From Home Energy Audit to Retrofit and Beyond

An Integrated Approach to Residential Program Evaluation for Utilities

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DTE Energy
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From Home Energy Audit to Retrofit and Beyond

by

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Abstract

Many in Michigan, like countless others across the United States, live in energy inefficient, detached single-family homes. There is an enormous opportunity to decrease state residential energy consumption and its subsequent greenhouse gas emissions, improve occupant comfort, and bolster home values by auditing and retrofitting these homes with more efficient energy systems. In accordance with Michigan state law PA 295, DTE Energy maintains an energy optimization (EO) program aimed at conserving electricity and gas. Under this program, the utility company offers residential customers several options and incentives to invest in energy saving measures. However, participation by homeowners has been limited.

Through collaboration between the University of Michigan and DTE Energy, this project sought to evaluate the effectiveness of the utility's audit-to-retrofit programs and overall residential EO program. Software tools—including MySQL (a relational database management system), R (a statistical analysis package), ArcGIS (a geographic information system), and SurveyGizmo (an online survey development platform) — facilitated quantitative and qualitative program evaluation. These findings informed actionable recommendations to increase program participation, improve customer satisfaction, and target future EO participants.

This comprehensive assessment examined both temporal and spatial scales and should help create better mechanisms for data storage, manipulation, and visualization. Large-scale data analysis in the context of residential energy efficiency is becoming increasingly necessary and important for utilities. An integrated approach such as the one laid out in this report could improve the way utilities like DTE Energy implement home energy efficiency programs, assess these programs, and help increase participation for future programs.

Acknowledgements

DTE Energy has a standing relationship with the University of Michigan and has collaborated on past projects with the Center for Sustainable Systems (CSS) and the School of Natural Resources and Environment (SNRE).[i] Project development began in November 2011, our team was formed in February 2012, and work was completed in May 2013.

We would like to express our sincere gratitude to Bob Fegan of DTE Energy, who introduced us to the home energy improvement process, gave us invaluable insight into the utility's energy optimization (EO) program throughout the project, and provided us with the data and funding necessary to complete our analysis. Bob's dedication to our team and this project ensured its success. On the EO pilots team at DTE Energy, we would also like to thank Thelma Dobson for helping review this report and Kelsey Tremberth for her data support. Help from other DTE Energy staff throughout the organization during the course of the project was also appreciated.

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We would also like to extend our thanks to Nick Rajkovich, a PhD candidate at the University of Michigan's Taubman College of Architecture and Urban Planning, whom we met at the American Council for Energy Efficient Economy (ACEEE) 2012 Summer Study and has been assisting us with all aspects related to the program evaluation process since then.

Our gratitude also goes out to the local contractors who let us shadow an energy audit with them as well as the homeowners who graciously let us into their homes and agreed to be interviewed on their audit and retrofit experiences.

We would also like to acknowledge the support of other local stakeholders, including the Michigan Public Service Commission, Michigan Saves, BetterBuildings for Michigan, Clean Energy Coalition, City of Ann Arbor Energy Office, and WARM Training Center.

Lastly, we would like to thank Rob Schildgen of Priority Energy in Chicago for coming to Ann Arbor to lead a customized training course on home energy auditing for our team.

[i] Previous collaborations can be found at the following links: http://deepblue.lib.umich.edu/handle/2027.42/38882 (2006) and http://deepblue.lib.umich.edu/handle/2027.42/69236 (2010).

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Disclaimer

The views and opinions expressed in this report are held by the student research team and do not necessarily reflect the organizational perspectives of DTE Energy, the Center for Sustainable Systems, or the University of Michigan more broadly. Our team does not endorse any specific software or technology mentioned in this report. References to such software or technology are for informational purposes only and do not imply a promotion of that product. Reproduction, distribution, republication, or retransmission of material contained in this report is strictly prohibited without the prior written permission of Bob Fegan of DTE Energy.

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Executive Summary

Executive Summary

As an opus requirement for the Master of Science degree in the School of Natural Resources and Environment at the University of Michigan, our team of four graduate students completed a project with DTE Energy to assess the performance of their residential energy optimization (EO) program and recommend strategies for improvement. This project has three primary objectives:

1. **Collect data on how single-family households in Michigan use and save energy,**

2. **Assess the performance of DTE Energy's current home energy audit and retrofit programs and overall residential EO program, and**

3. **Recommend ways to increase program participation within the utility's residential customer base.**

Several avenues of research were pursued to accomplish the aforementioned tasks. The results of an existing energy optimization pilot program known as the whole home performance pilot program (WHPPP) were examined. The products in this report include annual electricity and gas savings from monthly billing data and charts of predicted and evaluated energy savings, as shown in Fig. ES-1.

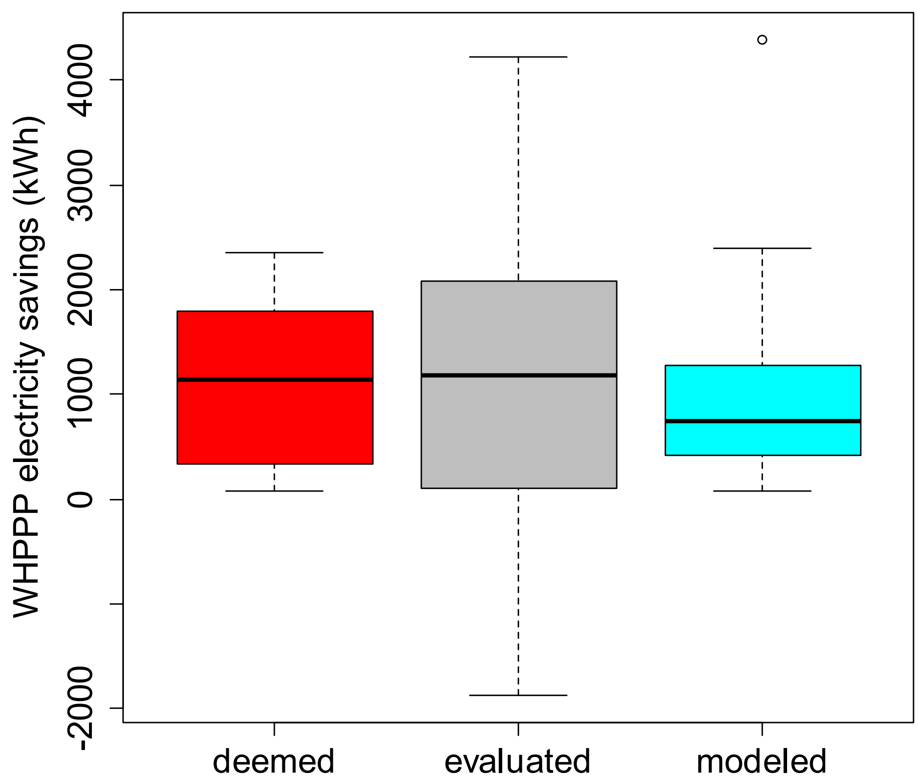

Figure ES-1. A comparison of deemed, evaluated, and modeled annual on-site electricity savings in kilowatt-hours (kWh) from the pilot program (n = 20 houses for each group except modeled, which was missing 3 houses).

In addition to the discussion of these quantitative research products this report covers the following qualitative results. The perspectives of home energy auditors and contractors were sought. An online survey was conducted to reveal how contractors currently reach out to customers, and the effectiveness of these outreach efforts. Finally, in-depth interviews with a small group of homeowners who underwent the energy optimization process were conducted to reveal nuances about the motivations for investing in energy efficiency that were not captured in more generalized third-party surveys.

The findings of this research suggest that DTE Energy could increase participation by implementing a more concerted marketing strategy that includes contractor training, as well as placing greater emphasis on non-financial benefits of energy optimization, such as home safety, indoor air quality, and thermal comfort. In addition, access to energy optimization incentives can be streamlined for both homeowners and home improvement professionals.

Finally, the spatial analysis of home improvement contractor and business coverage reveals where there are geographic gaps with a lack of participation in DTE Energy's residential EO program. Given the data availability of participation rates at various zip codes, DTE Energy can focus marketing efforts in areas with relatively high population concentrations coupled with relatively low participation rates, as shown in Fig. ES-2.

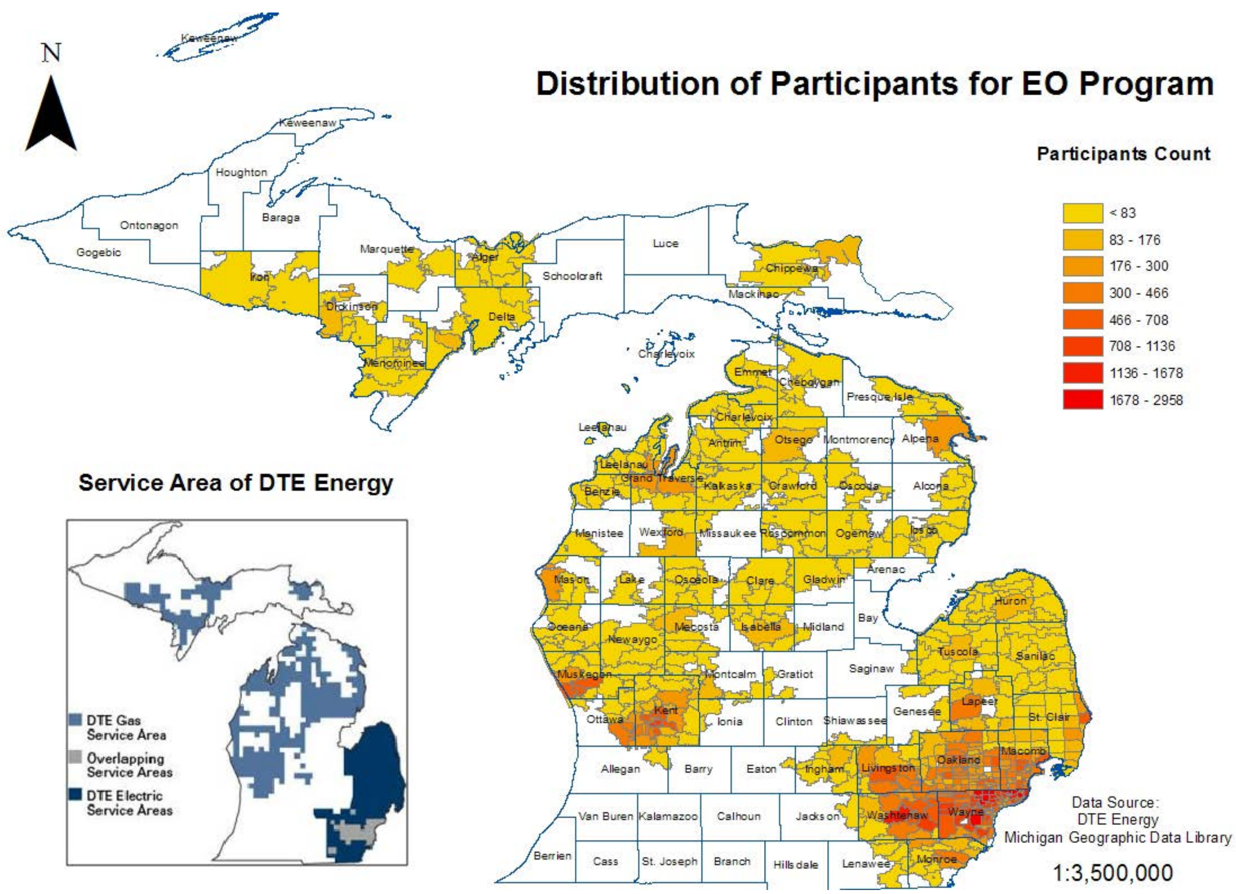

Figure ES-2. A map of participation in DTE Energy's residential EO program with an inset of the utility's gas, electric, and combined service territories.[1]

From our analysis, we have generated a few key recommendations for the utility which should help improve customer relations, increase EO participation, and aid in future program evaluation. These key recommendations are summarized below:

Promote auditor training opportunities
Provide access to training and continuing education for contractors, especially outside of Detroit, Ann Arbor, and Grand Rapids. Currently some home improvement professionals are installing energy saving upgrades without going through the audit process. Installation without any assessment of the home's energy use inevitably diminishes the effectiveness of the upgrades and the energy bill savings that can be achieved.

Ensure better screening of the contractor directory
Ensure that contractors who are listed as auditors on DTE Energy's energy efficiency vendor directory are certified, and ensure that the directory is up-to-date. Currently, up to 10% of contractors listed have out-of-date contact information, and it is not always clear which auditors possess which kind of certifications, particularly those recommended by the utility for comprehensive energy audits.

Automate audit and upgrade rebate filing
Switch to an automated online filing system to increase the speed of submission, decrease reporting errors, and collect rebate application data for further analysis. Multiple respondents to our contractor survey suggested that the current rebate submissions process is too complicated and requires too much paperwork. Some have even commented that the amount of rebates given simply is not worth the time necessary to make the proper submissions. Mapping of participation through rebate filing data shows where the biggest opportunities exist to promote EO services.

Collect data from home energy audits
Enable greater ability for analysis of energy savings through collecting customer information, billing history, and building characteristics during the home energy audit. The data collected in the rebate filings is limited. More thoroughly collected data and better integrated databases would provide DTE Energy with greater opportunities for calculating energy savings and targeted marketing to homeowners who have already participated in the EO program or are likely to participate in the future.

Encourage contractors to customize audit reports
Rank upgrade recommendations in terms of energy savings, as well as qualitatively describe the impact of each recommendation on thermal comfort and resident health and safety. A financial analysis of the pilot EO program suggests that only particular scenarios yield positive financial returns. However, the second most important factor – as demonstrated by the aforementioned auditor survey – that influences customer decisions is home comfort. Auditors can make a persuasive case for EO upgrades, if they customize audit reports to reflect both the financial and non-financial benefits of these home improvements.

Target customers through data analytics
Identify prospective EO participants using maps showing metrics, such as past program participation, average household energy consumption, and relative utility cost burden, by zip code. More sophisticated data analytics like this can assist the utility in finding the customers with the greatest need and who would benefit the most from home energy improvements. Sending targeted email, direct mail, and on-bill messaging to these homeowners will likely increase participation in both the comprehensive audit-to-retrofit and low-income programs.

In the report that follows, we delve into our research methods, results of our analysis, and some further discussion in the following sections:

Pilot performance evaluation | An assessment of an experimental home energy optimization pilot program; this describes the extent to which evaluated energy savings corresponded to predicted savings;

Home efficiency valuation | A financial impact analysis of the pilot program;

Spatial analysis | An analysis of the participation and potential service gaps in the coverage of DTE Energy's existing energy optimization program;

Auditor and contractor survey | An analysis of how home improvement professionals currently do business, and potential problems that would inhibit EO participation;

Customer engagement and satisfaction | A comparison between in-depth qualitative interviews with customers about their experiences in the home energy improvement process and relevant third-party surveys.

Section 1

Introduction

1. Introduction

1.1 Background

In an era of increasing energy consumption and greenhouse gas (GHG) emissions, assessment and improvement of home energy efficiency could play a major role in alleviating both of these challenges. In the United States, buildings produce about 40% of all GHG emissions[2], about half of which are produced by homes[3]. Furthermore, over 85% of buildings in the US are more than 15 years old, and about 65% are more than 30 years old.[4] Given that new buildings are unlikely to replace aging residential and commercial infrastructure on a large scale in the near future, there are significant opportunities for improvement through retrofitting and weatherizing the existing building stock. In Michigan, as is the case for most of the US, space heating and cooling improvements hold the greatest potential for energy savings[5], as shown in Fig. 1 below.

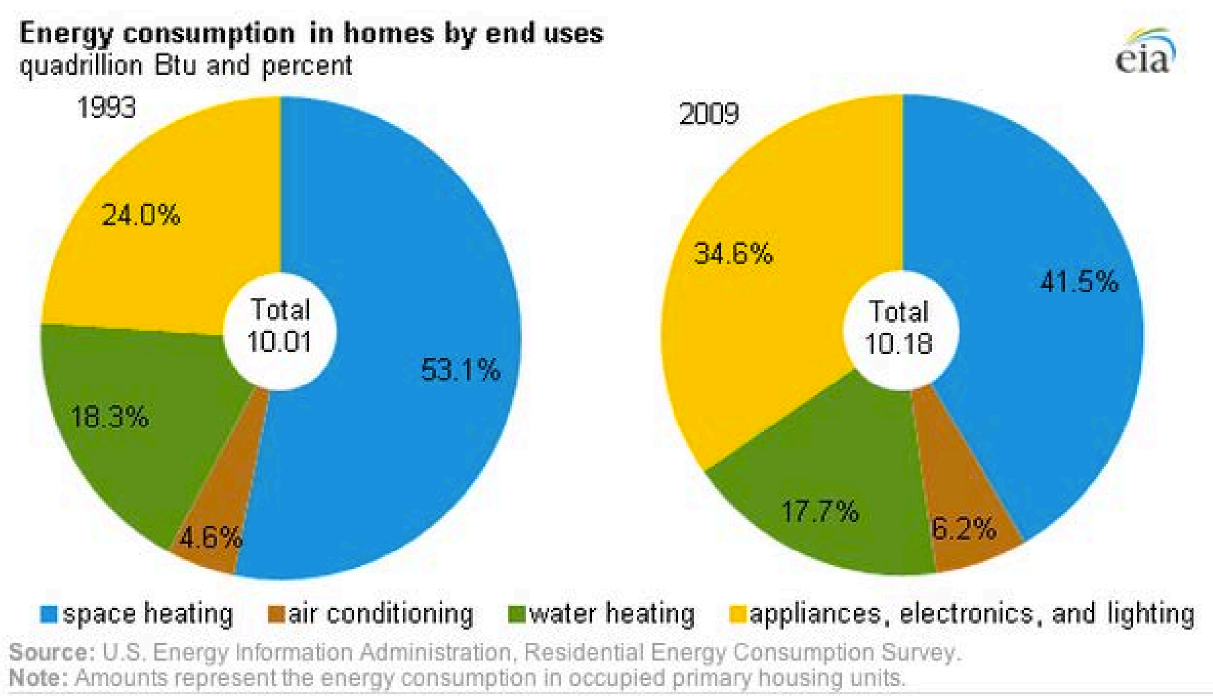

Figure 1. The average distribution of on-site home energy consumption in the United States – a comparison of use between 1993 and 2009.[6]

According to the *Roadmap for the Home Energy Upgrade Market* report, the potential market for residential energy efficiency is vast and mostly untapped.[7] This project targets owners of single-family homes in DTE Energy's service territory.[8] As shown in Fig. 2, these types of households account for the plurality, if not majority of housing across all income levels in the US, as well as in Michigan[9], and therefore has the biggest potential impact. Moreover, many low-income and middle-income homeowners do not have the financial means to keep up with rising utility costs and could greatly benefit from energy efficiency and weatherization programs.[10]

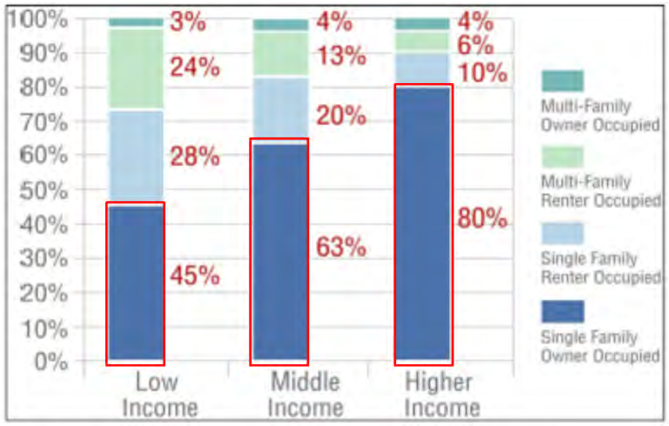

Figure 2. Percentage of US home ownership by income level (Census 2010).[11]

Another reason to focus on single-family homes is that the average home size in the US is getting bigger. Statistics from the US Energy Information Administration show that new homes built after 1990 are on average 30% larger than those built in the prior decade.[12] On the other hand, these newer, bigger homes only consume 2% more energy than their pre-2000 predecessors. These statistics are cause for some optimism, for it clearly demonstrates that American houses are becoming significantly more energy efficient in the 2000s, relative to the previous decade. Nevertheless, these statistics also reveal that the absolute quantity of home energy consumption remains on the rise, and that residential energy efficiency gains can easily be offset by greater overall consumption. These trends elevate the significance of this project in two ways. First, increasing overall home energy consumption highlights the continued need for participation in home energy efficiency programs. Second, as post-2000 homes inevitably deteriorate with age, and as future technological advances further expand energy efficiency opportunities, home energy audits and upgrades will remain a relevant factor for mitigating energy consumption and the climate change effects thereof.

Compliance to state regulation was also a factor in the decision to pursue this project from the perspective of DTE Energy. The Michigan state legislation known as Public Act 295 of 2008 (PA 295) required that all electricity and natural gas utilities (other than suppliers of renewable electricity) establish energy optimization programs.[13] This requirement sought to delay utility cost increases to Michigan residents by mitigating increasing energy consumption, thus delaying the need to build additional power generation capacity. For example, it called for annual consumption reductions of 1% and 0.75%, respectively, of retail electricity and gas sales from the preceding year, in 2012. While utilities are not punished for failing to meet savings quotas, they are given incentives to implement such programs. Namely, EO programs can be capitalized and earn profit, and shareholders are allowed to receive performance incentives for exceeding the annual energy saving target.

Despite the benefits, many utilities have been having trouble convincing residential property owners to undertake the necessary processes and investments to enhance and upgrade their home energy efficiency[14]—as is the case with this team's sponsor, DTE Energy.

DTE Energy currently offers three home energy audit options to its customers. The simplest option is the MyEnergy Analyzer, an online self-assessment completed by the customer.[15] Upon completion, the utility sends the customer an energy efficiency kit. The second option is the Home Energy Consultation, which consists of an in-home consultation, an energy conservation action plan, and installation of efficiency lighting and piping insulation.[16] The third option is a comprehensive energy audit through the Home Performance Program[17], which typically consists of the following components:

- Outside/structural observation,
- Indoor assessment of all points of infiltration (location, size, type),
- Blower door test (as shown in Fig. 3 below),
    - Measure the rate of air infiltration,
- Infrared scans (as shown in Fig. 4 on the next page),
    - Identify areas in the house that have a high thermal gradient,
- Furnace, water heater, and insulation check, and
- Report with data analysis and improvement recommendations.

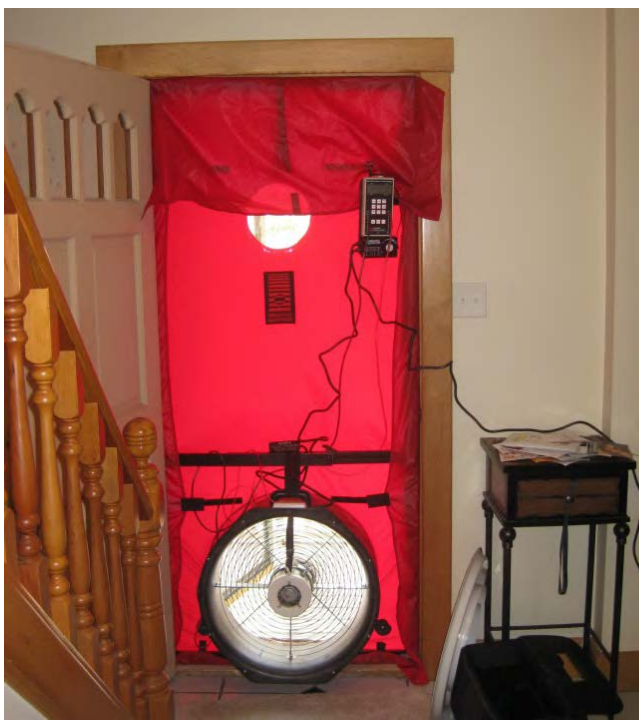

Figure 3. Blower door test to measure the rate of air infiltration (photo by Andrew Eilbert).

Currently under this option, DTE Energy offers a $75 rebate on the cost of the audit, and up to an additional $1,050 for insulation and air sealing upgrades and up to $450 for a furnace replacement. Other incentives are offered for window replacements and rebate multipliers are available for when three measures or more are taken together.[18]

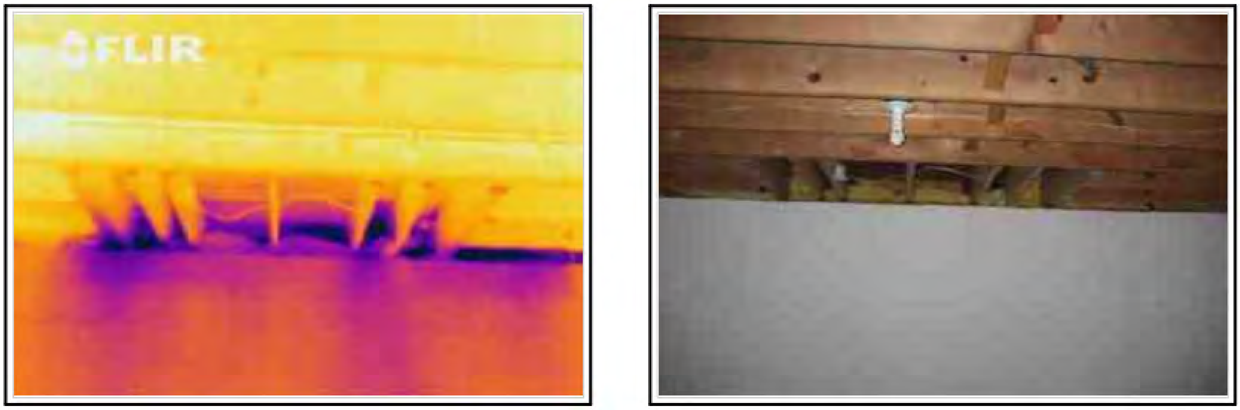

Figure 4. Side-by-side comparison of an infrared picture and a photograph of the band joist, where deeper colors (purple-blue) indicates a higher temperature gradient and points of air infiltration (courtesy of Prashanth Gururaja).

Despite the wide range of options offered, the home energy audit program has so far fallen short of DTE Energy's expectations. During the initial meeting, our client outlined three major problems that hindered widespread adoption of residential energy audits.

I. Lack of participation | Despite heavy marketing and promotional pricing, only a small fraction, less than 10 percent by current estimates, of DTE Energy customers perform energy audits. Only a smaller fraction of homeowners actually invest in efficiency measures of any kind.

II. Lack of incentives | A whole home energy upgrade involves a high upfront cost–usually in the range of $5,000-10,000–to the property owner, and the payback may not be realized for more than 20 or 30 years. DTE Energy's rebate program, which partially subsidizes the cost of the audit and retrofit, does little to offset the large upfront cost of the investment. The client has concluded that the direct financial incentive alone is inadequate for attracting customers, and that non-financial incentives are needed.

III. Lack of standardized processes | Comprehensive energy audits are not completed by DTE Energy but by independent contractors. Consequently, methods, standards, and results vary widely from contractor to contractor, and from property to property. A significant amount of time is spent standardizing, assessing, and inputting the results of audits so as to process rebate payments. Furthermore, audit results are currently used for little more than receipts for rebate distribution.

Upon further investigation, it was decided that the focus of this particular project should remain on the first two problems, and that the third issue of standardized processes could not realistically be accomplished over the course of this project. The primary reason for this is the nature of the home energy auditing business. This is a highly fragmented business[19], which mainly consists of small independent contractors (usually those that employ less than 10 people). All of these contractors have their independent operational procedures, customer base (which is built largely through word-of-mouth recommendations), and their unique application of auditing standards. Furthermore, every house has a unique set of parameters (building characteristics such as size, age, and surrounding environment) and needs. Given these conditions, it is practically impossible to impose business concepts such as lean transformation and process standardization to improve and unify the audit process. Therefore, it is far more realistic to make recommendations that address the first two issues–participation and incentives.

While non-financial incentives of home improvements, such as decreasing the risk of carbon monoxide (CO) poisoning, asbestos inhalation, or structural damage from moisture, are important motivating factors for retrofitting, this report does not try to quantify these health and safety benefits. We direct readers to other studies on indoor air quality[20] and healthy buildings[21] for further discussion and analysis of these issues.

1.2 Stakeholder Interactions

There are three key stakeholders in the home energy audit and retrofit process: homeowners, contractors (and independent auditors), and the utility. In Fig. 5 below, we have created a conceptual model with the primary interactions of the key stakeholders.

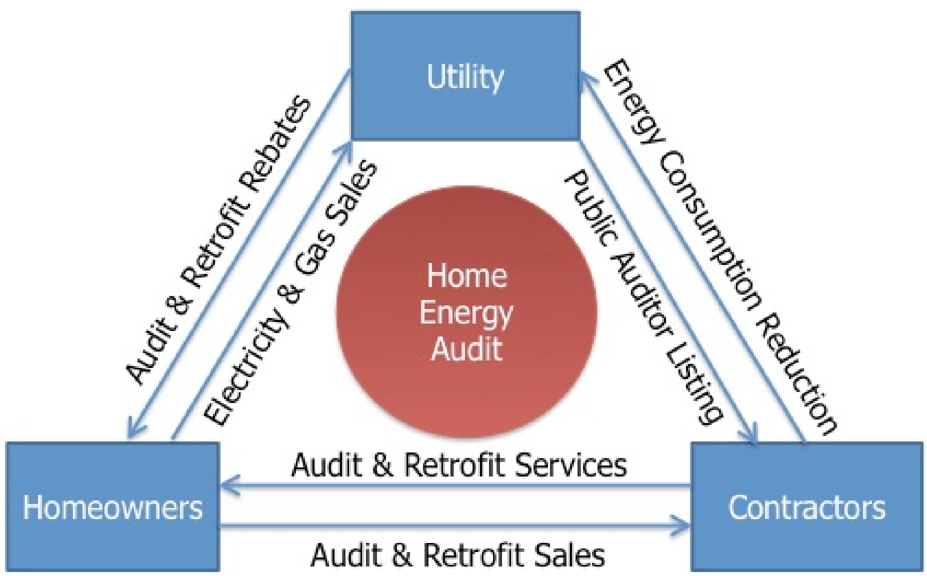

Figure 5. A conceptual model of the primary interactions between key stakeholders in the home energy audit process.

