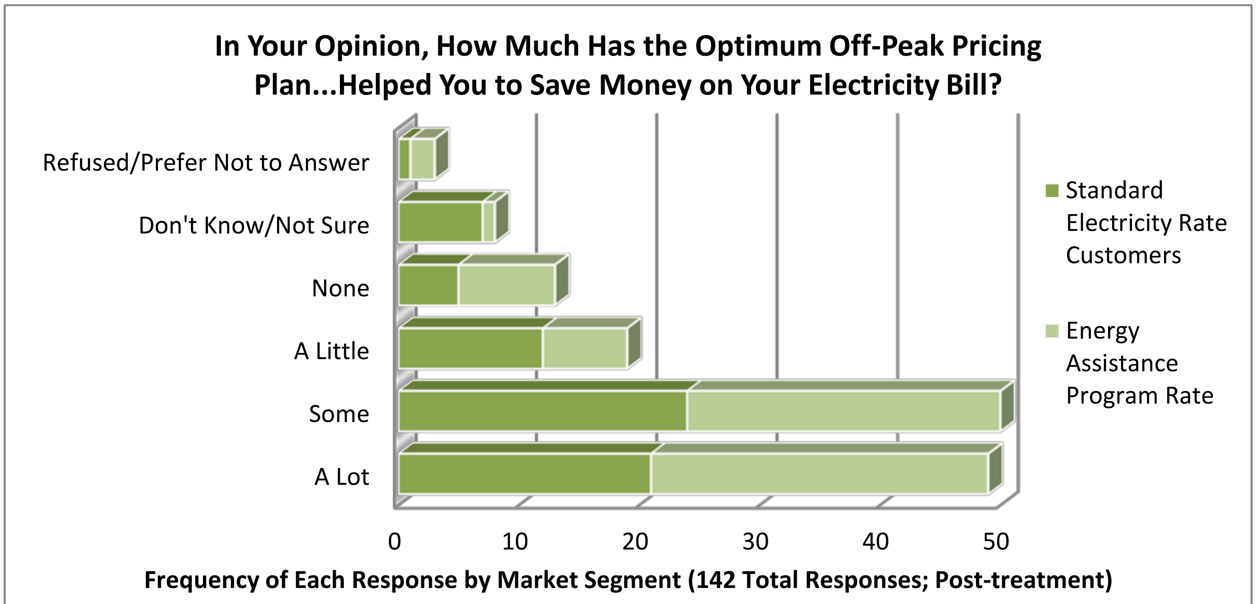

After the Study is Over, If It Were an Option, Would You Prefer to Stay on the Optimum Off-Peak Pricing Plan or Go Back to Your Standard Pricing Plan You Were on Before the Study?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Prefer the Optimum Off-Peak Pricing Plan
Prefer the Standard Pricing Plan
0
20
40
60
80
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

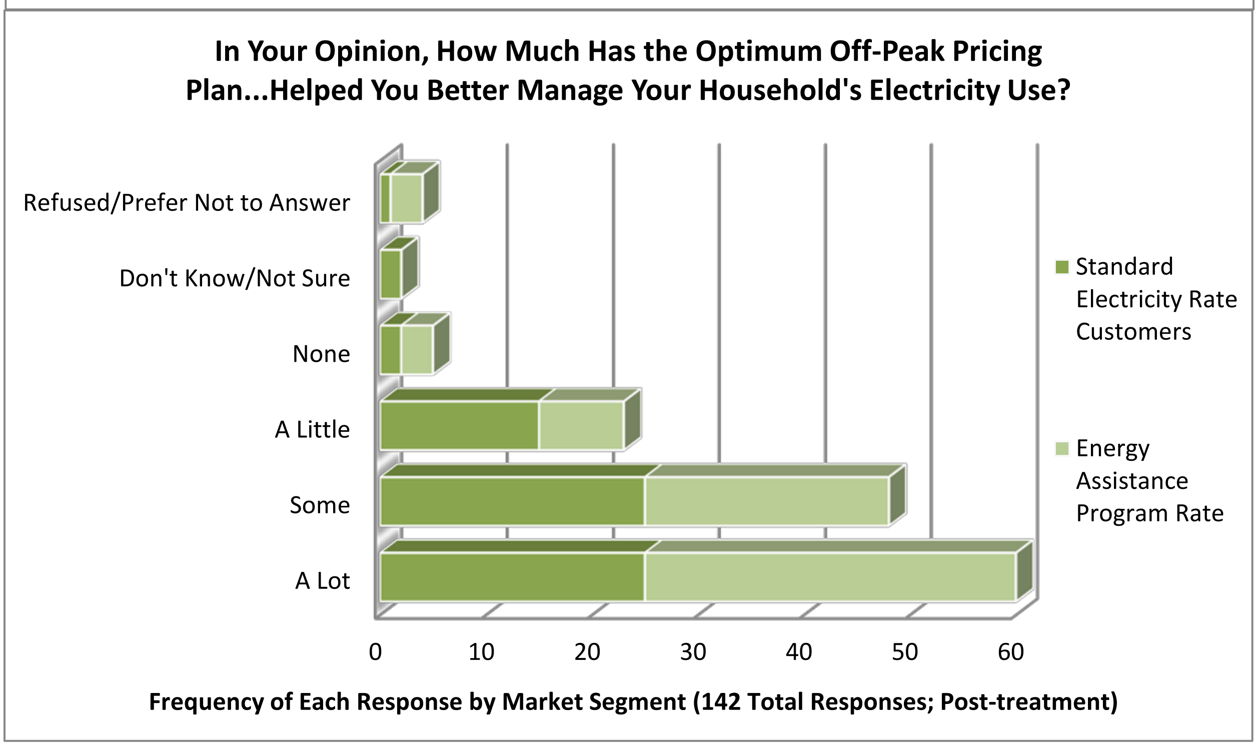


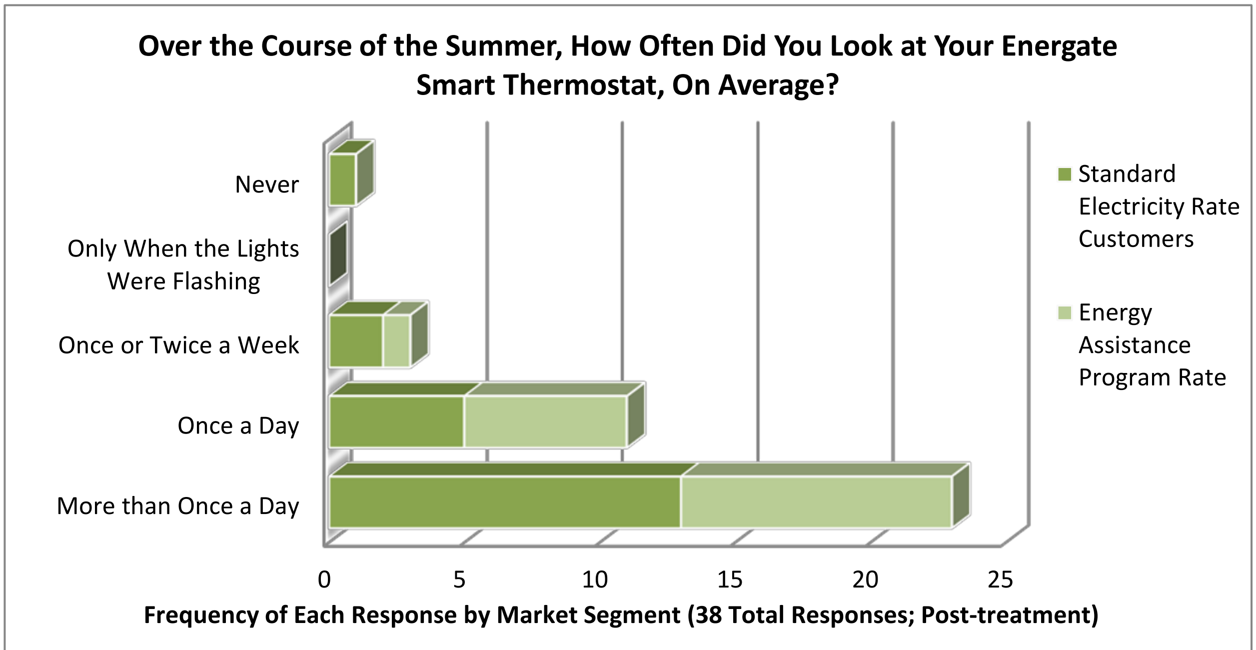
In Your Opinion, How Much Has the Optimum Off-Peak Pricing Plan...
Made You Aware of Your Household's Electricity Use? Would You Say...
Refused/Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
20
40
60
80
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

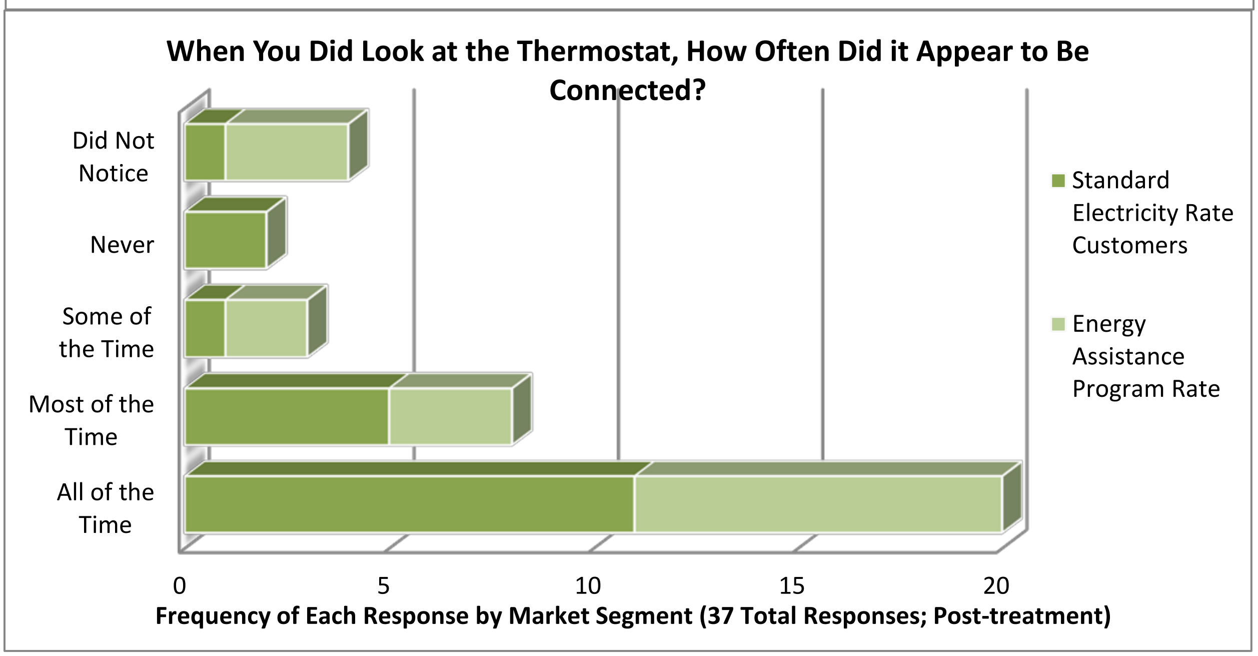


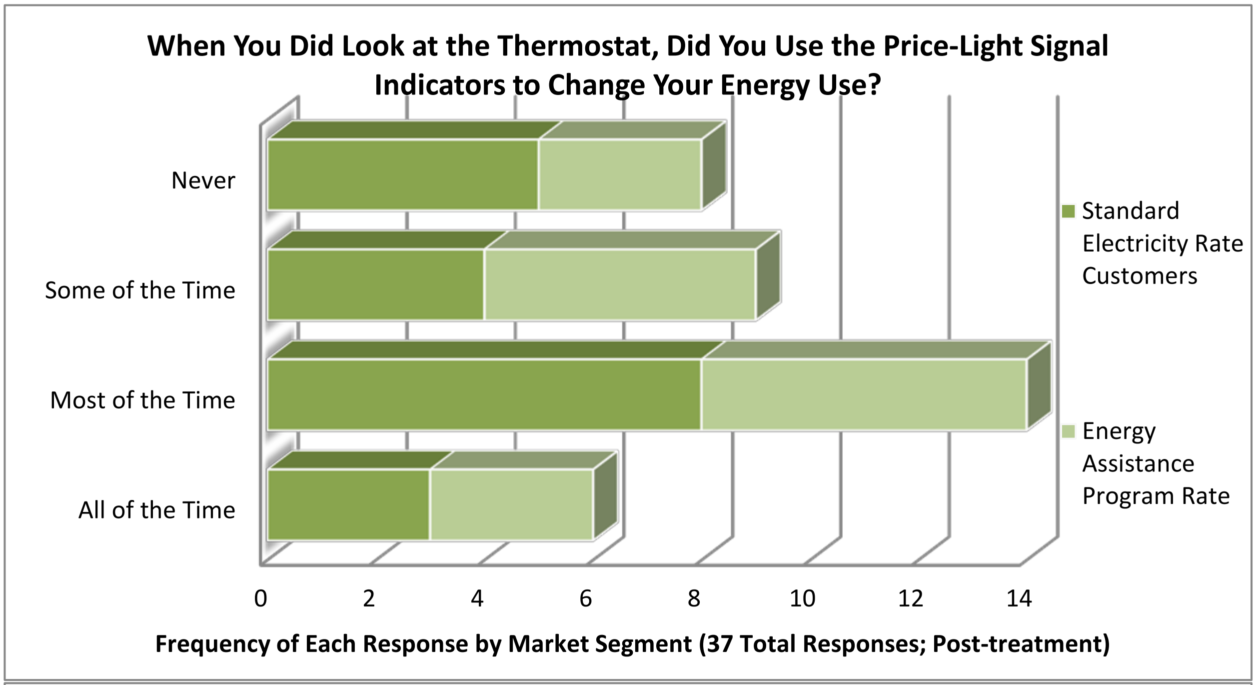
In Your Opinion, How Much Has the Optimum Off-Peak Pricing Plan...Motivated You to Change Your Electricity Use Habits?
Refused/Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
20
40
60
80
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

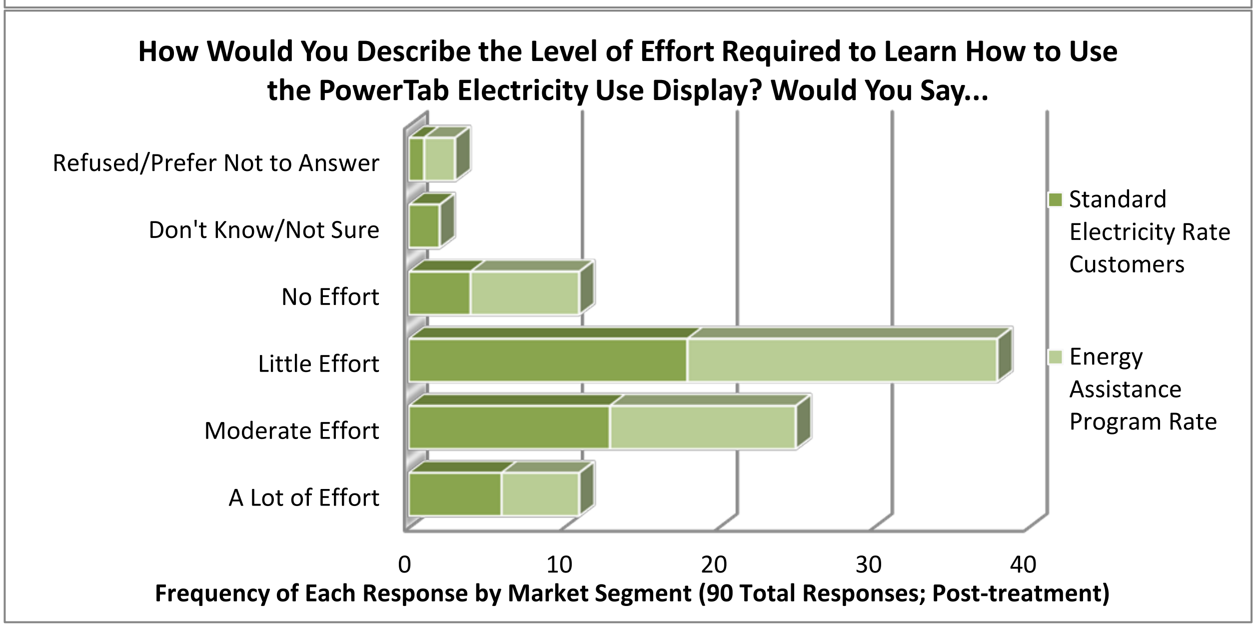

In Your Opinion, How Much Has the Optimum Off-Peak Pricing Plan...Helped You to Save Money on Your Electricity Bill?
Refused/Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
10
20
30
40
50
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

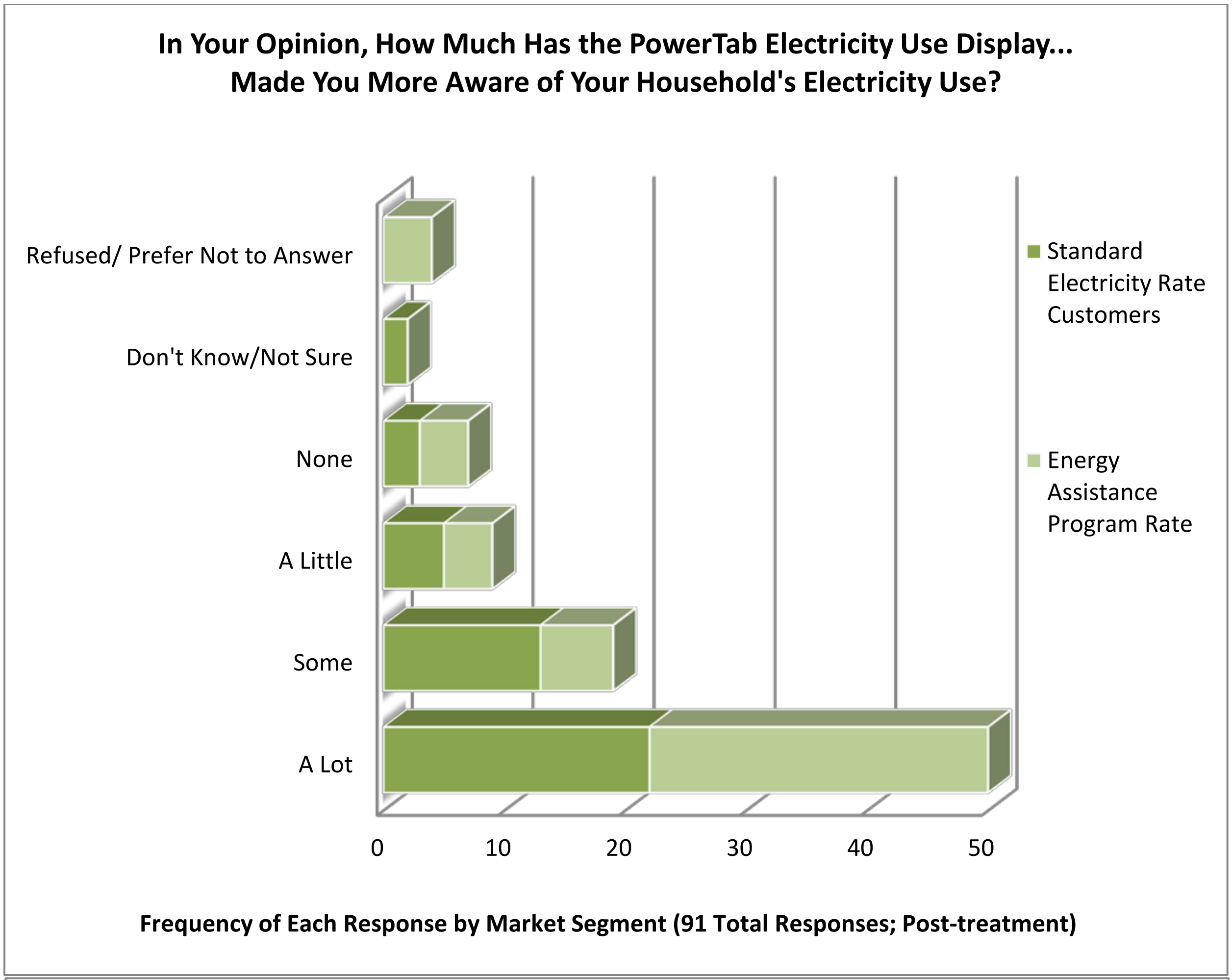

In Your Opinion, How Much Has the Optimum Off-Peak Pricing Plan...Helped You Better Manage Your Household's Electricity Use?
Refused/Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
10
20
30
40
50
60
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

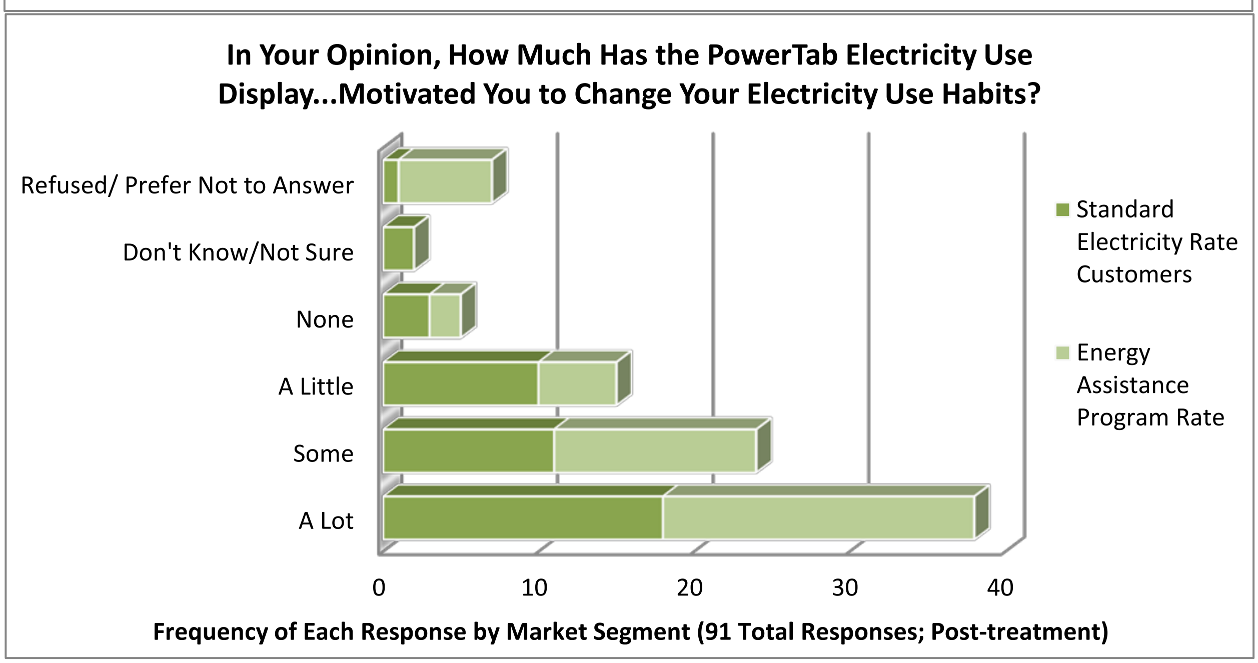

Over the Course of the Summer, How Often Did You Look at Your Energate Smart Thermostat, On Average?
Never
Only When the Lights Were Flashing
Once or Twice a Week
Once a Day
More than Once a Day
0
5
10
15
20
25
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

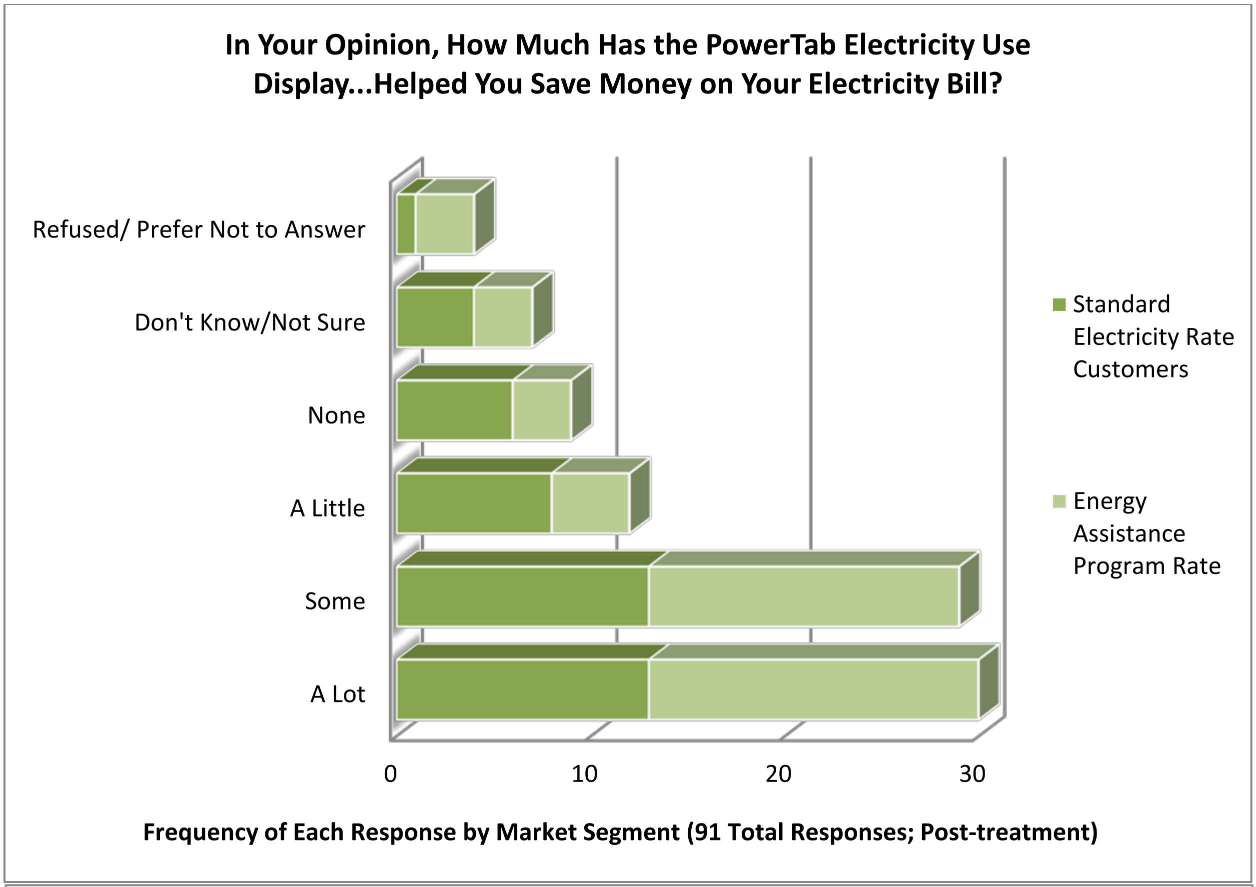

When You Did Look at the Thermostat, How Often Did it Appear to Be Connected?
Did Not Notice
Never
Some of the Time
Most of the Time
All of the Time
0
5
10
15
20
Frequency of Each Response by Market Segment (37 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

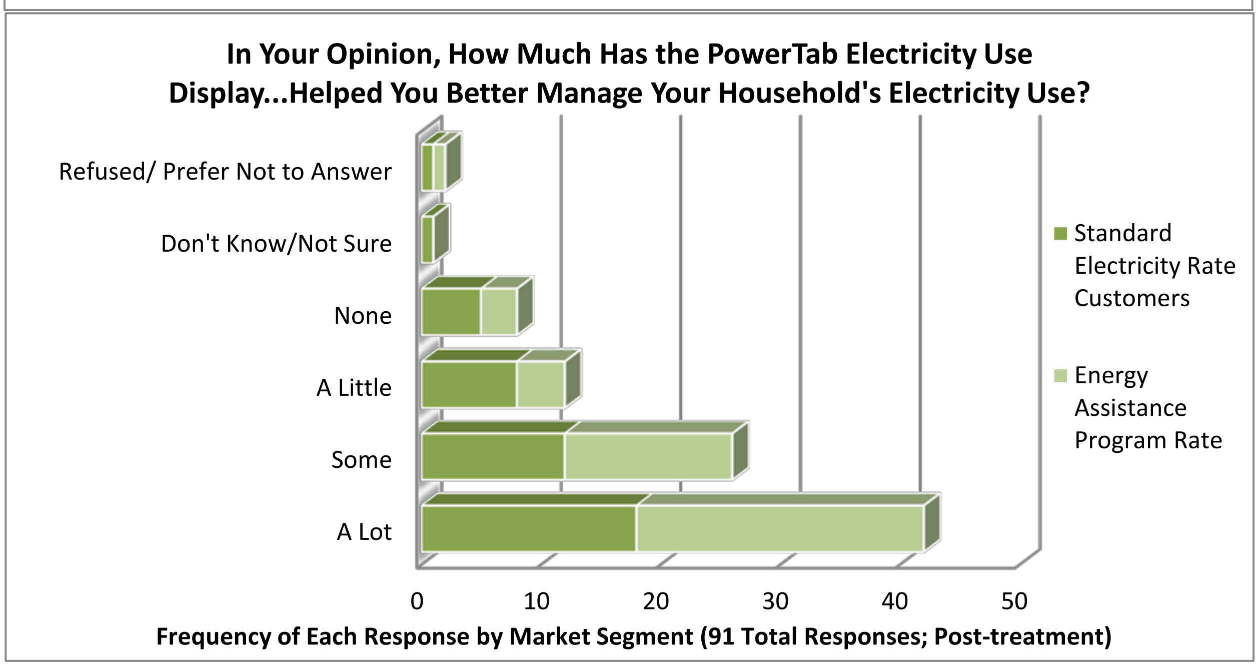

When You Did Look at the Thermostat, Did You Use the Price-Light Signal Indicators to Change Your Energy Use?
Never
Some of the Time
Most of the Time
All of the Time
0
2
4
6
8
10
12
14
Frequency of Each Response by Market Segment (37 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

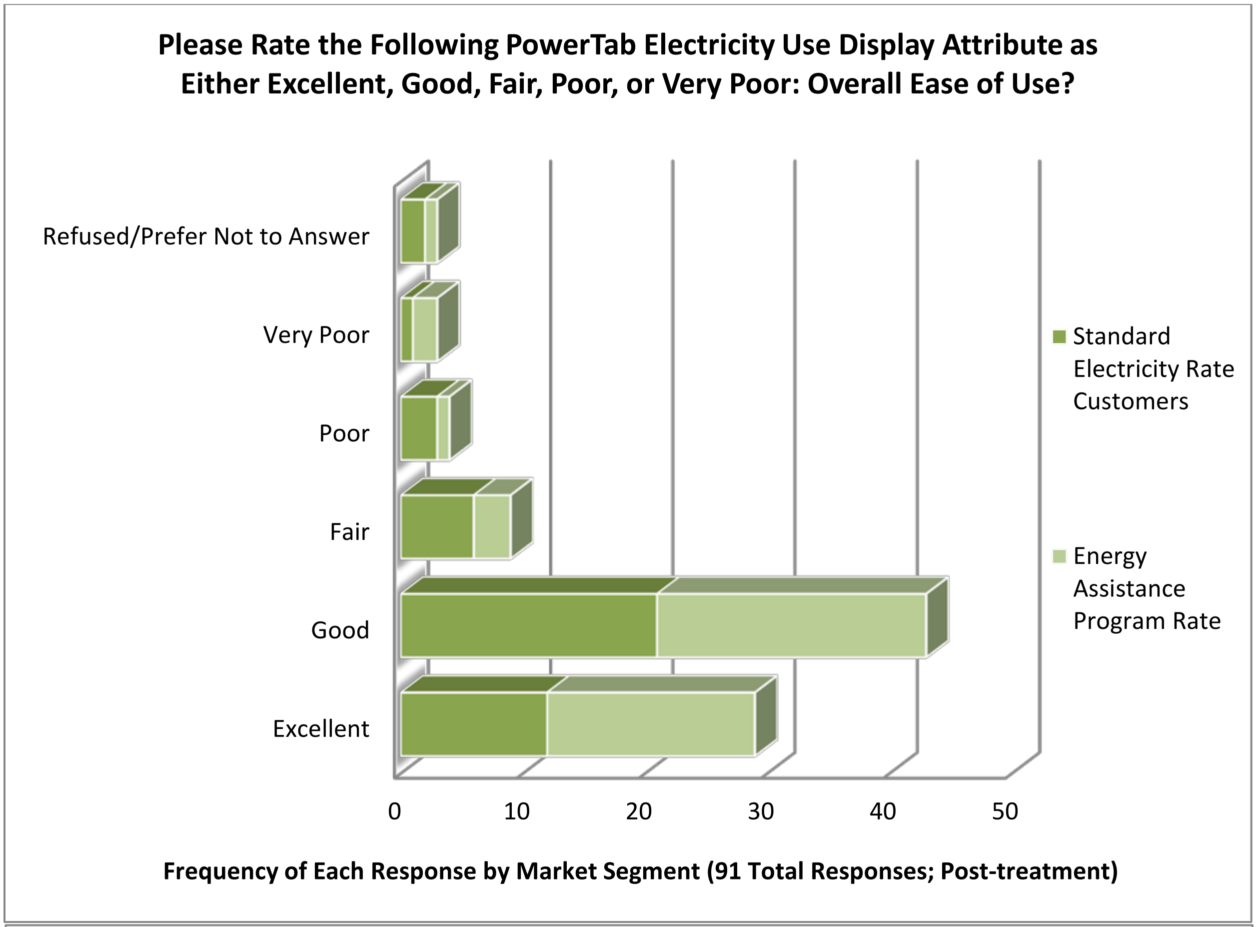

How Would You Describe the Level of Effort Required to Learn How to Use the PowerTab Electricity Use Display? Would You Say...
Refused/Prefer Not to Answer
Don't Know/Not Sure
No Effort
Little Effort
Moderate Effort
A Lot of Effort
0
10
20
30
40
Frequency of Each Response by Market Segment (90 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

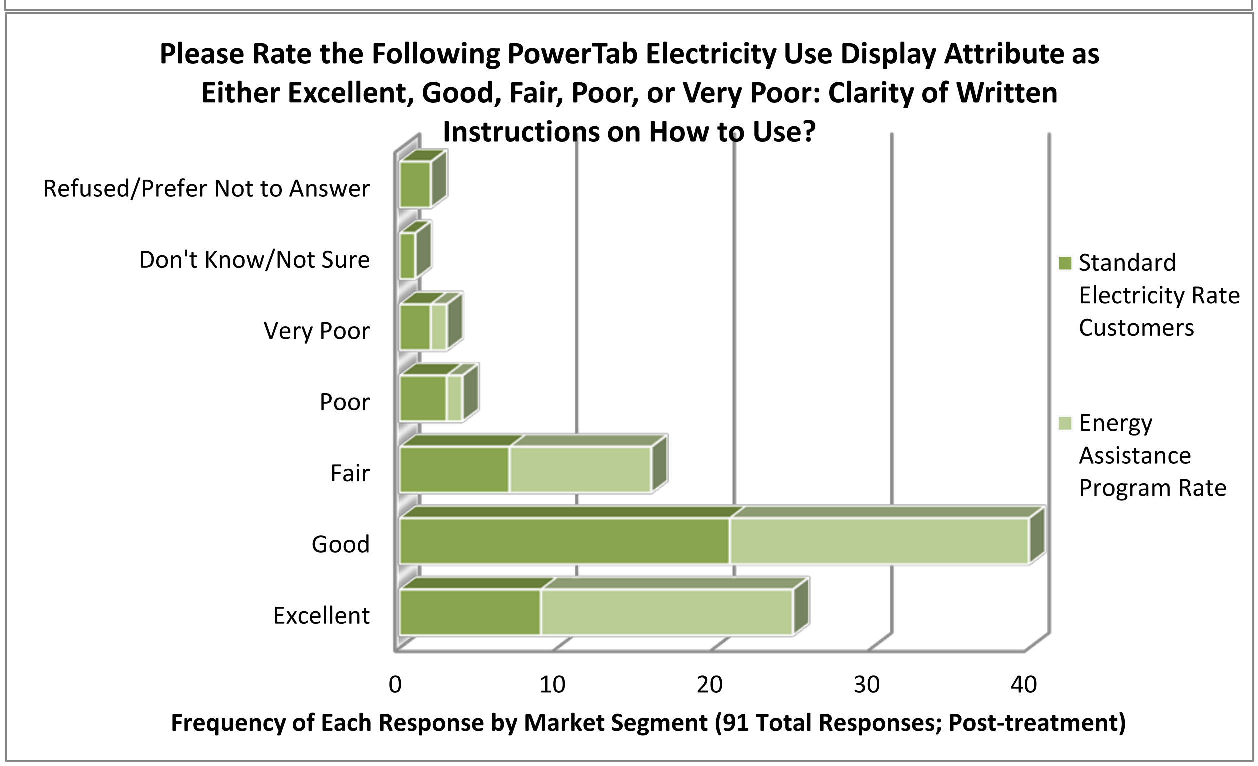

In Your Opinion, How Much Has the PowerTab Electricity Use Display...
Made You More Aware of Your Household's Electricity Use?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
10
20
30
40
50
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)

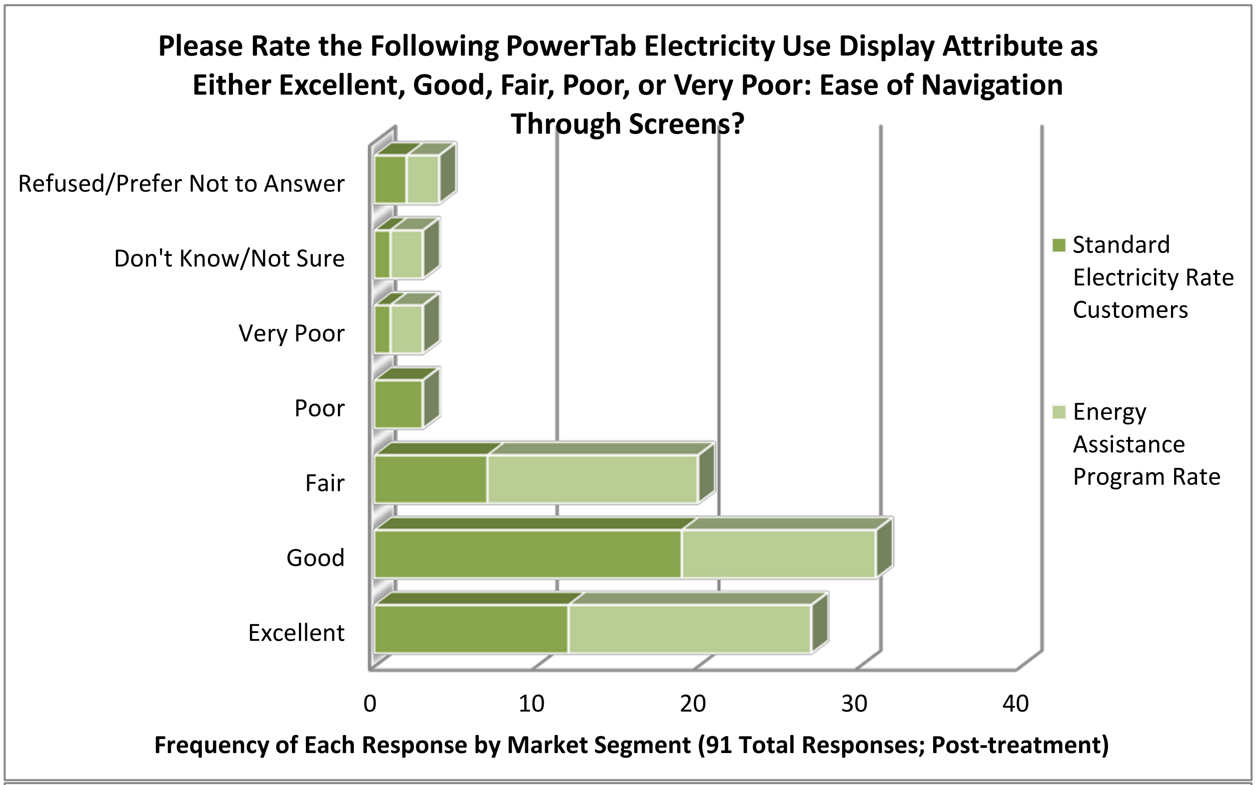

In Your Opinion, How Much Has the PowerTab Electricity Use
Display...Motivated You to Change Your Electricity Use Habits?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
10
20
30
40
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)


In Your Opinion, How Much Has the PowerTab Electricity Use Display...Helped You Save Money on Your Electricity Bill?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
10
20
30
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)

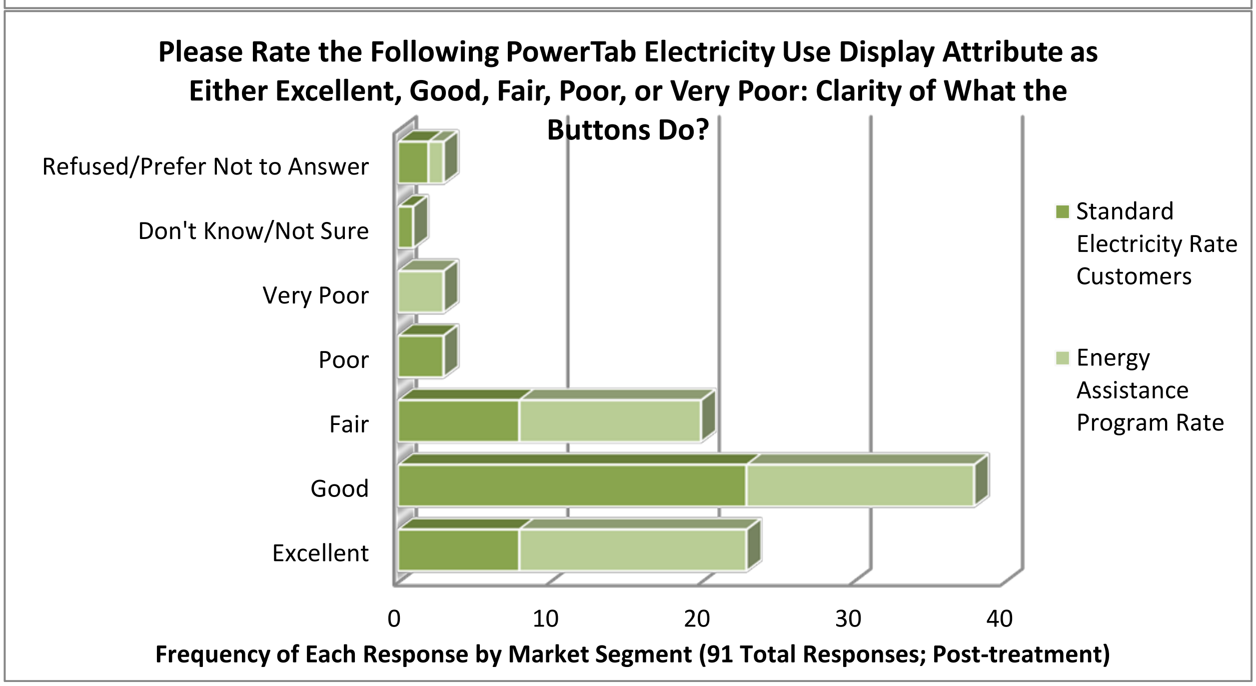

In Your Opinion, How Much Has the PowerTab Electricity Use Display...Helped You Better Manage Your Household's Electricity Use?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
10
20
30
40
50
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)


Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Overall Ease of Use?
Refused/Prefer Not to Answer
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

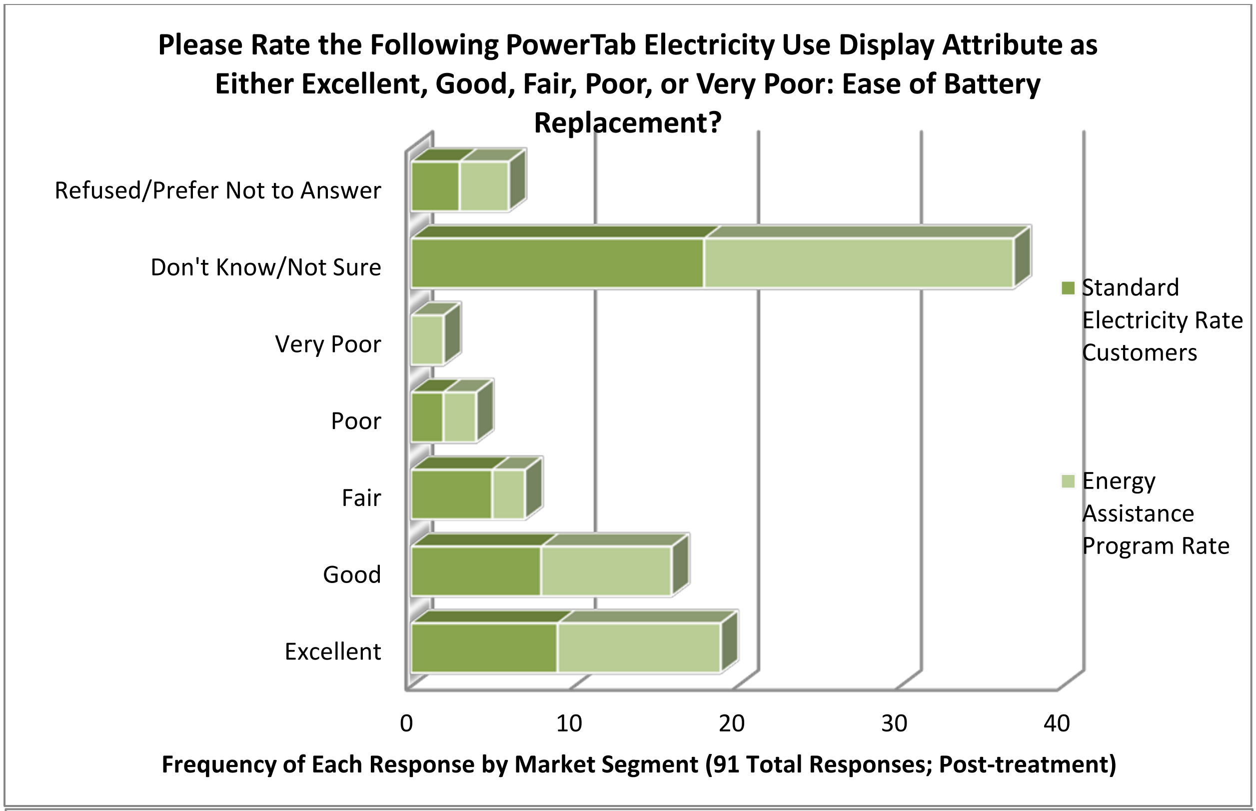

Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Clarity of Written Instructions on How to Use?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate



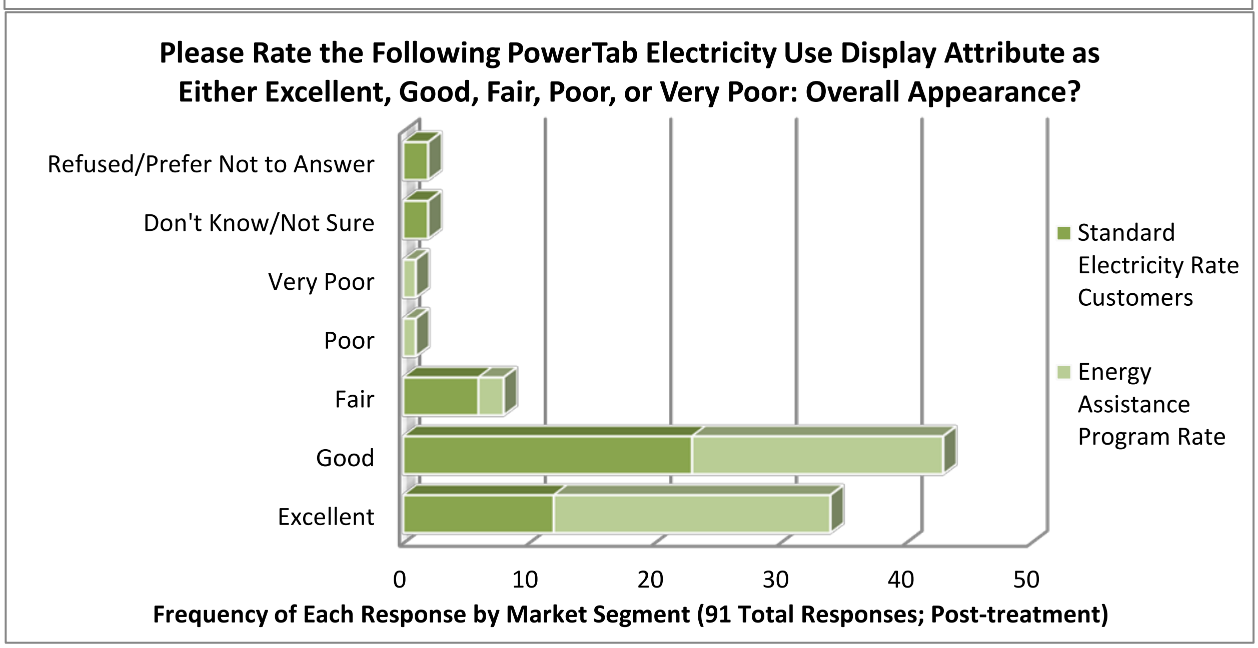
Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Ease of Navigation Through Screens?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate



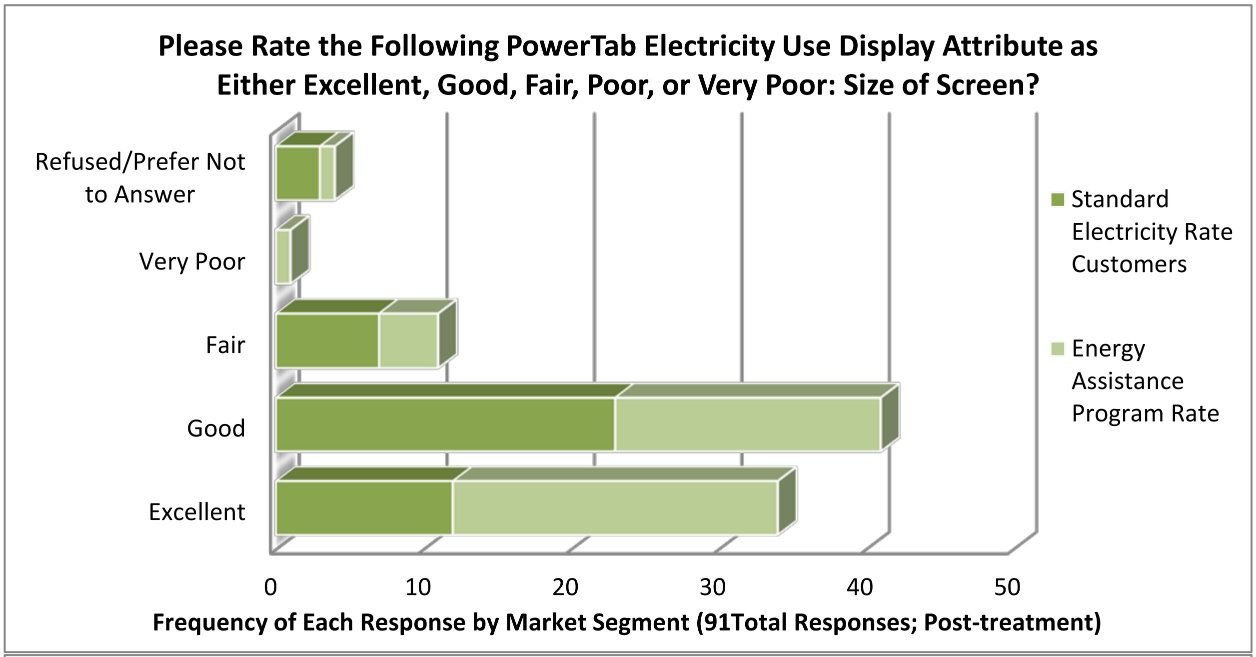
Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Clarity of What the Buttons Do?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

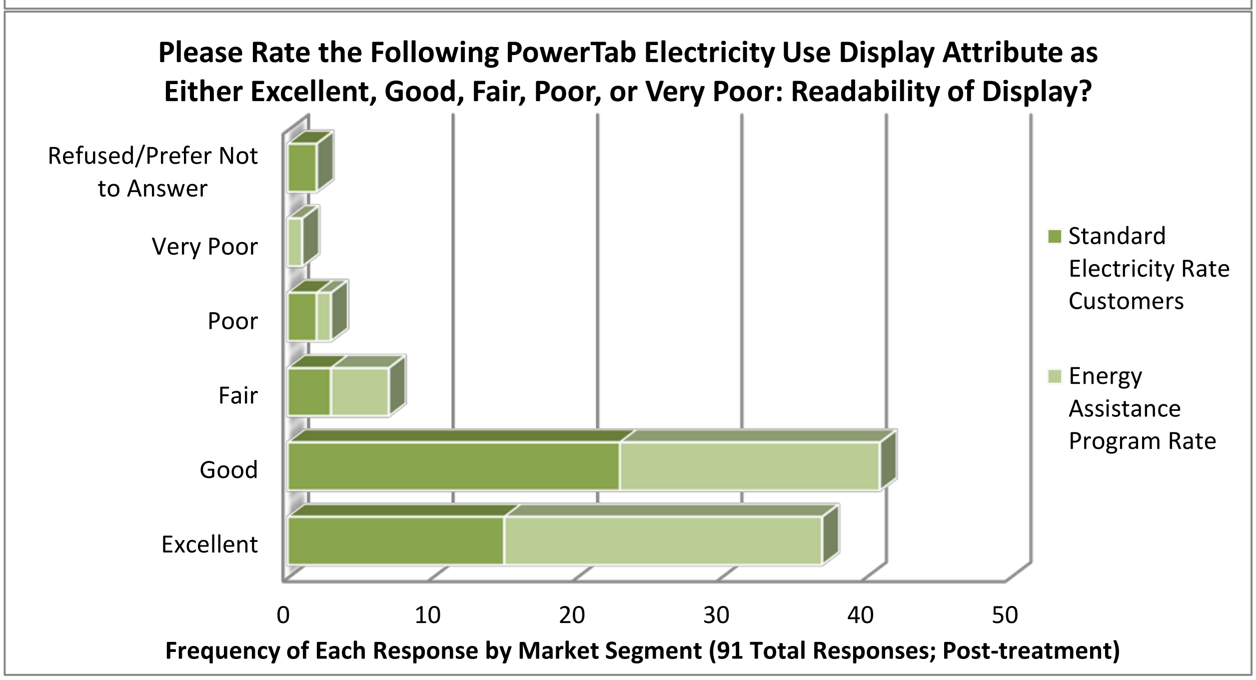


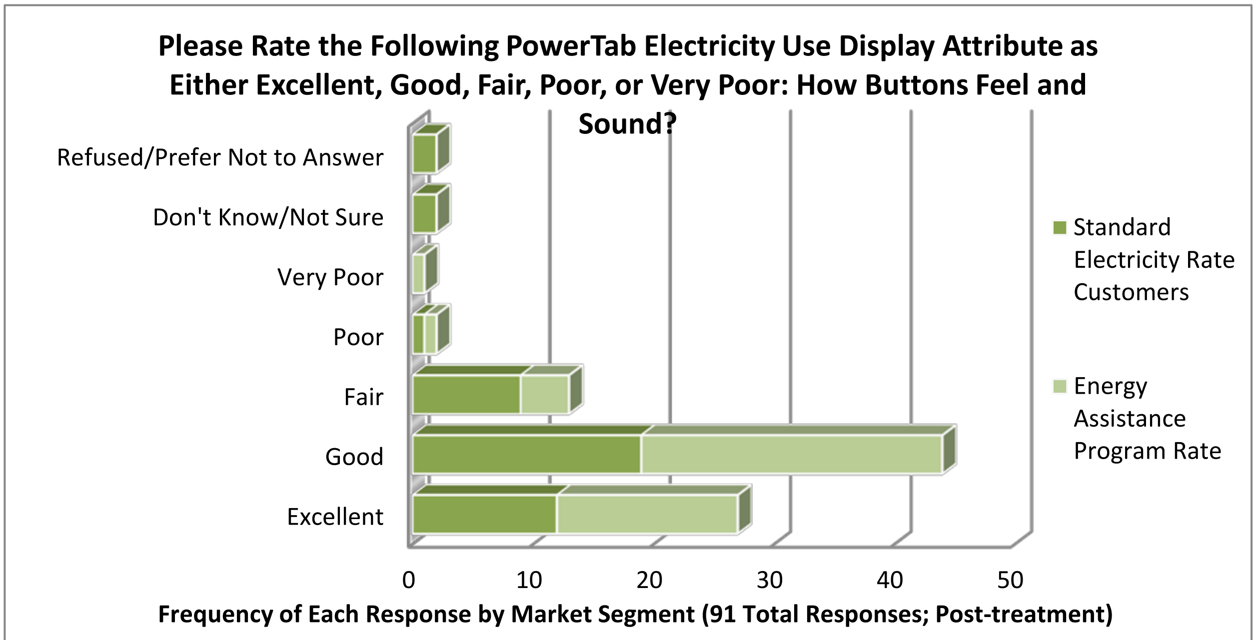
Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Ease of Battery Replacement?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate



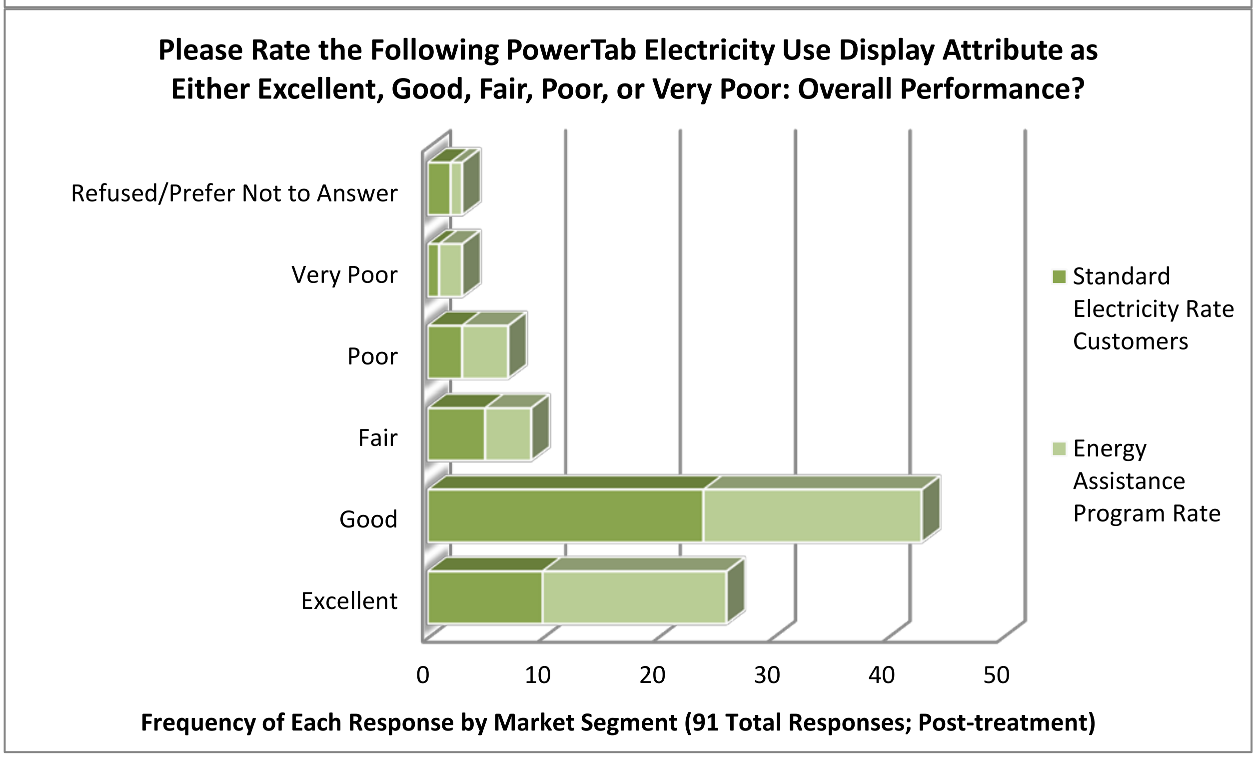
Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Overall Appearance?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate


Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Size of Screen?
Refused/Prefer Not to Answer
Very Poor
Fair
Good
Excellent
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

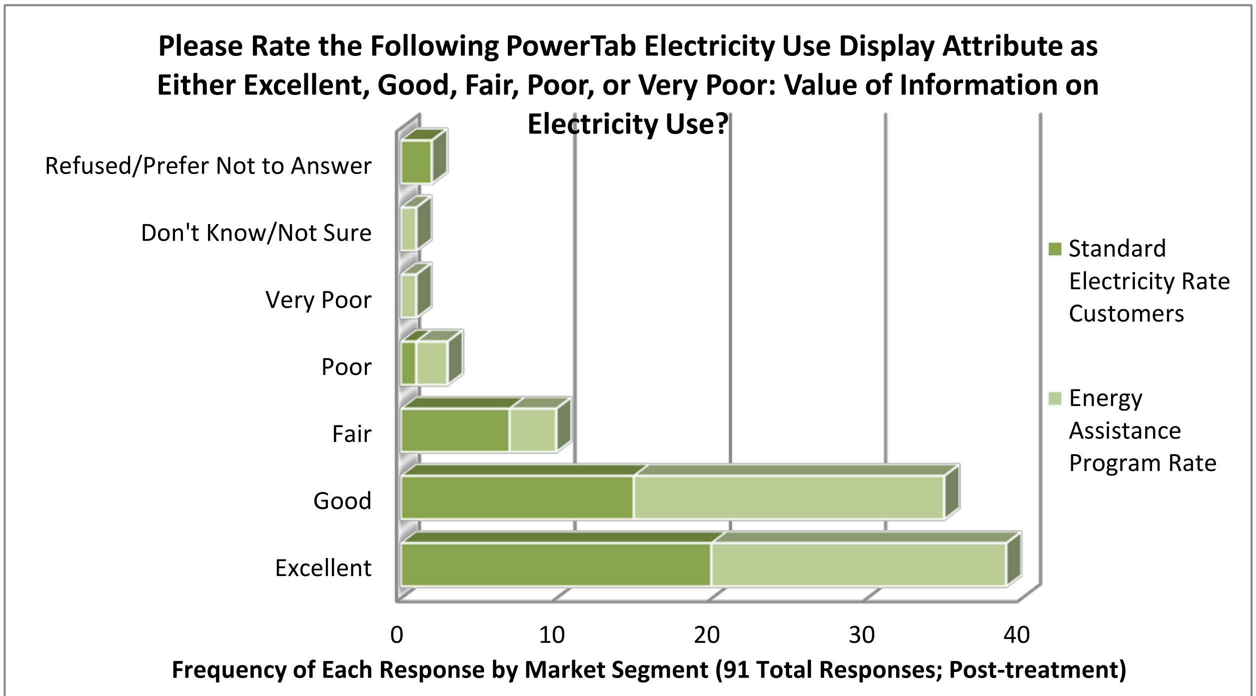

Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Readability of Display?
Refused/Prefer Not to Answer
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

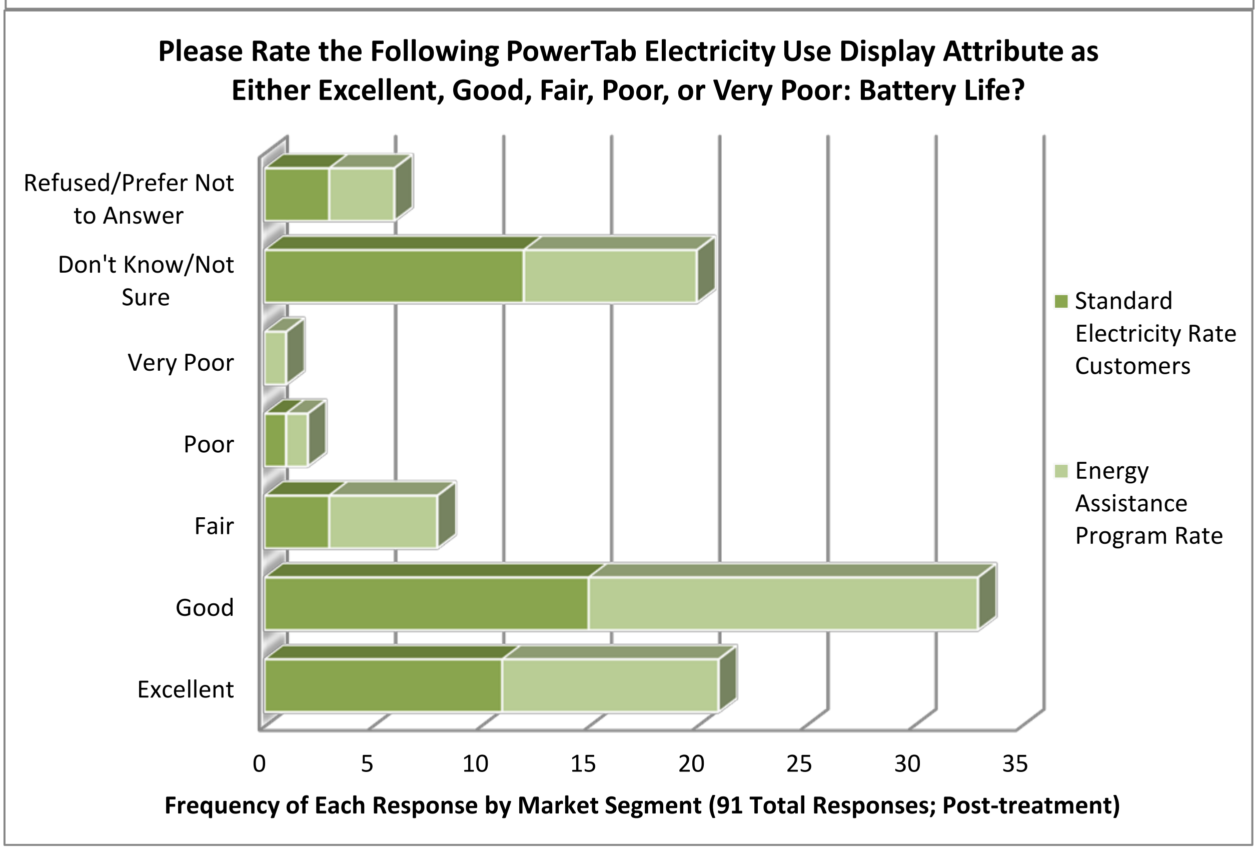


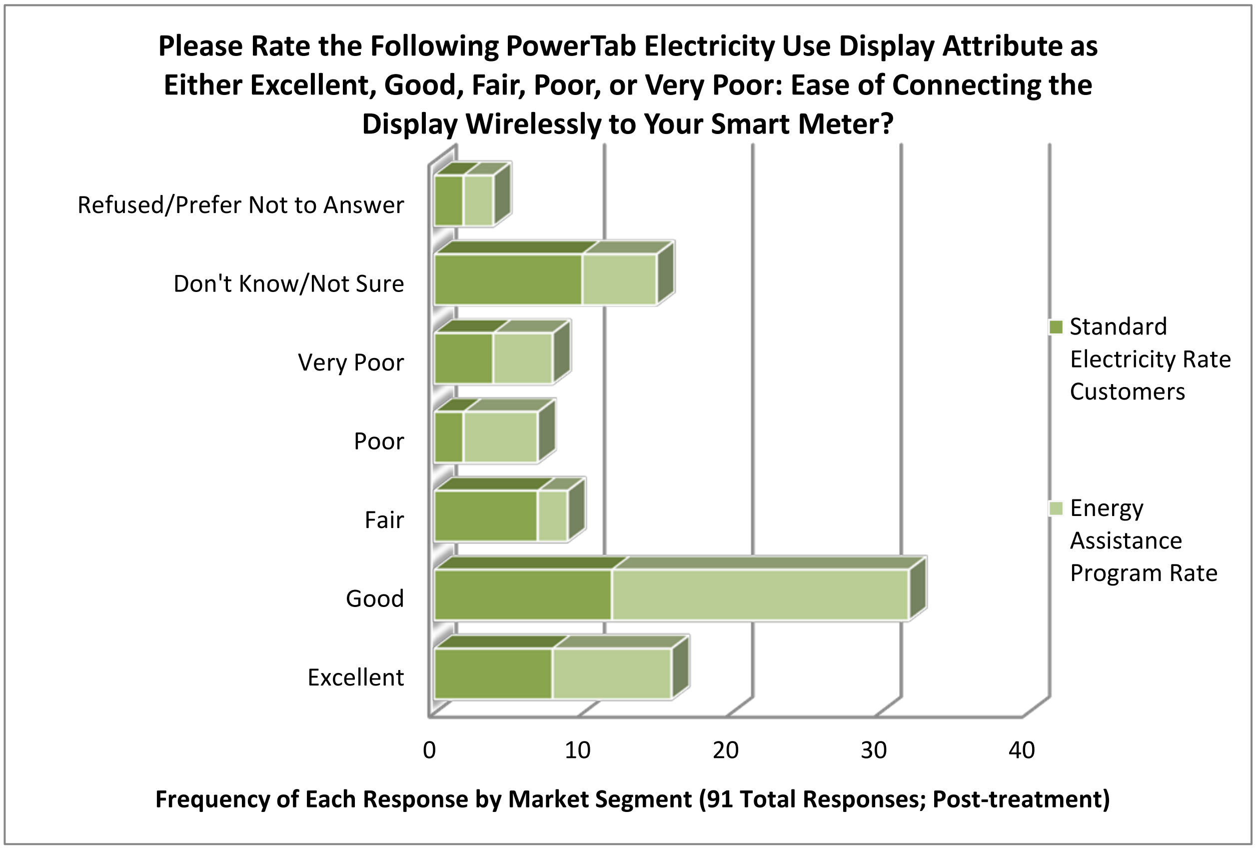
Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: How Buttons Feel and Sound?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

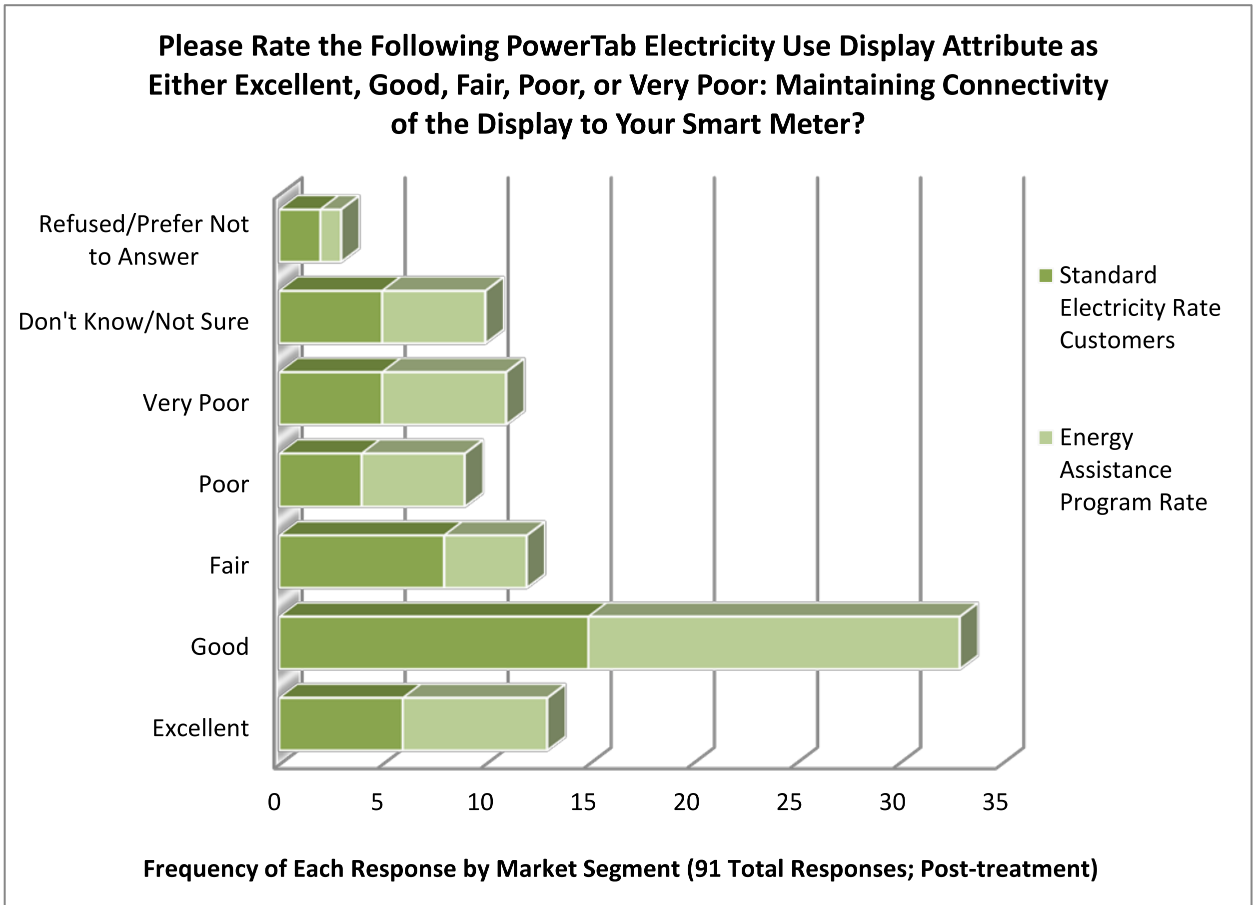


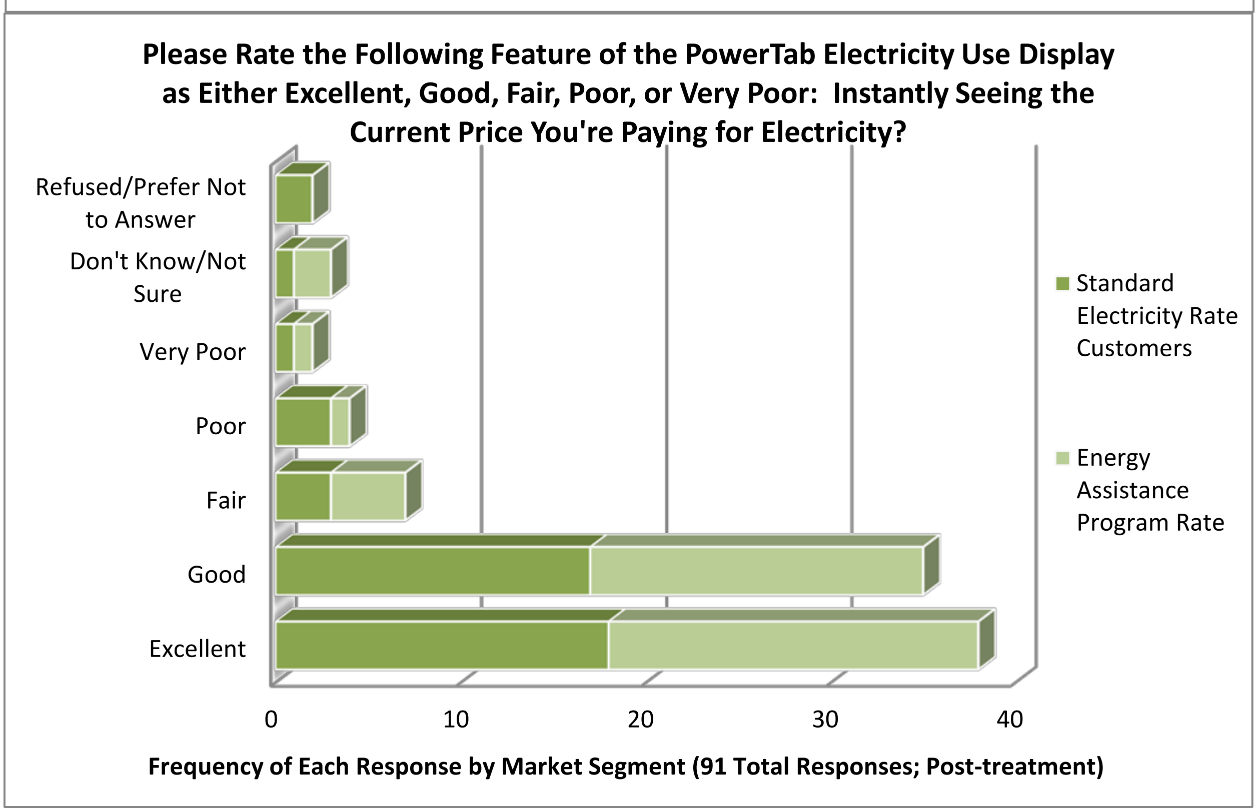
Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Overall Performance?
Refused/Prefer Not to Answer
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

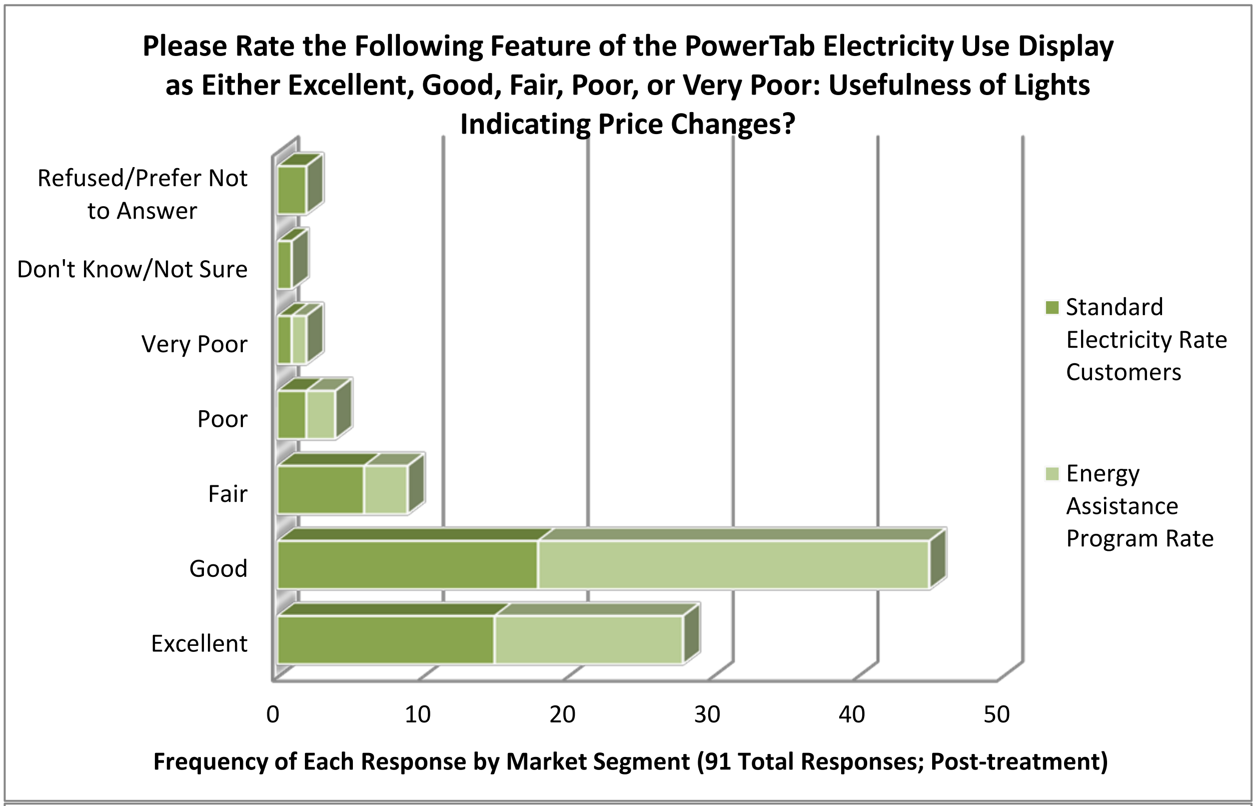

Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Value of Information on Electricity Use?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

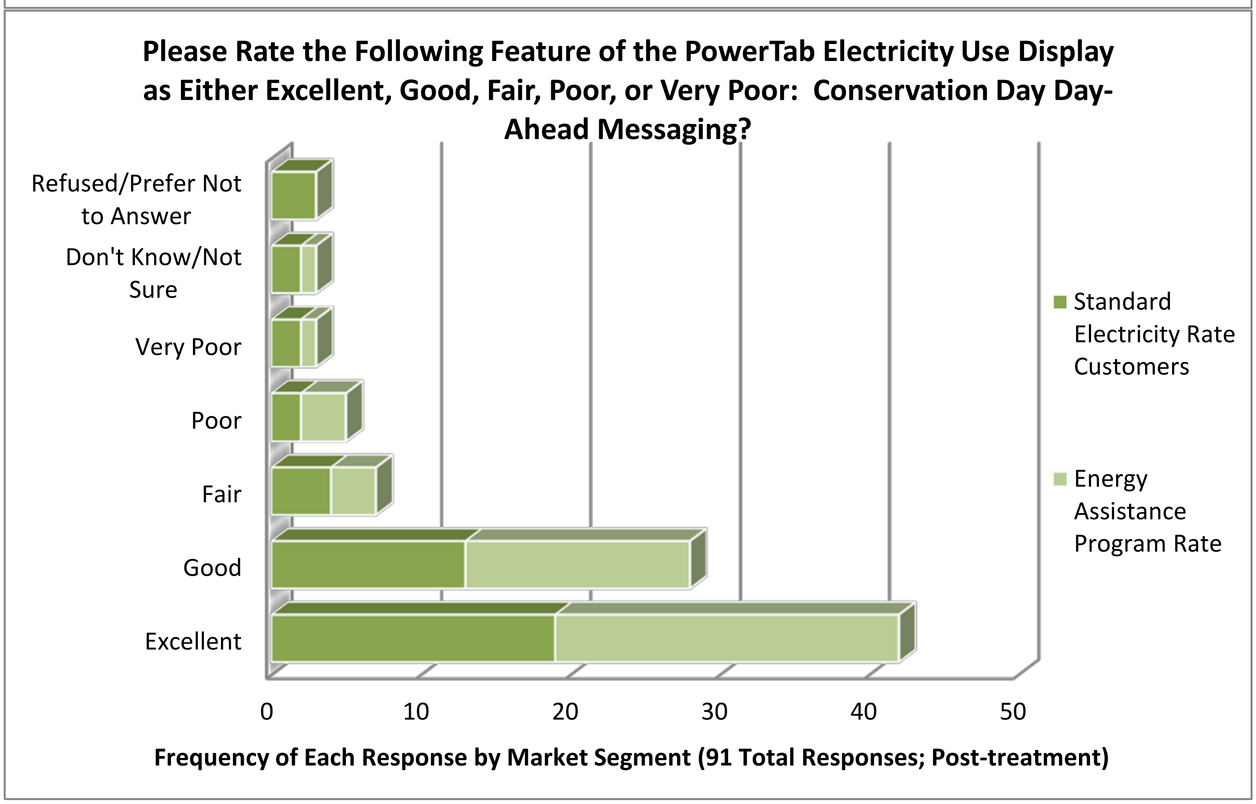

Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Battery Life?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
5
10
15
20
25
30
35
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