1.3 Project Objectives

Evaluation, measurement, and verification (EM&V)[22] for energy efficiency programs has been fairly well established over the last decade. Our research follows guidelines first set out by the US Environmental Protection Agency (EPA)[23] and then updated by the State and Local Energy Efficiency Action Network (SEE Action)[24], as well as prior Michigan program evaluation studies[25,26]. Using these sources as precedence, this project has three primary objectives:

1. **Collect data on how single-family households in Michigan use and save energy**
   Single-family households are the primary customers of home energy improvement services. By collecting and organizing data on such customers, particularly through surveys, interviews, monthly utility bills, pilot data, EO statistics, and census demographics, the team was able to conduct analysis to help the utility make better informed decisions.

2. **Assess the performance of DTE Energy's current home energy audit-to-retrofit programs and overall residential EO program**
   This research analyzed how the utility, independent contractors, and customers interact with each other, quantified the effectiveness of residential EO pilots and the overall program, and determined the extent to which homeowner needs are satisfied.

3. **Recommend ways to increase participation of the utility's residential customers**
   Based on the team's high-level understanding of the previous two objectives, recommendations were made on how to bridge the gap between homeowner expectations and DTE Energy's current programs.

1.4 Areas of Research

Given our discussions with DTE Energy and their EM&V needs, our team focused specifically on the following areas of research:

- **Quantify the effectiveness of a recent DTE Energy pilot to save energy and money**
  Calculate annual energy savings from pre- and post-retrofit billing data of climate-normalized gas and electricity use;

- **Compare evaluated annual energy savings to modeled and deemed savings**
  Contrast evaluated savings to the results of energy modeling software and the public service commission's Michigan Energy Measures Database[27];

- **Assess pilot and overall program performance through benchmarking**
  Analyze the performance of pilot houses in comparison to local, utility service territory, state, and regional averages;

- **Characterize home energy improvement services in Michigan**
  Survey residential auditors and contractors to understand how their businesses work and how they can be better served by the utility;

- **Find the motives that drive Michigan homeowners to energy efficiency**
  Pinpoint the reasons for home energy auditing and retrofitting through a small series of interviews and relevant third-party surveys;

- **Visualize current EO participants and identify future customers to participate**
  Use state census demographics and aggregated EO statistics to map and target specific homeowners for new EO initiatives.

1.5 Report Organization

The results of this research project are organized in the following manner:

Introduction | An overview of project goals, methods, and significance is provided.

Evaluation of pilot performance | The experimental EO pilot program undertaken by DTE Energy has been evaluated for effectiveness based on the pilot's stated goals by the utility and participating homeowners.

Valuation of home energy upgrades | The financial outcomes for the participants in the pilot evaluation are discussed in detail in this section.

Spatial analysis | Based on pilot program and US census data, the geography behind the home energy audit and improvement business will be mapped out in a visually convenient way, so as to show where audits and improvements occur most frequently in Michigan, specifically in DTE Energy's service territory, and also locate geographic gaps of contractor availability and EO program participation, and discuss possible reasons for these gaps.

Description and synthesis of auditor surveys | As part of the research, local energy audit and home improvement service providers were asked to complete an anonymous, online survey regarding their observations and opinions about the local market. This section will summarize and synthesize survey results.

Customer engagement and satisfaction | A number of in-depth interviews with homeowners were conducted as part of this research. Comparisons between interviewee responses and some relevant third-party surveys are explored.

Key findings and recommendations | This section outlines actionable recommendations for DTE Energy and other stakeholders to increase participation in residential audits and upgrades, with the ultimate goal of moving closer to the energy conservation goals of DTE Energy, as well as the State of Michigan. It also outlines shortcomings within the research and suggests possible areas for further exploration.

Appendices and references | It contains additional data and external research referenced in the report.

Section 2

Pilot Performance Evaluation

2. Pilot Performance Evaluation

2.1 Introduction

An easy and effective way to assess a utility-scale residential energy efficiency program is to consider the performance of individual participating houses. While energy savings of individual houses may vary widely depending on several factors, such as the number of occupants and resident behavior, the aggregated savings over a large group of houses should be representative of the program's overall performance.

DTE Energy has run a number of residential pilot programs since the EO program's inception in 2008. One of the largest such pilot programs was a comprehensive audit-to-retrofit program implemented by a local contracting company who has requested to remain unnamed in this report. Therefore, this pilot program will be referred to as the whole home performance pilot program (WHPPP) or simply "the pilot" going forward.

The WHPPP included 106 self-selected houses in Wayne and Washtenaw counties, with most participants located in Ann Arbor. To better visualize participation in the pilot, we mapped participant counts by zip code in Fig. 6. The program began in June 2010 and all associated retrofits were finished by the end of December 2010. Every participant had combined services from DTE Energy—electricity provided from Detroit Edison and natural gas from MichCon.[28] Audits and retrofits were performed by the same contractor. Participants were eligible for up to $3,500 in rebates from the utility and contractor, although rebates were dependent on which efficiency measures they chose to install. Each household selected their own suite of measures from the list of rebated options. Since itemized measures were only provided for 20 pilot houses, we chose to analyze whole home energy savings agnostic to the measures installed.

In Table 1 below, the total (cumulative) and average costs of the WHPPP are summarized. The average retrofit cost was just over $9,000 per participant but after rebates, the retrofit cost to each participant was about $6,150 on average.

Table 1. Total and average costs for customers participating in the WHPPP.

COST TO CUSTOMER	Total cost	Average cost per house
Upgrade installations	$961,329	$9,069
Rebates	-$308,676	-$2,912
NET	$652,653	$6,157

In the next section, results of a financial model to determine the cost-effectiveness of upgrades are presented. This section will also contain a brief discussion on the development of a predictive linear regression model to estimate energy savings.

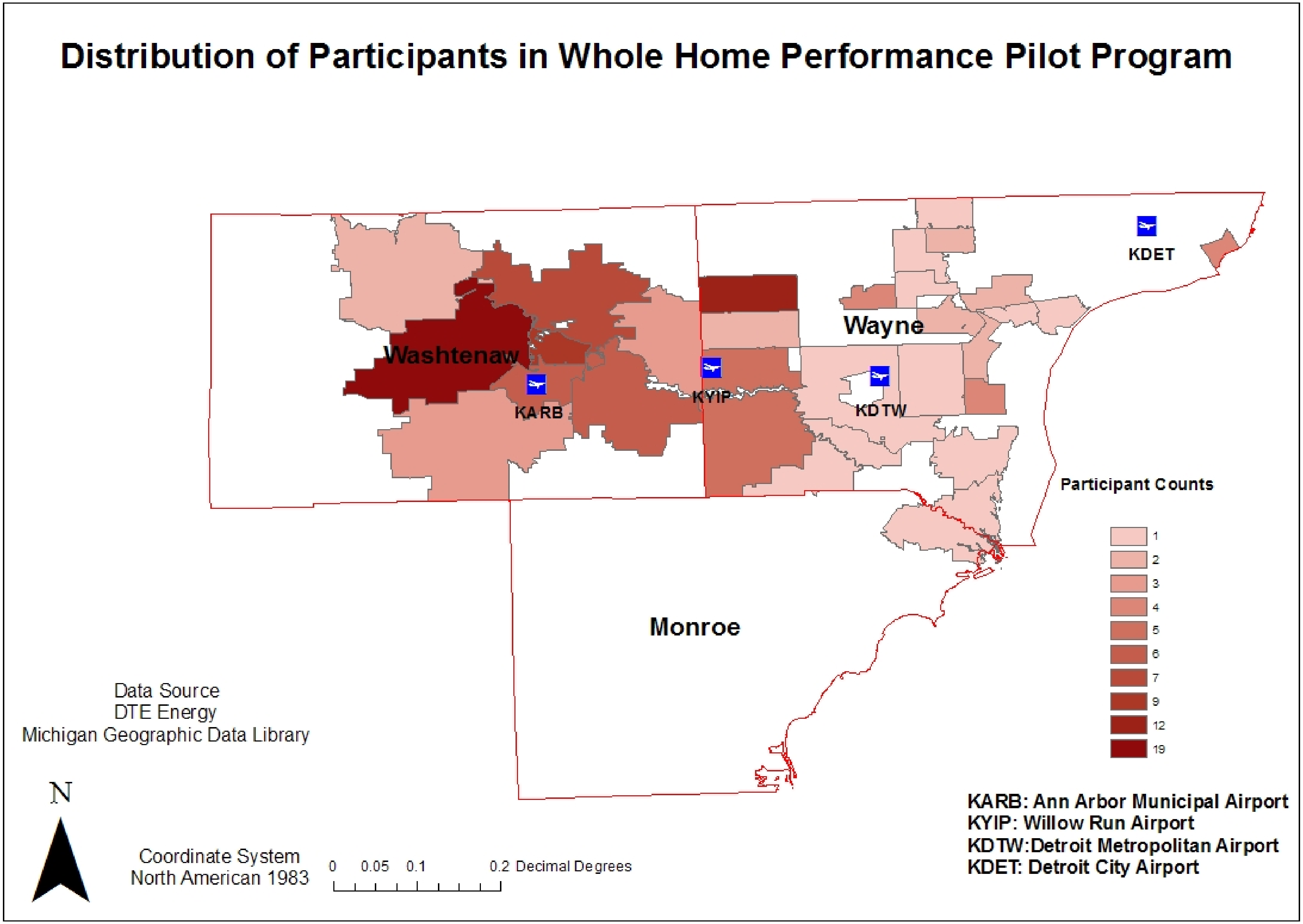

Figure 6. A distribution map of the 106 WHPPP participants in southeast Michigan and the four airport weather stations utilized for climate normalization.

2.2 Methods and Results

2.2.1 Annual Energy Savings

One of the primary goals of this project was to calculate annual energy savings for each pilot house. DTE Energy provided monthly gas and electricity use from billing data as well as detailed profiles of the pre-retrofit building characteristics of all houses but redacted customer identification numbers, names, and specific street addresses to preserve confidentiality. Since the climate varies from day to day, month to month, and year to year, normalization was needed to compare months with significantly different energy use. To accomplish this normalization, we purchased the number of heating and cooling "degree days" per month from DegreeDays.net.[29]

Degree days | The purchased weather data consists of monthly heating degree days (HDD) and cooling degree days (CDD). HDD is defined as the sum of degrees if the average ambient daily temperature $\bar{T}_i$ is below a base temperature T_b, and otherwise zero. In this case, we upheld convention and set the base temperature, which is equal to the house's internal setpoint thermostat temperature, to 65 °F. Similarly, CDD is defined as the sum of degrees if $\bar{T}_i$ is above T_b, and otherwise zero. These definitions for HDD and CDD are summarized below in Eq. 1 and Eq. 2, respectively,

$$HDD = \begin{cases} \sum^{n} (T_b - \bar{T}_i), if \bar{T}_i < T_b, \\ 0, if\ \bar{T}_i \geq T_b, \end{cases} \qquad (Eq. 1),$$

$$CDD = \begin{cases} \sum^{n} (\bar{T}_i - T_b), if\ \bar{T}_i > T_b, \\ 0, if\ \bar{T}_i \leq T_b, \end{cases} \qquad (Eq. 2),$$

where n is the number of days in any given month and i is an index for a given day. We even decided to purchase HDD and CDD data for 65 ± 6 °F to give the opportunity to perform some future sensitivity analysis and explore Jevon's paradox, or the "rebound effect" of improved efficiency leading to higher setpoint temperatures and energy use.[30]

City to airport weather station mappings | All the pilot houses had their gas and electricity use normalized by HDD and CDD from one of four nearby airport weather station in Wayne and Washtenaw counties: Ann Arbor Municipal Airport (KARB), Detroit Metro Airport (KDTW), Willow Run Airport (KYIP), or Young Detroit City Airport (KDET).

Weather station selection was not done through a formal distance calculation because the utility only provided generalized street addresses of the pilot houses for customer privacy; rather, which weather station to use for each house was determined quickly based on its city or town's proximity to an airport and its relative development density compared to the airport. For example, houses in Dearborn were mapped to the KDET airport in downtown Detroit instead of the more suburban set KDTW airport. A full list of city to weather station mappings is included in Table 2.

Table 2. Mapping of each city with WHPPP participants to the most appropriate airport weather station.

City	County	Airport	Airport Code
Allen Park	Wayne	Detroit Metro Airport	KDTW
Ann Arbor	Washtenaw	Ann Arbor Municipal Airport	KARB
Belleville	Wayne	Willow Run Airport	KYIP
Dearborn	Wayne	Young Detroit City Airport	KDET
Dearborn Heights	Wayne	Young Detroit City Airport	KDET
Detroit	Wayne	Young Detroit City Airport	KDET
Dexter	Washtenaw	Ann Arbor Municipal Airport	KARB
Garden City	Wayne	Detroit Metro Airport	KDTW
Grosse Pointe	Wayne	Young Detroit City Airport	KDET
Grosse Pointe Park	Wayne	Young Detroit City Airport	KDET
New Boston	Wayne	Detroit Metro Airport	KDTW
Redford	Wayne	Detroit Metro Airport	KDTW
Riverview	Wayne	Detroit Metro Airport	KDTW
Rockwood	Wayne	Detroit Metro Airport	KDTW
Romulus	Wayne	Detroit Metro Airport	KDTW
Saline	Washtenaw	Ann Arbor Municipal Airport	KARB
South Rockwood	Wayne	Detroit Metro Airport	KDTW
Southgate	Wayne	Detroit Metro Airport	KDTW
Taylor	Wayne	Detroit Metro Airport	KDTW
Trenton	Wayne	Detroit Metro Airport	KDTW
Ypsilanti	Washtenaw	Willow Run Airport	KYIP

For simplicity, we chose to set the pre-retrofit period from June 2009 to May 2010 and the post-retrofit period from January 2011 to December 2012 for all the houses instead of calculating savings dynamically depending on when the retrofit was performed. With more billing data from DTE Energy, there would be a chance to check if the energy savings were persistent over time.

Climate normalization | We assumed that gas is used only for heating and electricity only for cooling. To calculate the normalized gas use or, “normalized heating load,” we divided the billed gas use measured in 100 cubic feet (CCF) by the HDD for that month and then multiplied by the long-term HDD average for the appropriate weather station and month.[ii] Our long-term monthly averages were derived from degree days ranging from September 2000 to October 2012 due to data availability on DegreeDays.net at the time of purchase. To avoid months where the HDD could drop to zero, our HDD normalization procedure was only applied from November to March. Similarly, “normalized cooling load” is defined as the billed electricity use measured in kilowatt-

[ii] There was no information given about the type of heating system in each WHPPP house, so we assumed that all the pilot houses had gas furnaces, like a majority of Michigan homeowners.

hours (kWh) divided by the CDD for that month and then multiplied by the long-term CDD average for that month.[iii] Similarly, this CDD normalization is only applied from June to August. Months with insignificant heating or cooling loads, namely April and May as well as September and October, were left unnormalized. This is the convention used in literature.[31] While estimating and then excluding the baseload gas and electricity use[iv] for each house may have yielded more accurate results, this was avoided to simplify the coding.

Annual climate-normalized site energy savings | The climate-normalized annual site energy savings (AES) were computed from the normalized heating and cooling load. Annual energy savings were computed by subtracting the post-retrofit energy use (EU_{post}) from pre-retrofit energy use (EU_{pre}) over each 12-month period specified above. The annual percent energy savings ($APES$) was then simply the difference between pre- and post-retrofit energy use over the pre-retrofit energy use. Annual energy savings was reported in British Thermal Units (BTUs) using the conversions of 3,412 BTU per kWh of electricity and 102,000 BTU per CCF of gas. These calculations have been summarized in the Eq. 3 and Eq. 4 below:

$$AES = EU_{pre} - EU_{post} \qquad (Eq. 3),$$

$$APES = \frac{AES}{EU_{pre}} \qquad (Eq. 4).$$

We wrote a MySQL[v] script to automate energy savings calculations based on the formulas given above. We were able to generate savings outputs for 88 pilot houses, as shown below in Fig. 7. Eighteen houses were excluded because of incomplete or inadequate billing data. The average WHPPP house saved about 15% of its energy per year—specifically 1,291 kWh of electricity and 205 CCF of natural gas annually, which equates to about $305 of annual utility costs. The houses in red actually used more energy after completing their retrofits and the houses in royal blue saved over 50% annually.

A quantitative test of the difference in energy use for each pilot house pre- and post-retrofit was done using the R statistical package[vi]. Using a paired t-test, we found that the electricity and gas use in the collection of homes was significantly lower after retrofit (both $p < 0.0001$). Thus, there is no question that the efficiency upgrades were effective in terms of energy savings. The next section will address whether these upgrades were cost-effective.

[iii] Of the 106 pilot houses, only 16 did not have an air-conditioning unit. We did not, however, omit those houses from the normalization. Other electric air circulation equipment, such as fans, was still assumed to increase electricity use during the summer months.

[iv] That is, baseload energy use is consistent throughout the year regardless of the month or season, such as running electronics, kitchen appliances, clothing washers and dryers, and can be estimated from fitting a linear regression line to electricity use and another regression line for gas use separately and then finding the y-intercepts. These intercepts should be decent approximations of baseload gas and electricity use.

[v] MySQL is an open-source relational database system that has its own storage framework and programming language and is available for download at http://www.mysql.com.

[vi] R is open-source software for statistical analysis and data visualization and is freely available for download at http://www.r-project.org.

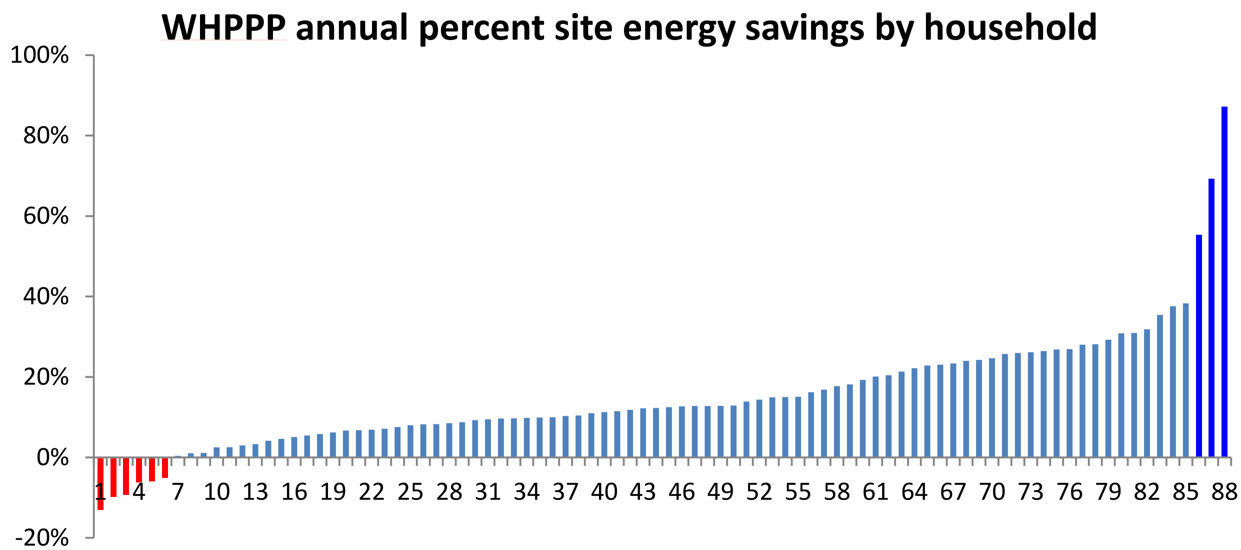

Figure 7. Annual on-site energy savings for each WHPPP house. Houses in red used more energy post retrofit and houses in royal blue actually saved more than 50% annually (n = 88 houses, $\bar{x} = 15.41\%, sd = \pm 15.13\%$).

There any number of explanations for these outliers, including a change in ownership, occupancy, or simply having homeowners believe that they could use more energy after their retrofit, known colloquially as the rebound effect[32]; however, it is impossible to know the reason for a particular outlier without having a more detailed conversation with the homeowner. Our team had no means of contacting participants and will let the utility follow up. Annual percent gas savings (Fig. A-1) and percent electricity savings (Fig. A-2) are included in Appendix A.

Site and source energy savings and CO_2 reductions | We also took into consideration the cumulative environmental impact of the WHPPP on reducing energy demand and greenhouse gas emissions. In a life cycle approach, there is an emphasis to include upstream fuel effects of natural resource extraction and processing, energy generation, and transmission and distribution. In the buildings sector, primary energy use is often referred to as source energy use[33], which adds in upstream impacts of the fuel. Our results in Fig. 7 were exclusively for downstream or site energy savings, so we have included both the cumulative site and source energy savings in Table 3 for the 88 houses where evaluated savings could be calculated as well as the projected energy savings for all 106 WHPPP participants. Source-to-site ratios are national averages (3.365 for electricity and 1.092 for gas) taken from the default settings of the Building Energy Optimization (BEopt) [vii] software for building energy optimization.[34] To calculate the CO_2 reductions, we used BEopt's carbon factors for electricity and gas (1.67 pounds of CO_2 equivalent per kWh of electricity and 14.47 pounds of CO_2 equivalent per therm of natural gas, respectively; assume 1 therm = 1.024 CCF of gas). In this case, we assumed that all the upstream and downstream emissions would also be avoided due to the energy not consumed by the various efficiency measures installed across the 88 pilot homes.

[vii] BEopt is a software package developed by the US National Renewable Energy Laboratory (NREL) for modeling the optimal suite of cost-effective energy efficiency measures on new and existing homes and is available for download at http://beopt.nrel.gov.

Table 3. Listing of WHPPP's total annual site and source energy savings and CO_2 reductions (MMCF = 10^6 cubic feet of natural gas; MWh = megawatt-hour of electricity; lbs = pounds of CO_2 equivalent).

Whole home performance pilot program (WHPPP) energy savings and CO_2 reductions	Evaluated (88 houses)	Projected (106 houses)
Total annual site gas savings	1.801 MMCF	2.169 MMCF
Total annual site electricity savings	113.6 MWh	136.8 MWh
Total annual site energy savings	2.22×10^9 BTU	2.67×10^9 BTU
Total annual source energy savings	3.31×10^9 BTU	3.99×10^9 BTU
Total annual source CO_2 reductions	929,790 lbs	1,119,980 lbs

Using light-duty vehicle emission rates and an average of miles driven annually[viii], this projected CO_2 reduction is equivalent to taking a car from each WHPPP house off the road for a year.[35] Nonetheless, this pilot represents a 0.0009% reduction in DTE Energy's annual residential electricity demand and 0.0019% reduction in annual residential gas demand. In other words, roughly 117,000 homeowners would need to participate in a similar comprehensive audit-to-retrofit pilot program to see a 1% reduction in residential electricity sales, as targeted for 2012 in PA 295. Similarly, almost 42,000 homeowners would need to participate in a similar pilot to see a 0.75% reduction in residential gas sales.

2.2.2 Evaluated versus Predicted Energy Savings

The WHPPP contractor used the Targeted Retrofit Energy Analysis Tool (TREAT)[ix] to predict the energy use after their proposed retrofit. With billed post-retrofit energy use now available, it was possible to compare the evaluated savings from our climate-normalized calculations to TREAT modeled savings. To test the agreement between modeled and evaluated savings we created a scatterplot in R to see how well the TREAT model predicted energy savings, as shown for every pilot house with sufficient data in Fig. 8. In this test, perfect agreement between evaluated and modeled energy savings would occur if the data was well fit by a regression line with a slope of 1. By quick inspection, clearly the data is not well fit by the 1:1 regression line.

This lack of agreement cannot easily be resolved. Our team was not supplied with all the assumptions and data that went into the TREAT model or participant contact information for follow up. There are many possible reasons for these two approaches to yield different results, such as climate-normalization technique, changes in occupancy and behavior, or even wrongly modeling (feedback) interactions between measures. Model validation would require further investigation and was beyond the scope of this project. Scatterplots for modeled and evaluated annual gas savings (Fig. A-3) and electricity savings (Fig. A-4) are located in Appendix A.

[viii] Here we used the US EPA's fleet average CO_2 emission rate for model year (MY) 2012 of 326 grams per mile and assumed an annual vehicle miles traveled (VMT) per participant of 15,000 miles.

[ix] TREAT is a proprietary energy audit simulation software package that is available for purchase from Performance Systems Development at http://psdconsulting.com/software/treat.

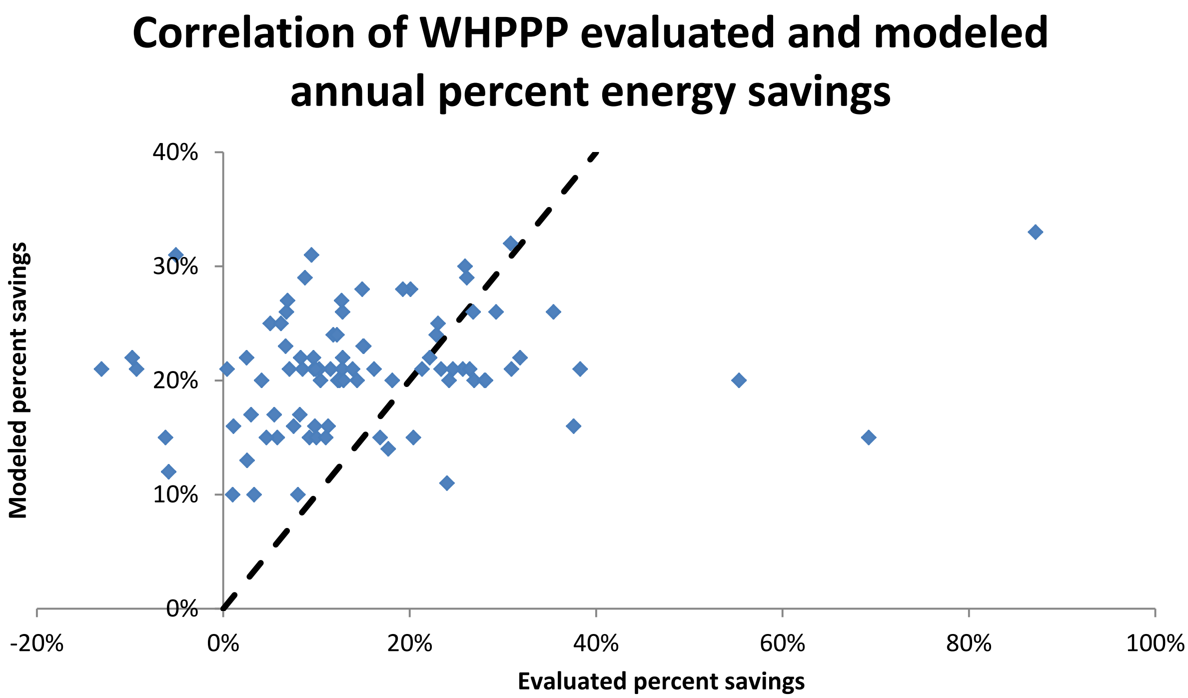

Figure 8. A scatterplot of WHPPP evaluated and modeled annual percent energy savings, in which the data is not well fit by the 1:1 regression line (n = 88 houses).

Aggregated evaluated, deemed, and modeled savings | The Michigan Public Service Commission maintains an extensive database of energy and cost savings of various home energy upgrades, which helps DTE Energy and other utilities in the state set EO surcharge rates. Deemed savings are based directly on this Michigan Energy Measures Database (MEMD).[36] Although we will not go into any further detail about the MEMD in this report, we were interested to understand how well the deemed savings were predicting evaluated savings.

For an aggregate comparison of evaluated, modeled, and deemed savings, we created boxplots of the WHPPP results for both electricity and gas in Fig. 9 and 10, respectively. These plots only include 20 quality control houses where data was itemized by measure. Measures installed on these houses consists primarily if not entirely of upgrades rebated by the utility, including but not limited to compact fluorescent light bulb (CFL) installation, air infiltration and duct sealing, attic (ceiling) and band joist[x] insulation, furnace, water heater, and air conditioner replacement. Fig. A-5 in Appendix A has the distribution of measures among the participants from a third-party survey. All the groups had 20 houses except the modeled electricity group where 3 houses were omitted because of missing data. The box indicates the 25th percentile, median, 75th percentile, the whiskers indicate the maximum and minimum, and the points are shown when they fall more than 1.5 interquartile ranges (IQR, equal to the range of the box) outside of the original IQR. The averages are shown in Table A-2 in Appendix A.

[x] The band joist is the bottom-most wood framing of the foundation that runs the entire perimeter of the house. Its external face is often directly adjacent to the outside making it vulnerable to temperature swings and moisture.