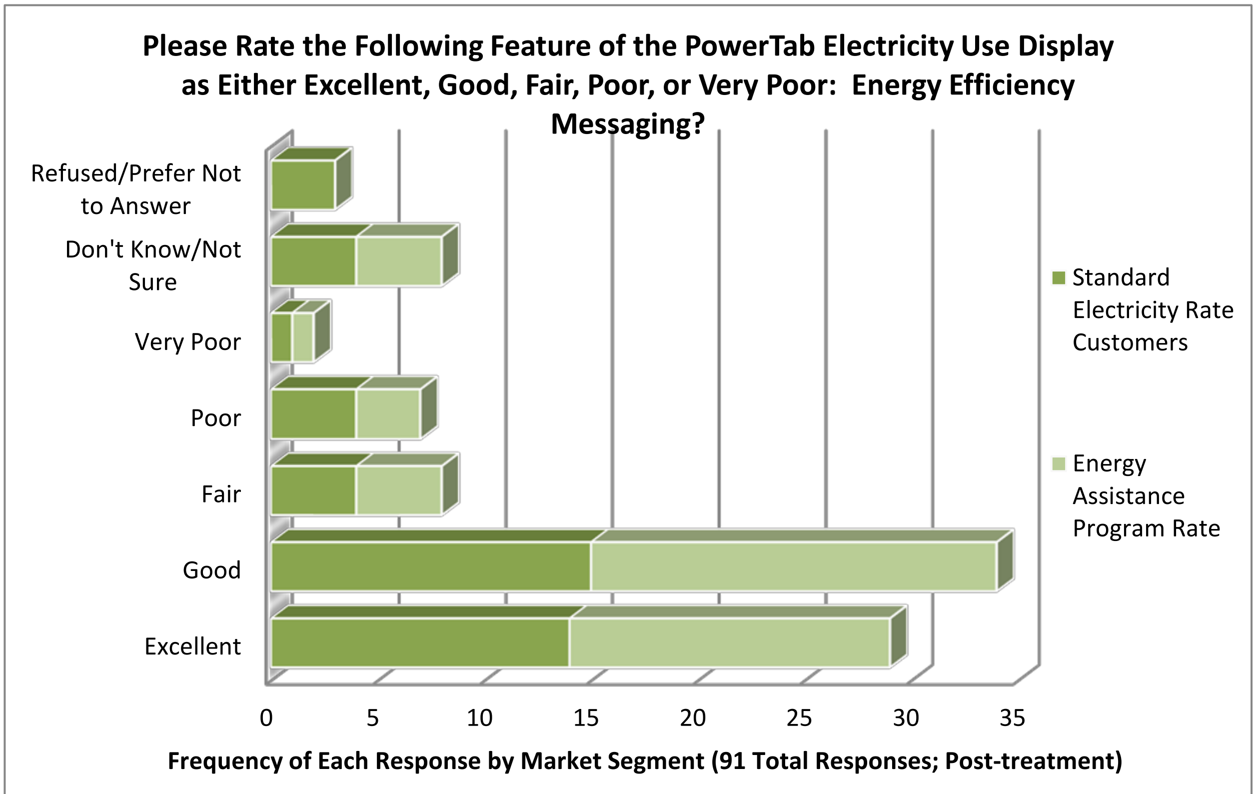

Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Ease of Connecting the Display Wirelessly to Your Smart Meter?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

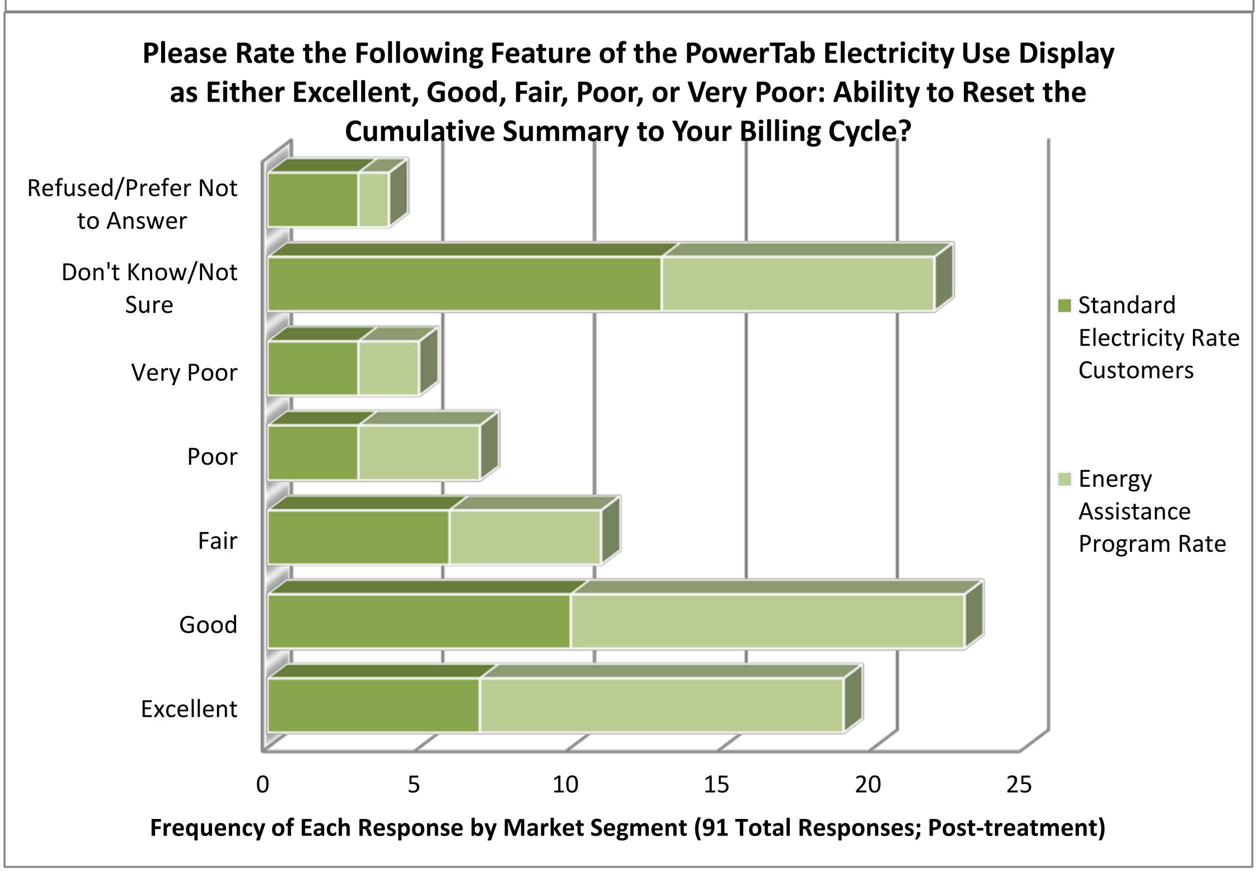

Please Rate the Following PowerTab Electricity Use Display Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Maintaining Connectivity of the Display to Your Smart Meter?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
5
10
15
20
25
30
35
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)

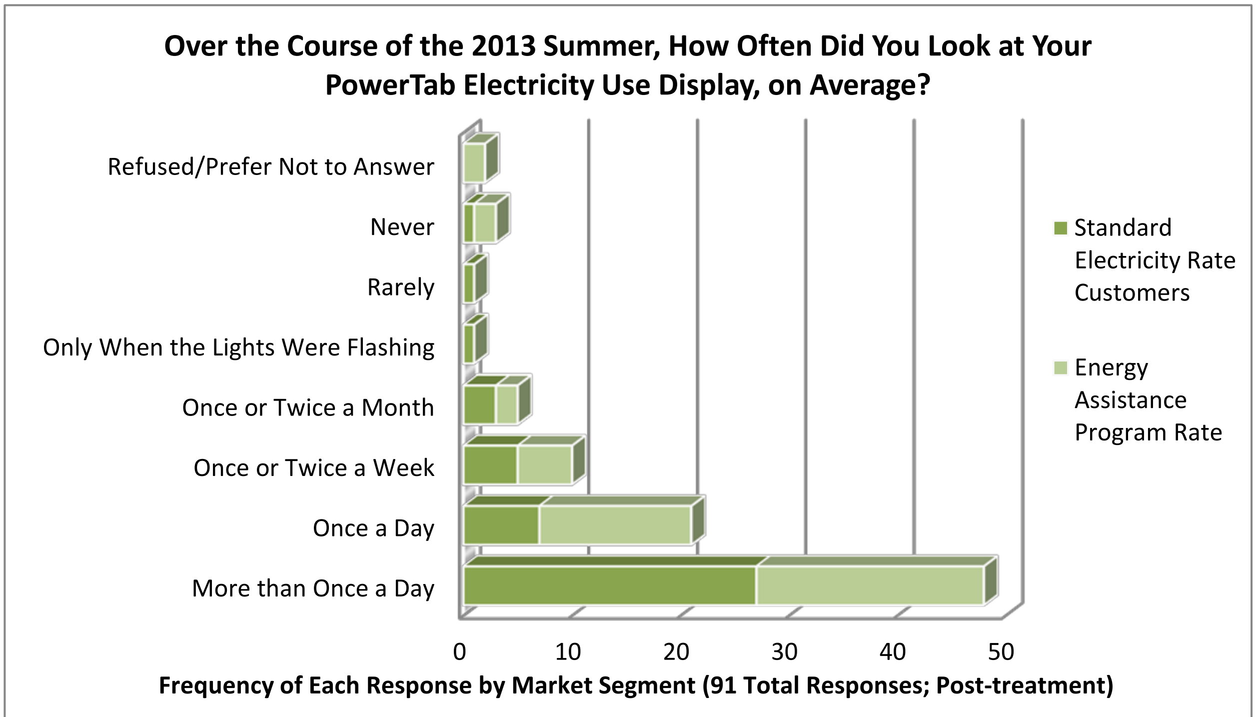

Please Rate the Following Feature of the PowerTab Electricity Use Display as Either Excellent, Good, Fair, Poor, or Very Poor: Instantly Seeing the Current Price You're Paying for Electricity?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)

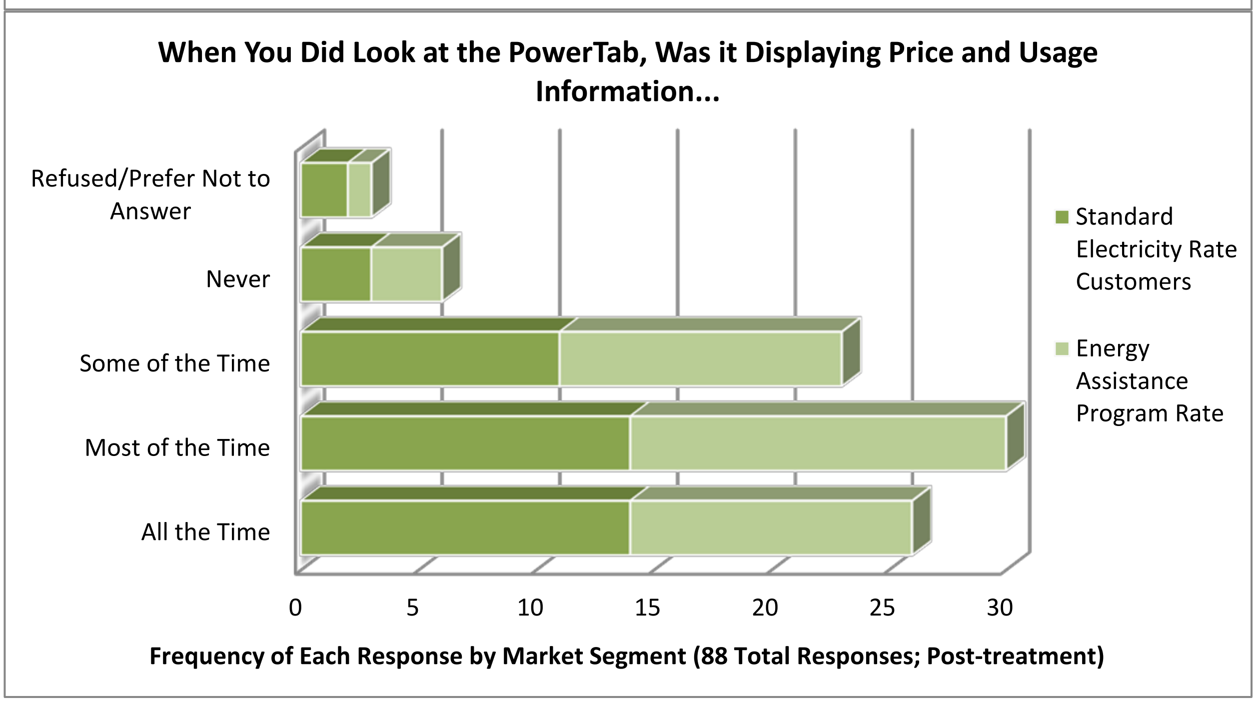

Please Rate the Following Feature of the PowerTab Electricity Use Display as Either Excellent, Good, Fair, Poor, or Very Poor: Usefulness of Lights Indicating Price Changes?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

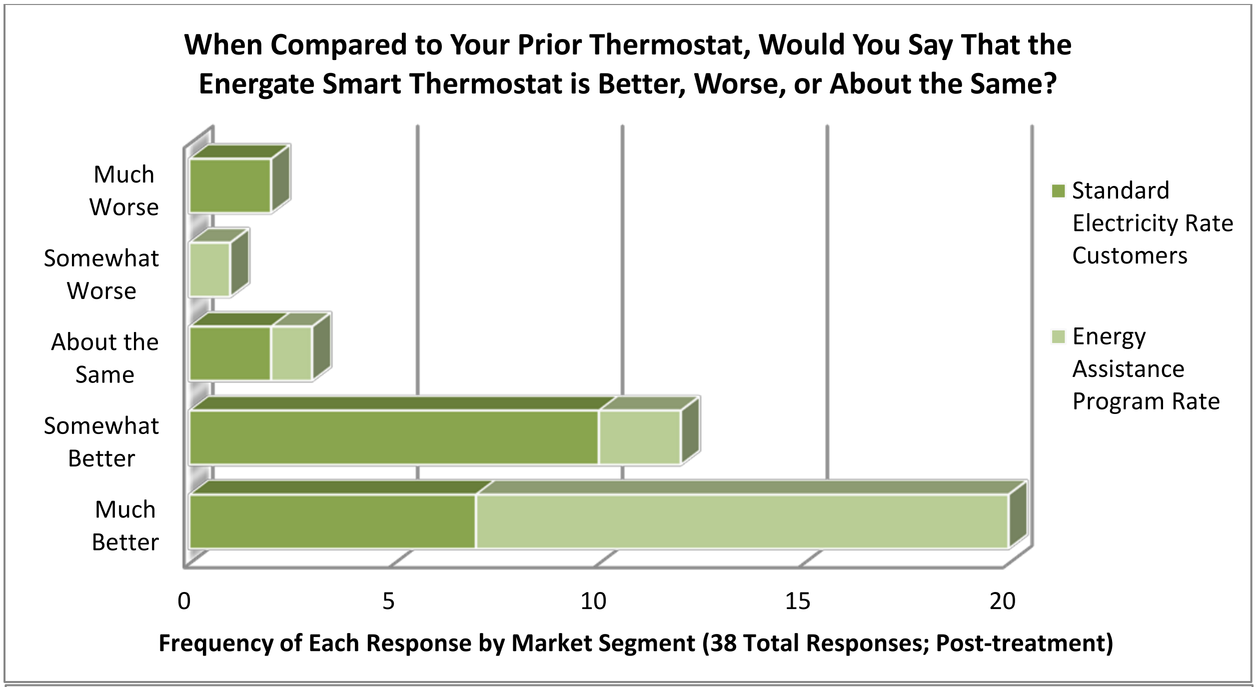

Please Rate the Following Feature of the PowerTab Electricity Use Display as Either Excellent, Good, Fair, Poor, or Very Poor: Conservation Day Day-Ahead Messaging?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

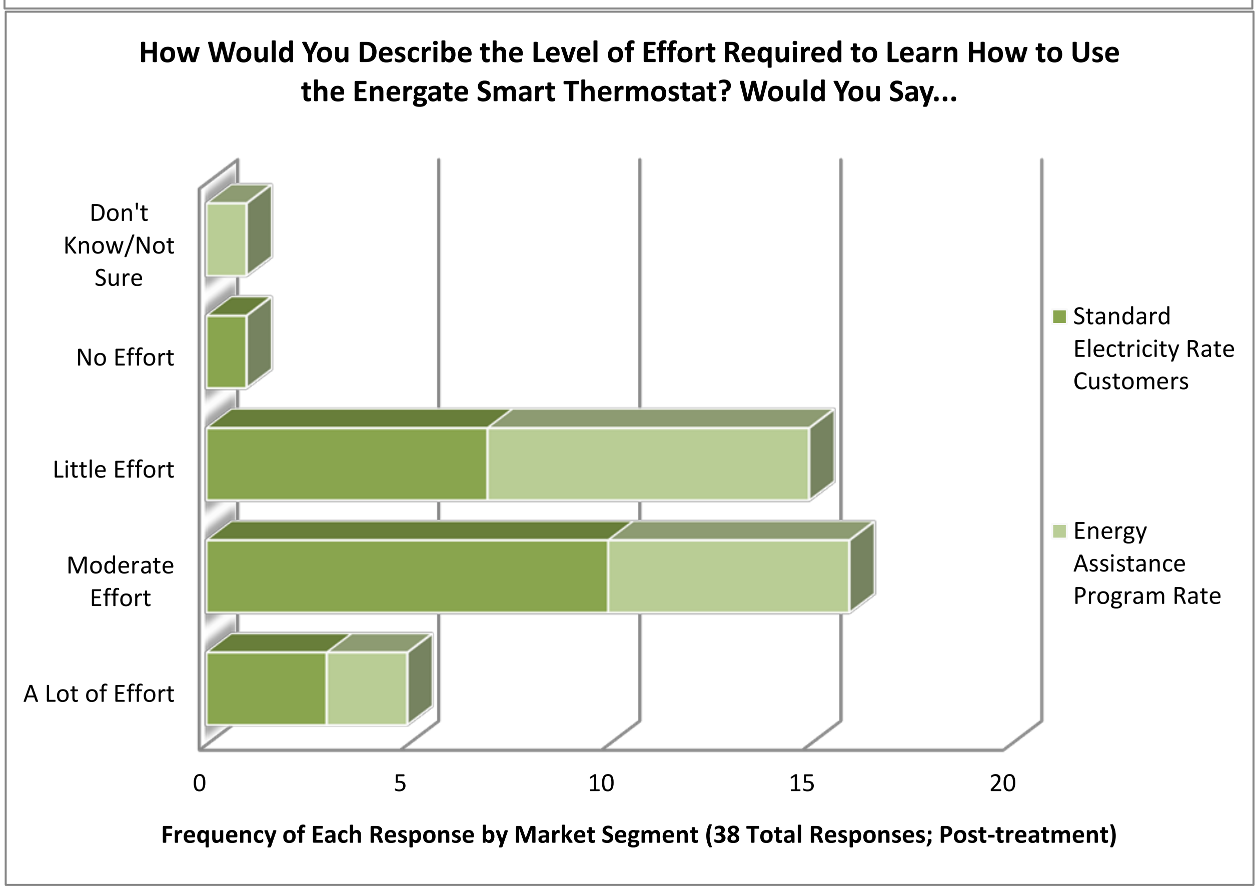

Please Rate the Following Feature of the PowerTab Electricity Use Display as Either Excellent, Good, Fair, Poor, or Very Poor: Energy Efficiency Messaging?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
5
10
15
20
25
30
35
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

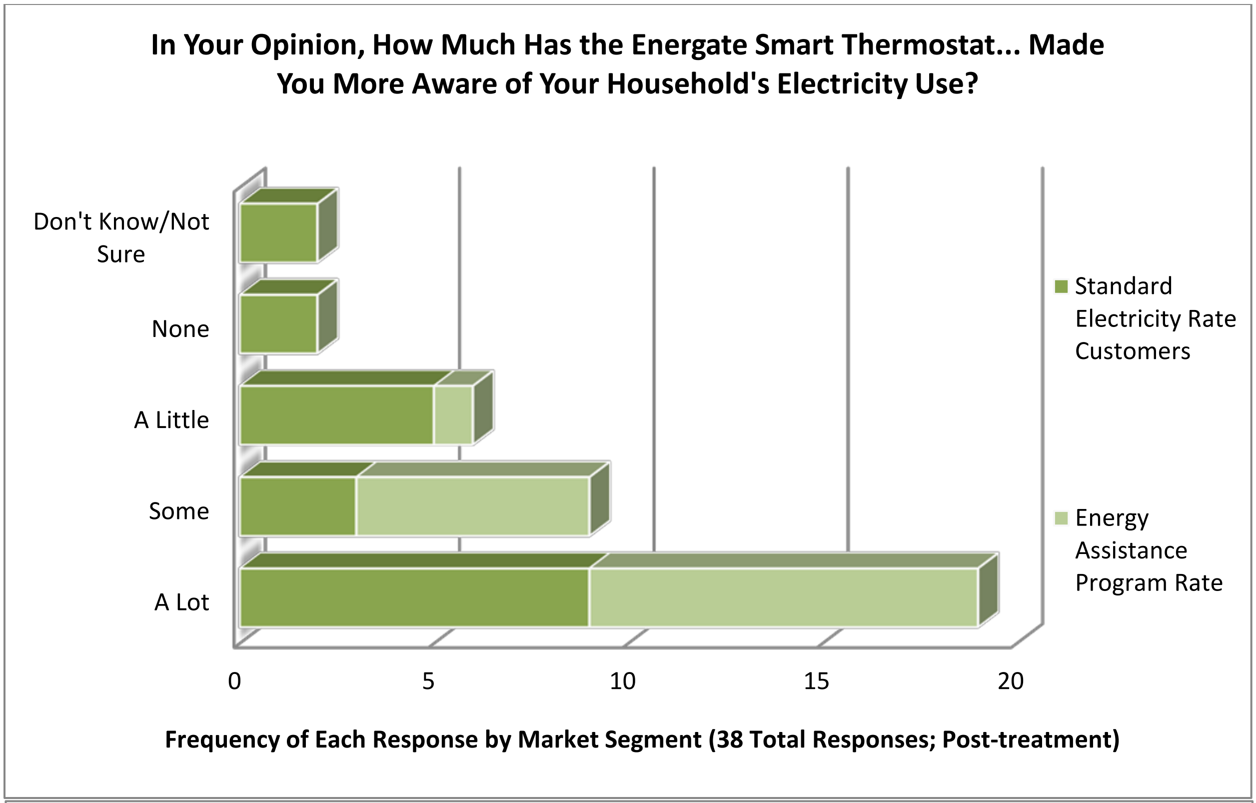

Please Rate the Following Feature of the PowerTab Electricity Use Display as Either Excellent, Good, Fair, Poor, or Very Poor: Ability to Reset the Cumulative Summary to Your Billing Cycle?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
5
10
15
20
25
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

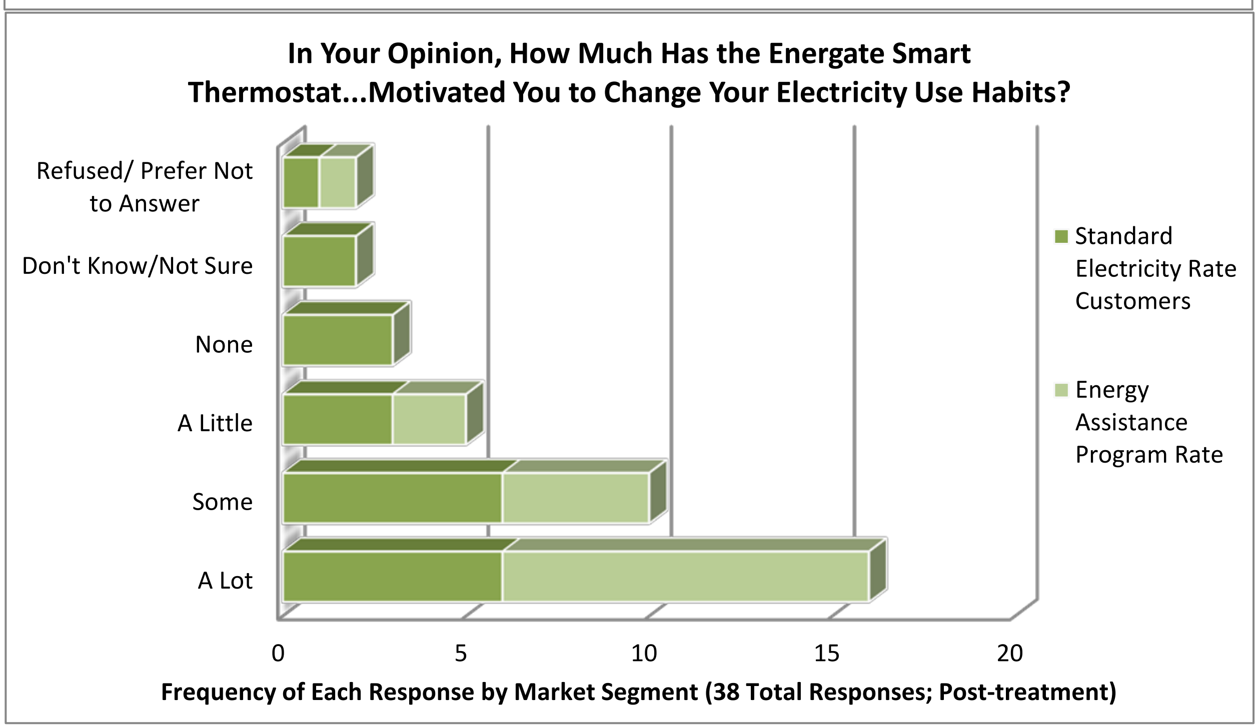

Over the Course of the 2013 Summer, How Often Did You Look at Your PowerTab Electricity Use Display, on Average?
Refused/Prefer Not to Answer
Never
Rarely
Only When the Lights Were Flashing
Once or Twice a Month
Once or Twice a Week
Once a Day
More than Once a Day
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

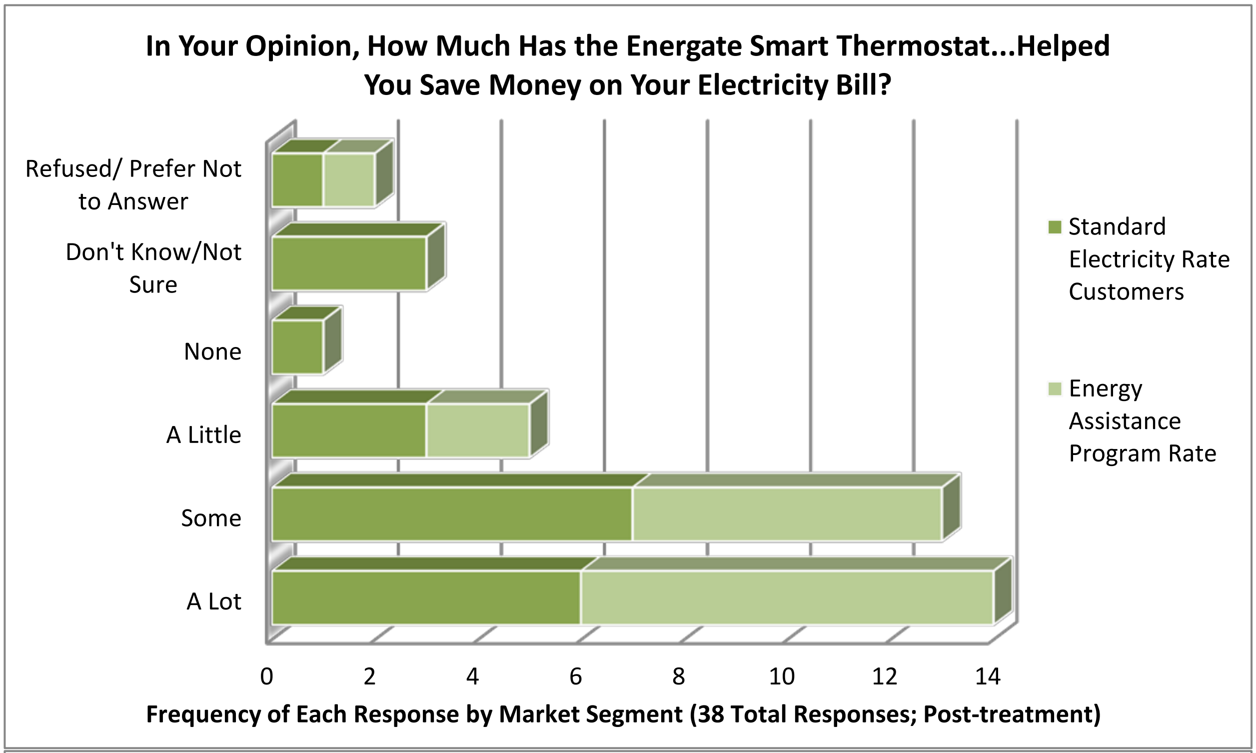

When You Did Look at the PowerTab, Was it Displaying Price and Usage Information...
Refused/Prefer Not to Answer
Never
Some of the Time
Most of the Time
All the Time
0
5
10
15
20
25
30
Frequency of Each Response by Market Segment (88 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

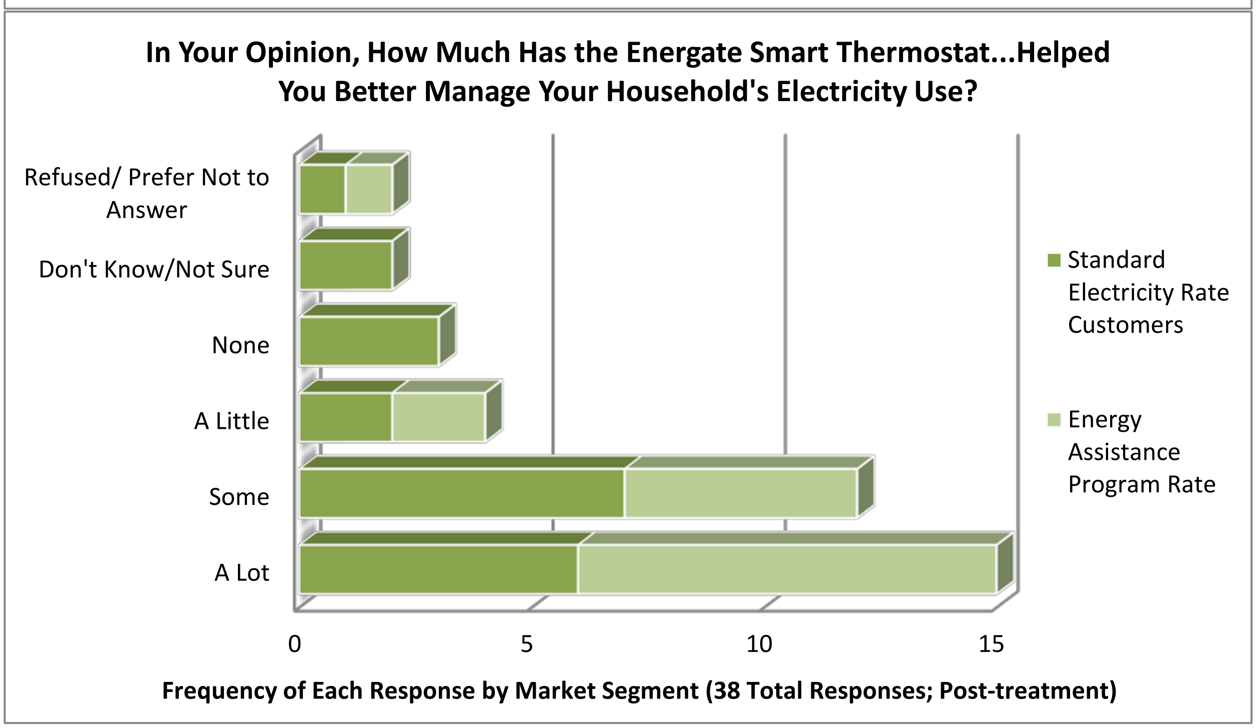

When Compared to Your Prior Thermostat, Would You Say That the Energate Smart Thermostat is Better, Worse, or About the Same?
Much Worse
Somewhat Worse
About the Same
Somewhat Better
Much Better
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

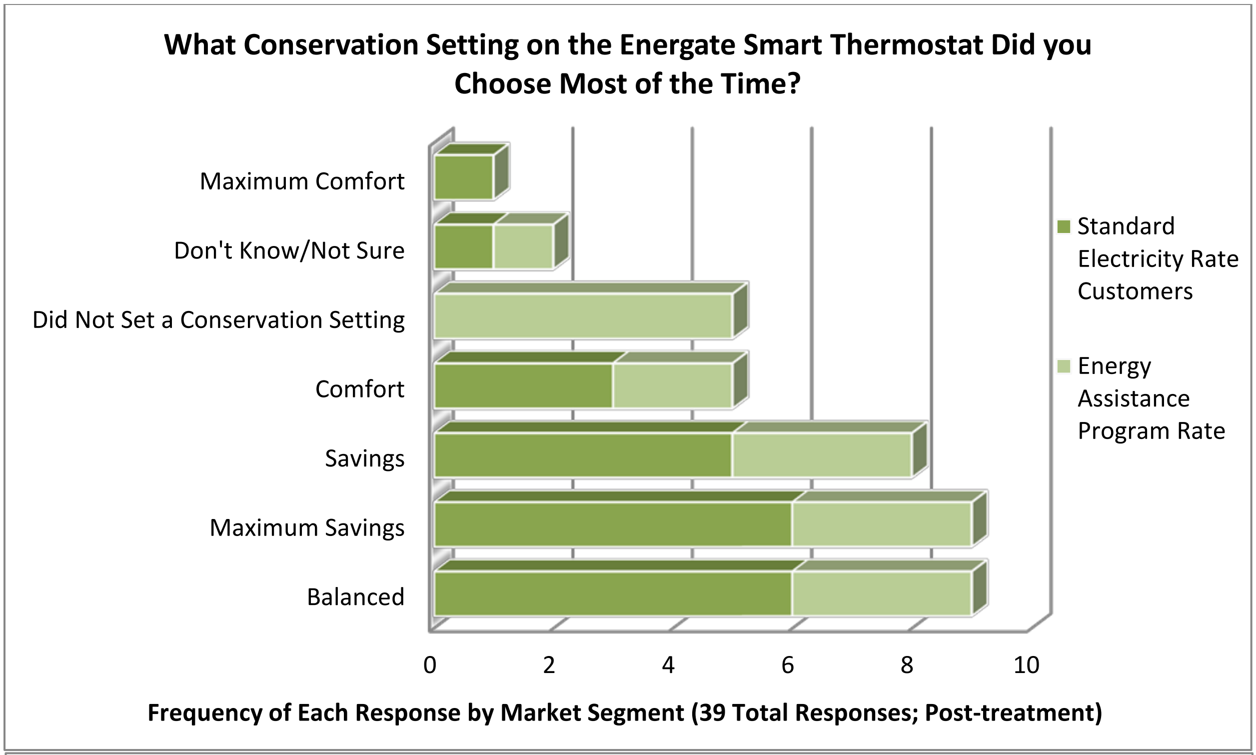

How Would You Describe the Level of Effort Required to Learn How to Use the Energate Smart Thermostat? Would You Say...
Don't Know/Not Sure
No Effort
Little Effort
Moderate Effort
A Lot of Effort
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

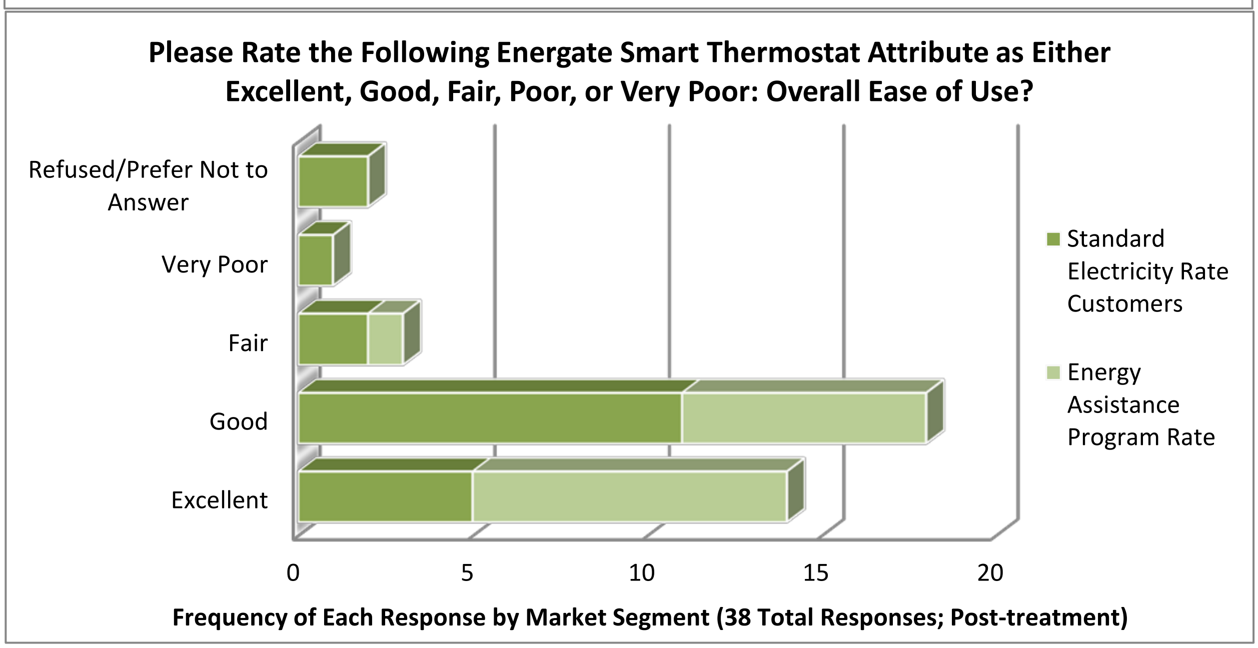

In Your Opinion, How Much Has the Energate Smart Thermostat... Made You More Aware of Your Household's Electricity Use?
Don't Know/Not Sure
None
A Little
Some
A Lot
0
5
10
15
20
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)

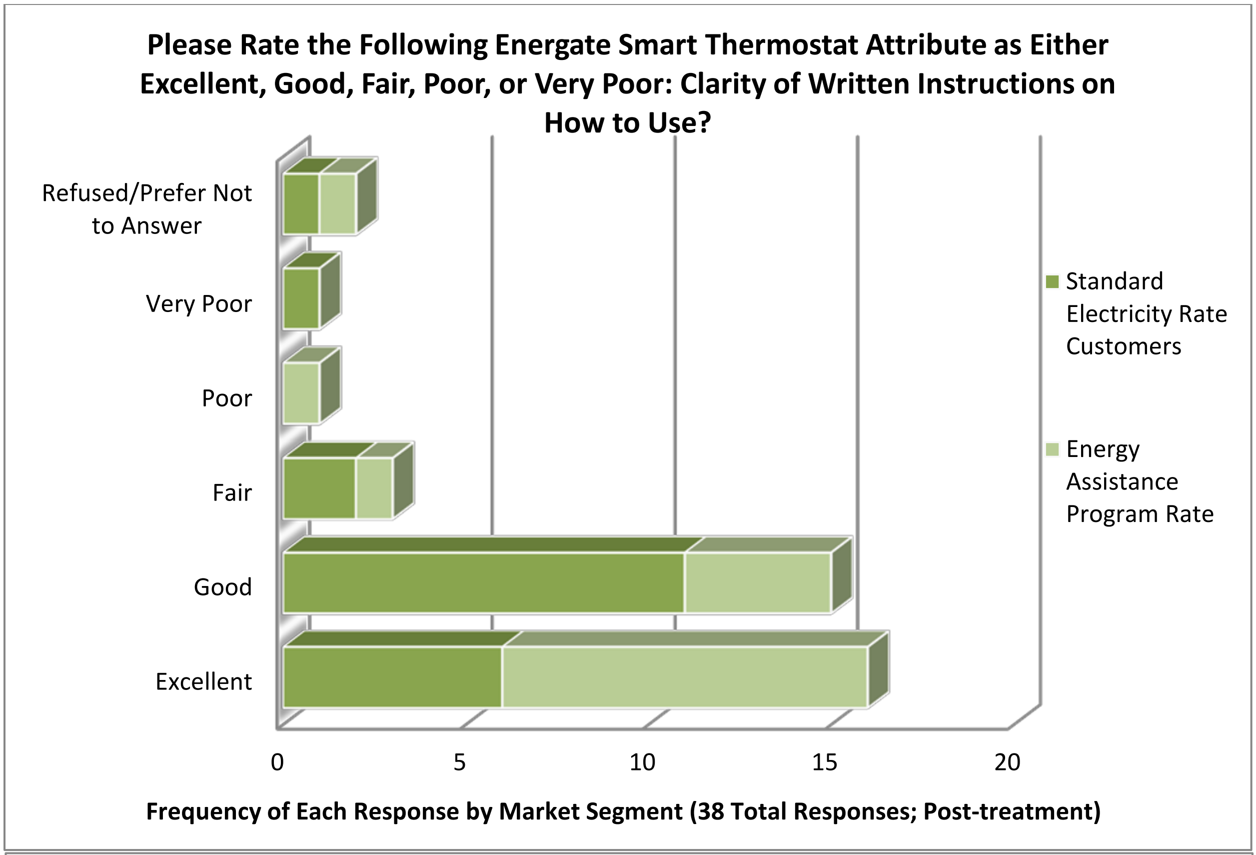

In Your Opinion, How Much Has the Energate Smart Thermostat...Motivated You to Change Your Electricity Use Habits?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
5
10
15
20
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)

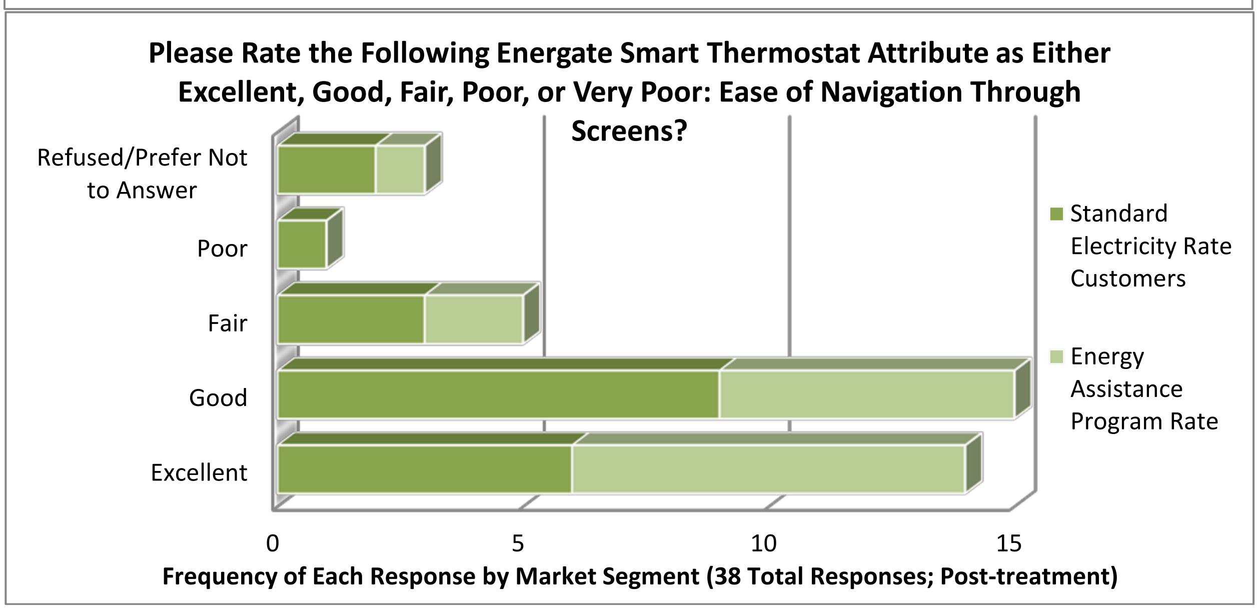

In Your Opinion, How Much Has the Energate Smart Thermostat...Helped You Save Money on Your Electricity Bill?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
2
4
6
8
10
12
14
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

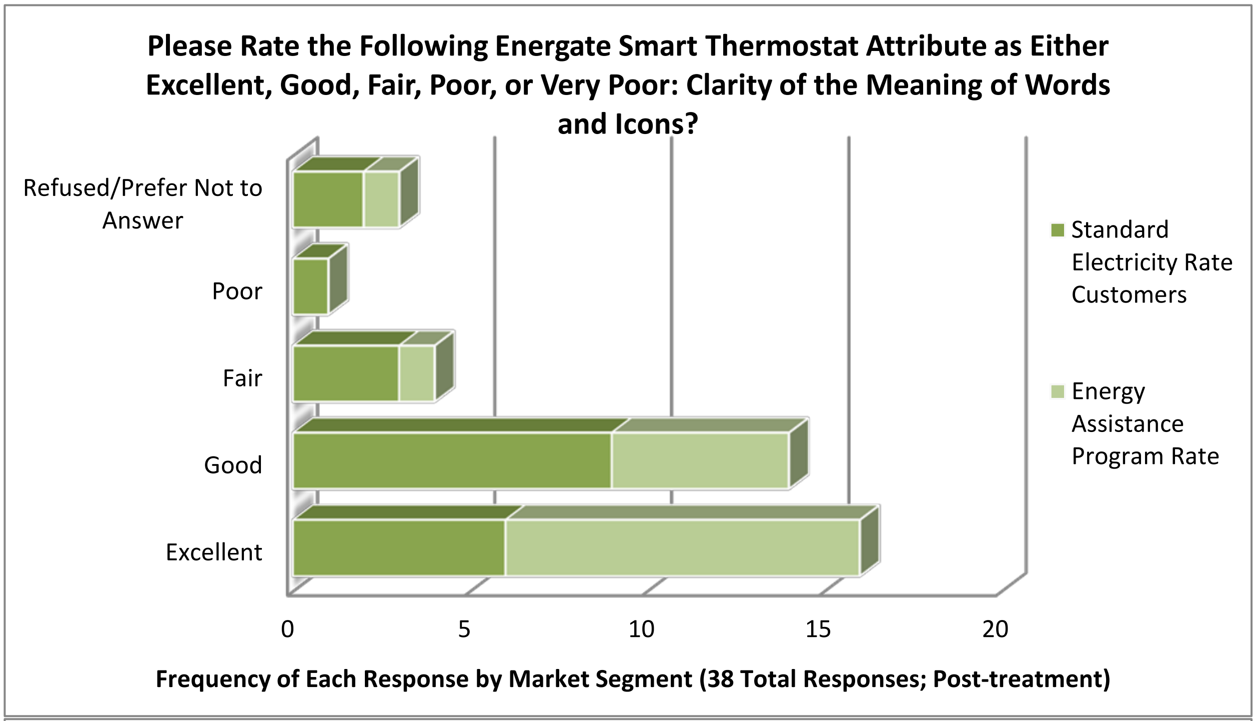

In Your Opinion, How Much Has the Energate Smart Thermostat...Helped You Better Manage Your Household's Electricity Use?
Refused/ Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
5
10
15
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

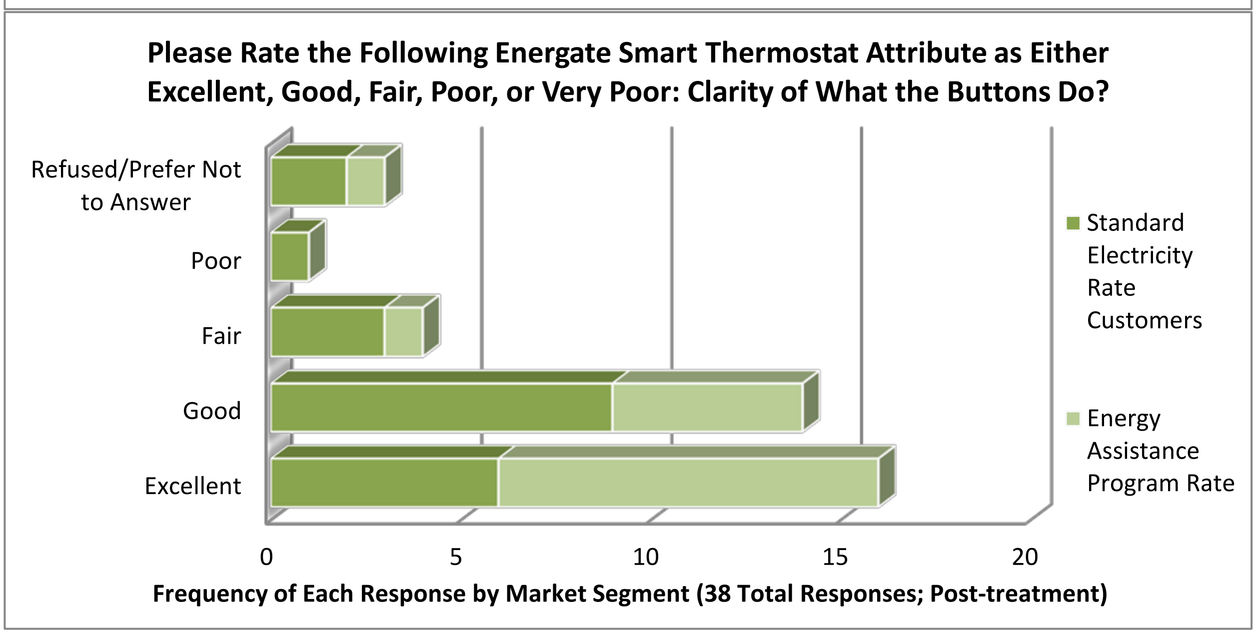

What Conservation Setting on the Energate Smart Thermostat Did you Choose Most of the Time?
Maximum Comfort
Don't Know/Not Sure
Did Not Set a Conservation Setting
Comfort
Savings
Maximum Savings
Balanced
0
2
4
6
8
10
Frequency of Each Response by Market Segment (39 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

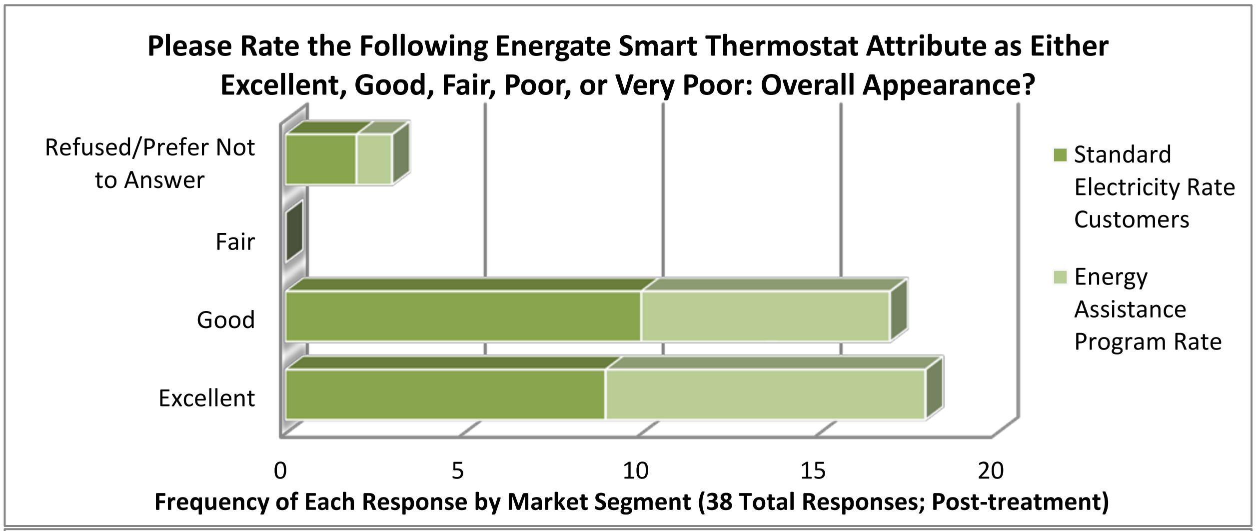

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Overall Ease of Use?
Refused/Prefer Not to Answer
Very Poor
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

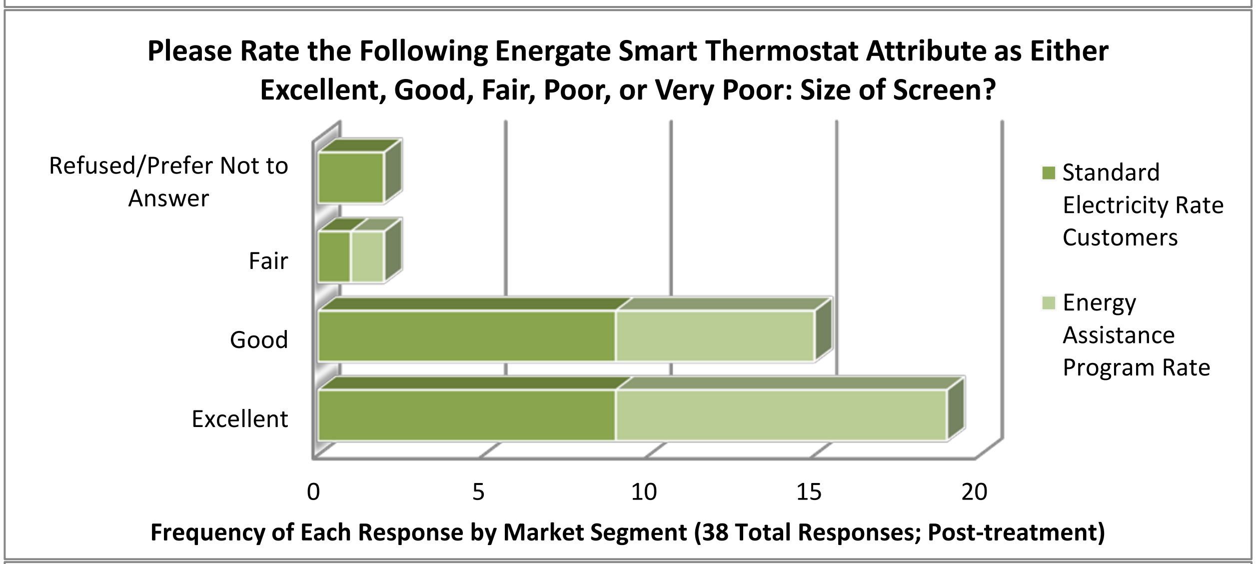

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Clarity of Written Instructions on How to Use?
Refused/Prefer Not to Answer
Very Poor
Poor
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