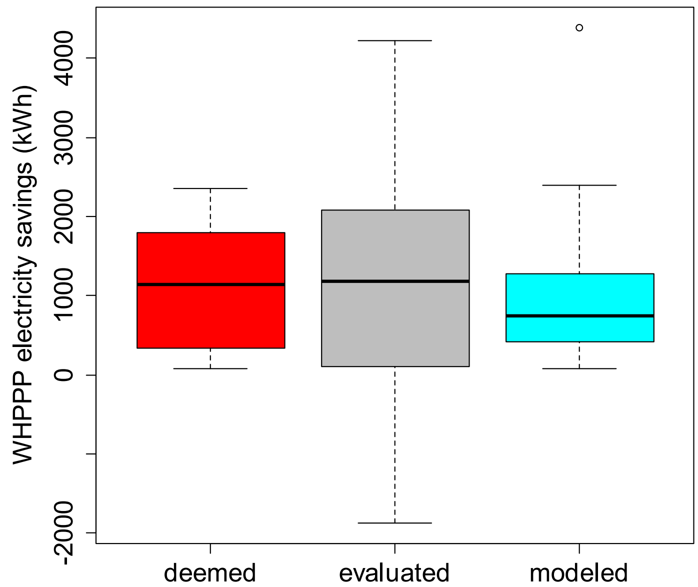

Figure 9. Boxplots of WHPPP deemed, evaluated, and modeled annual electricity savings (n = 20 houses, except the modeled group that did not have data for 3 houses).

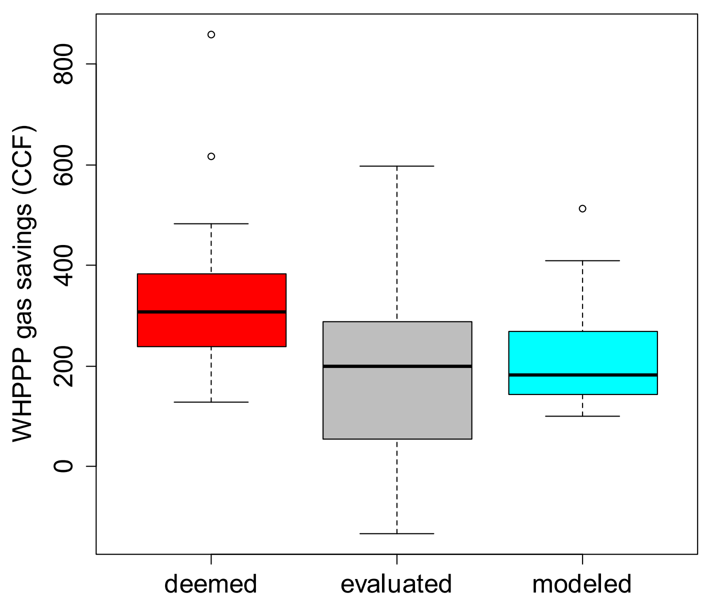

Figure 10. Boxplots of WHPPP deemed, evaluated, and modeled annual gas savings (n = 20 houses for all groups).

The evaluated savings have the most variation for both the electricity and gas plots. The deemed savings over-predict the evaluated gas savings and are nearly the same for evaluated electricity savings. The modeled savings are similar to evaluated gas savings but slightly less than evaluated electricity savings. These results are mostly unremarkable, but it is useful to see that the aggregated deemed and modeled savings are similar to the aggregated evaluated savings.

Therefore, we can say that there is not very high agreement on an individual house basis yet fairly good agreement in aggregate. This implies that the deemed savings estimates are reasonably accurate, although more so for electricity than gas in this case.

2.2.3 Predictive Statistical Models of Energy Savings

Correlation testing of energy savings and pre-retrofit building characteristics | We explored whether it was possible to predict potential energy savings based on existing, pre-retrofit building characteristics. First, we ran a series of correlation tests to see if there were relationships between energy savings and pre-retrofit characteristics, including house age (years), floor area of conditioned space (ft^2), air leakage rate (measured in cubic feet per minute (CFM) at 50 Pascals of pressure during a blower door test), thermal resistance of ceiling (roof) insulation (R-value reported in ft^2·°F·h/BTU), and initial capital investment for the home upgrades (US dollars). Two houses without air leakage rates were omitted and the house with nonsensical savings of over 90% was also omitted. Unfortunately, energy savings was not well correlated to any of the pre-retrofit characteristics, as shown in the first row of the matrix of scatterplots (Fig. A-6) in Appendix A.

Correlations between the pre-retrofit characteristics themselves are also of interest. If characteristics are highly correlated, then including both factors in a model would essentially double-count them. We did find two significant correlations: 1) between house age and log-transformed floor area (n = 85 houses, $p < 0.001$) and 2) between house age and log-transformed ceiling insulation ($p < 0.05$). Fig. 11 shows that older homes tend to have less square footage (left plot), as well as less ceiling insulation (right plot). Full statistical results can be found in Appendix A.

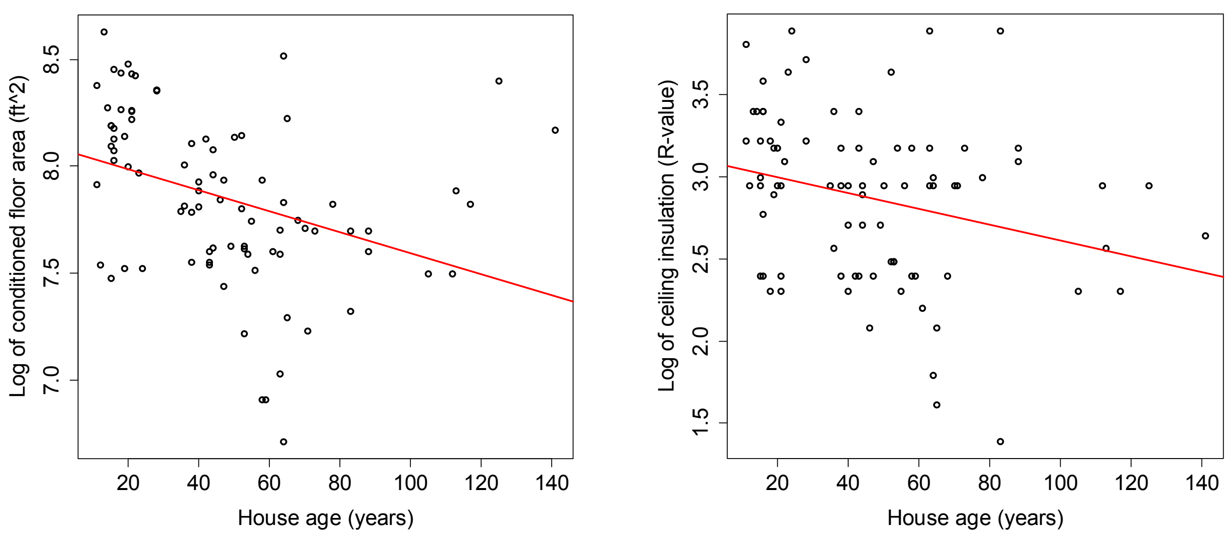

Figure 11. Scatterplots with best-fit regression lines of the two significant relationships found amongst building characteristics: left plot shows the correlation of log-conditioned floor area (ft^2) with house age (years) ($n = 85$ houses, $p < 0.001$); right plot shows the correlation of log-ceiling insulation (ft^2·°F·h/BTU) and house age ($p < 0.05$). Plots of all correlation combinations included in Fig. A-6.

2.3 Discussion

Automating calculations through writing scripts in MySQL and R enables quick and easy processing of annual energy savings by household. A well-written script that synchronizes data on customer gas and electricity use as well as localized degree days can be used time and time again and can greatly reduce the risk of calculation errors. This ensures repeatability of the analysis so that energy savings can be assessed over time and across houses elsewhere in the utility's service territory.

Generally, the WHPPP should be viewed as a successful pilot, where on average participants saved about 15% annually based their pre-retrofit energy use, or around $305 each year. There were 9 obvious outliers within the 88 WHPPP houses analyzed that either used more energy post retrofit or had over 50% savings. Cumulatively, the pilot avoided over one million pounds of CO_2, which is roughly equivalent to taking a car from each participating household off the road for a year.

In the future, it would be worthwhile to see how these WHPPP pilot houses compare to other randomly selected houses within DTE Energy's combined gas and electricity service territory. We have begun this process by benchmarking pre- and post-retrofit gas and electricity use of all 88 pilot houses against averages by zip code and service territory with data provided by DTE Energy as well as household averages for Michigan and the Midwest from the US Energy Information Administration's latest Residential Energy Consumption Survey (RECS) from 2009[37] in Fig. A-8 in Appendix A.

We found that there was substantial variation from house to house when comparing the modeled savings generated through TREAT and the evaluated savings that we calculated using monthly utility bills; however, there was good agreement between the evaluated, deemed, and modeled savings estimated from the MEMD, and the modeled savings when considering an aggregate group of 20 houses. This indicates that both the MEMD and TREAT are fairly accurate at predicting aggregated energy savings, even if they cannot reliably predict savings for any individual home.

Additionally, we investigated whether it was possible to build a linear regression model that could predict which pre-retrofit building characteristics, like house age and ceiling insulation, would affect energy savings. While our results for the full linear model were not significant ($p > 0.05$), further statistical analysis should be considered. A model like this could help DTE Energy and other utilities target future EO participants and it warrants some attention.

Section 3

Home Efficiency Valuation

3. Home Efficiency Valuation

3.1 Introduction

Using the data provided by the pilot program, the project team conducted a discounted cash flow analysis to assess the average consumer's ability to obtain a financial return on a home improvement investment within DTE Energy's service territory. Our financial model was built roughly around the US EPA's cost-effectiveness framework.[38] The initial results from our analysis were not encouraging; they showed that even with substantial rebates from the utility company and a low discount rate, the financial breakeven period (using net present value calculations) still exceeded 30 years. However, under the default scenario, if the home was sold within 5 years, the salvage value of the upgrades will result in a positive NPV.

3.2 Methods and Results

3.2.1 Cash Flow Model of Home Energy Upgrades

Annual savings are calculated (gas + electric) over a 35-year period as free cash flows (FCF). FCF incurred each year as a result of a home improvement upgrade (in other words, the annual savings resulting from reduced energy consumption) is multiplied by the appropriate discount factor for that year. This will produce a present value (PV) of the savings that are projected in future years. These savings are then added up to calculate the cumulative PV of the savings in a given time period. Time periods of 5 years increments, up to 35 years were used in this model. This represents the total financial return of a home improvement investment. The initial investment is then subtracted from the total PV to find net present value (NPV).

Predictive cash flow model assumptions | This model assumed averages for the following variables: electricity and gas use reduction, utility prices, initial capital investment for the upgrades, and rebates received. This model also assumed a uniform discount rate applicable to every homeowner in the program. However, given that every home is different, and therefore will receive different upgrades, incur different costs, and therefore be eligible for different rebates, this model should not be interpreted as a predictive model for the investment outcome of any particular home energy audit and upgrade. The model only represents aggregate outcomes for the WHPPP.

WHPPP cost savings | This calculation represents the amount of money saved each year in the form of reduced energy bills. Basic cost savings S for each year are simply the sum of the average WHPPP gas use reduction (G_R, in CCF) from the previous section multiplied by an average gas rate (p_G, price per CCF) and the average WHPPP electricity use reduction (E_R, in kWh) multiplied by an average electricity rate (p_E, price per kWh). The basic cost savings are expressed in the following formula:

$$S = G_R \cdot p_G + E_R \cdot p_E \qquad (Eq. 5).$$

Average gas and electricity prices were pulled from the EnergyPlus[xi] file for Detroit.[39] However, one must also take into account the fact that utility prices are not static, so annual compound price increases of 3.2% and 2% were built into the gas and electricity prices, respectively, using pricing projections[xii] for electricity ($\mathrm{R_{IE}}$) and natural gas ($\mathrm{R_{IG}}$) from the US EIA's Annual Energy Outlook.[40] In other words, even if one assumes that the amount of total energy saved in each house may remain static each year, monetary savings over time t in this model are projected to increase from year to year due to increasing prices. Therefore, the revised savings S' with components for both gas ($\mathrm{S_G}$) and electricity ($\mathrm{S_E}$) are as follows:

$$S' = S_G + S_E = (G_R \cdot p_G)(1 + R_{IG})^{t-1} + (E_R \cdot p_E)(1 + R_{IE})^{t-1} \qquad (Eq. 6).$$

Loss of efficiency | Finally, one cannot assume that the effectiveness of home energy upgrades will stay constant. It is likely that some amount of wear and tear will occur over time, which would diminish the effectiveness of the upgraded equipment. Therefore, an annual rate of efficiency loss ($\mathrm{R_{EL}}$) of 0.5% was built into the equation. Therefore, the final savings projected S'' for each year can be written:

$$S'' = (S_G + S_E)(1 - R_{EL})^{t-1} \qquad (Eq. 7).$$

Depreciation | Depreciation (Dep) is the next element of the cash flow. It is reasonable to assume that upgraded equipment, such as new furnaces or improved insulation, has the effect of increasing property value, the minimal amount of the property value increase is assumed to be the cost of the upgrades. However, these upgrades become less valuable over time, therefore depreciation must be taken into account. The team made the assumption that the initial capital investment for the upgrade would be depreciated over a 20-year period, so a 5% straight-line depreciation expense is incurred annually for as long as the resident maintains ownership over the property. At the end of the 10- or 20-year period, any un-depreciated value remaining (if applicable) on the initial investment I is discounted at the appropriate year and added to the total PV as a salvage value V_S. This represents the additional property value incurred as a result of the upgrade at the time of sale.

$$V_S = I - (Dep \cdot t) \qquad (Eq. 8).$$

In this case, V_S is used if it is greater than 0, otherwise $V_S = 0$. The homeowner does not necessarily recoup the full salvage value of the investment for any given year. Often times, a home improvement investment will only be partially valued during sale of the property.[41] The choice to recoup the full value was strictly for simplification of our financial model. Other salvage value functions could be explored in future research.

Free cash flow (FCF) | The free cash flow (FCF) represents the incoming and outgoing cash flows of an investment; in the discounted cash flow model within a business context, the FCF is the unlevered operating cash flow (UOCF) minus the capital expenditures and changes in net

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[xi] EnergyPlus is a free building energy simulation software package developed by the US Department of Energy that is available at http://apps1.eere.energy.gov/buildings/energyplus/nrew.
[xii] In our model, 30-year (2011-2040) nominal price growth rates for gas and electricity were used over all timespans for simplicity.

working capital. In this context, however, there are no additional capital expenditures and no changes in working capital, therefore both are assumed to be zero and so the FCF and the UOCF are the same.

In our case, the “revenue” consists of the savings incurred, and the only “cost” is the depreciation expense. Furthermore, since the model is being calculated for an individual taxpayer, not a business entity, the tax would not apply. It is presumed that whatever income the average homeowner uses to fund this home upgrade would have already been taxed. The only potential tax that would be incurred is the income tax from the interest earned on the savings, if that money was placed in an individual’s savings accounts. Given that current interest rates on savings accounts are near zero, the additional income tax burden would be negligible and subsequently assumed to be zero.

Discount rate and discount factor | In the context of home improvement upgrades, this represents the opportunity cost of undergoing home improvement investments. This could vary widely based on individual homeowners’ circumstances. For example, if the homeowner is a savvy stock trader who can secure returns of 15% a year by investing in mutual funds, then the opportunity cost – and therefore the discount rate – of investing that money into home upgrades instead would be 15% of the initial investment, for this is how much money the homeowner would forego by not investing in the mutual fund. On the other hand, if the homeowner’s next best investment alternative is a savings account that yields 0.5% interest, then the discount rate for that individual is 0.5%. The same principle applies if the homeowner takes out a loan to finance the upgrade. In this case, the interest rate of the loan would be the opportunity cost of investment, given that this is the amount that the homeowner could have avoided paying if he chose not to pursue home upgrades. For example, Michigan Saves, a state-run program, currently offers loans through the Home Energy Loan Program ranging from $1,000 up to $20,000 with a fixed 7% interest rate.[42] Once the discount rate (R_D) is determined, a discount factor (F_D) for the appropriate year t is calculated by using the following formula:

$$F_D = \frac{1}{(1 + R_D)^t} \quad (Eq. 9).$$

This discount factor represents the percentage of monetary value remaining in a future return. [xiii] The final step of the discounted cash flow analysis is to find the NPV over a timespan of n years as follows:

$$NPV = (R_B - C) + \sum^{n} F_D(S'' + V_S) \qquad (Eq. 10),$$

where C is the initial cost of upgrades and R_B is value of the rebates, if applicable. A positive NPV represents positive financial returns, whereas negative NPV represents a money losing proposition. Fig. 12 shows average NPV calculations at 5-year increments for 35 years.

[xiii] For example, assuming a discount rate of 5%, in 5 years the discount factor would be $1/(1 + 0.05)^5$, which would equal approximately 0.7835. Assuming a 5-year savings of $500, the PV of the savings is approximately $\$500 * 78.35\% = \$391.76$. In other words, $500 savings 5 years from now is worth about $391.76 today.

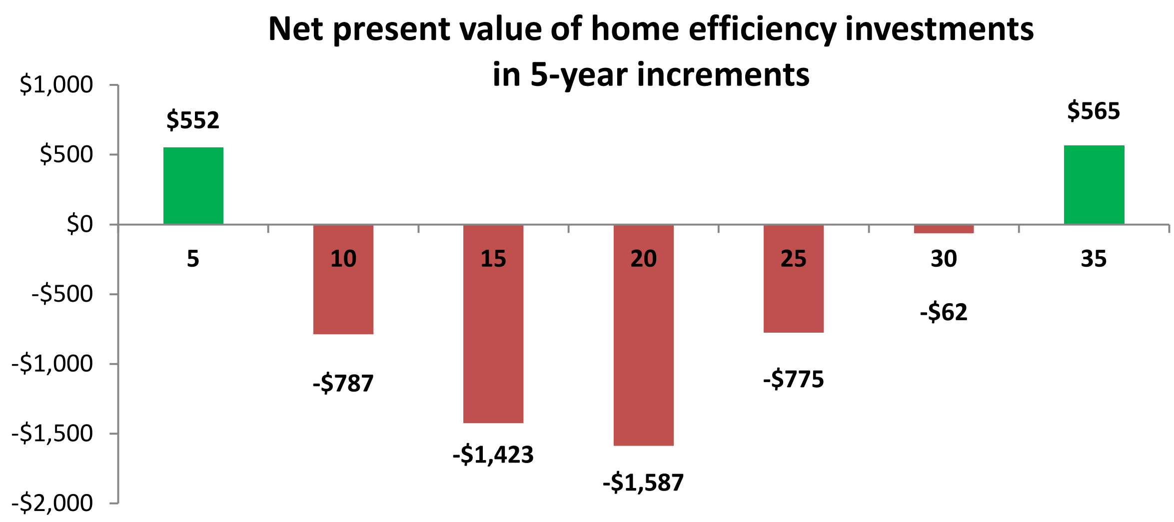

Figure 12. Net present value of an average WHPPP home efficiency investment over a 35-year timespan.

These results show that given the default assumed discount rate of 5%, an average WHPPP house would yield negative financial returns at all periods within the time frame except the 5-year period, and that the average homeowner within this pilot would have to live in the house for more than 30 years in order to breakeven. The 5-year investment period yielded a positive NPV because of the significant salvage value that would be recouped if the homeowner were to sell his property. In the default scenario, the negative NPV peaks at the 20-year period, which is yet another cause for concern, as shown in Table 4.

Table 4. Sensitivity analysis of NPV for a home efficiency investment when holding the efficiency loss at 0.5%.

Net present value (NPV) of a whole home efficiency upgrade with a fixed efficiency loss rate (including the salvage value of investment)			
	Timespan of home ownership		
Discount rate (assume efficiency loss rate = -0.5%)	10 years	20 years	30 years
3%	$84	-$625	$1,860
5%	-$787	-$1,587	-$62
7%	-$1,507	-$2,324	-$1,376
9%	-$2,106	-$2,895	-$2,299

According to the National Association of Home Builders (NAHB), in the Midwest, the estimated length of homeownership for 50% of the population is 17 years.[43] This implies that for the plurality (if not majority) of homeowners within DTE Energy's service territory, the length of homeownership is close to the negative peak of the NPV. Although the savings and costs to homeowners will vary widely on a case-by-case basis, if the assumptions are representative, this data suggests that the pilot program is unlikely to yield positive financial returns for the majority of its participants under our baseline conditions. However, sensitivity analysis in Table 4 demonstrates that with a reduction in the discount rate to 3%, homeowners will have a positive NPV for over 10 years before it dips negative temporarily.

Our other sensitivity analysis in Table 5 also took into account varying rates for efficiency loss, and found that it does not affect NPV outcomes as much as does the discount rate.

Table 5. Sensitivity analysis of NPV for a home efficiency investment when holding the discount rate at 5%.

Net present value (NPV) of a whole home efficiency upgrade with a fixed discount rate (including the salvage value of investment)			
	Timespan of home ownership		
Efficiency loss rate (assume discount rate = 5%)	10 years	20 years	30 years
-0.3%	-$764	-$1,507	$95
-0.5%	-$787	-$1,587	-$62
-0.7%	-$808	-$1,666	-$213
-0.9%	-$831	-$1,742	-$359

3.3 Discussion

Under most scenarios modeled for the WHPPP, it would be difficult for the majority of customers to recoup the cost of energy optimization investments. However, this should not be cause for pessimism for homeowners. The modeled results only represent aggregate outcomes for the entire group of WHPPP participants, individual opportunity costs and house conditions vary widely. If further analysis deems these outcomes to be representative, a utility can still provide an attractive financial incentive to customers by securing low-cost financing (3% or lower), or by providing larger upfront financing mechanisms. In addition to utility rebates, these mechanisms include additional rebates from local or state government[44], incentives from third-party programs like BetterBuildings for Michigan[45], or federal tax credits for energy efficiency[46].

Financial benefits should not be the only measure for decision-making. Even if it were, the lifetime costs are far from prohibitive, even though the upfront costs may appear daunting to cash-strapped lower or middle income families. The total lifetime financial cost of energy optimization to the customer—under most circumstances modeled here—is less than $2,000. Given the thermal comfort and home safety benefits that energy optimization brings, $2,000 over the course of 15-20 years can be a worthwhile investment. In fact, auditor survey results (detailed in Section 5 of this report) suggest that home comfort is the second most important priority for homeowners' decision-making processes, a home improvement professional can make a compelling case for homeowners to move forward with energy optimization investments, even to a financially savvy customer. To better educate and incentivize homeowners, DTE Energy can place emphasis on non-financial incentives, as well as the minimal lifetime cost of energy optimization.

Section 4

Spatial Analysis

4. Spatial Analysis

4.1 Introduction

Geographic visualization of the current outreach of DTE Energy's residential energy optimization program will yield a better understanding of where the program is already running well and, more importantly, where more effort is needed. In addition, including energy consumption patterns into the marketing strategy enables companies to identify locations with the most potential for home energy efficiency improvements. Lastly, the service gap analysis for home energy improvement contractors was conducted to illustrate locations without available EO services.

In this section, we also identify areas in DTE Energy's service territory with high total and average residential energy consumption as well as areas that have a relatively high utility cost burden compared to annual income. These are the areas in the most urgent need of home energy efficiency and stand to benefit the most from DTE Energy's EO program.

4.2 Methods and Results

4.2.1 Visualization of Residential Energy Optimization Participation

In order to better evaluate the success of the residential EO program across the state of Michigan, a series of maps were created to display the number of participants in each zip code. The ability to geographically map participation level gave new insights into where to promote the energy optimization program based on demographic information, participation history, and other factors. Seeing this information combined visually on maps makes the decision-making process more fact-based and easier to communicate within the company and to any partners.

Mapping participation for EO program | Participant data based on rebate filings from 2011 in spreadsheet format was provided to our team by DTE Energy. In each zip code, the customers who participated in specific EO sub-programs, including audit and weatherization, energy efficiency assistance, appliance recycling, and others, were recorded. While most interested in the audit and weatherization category, we started working with total participation dataset because it was more robust and easily understood. We found later that the audit and weatherization data followed similar but slightly more exaggerated trends as the full dataset of total customers participating DTE Energy's residential EO program, as shown in Fig. B-1 in Appendix B. Since the utility provided the total number of customers in each zip code, the percent of customers participating in each zip code was also calculated. In order to map the participation level, data for the geographic boundary of each zip code area was also downloaded from the Michigan Geographic Data Library.[47]

In ArcGIS[xiv] we joined the EO participant counts and boundary layers using zip code as the

[xiv] ArcGIS is a geospatial analysis software program developed by the Environmental Systems Research Institute (ESRI) and information about licensing and pricing can be found at http://www.esri.com/software/arcgis.

common attribute, so that the new table contained not only the original field of participation dataset, such as participant counts and total customers, but also the geographic boundary of each zip code. After the new dataset was cleaned, a graduated color scheme was implemented to color code the areas to illustrate differences among the participant counts of various zip codes. Areas without color are outside of DTE Energy's service territory or have no participation.

However, the simple absolute number of participants could not accurately identify the zip codes in which customers are most or least enthusiastic about energy efficiency, since this number could be dramatically affected or even determined by the total customer count. Therefore, the total number of customers was used to normalize the number of participants and compute a participation percentage. Another map with the participation percentage by zip code was created, as shown in Fig. B-2 in Appendix B.

Around 80% of participants are concentrated in four southeast counties – Oakland, Macomb, Washtenaw and Wayne. Participation is particularly high in Wayne County, which accounts for about 50% of the total, as shown in Fig. 13 and 14. One reason for this pattern is that these counties are the territory where DTE Energy provides combined service for both gas and electricity[48], so the company's marketing strategy is more targeted towards these areas. In addition, several subsidized programs, such as their Energy Efficiency Assistance Program[49], are in effect for low-income families within Wayne County. This explains the extremely high participation level along the northern boundary of Wayne County, where the median household income is among the lowest in Michigan.[50]

By comparing the map for participant counts to the map with absolute number of participants normalized by total customers, we found that the general pattern does not change much, with the exception of a few anomalous zip codes located, for example, in Alcona, Ingham, and Isabella Counties. Few DTE Energy customers reside in these outlier areas, so even one participant can inflate the percentage.

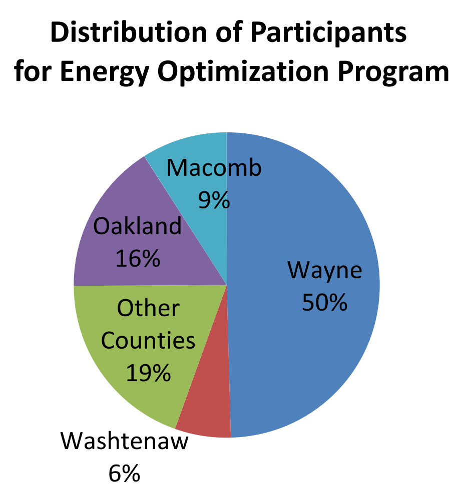

Figure 13. Distribution of participants in EO programs by county in DTE Energy's service territory.

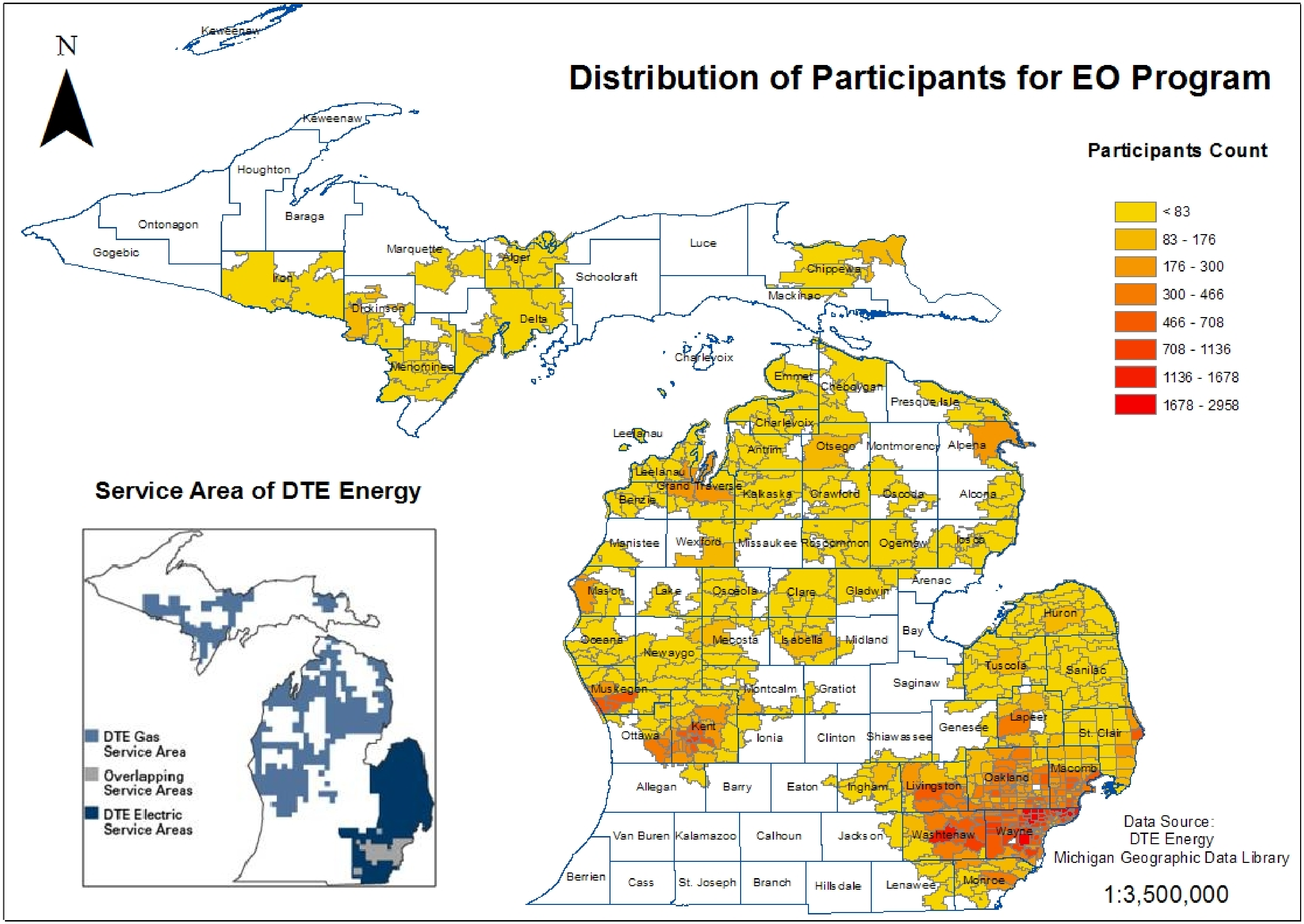

Figure 14. A map of participation in DTE Energy's residential EO program with an inset of the utility's gas, electric, and combined service territories. Red areas indicate higher participation and yellow areas indicate lower participation.

4.2.2 The Relationship of Energy and Income

By mapping Michigan's residential energy use at the zip code level, see Fig. B-3 and B-4, the utility company could gain a better understanding of energy distribution and identify where the EO program should be targeted. Placing the energy consumption in the context of zip codes enables DTE Energy to find priority areas for the EO program. A similar study was conducted by the researchers from Columbia University for building energy in New York City.[51]

Residential energy use in Michigan | Combining the 2012 aggregate zip code energy use dataset from DTE Energy and demographic census data, we found the total energy use (TEU_z) for each zip code z. This was calculated by converting the average annual electricity (E_z) and gas use (G_z) per household into a common energy unit (BTU, as in Section 2) and then scaling that by the total number of households (H_Z) in the zip code from US Census Bureau data[52]. This process is summarized in the equation below:

$$TEU_z = H_z(E_z + G_z) \quad (Eq. 11).$$

In addition, household average annual energy use is a good indicator of savings potential—a house with dramatically high use is more likely to have greater opportunity for efficiency gains. Therefore, mapping the average consumption is helpful for identifying areas that have a greater potential for energy savings.

Observations from the average annual energy use map and EO participation map suggest that awareness of and participation in energy efficiency programs is still very low. For example, in the zip code along the northern boundary of Huron County, average energy use is extremely high compared with other places; that zip code in Huron County has almost 2,000 customers but only 50 have participated in the EO program. Similar situations also exist in Sanilac and Oakland Counties, which have significant gaps to be filled by the EO program.

According to the total residential energy use map, most energy is consumed in the five counties around Detroit—Wayne, Washtenaw, Macomb, Oakland, and Livingston. In addition, several areas with intensive energy consumption are scattered in other counties, such as Isabella, Grand Traverse, and Muskegon.

Income spent on utility bill | According to a recent report, family incomes have not kept pace with the rising cost of energy.[53] Lower-income families are more vulnerable to energy costs than higher-income families because energy represents a larger portion of their household budgets. In 2006, households in poverty, more than 13 million nationally, spend an average of 25% of their entire annual income on their energy bills just to maintain their modest levels of consumption.[54] The EO program could play a more active role in alleviating the burden for families with a relatively high percentage of median household income spent on their utility bills.

To determine where in DTE Energy's service territory customers experience the most dramatic utility cost burden, the percent of median household income spent on their utility bill was generalized in Eq. 12. The money spent on the utility bill is the zip code-specific household average annual electricity (E_z) and gas use (G_z), as noted earlier in this section, multiplied by the corresponding average gas (p_G) and electricity price (p_E) utilized in our financial analysis in the previous section. This yields an average annual utility cost by zip code z, which is then divided by the annual median household income (MHI_z) for the appropriate zip code to find the percent income (PI_z) spent on the utility bill, such that

$$PI_z = \frac{E_z \cdot p_E + G_z \cdot p_G}{MHI_z} \qquad (Eq. 12).$$

In a few areas where DTE Energy did not provide both gas and electricity use data, we were not able to estimate the energy costs, and therefore those areas had to be omitted from further analysis. Fortunately, there were not many zip codes provided without both gas and electricity data. In the same way total energy use was mapped, this percent income metric was also linked with the geographic boundary of each zip code and mapped in ArcGIS, as shown in Fig. 15.

Saving money on utility bills is one of the best incentives to catalyze customers to participate in an energy efficiency program, especially for low-income families, who normally spend larger portions of their income on energy. Identifying groups with large utility bills would be meaningful for DTE Energy, and help them promote their low-income energy efficiency programs. In addition to several zip codes in the Detroit area, where the utility cost burden was roughly 10%, there are some other counties such as Huron, Muskegon, Ogemaw, and Newaygo, where the utility cost burden was also relatively high.

4.2.3 Contractor Service Gap Analysis

For contractors participating in DTE Energy's EO program, the distance between their base and the homeowners they serve determines the geographic coverage of their services. From the customer perspective, the search tool on DTE Energy's online energy efficiency directory is a primary method of finding a home energy improvement contractor; its design is also based on the distance between the location of homeowners and contractors.[55] For example, once the customer inputs their zip code and the type of energy service needed, the search engine will list the contractors who are within a certain distance. Therefore, the geographic service area of home improvement contractors plays a critical role in the success of the EO program.

Many auditors in Michigan also work as efficiency upgrade and retrofit contractors, in addition to assessing home energy performance through audits. As seen in the auditor and contractor survey in the next section though, not all contractors necessarily conduct energy audits.
To determine these contractor service gaps in DTE Energy's service territory, we conducted a series of GIS analyses based on the distance that contractors are willing to travel to provide service, including 1) Euclidean (simple radial from their base location) distance, and 2) road network (driving) distance.

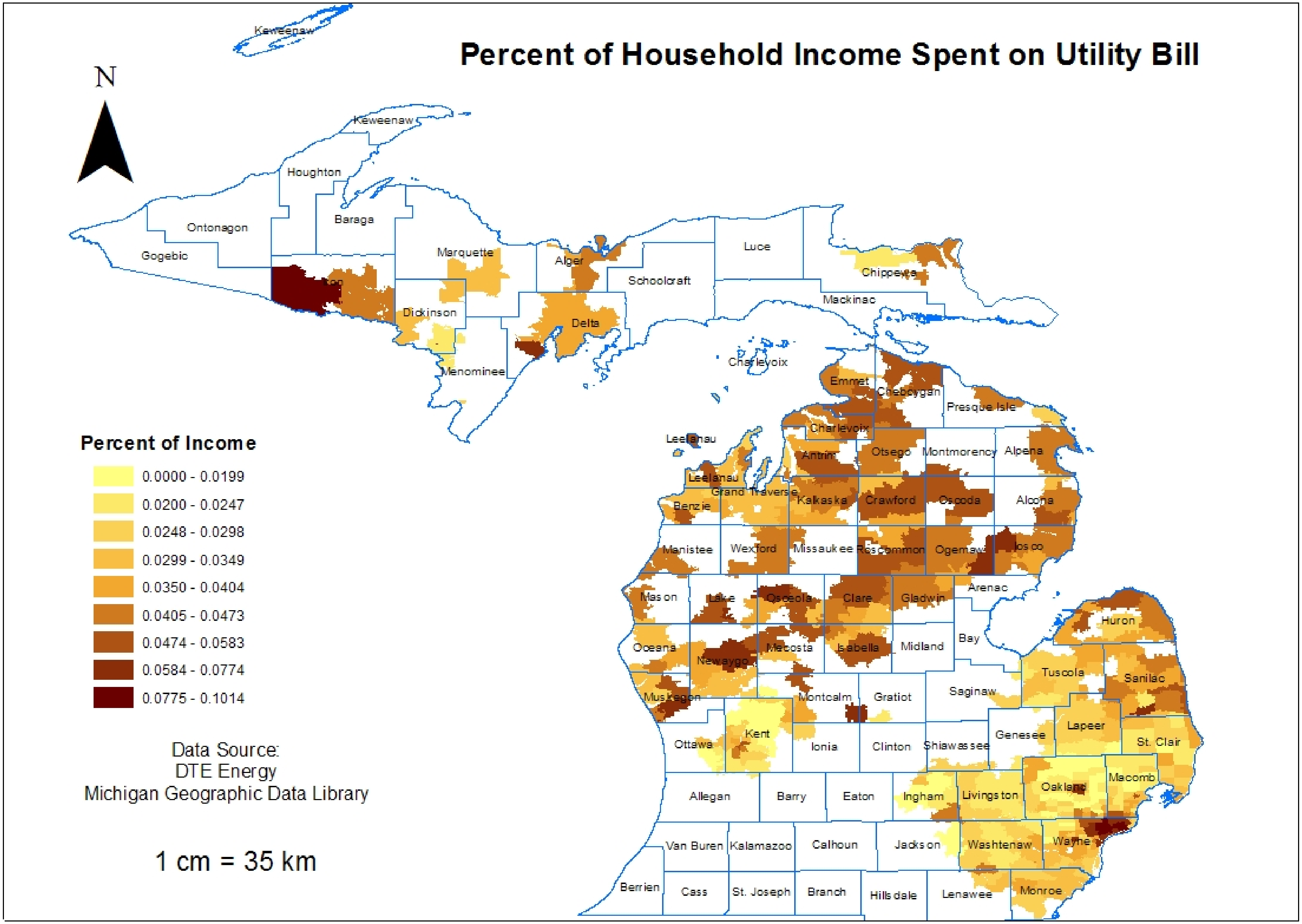

Figure 15. Map of utility cost burden per zip code as a percentage of annual median income that goes to the utility bill in DTE Energy's service territory. Darker color areas have a higher utility cost burden and lighter color areas have a lower utility cost burden.

Specifying the location of contractors was the first step in detecting the EO service area gaps. Through the geocoding of street addresses in ArcGIS, information from more than 1,000 contractors listed in DTE Energy's directory was used to create a set of points representing contractor business locations.[xv]

Service gap by Euclidean distances | For the purpose of calculating and displaying the distance to the nearest contractor, the Euclidean distance tool[56] in ArcGIS was employed. The output raster[xvi] contained the measured distance from every cell to the nearest source and then a graduated color scheme was applied to the output.[57] In this case, the reddish colors represent areas where the energy contractors are close to the customers and the greenish colors represent areas where the energy contractors are further away from customers. From this distance map (Fig. B-5), we know generally where potential service gaps are located.

In order to better detect and refine potential service gaps, Euclidean distance raster maps are used in our analysis to explicitly illustrate where the distance between customers and energy contractors is greater than the distance that energy contractors are typically willing to travel. Yet, a better estimate than Euclidean, straight-line distance is one based on travel route, which is determined by the length of the road distance to the destination. To improve this evaluation, we analyzed the road distribution network.

Service gap by road network distances | The Michigan road network layer was downloaded from the Michigan Geographic Data Library. In order to increase the processing speed of the network analysis, smaller roads below county level were omitted. Since this analysis was run at a state scale, trimming the smaller roads from the network should not dramatically affect the accuracy of the results. We ran this analysis for one-way distances of 30 kilometers and 40 kilometers, respectively (roughly 30 miles and 50 miles roundtrip). The output layer showed the boundaries of the areas in which contractors are willing to travel to provide service. The areas without coverage are regarded as contractor service gaps. The contractor service gap layer was then overlaid on top of another layer with total customers by zip code to illustrate where customers lack access to home energy audit and upgrade services, as shown in Fig. 16.

Most contractors are concentrated in the Detroit metropolitan area, where the residents are also already the most active in DTE's residential EO program. Other areas do not have the same level of coverage available. Even assuming that contractors are willing to travel about 50 miles roundtrip, some areas in the northern part of the Lower Peninsula, such as Crawford and Roscommon Counties, as well as parts of the Upper Peninsula still do not have coverage. Although these areas may be relatively sparsely populated compared to Detroit and its suburbs, residents outside of greater Detroit also need access to home energy improvement contractors. It seems that promoting contractor training and education in those service gaps would be an effective way to increase participation in the EO program.

[xv] Note that ArcGIS was not able match all the addresses perfectly, so Google Earth was also utilized as a supplementary tool to locate some contractors whose addresses could not be found on ArcGIS.
[xvi] A raster map is comprised of a matrix of cells (or pixels) that is organized into a grid, where each cell is assigned a value (or weight) individually, for meaningful representation.

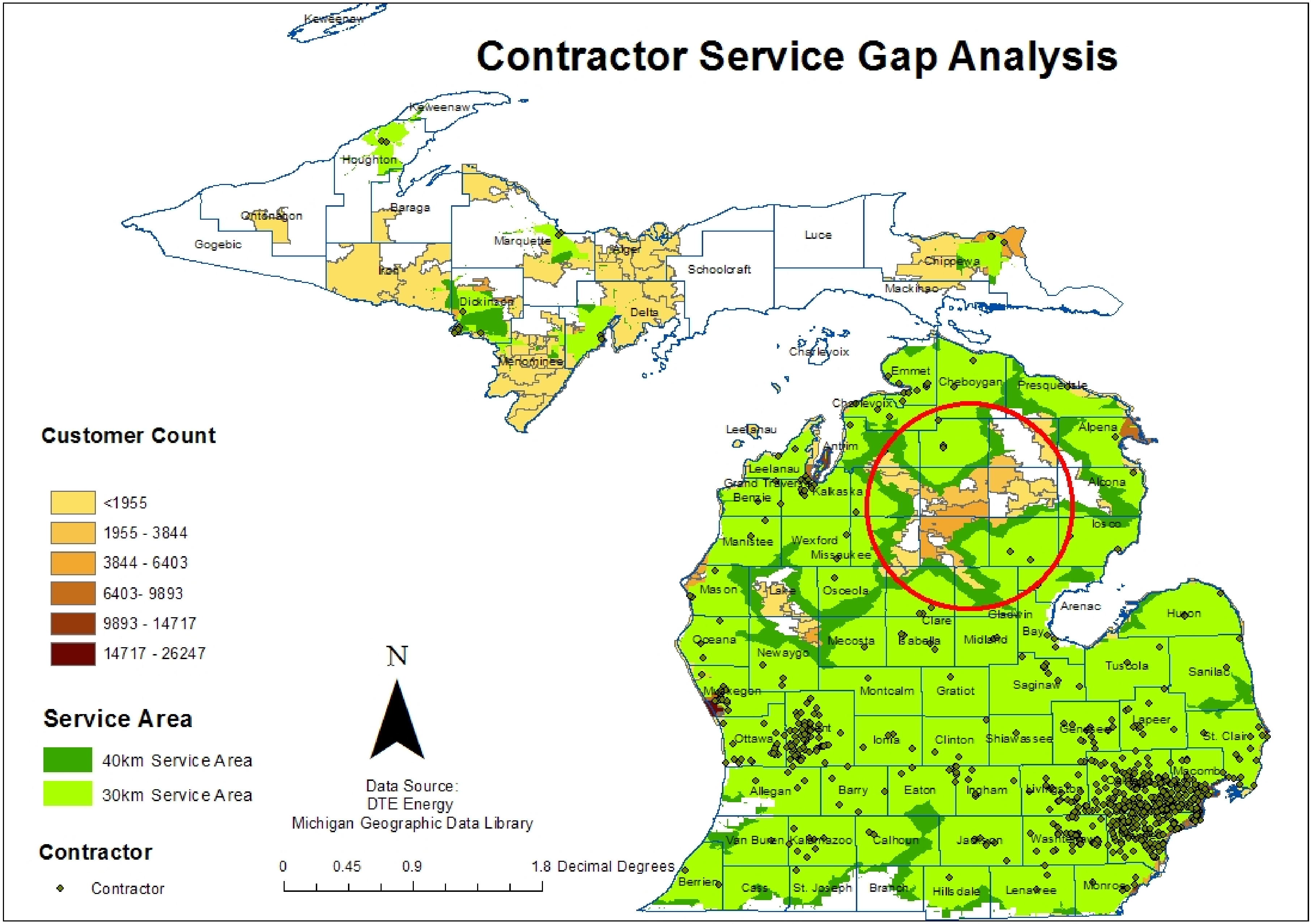

Figure 16. Map of contractor service gaps determined by road network distances. The light green areas indicate up to 30 miles of roundtrip driving is necessary and the dark green areas indicate up to 50 miles of roundtrip driving is necessary. Areas with residential customers beyond these driving distances are identified as service gaps.

4.3 Discussion

Using maps to visualize participation and energy use data is an effective way for a utility to find areas where there is a need for expanded EO services. In DTE Energy's service territory, there are still several geographic areas where customers have a large utility cost burden yet current EO participation is minimal. In addition, the contractor service gap analysis also reveals that the northern part of the Lower Peninsula and much of the Upper Peninsula is lacking in home energy efficiency service providers. These gaps underscore the need for more contractor training and continuing education opportunities, particularly outside of the utility's combined gas and electricity service territory. DTE Energy can easily promote both online and classroom courses to help more contractors become certified home energy auditors, especially beyond the metropolitan areas of Detroit and Grand Rapids.

In addition, by mapping social factors and other demographics, a utility company may be able to determine what type of programs and incentives are most likely to succeed with different segments of the population.[58] Demographics can yield useful insights for the formulation of niche marketing strategies. Given that limited census data was utilized in our analysis, a few other demographic factors including house age, poverty level[59], and number of rooms per house were selected for statistical analysis in relation to EO participation.

We ran a linear regression model to test whether EO program participation could be predicted by the aforementioned demographic factors. However, although the census demographics may be related to participation, the data was not normally distributed (Shapiro-Wilk: $p < 0.05$, see Appendix B), and thus violated a necessary assumption for a linear model. Future research could focus on finding a more appropriate model and the best demographics to predict program participation.

Section 5

Auditor and Contractor Survey

5. Auditor and Contractor Survey

5.1 Introduction

As part of the effort to evaluate how home energy auditors interact with customers, as well as with the utility, a survey developed using SurveyGizmo[xvii] was emailed to a large list of home improvement professionals in Michigan. The goals of this survey were to reveal how auditors currently attract new customers and grow their home improvement business, gain insights about the local energy auditing and home upgrades market, and seek auditors' perspectives on how to improve DTE Energy's residential energy optimization program. Given that energy auditors are closest to the customer in the home improvement value chain, and are likely to interact with customers on a near-daily basis, their opinions delivered invaluable insights on the current dynamics of the residential EO program.

In an anonymous online survey that took approximately 10-15 minutes to complete, a series of 33 questions were posed to over 1,000 home improvement contractors operating in DTE Energy's service territory. The majority of these survey participants are listed as residential contractors on DTE Energy's energy efficiency vendor directory[60]. Home energy auditors not listed by the utility but listed on the Michigan Saves contractor directory[61] were also surveyed. The questions were divided into four broad categories:

1. **Services provided** - type of services the contractors offer and to whom (the survey revealed that not all those listed actually serve residential customers).

2. **Customer outreach** - how contractors advertise service, to whom they advertise and the most effective methods of outreach, and seasonality of business.

3. **Post-audit operations** - incentives used to persuade customers to follow through on energy-related home upgrades, and most popular service provided.

4. **Business demographics** - statistics on the businesses and contractors themselves, such as which counties they serve, how many employees their companies have, and how many years they have been in business.

Given the survey length, the team realized that many contractors may be discouraged from completing it. Therefore, the team incentivized participation by entering respondents who finished the survey in its entirety into a random drawing to win one of five Home Depot gift cards.

Given the length of the survey, and the length of responses, it would not be practical to include a complete set of survey results in the main body of this research report. Summarized results are available in Appendix C. A few key results will be presented and discussed in this section.

[xvii] SurveyGizmo is an online survey development platform and more information about monthly subscriptions and other services can be found at http://www.surveygizmo.com.

5.2 Methods and Results

5.2.1 Home Energy Audit and Upgrade Marketing

Survey results–when taken into account with our other analyses–revealed several flaws within the home energy improvement "ecosystem" that prevent widespread use of energy audit and retrofit services.

Perhaps the most challenging of these flaws is the fragmented nature of the home energy improvement business. The survey shows that the overwhelming majority of contractors that provide auditing services are small firms consisting of 11 employees on average. Further, it shows that the most effective method of advertising to customers is word-of-mouth referrals by current customers, followed by company website visits, as shown in Table 6.

Table 6. Survey Question 4. Out of all the advertising methods you use, which are the most effective (please rank your top three methods from the list) (n = 138 respondents)? The total score is a weighted summation of individual respondent rankings.

Item	Total Score	Overall Rank
referrals by existing customers	146	1
company website	74	2
newspaper/magazine ads	31	3
referrals by utility companies	31	4
other __________ (specified above)	30	5
social media (i.e. Facebook, Twitter, etc.)	27	6
company brochures/pamphlets	20	7
direct marketing (i.e. cold calls)	13	8
TV ads	10	9
lead generation database	5	10
company e-mail newsletter	4	11

In fact, when asked to rank the effectiveness of each advertising method, word-of-mouth scored[xviii] twice as high as the next best alternative. This shows that small contractors likely do not have the resources or expertise to engage in active, coordinated, and sustained advertising efforts to reach out to potential customers. More than any other method, they rely on ad hoc referrals from existing customers to gain new business. As a result, residents in DTE Energy's service area are poorly informed about the availability and benefits of EO services, if at all.

A misaligned incentive is the next big challenge that faces DTE Energy. The survey shows that monetary incentives, namely reduced energy bills along with federal and local tax incentives, are the most effective means for auditors to persuade homeowners to invest in home improvements once the audit is completed, as shown in Table 7. Assuming that auditors can

[xviii] Scores are calculated through weighting based on the ranked choices from each respondent and then summed over all respondents and reported as the total score. Each respondent has equal weight.

effectively gauge customer motivation based on daily interactions, this clearly demonstrates that the average homeowner cares about financial returns more than anything else.

Table 7. Survey Question 22. Out of the incentives you use, which ones do you find most effective at convincing customers to invest in efficiency upgrades (please rank your top three incentives) (n = 71 respondents)? The total score is a weighted summation of individual respondent rankings.

Item	Total Score	Overall Rank
utility rebates/energy bill savings guarantees	129	1
occupant comfort	63	2
federal incentives (i.e. energy efficiency tax credits)	54	3
state and local government incentives (i.e. Michigan Saves)	35	4
health/safety improvement	34	5
contractor discounts	21	6
home price/value increase	20	7
other _________ (specified above)	16	8
third-party programs (i.e. Better Buildings for Michigan)	13	9

As discussed in Section 3, it may take up to 30 years to fully recoup the investment for a suite of efficiency measures. Some savvy investors would be unlikely to pursue energy-saving upgrades if a financial return was the primary and only motivation—as it appears to be based on survey results. However, this question also confirms that home comfort is a significant consideration, and it is the next best incentive for customer buy-in.

5.2.2 Home Improvement Services in Michigan

While distributing the survey, the research team observed another obstacle for homeowners when pursuing energy reduction improvements—an outdated contractor directory. When the team sent the survey, well over 100 messages bounced due to inaccurate email addresses. Given that the survey was distributed to approximately 1,000 potential respondents, this means that 10% of contractors listed do not have up-to-date contact information. In addition, the survey responses showed that approximately 25% of contractors do not serve homeowners at all but remain on DTE Energy's residential contractor directory, as reflected in Fig. 17.

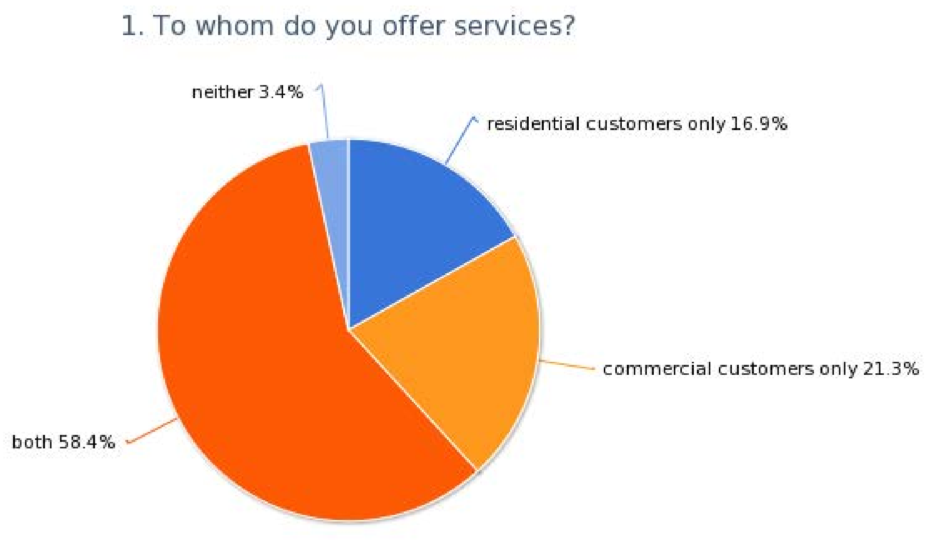

Figure 17. Survey Question 1. To whom do you offer services (n= 173 respondents)?

Even when the potential customer successfully contacts a residential contractor, only about one-third of these contractors actually provide home energy audit services, as seen in Fig. 18. While it is possible to filter by those who provide comprehensive energy audits, this feature is far from obvious. Furthermore, DTE Energy maintains a separate spreadsheet with a listing of participating contractors who offer audits through their Home Performance Program.[62] This listing is incongruent with the online contractor directory tool. For example, if a customer wished to find auditors located in Ann Arbor using the directory, it would only yield two auditors in Ann Arbor (as well as other auditors nearby). However, the Home Performance Program list has five auditors in Ann Arbor alone. This is confusing and should be amended. The directory should be synchronized with the participating contractor list so that the same auditors are listed regardless of where one looks for contact information.

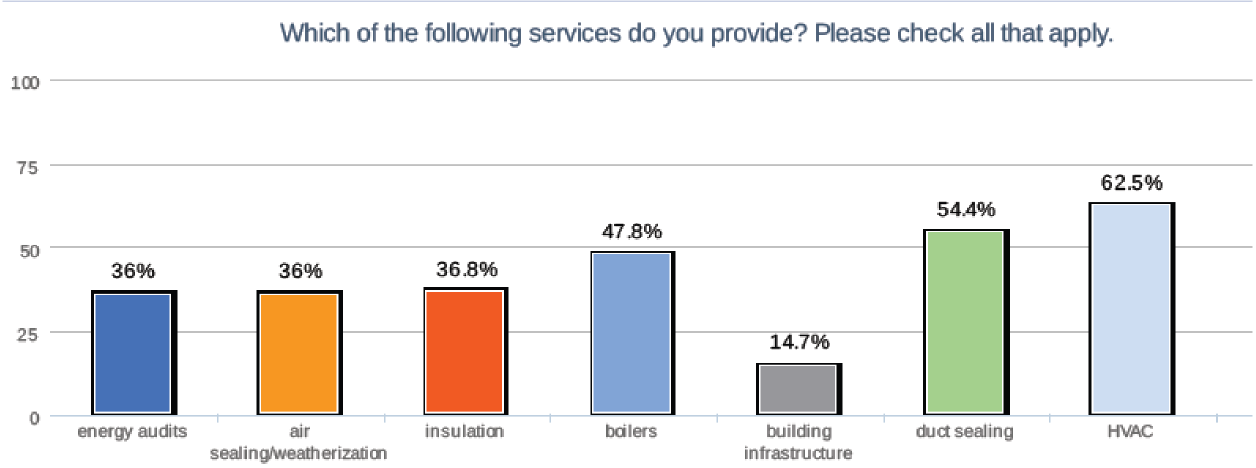

Figure 18. Survey Question 2. Which of the following services do you provide (n = 138 respondents)?

From a customer perspective, this means that when a homeowner wants to refer to the utility's contractor directory and inquire about auditing or home upgrade services, there is a good chance that he will either reach out to the wrong contractor or fail to reach someone at all. Moreover, given that homeowners tend to rely on word-of-mouth recommendations more than any other method of selection, if a homeowner does not happen to personally know another homeowner who has gone through the process with a contractor, he or she will likely have a difficult time selecting a home improvement company whom he or she considers trustworthy amongst the hundreds on DTE Energy's directory. On the other hand, compared to the other aforementioned bottlenecks that hinder the adoption of audits and upgrades, this one is relatively easy to mitigate. DTE Energy can start by removing outdated contact information, as well as separating those who do not serve residential customers and placing them into an independent directory for commercial and industrial customers.

5.3 Discussion

Assuming that the survey results are representative, audit and retrofit service companies can generally be divided into three categories by size – a large number of independent contractors consisting of 1-10 employees, several small companies of 20-40 employees, and a few larger companies with more than 40 employees. Comparing data of these three company categories showed some nuanced differences in terms of the service they provide, but there were no evident differentiators that stood out from the survey results.

In terms of target customers, independent contractors are more likely to focus solely on residential customers, whereas small and large companies tend to serve both residential and commercial. Although the survey did not explicitly ask for the percentage of revenues by customer type, one would speculate that large companies would put greater marketing focus on commercial clients, given that commercial clients are few in number and likely purchase services in larger volumes. Another indicator that larger companies are more focused on commercial business is that relative to independent contractors and smaller firms, they have a significantly lower rates of customers agreeing to conduct home energy audits, and slightly lower rates of follow up sales on home improvement services following the audit. This shows that revenues for larger companies likely come from either a significantly greater volume of home energy audits, or they generate most of their revenue from other services. The survey results indicates that large companies do not complete more home audits in the course of a year, so the latter explanation is far more likely.

Setting aside the differences in target market, there is surprisingly little relation between company size and the way they approach residential customers. In terms of pricing, nearly all companies charge $0-$500 for a home energy audit; larger companies do not necessarily charge more or less for audits. In terms of distance traveled, there is similarly little relation. Initially the research team hypothesized that a larger company would be more willing and able to cover a wider geographical area (by allowing its employees to travel further away from business headquarters), but that was not the case. It is possible companies are willing to travel further for commercial clients, but that is outside the scope of current research, as its sole focus is residential home improvement.