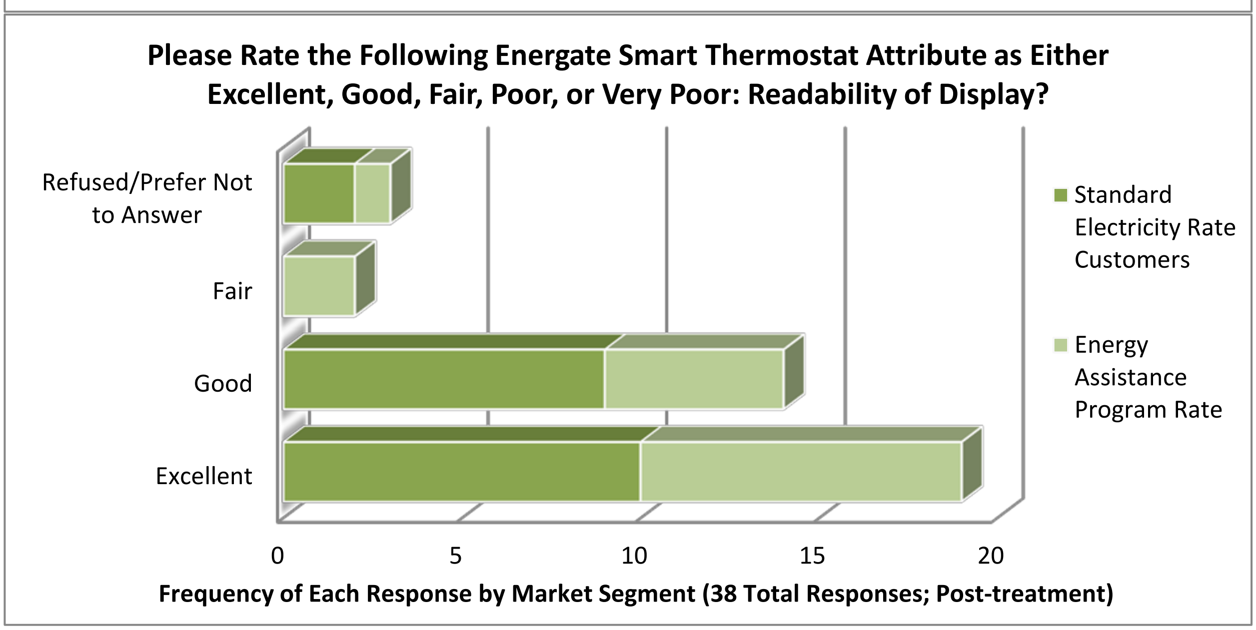

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Ease of Navigation Through Screens?
Refused/Prefer Not to Answer
Poor
Fair
Good
Excellent
0
5
10
15
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

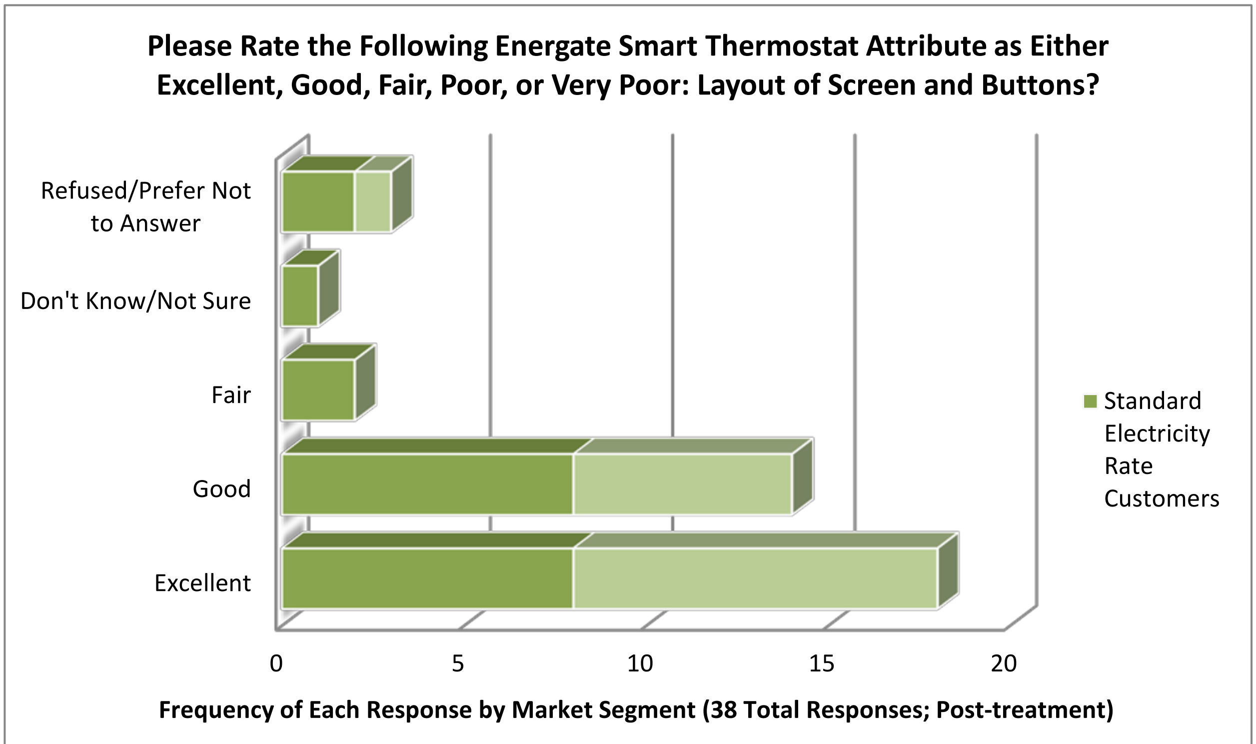

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Clarity of the Meaning of Words and Icons?
Refused/Prefer Not to Answer
Poor
Fair
Good
Excellent
0
5
10
15
20
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)

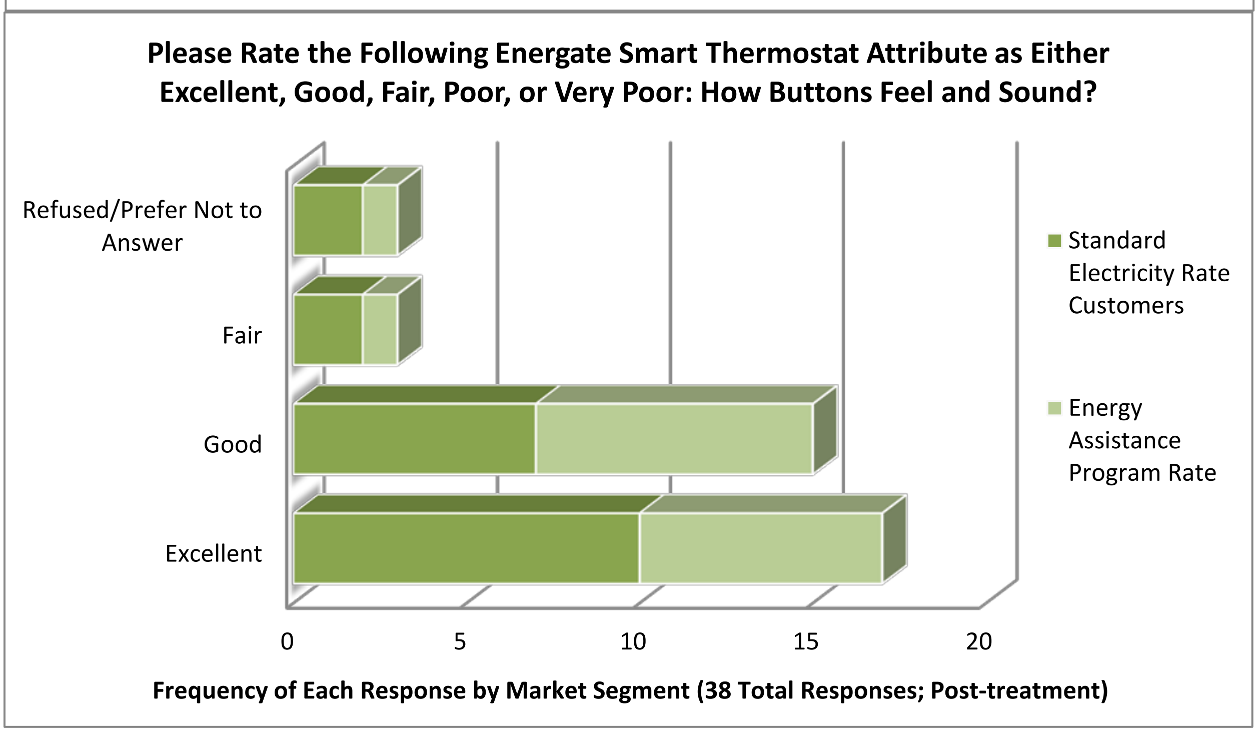

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Clarity of What the Buttons Do?
Refused/Prefer Not to Answer
Poor
Fair
Good
Excellent
0
5
10
15
20
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)

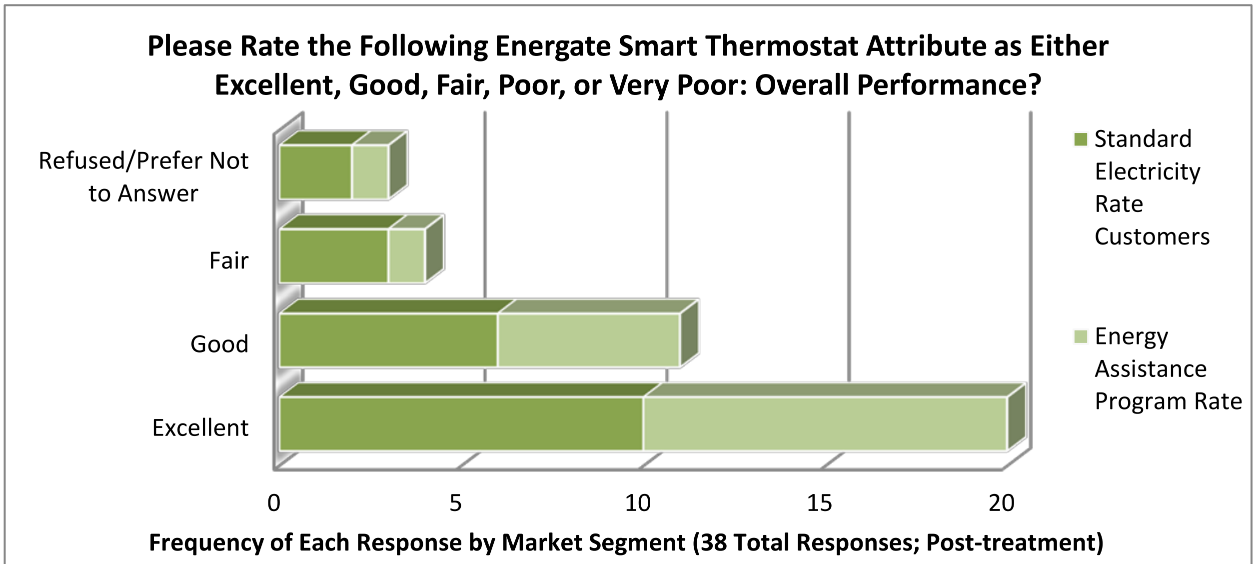

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Overall Appearance?
Refused/Prefer Not to Answer
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

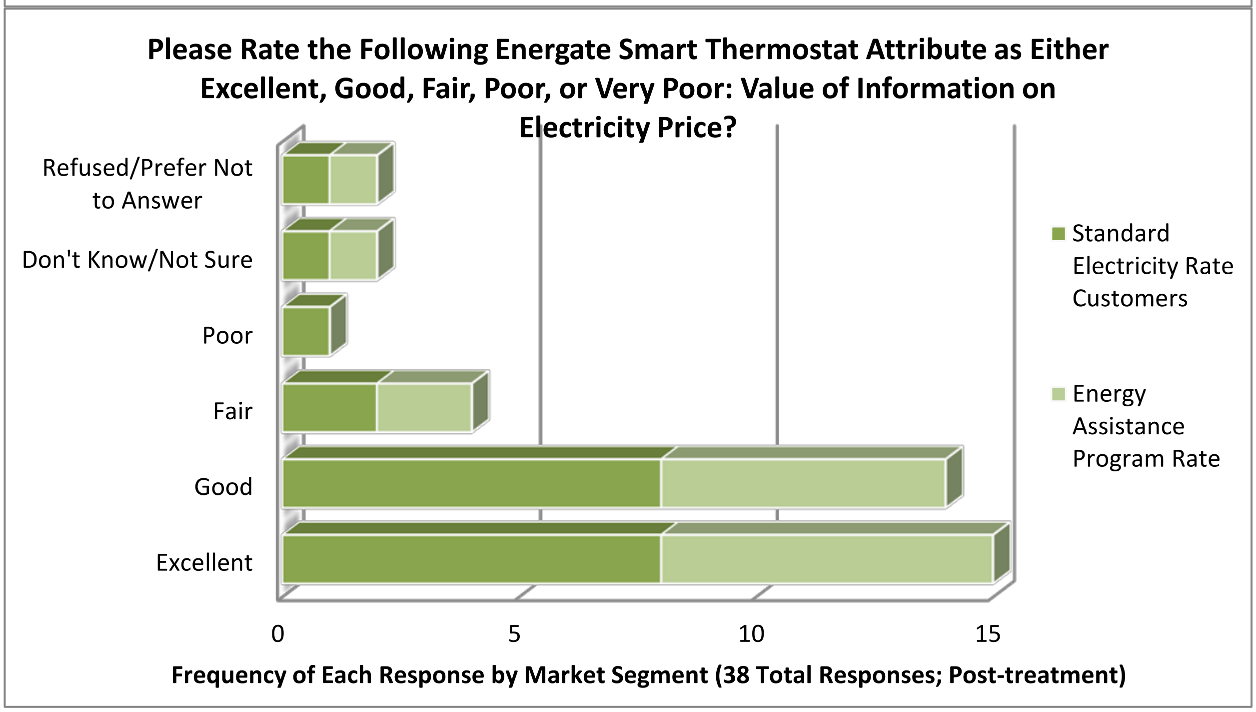

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Size of Screen?
Refused/Prefer Not to Answer
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

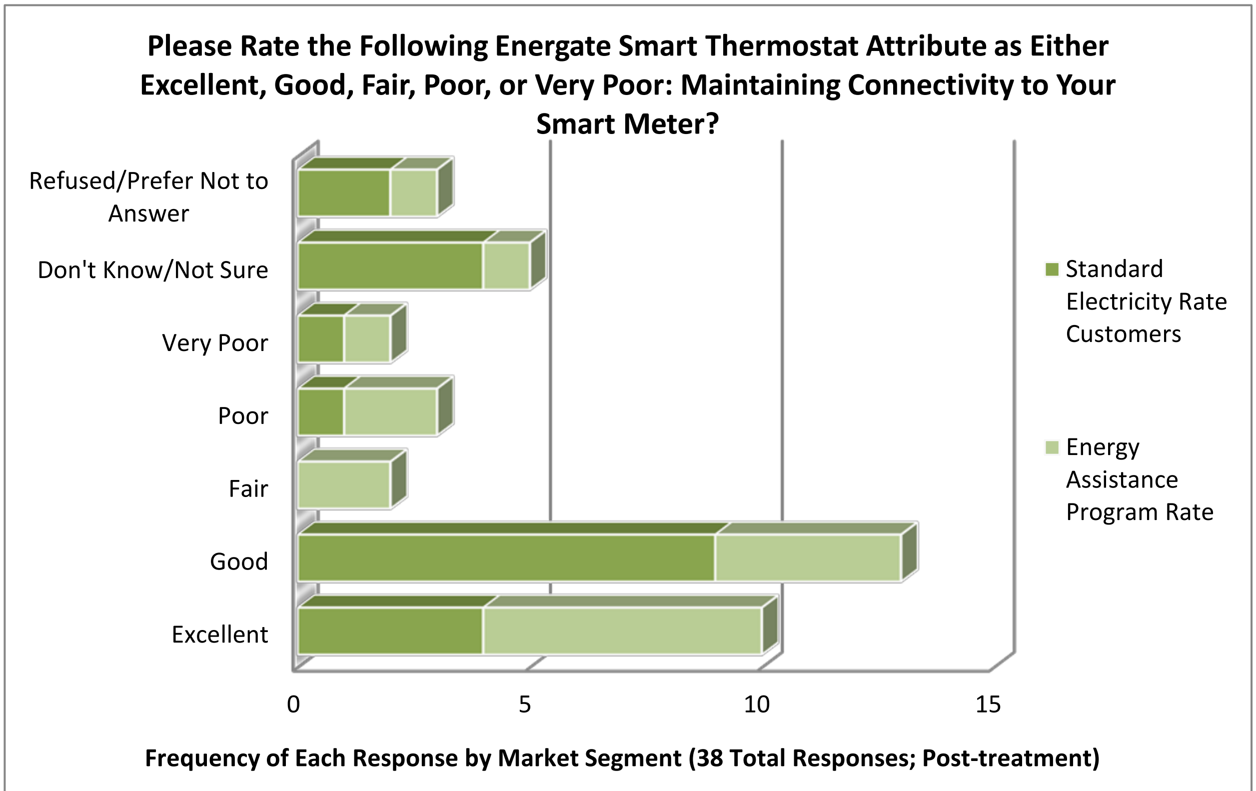

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Readability of Display?
Refused/Prefer Not to Answer
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

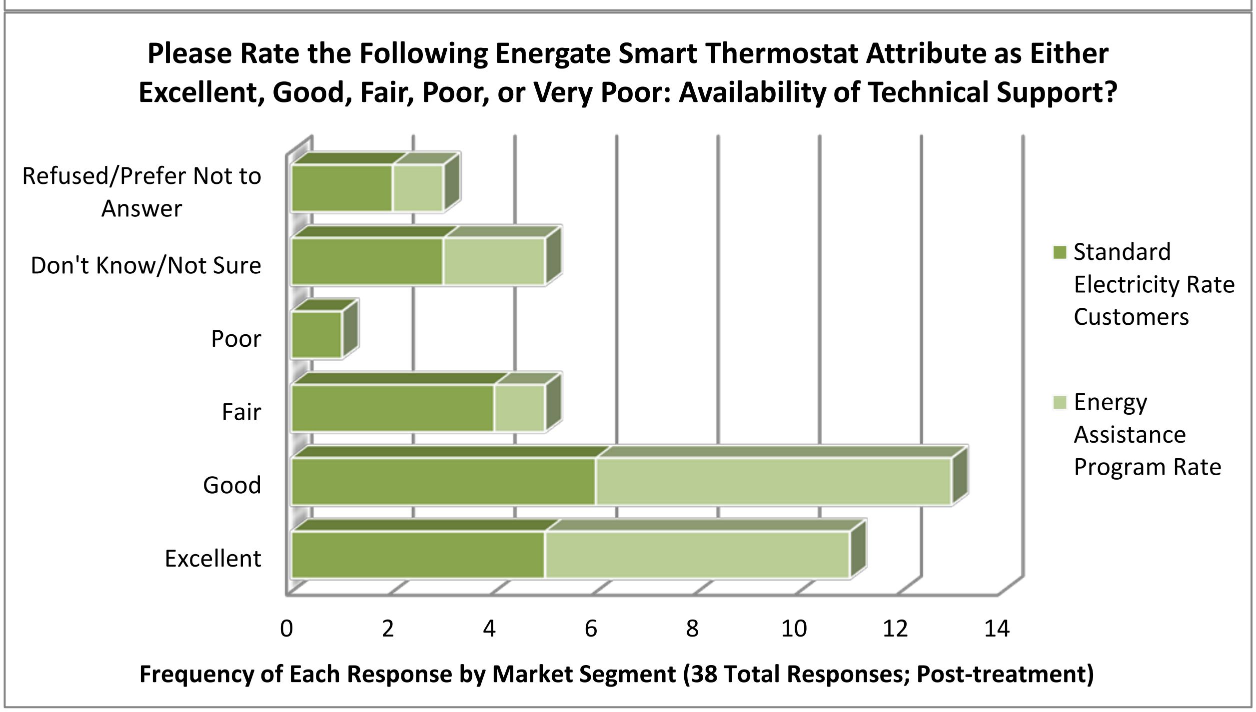

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Layout of Screen and Buttons?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers

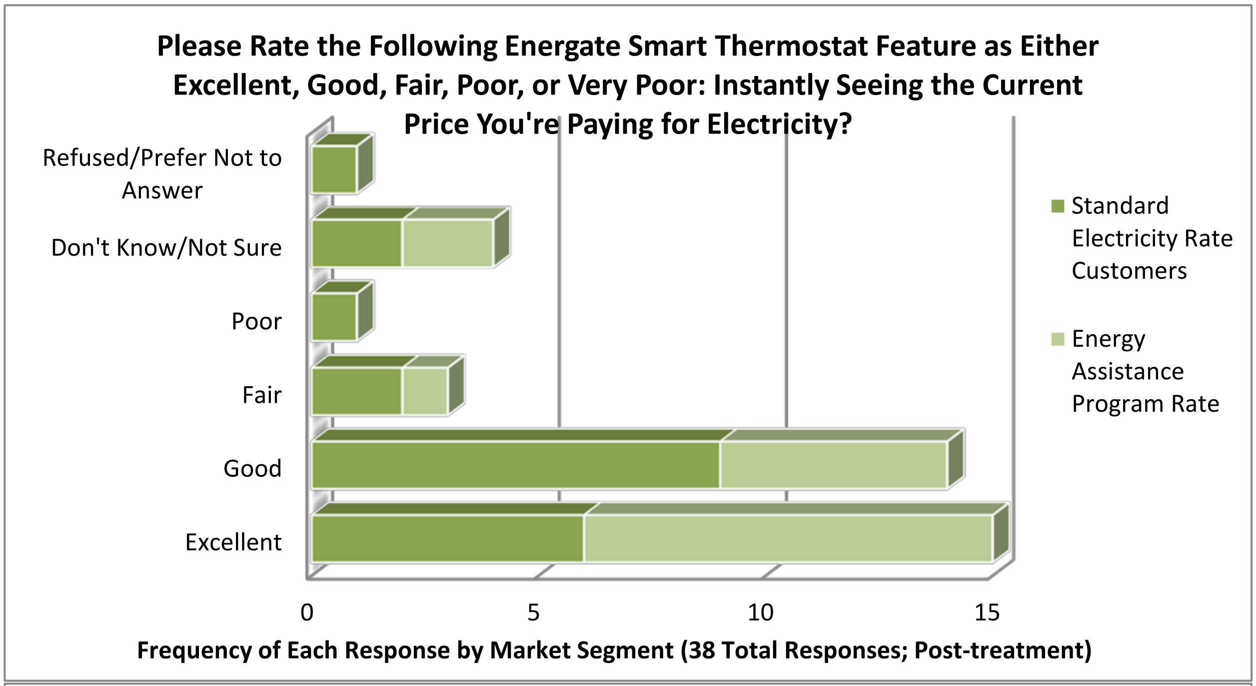

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: How Buttons Feel and Sound?
Refused/Prefer Not to Answer
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

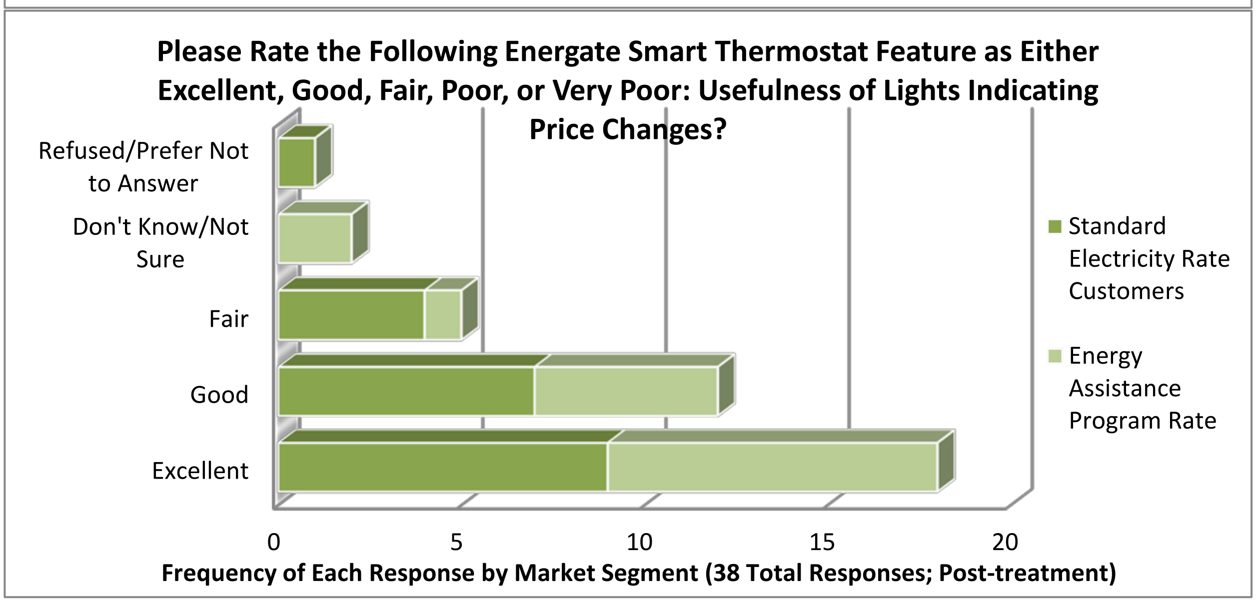

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Overall Performance?
Refused/Prefer Not to Answer
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

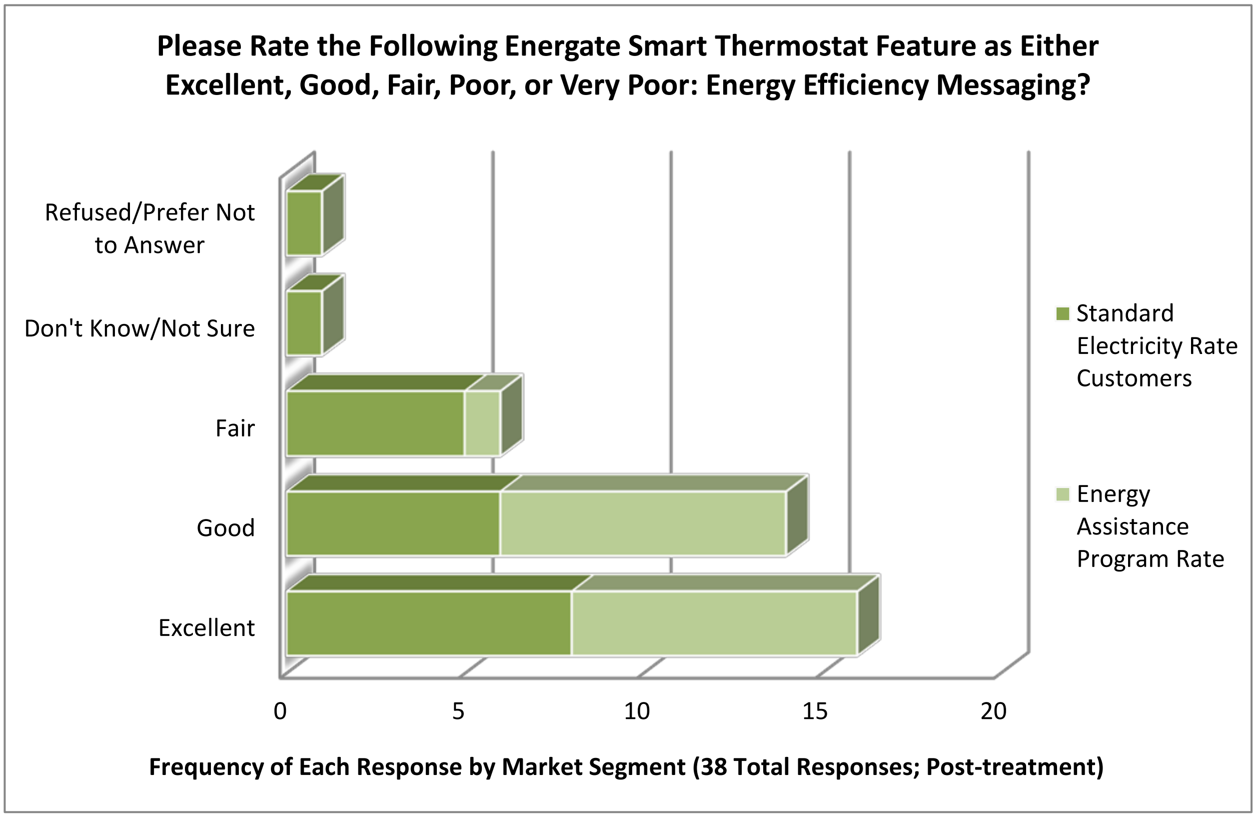

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Value of Information on Electricity Price?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Poor
Fair
Good
Excellent
0
5
10
15
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