The results showed that auditors use a wide array of software to model home improvement options and energy savings and that they hold a variety of different certifications. However, given that the average homeowner is unlikely to be aware of these different certifications and software options, unless he or she is extremely well-versed in building sciences, those options are unlikely to factor into his or her decision-making. Nevertheless, knowing which modeling software was used and which auditor certification the contractor holds would help the utility in standardizing the data for rebate filings and future EO evaluation. Much of the data collected during the audit either never makes it to DTE Energy or often goes unutilized, even if it does. An automated filing system in which contractors upload audit and retrofit data for both rebates and further analysis would make great strides in alleviating these data collection issues.

The lack of discernible differences, especially from a customer perspective, suggests that home energy audit and retrofit services are largely undifferentiated or at least perceived as such. This could be yet another source of potential difficulty for customers, since the lack of differentiation means that customers have limited resources to determine the right contractor for them, and that company size among other factors is not necessarily an indicator of better quality, pricing, or service level.

Section 6

Customer Engagement and Satisfaction

6. Customer Engagement and Satisfaction

6.1 Introduction

One of the primary research objectives of this project was to determine what motivates homeowners to spend money on home energy audits and upgrades. Utilities like DTE Energy want to understand why customers engage in audit-to-retrofit programs so as to better assess the performance of their existing EO program. After analyzing previous third-party surveys, we conducted our own qualitative analysis through interviewing a few DTE Energy customers who recently had an energy audit and/or an upgrade installed in their home. We examined two surveys: 1) the a2energy survey, and 2) the WHPPP pilot survey conducted by an independent consulting firm for DTE Energy.[xix] We then drew some comparisons between our interviews and the surveys.

a2energy survey | This survey was conducted jointly by Clean Energy Coalition (CEC)[63] and the City of Ann Arbor[64] in August 2012, in which 611 attendees of the Mission Zero Festival[65] and city's annual Green Fair[66] responded. The survey had 8 questions focused on customer preference and behavior, seeking to identify common actions taken by the participants to improve energy efficiency in their homes as well as reasons for inaction. The survey also gauged familiarity with incentives. The survey data was meant to inform and direct future energy efficiency outreach efforts for the a2energy[67] program. It found that cost savings (87%) and environment and climate change (85%) were the most frequently selected motivating factors.

WHPPP participant survey | A customer satisfaction survey was conducted in March 2011 among WHPPP participants. It provided research for more effective planning and communication between consumers and other key stakeholders, and helped to identify specific solutions for improvement of contractor services. This customer satisfaction survey focuses on finding strategies that will allow DTE Energy to clearly communicate their home performance and improvement services to potential future users.

WHPPP surveys were conducted either online or by phone. This survey contained both quantitative and qualitative questions, including a series of closed and open-ended questions to elicit in-depth customer feedback. In total, 55 out of 106 WHPPP participants (52%) participated in the survey. There were 31 questions in total, covering topics from pre-audit to post-audit and beyond. Demographic information was also recorded.

As part of our project, we shadowed several local contractors during home energy audits in order to understand the reasons that drive customers to seek energy efficiency improvements. Our team did follow-up, supplementary interviews with some homeowners from the shadowed audits. In total, three homeowners were interviewed, so given the small sample size, we cannot draw broad conclusions from these interviews. However, the interviews have been helpful as we

[xix] Full results of the a2energy survey can be requested from the City of Ann Arbor's Energy Office by email at energy@a2gov.org; more information on the WHPPP survey can be requested from Bob Fegan of DTE Energy at feganb@dteenergy.com.

analyzed homeowner motivations and preferences and also for comparison against the a2energy and WHPPP surveys.

6.2 Methods and Results

6.2.1 In-depth Customer Interviews

All three interviewees work in the field of environmental and energy management and were likely to have participated in a pilot program like WHPPP had it been run within the last year. This analysis will focus on qualitative differences compared to a2energy survey and WHPPP survey results and the reasons for those differences.

Question development | We developed a face-to-face interview with 26 questions in total, attached in Appendix D, that took approximately 30 minutes to complete. These interviews attempted to discover the reasons that drove these homeowners to have an audit and to invest in home energy upgrades. The interviews contained mainly open-ended questions, so as not to lead the interviewees into certain answers but rather let them formulate and express their own opinions about the audit and retrofit process.

6.3 Discussion

The WHPPP survey found that 30% of participants learned about the audit-to-retrofit program from DTE Energy's website, as shown in Fig. 19; however, only one of the customers interviewed knew where to find home performance program or rebate information on the utility's website. The other two interviewees complained about the lack of visibility of the audit program.

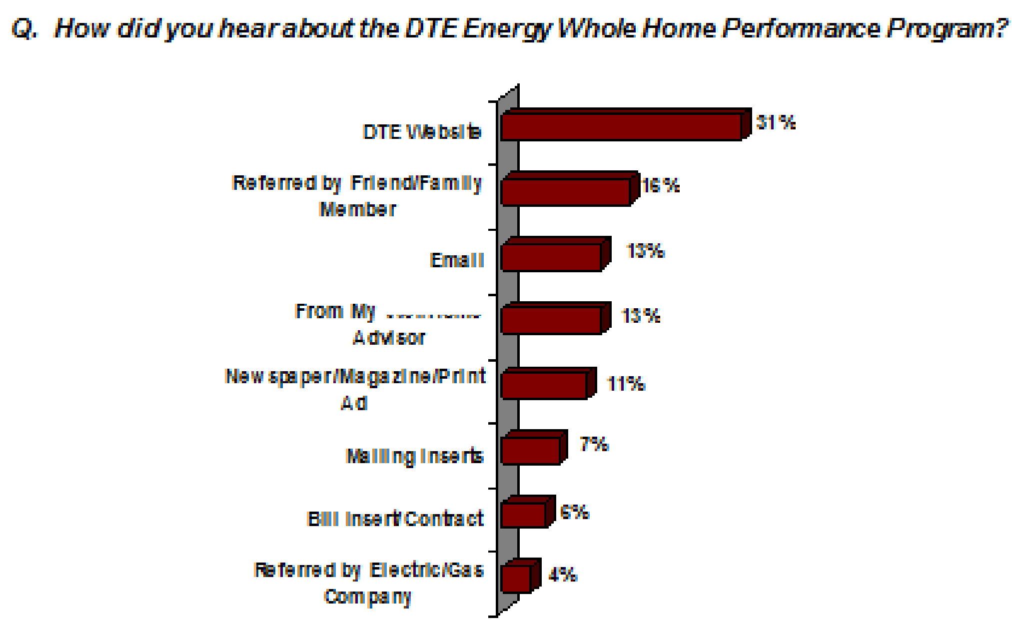

Figure 19. A display of the most effective methods of advertisement for the WHPPP (n = 55 respondents).

All of the homeowners interviewed mentioned that they needed more easily accessible information about the EO program and EO rebates delivered to them through email and direct mail, or even on their utility bills. One interviewee suggested that DTE Energy engage customers by telling a story about how their neighbors are saving money and feeling safer and more comfortable after their home energy improvement. Another suggestion was to have more information available about what homeowners could expect when going through an audit and retrofit process.

Environmental motives | None of our interviewees mentioned the environment as a motivating factor for making home energy improvements, since it was not referenced in our questions explicitly, even though all of them had environmentally-related careers. However, they all thought climate change mitigation was an important motivating factor after the interviewer hinted at it. This is interesting because in the a2energy survey, 522 out of 611 surveyed said that they wanted to be more energy-efficient for the environment—making it the second most highly cited (and the most highly ranked) reason for making home energy improvements. Cost savings was cited by 534 out of 611 as the single most important (but second ranked) reason for spending money on improved home energy efficiency, as shown in Fig. 20 and 21.

These responses have much to do with the survey setting. At an environmentally-themed event, it is no wonder that nearly all respondents indicated that environmental protection was a key motivator for decisions related to energy efficiency. When asked about their willingness to pay for environmental benefits, it should be noted that people tended to respond with "what they think they should do," instead of, "what they really do." That is, when asked about environmental issues, it seems that people tended to overstate their care for public welfare. Therefore, we recommend that DTE Energy and service providers mention a reduction in emissions only as an added benefit of their home improvement along with monetary savings. This program may help bring about more environmental awareness, but the utility should be aware that even the most environmentally-minded customers may not be willing to spend money solely for the sake of public welfare.

Figure 20. Results from the a2energy survey showing the greatest motivations for home energy efficiency (n = 611 respondents). Multiple selections were possible.

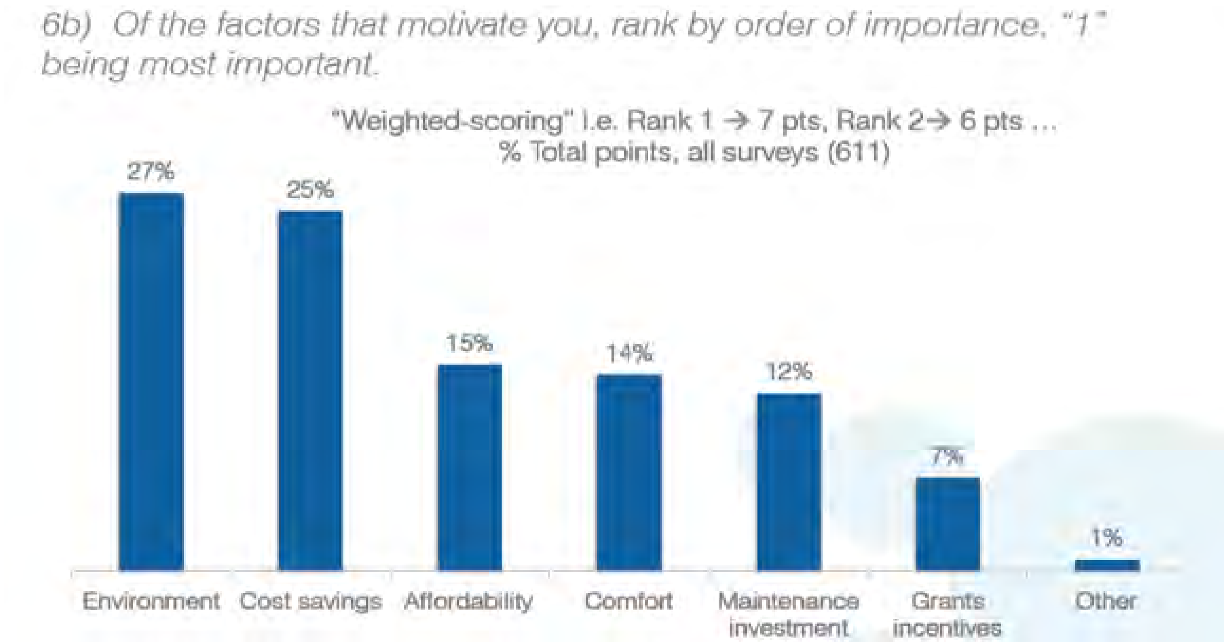

Figure 21. A scored ranking of the motivations for home energy efficiency from the a2energy survey (n = 611 respondents).

Behavior changes | In the a2energy survey, as seen in Fig. 22, around 90% of respondents claim to have changed their behaviors to be more energy efficient. However, our interview results suggest that customers prefer to have higher comfort levels for similar utility costs, so they would prefer to not change their behaviors, particularly regarding setpoint temperatures of their thermostats. Some may even raise temperatures if they know they can now afford it. This also shows that while cost savings may be attractive, more emphasis should be placed on improved thermal comfort for the residents. Also, for those who claim they did not see any savings on their bills, it is possible that their habits may account for the lack of change. It is useful to tell customers that after they invest in an energy audit and retrofit, they can expect 1) a higher comfort level with the same utility costs, or, 2) the same comfort level but lower utility costs, or even 3) a higher comfort level and lower utility costs in some cases.

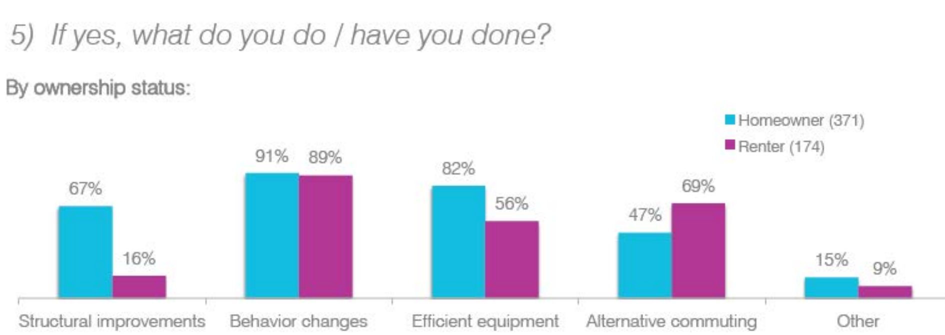

Figure 22. The percent of respondents (homeowner or renter) from the a2energy survey who participated in efficiency initiatives (n = 545 respondents). Multiple selections were possible.

Follow-up communication | All of our interviewees were interested in learning more about the audit process. They were curious about the conditions of their own homes and about their personal energy use as well as potential areas for improvement. For our interviewees and similar customers, just providing them recommendations on what measures should be taken is not enough; more information and data sharing is required. All of the homeowners interviewed were satisfied with the audit process, learned a lot from their energy auditor, and found the official audit report useful for future efficiency upgrade planning. One interviewee mentioned that she was disappointed with the lack of follow-up after the audit. Good communication and follow-up throughout the audit and retrofit process are important elements of attracting customer investment and completing a successful home energy improvement.

The audit reports should include information beyond the data and results from the home assessment itself. The reports should include prioritized recommendations to aid homeowners in deciding which efficiency measures they should undertake in the near-term and long-term future. Homeowners value the auditor's professional opinion and are likely to go forward with measures that the auditor has recommended as top priorities, so long as they are supported by evidence in the audit data.

Hassle-free strategies | One of our interviewees suggested the utility should try to make the rebate process as "hassle-free" as possible. That is, the contractor and the utility should strive to make the home energy improvement process as quick and as easy as possible for the customer. Customers are typically very busy with their daily lives, so making time for an energy audit and retrofit may be inconvenient. A certified auditor may be able to save customers a significant amount of money and time, but if their rebate application is held up by the utility, the homeowner may lose interest in home energy improvements. It is the responsibility of both the contractor and the utility to guide the homeowner on how to apply for utility rebates and other financial incentives. In fact, it is in their self-interest to do so.

Third-party incentives, such as the options available through BetterBuildings for Michigan, and even federal tax credits, are available for knowledgeable homeowners. It would be especially helpful if homeowners had an online tool to easily estimate the financial benefits of different efficiency upgrades. More contractors should promote loans from Michigan Saves as a method to spread out capital investment. Alleviating customer concerns about rebates and offering more home improvement information and assessment tools on a single website are two key parts of a hassle-free strategy. This would allow customers to easily perform their own simple cost-benefit analysis and evaluate how different home energy improvements might help them.

Do-it-yourself (DIY) projects | It is helpful for contractors to give customers some quick-fix, do-it-yourself (DIY) suggestions after an energy audit. It is also helpful to have these DIY suggestions called out separately from the other recommendations. That said, audit reports should still be succinct; a long audit report does not add any more value for the homeowner. The best approach is to keep the report short, highlighting quantitative evidence—such as results of blower door tests and infrared images---clearly pointing out what the homeowner should do. Similarly, it is important for auditors to provide references for contractors who can perform the types of upgrades that have been recommended, if they do not provide that type of service themselves.

A home energy improvement success story | One of the interviewees shared his personal experience and success story from his home energy improvements. With young children in the house, he had had some upgrades installed, but his mother, who lived next door in a house with the identical structure and square footage, had not. The first winter after the retrofit, his bill decreased 28% compared to his mother's bill, even though he typically kept his house warmer than his mother's because of the babies. He then recommended that his mother have an audit and upgrades on her house so that she can have similar comfort and cost-saving benefits. This is a great anecdote for contractors to tell people who are deciding whether or not to invest in home energy improvements.

Section 7

Conclusions

7. Conclusions

7.1 Key Findings

This project has applied an integrated approach to evaluating DTE Energy's residential energy optimization (EO) program across both spatial and temporal scales. Combining the results of our various areas of research addresses how effective the EO program has been in the past and how the utility can increase future EO participation. These findings—which have been discussed thoroughly in previous sections—are summarized below:

Pilot performance evaluation

- Automating the annual energy savings calculations using computer scripts will increase the speed, accuracy, and repeatability of those calculations during program evaluation.
- The average whole home performance pilot program (WHPPP) participant is saving roughly 15% on energy per year—1,291 kWh of electricity and 205 CCF of natural gas annually, which equates to $305 each year.
- Modeled energy savings from the Targeted Retrofit Energy Analysis Tool (TREAT) and deemed savings from the Michigan Energy Measures Database (MEMD) did not accurately predict the evaluated savings of individual houses, but all the calculation methods have good agreement in aggregate.
- There were no significant correlations found between post-retrofit energy savings and pre-retrofit building characteristics of the house, but there may be potential to build a linear regression model that can predict which building characteristics, such as house age, square footage, or air leakage rate, will have the greatest correlation with future energy savings.

Home efficiency valuation

- Based on our net present value (NPV) calculations, there were only certain conditions where home efficiency upgrades were a net positive investment for the average homeowner, such as a low discount rate, a low degradation in efficiency gains, and a sizable rebate off the initial purchase.
- The model exhibited an interesting parabolic pattern over time, where the home efficiency investment would have a positive NPV for the first 5 years because of a high salvage value, then fall in value for the next 15 years due to depreciation and efficiency losses before rising in value and being driven positive again after another 15 years by fuel price inflation.
- Without any salvage value the model would have a progression from a negative NPV after the initial investment to a positive one over time.
- When considering that most home efficiency investments are likely not going to cost the customer much more or less over 20 or 30 years, non-monetary benefits like thermal comfort and improved indoor air quality become more important to potential customers.

Spatial analysis

- Mapping via geographic information systems (GIS) revealed that current residential EO participation was concentrated in the greater Detroit, Ann Arbor, and Grand Rapids areas.
- General EO participation trends of high concentrations in metropolitan areas were even more exaggerated for homeowners who participated in the audit and weatherization sub-program specifically.
- The percent income spent on utility costs (average annual energy costs divided by median household income) is highest in the low-income neighborhoods around Detroit as well as many rural areas in the northern portion of the Lower Peninsula and in the Upper Peninsula.
- Total and average energy use (combining gas and electricity data) showed similar trends with a bias towards more use in urban areas.
- Depending on willingness to travel, there may be some service gaps for energy efficiency contractors in parts of the northern Lower Peninsula as well as in the Upper Peninsula.
- Visualizing EO participation, energy use, and census data through GIS mapping is a highly effective way to understand program performance and target future EO participants.

Auditor and contractor survey

- Roughly two-thirds of Michigan contractors surveyed provided HVAC services, but only one-third surveyed indicated that they performed home energy audits.
- According to the survey results, 70% of contractors indicated that they performed less than 20 home energy audits per year and it is safe to presume that most of them are not performing any audits at all.
- Despite many contractors now having an online presence—websites, email newsletters, and social media accounts—existing customer referrals continue to be the best method for acquiring new business.
- Contractors reported that utility rebates were the most effective way of driving investment in home efficiency and over 80% of contractors surveyed responded that they used utility rebates to help sell efficiency upgrades.

Customer engagement and satisfaction

- Homeowners indicated thermal comfort and cost savings on their utility bills were the primary motivations for investment in home improvements.
- Environmental benefits are a non-starter for many and rarely affect decisions for even the most environmentally-minded homeowners, even though most respondents said it influenced their decision-making process on the a2energy survey.
- Audit reports should provide a prioritized list of recommended efficiency measures that helps the customer chose whether or not to implement a particular measure.
- Customers tend to trust expert advice from auditors when that advice is supported by hard evidence like the results from a blower door test or an infrared image.

7.2 Future Research

There are a number of avenues for potentially continuing research in the future, but we have highlighted the four most promising ones below:

1. **Low-income pilot performance evaluation |** DTE Energy provided data for another pilot program, one targeted to low-income communities. It would be worthwhile and informative to go through the same assessment steps with this pilot as the WHPPP. The energy savings calculations for each house could be automated using the same MySQL script as before, compared to its modeled and deemed savings, and then benchmarked against houses in the WHPPP and elsewhere.

2. **Auditor service gap analysis |** Now that we have a better understanding that not all the contractors listed on DTE Energy's EO vendor directory actually perform home energy audits, we have obtained a dataset from Michigan Saves, which has a list of around 300 contractors who are certified as home energy auditors. By replicating our analysis for mapping contractor service areas through geocoding, we can start with the auditors' business addresses and rerun the road network distance calculations. We can produce a new map that shows explicitly where auditor services are available and where more auditors are needed.

3. **Predictive linear regression models |** Further statistical analysis is warranted to see if better results can be obtained for predicting energy savings according to pre-retrofit building characteristics. Similar statistical work is needed to see if one can predict residential EO participation based on particular census demographics. If there are significant relationships with these dependent variables, then it may be possible to develop a linear regression model that assists the utility in selecting specific homes and communities to target for future EO programs.

4. **Rebound effect scenarios and sensitivity |** Since DegreeDays.net has heating and cooling degree days (HDD and CDD) across a range of base temperatures (65 ± 6 °F) for any given weather station, there is an opportunity to test the sensitivity by changing the base temperature. Furthermore, scenarios in which customers "rebound" to a higher base temperature post retrofit can also be incorporated into the MySQL code. Setting up a few rebound scenarios where setpoint temperatures would rise in the winter for more heating and would drop in the summer for more cooling would lend some valuable insights about how influential the rebound effect is on home energy savings.

7.3 Recommendations

Our data analysis generated a few observations that should help DTE Energy improve the success of their residential EO program in the future. Our key recommendations include ways to analyze program performance data, increase customer participation, and improve homeowner satisfaction with the EO program and the utility in general. The EO program is one of the only ways that the utility interacts with residential customers besides billing, so this program is an integral part of building positive customer relationships. Our key recommendations are highlighted and further explained below:

1. Promote auditor training opportunities

Our auditor survey showed that many Michigan contractors are not conducting home energy audits and even fewer are certified auditors. Having a contractor with skills to perform a pre- and post-retrofit audit is a crucial part of the whole home improvement process and facilitates greater understanding of the home's energy performance. Lacking access to auditor training, many contractors will continue to perform home energy upgrades without audits. Without audits, much of the ability to check the quality of their work and to assess the effectiveness of the upgrades to save energy will be lost.

The utility should be more proactive about promoting auditor training and other continuing education opportunities for contractors. Many contractors reported being interested in both traditional classroom and online learning opportunities. There are plenty of vendors that specialize in contractor education and DTE Energy should consider providing incentives for contractors to enroll in such classes. As we have seen in the contractor service gap maps generated from our spatial analysis, these types of education and training opportunities are especially needed outside the Detroit and Grand Rapids metropolitan areas.

Certification of the contractors performing audits will lead to greater standardization and consistency in the auditing process. More certified auditors will ensure that more of the upgrades installed will emphasize resident health, safety, and comfort. DTE Energy can also likely improve energy savings and customer satisfaction when homes are audited by certified professionals prior to retrofitting. Providing contractors access to education and training opportunities is a critical component of running a more successful EO program.

2. Ensure better screening of the contractor directory

DTE Energy currently requires a homeowner to have a comprehensive energy audit conducted by a certified auditor to be eligible for any home performance rebates. Well over 90% of contractors listed on the utility's energy efficiency directory indicated that they performed audits and had at least one auditor certification; however, our survey indicated that only one-third of contractors were conducting audits. A better system is needed to ensure that the contractors who are conducting audits and applying for any EO rebates—not just home performance rebates—actually hold auditor certifications.

Likewise, a number of contractors in the directory have outdated contact information or are simply out of business. Nearly 10% of all our emailed surveys bounced. This directory is a primary method for customers to find home energy improvement contractors and it should be updated to more accurately reflect which contractors are performing audits, which certifications they currently hold, and how to best contact them. An up-to-date, wellmaintained directory is an effective way to assist customers in locating and selecting certified auditors and would likely increase audit participation.

3. Automate audit and upgrade rebate filing

There are many benefits of transitioning to an online automated filing system for audit and upgrade rebates, including increasing the speed of submission, reducing the amount of paperwork required of contractors, decreasing reporting errors, and having a wealth of data on individual homes that is readily available. We found in our research that both customers and contractors indicated that the difficulty of filing rebates was a deterrent to participating in the EO program. An automated system would allow the utility to engage with contractors who were having difficulties during the submission process through a web chat or phone hotline. Our survey showed that over 80% of contractors thought rebates spurred investment in audits and upgrades, so it is important that contractors have confidence in the filing system and can guarantee homeowners that those rebates will be realized.

Furthermore, an automated system will vastly increase the amount of information that DTE Energy has to analyze from audits and upgrades. Much of the data submitted on paper rebates is never captured or utilized in any way. Compiling these filings into a computer database enables the utility to then track the energy use in participating homes and apply targeted EO marketing through email, direct mail, or even on their monthly bills. Those homeowners who already participated are much more likely to have a favorable view of the EO program and participate in future efficiency initiatives. Targeted communication is also an opportunity for the utility to educate EO participants about degree days so they can assess the effectiveness of their upgrade through a normalized energy savings calculation.

4. Collect data from home energy audits

While a lot of data potentially of interest to a utility company is already available from home energy rebates, information collected during home audits is largely not even being tapped. During a pre-retrofit audit, a great deal of information on the home's characteristics—such as age, floor area, air leakage rate, insulation values, and furnace efficiency—as well as demographic information like the number of occupants and data on past gas and electricity consumption—are collected by the auditor. After the upgrades, a post-retrofit audit then catalogs what efficiency measures have been installed but cannot yet assess how well they are performing because such a short period of time has elapsed. All of this audit data would be extremely beneficial in quantifying energy savings both by fuel type and by household. By collecting this type of data, the utility could then measure and also verify the persistency of energy savings over time.

The simplest way to collect audit data would be to require that it be submitted with the audit rebate application through the automated filing system. There needs to be guidelines on which parameters would be collected but once the template is created, it would be easy to require an official audit data collection form be submitted with the rebate application. This would facilitate many more opportunities to compare evaluated results to the deemed estimates from the MEMD and modeled projections.

5. Encourage contractors to personalize audit reports

Audit reports are important tools for contractors to communicate home performance test results to homeowners and to tell them what upgrades would be the most effective for achieving the homeowner's own desired outcomes—whether it be cost reductions, energy savings, or thermal comfort. Often, though, audit reports only provide the results of tests performed or pictures taken but fail to give any advice about which specific upgrades the contractor would most highly recommend. A prioritized list of recommendations is paramount to selling any upgrades because customers value the contractor's professional opinion in their decision-making process.

Since the utility is providing incentives for audits and upgrades, DTE Energy should make sure that contractors are communicating with homeowners effectively. Some documentation about what constitutes a good audit report should be prepared and posted on the EO website or disseminated to contractors, perhaps through an email to those in the energy efficiency directory. Additionally, it may be useful for the utility to provide some example audit reports for new contractors or those looking to improve their customer communications.

6. Target customers through data analytics

Finding more homeowners to participate in the future is essential for creating any type of energy efficiency market transformation. Data analytics like the ones highlighted in our spatial analysis should assist DTE Energy in targeting customers who would have the greatest need of EO services and would benefit the most from a home energy audit and retrofit. For example, customers in areas with particularly high average household energy use or customers in densely populated areas but relatively low previous EO participation would be ideal candidates to participate in future audit-to-retrofit pilot programs. Similarly, customers who spend a relatively large percentage of their annual income on utility bills would stand to benefit from participating in the utility's weatherization and energy efficiency assistance programs. These customers can receive targeted marketing and promotions through email, direct mailing, or even on-bill messaging. Other initiatives like simply following up with customers who have participated in previous years should be effective strategies for increasing current participation in the EO program.

For many residential customers, a utility company is only contacted when there is a problem, such as when their home temporarily loses electricity or a natural gas leak is detected. Residential energy optimization is an excellent customer-facing program for DTE Energy to build and improve relations with homeowners by helping to make their homes more energy efficient, safe, and comfortable.

7.4 Final Thoughts

This report laid out a data-driven conceptual methodology for evaluating residential energy efficiency programs for utilities like DTE Energy. Our work on this project was meant to be an illustrative approach rather than an exhaustive analysis. New paradigms in data storage, manipulation, and visualization are needed to adequately evaluate, measure, and verify the performance of these energy efficiency programs across different times and geographic locations. We hope that utilities like DTE Energy will adopt software tools, such as MySQL, R, and ArcGIS, to expedite and ultimately improve the program evaluation process. The results of this integrated program evaluation will assist the utility in recruiting more homeowners to participate in their energy optimization program. Further research based on data collected over longer time periods can be used to enhance these findings in the future.