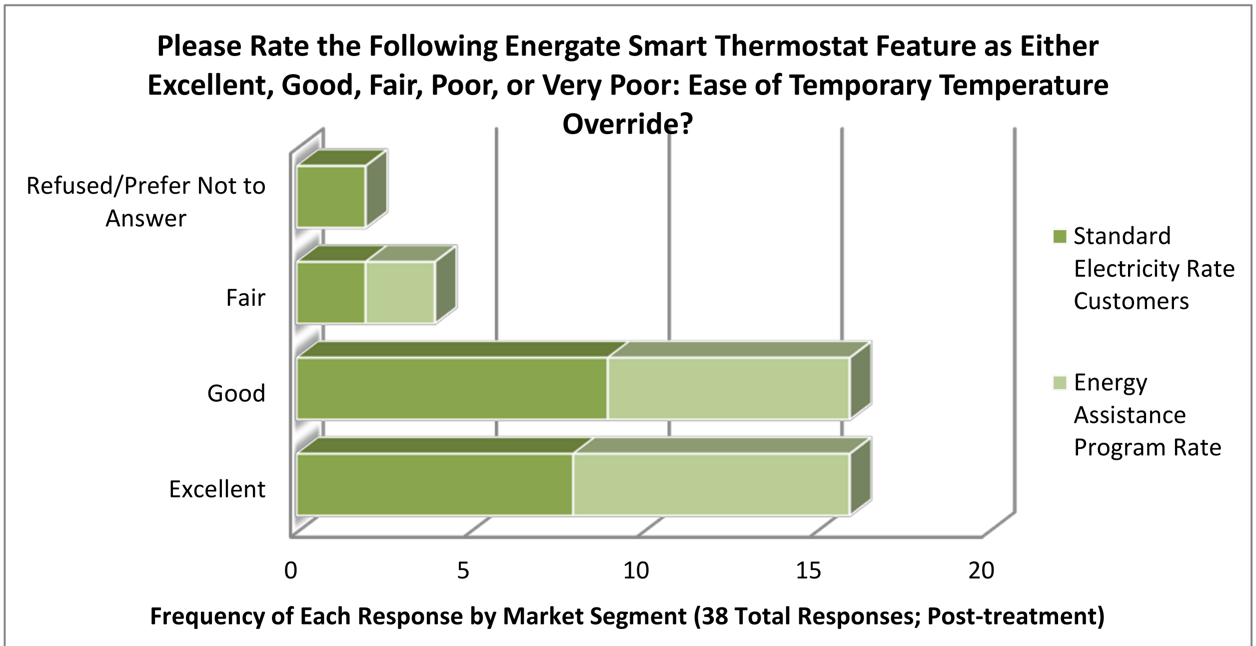

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Maintaining Connectivity to Your Smart Meter?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Poor
Poor
Fair
Good
Excellent
0
5
10
15
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

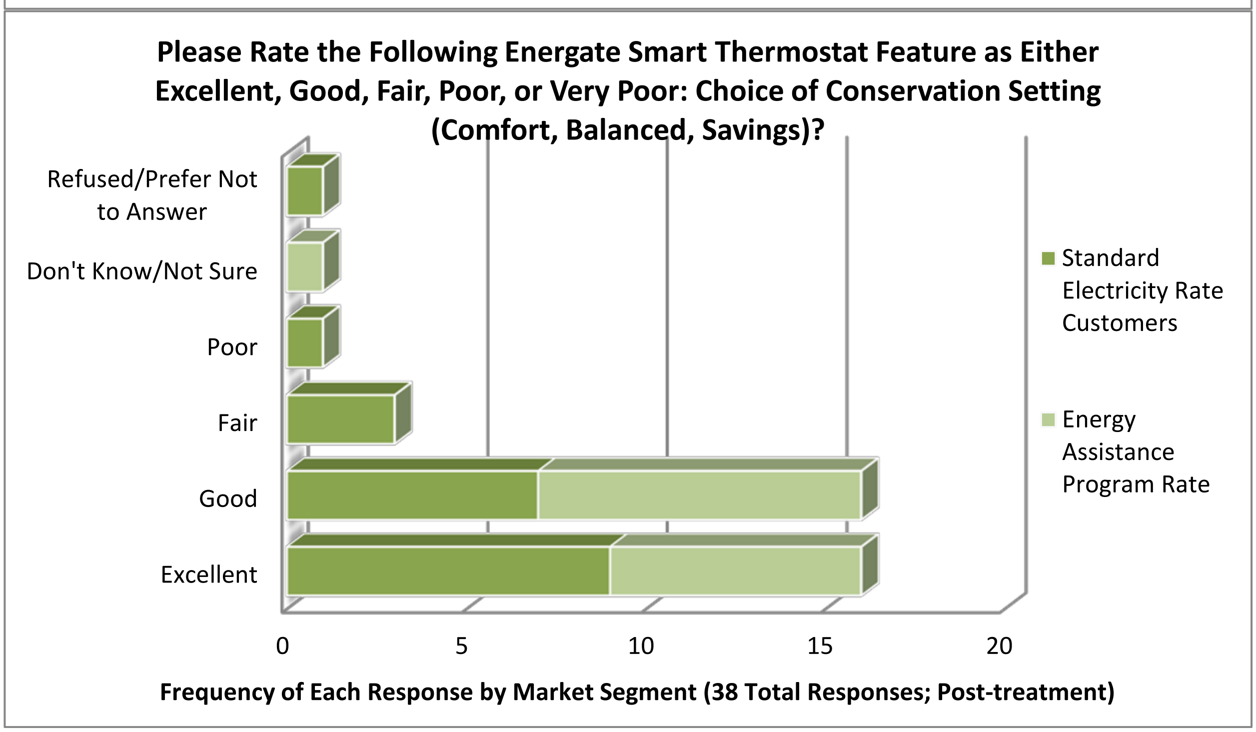

Please Rate the Following Energate Smart Thermostat Attribute as Either Excellent, Good, Fair, Poor, or Very Poor: Availability of Technical Support?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Poor
Fair
Good
Excellent
0
2
4
6
8
10
12
14
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

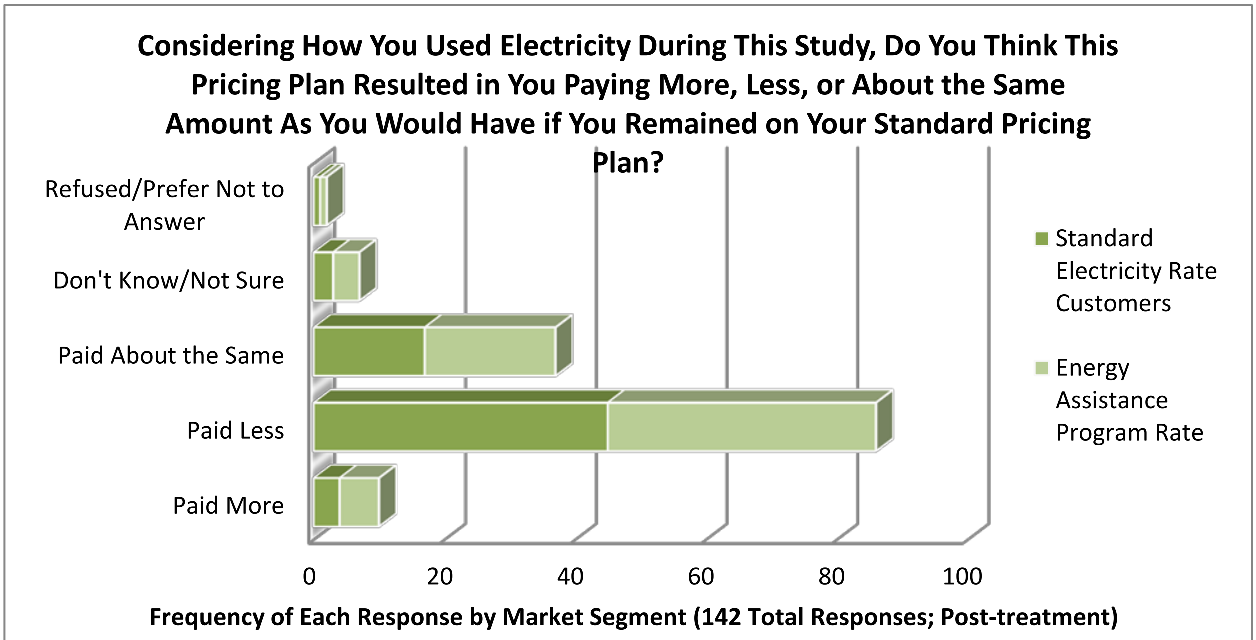

Please Rate the Following Energate Smart Thermostat Feature as Either Excellent, Good, Fair, Poor, or Very Poor: Instantly Seeing the Current Price You're Paying for Electricity?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Poor
Fair
Good
Excellent
0
5
10
15
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

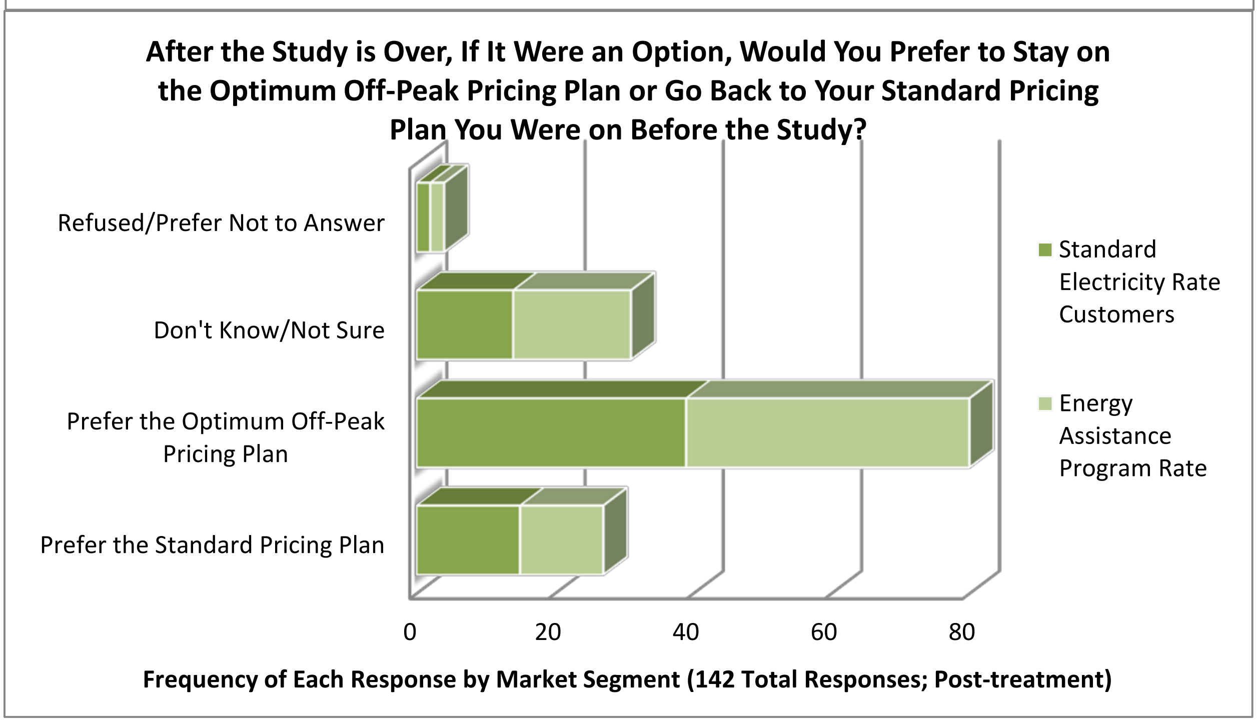

Please Rate the Following Energate Smart Thermostat Feature as Either Excellent, Good, Fair, Poor, or Very Poor: Usefulness of Lights Indicating Price Changes?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

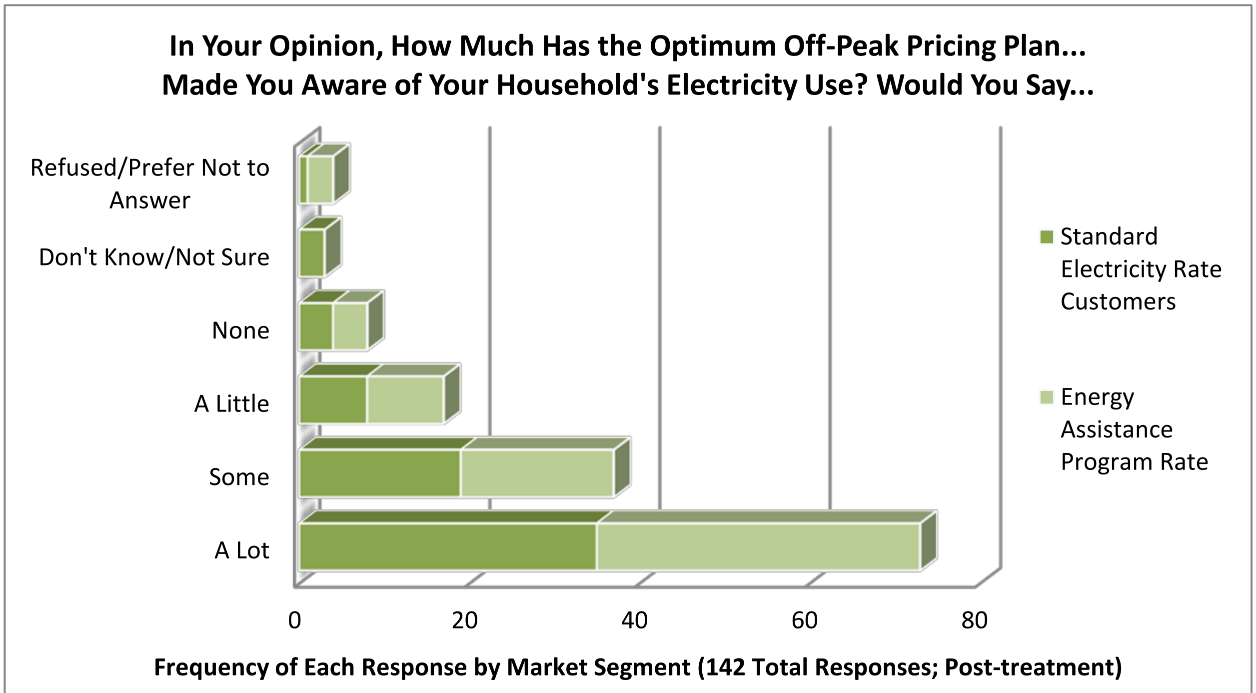

Please Rate the Following Energate Smart Thermostat Feature as Either Excellent, Good, Fair, Poor, or Very Poor: Energy Efficiency Messaging?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

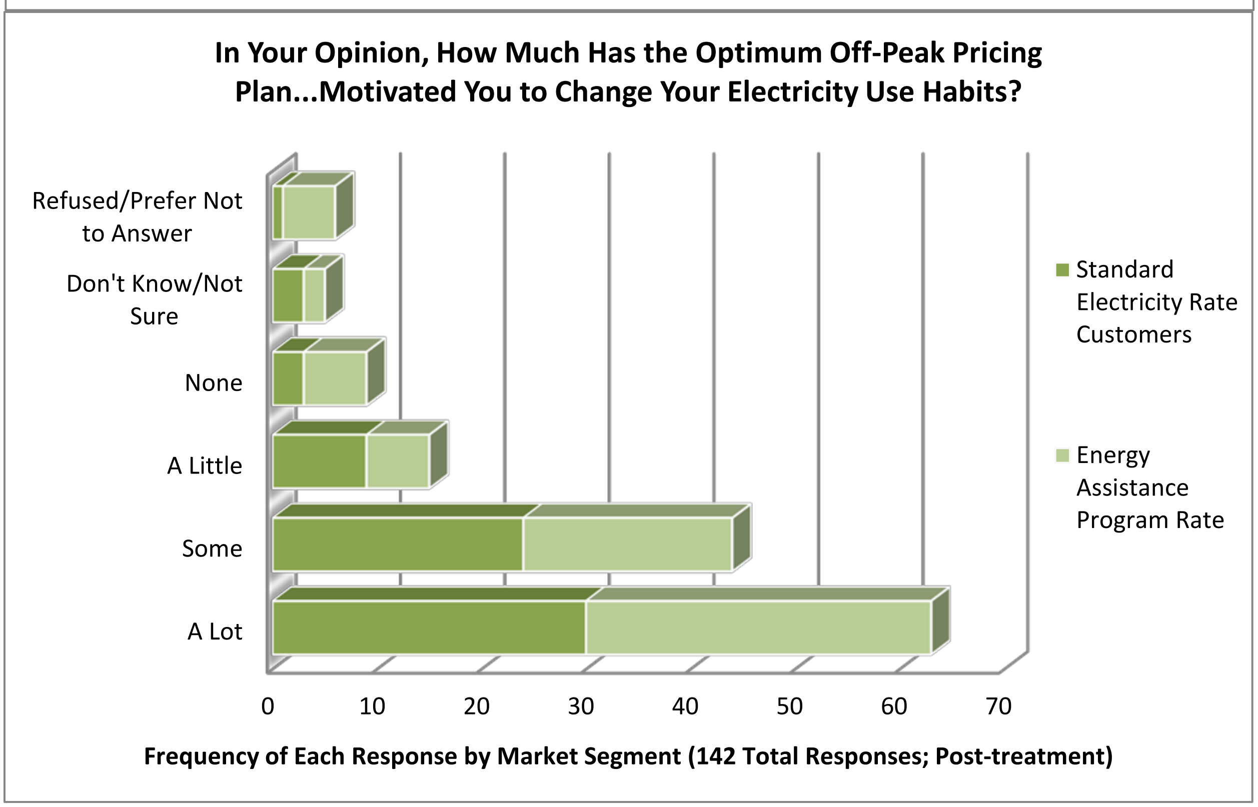

Please Rate the Following Energate Smart Thermostat Feature as Either Excellent, Good, Fair, Poor, or Very Poor: Ease of Temporary Temperature Override?
Refused/Prefer Not to Answer
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

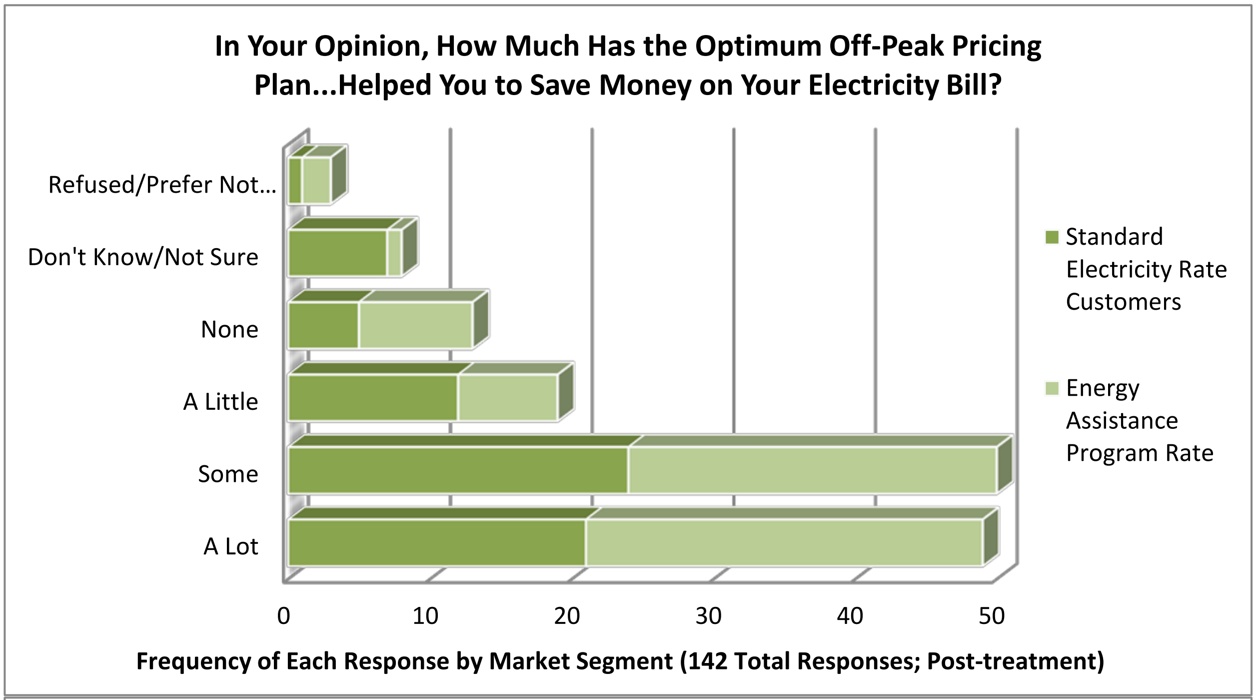

Please Rate the Following Energate Smart Thermostat Feature as Either Excellent, Good, Fair, Poor, or Very Poor: Choice of Conservation Setting (Comfort, Balanced, Savings)?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Poor
Fair
Good
Excellent
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

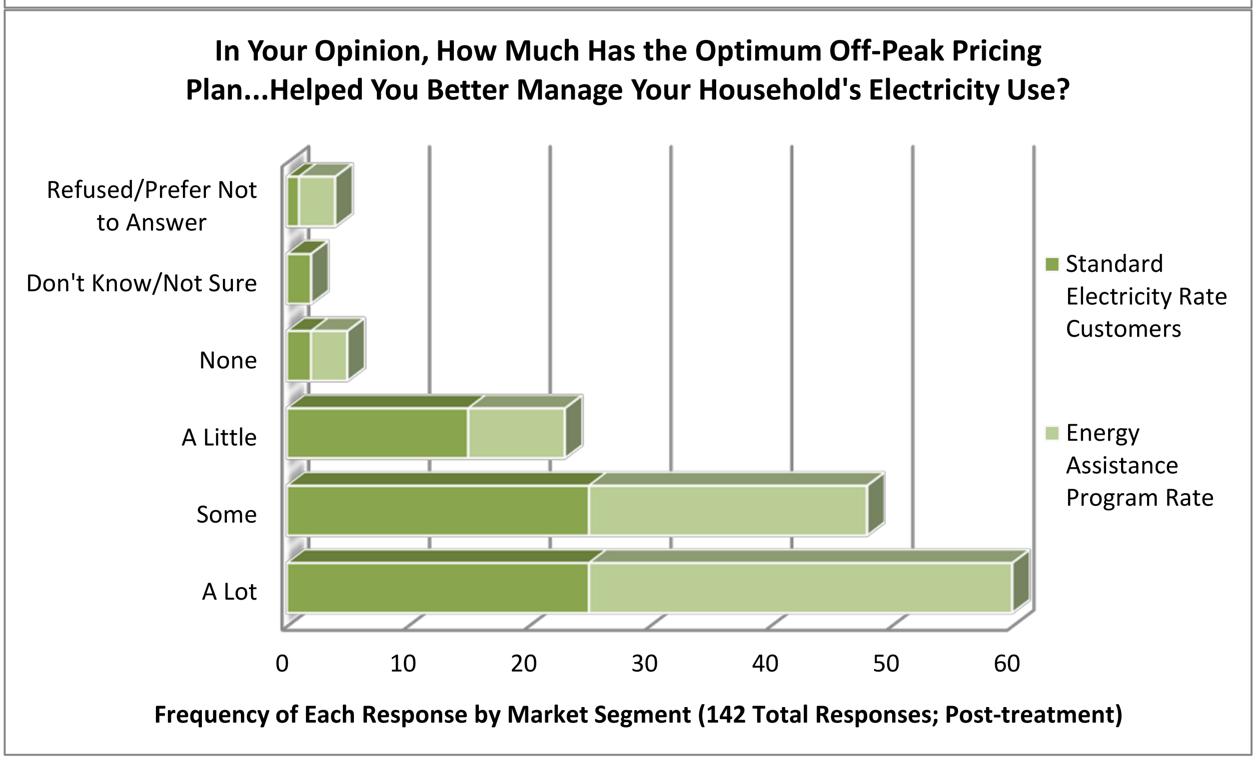

Considering How You Used Electricity During This Study, Do You Think This Pricing Plan Resulted in You Paying More, Less, or About the Same Amount As You Would Have if You Remained on Your Standard Pricing Plan?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Paid About the Same
Paid Less
Paid More
0
20
40
60
80
100
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

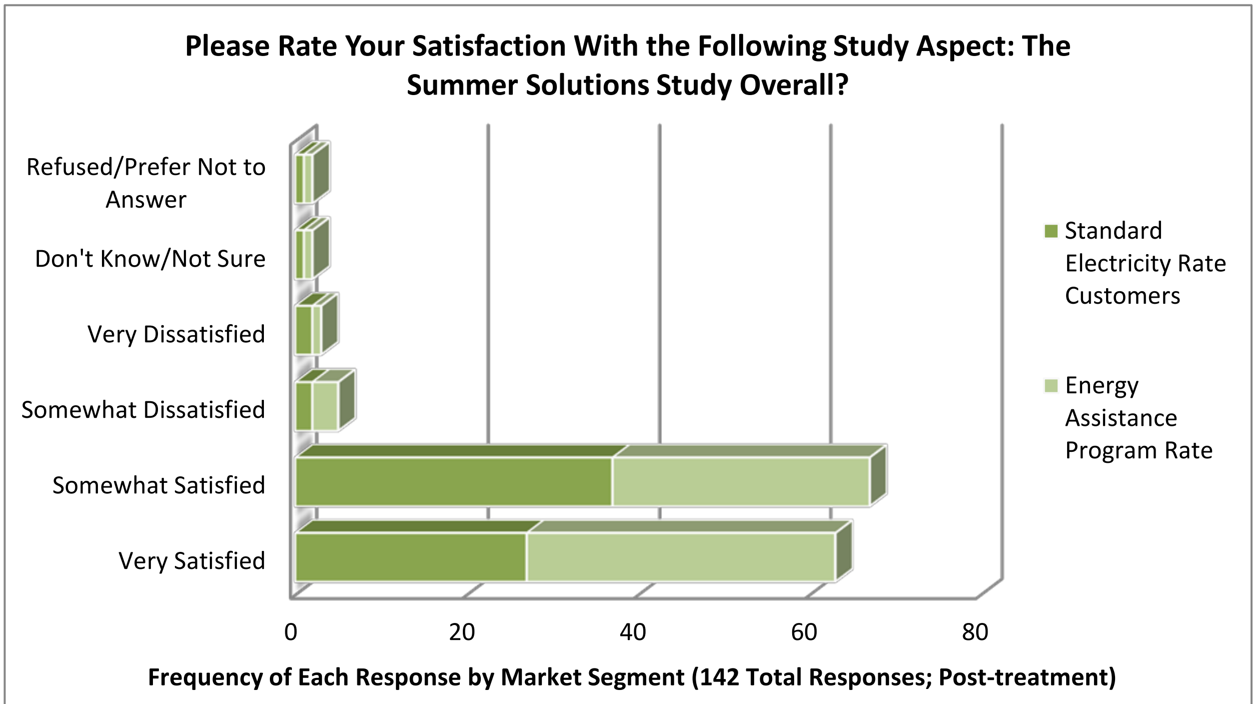

After the Study is Over, If It Were an Option, Would You Prefer to Stay on the Optimum Off-Peak Pricing Plan or Go Back to Your Standard Pricing Plan You Were on Before the Study?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Prefer the Optimum Off-Peak Pricing Plan
Prefer the Standard Pricing Plan
0
20
40
60
80
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