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Appendix A

Supplement to Section 2 (Pilot Performance Evaluation)

Appendix A

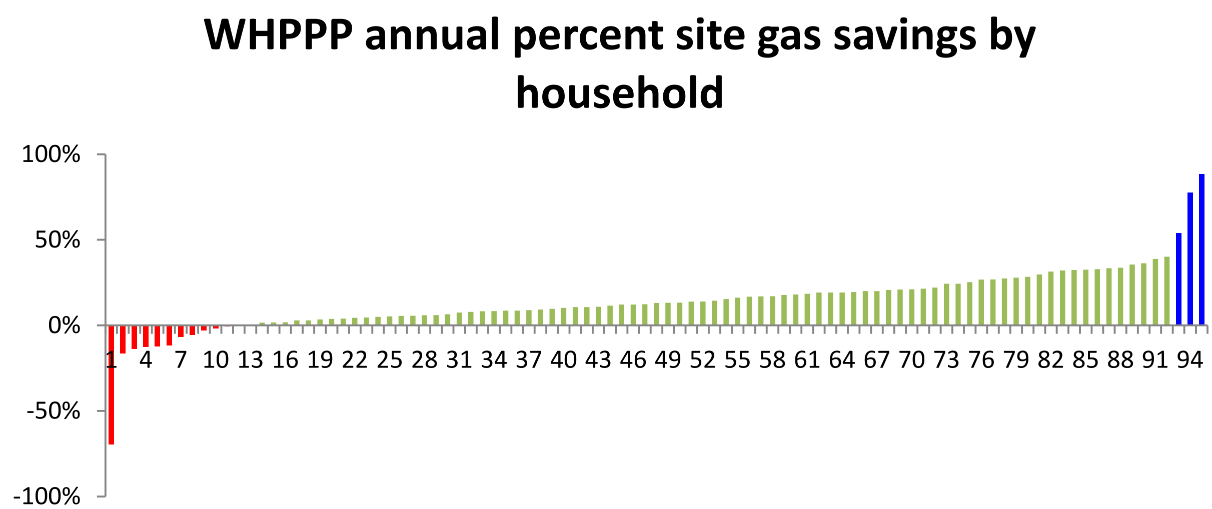


Figure A-1. Annual on-site gas savings for each WHPPP house. Houses in red used more energy post retrofit and houses in royal blue actually saved more than 50% annually (n = 95 houses, $\bar{x} = 14.38\%, sd = \pm 18.62\%$). Houses are sorted by magnitude of savings and the order of houses does not correspond to the order below in Fig. A-2 or Fig. 7 in text.

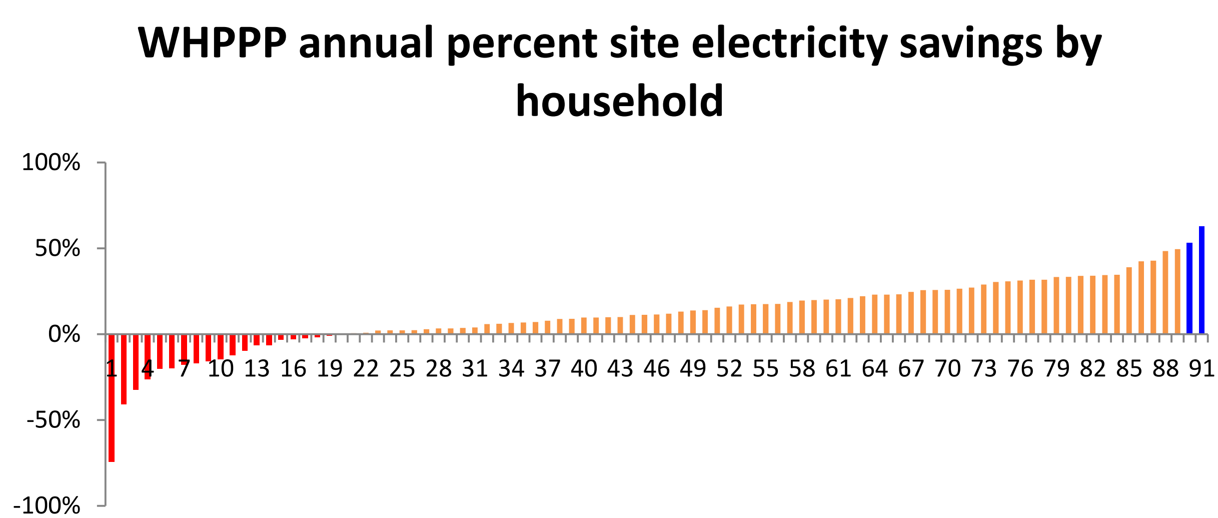


Figure A-2. Annual on-site electricity savings for each WHPPP house. Houses in red used more energy post retrofit and houses in royal blue actually saved more than 50% annually (n = 91 houses, $\bar{x} = 11.84\%, sd = \pm 21.04\%$). Houses are sorted by magnitude of savings and the order of houses does not correspond to the order above in Fig. A-1 or Fig. 7 in text.

Table A-1. R output of paired t-tests of the difference between pre-retrofit and post-retrofit gas use and the difference between pre-retrofit and post-retrofit electricity use. There was a significant reduction for both the electricity (n = 88 houses, $p < 0.0001$) and gas case (n = 88 houses, $p < 0.0001$).

```
> t.test(preretrofitgasuse,postretrofitgasuse,paired=TRUE)

        Paired t-test

data:  preretrofitgasuse and postretrofitgasuse

t = 4.9094, df = 87, p-value = 4.234e-06

alternative hypothesis: true difference in means is not equal to 0

95 percent confidence interval:

 121.8220 287.5655

sample estimates:

mean of the differences

               204.6938
```

```
> t.test(preretrofitelectricityuse,postretrofitelectricityuse,paired=TRUE)

        Paired t-test

data:  preretrofitelectricityuse and postretrofitelectricityuse

t = 6.0732, df = 87, p-value = 3.207e-08

alternative hypothesis: true difference in means is not equal to 0

95 percent confidence interval:

  868.3365 1713.2134

sample estimates:

mean of the differences

               1290.775
```

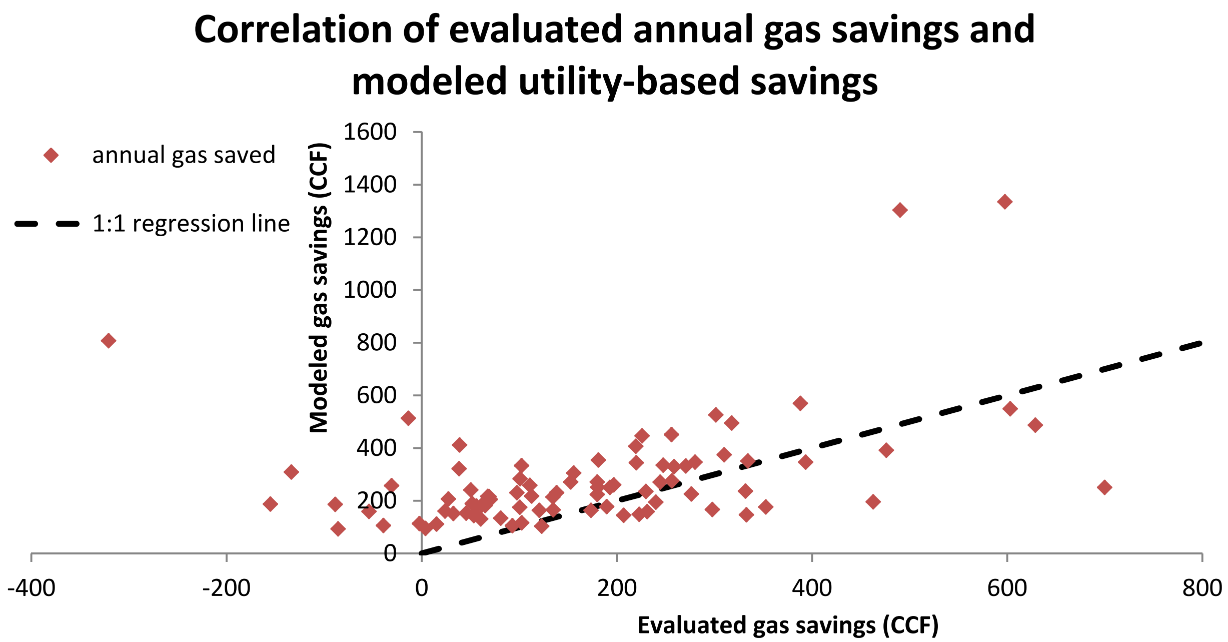


Figure A-3. A scatterplot of WHPPP evaluated and modeled annual gas savings, in which the data is not well fit by the 1:1 regression line that indicates perfect agreement (n = 87 houses). One of the 88 houses evaluated was removed for unrealistically high savings.

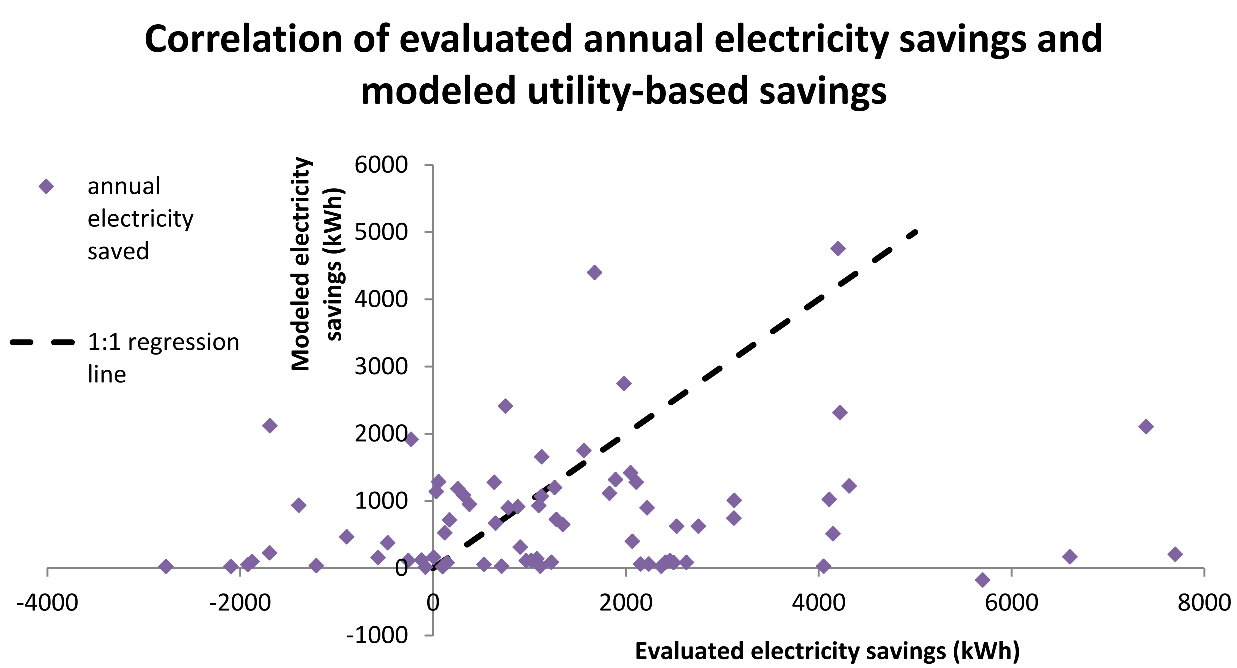


Figure A-4. A scatterplot of WHPPP evaluated and modeled annual electricity savings, in which the data is not well fit by the 1:1 regression line that indicates perfect agreement (n = 74 houses). There were 14 houses removed from the 88 evaluated due to a lack of modeled savings data.

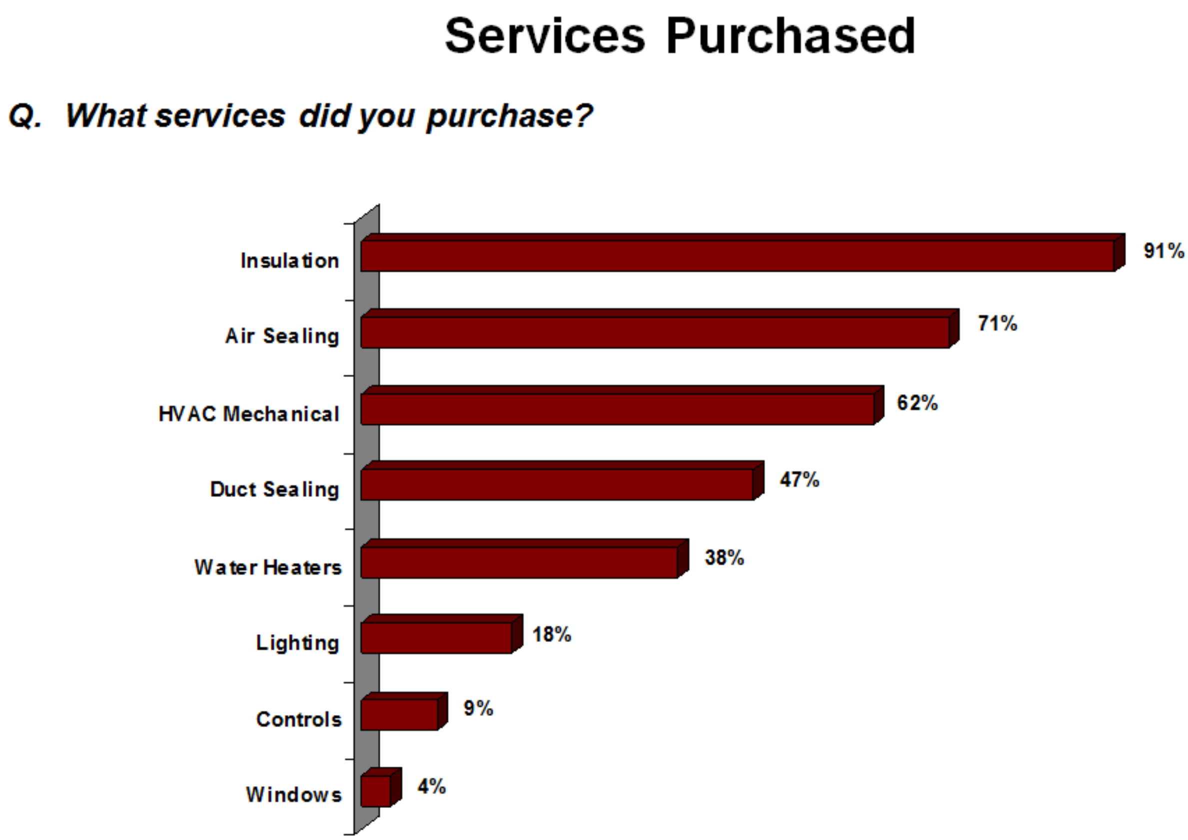


Figure A-5. Contractor services purchased and measures installed during the WHPPP as reported by participants during a third-party survey conducted by an independent consulting firm (n = 55 houses).

Table A-2. Comparison of aggregated averages of WHPPP electricity (kWh) and gas savings (CCF)(n = 20 houses, except for the modeled electricity group where n = 17).

WHPPP annual average energy savings		
Electricity (kWh)	**evaluated**	1,165.3
	deemed	1,078.2
	modeled	940.6
Gas (CCF)	**evaluated**	219.7
	deemed	339.3
	modeled	187.1

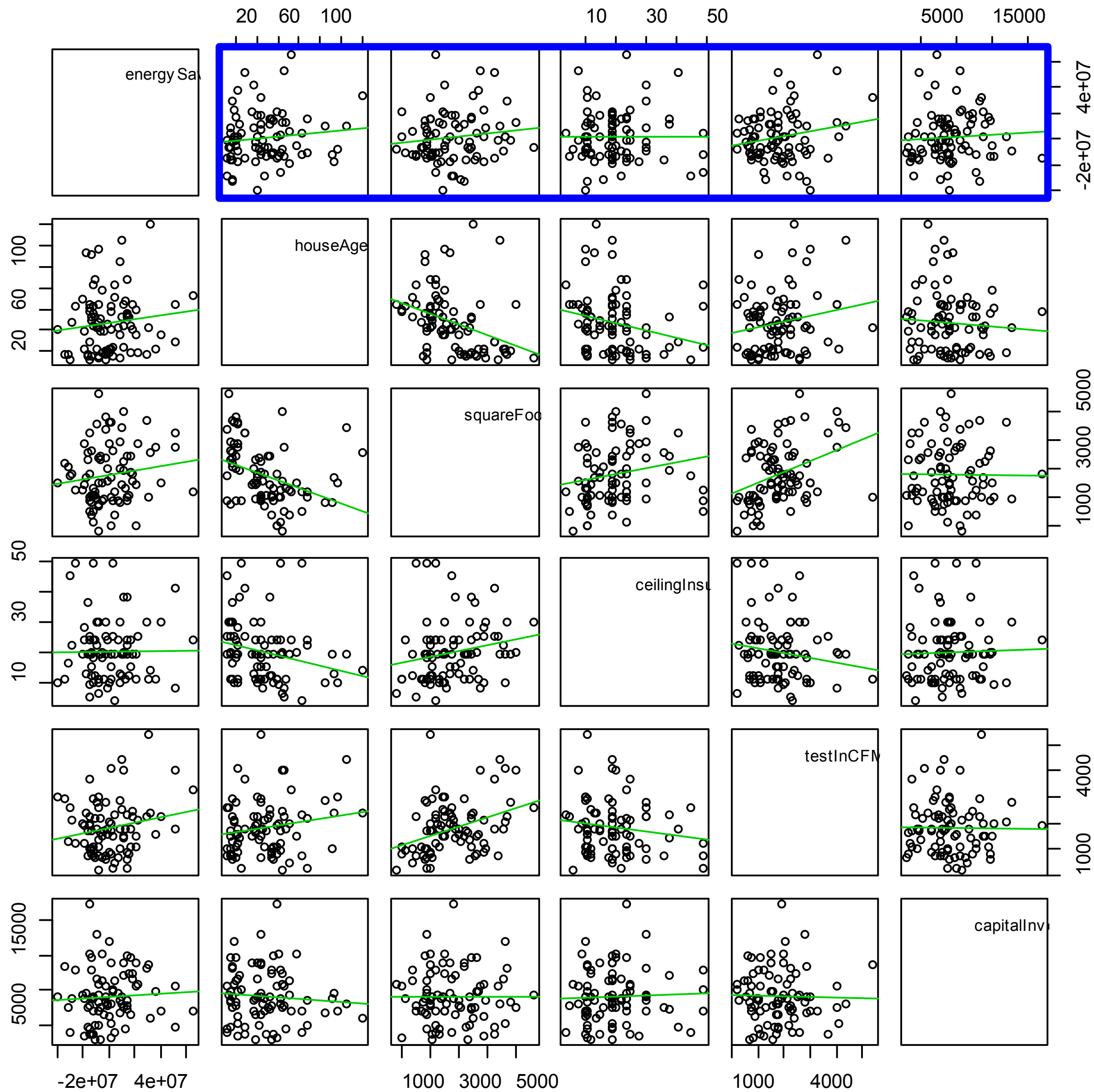


Figure A-6. A matrix of correlation scatterplots with best-fit regression lines to test the relationships between the WHPPP post-retrofit energy savings and the pre-retrofit house characteristics (n = 85 houses). The correlations highlighted in blue are between the savings and characteristics.

Table A-5. R output of Pearson's r values and p values for correlation testing between WHPPP energy savings and house pre-retrofit characteristics (n = 85 houses, α = 0.05; two houses were removed due to missing air leakage rates and another one was omitted for having nonsensical savings of over 90%).

```
> rcorr(as.matrix(whpppenergy[,2:7]))

                   energySavings houseAge squareFootage ceilingInsulation

energySavings               1.00     0.11          0.14              0.01
```

```
houseAge                0.11     1.00        -0.37              -0.25
squareFootage           0.14    -0.37         1.00               0.20
ceilingInsulation       0.01    -0.25         0.20               1.00
testInCFM50             0.19     0.19         0.37              -0.15
capitalInvestment       0.06    -0.08        -0.01               0.04
                  testInCFM50 capitalInvestment
energySavings            0.19              0.06
houseAge                 0.19             -0.08
squareFootage            0.37             -0.01
ceilingInsulation       -0.15              0.04
testInCFM50              1.00             -0.02
capitalInvestment       -0.02              1.00

n= 85

P
                  energySavings houseAge squareFootage ceilingInsulation
energySavings                   0.3057   0.2059        0.9601
houseAge          0.3057                 0.0005        0.0232
squareFootage     0.2059        0.0005                 0.0678
ceilingInsulation 0.9601        0.0232   0.0678
testInCFM50       0.0831        0.0860   0.0005        0.1650
capitalInvestment 0.5916        0.4500   0.9490        0.7445
                  testInCFM50 capitalInvestment
energySavings     0.0831      0.5916
houseAge          0.0860      0.4500
squareFootage     0.0005      0.9490
ceilingInsulation 0.1650      0.7445
testInCFM50                   0.8763
capitalInvestment 0.8763
```

Table A-6. Of the correlations that were significant, specifically between house age and log-transformed floor area and between house age and log-transformed ceiling insulation, the R output from the linear regression tests is shown. The log transformations were applied to correct for normality.

```
> summary(ln.age.size)

Call:

lm(formula = lnsquareFootage ~ houseAge, data = whpppenergy)

Residuals:

     Min       1Q   Median       3Q      Max

-1.06092 -0.20947  0.01326  0.24701  0.92925

Coefficients:

             Estimate Std. Error t value Pr(>|t|)

(Intercept)  8.084692   0.077455 104.379  < 2e-16 ***

houseAge    -0.004913   0.001406  -3.493 0.000767 ***

---

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3717 on 83 degrees of freedom

Multiple R-squared: 0.1282,     Adjusted R-squared: 0.1177

F-statistic:  12.2 on 1 and 83 DF,  p-value: 0.0007672


> summary(ln.age.insulation)

Call:

lm(formula = lnceilingInsulation ~ houseAge, data = whpppenergy)

Residuals:

     Min       1Q   Median       3Q      Max

-1.31029 -0.35845  0.05964  0.34152  1.19524

Coefficients:

             Estimate Std. Error t value Pr(>|t|)

(Intercept)  3.097139   0.102425  30.238   <2e-16 ***

houseAge    -0.004826   0.001860  -2.595   0.0112 *
```

```
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Residual standard error: 0.4915 on 83 degrees of freedom
Multiple R-squared: 0.07503,    Adjusted R-squared: 0.06389
F-statistic: 6.733 on 1 and 83 DF,  p-value: 0.01119
```

Table A-7. R output of Shapiro-Wilk tests to check if the two simple linear regressions of interest, 1) house age and square footage, and 2) house age and ceiling insulation, meet the assumption of normality (p > 0.05). Both regression models met this assumption.

```
> shapiro.test(resid(ln.age.size))
        Shapiro-Wilk normality test
data:  resid(ln.age.size)
W = 0.9859, p-value = 0.4869

> shapiro.test(resid(ln.age.insulation))
        Shapiro-Wilk normality test
data:  resid(ln.age.insulation)
W = 0.9873, p-value = 0.5769
```

Table A-8. R output of the full multiple linear regression (MLR) model with a p-value of the full model listed on the last line (p > 0.05), where there is no statistical significance.

```
> energyMLR <-
lm(energySavings~houseAge+squareFootage+ceilingInsulation+testInCFM50+capital
Investment,data=whpppenergy)
> summary(energyMLR)
Call:
lm(formula = energySavings ~ houseAge + squareFootage + ceilingInsulation +
    testInCFM50 + capitalInvestment, data = whpppenergy)
Residuals:
      Min        1Q    Median        3Q       Max
-41307493 -13222501  -1245204  11248569  60739148
Coefficients:
```

```
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)       -2493988.3 11410811.0  -0.219    0.828
houseAge            109186.2    85827.8   1.272    0.207
squareFootage         2872.2     2546.7   1.128    0.263
ceilingInsulation    55296.7   223514.6   0.247    0.805
testInCFM50           2068.1     2473.7   0.836    0.406
capitalInvestment      385.6      566.8   0.680    0.498
Residual standard error: 19350000 on 79 degrees of freedom
Multiple R-squared: 0.06446,    Adjusted R-squared: 0.005243
F-statistic: 1.089 on 5 and 79 DF,  p-value: 0.3733
```

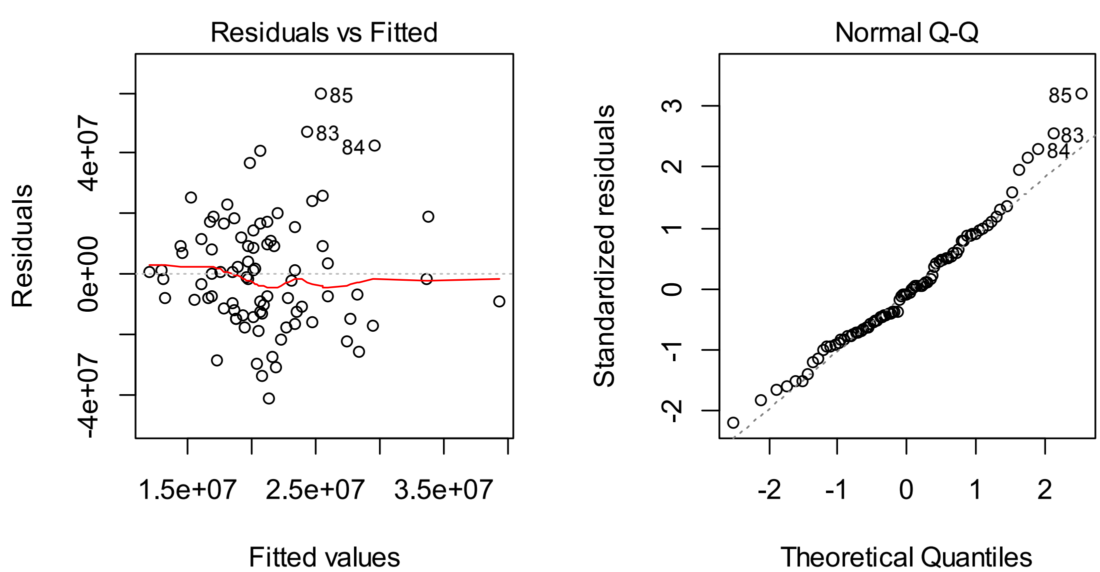


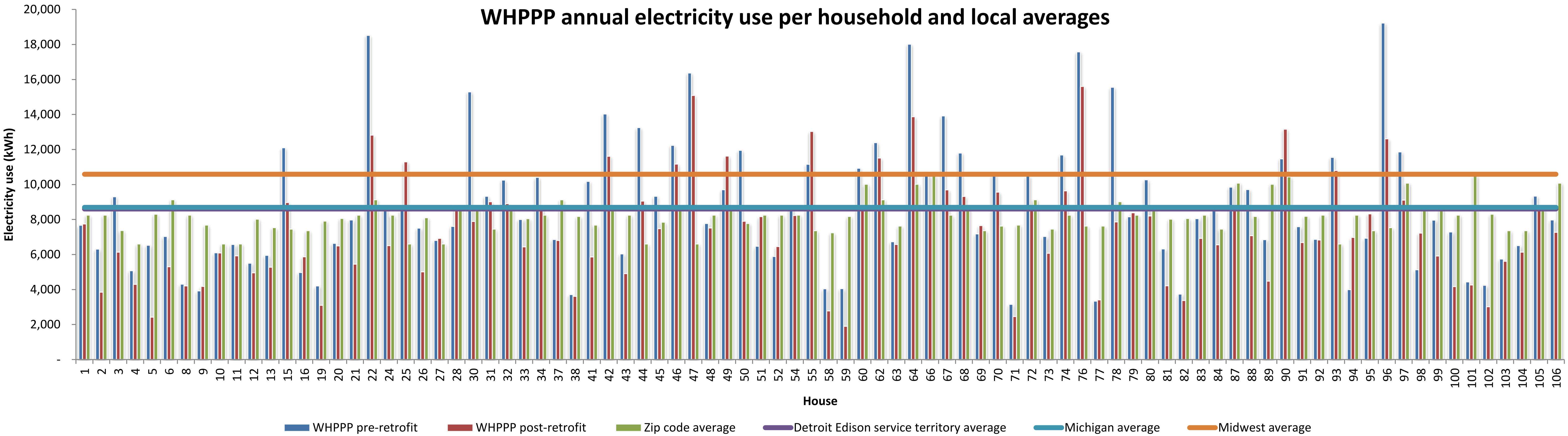
Figure A-7. NPP and Normal Q-Q plots of residuals for the full MLR model to predict energy savings from pre-retrofit characteristics generated in R.

Table A-6. R output of Shapiro-Wilk test for normality of the MLR of WHPPP energy savings ($p > 0.05$).

```
> shapiro.test(resid(energyMLR))

        Shapiro-Wilk normality test

data:  resid(energyMLR)
W = 0.9753, p-value = 0.1023
```



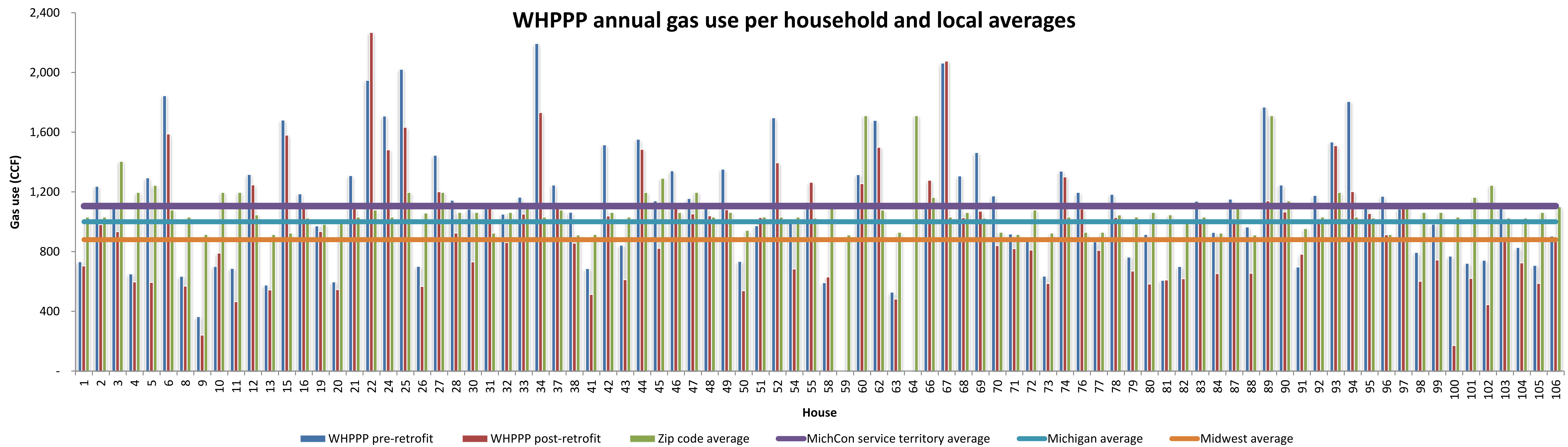


Figure A-8. Benchmarking of pre- and post-retrofit gas and electricity use for all WHPPP houses against local, state, and regional averages. Houses retain DTE Energy's original numbering, although18 houses are omitted due to insufficient data. House 59 and 64 excluded for display purposes from gas use graph (n = 88 houses for electricity and 86 houses for gas).

Appendix B

Supplement to Section 4 (Spatial Analysis)

Appendix B

Table B-1. List of maps in Appendix B.

Table B-2. R output of a Shapiro-Wilk test to check the normality of the linear model to predict EO program participation from census demographics ($p < 0.05$). The data is not normally distributed and fails to meet this assumption, so full model results cannot be reported.

```
RegModel.1<-
lm(percentEOparticipation~age5039+income+percentagepoverty+room69,

  data=wholevariable)

> shapiro.test(resid(RegModel.1))

        Shapiro-Wilk normality test

data:  resid(RegModel.1)

W = 0.8496, p-value < 2.2e-16
```

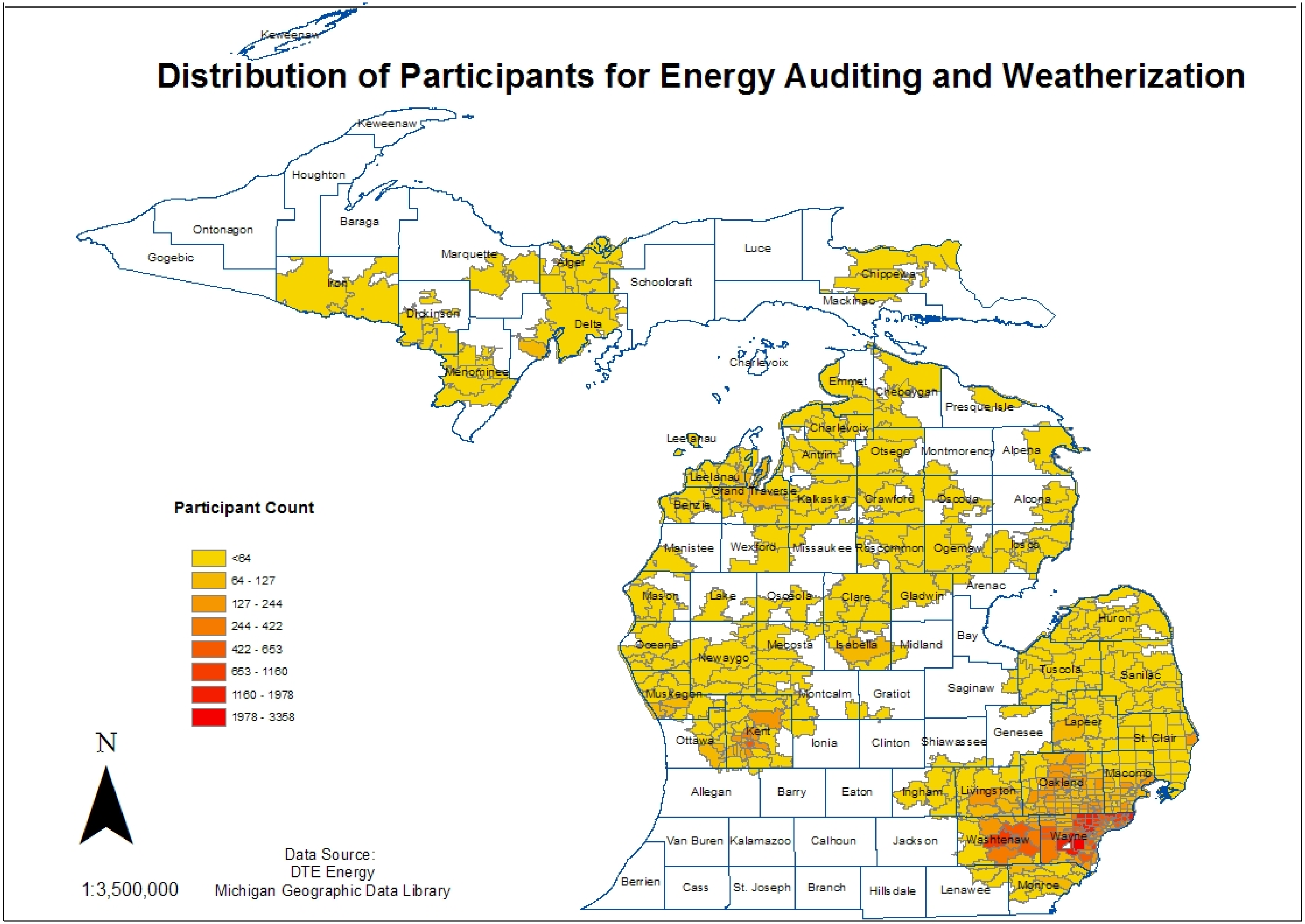


Figure B-1. Map of energy auditing and weatherization by zip code through DTE Energy's residential EO program. Red areas indicate higher concentrations of participation.

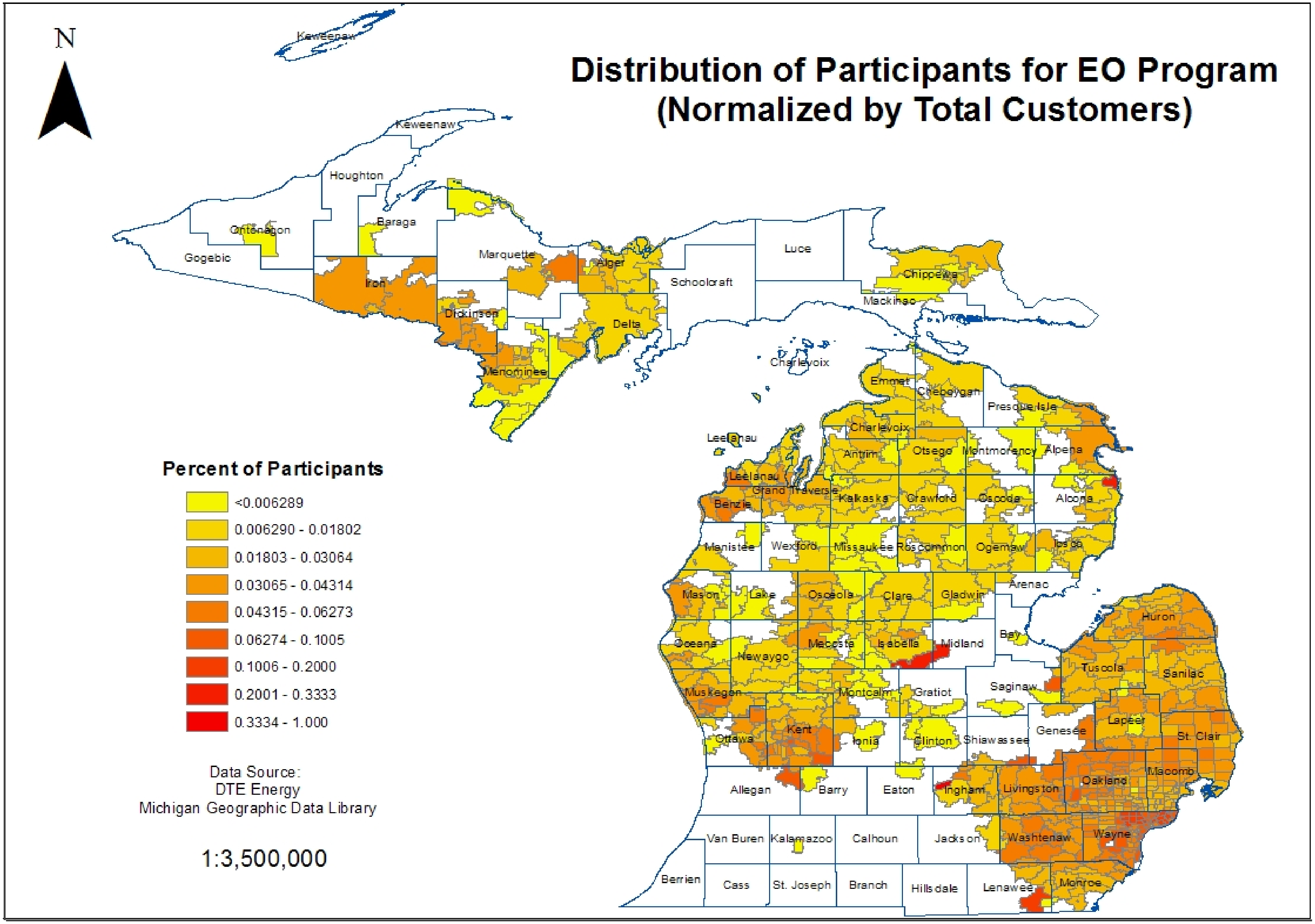


Figure B-2. Distribution map of participation percentage by zip code in DTE Energy's residential EO program. Red areas indicate higher percentages of participation. High percentages in rural areas, namely in Alcona, Isabella, and Ingham Counties can be discounted due to low customer counts.

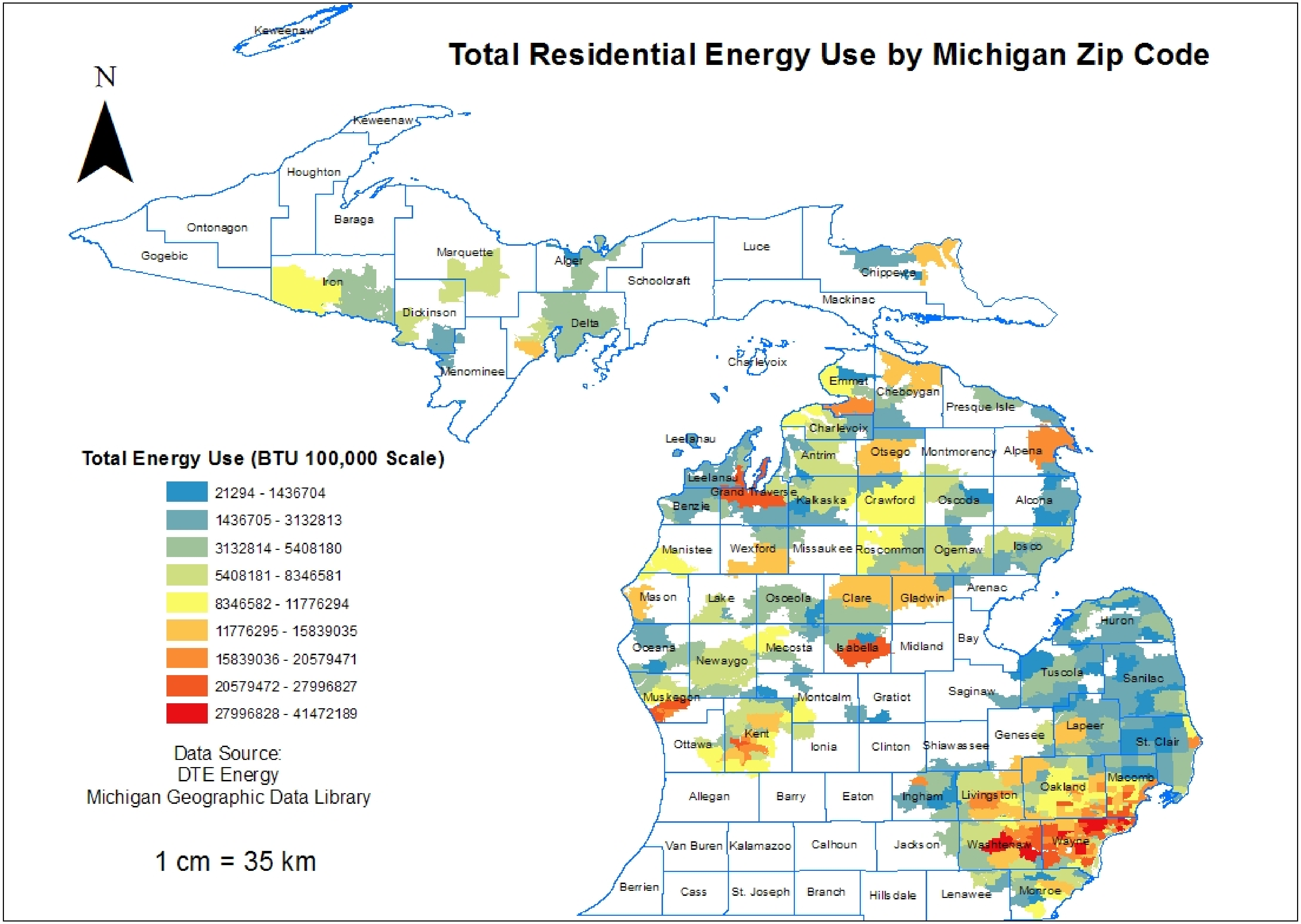


Figure B-3. Map of total residential annual energy consumption by zip code in DTE Energy's service territory. Red areas show higher consumption and blue areas show lower consumption.

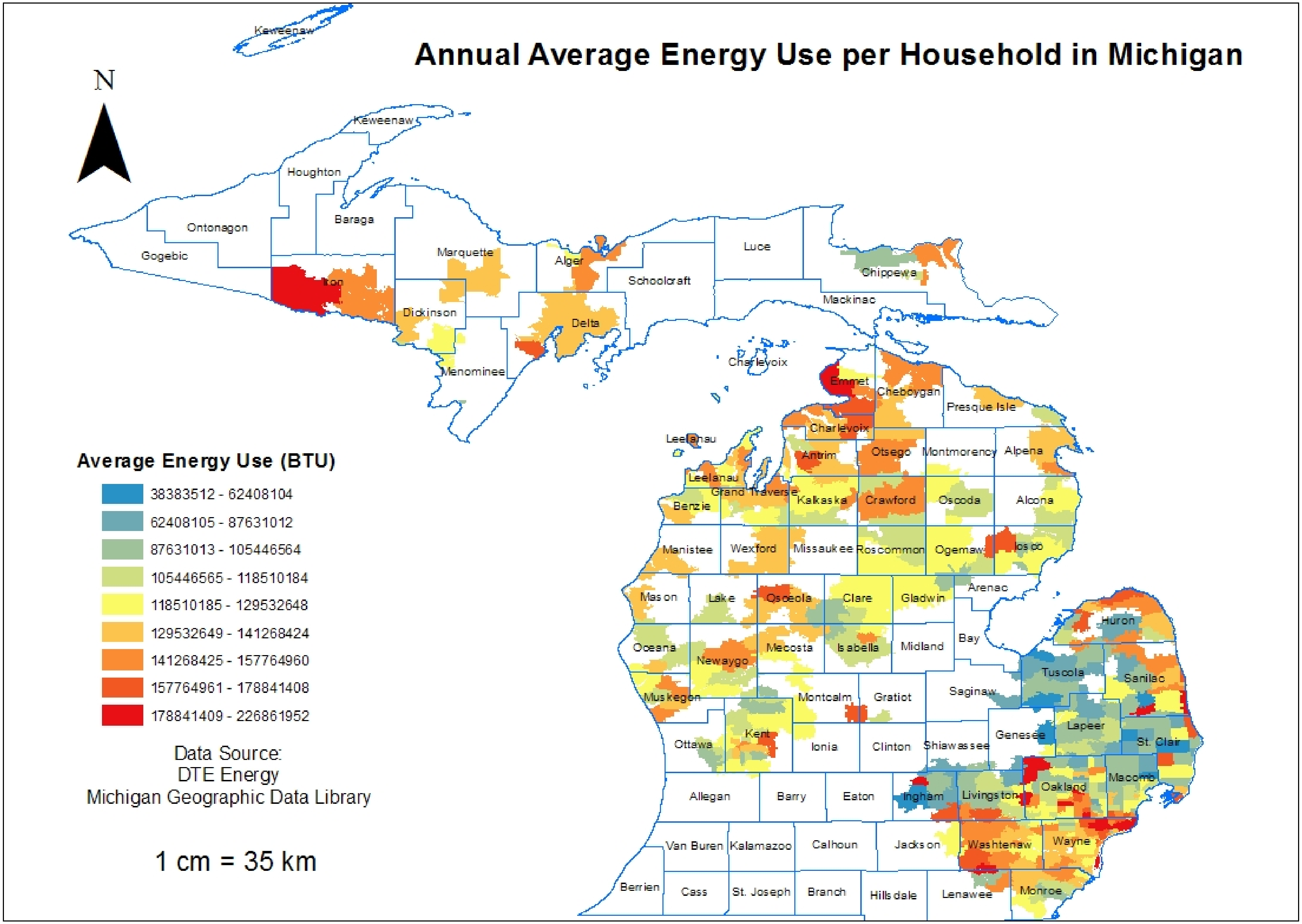


Figure B-4. Household average annual energy use by zip code within DTE Energy's service territory. Red areas show higher use and blue areas show lower use.

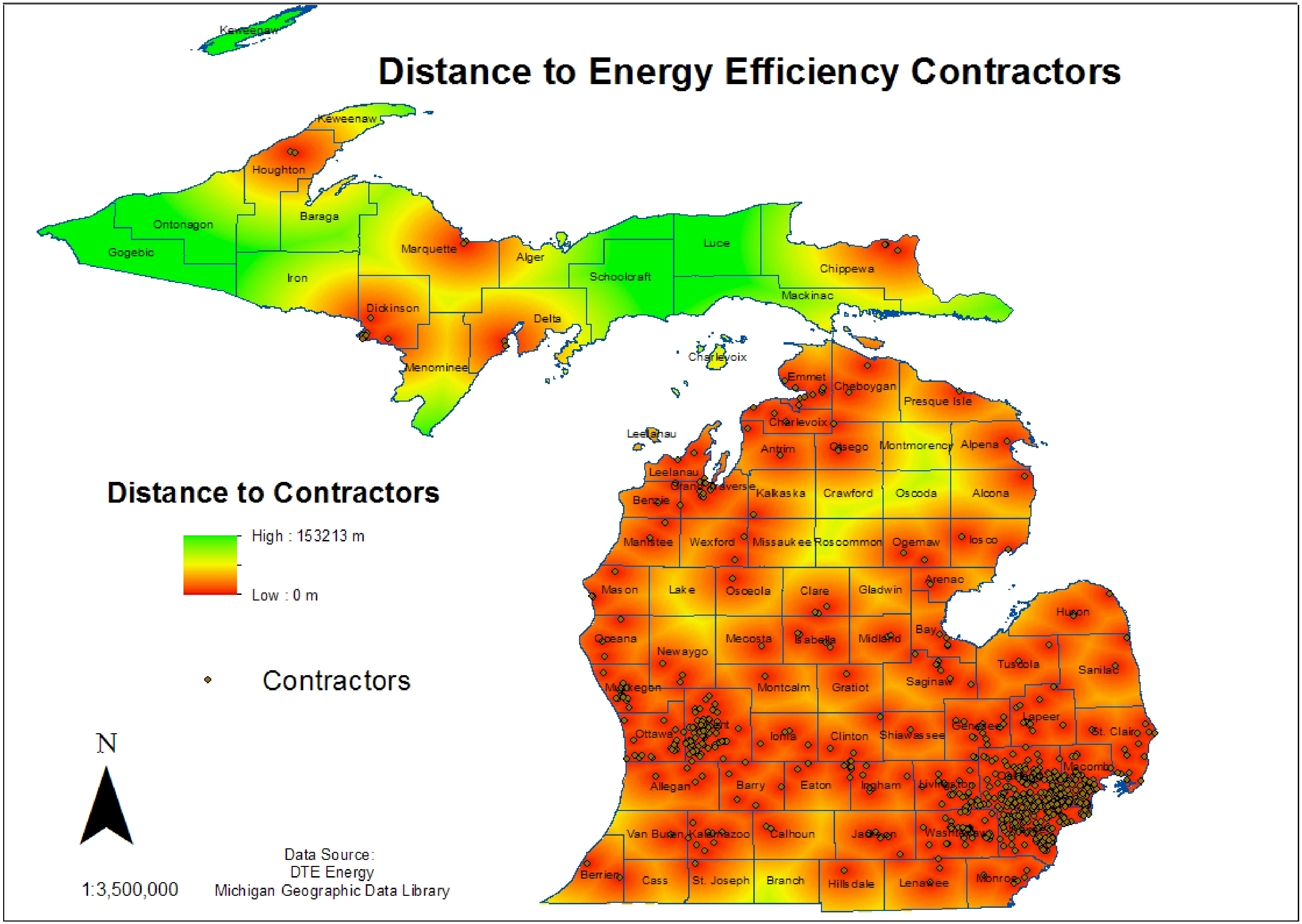


Figure B-5. Coverage map of home energy improvement contractors in DTE Energy's service territory. Green areas indicate greater distances needed for contractors to travel and red areas indicate shorter distances.

Appendix C

Supplement to Section 5 (Auditor and Contractor Survey)

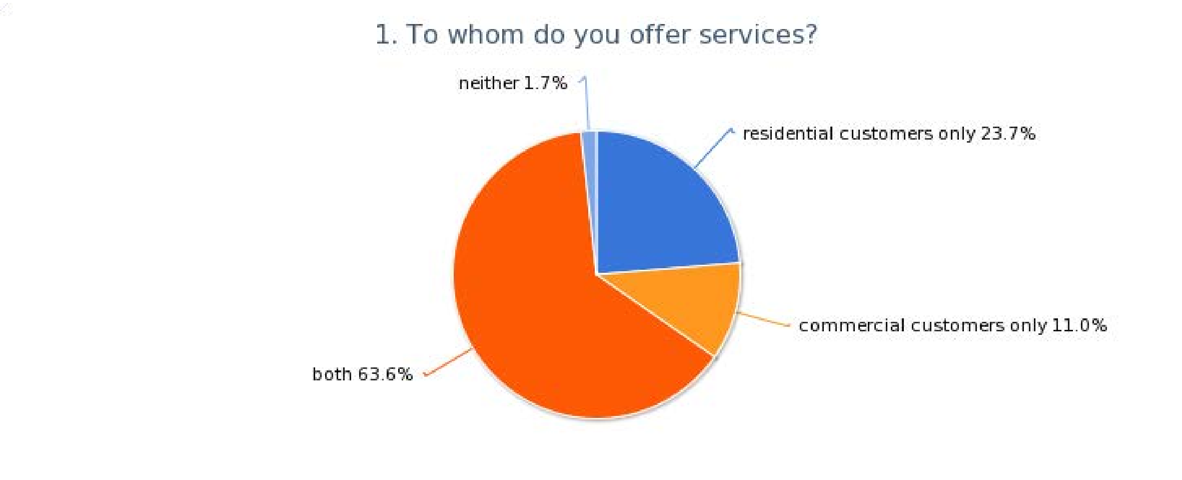
Appendix C

Online Surveys, Data Collection and Integration
www.SurveyGizmo.com

Summary Report - May 10, 2013

Survey: Michigan Home Energy Auditor and Contractor Survey

1. To whom do you offer services?

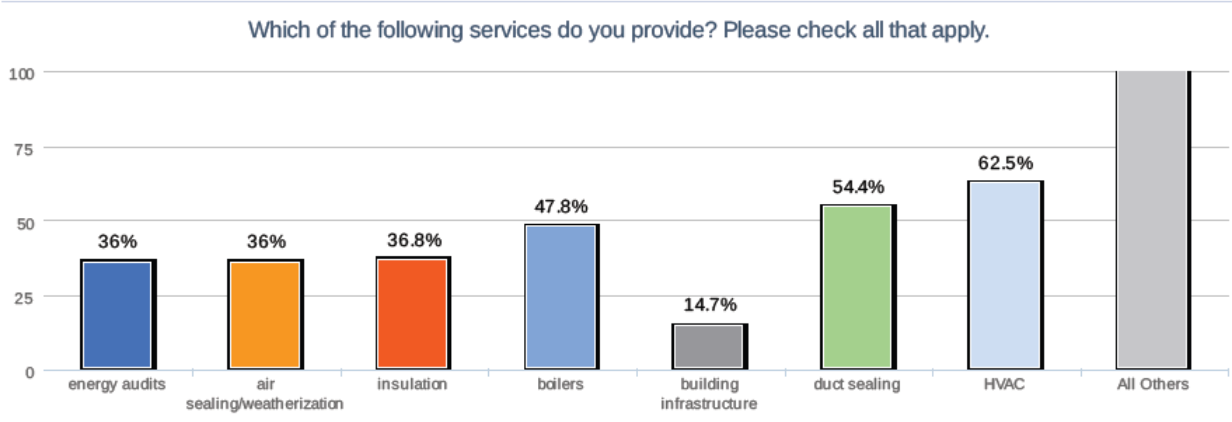


Value	Count	Percent
residential customers only	41	23.7%
commercial customers only	19	11.0%
both	110	63.6%
neither	3	1.7%

Statistics

Total Responses	173

2. Which of the following services do you provide (please check all that apply)?

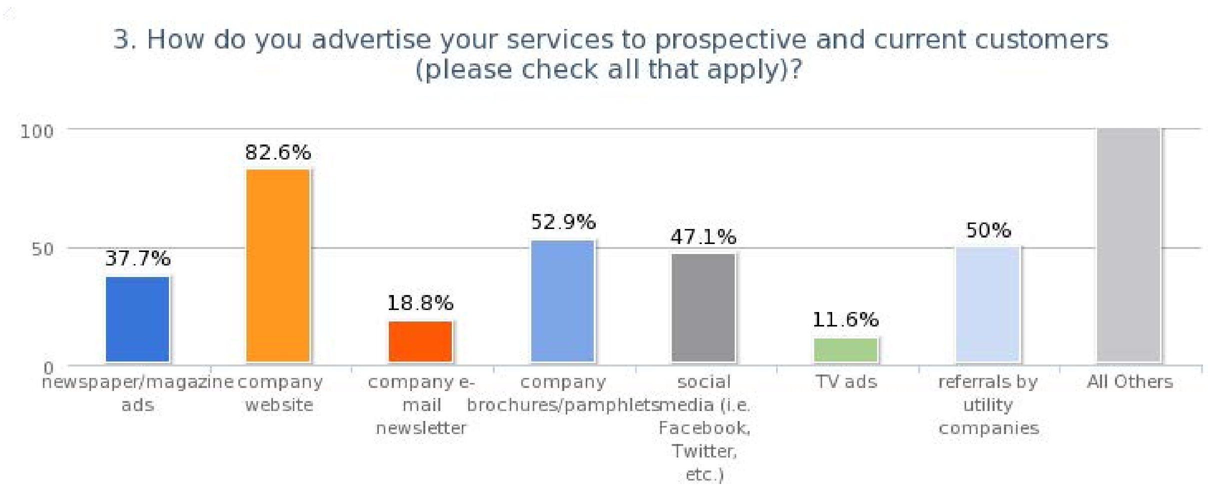


Value	Count	Percent
energy audits	50	36.2%
air sealing/weatherization	49	35.5%
insulation	52	37.7%
boilers	65	47.1%
building infrastructure	20	14.5%
duct sealing	74	53.6%
HVAC	85	61.6%
lighting	44	31.9%
renewable energy	35	25.4%
roofing	21	15.2%

water heaters	82	59.4%
windows & doors	37	26.8%
other __________ (please specify)	15	10.9%

Statistics	
Total Responses	138

3. How do you advertise your services to prospective and current customers (please check all that apply)?



Value	Count	Percent
newspaper/magazine ads	52	37.7%
company website	114	82.6%
company e-mail newsletter	26	18.8%

company brochures/pamphlets	73	52.9%
social media (i.e. Facebook, Twitter, etc.)	65	47.1%
TV ads	16	11.6%
referrals by utility companies	69	50.0%
referrals by existing customers	126	91.3%
direct marketing (i.e. cold calls)	47	34.1%
lead generation database	29	21.0%
other __________ (please specify)	35	25.4%

Statistics	
Total Responses	138

4. Out of all the advertising methods you use, which are the most effective (please rank your top three methods from the list)?

Item	Total Score[1]	Overall Rank
referrals by existing customers	295	1
company website	128	2
other __________ (specified above)	60	3
referrals by utility companies	52	4
newspaper/magazine ads	47	5

Item	Total Score[1]	Overall Rank
social media (i.e. Facebook, Twitter, etc.)	46	6
direct marketing (i.e. cold calls)	45	7
company brochures/pamphlets	35	8
lead generation database	25	9
TV ads	18	10
company e-mail newsletter	10	11
Total Respondents:		

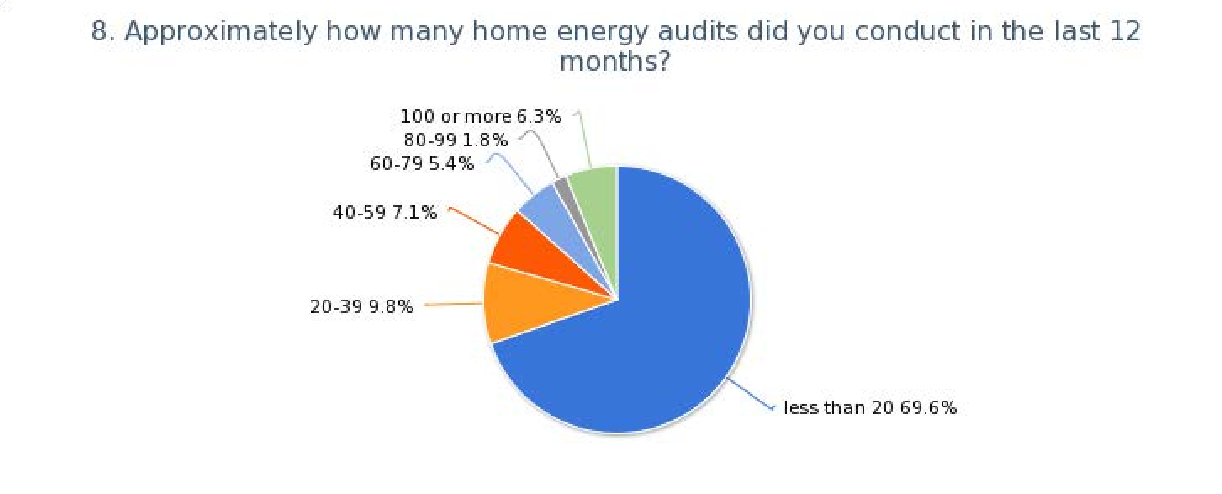
[1] Score is a weighted calculation. Items ranked first are valued higher than the following ranks, the score is the sum of all weighted rank counts.

6. In your experience, what type of property owners are most likely to inquire about or request home energy improvement services (please rank the choices below)?

Item	Total Score[1]	Overall Rank
homeowner in his/her own place of residence	417	1
prospective buyer/investor wishing to audit properties prior to purchase	202	2
property owner of his/her rental property	188	3
home/property owner assessing a residential property about to be sold	145	4
Total Respondents:		

[1] Score is a weighted calculation. Items ranked first are valued higher than the following ranks, the score is the sum of all weighted rank counts.

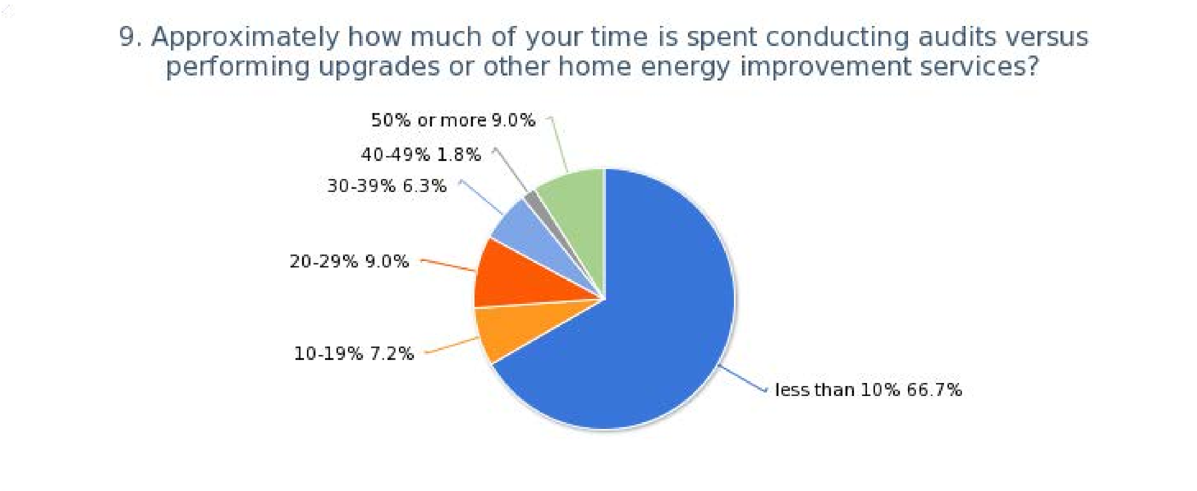
8. Approximately how many home energy audits did you conduct in the last 12 months?



Value	Count	Percent
less than 20	78	69.6%
20-39	11	9.8%
40-59	8	7.1%
60-79	6	5.4%
80-99	2	1.8%
100 or more	7	6.3%

Statistics	
Total Responses	112

9. Approximately how much of your time is spent conducting audits versus performing upgrades or other home energy improvement services?

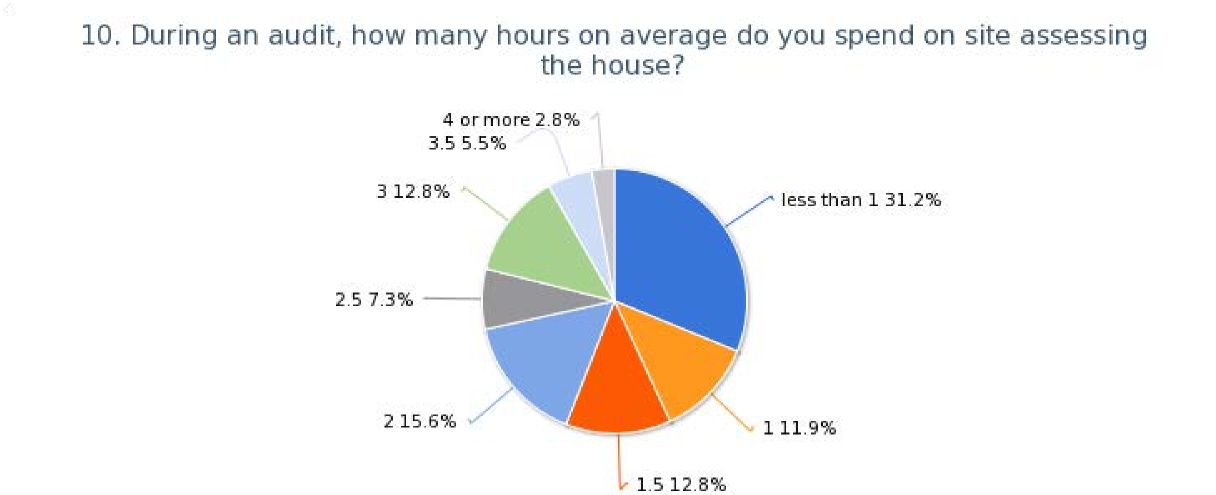


Value	Count	Percent
less than 10%	74	66.7%
10-19%	8	7.2%
20-29%	10	9.0%
30-39%	7	6.3%
40-49%	2	1.8%
50% or more	10	9.0%

Statistics	
Total Responses	111
Sum	597.0
Avg.	22.1

StdDev	9.2
Max	41.0

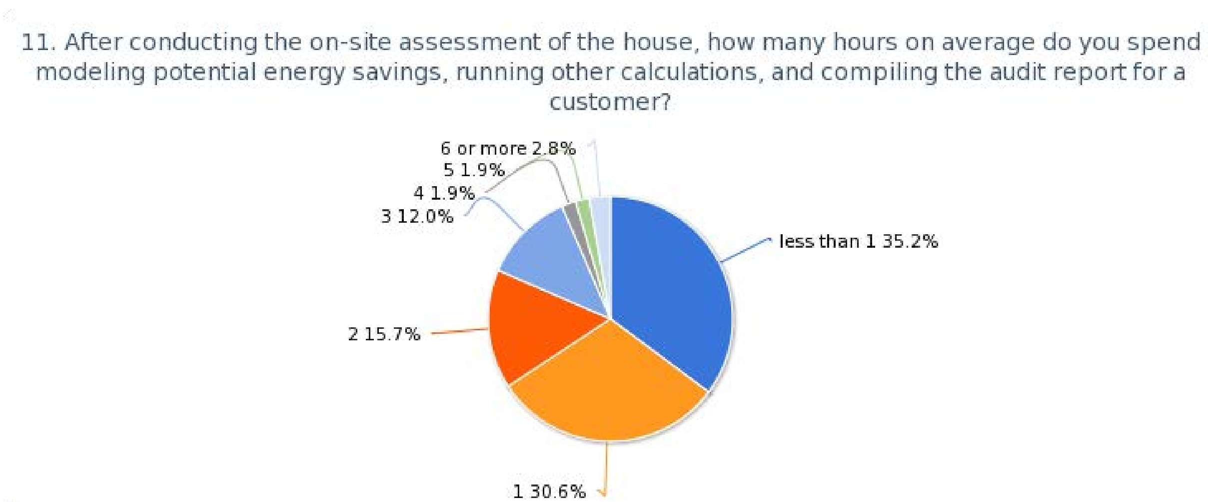
10. During an audit, how many hours on average do you spend on site assessing the house?



Value	Count	Percent
less than 1	34	31.2%
1	13	11.9%
1.5	14	12.8%
2	17	15.6%
2.5	8	7.3%
3	14	12.8%
3.5	6	5.5%
4 or more	3	2.8%

Statistics	
Total Responses	109
Sum	142.0
Avg.	2.1
StdDev	0.8
Max	4.0

11. After conducting the on-site assessment of the house, how many hours on average do you spend modeling potential energy savings, running other calculations, and compiling the audit report for a customer?



Value	Count	Percent
less than 1	38	35.2%
1	33	30.6%
2	17	15.7%

3	13	12.0%
4	2	1.9%
5	2	1.9%
6 or more	3	2.8%

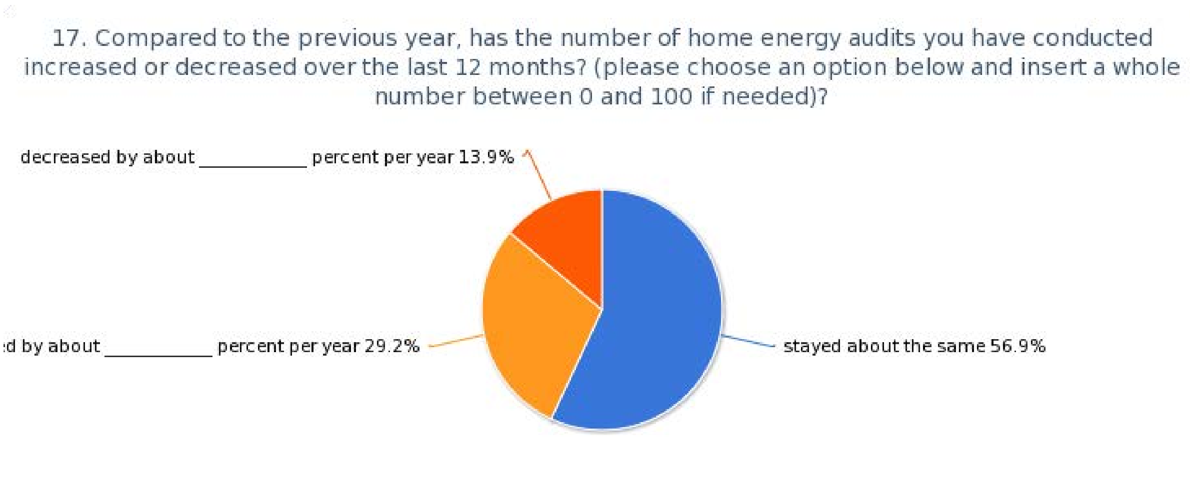
Statistics	
Total Responses	108
Sum	124.0
Avg.	1.9
StdDev	1.0
Max	5.0

14. In any given year, during which months do you usually receive the largest number of requests for home energy audit services (please rank the time periods below)?

Item	Total Score[1]	Overall Rank
Oct - Dec	210	1
Jan - Mar	180	2
Apr - Jun	134	3
Jul - Sep	131	4

Item	Total Score[1]	Overall Rank
Total Respondents:		
[1] Score is a weighted calculation. Items ranked first are valued higher than the following ranks, the score is the sum of all weighted rank counts.		

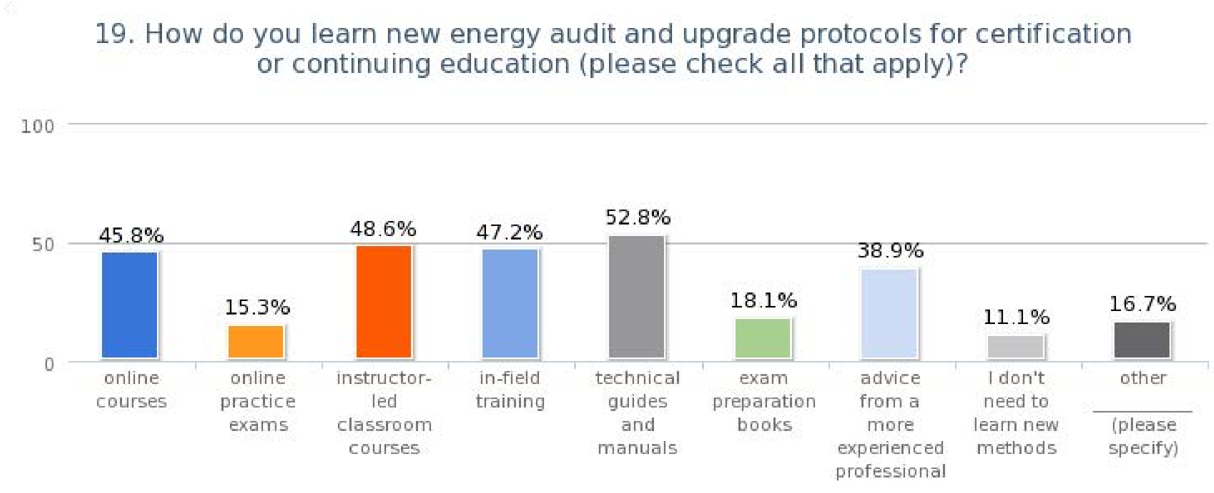
17. Compared to the previous year, has the number of home energy audits you have conducted increased or decreased over the last 12 months? (please choose an option below and insert a whole number between 0 and 100 if needed)?



Value	Count	Percent
stayed about the same	41	56.9%
increased by about ____________ percent per year	21	29.2%
decreased by about ____________ percent per year	10	13.9%

Statistics	
Total Responses	72

19. How do you learn new energy audit and upgrade protocols for certification or continuing education (please check all that apply)?



Value	Count	Percent
online courses	33	45.8%
online practice exams	11	15.3%
instructor-led classroom courses	35	48.6%
in-field training	34	47.2%
technical guides and manuals	38	52.8%
exam preparation books	13	18.1%
advice from a more experienced professional	28	38.9%
I don't need to learn new methods	8	11.1%
other ___________ (please specify)	12	16.7%

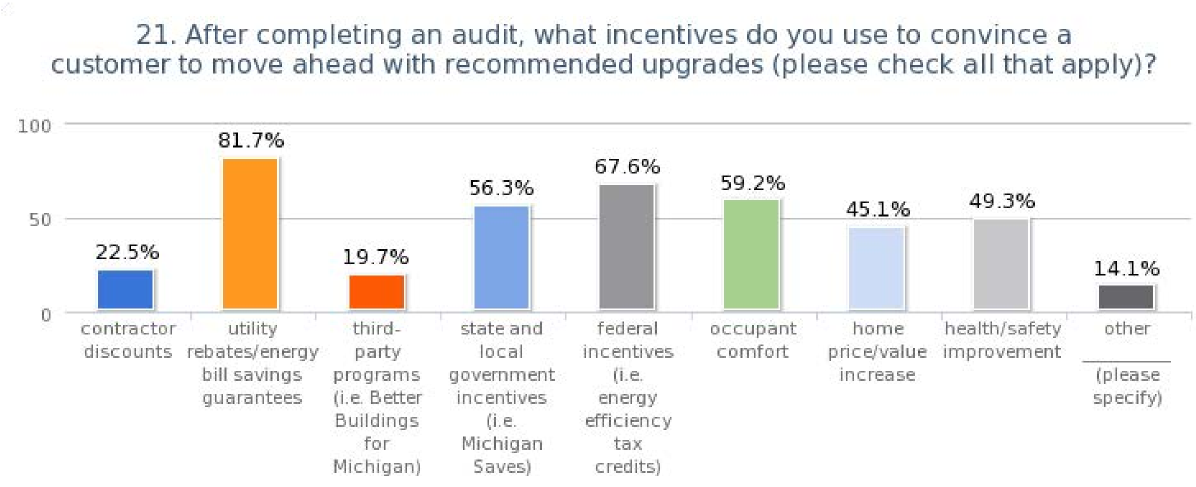
Statistics	
Total Responses	72

20. How do you prefer to learn new energy audit and upgrade protocols for certification and continuing education (please rank your top three preferences)?

Item	Total Score[1]	Overall Rank
instructor-led classroom courses	109	1
online courses	96	2
in-field training	51	3
technical guides and manuals	37	4
advice from a more experienced professional	36	5
not applicable	30	6
online practice exams	12	7
other ___________ (specified above)	9	8
exam preparation books	8	9
Total Respondents:		

[1] Score is a weighted calculation. Items ranked first are valued higher than the following ranks, the score is the sum of all weighted rank counts.

21. After completing an audit, what incentives do you use to convince a customer to move ahead with recommended upgrades (please check all that apply)?



Value	Count	Percent
contractor discounts	16	22.5%
utility rebates/energy bill savings guarantees	58	81.7%
third-party programs (i.e. Better Buildings for Michigan)	14	19.7%
state and local government incentives (i.e. Michigan Saves)	40	56.3%
federal incentives (i.e. energy efficiency tax credits)	48	67.6%
occupant comfort	42	59.2%
home price/value increase	32	45.1%
health/safety improvement	35	49.3%
other __________ (please specify)	10	14.1%
F. tax benefits	0	0.0%

Statistics	
Total Responses	71

22. Out of the incentives you use, which ones do you find most effective at convincing customers to invest in efficiency upgrades (please rank your top three incentives)?

Item	Total Score[1]	Overall Rank
utility rebates/energy bill savings guarantees	137	1
occupant comfort	65	2
federal incentives (i.e. energy efficiency tax credits)	56	3
health/safety improvement	37	4
state and local government incentives (i.e. Michigan Saves)	37	5
contractor discounts	21	6
home price/value increase	20	7
other __________ (specified above)	16	8
third-party programs (i.e. Better Buildings for Michigan)	13	9
Total Respondents:		

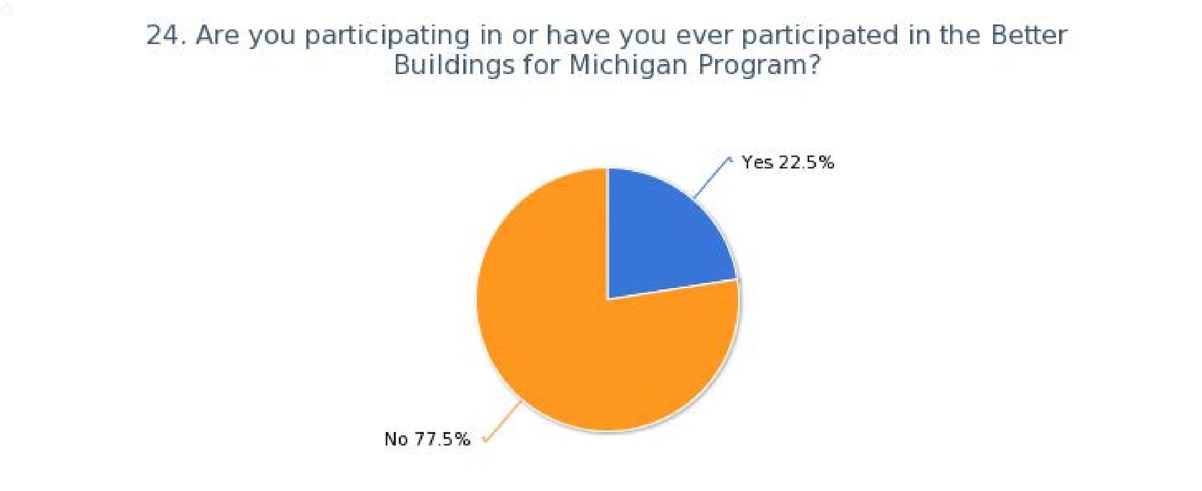
[1] Score is a weighted calculation. Items ranked first are valued higher than the following ranks, the score is the sum of all weighted rank counts.

23. What are the most popular home improvement upgrades customers request from your business (please rank the top three services)?

Item	Total Score[1]	Overall Rank
HVAC	102	1
insulation	85	2
air sealing/weatherization	75	3
water heaters	34	4
boilers	32	5
lighting	21	6
windows & doors	18	7
duct sealing	15	8
renewable energy	13	9
building infrastructure	6	10
roofing	4	11
other ___________ (specified above)	0	12
Total Respondents:		

[1] Score is a weighted calculation. Items ranked first are valued higher than the following ranks, the score is the sum of all weighted rank counts.

24. Are you participating in or have you ever participated in the Better Buildings for Michigan Program?



Value	Count	Percent
Yes	16	22.5%
No	55	77.5%

Statistics	
Total Responses	71

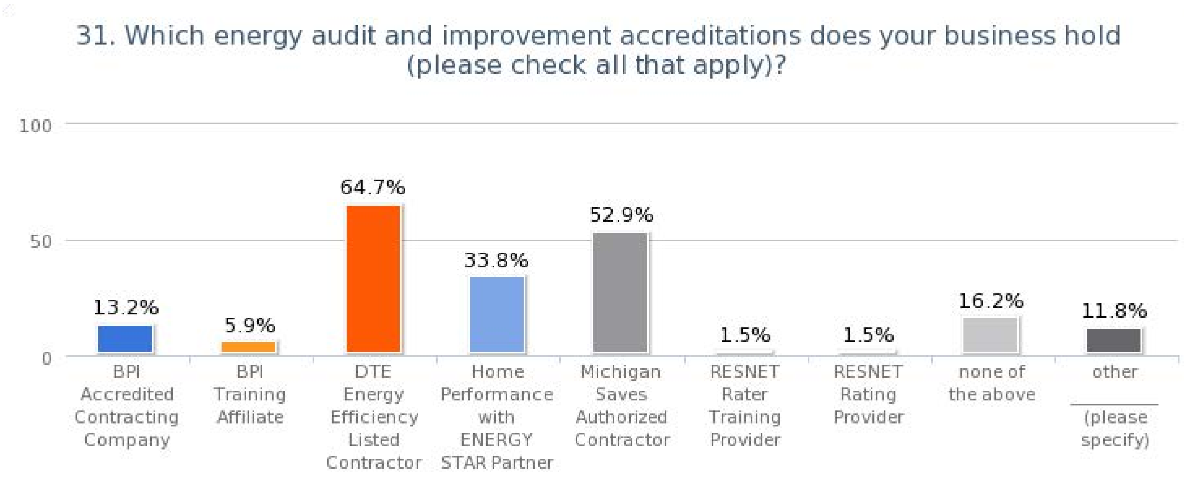
30. Which energy audit and improvement professional certifications do you or your employees hold (please check all that apply)?

Value	Count	Percent
AEE Certified Energy Auditor	3	4.4%
AEE Certified Energy Auditor - Master's Level	1	1.5%
AEE Certified Energy Manager	4	5.9%
BPI Air Conditioning and Heat Pump	7	10.3%
BPI Envelope	18	26.5%
BPI Building Analyst	25	36.8%
ENERGY STAR HVAC Contractor	20	29.4%
RESNET HERS Rater	9	13.2%
USGBC LEED Green Associate	4	5.9%
USGBC LEED Accredited Professional	7	10.3%
none of the above	18	26.5%

other __________ (please specify)	12	17.7%

Statistics	
Total Responses	68

31. Which energy audit and improvement accreditations does your business hold (please check all that apply)?

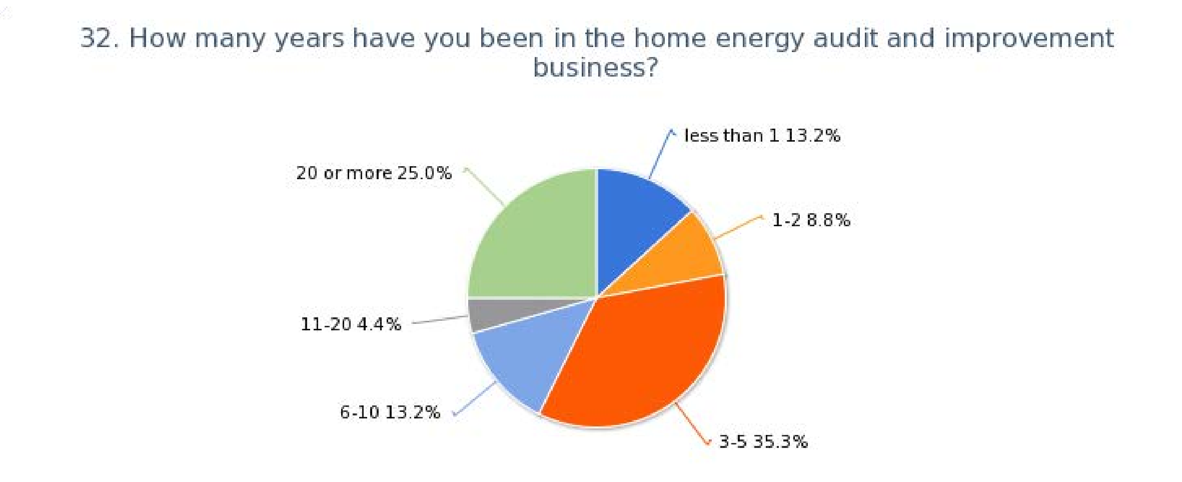


Value	Count	Percent
BPI Accredited Contracting Company	9	13.2%
BPI Training Affiliate	4	5.9%
DTE Energy Efficiency Listed Contractor	44	64.7%
Home Performance with ENERGY STAR Partner	23	33.8%
Michigan Saves Authorized Contractor	36	52.9%

RESNET Rater Training Provider	1	1.5%
RESNET Rating Provider	1	1.5%
none of the above	11	16.2%
other __________ (please specify)	8	11.8%

Statistics	
Total Responses	68

32. How many years have you been in the home energy audit and improvement business?

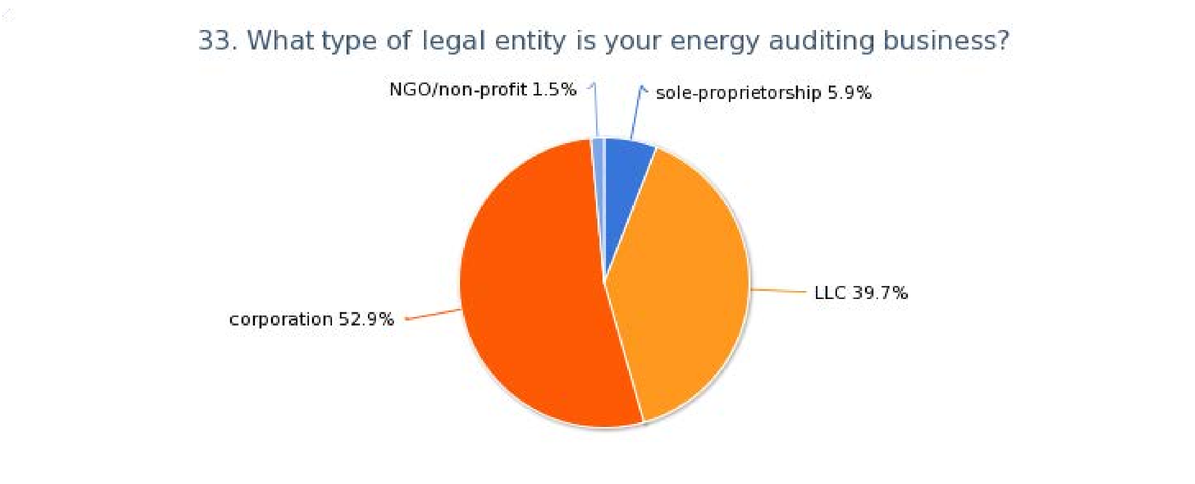


Value	Count	Percent
less than 1	9	13.2%
1-2	6	8.8%

3-5	24	35.3%
6-10	9	13.2%
11-20	3	4.4%
20 or more	17	25.0%

Statistics	
Total Responses	68
Sum	165.0
Avg.	3.9
StdDev	2.5
Max	11.0

33. What type of legal entity is your energy auditing business?



Value	Count	Percent
sole-proprietorship	4	5.9%
LLC	27	39.7%
corporation	36	52.9%
NGO/non-profit	1	1.5%
government agency	0	0.0%

Statistics	
Total Responses	68

Appendix D

Supplement to Section 6 (Customer Engagement and Satisfaction)

Appendix D

Table D-1. List of follow-up interview questions for customers who recently had home energy audits.

1. Do you own or rent your house?
2. How many people are currently living in the house? How many adults? How many children?
3. When was your house built?
4. How many stories do you have in your house?
5. What is the square footage of your house?
6. What is the primary way you heat your home in the winter? For example, do you use a natural gas furnace? Do you ever use another method to provide heat such as a fireplace or space heater?
7. What is the primary way you cool your home in the summer? For example, do you use central air conditioning unit? Do you ever use room air conditioning units?
8. What are your monthly utility costs in the summer? In the winter?
9. Where did you first learn about home energy audits?
10. What motivated you to conduct the audit? *Follow up:* Was the issue that motivated you to have an audit isolated or persistent?
11. What did you expected to pay for the audit? How much did you actually pay?
12. Please evaluate your satisfaction of the overall auditing process.
    a) Outstanding
    b) Very Good
    c) Good
    d) Fair
    e) Poor
    f) Don't Know
13. Of the efficiency measures recommended by the auditor, did you undertake any of them?
    (Yes, go 14 and 15; No, go 16.)
14. If so, which upgrade(s) have you done?
15. Please evaluate the upgrading/retrofitting process.
    a) Outstanding
    b) Very Good
    c) Good
    d) Fair
    e) Poor
    f) Don't Know
16. If not, why did you choose not to do any efficiency measures? Follow-up:
17. If you decide to do efficiency measures in the future, would you use the same contractor for the upgrade as the audit?
18. Do you have any other plans to renovate in the near future?
19. What part of your energy audit experience are you most satisfied with?
20. What part are you least satisfied with?
21. Would you recommend an audit or energy saving measures to others? *Follow-up:* Why or why not?
22. After the upgrade, what percentage of energy cost savings did you hope to see on your monthly bill? And if known, how much did you actually save? Or do you know the savings in terms of energy?
23. What could be done to improve the effectiveness of the auditing and/or the energy retrofitting process?
24. What could be done to increase the visibility of DTE Energy's residential efficiency program?
25. What could be done to encourage more homeowners to participate in energy audits?
26. Any other ideas/comments that you care to share?