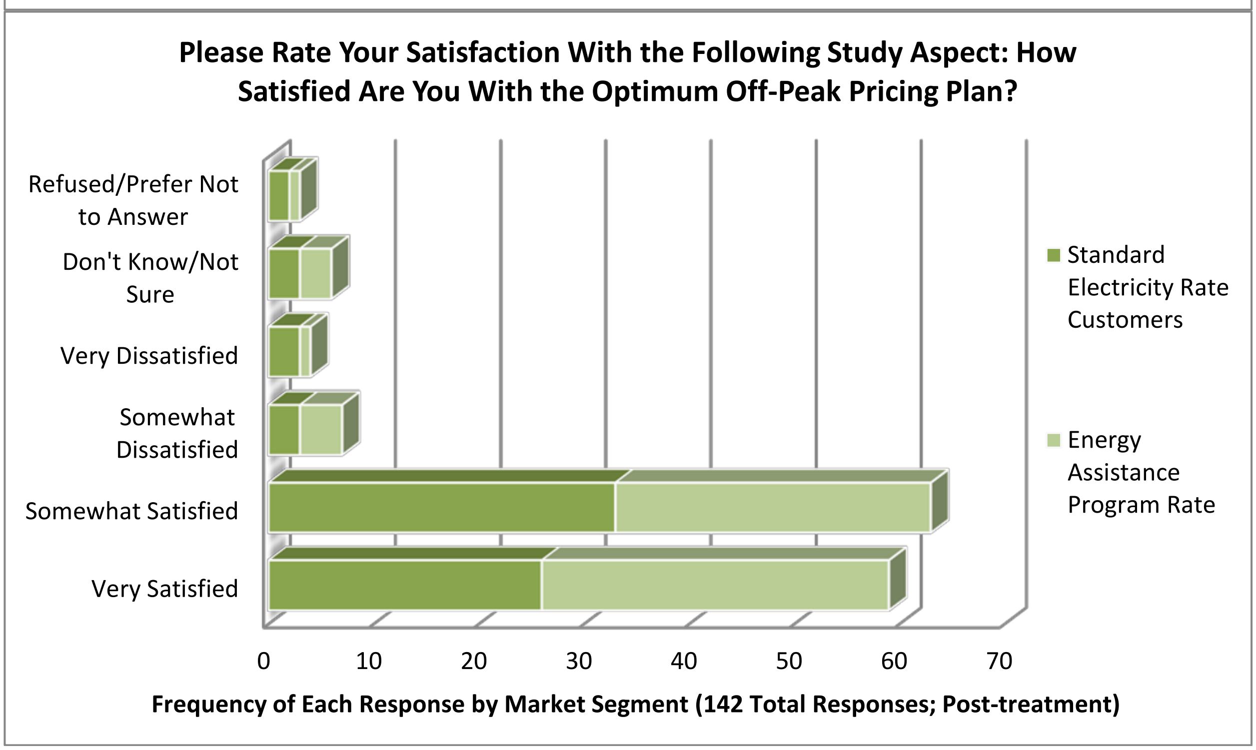

In Your Opinion, How Much Has the Optimum Off-Peak Pricing Plan...
Made You Aware of Your Household's Electricity Use? Would You Say...
Refused/Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
20
40
60
80
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

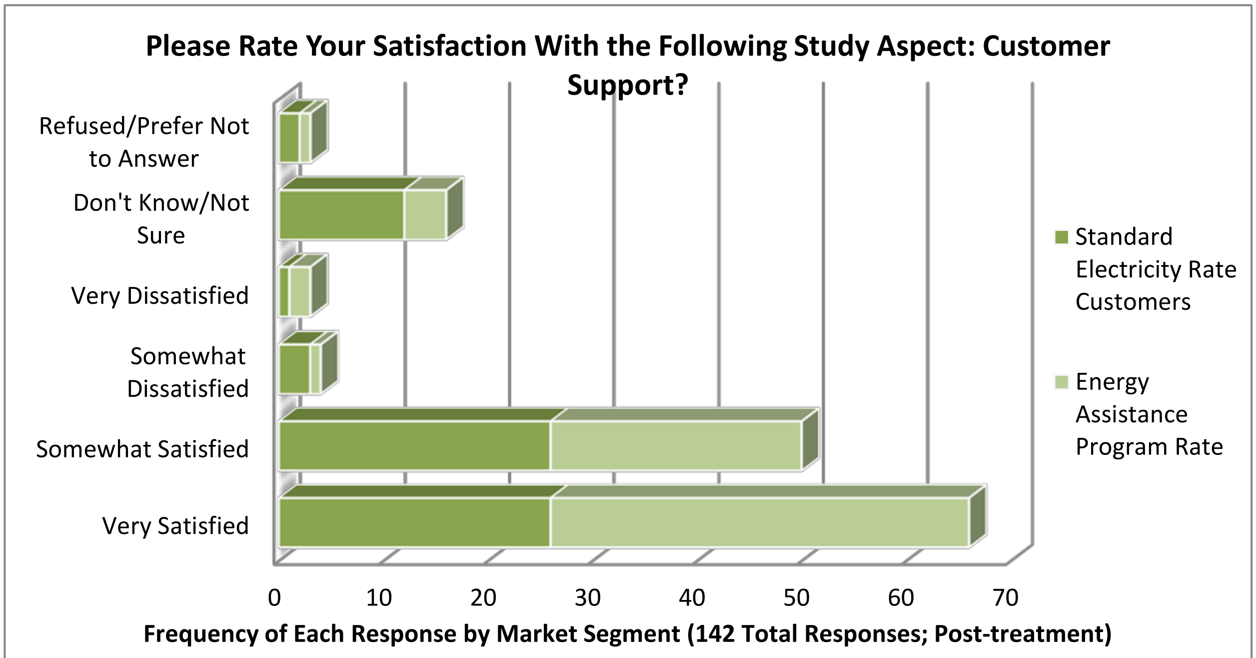

In Your Opinion, How Much Has the Optimum Off-Peak Pricing Plan...Motivated You to Change Your Electricity Use Habits?
Refused/Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
10
20
30
40
50
60
70
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

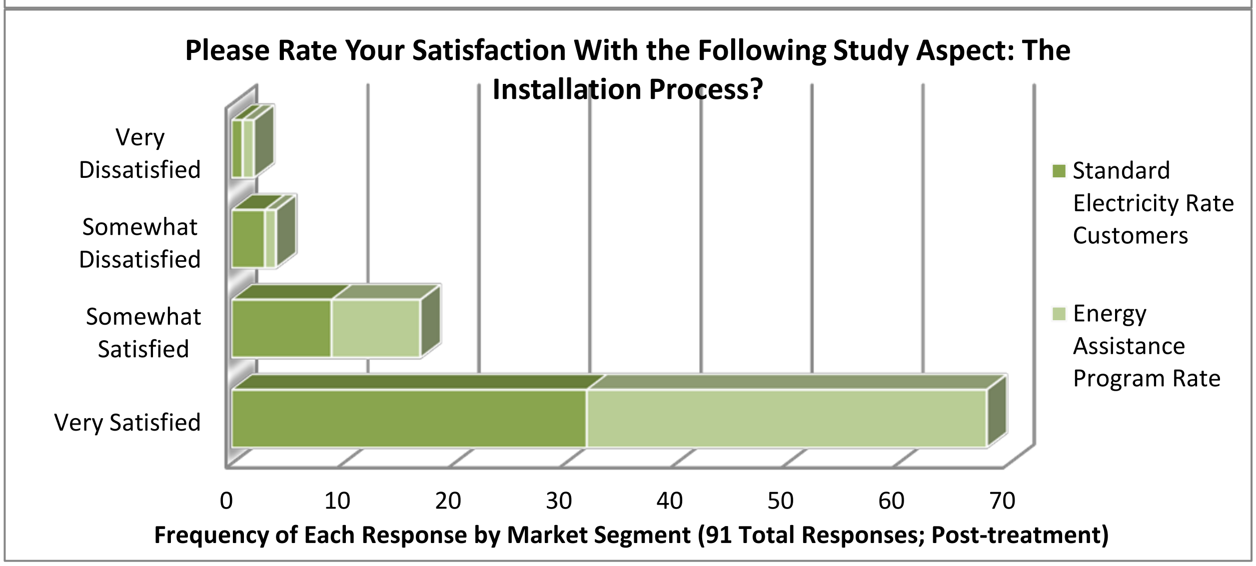

In Your Opinion, How Much Has the Optimum Off-Peak Pricing Plan...Helped You to Save Money on Your Electricity Bill?
Refused/Prefer Not...
Don't Know/Not Sure
None
A Little
Some
A Lot
0
10
20
30
40
50
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

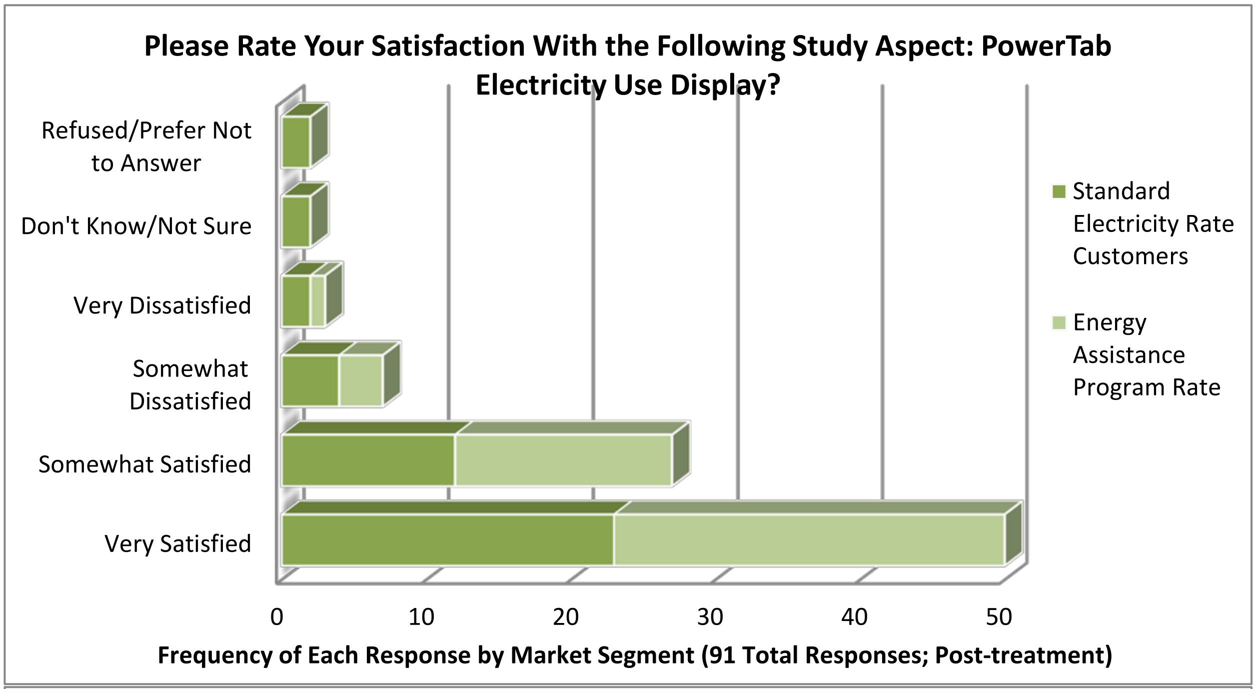

In Your Opinion, How Much Has the Optimum Off-Peak Pricing Plan...Helped You Better Manage Your Household's Electricity Use?
Refused/Prefer Not to Answer
Don't Know/Not Sure
None
A Little
Some
A Lot
0
10
20
30
40
50
60
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)

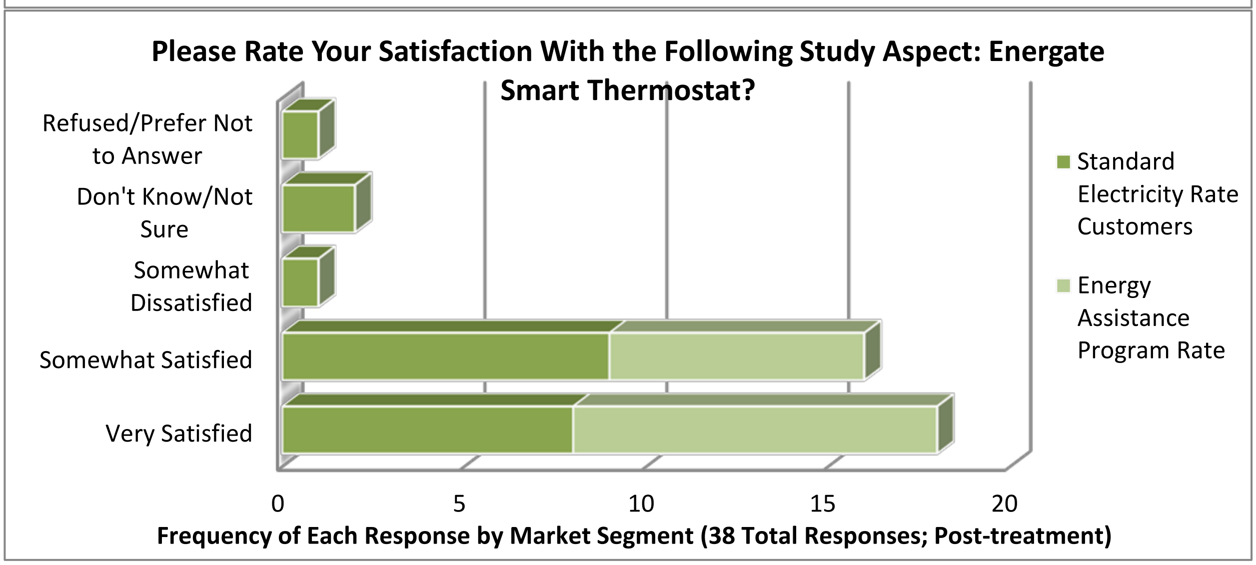

Please Rate Your Satisfaction With the Following Study Aspect: The Summer Solutions Study Overall?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Dissatisfied
Somewhat Dissatisfied
Somewhat Satisfied
Very Satisfied
0
20
40
60
80
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

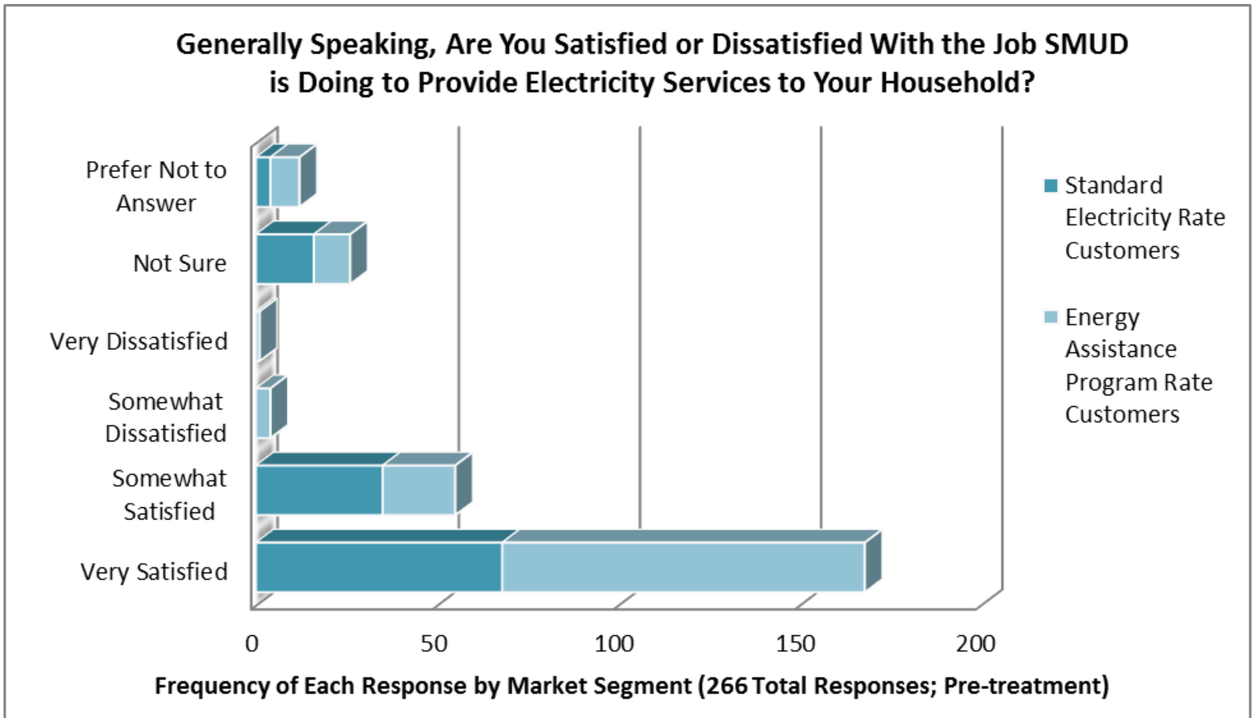

Please Rate Your Satisfaction With the Following Study Aspect: How Satisfied Are You With the Optimum Off-Peak Pricing Plan?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Dissatisfied
Somewhat Dissatisfied
Somewhat Satisfied
Very Satisfied
0
10
20
30
40
50
60
70
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

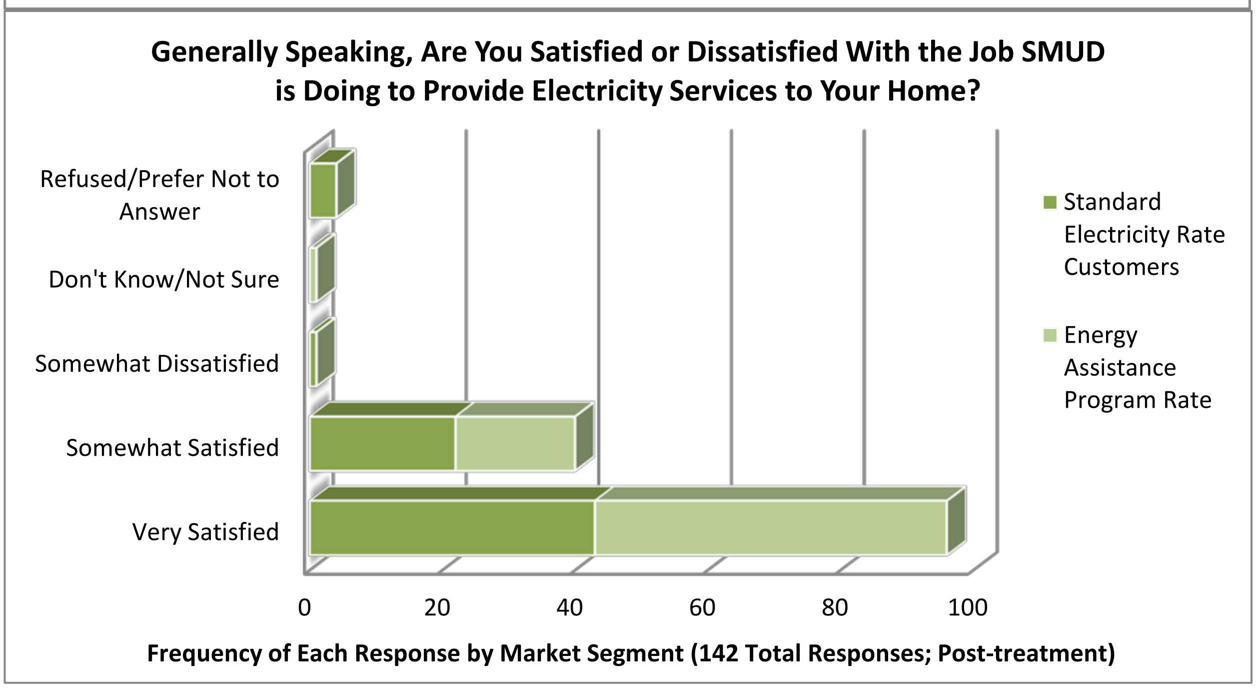

Please Rate Your Satisfaction With the Following Study Aspect: Customer Support?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Dissatisfied
Somewhat Dissatisfied
Somewhat Satisfied
Very Satisfied
0
10
20
30
40
50
60
70
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate

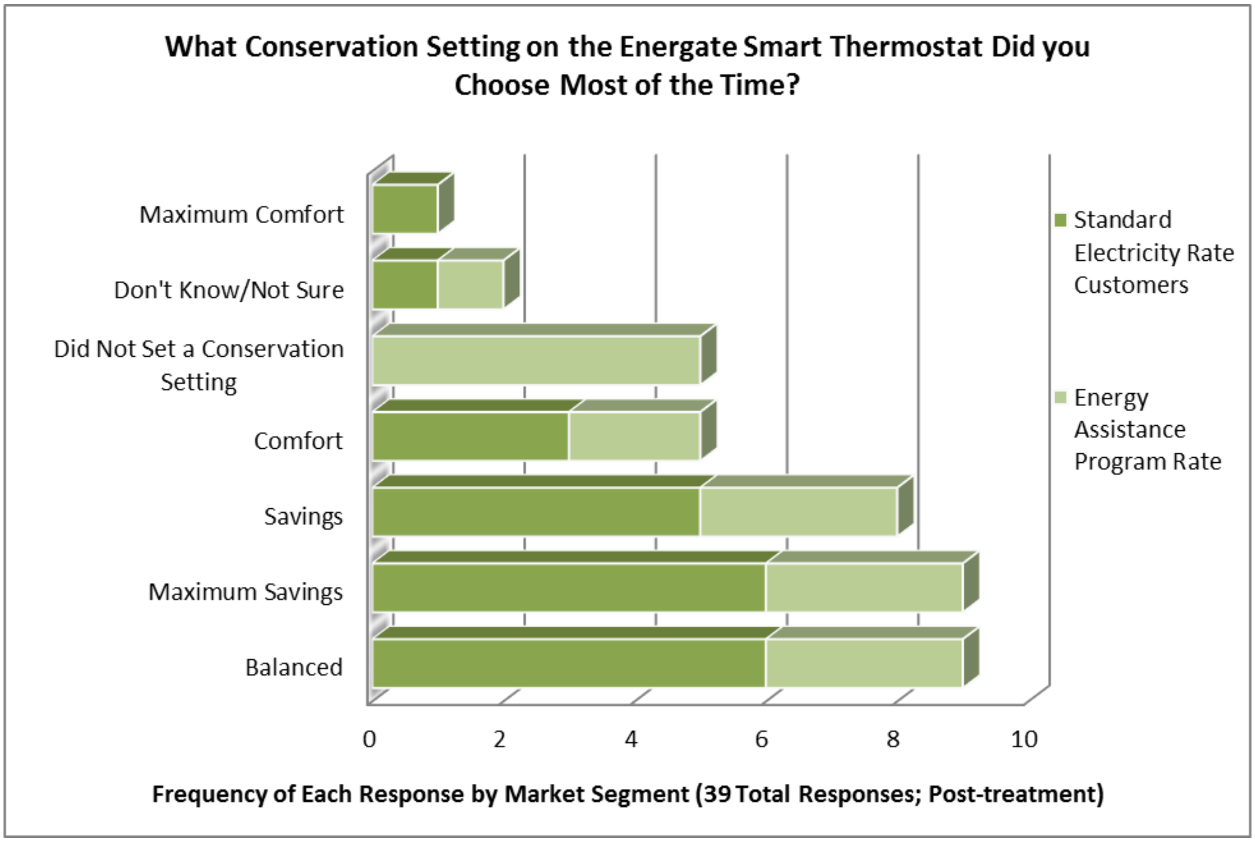

Please Rate Your Satisfaction With the Following Study Aspect: The Installation Process?
Very Dissatisfied
Somewhat Dissatisfied
Somewhat Satisfied
Very Satisfied
0
10
20
30
40
50
60
70
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate


Please Rate Your Satisfaction With the Following Study Aspect: PowerTab Electricity Use Display?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Very Dissatisfied
Somewhat Dissatisfied
Somewhat Satisfied
Very Satisfied
0
10
20
30
40
50
Frequency of Each Response by Market Segment (91 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate


Please Rate Your Satisfaction With the Following Study Aspect: Energate Smart Thermostat?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Somewhat Dissatisfied
Somewhat Satisfied
Very Satisfied
0
5
10
15
20
Frequency of Each Response by Market Segment (38 Total Responses; Post-treatment)
Standard Electricity Rate Customers
Energy Assistance Program Rate


Generally Speaking, Are You Satisfied or Dissatisfied With the Job SMUD is Doing to Provide Electricity Services to Your Household?
Prefer Not to Answer
Not Sure
Very Dissatisfied
Somewhat Dissatisfied
Somewhat Satisfied
Very Satisfied
0
50
100
150
200
Standard Electricity Rate Customers
Energy Assistance Program Rate Customers
Frequency of Each Response by Market Segment (266 Total Responses; Pre-treatment)


Generally Speaking, Are You Satisfied or Dissatisfied With the Job SMUD is Doing to Provide Electricity Services to Your Home?
Refused/Prefer Not to Answer
Don't Know/Not Sure
Somewhat Dissatisfied
Somewhat Satisfied
Very Satisfied
0
20
40
60
80
100
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (142 Total Responses; Post-treatment)


What Conservation Setting on the Energate Smart Thermostat Did you Choose Most of the Time?
Maximum Comfort
Don't Know/Not Sure
Did Not Set a Conservation Setting
Comfort
Savings
Maximum Savings
Balanced
0
2
4
6
8
10
Standard Electricity Rate Customers
Energy Assistance Program Rate
Frequency of Each Response by Market Segment (39 Total Responses; Post-treatment)

APPENDIX E: Fenestration Field Data Collection Workbook

Address:			Name of Apt. Complex:	
			Building #:	Total # of Buildings on Site:
Date:		Data Collector:	Sketch/Diagram of Exterior Dimensions Notes: See Attached Page	
Code Assigned	Window Make/ Manufacturer Code (NFRC temporary or AAMA permanent gold label)	Window Model / Product Line	General Notes About Building or Windows:	
A				
B				
C				
D				
E				
F				

Orient-ation	Code Assigned	Operator Type[3]	Width	Height	SHGC	U-Factor	Count	Notes	Panes	Frame[1]	Tint[2]	Grids[4]	Spacer		Low E	Shading Devices (Should Match Total)			
			(Feet)	(Feet)					(1/2/3)				Width (in)	Type[5]	In/Out/No	Fin	Awning	Build. Shading	None

1) Frame: M = Metal, V = Vinyl, VC = Vinyl clad metal or wood, O = Other

2) Tint: CL = Clear, TI = Tinted

3) Operation: F = Fixed, C = Casement, VS = Vertical Slider, HS = Horizontal Slider, SL = Sliding Door, FD = French Door, T = Tilt/Turn

4) Grids: ON = On, B = Between, TD = True Divided Lights, N = None

5) Spacer Type: WE = Warm Edge, M = Metal, MT = Metal Thermal Break

Address:						
Date:	Data Collector:					
# of Buildings on Site:						
Building # (s)*:						
Front Orientation:						
Number of Floors:						
Total Building Area:						
# of Dwelling Units						
# and Sq. Ft. of Studio Units						
# and Sq. Ft. of 1 BR Units						
# and Sq. Ft. of 2 BR Units						
# and Sq. Ft. of 3 BR Units						
# and Sq. Ft. of 4 BR Units						
Front Wall Width:						
Front Wall Height**:						
Left Wall Width:						
Left Wall Height:						
Back Wall Width:						
Back Wall Height:						
Right Wall Width:						
Right Wall Height:						
Other Wall Width:						
Other Wall Height:						
Other Wall Width:						
Other Wall Height:						
Wall Material:						

*Identical buildings can be listed together

**Building Height can be in Stories or Feet.

Notes: