Energy Tracking Software Platform

Accelerated Data Works, INC.
DE-SC0004609

Final Scientific/Technical Report
Project Director: Ryan Davis
Team Members: Nathan Bird, Russ Tyndall, Jesse Burke, Rebecca Birx, Hal Knowles, Nick Taylor

Executive Summary

Energy efficiency and conservation are important issues with implications for national security, environmental protection, and household living expenses. The Compare And Conserve (CnC) software platform, formerly Gainesville-Green.com, seeks to maximize building energy efficiency and conservation by providing building occupants and other related stakeholders with consumptive use feedback, expressed in either "as-billed" or "as-compares" formats, along with information that explains what each comparison means, what conclusions might be valid, and what actions may be worth taking to improve future building performance. In other words, this software platform provides insights into past, present and future building energy consumption patterns by enabling relevant comparisons and facilitating meaningful conservation actions.

The technology behind CnC is defined as a platform because there are many solutions built around the base system. The platform is a combination of databases, interactive web site, and support systems that enable flexible information tailoring to empower diverse stakeholders to meet their unique energy efficiency and conservation goals and objectives. At its simplest, the platform combines monthly consumption data with other public data to make useful comparisons. Yet behind this simple formula are two unique and powerful innovations – spatially linked data and relationally linked comparisons.

We know of no other publicly open, monthly meter resolution, GIS-driven, utility consumptive use database, and graphical user interface (GUI) in the United States. The map-based GUI is an evolving innovation developed by Acceleration while the mathematical formulas and science behind relational comparisons are an innovation developed by the University of Florida Program for Resource Efficient Communities (UF/PREC). This private-public partnership allows for both the rapid revision of the business sector and the scientific rigor of the academic sector.

These unique features and its multi-stakeholder design approach provide CnC a new niche in an emerging market. Homeowners have access to tools that allow them to review their historical use as compared to other homes (from neighbors down the street, to anonymous homes most similar in construction, to a network of friends around town) and track progress toward a smaller energy footprint. Real estate agents have access to consumption data, allowing for sharing comparisons with potential home buyers. Home builders have the opportunity to compare their homes' and neighborhoods' energy efficiency with competitors. Home energy raters have a tool for gauging the progress of their clients after efficiency changes. Local government staff and officials in building regulation and growth management departments have access to data about operational (i.e., "as occupied") building performance to complement records of asset (i.e., "as designed/built") building conditions. Lending institutions have access to the utility related aspects of living expenses for homeowners, which may improve loan risk assessment and customer service. And, social groups are able to help encourage members to reduce their energy bills and help their environment.

Goals and Objectives vs. Actual Accomplishments

Almost as soon as the SBIR I award was announced, Acceleration won a contract with the local utility and shifted focus from home owners to renters. Locally, mismatched incentives frequently leave renters out of most demand side management (DSM) programs, thus missing a significant market sector. Renters have difficulty justifying long-term investments in a short-term living situation and landlords, who do not pay the utility bill, have difficulty justifying long term investments where they do not reap the benefits. Landlords who make efficiency improvements would need to raise rent to recoup their investments, and higher rent is a risky proposition. This condition is worse with lower rent properties and lower income renters, creating a cycle of poverty in which as much as 50% of the renter's income is spent on utilities.

In many cases renters would be better off with higher rent and lower utility bills but there is not an easy way to demonstrate this to renters or landlords.

Acceleration created a website, ToolsForTenants.com, to display estimated utility bills for different apartment complexes. The goal is to create a market-driven incentive for landlords to improve efficiency. Renters can now factor energy costs into their housing decisions. The site allows simple comparisons between hundreds of area apartment complexes, reporting estimated costs in easy-to-understand dollars.

Many of Acceleration's initial goals were focused on the single family homeowner market; the early spotlight on the rental market introduced a new set of goals and success metrics. Significant progress was made along the original lines of research, and some interesting discoveries were made along the way that guided the software and business development.

Summary-Original Success Metrics:

1. Increases in website traffic including individual, group, and business use

   Website traffic has certainly increased, split across the two websites, Gainesville-Green.com and ToolsForTenants.com. There are anecdotal reports for increased business use among local energy efficiency businesses and real-estate businesses. Additionally, there will be an article in a local magazine in April 2011 that will likely increase the individual traffic.

2. Having 1000 users who have participated by claiming homes or creating comparison groupings

   Gainesville-Green.com has 137 registered users. These users have claimed 132 homes, created 205 groups, and included 1209 homes in those groups. The ToolsForTenants.com website does not currently incorporate a registered users feature set as all site comparisons are publicly available.

3. Lowered energy consumption of homes that have been claimed (by active users) on the website versus those that haven't

   The early work focused on the rental market, and there was not enough time to run relevant pre/post comparisons for new registered users. In order for a pre/post comparison to be significant, there needs to be consumption data available for some time before and after the event.

4. Capability to evaluate DSM effectiveness levels as verified by UF/PREC

   Algorithms were designed to calculate DSM effectiveness, and apply UF/PREC's Annual Community Baseline (ACB) technique at a monthly resolution. See "Quantifying Household Energy Performance Using Annual Community Baselines" attached for a more detailed description of the ACB techniques in development and testing.

5. Seventy five percent of users find the data provided by the site to be meaningful, understandable and helpful in analyzing their energy consumption patterns as assessed by online survey.

Extensive qualitative user data was gathered via a multidisciplinary series of usability tests and focus groups (University of Florida IRB-02 #2011-U-0003). This combination of individual user testing and semi-structured group interviews was developed as a first phase investigation into how diverse users with unique needs perceive of the website, its features, and its functions. Approximately 1,500 minutes of individual usability testing audio feedback for 37 separate individuals and 440 minutes of focus group audio feedback for 7 separate stakeholder groups was collected. More complete details are described in the usability testing section below.

6. Feedback from user base (via an onsite questionnaire) that implies a growing user commitment toward sustainability and more efficient lifestyles.

   See response to #5 above and additional detail in the usability testing section below.

7. PREC research and physical location verification that validates the analysis presented by the site

   No physical location verification was necessary. Acceleration worked with UF/PREC to develop and automate regression analysis in conformance with their research.

Summary-Usability Testing & Focus Group

An important component of our SBIR Phase 1 work involved the evaluation of household utility service information needs through the usability testing and focus group discussion of Gainesville-Green.com with customers and home energy related industry professionals within the Gainesville Regional Utilities service territory. Major topics addressed included: (1) the website's task support capacity enabling users to meet their home energy performance goals; (2) ease, efficiency, and intuitiveness of website use; (3) aesthetics of the graphical user interface; (4) relevance of information presented by user group need; and (5) knowledge, attitudes, and/or beliefs on home energy issues and conservation behaviors.

Testing Methodology

Our mixed-mode evaluation combined individual human-computer interface (HCI) usability testing ranging from 30-53 minutes, immediately followed by semi-structured focus group interviews ranging from 54 to 78 minutes. Participants were recruited using a combination of nonprobabilistic convenience sampling and snowball sampling of key informants within our six identified stakeholder groups. Wherever possible, we focused on recruiting participants with an interest in home energy performance as they are the most likely users of our website. These participants included homeowners involved in local environmental initiatives, homebuilders who participate in programs like Energy Star and/or Building America, certified home energy raters, real estate agents and brokers involved in local green building sales efforts, and financial industry stakeholders with knowledge about energy efficient mortgages and lending processes.

Participants were provided the following free "tokens of appreciation" for their participation in the usability testing and focus groups:

a. A one-page (front and back) quick reference guide for GRU energy efficiency rebates and programs. (Note: Donated by GRU)

b. Two compact fluorescent light bulbs. (Note: Donated by GRU)

c. Handbook –"Options for Clean Energy Financing Programs: Scalable Solutions for Florida's Local Governments." (Note: Donated by the University of Florida Program for Resource Efficient Communities – http://buildgreen.ufl.edu/FloridaGuide_order.pdf)

Usability testing was developed and deployed as influenced by industry trends and experience.[1,2] As such, we used separate waves of small groups of individuals allowing for refinements to the website after each wave. Participants sat at a separate individual computer terminal in the training room of the University of Florida Survey Research Center. Participants were asked to follow a series of ordered scenarios and tasks while "thinking out loud" by speaking into headset microphones as they worked through the tasks and moved through the website.

Focus group interviews were based on the methods and principals espoused in Richard Krueger's six characteristics of focus groups as detailed in the points below.[3]

1. Small Groups of People – With mini-focus groups typically consisting of four-to-five individuals and conventional focus groups consisting of six-to-twelve individuals, we aimed for a minimum of four and a maximum of eight participants in each of our seven sessions. This size range was determined to provide an optimal mix of "opportunity to share ideas" while still maintaining a sufficient overall "pool of ideas" across a diversity of potential user groups.

2. Conducted in Series – In order to maximize the opportunity for pattern detection across and within diverse stakeholder groups we held seven separate group sessions over a three week period. These seven sessions consisted of six different stakeholder types, though one stakeholder type had two separate groups. The group types, session names, and number of respective participants are shown below in the order in which they were conducted.

    a. Homebuilders (Group 1): 6 Participants

    b. Homeowners: 5 Participants

    c. Realtors®: 7 Participants

    d. Local Government Staff/Officials: 6 Participants

    e. Home Energy Raters/Auditors: 4 Participants

    f. Homebuilders (Group 2): 4 Participants

    g. Bankers/Loan Originators: 5 Participants

3. Homogeneous – Focus groups function best when participants share similarities in the traits and subject matter under investigation. We choose to categorize and group our stakeholder types according to homogeneity in the particular perspective we believed they would bring to the discussion. Though we only held one specific home owner group, we asked all of the other professional/trade groups to wear "two hats" during their sessions. The

[1] Krug, S. (2000). Don't Make Me Think: A Common Sense Approach to Web Usability. Indianapolis, Indiana, New Riders Publishing.
[2] Barnum, C. M. (2002). Usability Testing and Research. New York, NY, Longman.
[3] Krueger, R. A. (1994). Focus Groups: A Practical Guide for Applied Research. Thousand Oaks, CA, SAGE Publications.

main hat, and thus their most important perspective, would be that of their profession/trade, while their secondary hat would be that of a homeowner/renter.

4. Data Collection – Our focus groups were designed to support our website usability testing and to gather additional insights into how utility consumptive use data and visual analytics might inform and motivate various stakeholder groups that interface with the homebuilding, home buying, home owning, and mortgage lending processes.

5. Qualitative in Nature – As Krueger[4] describes, our process was not to build consensus but rather "to determine the perceptions, feelings, and manner of thinking of consumers regarding products, services, or opportunities." Our research team utilized a semi-structured open-ended group discussion facilitation approach designed to provide qualitative data that will be inductively analyzed to help immediately improve the website design and function, as well as to lay the foundation for the creation of a quantitative survey instrument to be developed and deployed for a more randomized and generalizable application in SBIR Phase 2. All focus groups were audio recorded. Transcriptions for both the usability tests and the focus groups will be ongoing into SBIR Phase 2 to enable qualitative data analysis (QDA) using the ATLAS.ti 6.2 software suite. Text coding, pattern recognition, and other QDA approaches will be used to perform a complete analysis to both pursue publication in a peer-reviewed journal as well as to inform the development of the quantitative survey instrument.

6. Focused Discussion – Merging a mixed-mode evaluation approach allowed for the usability testing scenarios to serve as a predetermined, but flexible, interview guide for the focus group discussions. These scenarios and their associated tasks were developed to be logical and understandable to the stakeholders without providing a detailed step-by-step guide to the website. These scenarios placed participants in situations that we believe may occur with the diverse users of the website. More specifically, these scenarios were a guide, not rules, which allowed our testing participants an opportunity to flow through the site and use its various features on their own terms (meaning sometimes with clarity and certitude and sometimes with confusion and frustration depending on how well the site serves their needs). Complete usability testing scenarios and a basic focus group facilitators guide can be found in the "SBIR Research Project Facilitators Guide" attached.

Thematic Areas, Major Preliminary Needs, & Responses

Themes	User Defined Needs / Statements	Project Team Proposed Responses
Purpose	More overt and instantaneous snapshot of website purpose and major capabilities	Build around the CompareAndConserve.com branding via three major capabilities: (1) how you are doing; (2) how you compare; and (3) what you can do now
Purpose	The site's power and depth of functionality only becomes apparent after extensive use and experimentation	Simplify primary user pages and break out advanced features into more defined spaces less prone to novice user confusion
Default values	Dollar/cash flow as most important default units of comparison	Two options: (1) procure monthly utility billing costs directly; or (2) approximate bill using current rate structure and show all historical data in current dollars
Comparisons	More coherent description of comparison(s) being viewed (at any given time) with	Refine legends, narrative, and comparison selection options to improve clarity while still

[4] Krueger, R. A. (1994). Focus Groups: A Practical Guide for Applied Research. Thousand Oaks, CA, SAGE Publications.

	improved clarity about conclusions that may (or may not) be made from the comparison	maintaining adaptive tailoring capacity
Comparisons	Make users more aware of the difference (i.e., "the gap") between building assets and occupant behavior and provide some form of implicit acceptance that users are held accountable to fully understand and appropriately act on this information Relieve anxiety about the potential for "others" to misuse or misunderstand information displayed and the perceived unpredictability of human behavior within homes	Improve homepage "snapshot" about site's capabilities, consider a pop up or other symbolic device as a "warning" or "caveat" statement, and/or provide adequate explanation in "next steps/recommended actions" section Explain the differences and engage users to actively "mind the gap" and "bridge the gap" between building systems and human behavior by improving the database with more tailored asset and operational information specific to their home(s)
Search	Unnecessarily long pass through times and difficulty in finding a home, a neighborhood, and/or other search options	Improve the intuitiveness of all potential search pathways including pros/cons of each and relevance of each according to user group
Wayfinding	Some confusion about where to go to find various site features, to return to previously viewed comparisons, and to generally navigate the site	Simplify homepage and improve wayfinding, segmentation, and front/back doors to key site features for the unique user needs and expectations as discussed in each stakeholder focus group
Visualizations		Improve design, legends, and explanations of maps, charts, graphs, and other visualizations
Consistency & Debugging	Sporadic bugs and site inconsistencies in layout, graphics, narrative, iconography, etc.	Improve consistency of information and its presentation across each webpage within the website and continue debugging problematic areas as they arise
Privacy	General acceptance that this information is already "out there" and that its resolution as displayed on the site (i.e., monthly, meter-scale) is fine-grained enough to offer some meaningful insights without being to fine-grained to invade on daily life and/or specific personal behaviors	Provide a more overt user privacy section explaining the site features, default and optional protection measures, and other relevant issues/considerations surrounding data privacy

Gainesville-Green.com home page before focus group testing:

Gainesville-Green.com home page after focus group testing:

Project Activities (Objectives vs. Actual)

Actual project activities remained faithful to the proposed objectives and activities, with several significant shifts to address the rental needs of the local utility. Each major activity from the SBIR I proposal is addressed below.

Comparison and Ranking Algorithms

Goal

Several different ranking algorithms will be developed to make the following types of comparisons:

1. A home versus a set of homes

2. A home versus another home

3. One set of homes versus another, disjoint set of homes

4. A home versus itself over time

Acceleration will provide data and implementation assistance to PREC for refining and evolving these algorithms. Acceleration and PREC have devoted significant resources toward this goal and have already started testing various algorithms for ranking homes. Acceleration will develop software to facilitate more efficient evaluation of the comparison methodologies.

Actual

The major initial effort was importing and combining new data. An updated consumption data dump was received from the local utility in a new data format. This plaintext format had quirks and inconsistencies, and much effort was put forth cleaning and aggregating the new consumption data into single monthly per usage type readings per customer.

The regression modeling required additional data from the property appraiser, and import routines were revised to incorporate property use codes, building use codes, home year built, neighborhood code, and to improve address accuracy. The latest bulk export provided by the property appraiser covering 2010 homes was also imported. This plaintext format exposes data entry errors, and several heuristics were developed to choose the best information for a home from several possible positions in the export file.

To support apartment complex comparisons, consumption data was imported for homes that do not exist in the property appraiser database. Apartments were grouped by apartment complex, using the utility billing address to link them together. Data availability is a large problem in this space; there are no reliable existing data sources matching individual apartment numbers to rent, heated area, or other building characteristics that can be used to improve comparisons. Apartment complex data (beds, baths, size, rent) was gathered manually via internet searches. Apartment consumption data was analyzed to determine if the size of the apartment could be derived from the usage patterns, but none were found. Apartment comparisons are made based on electricity usage only. Water and gas usage were too sparse or too consistent to use as a comparative factor. The process:

1. For each month calculate:
    1. The average (kWh), standard deviation (kWh), and number of meter reads for all apartments, per apartment complex
    2. The average (kWh), standard deviation (kWh), and number of meter reads for all apartments, aggregating over all apartment complexes
2. If the most recent month of data for a complex has more than 3 standard deviations fewer meter reads, ignore it - this adjusts for different apartments on different meter read and billing schedules
3. Throw out data for individual apartment monthly readings that have more than 3 standard deviations over the mean for their complex
4. Calculate average kWh per complex per month using the remaining data

This average is then converted to dollars using an implementation of the utility’s tiered billing formula. Apartment complexes are compared based on these final averages.

Work was done to apply the PREC ACB™ protocol at a monthly level. Following the ACB™ protocol, equivalent kilowatt hours (ekWh) was calculated for all homes. A dataset was generated to train the regression model, and then a larger set was used for to test the model’s predictive accuracy. Many different regression models were tested and automated using the R statistics software. Training data was creation process:

- Choose year to be modeled
- Select homes matching ALL of the following conditions:
    - 12 months of kWh usage for the year
    - Building use code is single family home
    - Property use code is single family home
    - Year built is available
    - Square feet is available and non-zero

- Select ekWh rows matching ALL of the following conditions:
    - Year is the modeled year
    - Amount is NOT in the top or bottom 2% of readings for each month
- Calculate age of home: modeled year - year built

Many different regression formulas were evaluated, and the best fit was selected and used to generate predicted usage for 36367 homes in 2010 (out of 43537 homes in our dataset, or 83.5%). Data availability was a significant problem. The set of homes that can be predicted is limited by the data from the property appraiser and utilities. Systems were developed to automate testing and evaluation of different regression models. PREC has refined this model further as part of independent testing and verification, see "Monthly Community Baseline" protocol in the appendix.

Many comparisons can be made based on the difference between actual and predicted ekWh usage.

This evaluative approach uses a "micro" scale multivariate regression methodology that evaluates annual, population-level, and comparison-group baselines of a treatment group versus a control group based on a census of utility and property appraiser household data. This "difference of the differences" method prevents the performance impacts of DSM and other energy conservation programs from being overstated or obscured as a result of non-program effects (such as economic conditions, weather conditions, rebound effects, free riders and free drivers, spillover, etc.).

Specifically, absolute energy use (*E*) of a given residential unit (*u*) in a specified time period (*t*) is a function of: 1) home building structural attributes (*H*) such as conditioned area and wall type; 2) number and type of energy systems or components within the home (*S*) such as HVAC systems, kitchen appliances, and electronics; 3) resident demographics (*D*) such as the number of occupants and their income and education level; 4) resident behavior (*B*) such as thermostat settings and length of showers; 5) electricity and natural gas prices (*P*); and 6) weather and climate variability (*C*).

$$E_{t,u} = f\left(H_{t,u}, S_{t,u}, D_{t,u}, B_{t,u}, P_t, C_t\right)$$

Conclusions

Many existing approaches to improving home energy efficiency and conservation lack sufficient accountability, transparency, and adaptability to changing programmatic and performance circumstances. Furthermore, existing approaches often focus solely on addressing the needs of home occupants without adequately serving the other diverse stakeholders that may further improve the market penetration and performance efficacy of energy efficiency and conservation programs. However, our approach offers a pathway for simultaneously addressing the unique user needs of home occupants as well as professional, trade, and utility stakeholders. SBIR Phase 1 enabled our collaborative team to gather an in-depth qualitative data set, rich with diverse feedback from six key stakeholder groups. With this data set, we believe we have created a product from which we can mine additional insights as analysis progresses. We intend to use these insights to continue guiding website refinement, to help the industry work toward unifying long-standing home energy asset rating protocols with the still nascent operational rating protocols, and to inform future data gathering efforts.

Based on focus group interviews, having a meaningful comparison is essential. In fact, it may be the most essential criteria of home energy feedback. Every focus group stated that "apples to apples" comparisons are necessary. All stakeholder groups expressed concern that "other" people may misled by the feedback and draw invalid conclusions. Yet our research team found this interesting because of the implication that "others" would clearly confuse or misunderstand something that virtually all individual stakeholders recognized – that human behavior within buildings can have a profound and confounding effect on utility consumption patterns.

To help control for as many known and potentially confounding variables, our team is developing and refining a regression modeling approach as the engine behind the comparisons. Yet, this approach is in its infancy and there are many additional factors that may be imported from the property appraiser and tested for predictive accuracy. More regressions will be tested.

However, the actual vs. predicted comparisons pose a GUI problem. These comparisons will need to be recast into terms and figures more easily understandable and preferably measured in dollars – another common concern coming out of the focus groups.

General Usability and Human Computer Interfaces

General Goal

Acceleration will produce multiple candidate designs and go through the industry-standard practices of focus group and A/B testing. Three iterations of candidate design and test group feedback are planned. The first iteration will be significantly different designs; the second two rounds will refine and improve on the best designs from the first round. Test candidates will be private citizens from Gainesville, FL.

Actual

Focus group testing was very productive. A total of 7 focus groups were run over the course of 3 weeks. Iterations were performed between each focus group, with major and minor changes being executed. Group members worked individually for roughly 45 minutes, and then were brought together for a round table discussion. All individual and group discussions were recorded. There was early and consistent consensus on UI problems, and all iterations evolved from our initial candidate design. Mockups were made for more simplified versions of the website, as requested by focus groups, and several popular requests were implemented:

- Combined search box to search for addresses, groups, and subdivisions from one place
- Auto-complete searching for subdivision names
- Simplified home page with more clear direction on what to do
- Comparison settings persist as the user views different reports
- Dialogs to guide the user through login, home claiming, and group management
- More responsive comparison selecting interfaces to automatically submit the form when a setting is changed

ToolsForTenants.com was informally focus group tested amongst utility employees.

Enhanced Visualization Goal

Data visualizations are a useful tool for energy consumers to draw conclusions about their usage. Acceleration will test different visualizations for effectiveness in presenting data, accuracy of user conclusions, and attractiveness.

Specific approaches to be tested include map overlays (e.g. heat maps of area usage, color-coded pin marked displays, etc.), various line and bar chart configurations, and simplistic color-coded badges for inclusion in user-profiles on other sites. This line of research will proceed in conjunction with the usability testing of the website interface and ranking methodology research.

Actual

Focus group testing was extremely useful here, as well. Much of the visualization techniques were considered too technical for a broad audience, or unclear altogether. Many improvements were made to better explain the information being displayed and provide more views of consumption. Several popular requests were implemented:

- Automatically load map pins as the user pans the map
- Improved map legend
- Multi-year views of consumption
- Bar chart color selection and legend improvements
- Ability to dynamically add and remove lines from the comparison graph

Before/After Tools Goal

Consumers are bombarded with estimated efficiency savings. These tools would provide more concrete measurements about the actual effect of efficiency actions taken by a user by allowing them to compare before and after time periods attempting to normalize out confounding factors. This algorithm will be developed by PREC with reference implementation and testing executed by Acceleration. This line of research will closely follow the comparison methodology research.

Actual

The before/after algorithm is in progress, an alteration of the DSM evaluation algorithm used in PREC's ACB protocol. This algorithm is largely dependent on the regression analysis to generate predicted values and then calculate actual – predicted for time periods before an improvement, and time periods after an improvement. Several UI mockups were made. Working at a monthly resolution (as opposed to the ACB's yearly resolution) introduces new challenges, chiefly data availability. The data availability requirements of the regression modeling extend to this process too. The following scheme has been developed:

- Determine the month and year when the action to be tested was performed
- Using regression modeling, calculate the predicted usage (ekWh) for the 12 months before and after the action, excluding the month the action was performed
- Calculate actual – predicted usage(ekWh) for the pre and post period
- Run a basic Student's T test to determine if there is a statistically significant difference in the mean of the pre and post calculations
- Monthly savings is approximated by subtracting the mean of the pre set and the mean of the post set

Work to automate these calculations and incorporate them into the website is ongoing. Focus groups indicated less interest in this style of comparison and more in group comparisons to determine if building techniques or neighborhoods were significant.

Conclusions

Focus group testing quickly refined the site and led to a re-prioritization of the existing to-do list. There were many common points made by the different focus groups, and these will continue to guide development in the future.

One of the biggest conclusions is that the purpose of the site is not immediately clear. To address this concern we have begun a re-branding process using the name CompareAndConserve.com. That name immediately informs the user what the site is for and sets better expectations for what they should be able to do.

Most groups strongly felt comparisons and usage should be presented in dollars, not gallons or kilowatt hours. Dollars is a universal metric, and most professional groups wanted this option available.

The specific stakeholder groups originally identified each had their own ideas of what they would want to see, and attempting to unify these into a "one size fits all" user interface is not practical. Many users were initially confused by the density of information, then quickly reversed themselves and wanted more in-depth views specific to their interest or occupation.

All groups also wanted actionable recommendations. Users felt well informed about their usage compared to the area, but were left with the "now what?" question. Future work will include a "recommendation engine" to examine the usage of a home to create tailored recommendations for ways to improve efficiency. This engine will be designed to adapt and learn from what is working within the utility service territory via utility provided feedback on demand side management, rebate, and incentive programs, as well as crowdsourced data from website users.

In each focus group we probed into the attitudes, perceptions, and opinions of participants regarding the complete, open, and transparent displaying of address-scale, monthly resolution utility consumptive use data. Though a handful of participants expressed some mild discomfort about these data being available, there was a general acceptance that this information is already "out there." Additionally, there was general agreement that the data resolution as displayed on the site (i.e., monthly, individual meter-scale, and posted at approximately 1-2 months post consumption) is fine-grained enough to offer some meaningful insights without being too fine-grained to invade on daily life and/or specific personal behaviors. Rapid time interval smart meter data, such as every 5-15 minutes was generally viewed as considerably too sensitive and too private to be shared openly as it might reveal daily, or even hourly, patterns of occupant behavior.

The focus groups confirmed the UI and data decisions made for ToolsForTenants.com, especially for a non-technical audience: comparing in dollars, keeping comparisons simple, don't overwhelm with numbers.

Weatherization Support

Goal

This feature supports weatherization groups, allowing them to identify homes to weatherize and track the effects of their efforts. Acceleration will interview weatherization groups in Gainesville, FL to ascertain needs, and field-test a prototype. Weatherization groups will be given special functionality allowing them to tag homes, record extra information, and manage workflow.

Actual

One of the focus groups was made up of home raters, who provided valuable feedback. Depending on the rater, historical data was essential or useless. The decision was made to focus on the raters who thought historical data was important; features were added to support their work.

Conclusions

The mixed opinions of home raters was interesting, with some raters insisting that historical data adds no value to their current auditing process, and others accepting the data as a way to both target customers and prove the value of their services. The individual rater's faith in the HERS/LEED certification process seemed to determine which side of the line they fell on.

Weatherization groups that want to incorporate Gainesville-Green.com data were interviewed separately, and contracts will be pursued with them to add weatherization-focused interfaces and incorporate their expert knowledge into the system.

Consumer Outreach

Goal

Acceleration will develop, print, and email reports summarizing energy consumption. These reports will be customized for each recipient, and be downloadable as a PDF file.

Actual

Home Energy Reports were developed and cycled through many revisions, guided by focus group discussions and feedback. Users were given the ability to easily share a home report via email, Facebook or Twitter, which seemed to cover most desires for printing. Weatherization groups requested the ability to print a report, and the interfaces were updated to support better printing from a web browser. Mockups were made for a printable report suitable for mailing.

A flyer promoting ToolsForTenants.com was also produced, to be printed and distributed locally.

Conclusion

There has been no demand for a downloadable PDF. After talks with other utilities, there is demand for a printable, easy-to-mail version of the home report.

Integration with other sites

Goal

There are many other websites that offer home-related or energy-related data that could interact with the platform. Some examples include: zillow.com, walkscore.com, openei.org, data.gov, and google.org. Acceleration will research the capability and capacity for integration. Research result is an integration matrix listing potential third parties, integration features, availability, and cost estimates. Once the integration research is complete, Acceleration will use the integration matrix to implement the most promising integrations as time allows.

Actual

Acceleration inspected several different APIs. While some sources look promising, those featuring interactive components were most compelling. Twenty-eight different services and data sources were evaluated, with varying stages of prototype, mockup, and implementation. Much effort was spent on the now deprecated Google Base API, but ultimately its search results were too unpredictable and unstructured to be of value.

Many notable services were rejected due to unreasonable Terms of Service with branding and data requirements beyond reason. One service required approval before being granted access to testing. A request was sent; however, no response was ever received. Other services found to be inapplicable: Google Powermeter is focused on smart meters only, Yelp.com has nothing to do with residences, Zillow.com is focused on home prices, etc. Many national data sources available on data.gov cover supply-side energy data.

In the end, the two most promising integrations were completed: the ShareThis link sharing service was added to the site, and browser-based tools visitors can use with other sites, notably Zillow.com and the Alachua County Property Appraiser. These small browser add-ons (bookmarklets) make it easy to access relevant home energy reports on

Gainesville-Green.com. On the search results pages or home detail pages on the target sites the bookmarklets will create links that bring visitors to the corresponding home report on Gainesville-Green.com.

Conclusions

There are many sources of data, but few reliable or consistent ones. There were several promising sources that were not integrated due to time constraints, but are planned for future iterations:

- Third party authentication providers – instead of requiring users to create an account, it is possible to let them login via a trusted third party (Twitter, Facebook, Google, OpenID).
- Walkscore.com – this service provides an estimate of how “walkable” a location is based on proximity to shopping, mass transit, and other factors.
- 2000 Census data – the 2000 census has zip code and census data that could solve the data availability problems when incorporating locations into regression analysis
- Weather data – multiple sources were identified for detailed weather information which could inform the regression modeling.

External data sources are a mixed blessing; they can improve the quality of the dataset but also increase the error and inconsistency. Future third-party integrations will focus on improving user interactivity. The current major data sources (the utility and property appraiser) are the best sources available for the desired data resolution.

In the case of individual apartment data, no decent data source exists. Interviews with the property appraiser indicated no governmental needs or desires for per-apartment information. A management company revealed a common practice of inflating square footage in advertising by including porches and utility closets, further casting doubt on the apartment data that was captured.

Small Form-Factor Website

Goal

To develop the user community and make energy information more accessible, Acceleration will produce a low-bandwidth version of the web site optimized for small screen devices such as smart phones and netbooks. Netbook and smartphone sales have soared and having an interface specific to this audience will enable users to interact with their energy data during times away from their desks (e.g. riding the subway). This design will be driven by the HCI research outlined above.

Actual

After initial testing with an iPhone and Android-based phone, it was found that a totally separate mobile-focused website was not necessary. The site was changed to display slightly differently on mobile browsers, and extensive testing was performed on an iPhone, iPad, and Android phone.

Conclusions

Small form factor websites are useful, but the Gainesville-Green.com audience is not likely to use them except on rare occasions. The weatherization group expressed a desire to use an iPad with their customers, but most use is from a normal desktop computer.

From the focus groups and other informal interviews, the demand for mobile views of this data is driven by the real estate and weatherization agents, who would want specialized views of the data to support their work. A mobile version that uses a phone's GPS to load nearby houses would be ideal. Another suggestion for mobile use is a guided home audit where the user enters data into their phone as they go. Both these applications are very specialized and will be pursued with their respective stakeholder groups.

Accessibility

Goal

Acceleration will review accessibility guidelines published by the World Wide Web Consortium and Section 508 of the 1998 Rehabilitation Act and apply recommendations to both the main and small form-factor versions of the website. This will enable users with a variety of handicaps to participate in the program, further developing the user community.

Actual

Effort was put in to making standards-compliant web pages that would be available to screen-readers, applying meta-data where applicable. Unfortunately, the site is very visual, and there are few practical solutions.

Conclusions

The visual aspects of the site need to be augmented with textual descriptions. So far the site has shied away from drawing conclusions about a home based on its consumption and straightforward data analysis. Employing the regression comparison protocol will give confidence to draw more conclusions about a home, and provide more valuable text for screen readers.

Additional Documentation / Explanation Text

Goal

To advance user education and understanding of energy issues, Acceleration will decorate the website with informational dialogs that appear upon a user's request. This information will allow curious users to learn more about the underlying math and science. The specific text will be written in cooperation with PREC scientists to ensure the explanations are accurate and understandable for the layperson.

Actual

Several help systems were tested, and the most user-friendly interface was selected. Several pages were decorated with help content, and the "About" and "FAQ" pages were updated to list additional details where possible. These explanations were driven by focus group questions. Small help icons indicate spots where users can click to be presented with more information.

Conclusions

Textual explanations are a mixed blessing. If text is constant on the screen, most users will skip it completely, especially on a graphic-heavy site like Gainesville-Green.com. If the text is shown as a popup window, users will instinctively close it before reading. Having the explanation text available after a mouse click is a good balance. The focus groups provided clear guidance for what components needed more explanation.

Application Programming Interfaces (APIs) and GIS integration

Goal

To encourage community involvement and analytic discovery, Acceleration will develop a series of web-based

APIs to allow third party programs to interact with consumption data housed on the platform.

The first API Acceleration will create will be export functionality to allow academics and professionals to import consumption data into existing GIS systems and analyze energy relationships within their own data sets. Acceleration will support the standard Keyhole Markup Language (KML) format used by products such as Google Earth and ESRI ArcView.

The second API Acceleration will develop is a programmatic interface for external programs to read and add annotations and tags to buildings. This supports external groups (e.g. weatherization efforts) performing analysis and tracking within the platform.

Actual

A KML export of map views was implemented, allowing integration with Google Earth. Talks with weatherization groups determined there was no demand for an API they could consume.

Conclusion

Downloading KML and viewing it in Google Earth did not add any value over the in-browser Google map. Google Earth also displayed some odd bugs where some map pins would not be visible. None of the stakeholder groups we interviewed have made IT investments significant enough to benefit from an API at this time. For most of our stakeholders, data entry was all going to be done manually.

User-Contributed Data

Goal

Acceleration will implement a user-contribution system to permit interested consumers to add annotations and information about their homes. They will be allowed to add building characteristics, consumption data, and notes about efficiency actions they have performed. This will allow users outside an area to participate even if their utility company is not. These annotations can be publicly viewable and will be represented in data visualizations to support independent analysis.

Actual

The website features now provide an opportunity for users to login, claim their home, create groups of homes, and record the pattern of energy consumption and/or the progress of energy-saving measures across one or more homes over time. This user contributed data may be kept private to the individual user or, offered as public information to anyone viewing that home's energy report.

Conclusions

Thus far, there has been little demand for these features. The focus group for homeowners expressed little desire in tracking their changes, especially given how infrequent the consumption data is updated. There is a trust issue with allowing user-contributed data on things like consumption data and building characteristics. The focus groups indicated interest in users filling out small surveys on things like "number of residents" that weren't found anywhere else, but there was a common distrust about the validity and accuracy of user contributed data. Many stakeholders within the focus groups felt user contributed data may quickly become inaccurate as life circumstances frequently change and concerns were expressed that inaccurate data may lead to false conclusions.

However, there are many websites that are viewed as offering valuable services that depending heavily, or wholly, on user-generated content. Anyone can say anything on a website like Twitter.com, yet the crowdsourced text, images, and networks that emerge from this site are valuable beyond their perceived risks associated with inaccurate, or even deliberately falsified or misleading information. UF/PREC has previously proposed a multi-tier home performance model in response to relevant U.S. Department of Energy Requests for Information. In such a crowdsource dependent model, tiers might be as follows:

1. Tier 1: Cleaned but unaltered utility consumptive use data and property appraiser data
2. Tier 2: Tier 1 data plus unverified user-input data such as updates on home asset characteristics, energy retrofits, and self-audit responses
3. Tier 3: Tier 1 or 2 data plus third-party verified home energy audit responses performed by non-occupants (e.g., Realtors®, home inspectors, etc.)
4. Tier 4: Tier 1, 2, or 3 data plus third-party verified home energy rating calculations performed by certified professionals using authorized home performance engineering models and methods

Our website in conjunction with a crowdsourced, tiered approach to tracking operational performance may prove quite valuable to the U.S. Department of Energy or the U.S. Environmental Protection Agency should they decide to integrate utility consumptive use data into existing home energy programs like Building America and Energy Star, respectively.

Facebook.com

Goal

To engage and attract more users, Acceleration will produce an application that runs within the Facebook.com interface. This integration leverages existing social networks allowing direct comparisons to a user's self-selected peer group. Self-selection is a key factor in behavioral science of social norms. Facebook is a good way to encourage usage of the system via "invite your friends" features that are common among viral applications. Each user will have a color-coded badge that changes based upon their energy consumption. Acceleration will develop the application, and PREC will provide algorithms for ranking inside the peer group.

Actual

The Facebook API and application process was investigated. Ultimately, the decision was made to passively integrate Facebook via the ShareThis service, which allows users to share the URL for a home report on Facebook. This service was implemented on Gainesville-Green.com and ToolsForTenants.com.

Conclusions

There is no good mapping between physical address and someone's friends on Facebook, so having access to a user's Facebook friends does not give any relevant data. If someone wants to share with their Facebook friends, they can post a link to their Facebook page, and the ShareThis service accomplishes that very easily. There were several ideas for a more active Facebook application that automatically posts about home consumption, but the infrequency of data updates makes this a much less attractive option. It was concluded that few people would jump through the multi-step process to enable a Facebook application with such a small benefit. The other major Facebook integration options (comments and "Like" buttons) were rejected as overkill. The "share this" functionality to post a link simply and cheaply covers all current use cases.

For ToolsForTentants.com, the primary use case is for renters to share information with their potential roommates as part of the apartment search process. There is no need beyond simple link sharing.

Scalability / Infrastructure Improvement

Goal

As needed, Acceleration will adapt the underlying server and programming architecture to ensure fast, reliable access to the website. This will entail load testing, code profiling, code refactoring, multi-level caching, database replication, database partitioning, and hardware upgrades.

Actual

Many rounds of testing and performance tuning were completed. Database queries were rewritten, database indexes were tested, and massive speed improvements were achieved. The templating system was dramatically improved, allowing the designers more convenient access to improve the site's look and visual presentation. Performance measurements were validated using statistical tests to ensure only code changes with significant speed improvements were accepted. Experiments with embedding an SNMP server with custom counters to track real-time performance were also performed.

These speed gains were essential to many new features, notably the comparison settings and the real-time map interactivity.

With ToolsForTenants.com, several caching schemes were tested, and in the end the site is basically static content. All calculations can be done in advance, and there are no server-side requirements for the interactive user features.

Conclusions

Consistent profiling and optimization helped eliminate bottlenecks before they became serious. Site speed has not yet been a problem and it is believed that the site could handle a good deal more traffic before that becomes an issue. Next steps involve more profiling and instrumentation of the site to easily assess future changes.

ToolsForTenants.com will be updated to further reduce the server-side components and aggressively cache all content. The content only updates when new consumption data or apartment data is available, which are both infrequent events.

Products Developed

Publications

- Pierce H. Jones, Nicholas W. Taylor, M. Jennison Kipp, Harold S. Knowles, (2010) "Quantifying household energy performance using annual community baselines", International Journal of Energy Sector Management, Vol. 4 Iss: 4, pp.593 – 613.
- Pierce Jones, Ujjval K. Vyas, Nicholas Taylor, M. Jennison Kipp, (2010) "Residential Energy Efficiency: A Model Methodology for Determining Performance Outcomes", Real Estate Issues, Vol. 35 No. 2, pp.41-47

Websites

Several websites were developed under the award.

EnergyIT.com

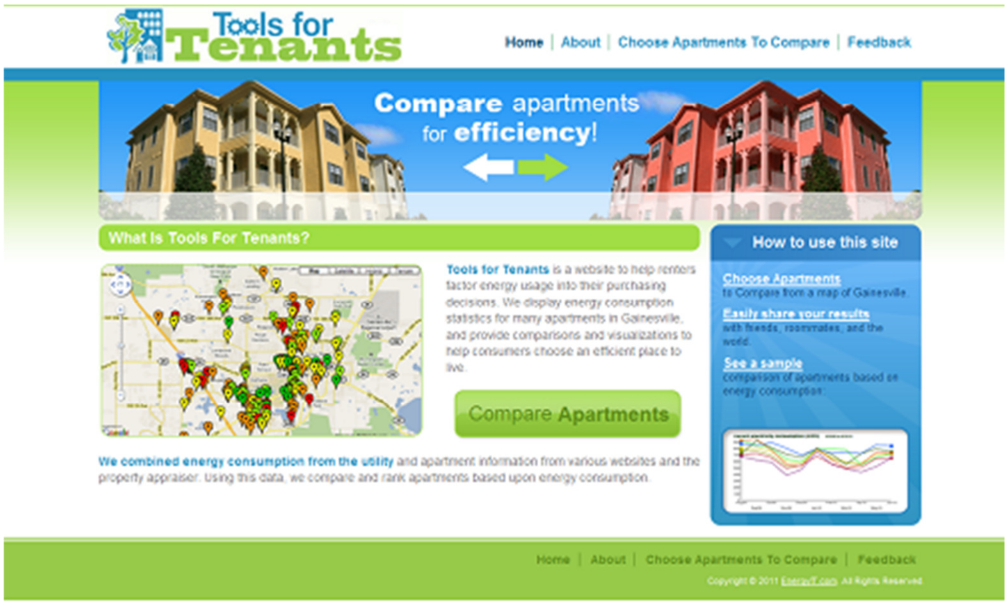
This site is the business umbrella for all energy tracking solutions and is designed to provide information about our energy tracking software and promote sales.

CompareAndConserve.com (formerly Gainesville-Green.com)

This website helps homeowners conserve energy through education and competition. Currently operating as Gainesville-Green.com, a rebranding process is underway to change to the name CompareAndConserve.com (purchased in late 2010). Gainesville-Green.com will remain available as an example of visual customization.

ToolsForTenants.com

This website helps renters factor energy usage into their purchasing decisions. Developed with support from the local utility, this project is ready for expansion into other markets.



Networks or Collaborations Fostered

Contact was made with several Florida power companies, and a shared repository for utilities to update consumption data was created. Contacts have been made, and relationships are being explored, with the following utilities, energy service companies, governmental agencies, banks, and local trade groups:

- Abundant Power
- Alachua County, Florida – Department of Growth Management
- Austin Energy
- Capital City Bank
- City of Gainesville, Florida – Planning Department and Building Inspections Department
- Clay Electric Cooperative
- Gainesville-Alachua County Association of Realtors®
- Gainesville Regional Utilities (GRU)
- JEA (formally Jacksonville Electric Authority)
- US DOE – National Renewable Energy Laboratory: Development Team for the National Residential Efficiency Measures Database
- Orlando Utilities Commission (OUC)

Within these relationships, our team is investigating a variety of future directions including, but not limited to the following:

1. Unifying home energy asset rating and operational rating methodologies and interactions
2. Developing and deploying user interface, measurement, and verification services for energy efficiency financing programs

3. Refining the customization, relevance, and efficacy of home energy efficiency and conservation retrofit recommendations and advice
4. Improving the data exchange from relevant governmental agencies as guided by the emerging open government initiatives
5. Crowdsourcing unique household data on home energy efficiency and conservation measures while maintaining individual privacy

In addition, discussions are underway to resell our software through Atlanta based Enercom, a software provider representing over 400 energy utilities nationwide.

Techniques

To process incoming data, two simple data pipelines were established, one for property appraiser data and one for consumption data. Each pipeline merges and follows these steps:

1. Import from flat files to a PostgreSQL database. This involves some initial data cleaning steps:
    a. Normalizing address information (e.g.: “avenue” to AVE, “street” to ST, etc)
    b. Splitting address data into house number, street name/number, street type, quadrant, city, zip code
    c. Parsing text into numeric data
    d. Calculating parcel centroids to get geospatial coordinates for each home that will be visually appealing on a Google map
2. Clean data - depends on data source, includes tasks like:
    a. Discarding duplicate rows
    b. Sum multiple usage records that apply to the same month and home
3. Match import data with existing dataset
4. Extend the dataset with matched records
5. Link imported property and consumption data together, and add those new homes to the dataset
6. Recalculate derived data based on the new consumption and property data
    a. Recalculate ekWh, CO2e, apartment complex averages
    b. Re-run regression analyses and update predicted usage amounts
7. Update the live websites to use the new dataset

The process takes many hours to complete, and is partially automated. Most of these tasks take place inside PostgreSQL, using the PL-R add-on to use the R statistics software with minimal import/export chores.

Inventions

The monthly application of the PREC ACB™ protocol is a new invention. Though still under development and refinement, this “regression analysis approach is a relatively inexpensive, simple, rigorous, transparent, and replicable method for generating robust estimates of performance impacts of any energy conservation program.”[5] It offers a wide range of potential long term outcomes and innovations including, but not limited to the following:

1. Personally tailored home performance comparisons and feedback

[5] Pierce H. Jones, Nicholas W. Taylor, M. Jennison Kipp, Harold S. Knowles, (2010) "Quantifying household energy performance using annual community baselines", International Journal of Energy Sector Management, Vol. 4 Iss: 4, pp.593 – 613.

2. Improved customer group segmentation for program analysis, strategic marketing, and tailored customer service
3. More “fair” comparative feedback with improved control for the commonly challenging utility service territory-wide variables of environmental, social, and economic trends.
4. Improved estimates of potential savings from home energy efficiency and conservation programs from evaluating weatherization retrofits to ground-truthing “green” building rating and certification systems

Comparison Algorithm

Our computer modeling was limited to straightforward multivariate regression models, described earlier in this report. These models were verified by examining residuals on the entire applicable data set for the year, and the F-Statistic and R^2 values of the regression itself. The basis of the model is the PREC ACB™ protocol, which was has been peer reviewed and published.[6]

[6] Ibid.

MONTHLY COMMUNITY BASELINES: A PROTOCOL FOR USING METERED CONSUMPTION DATA TO CREATE VALID, TRANPARENT COMPARISONS AND VERIFY HOME PERFORMANCE

Nicholas Taylor[1], Jennison Kipp, and Pierce Jones
University of Florida

MONTHLY COMMUNITY BASELINES (MCB) PROTOCOL

With the central goal of generating appropriate, useful and robust energy performance measures via simple, valid, transparent, and replicable analysis methods, we have developed the Monthly Community Baseline (MCB) protocol. The key attribute that distinguishes the MCB protocol from standard energy program evaluation approaches is that it benchmarks energy performance by applying traditional regression methods in a fundamentally non-traditional way. Unlike conventional regression approaches, the MCB analyses do not explain or interpret the independent (or explanatory) variable parameter coefficients and their corresponding levels of statistical significance. Instead, they use estimates (specifically, the *predicted* dependent variable values) derived from conventionally-constructed multivariate regression models as the energy performance benchmarks (baselines) for individual households in a given utility and in a given time period.

Following MCB protocol, the absolute and relative differences between baseline and actual (metered) energy performance (mathematically equivalent to the regression equation residuals) are interpreted as *static* MCB energy performance measures. Changes in the regression equation residuals over time for individual households or subsets of households of interest are then calculated and interpreted as *dynamic* MCB energy performance measures. The magnitude and statistical significance of performance improvements (i.e., positive energy savings) or performance degradation (i.e., negative energy savings) attributable to utility demand side management programs or other energy efficiency interventions can then be estimated, with confidence that the energy performance measures being evaluated have been effectively normalized against the utility's entire "community baseline", or appropriate comparison group. The MCB technique is most effective when a full census of utility and property appraiser data are available for the key energy consumption parameter(s) of interest and for each of the housing parameters needed to construct a defensible multivariate regression equation. The technique can also be used to evaluate household water consumption data and water efficiency programs. A complete discussion and explanation of the MCB methodology is forthcoming from the University of Florida's Program for Resource Efficient Communities.

[1] nwtaylor@ufl.edu; 352-392-3121

DATA SCREENING

1. Only single-family, detached homes are used
2. Monthly data is limited to those greater than 150 ekWh/month and less than 5,000 ekWh/month.
3. Only readings accounting for between 20 and 40 days are used.
4. Only homes that are less than 150 years old are used.
5. Only homes with less than 5,000 square feet of conditioned floor area are used.

CREATE BASELINE

A least squares regression model is created for *each month in each year* using the following form.

$$\gamma = \mu + UserGroup_{block} + HeatedArea + Vintage + DaysInReading + \varepsilon$$

Where:

Y is the response variable, energy consumption in equivalent kilowatt hours per month

μ is the population mean of the response variable

$UserGroup_{block}$ is a blocking variable that indicates if there is natural gas factored into the monthly energy consumption

HeatedArea is an independent variable that indicates the square feet of conditioned floor area for each home

Vintage is the age, in years, for each home

DaysInReading is the number of days in the billing cycle for each reading

ε is the deviation from the population mean

BASELINE APPLICATION

The regression predicted baseline can be serve as a tool to compare home or groups with residual values providing standardized static and dynamic measures.

STATIC MEASURES

Static measures are performance indicators used to compare homes in the same time period (ie the same month in the same year). The subscript $_{M1}$ indicates that each reading should come from the same month of the same year.

One home can be compared to another single home in a single month with the following method:

$$(Actual_{M1} - Predicted_{M1})_{test\ home} - (Actual_{M1} - Predicted_{M1})_{comparison\ home}$$

One home can be compared to a group of homes:

$$(Actual_{M1} - Predicted_{M1})_{test\ home} - \sum_{i}^{n} \frac{(Actual_{M1} - Predicted_{M1})_i}{n}$$

Two groups of homes can be compared:

$$\left(\sum_{i}^{n} \frac{(Actual_{M1} - Predicted_{M1})_i}{n}\right)_{test\ group} - \left(\sum_{i}^{n} \frac{(Actual_{M1} - Predicted_{M1})_i}{n}\right)_{comparison\ group}$$

DYNAMIC MEASURES

Dynamic Measures are used to estimate savings over time related to various conservation measures. The subscripts used in the notation below indicate that comparisons are made between readings taken for the same month ($_{M1}$) in subsequent years ($_{Y1,\ Y2}$). This gives a comparison of pre- versus post- implementation performance.

- One home can be compared with itself to estimate savings related to energy conservation measures using the following method:

$$(Actual - Predicted)_{Y2M1} - (Actual - Predicted)_{Y1M1}$$

- A group of homes can be compared with itself to estimate savings related to energy conservation measures using the following method:

$$\left(\sum_{i}^{n} \frac{(Actual - Predicted)_i}{n}\right)_{Y2M1} - \left(\sum_{i}^{n} \frac{(Actual - Predicted)_i}{n}\right)_{Y1M1}$$

ASSESSMENT OF ENERGY TRENDS

The monthly community baseline can be used to identify abnormalities in consumption for single homes to help identify appropriate recommendations for conservation measures. Homes should be measured against MCB values for peak and base load months. In January or February, when heating load is generally at its peak, deviations from MCB gives an indication of the efficiency in a home's heating system and building envelope. In March or April, when little heating or cooling is necessary, base load energy use can be assessed. Deviations from MCB can give indications about efficiencies of water heating, refrigeration, lighting, appliances and general plug load. In July or August, when cooling load is generally at its peak, deviations from MCB gives an indication of the efficiency of a home's cooling system and building envelope. For months falling in these three time periods the following method can be used to indicate abnormalities in consumption for single homes.

$$IF \quad \left[\left(\frac{Actual_{M1} - Predicted_{M1}}{Predicted_{M1}}\right)_{test\ home} > 0.2\right]$$

Then there are potentially problems with behavior, building envelope, or heating equipment

$$IF \quad \left[\left(\frac{Actual_{M4} - Predicted_{M4}}{Predicted_{M4}}\right)_{test\ home} > 0.2\right]$$

Then there are potentially problems with water heating, refrigeration, lighting, appliances and plug load

$$IF \quad \left[\left(\frac{Actual_{M8} - Predicted_{M8}}{Predicted_{M8}}\right)_{test\ home} > 0.2\right]$$

Then there are potentially problems with behavior, building envelope, or cooling equipment

Analysis of relative performance between heating and cooling seasons may provide further insights on structural versus mechanical problems.

Quantifying Household Energy Performance Using Annual Community Baselines

Pierce H. Jones[1,]*, Nicholas W. Taylor[2], M. Jennison Kipp[3], and Harold S. Knowles[4]

Forthcoming: accepted July 13, 2010 for publication in the International Journal of Energy Systems Management under copyright by Emerald Group Publishing.

1. Introduction

This paper describes an approach using metered data to estimate annual community energy consumption baselines for single-family detached homes in the Gainesville Regional Utility (GRU) service area of Alachua County, Florida, United States. Further, it details methods using these baselines to make direct comparisons of individual households' energy consumption and evaluate the performance impacts of three prescriptive demand side management (DSM) programs. This approach demonstrates the potential for application to a range of energy efficiency programs and utility service areas to improve impact evaluations and estimates of energy savings.

1.1 Building-Sector Energy Efficiency

Housing has an important role to play in decreasing overall energy consumption and associated Greenhouse Gas (GHG) emissions. Over the last decade the residential building sector accounted for over 20% of total U.S. energy consumption (EIA, 2009, p. 38), and this is an important sector to evaluate given that "single-family detached homes are the most energy-intensive housing type" (EIA, 1999). Despite residential energy intensity decreasing 9% from 1985 to 2004, total residential household and per capita energy use rose as house sizes increased while household occupancy decreased (DOE, 2008, p. 12). For all buildings (residential and commercial) GHG emissions averaged a 2.1% annual growth rate over approximately the same period (McMahon, McNeil *et al.*, 2007, p. 95).

Because of the building sector's size and relatively inefficient energy consumption patterns, it is a high-priority target for policies aiming to mitigate climate change and improve energy security. Improvements in energy efficiency "probably offer the greatest potential to provide [GHG emissions mitigation] wedges" for the United States (Pacala and Socolow, 2004, p. 969). Many estimates of the potential for reducing household energy consumption indicate that the residential building sector is and will continue to be a critical player in achieving this potential (Dietz *et al.*,

[1] *Corresponding Author, Professor and Director, Program for Resource Efficient Communities, University of Florida, Gainesville, FL, United States, piercejones@ufl.edu
[2] Housing Systems Analyst, Program for Resource Efficient Communities, University of Florida, Gainesville, FL, United States, nwtaylor@ufl.edu
[3] Resource Economist, Program for Resource Efficient Communities, University of Florida, Gainesville, FL, United States, mjkipp@ufl.edu
[4] Research Assistant, Program for Resource Efficient Communities, University of Florida, Gainesville, FL, United States, hknowles@ufl.edu

2009; Horowitz, 2007). Some studies have projected that a whole-building systems integration of current best practices can reduce residential energy intensity between 30-40% at little or no additional cost, and possibly up to 70-90% in optimal situations (Affordable Comfort Inc., 2007; McMahon, McNeil *et al.*, 2007, p. 95; DOE, 2008, p. 12).

Federal and state governments promote energy efficiency in the residential sector with a variety of programs, some flexible and others highly prescriptive. For new residential construction the best known examples are the US Environmental Protection Agency's (EPA) ENERGY STAR® Homes program, which essentially requires a home to be ~15% more energy efficient than one built to code[1], and the US Department of Energy's (DOE) Building America Builders Challenge, which requires homes to be ~30% more energy efficient than houses built to code[2]. These two programs set performance thresholds rather than directly requiring specific practices and/or materials and both are flexible in the sense that builders can choose through design and product specification how to achieve the required efficiency targets. For existing housing the best known program is the DOE's Weatherization Assistance Program (WAP), a highly prescriptive retrofit program that ranks explicit residential retrofits and funds them in priority order[3].

Both the ENERGY STAR and Builders Challenge programs rely on Home Energy Rating System (HERS) Index scores as performance measures. A HERS rater uses an energy efficiency software package, EnergyGauge®[4], to perform an energy analysis of a home's design and specified components (windows, insulation, etc.). The rater then conducts on-site inspections, typically including a blower door test (to measure the air infiltration of the house) and a duct test (to measure leakage in Heating, Ventilation and Air Conditioning (HVAC) duct systems). Results of these tests, along with inputs derived from the plan review, are evaluated in reference to a similar home built to code and are then used to generate a home's HERS Index score[5]. ENERGY STAR and Builders Challenge program designations are awarded before a new home is occupied on the basis of HERS Index score meeting specific thresholds. Smith and Jones (2003) found that annual household energy consumption for ENERGY STAR qualified homes was significantly lower (~12% less) than conventionally built homes. However, post-occupancy household energy consumption data are seldom used to evaluate the success of these energy efficiency programs in achieving actual absolute or relative energy savings.

1.2 Demand Side Management (DSM) Program Goals and Outcomes

Historically, utility demand-side management (DSM) programs were designed to encourage consumers to modify their level and pattern of electricity usage in an effort to delay investments in new power plants and to manage costly peak electric demand (EIA, 1999). More recently, DSM programs have become linked to public policy concerns such as reducing financial burdens on low income households and reducing GHG emissions. Today, a fundamental goal of many DSM programs is to change patterns of energy use, thereby reducing absolute energy consumption and associated GHG emissions. Investor-owned utilities in Florida must submit DSM plans to the Public Service Commission as part of their responsibilities as regulated monopolies. Both investor-owned and municipal utilities are required to report DSM impact annually to the DOE Energy Information Administration (EIA) via Form EIA-861 (EIA, 2007). As DSM programs have moved more directly into the public policy sphere, utilities have shown a growing interest not only in implementing programs with meaningful energy consumption impacts, but also in maintaining the perception of successful programs.

Utility energy conservation programs (as well as national, state and local governments) are relying increasingly on incentives linked to "green certification" protocols to reduce residential energy use. Programs like ENERGY STAR are perceived to increase brand power for premium product pricing while encouraging reduced energy consumption:

> "If you purchase an energy-efficient product, you may be eligible for a federal tax credit…ENERGY STAR distinguishes energy efficient products which, although they may cost more to purchase than standard models, will pay you back in lower energy bills within a reasonable amount of time, [even] without a tax credit"[6].

Like many other power providers, GRU links one of its largest DSM rebates directly to the Home Performance with ENERGY STAR Program, "a whole-house approach developed to assist residential electric customers in upgrading existing homes to reduce energy use [and] lower their bills"[7].

All of the described programs' performance baselines rely on projected energy savings that are calculated from the energy efficiency characteristics of applied upgrades (such as programmable thermostats, ceiling fans and water heaters). The methods used to project energy savings can range from simplistic, such as a directly comparison of incandescent and compact fluorescent lamp energy use over a given period of time, to sophisticated, holistic processes using simulation modeling and direct testing, such as HERS Index scoring. Essentially, all program rebates, tax credits and energy efficiency designations are awarded on the front-end with no validation of post-occupancy energy consumption required.

This has led to a tendency in the building industry to rely on program labels and designations rather than on direct measurement of actual performance. There is growing concern that voluntary programs, such as the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) programs, can mask a lack of energy-focused design behind other non-energy criteria, inaccurately estimate the actual energy in occupied buildings, and/or fail to acknowledge that performance persistence may degrade over time (Stein and Meier, 2000; Cannon *et al.*, 2008; Gifford, 2008; Jones and Vyas, 2008; Lstiburek, 2008; Malin, 2008; Del Percio, 2009; Scofield, 2009). These concerns are likely to be exacerbated if caps on GHG emissions are imposed.

Utilities can address these concerns directly, especially as they relate to DSM programs. Since they collect monthly energy consumption data (essential to their customer billing functions), they can directly quantify individual household energy consumption patterns and changes attributable to DSM programs. Property appraiser data also are available that provide basic building characteristics of individual homes, which are important factors affecting residential energy consumption and efficiency potential. By merging utility and property appraiser data, direct comparisons of individual households' energy consumption can be made and impacts of various prescriptive DSM programs can be evaluated.

1.3 Energy Use and Performance Baselines

Utilities reward customers with cash rebates for energy-efficiency upgrades that are presumed to reduce actual energy use and reduce GHG emissions, and DSM program performance is often evaluated based on its relative cost-effectiveness (e.g., cents per kWh saved or GHG emissions avoided) (Gillingham *et al.*, 2006). At the same time, "utility energy efficiency programs are taking center stage in ongoing discussions about U.S. energy policy and how best to combat climate change" (Arimura *et al.*, 2009, p. 24). In this context, the appropriate construct, interpretation, and application of energy performance baselines and specification of models to estimate savings are important (Parfomak and Lave, 1996; Schiller, 2007). The Model Energy Efficiency Program Impact Evaluation Guide emphasizes this point:

> "A major impact evaluation decision is selecting the baseline. The baseline defines the conditions, including energy consumption and related emissions that would have occurred without the subject program. The selection of a baseline scenario always involves uncertainty because it represents a hypothetical scenario" (Schiller, 2007, p. 4-2).

Sophisticated engineering, econometric, and mixed-model approaches have been developed to minimize uncertainty in specification of baseline scenarios and improve methods for evaluation of DSM program impact. Using these standard approaches, utility analysts and independent consultants are analyzing metered consumption data, estimating energy demand response to specific DSM programs, and calculating associated energy savings (Gillingham *et al.*, 2006). When funding is sufficient, the analyses attempt to quantify free rider, spillover, and rebound effects. However, the relatively high cost of complex modeling approaches (Schiller, 2007) and the variability of estimates across utilities justify continued pursuit of simple, valid, transparent and replicable methods for establishing energy performance baselines and measuring program impacts. In this paper, we describe a regression analysis approach that aims to satisfy these key methods criteria – simple, valid, transparent, and replicable – while generating robust estimates for the measures of interest.

Engineering Models

Empirical models are commonly used to project or estimate energy savings from DSM and other utility conservation and efficiency programs. Engineering models (such as the EnergyGauge® software that underpins the HERS Index) are typically constructed at a micro scale and are particularly useful for delineating the upper bounds of energy-efficiency potential for structural, mechanical, and electrical features of a home. Output from such models serves as benchmarks for measuring changes in performance after an appliance or equipment upgrade and/or for evaluating a new home's actual performance. They are particularly useful when constructed and applied at a whole-house systems level. Energy performance measures derived from engineering models alone, however, are limited in scope of application. They typically do not account for variability driven by factors independent of the home's engineered design and building features (such as occupant demographics and behavior). Furthermore, they cannot be easily scaled up to provide valid expectations about and estimates of performance at the community or utility level.

Econometric Models

Conversely, econometric models are typically constructed at a macro scale using self-reported electric utility data on energy consumption and savings (e.g., those supplied to the Energy Information Administration (EIA) via Form EIA-861[8]). These models often include data on critical energy demand determinants such as service population characteristics, utility rates, and climate data to estimate DSM program impacts within and across samples of utilities. While such econometric approaches are well-established and typically robust, they are designed for use at a macro level and are dependent on the quality of data that have already been aggregated by individual utilities (e.g., Horowitz, 2007; Arimura *et al.*, 2009), and they may not generate appropriate estimates of energy savings and cost-effectiveness when scaled down to the individual household or DSM-program level. Furthermore, methods used by individual utilities to calculate energy savings vary and the original data used to estimate key model parameters are often not readily accessible to the empirical research community. Finally, given uncertainties surrounding the original estimates of key independent variables (e.g., energy savings) applied in large scale econometric models, it is difficult to know whether changes in energy consumption via DSM programs are being measured using the most suitable performance baselines.

Are reported energy savings generated from and used by engineering and econometric models consistent in magnitude and precision with actual efficiency gains or are they simply gross estimates of change relative to a static baseline? Complex modeling that adjusts consumption measures for a wide range of independent variables can perform well in terms of producing precise, robust estimates of savings and isolating DSM program impacts (Parfomak and Lave, 1996; Gillingham *et al.*, 2006). Access to data that would improve or allow scaling of these analytical methods, however, is often expensive (Schiller, 2007). Central to the premise of this paper, we think that a more appropriate baseline for adjusting actual energy consumption data can be constructed to facilitate cost-efficient analyses at the utility scale. We propose that with this alternative baseline methodology, valid energy savings and impact assessment results can be achieved using a parsimonious – yet still logical and functional – approach to modeling residential energy use.

1.4 Annual Community Baselines (ACB) Approach

To improve estimates of energy savings, we propose using a “micro” scale multivariate regression methodology based on a census of utility and property appraiser household data. We have applied this approach in the GRU service territory to: 1) establish new measures of energy performance by constructing annual community energy consumption baselines against which actual (metered) household-level energy consumption (ekWh) is compared for the years 2004-2009, and 2) estimate energy savings attributable to each of three DSM programs implemented in 2007 using ACB estimates as the foundation for year-over-year performance comparisons.

Our proposed methodology is unique in that it: 1) defines a new household-level energy consumption baseline measure that we think produces more accurate performance measures, 2) uses a census of publicly-available data for the population of interest, merging metered utility data with property appraiser data; and 3) uses these census data with the new baseline measure to construct a simple model for evaluating changes in household-level energy consumption over time. These performance measures are then applied to estimate what we think are improved measures of energy savings attributable to each of the three DSM programs evaluated in this study.

The critical element that distinguishes our proposed energy performance measures is that they are calculated and interpreted using annual, population-level, comparison-group baselines that effectively normalize for community energy consumption patterns in any given year. Year-over-year changes in household consumption are evaluated relative to the community baseline, so residuals estimated from the ACB regression directly reflect our definition of meaningful and relevant energy performance measures (i.e., energy savings). Furthermore, because the annual performance measures themselves are derived from a regression-adjusted baseline approach, the data are normalized in such a way that year-over-year performance of individual households or groups of homes can be compared directly. This prevents the performance impacts of DSM and other energy conservation programs from being overstated or obscured as a result of non-program effects (such as economic conditions, rebound, free riders and free drivers, spillover and so on). In light of debate surrounding the need to account for these effects, which are "notoriously difficult to measure", we think that this feature of our model is particularly valuable (Heins, S. 2006; Herring, 2006).

2. Analysis Design and Methods

In developing our ACB model, we first considered the primary determinants of energy use of residential customers in a given utility service area, expressed generally in equation (1), and evaluated whether each was relevant and necessary for inclusion in the detailed analysis.

$$(1) \qquad E_{t,u} = f\left(H_{t,u}, S_{t,u}, D_{t,u}, B_{t,u}, P_t, C_t\right)$$

Absolute energy use (E) of a given residential unit (u) in a specified time period (t) is a function of: 1) home building structural attributes (H) such as conditioned area and wall type; 2) number and type of energy systems or components within the home (S) such as HVAC systems, kitchen appliances, and electronics; 3) resident demographics (D) such as the number of occupants and their income and education level; 4) resident behavior (B) such as thermostat settings and length of showers; 5) electricity and natural gas prices (P); and 6) weather and climate variability (C).

2.1 Scope

One of our central aims is to develop a reliable protocol for measuring energy savings that uses commonly-available data sources, is practical in application, and is readily portable. A census of the available and reliable data is included without restrictions on or distortions of subpopulations within. It is designed to quantify true programmatic impacts on the community and utility service area within the context of evolving social norms and economic drivers related to energy consumption. Selection of independent variables for estimating annual baselines represents the simplest form that can be used to produce valid, statistically sound results. It is important to note that the ACBs are complementary to, but not direct substitutes for conventional "business-as-usual" baselines; they provide another layer of information that we argue is critical for effective construction of baselines or reference scenarios.

The ACB technique provides a measure of savings in terms of reduced energy consumption that is a function of but not synonymous with "increased efficiency". In addition, this technique applies specifically to site energy use of buildings, not accounting for primary energy associated with losses in production and transmission from source to site. To translate analysis outcomes to reflect utility scale impacts, factors related to operational efficiencies must be considered but are beyond the scope of this paper.

2.2 Data

Sources

To construct and test our model, data were requested and obtained from three sources: the Alachua County Property Appraiser (ACPA); Gainesville Regional Utilities (GRU), and the National Climatic Data Center (NCDC). ACPA provided data on the physical characteristics, location, and sales of all properties in Alachua County, Florida as of November 2009. GRU provided two distinct datasets. The first included monthly, account-level, electric, natural gas and water consumption data for each residential and commercial customer from 1996 through 2009[9]. The second GRU dataset included information about all DSM program participants through September 2009. Monthly heating and cooling degree day data for 1996 through 2009 were obtained from the NCDC.

In identifying data to use in the analysis, fields were selected based on availability, accuracy, and their known relation to residential energy consumption. Monthly, account level, electric and natural gas data linked to the premise, customer identification number, and physical address were selected from the GRU database. Physical address, building type, US Department of Revenue (DOR) tax code, parcel number, number of bedrooms, number of bathrooms, conditioned floor area, year built and residential neighborhood listing were selected from the ACPA database. Physical address was used to link and merge the two databases to create an analysis dataset. GRU DSM program data including the type of incentive, installation date, and incentive amount were tagged to the analysis dataset by premise and customer numbers. Table 1 lists the fields included in each of the original databases.

Table 1: Original databases from which full analysis dataset was generated

ACPA Database	GRU Consumption Database	GRU Rebate Database	NCDC Database
Parcel Number	Premise Number	Premise Number	Heating Degree Days
Physical Address	Customer Number	Customer Number	Cooling Degree Days
Building Type	Physical Address	Rebate Type	Year
DOR Code	Meter read date	Rebate Amount	Month
Number of Bedrooms	Service Type	Installation Date	
Number of Bathrooms	Billed Consumption		
Conditioned Area			
Year Built			
Neighborhood Code			

Cleaning and Screening

The 2009 ACPA database listed 51,746 single family residential units. Of the ACPA units 35,091 were identified by physical address to be GRU customers during calendar year 2009. For purposes of this study these single-family homes formed a census list from which annual subsets were created for calendar years 2004 through 2009 (excluding 2007). For each annual subset, homes were screened to ensure that there were at least 350 and no more than 380 days of electric consumption data on record and that the necessary property appraisal data were available.

Monthly electric and natural gas consumption were combined and expressed in units of equivalent kilowatt hours (ekWh) to quantify total annual energy use. Annual consumption data were normalized to represent the full calendar year by taking average daily use for the number of days recorded and multiplying by 365. Residential units consuming less than 3,000 ekWh per year or more than 65,000 ekWh per year were removed from the dataset as either unoccupied homes or outliers. A schematic representation of the screening process and listing of the full populations of single-family residential units that met all screening criteria to be included in five calendar year databases from 2004 through 2009 (excluding 2007) are shown in Figure 1.

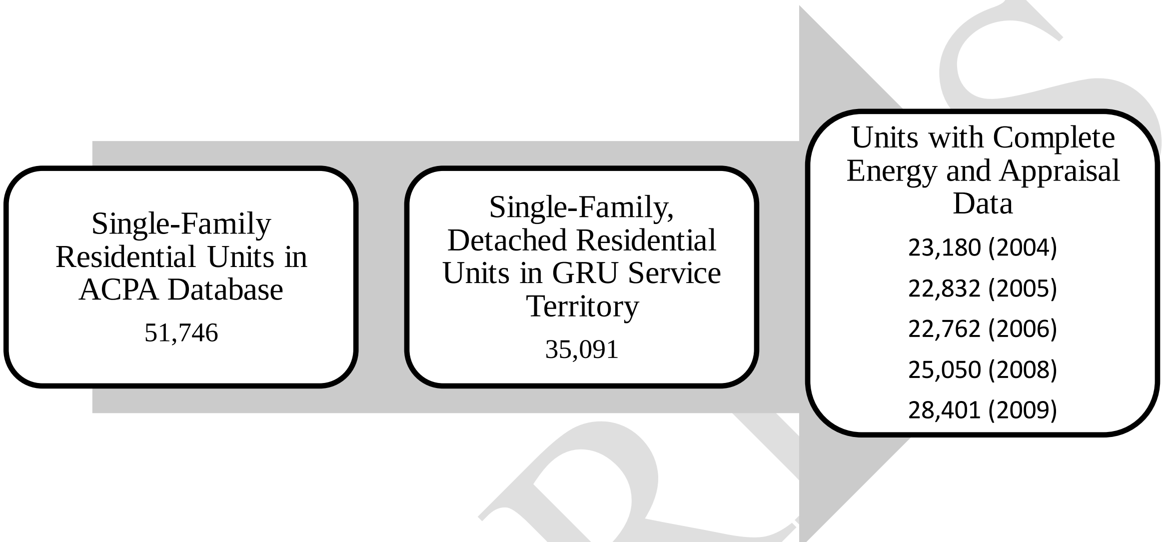


Figure 1: Diagram of initial data screening process to ensure no missing data or unoccupied homes.

2.3 ACB Model Specification

Each calendar year dataset was analyzed independently using multivariate regression, equation (2), to estimate predicted home energy use values for each residential unit in the census.

(2) $$EC_{t,u} = \beta_0 + \beta_1(Size\ Factor_{t,u}^{PC}) + \beta_2(Age_{t,u}) + \beta_3(Neighborhood_u) + \epsilon_{t,u}$$
where $Size\ Factor_{t,u}^{PC} = f(conditioned\ area, \#\ of\ bedrooms, \#\ of\ bathrooms)$

Annual energy consumption (*EC*) is the dependent variable with size factor (conditioned area, number of bedrooms and number of bathrooms), year built, and neighborhood code as independent variables. The number of bedrooms and bathrooms, and square feet of conditioned area are important explanatory factors for energy use because they are indicators of the number of people living in each home and HVAC demand, respectively. Using a principal components analysis (PCA), we transformed these highly correlated, yet distinct measures of home size into a single "size factor" predictor variable. Year built is also considered an important energy use predictor variable as it captures the building code under which the home was constructed and the common building practice used in that particular time period. To transform it to a more meaningful continuous value for use in regression, the year built variable was converted to home age by subtracting year built from the analysis year (2010). The property appraisal neighborhood code was selected as a geographic indicator for resident behavior and demographic variables (census block or zip code may substitute if necessary but may increase error in the model) and as an indicator of the materials, construction techniques and workmanship used in subsets of houses. These factors (size factor, age, and neighborhood code) were used to complete a regression analysis giving predicted energy use values for each home in each of the analysis years. These predicted values represent the Annual Community Baseline for absolute energy consumption ($\widehat{EC}_{t,u}$) in each year for each residential unit.

Residuals, $\hat{\varepsilon}_u$, derived from this ACB regression (equation (2)) are then interpreted as annual energy performance measures for each residential unit in each year; mathematically, they are calculated as actual minus predicted energy use

(3) $$\hat{\varepsilon}_{t,u} = (EC_{t,u} - \widehat{EC}_{t,u})$$

Overall annual performance of a given subset (*n*) of residential units in a given year (*t*) is calculated as the mean of the individual performance indicators (i.e., residuals) for that particular subset

(4) $$\overline{\hat{\varepsilon}_{t,u}} = \left(\sum_{u=1}^{n} \hat{\varepsilon}_{t,u}/n_t\right)$$

The absolute and relative year-over-year differences in the residuals for individual homes or subgroups of homes, equations (5a) and (5b), respectively, are then calculated to estimate changes in household energy performance over time

(5a) $$\Delta\hat{\varepsilon}_{t,u} = \left(\hat{\varepsilon}_{t_{post},u} - \hat{\varepsilon}_{t_{pre},u}\right)$$

(5b) $$\Delta\left(\hat{\varepsilon}_{t,u}/\widehat{EC}_{t,u}\right) = \left(\hat{\varepsilon}_{t_{post},u}/\widehat{EC}_{t_{post},u}\right) - \left(\hat{\varepsilon}_{t_{pre},u}/\widehat{EC}_{t_{pre},u}\right)$$

A second regression is used to estimate the magnitude and statistical significance of change in energy use (i.e., savings) for any given subset of the population relative to the census savings

(6) $$ES_{D,post-pre} = \gamma_0 + \gamma_1(Dummy) + \varepsilon$$

For this regression, equation (6), which essentially applies a basic analysis of variance statistical test, the changes in residuals between one year and the next for each residential unit (calculated using equations (5a) and (5b)) are used as the dependent variables and a dummy variable is used as the explanatory variable to distinguish the population sub-group of interest (coded '1') from all other residential homes in the population (coded '0'). The parameter coefficient, γ_1, estimated for the rebate dummy tells us the magnitude and direction of change in energy use, or energy savings, $ES_{D,post\text{-}pre}$ (such that a negative coefficient represents a decrease in energy use/increase in performance/positive energy savings for sub-group of interest while a positive change represents an increase in energy use/decrease in performance/negative energy savings). The p-test on the F-statistic for this regression provides a measure of statistical significance for these energy savings estimates.

2.4 Application of ACB to DSM

GRU's DSM programs were considered individually (single upgrades) for their numbers of participating households during calendar year 2007. Three programs were selected for evaluation: the Duct Sealing Rebate Program, the Refrigerator Buyback Program, and the Super SEER A/C Program. The Duct Sealing Rebate Program incentivizes customers to repair leaky ductwork to reduce pressure differential and associated air infiltration. The Refrigerator Buyback Program pays customers to dispose of secondary and unnecessary refrigerators and freezers to reduce energy consumption. The Super SEER A/C Rebate Program offers customers assistance in upgrading to HVAC equipment with a Seasonal Energy Efficiency Ratio (SEER) of 16+ or higher. GRU data were used to identify households that: 1) participated in one of the three selected programs during 2007; and 2) had not participated in any other GRU DSM programs. Homes that met these criteria were tagged; the number of tagged homes for each DSM program is shown in Table 2. For purposes of this analysis, the calendar year databases covering 2004 through 2009 (excluding 2007) were aggregated into a single database.

Table 2: Population sizes of residential units for rebate analysis

Rebate Type	N
Duct Sealing Rebate	123
Refrigerator Buyback	294
Super SEER A/C Rebate	148
Total	565

In addition to ACB, three conventional techniques were used to estimate energy savings attributable to the rebate programs. Energy savings estimates from the conventional techniques were then compared to those of the ACB approach to evaluate its relative effectiveness. For the purposes of this analysis, as in equation (6), 2006 performance is used as the reference or pre-installation standard, 2007 is the DSM intervention year, and 2008 and 2009 are the post-installation years. (Note that the term "baseline year" in this context refers to the conventional definition of the conditions that exist prior to an efficiency upgrade or other change: pre-installation. In this context, the ACB baseline year and reporting period years are all estimated using ACB regression, so this analysis technique actually includes four "baselines". Time Series, Time Series with Weather Normalized Annual Consumption (NAC), Time Series and Comparison Group, and Annual Community Baseline analyses were tested. (Explanations of these approaches were adapted from Schiller, 2007.)

- **Time Series** analysis was used to estimate savings by taking the difference between post upgrade energy use and pre upgrade energy use.

  Time Series Estimate = Post - Pre

- **Time Series NAC** used data normalized with heating and cooling degree data to calculate savings by taking the difference between post upgrade and pre upgrade energy use.

  Time Series NAC = $Post_{NAC}$ - Pre_{NAC}

- **Time Series and Comparison Group** analysis uses a difference in difference technique to estimate energy saving. The difference between average annual consumption of the census before and after upgrades to the sample population is subtracted from the post and pre upgrade consumption of the participants.

Time Series and Comparisons = $(Post_{participant} - Pre_{participant}) - (Post_{census} - Pre_{census})$

- **Annual Community Baseline** uses multivariate regression to create predicted home energy use values for each home in the census. Homes that participated in rebate programs were compared by taking the difference of their residuals (actual minus predicted values) before and after energy conservation upgrades. (These savings estimates were then used in a second regression analysis to estimate program impact, so they are similar to the commonly-used difference-in-difference approach, but with an additional difference adjustment using the first regression expression residuals) (Meyer, 1995).

ACB Analysis = $(Actual_{post} - Predicted_{post}) - (Actual_{pre} - Predicted_{pre})$

3. Results and Discussion

Each annual baseline graphed in Figure 2 represents the ordered range of expected energy use for DSM participant homes. The figure displays variability in expected consumption among homes and across years (as we expect from variability in climate, economic conditions, etc. across years, but also from changes in performance). Although these baselines only represent the DSM homes' performance baselines, they have been adjusted through the regression analysis using the entire census of homes. This effectively expands the number of comparables for each home to the maximum extent possible within the census. The area under each baseline represents the total energy consumption predicted for the DSM group in a given year. If the full census ACBs were plotted, their shapes would be similar to those shown in Figure 2 and the area under each baseline would represent the actual energy consumption for the given year.

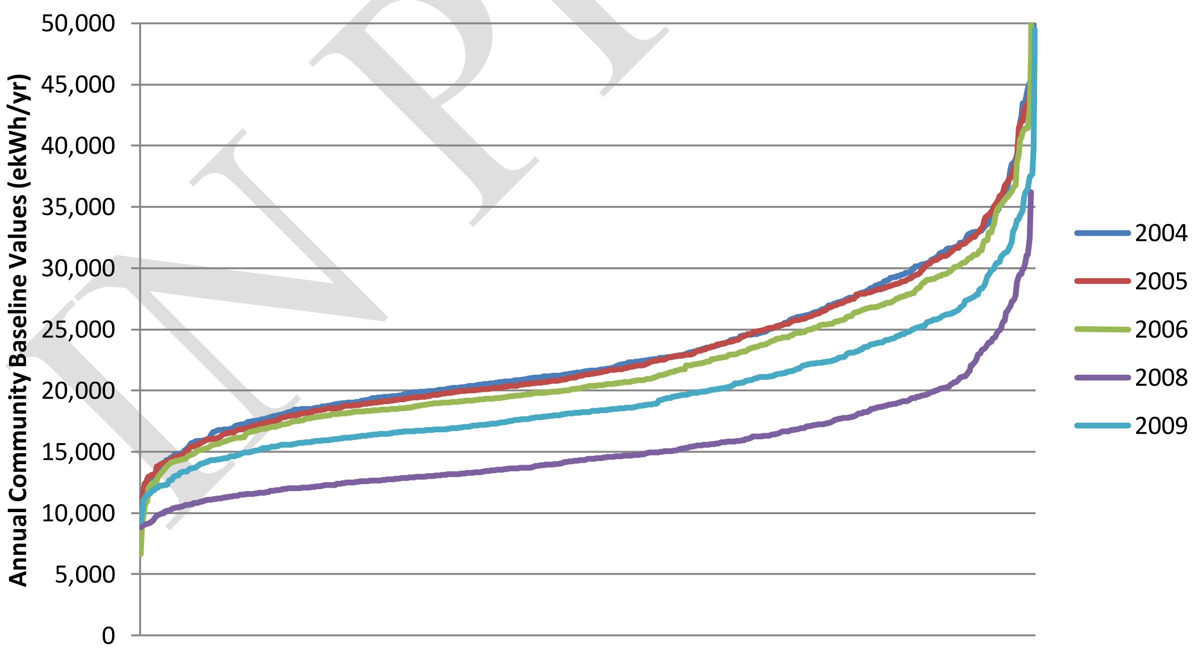


Figure 2: Annual energy use baseline value ranges presented by year for 2007 GRU rebate participants.

In Table 3, for each of the rebate programs the "Difference" values are equal to the average residuals in absolute terms while the "% Difference" are the residuals specified in relative terms so that it easier to interpret them as performance measures in a given year (i.e., the degree to which homes are consuming above or below the baseline). These values only compare within years between each DSM group and the entire population as represented by the baseline. In the years prior to 2007, the DSM participant homes were consuming more energy on average as determined by the ACB than their peer groups. In post-installation years (2008 and 2009) DSM participants reduced their consumption to points close to or below the baselines. These numbers are only annual performance indicators, not estimates of change in performance or programs savings. They can be compared across time within the context of the shifting annual baselines, but they alone cannot be used to estimate the effect of DSM participation on change in energy use and performance.

Table 3: DSM program participants' actual energy use (ekWh) relative to ACB-predicted energy use, 2004-2009.

Program		2004	2005	2006	2007	2008	2009
Duct Sealing Rebate	Actual	23,966	23,905	23,169		14,853	19,324
n = 123	Baseline	23,152	22,812	21,879		15,281	19,593
	Difference	814	1,093	1,290		-428	-268
	% Difference	3.52%	4.79%	5.89%		-2.80%	-1.37%
Refrigerator Buyback	Actual	23,326	23,817	22,999		15,401	19,822
n = 294	Baseline	23,017	22,682	21,891		15,467	19,502
	Difference	308	1,135	1,108		-66	320
	% Difference	1.34%	5.00%	5.06%		-0.43%	1.64%
Super SEER A/C Rebate	Actual	23,030	22,569	21,922		14,348	18,466
n = 148	Baseline	22,437	22,046	21,115		14,804	19,010
	Difference	593	523	808		-456	-544
	% Difference	2.64%	2.37%	3.83%		-3.08%	-2.86%

Figures 3-5 provide a visual representation of results in Table 5 and illustrate how the relative performance of DSM program participants changes from year to year. Notice that in all three figures, DSM participants' performance improved after 2007 relative to previous years, which indicates that the DSM programs *may* have had a significant effect on performance in 2008 and 2009. It is also worth noting that year over year changes in relative performance of the DSM participant groups are small relative to the changes in the ACBs.

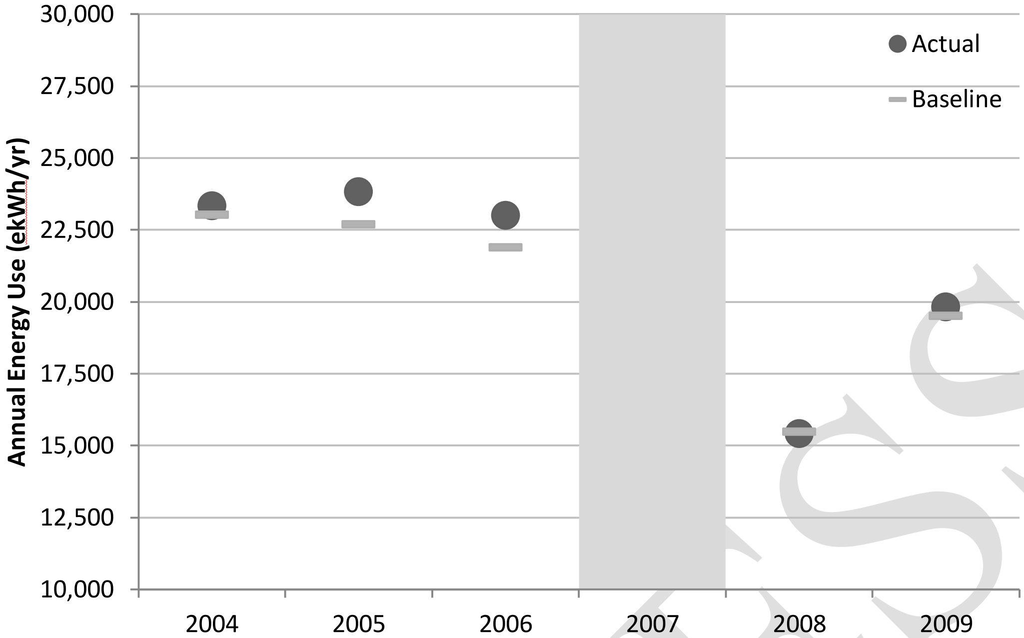


Figure 3: Average annual energy use for 2007 GRU Duct Sealing Rebate Program Participants as compared to their average Annual Community Baselines.

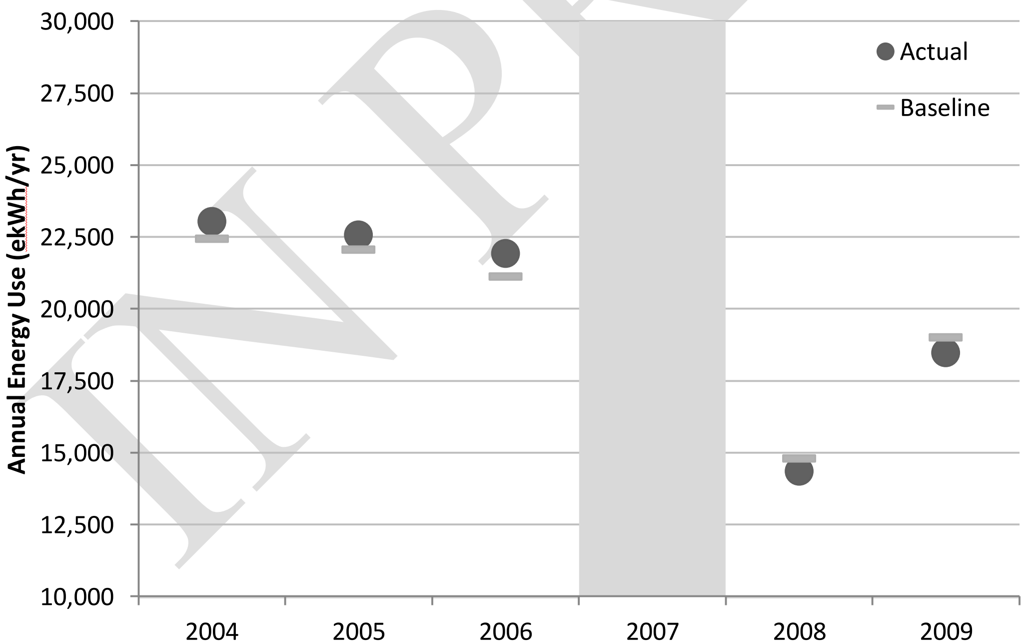


Figure 4: Average annual energy use for 2007 GRU Refrigerator Buyback Program participants as compared to their average Annual Community Baselines.

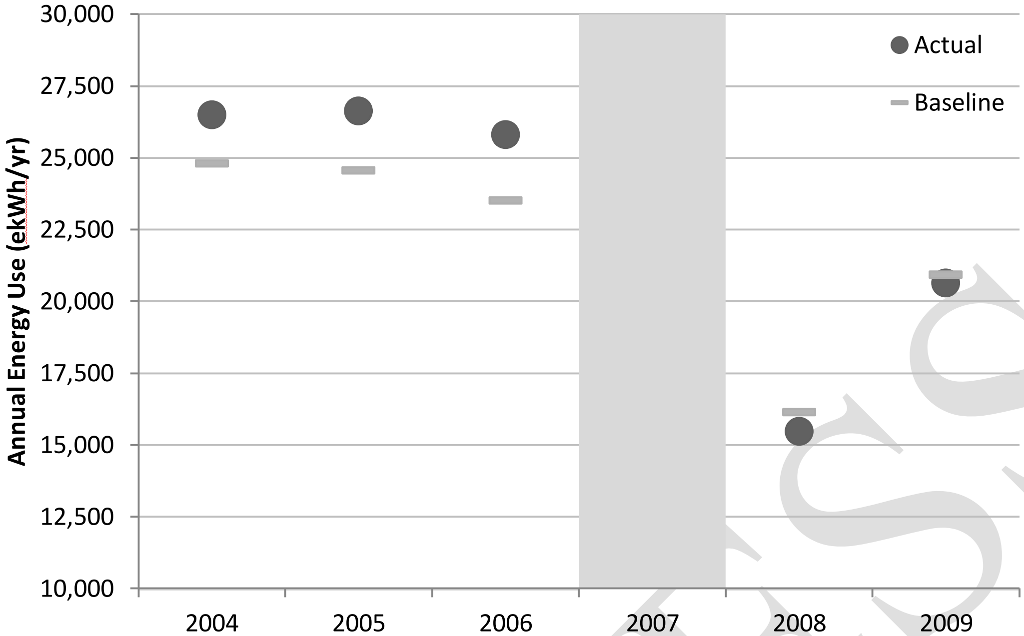


Figure 5: Average annual energy use for 2007 GRU Super SEER A/C Rebate Program Participants as compared to their average Annual Community Baselines.

Table 4 shows the estimates of energy savings attributable to each DSM program using each of the four analysis techniques. Recall that in all analyses, 2006 represents the pre-installation or reference year and 2008 and 2009 are the reporting period years. Results suggest that conventional analysis approaches are likely to overestimate savings significantly, ranging from an average across reference years and techniques of 2.5 times higher when applied to the Super SEER A/C Rebate to 4.9 times higher when applied to the Duct Sealing Rebate. Overall, ACB appears to give more stable savings estimates when compared across the two post-installation year analyses. For example, if time series analysis is used, an average savings of 10,351 ekWh/yr would be reported attributable to the Super SEER A/C Rebate program for the 2008 reporting period while the estimate for 2009 drops ~56% to 4,476 ekWh/yr; future reporting period estimates should improve our confidence in making this claim. Time series analysis results in the largest discrepancy in savings estimates for the two reporting periods, followed by time series analysis of weather normalized annual consumption (NAC). Although commonly used in the utility industry, these two techniques are understood by experts to be weak, if not unacceptable, for reports of program impacts (Schiller, 2007).

Table 4: Estimates of energy savings (ekWh/yr) across DSM programs using conventional techniques and ACB.

Program	Sample Size	Analysis Year	Time Series	Time Series NAC	Time Series Comparison	ACB
Duct Sealing Rebate	123	2008	-8,066***	-6,846***	-1,599***	-1,136**
		2009	-3,016**	-4,493**	-1,039**	-572
		Difference in estimates	5,050	2,353	560	564
Refrigerator Buyback	294	2008	-7,622***	-6,463***	-1,155***	-959***
		2009	-3,450***	-4,828***	-1,473***	-1,220***
		Difference in estimates	4,172	1,635	318	261
Super SEER A/C Rebate	148	2008	-10,351***	-9,122***	-3,884***	-2,786***
		2009	-4,776***	-6,316***	-2,799***	-2,191***
		Difference in estimates	5,575	2,806	1,085	595

Note: * indicates statistical significance at 10%, ** at 5%, and *** at 1% level.

Time series with comparison groups was the third comparison technique applied. In this case the entire census was used as the comparison group and DSM participant homes were evaluated based on census average energy use before and after program implementation. When homes are compared with others in the same geographic and utility service area, effects of energy prices and weather are inherently incorporated (because in any given time period, all homes experience the same prices and weather), so data are not normalized using price or climate data for this and the ACB analysis. Although this technique can provide more realistic estimates of savings than time series or time series NAC, results are highly dependent on data screening methods used to create comparison groups. Figures 6-8 graph the results in Table 6 as estimated energy savings across the four analysis techniques; they reinforce the potential for wide variation in deemed program impact as a result of the analysis technique used to adjust actual energy use and estimate savings.

Table 5 shows estimates for energy savings associated with the three DSM programs derived using ACB analysis. Estimates are presented in terms of both absolute and relative (percentage) savings. Table 5 also includes estimates for the effect (i.e., magnitude and significance) of the DSM on changes in annual performance and estimates the extent to which energy savings are directly attributable to the DSM program. Both the Refrigerator Buyback and the Super SEER A/C Rebate programs showed statistically significant changes in energy use associated with the efficiency upgrades.

(It should be noted that the Duct Sealing Rebate Program returned marginally significant savings in 2008 and savings that were not statistically significant in 2009.)

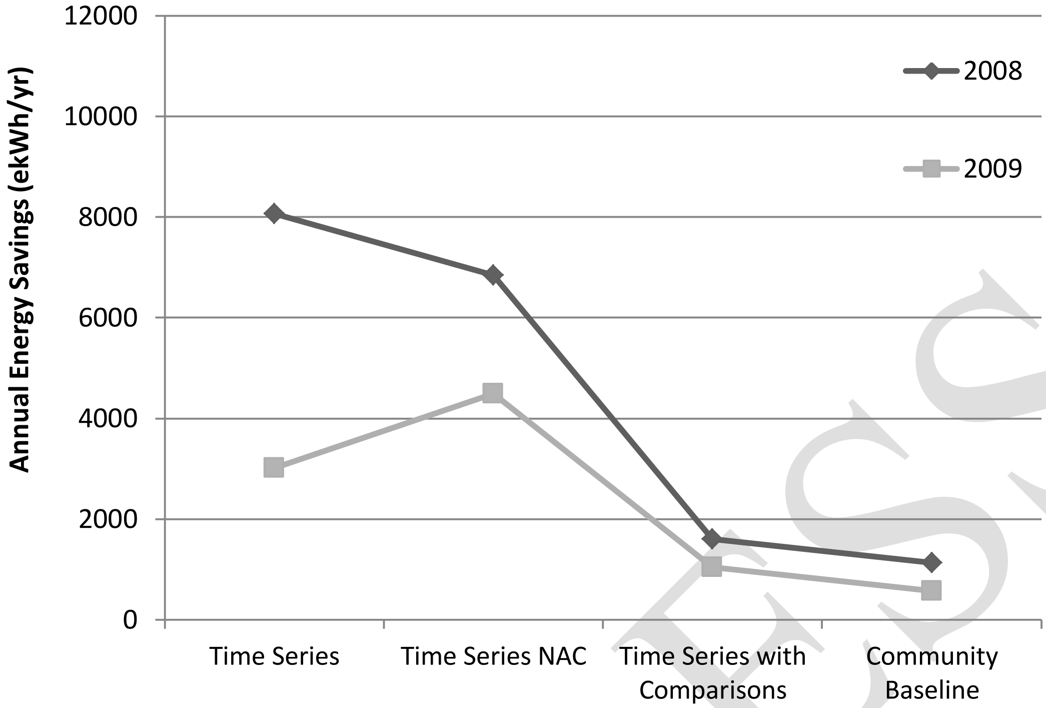


Figure 6: 2007 GRU Duct Sealing Program savings estimates using various analysis methods

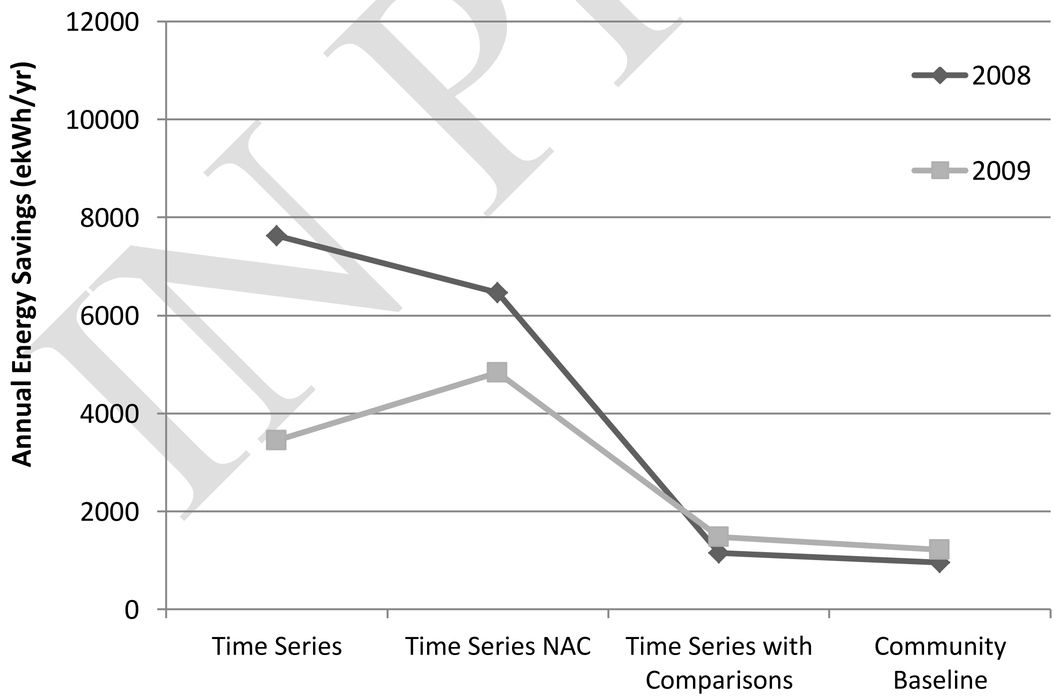


Figure 7: 2007 GRU Refrigerator Buyback Program savings estimates using various analysis methods.

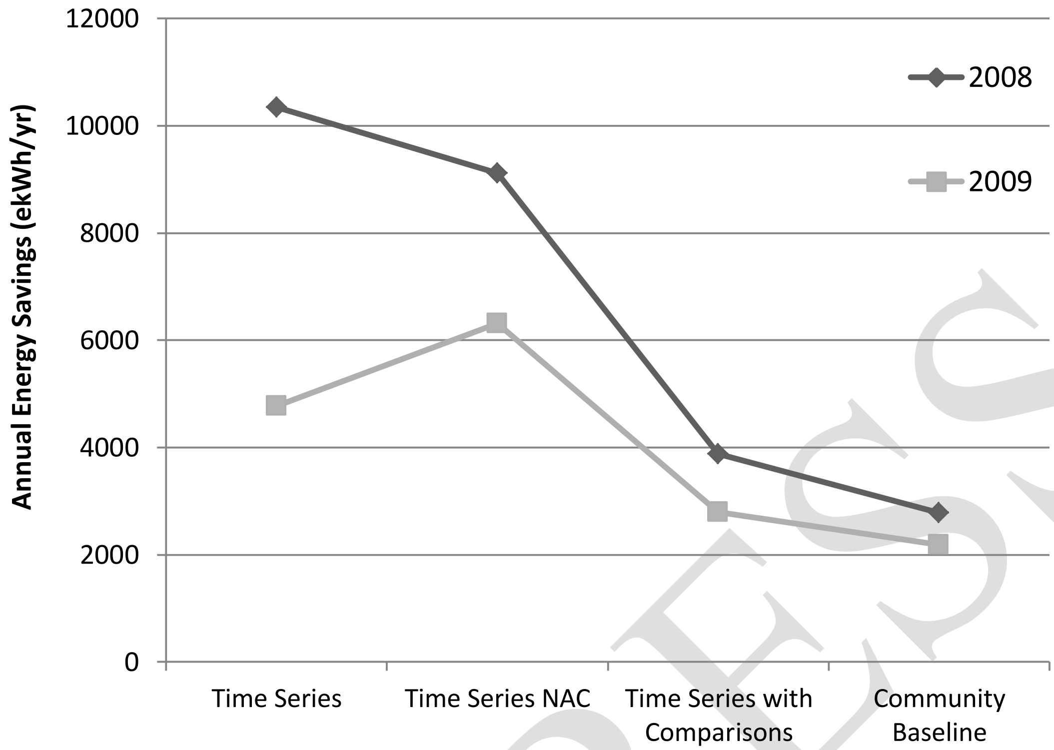


Figure 8: 2007 GRU Refrigerator Buyback Program savings estimates using various analysis methods

Table 5: Results of Rebate Savings Analysis using ACB technique, given as absolute and relative savings (ekWh).

Program	Sample Size	Analysis Year	ACB Savings (absolute)	ACB Savings (relative)
Duct Sealing Rebate	123	2008	-1,136**	-5.1%*
		2009	-572	-1.5%
Refrigerator Buyback	294	2008	-959***	-5.5%***
		2009	-1,220***	-6.4%***
Super SEER A/C Rebate	148	2008	-2,786***	-12.6%***
		2009	-2,191***	-8.9%***

Note: * indicates statistical significance at 10%, ** at 5%, and *** at 1% level.

4. Conclusions

Estimates of potential savings from energy efficiency programs are the key drivers for homeowner decision making and demand side management program design. If careful attention is not given to data screening, baseline development, model specification and final analysis, flawed estimates can lead to unexpectedly long payback periods for both utilities and their customers. Deemed savings for building retrofits are generally based on engineering analyses and typically do not take into account occupant behavior and other factors likely to affect performance. Savings measured using simple time-series modeling techniques do not properly account for environmental, economic, and social trends. Advanced econometric and mixed models that attempt to compare residential performance across geographic regions based on utility reported savings are typically at an aggregate level and may have flawed input that can distort impact estimates.

The proposed method of Annual Community Baseline analysis offers a tool that can provide accurate estimates of year-over-year changes in household energy consumption that in turn, can be used to fairly evaluate the impact of various energy conservation efforts. The ACB regression analysis approach is a relatively inexpensive, simple, rigorous, transparent, and replicable method for generating robust estimates of performance impacts of any energy conservation program. For utilities ACB analysis can be used to more effectively compare and prioritize their demand side management programs as shown in this study. We believe that ACB can provide an effective means to accurately depict real-world energy savings impacts and that it can work equally well for evaluating weatherization in existing homes or "green" certification programs applied to new housing.

Notes

1. ENERGY STAR is a labeling program of the U.S. Environmental Protection Agency designed to promote the adoption of energy efficient technologies in lighting, appliances, electronics, equipment, homes, and industrial buildings to reduce greenhouse gas emissions. See www.energystar.gov for more information.
2. Builders Challenge is a program of the U.S. Department of Energy that provides incentives – research results and marketing tools – for homebuilders to construct homes that excel in energy performance. The program's goal is to expand the market for "cost-neutral, net-zero energy homes" in the U.S. market. See www1.eere.energy.gov/buildings/challenge for more information.
3. The Weatherization Assistance Program (WAP) is a funding program administered through the U.S. Department of Energy Office of Energy Efficiency & Renewable Energy to help low-income families reduce their energy bills through improvements in home energy efficiency. See http://www1.eere.energy.gov/wip/wap.html for more information.
4. EnergyGauge® is a software tool for analyzing buildings' energy use performance, compliance with building codes, and economics of energy efficiency upgrades. See http://www.energygauge.com for more information.
5. The HERS® Index is a relative energy use index for rating buildings. A "HERS Index of 100 represents the energy use of the "American Standard Building" and an Index of 0 (zero) indicates that the Proposed Building uses no net purchased energy (a Zero Energy Building)". For additional details, see www.natresnet.org.
6. ENERGY STAR "Federal Tax Credits for Energy Efficiency" at http://www.energystar.gov/index.cfm?c=tax_credits.tx_index.
7. Gainesville Regional Utilities (GRU) "Home Performance with ENERGY STAR® Program" at http://www.gru.com/YourHome/Conservation/Energy/Rebates/homePerformance.jsp.

8. All electric utilities in the United States, its territories, and Puerto Rico are required to submit Form EIA-861 (Annual Electric Power Industry Report) each year to the U.S. Department of Energy, Energy Information Administration. It can be viewed/downloaded at http://www.eia.doe.gov/cneaf/electricity/forms/eia861/eia861.pdf. Instructions for completing the form, including details about how energy savings should be measured, can be viewed/downloaded at http://www.eia.doe.gov/cneaf/electricity/forms/eia861/eia861instr.pdf.

9. Due to data reliability and availability issues in 2007, these consumption data were not used in this study. Homes that were upgraded in 2007 were analyzed based on their metered consumption in years before (2006) and after (2008 and 2009) the upgrades.

References

Affordable Comfort Inc (2007), White Paper for July 2007 ACI Summit: "Moving Existing Homes Toward Carbon Neutrality", Waynesburg, PA, Affordable Comfort, Inc: 43, available at: http://www.affordablecomfort.org/images/Uploads/summit_white_paper_11_28_07_review_draftG.pdf.

Arimura, T., Newell, R., and Palmer, K. (2009). "Cost-Effectiveness of Electricity Energy Efficiency Programs", Resources for the Future, RFF DP 09-48.

Cannon, S., Vyas, U., Bedzek, R., Jewell, M., McCabe, M., Woods, J., Butters, F., and Del Percio, S. (2008). "Leadership Roundtable: Green Building: Balancing Fact and Fiction", *Real Estate Issues*, Vol. 33 no. 2, p. 1-12, available at: http://www.cre.org/publications/33_2.pdf.

Del Percio, S. (2009), "Henry Gifford & USGBC's Brendan Owens Consider Merits of LEED at NESEA Forum", *Green Real Estate Law Journal*, 13 Mar, available at: http://www.greenrealestatelaw.com/2009/03/nesea-forum-gifford-owens-usgbc/.

Dietz, T., Gardner, G., Gilligan, J., Stern, P., and Vandenbergh, M. (2009), "Household Actions Can Provide a Behavioral Wedge to Rapidly Reduce U.S. Carbon Emissions", *PNAS*, Vol. 106 no. 44, pp. 18452-18456.

DOE, (2008). "Energy Efficiency Trends in Residential and Commercial Buildings", Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, DC, available at: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/bt_stateindustry.pdf

EIA, (1999), "Electric Utility Demand-Side Management 1999", Energy Information Administration, U.S. Department of Energy, available at: (http://www.eia.doe.gov/cneaf/electricity/dsm99/dsm_sum99.html)

EIA, (2007). "Form EIA-861 Instructions. Annual Electric Power Industry Report", Energy Information Administration, U.S. Department of Energy, available at: http://www.eia.doe.gov/cneaf/electricity/forms/eia861/eia861instr.pdf. [Accessed April 31, 2010].

EIA, (2009). "Annual Energy Review 2008", Energy Information Administration, U.S. Department of Energy, available at: www.eia.doe.gov/emeu/aer/.

Gifford, H. (2008), "A Better Way to Rate Green Buildings", available at: http://www.energysavingscience.com/

Gillingham, K., Newell, R., and Palmer, K. (2006), "Energy Efficiency Policies: A Retrospective Examination", *Annu. Rev. Environ. Resour.* 31: 161-92.

Heins, S. (2006), "Energy Efficiency and the Specter of Free-Ridership: Is a Kilowatt Saved Really a Kilowatt Saved?", Feature Article, *Sustainable Facility*, available at: http://www.sustainablefacility.com/Articles/Feature_Article/aaf65d08bd629010VgnVCM100000f932a8c0____ [Accessed March 25, 2010].

Herring, H. (2006), "Confronting Jevons' Paradox: Does Promoting Energy Efficiency Save Energy", *International Association for Energy Economics Newsletter*, Vol. 15, 4th quarter, pp. 14-15.

Horowitz, M. (2007), "Changes in Electricity Demand in the United States from the 1970s to 2003:, *The Energy Journal*, Vol. 28, No. 3, pp.93-119.

Jones, P. and Vyas, U. (2008), "Energy Performance in Residential Green Developments: A Florida Case Study", *Real Estate Issues*, Vol. 33 no. 3, pp. 65-71, available at: http://www.cre.org/publications/33_3.pdf.

Lstiburek, J. (2008), "Prioritizing Green: It's the Energy Stupid", *Building Science Insights*, BSI-007, available at: http://www.buildingscience.com/documents/insights/bsi-007-prioritizing-green2014it-s-the-energy-stupid.

Malin, N. (2008), "Lies, Damn Lies, and...(Another Look at LEED Energy Efficiency)", *BuildingGreen.com*, available at: http://www.buildinggreen.com/live/index.cfm/2008/9/2/Lies-Damn-Lies-and-Are-LEED-Buildings-iLessi-Efficient-Than-Regular-Buildings.

McMahon, J., McNeil, M. *et al.* (2007), Chapter 9: Buildings. The First State of the Carbon Cycle Report (SOCCR). "The North American Carbon Budget and Implications for the Global Carbon Cycle", A. W. King, L. Dilling, G. P. Zimmerman *et al.* Asheville, NC, USA, National Oceanic and Atmospheric Administration, National Climatic Data Center: 95-102.

Meyer, B. (1995), "Natural and Quasi-Experiments in Economics", *JBES*, Vol. 13, no. 2, pp. 151-161.

Pacala, S. and Socolow, R. (2004), "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies", Special Section: Toward a Hydrogen Economy, *Science*, Vol. 305, no. 13, pp 968-972.

Parfomak, P. and Lave, L. (1996), "How Many Kilowatts are in a Negawatt? Verifying *Ex Post* Estimates of Utility Conservation Impacts at the Regional Level", *The Energy Journal*, Vol. 17, No. 4, pp.59-87.

Schiller, S. (2007), "Model Energy Efficiency Impact Program Evaluation Guide", National Action Plan for Energy Efficiency, prepared by Schiller Consulting, Inc., available at: www.epa.gov/eeactionplan.

Smith, M. and Jones, P. (2003), "The Impact of Energy Efficient House Construction on Homeownership Costs: a Comparative Study in Gainesville, Florida", *Family and Consumer Sciences J.*, AAFCS, Vol. 32, no. 1, pp. 76-97.

Stein, J. and Meier, A. (2000), "Accuracy of Home Energy Rating Systems", *Energy*, Vol. 25, no. 4, pp. 339-354, available at: http://dx.doi.org/10.1016/S0360-5442(99)00072-9.

UF UNIVERSITY of FLORIDA

IFAS Extension
Program for Resource Efficient Communities (PREC)

PO Box 110940
Gainesville, FL 32611-0940
352-392-5684
352-392-9033 Fax
www.buildgreen.ufl.edu

SBIR Research Project Facilitators Guide

Usability Test Introduction

Thank you for taking the time to participate in today's discussion on home performance. My name is Hal Knowles and I am a Research Associate at the UF Program for Resource Efficient Communities. You will each have a chance to introduce yourselves during the focus group discussion.

We'll begin our session by individually exploring a website in here for about the next 30 minutes followed by a more in-depth discussion in an adjoining conference room. Snacks and beverages will be available in this other room and the website will be projected on a screen for visual aid and reference as we move through our discussion.

Before we begin, let me review how this first portion will work:

- Website is in Beta
  - You are helping to troubleshoot and improve the website through iterative process
- Print out guides you through brief series of Scenarios and Tasks
  - Instructions are deliberately simplistic and open for interpretation
  - Provide an opportunity to explore the website features on your own terms
- Not a test
  - I will be observing how the site is being used
  - I can answer major questions, but would prefer you try to find your way through the site on your own
- Hoping for constructive feedback (both positive and negative)
  - Capture ideas as they occur
    - Use the headsets throughout the Scenarios and Tasks and "think out loud"
    - Brief keyword or short phrase style notes in the blank spaces and margins of your Scenarios guide
    - Keep notes simple and think of them as prompts for our focus group
  - Even basic errors are worth noting
  - Remember, think out loud!
- No outside distractions
  - Silence mobile phones
  - Remove watches and place them in your pocket if you believe you may be tempted to check the time

Website Use Scenarios (UF IRB-02 Protocol #2011-U-0003)

Purpose of These Scenarios: The Scenarios on the pages that follow will prompt you through a series of Tasks that will help you to explore a website. These Scenarios and Tasks are designed to help us evaluate the usability and relevance of this website for your personal and/or professional interests. More specifically, we hope to evaluate if the website achieves the following goals:

- Easy to learn
- Efficient to use
- Easy to remember functions and purposes of pages
- Low error rate and rapid recovery from errors
- Pleasant to use
- Adaptive to your unique user needs

As you work through these Tasks we ask that you "think out loud." In other words, while wearing the headset please speak freely and candidly about your user experience as you accomplish these Tasks. This may include positive or negative feedback about the website, your feelings as you explore it, errors that may present themselves, frustration if something is not intuitive, or any number of other thoughts that might arise as you play with the website.

Scenario 1 (Start: __________ | Stop: __________)

Scenario 1: You have become aware of the Gainesville Green website and determined that you would like to learn more about the service. Using your web browser, go to the following address and move through the tasks in alphabetical order:

http://staging.gainesville-green.com/

Task A: Search for the first home that comes to your mind. Look around the page for that home. Briefly get familiar with the information presented, but for now, do not click through to any other pages of the site.

Task B: In the space below, write down keywords or short phrases about your initial impressions of the website in your own words.

Scenario 2 (Start: __________ | Stop: __________)

__Scenario 2:__ You will be moving to Gainesville to accept a new job and you'd like to find a house that is energy efficient. A colleague at your new job the University of Florida mentions that an outreach team from the university collaborated with local builders on a few Energy Star homes in a subdivision named Madera Cluster Development Phase 1. Maybe that would be one place to begin your search! Conduct the tasks below in alphabetical order.

__Task A:__ Search for the Madera subdivision.

__Task B:__ Within Madera, find the home with the lowest overall electricity usage in the year 2010 as compared to other homes within only that subdivision.

__Task C:__ In the space below, write down the address and size of the home:

Address: ______________________________ | Size: _______________

__Task D:__ In the space below, write down the average monthly electricity consumption for this same home in the year 2010 overall:

Electricity (Amount): ______________________________ | (Units): _______________

__Task E:__ As you would like to find the best combination of home size and electricity consumption, now write down the average monthly electricity consumption for this same home in the year 2010 as adjusted for the size of the home:

Electricity (Amount): ______________________________ | (Units): _______________

Scenario 3 (Start: __________ | Stop: __________)

<u>Scenario 3:</u> In addition to finding an energy efficient home, you'd like to find one that either has a natural gas range or at least existing natural gas service so you can eventually upgrade for your favorite hobby…cooking! Starting where you left off from Scenario 2, conduct the tasks below in alphabetical order.

<u>Task A:</u> Determine if the same home from Scenario 2 will fit your needs and answer yes or no in the space below. Additionally, write down key words or a brief phrase describing how you can tell one way or the other?

Yes ☐ (or) No ☐

<u>Task B:</u> If the home from Scenario 2 does not meet your needs, find a natural gas serviced home in Madera with the lowest overall natural gas consumption in 2009. In the space below, write down the address and size of the home:

Address: ______________________________ | Size: _______________

<u>Task C:</u> In the space below, write down the approximate natural gas consumption from January 2009 for the home from Task B above:

Natural Gas (Amount): ______________________________ | (Units): _______________

<u>Task D:</u> In the space below, write down what type of natural gas appliances and/or systems this home from Tasks B & C above most likely has installed. What about the information on this page helped you to make your conclusion?

Scenario 4 (Start: __________ | Stop: __________)

<u>Scenario 4:</u> After going through Scenarios 2 and 3 above, you realize that comparing a home with both electricity and natural gas service to a home with only electricity service may complicate your search. Additionally, you'd like to see other options in the immediate area because you like the location. You decide to learn a bit more about how the homes are color coded so you can compare the Madera subdivision to another one across the street.

<u>Task A:</u> Find out how Gainesville Green calculates its rankings of homes. In the space below write the location (e.g., the name of a page) on the website where you found this information?

<u>Task B:</u> Compare the carbon footprint for the year 2010 for the homes in the Madera Cluster Development Phase 1 subdivision with the homes in the Idylwild Lane (Serenola) subdivision. In other words, only compare these two subdivisions with each other. In the space below, write down your immediate thoughts about what the color coded dot pattern of the homes in these two subdivisions means to you.

Scenario 5 (Start: __________ | Stop: __________)

Scenario 5: Now that you've explored some more hypothetical Scenarios, we'd like for you to undertake some tasks unique to you personally. As you conduct the tasks below in alphabetical order, think about how these comparisons may (or may not) be relevant to your personal and/or professional life.

Task A: Create a user account on Gainesville Green. (*Note: If you are already familiar with the website and have created an account in the past, please now log into that account*).

Task B: Claim your personal home. (*Note: If you are not a GRU customer or if your home does not appear in the Gainesville Green records you may claim the home from Scenario 2 for the purposes of this exercise*).

Task C: Create a new group of 5 homes of interest to you. Ideally, create this group using the home addresses of 5 close friends or colleagues with whom you feel you share common interests. Be sure to include your personal address in this group for a total of 6 homes in this new group. (*Note: These homes will need to be within the GRU service territory to appear in the Gainesville Green records*).

Task D: Add simple names to your group as well as the homes in your new group to make them easier to identify then always having to remember the addresses.

Task E: After you have created the group, go back to your personal home's information page. In the spaces below, write down your average monthly carbon footprint in 2010.

Your Home Carbon Footprint (Amount): ________ | (Units): ________

Task F: Compare your home's average monthly carbon footprint in 2010 to the average per month for all the homes within the physical subdivision within which your home is located. Make note of the percent difference between your average and the average from the other homes in your subdivision.

Subdivision Homes Carbon Footprint (Amount): ________ | (Units): ________ | (% Different) ________

Task G: Compare your home's average monthly carbon footprint in 2010 to the average per month for similar homes. Make note of the percent difference between your average and the average from the other similar homes.

Similar Homes Carbon Footprint (Amount): ________ | (Units): ________ | (% Different) ________

Task H: Compare your home's average monthly carbon footprint in 2010 to the average per month for all the homes within the personal group you just created in Task C above. Make note of the percent difference between your average and the average from the homes in your group of 5 friends or colleagues.

Group Homes Carbon Footprint (Amount): ________ | (Units): ________ | (% Different) ________

Task I: In the space below, write down keywords or short phrases about your thoughts on the relevance of these various comparison groups to you personally. Think about how the various group averages compared to your home. What do you think may be behind any differences in the comparisons?

Scenario 6 (Start: __________ | Stop: __________)

<u>Scenario 6:</u> To further help our researchers understand if this website is easy to use and provides relevant information, please conduct the following tasks in alphabetical order.

<u>Task A:</u> Evaluate any additional site tabs or links that have not already been covered by the previous Scenarios.

<u>Task B:</u> Go to the Feedback page. Remember back on all the tasks you have completed thus far. Did you notice any of the advertisements on any of the pages? Submit feedback on your perceptions about these advertisements (e.g., did you see them, are they relevant to the site, would you click through to any of them, etc.). (*Note: Use the feedback type named "UF Focus Group Feedback"*).

<u>Task C:</u> Submit one more additional feedback briefly highlighting how you feel the website could best integrate home energy efficiency improvement recommendations into the home energy reports in a tailored and personal fashion most relevant to your home's physical characteristics and your personal lifestyle. (*Note: Use the feedback type named "UF Focus Group Feedback"*).

Final Questions

1. Gender
    a. [ ] Female
    b. [ ] Male
2. Racial or ethnic background
    a. [ ] White/European
    b. [ ] Black/African American
    c. [ ] Hispanic/Latino
    d. [ ] Asian or Pacific Islander
    e. [ ] American Indian/Alaskan Native
    f. [ ] Other:____
3. What is your age? ____
4. What is your profession?
    a. Profession: ____________________________________ Title: ______________________________
    b. For how long? ____________________________________
5. What GRU utility services do you receive in your personal home? (Check all that apply)
    a. [ ] Electricity
    b. [ ] Natural gas
    c. [ ] Water
    d. [ ] Other: ____
6. Would you like to future correspondence from the project team? (Check all that apply)
    a. [ ] Announcements
    b. [ ] Additional research opportunities
    c. [ ] Learn more about new services & improvements
    d. [ ] Other: ____
    e. [ ] If yes to any of the above, please enter email: ____

Focus Group Introduction

Now that you've had a chance to explore the website a bit, I'd like to learn more about your experience with the website. Our discussion will begin with basic topics such as how the site is organized and what is working, or not working, about the site as a feedback tool. We will also touch on home performance issues at a larger scale and how this website addresses, or fails to address, some of these issues. That said, I am prepared to go in other interesting directions that you each may take the discussion. The focus of our discussion is on you, the user, and the unique needs you may have for a tool such as this website.

Before we begin our group discussion, let's agree on a few rules of engagement:

- Again, no outside distractions
- Active participation
    - May be prompted to talk
    - May be asked to move on
    - My role is to facilitate discussion…not necessarily to answer all questions or concerns
        - Afterward, I will debrief everyone at which time I can more completely answer questions
- Honest and open
    - Speak freely
    - No right or wrong answers
    - Feedback is anonymous
- Audio recorded
    - Loud clear voice
    - One at a time
    - Signal me if you'd like to add something but don't want to interrupt someone else
- Your role
    - By default, wear your industry/trade "hat"
    - I will clearly state if/when I'd like to hear perspectives from a different "hat" (e.g., as a homeowner)

How many of you have participated in a focus group before?

Do you have any questions before we begin?

Introductions around the room. Tell me your:

- Name, profession & title
- Duration of time practicing profession
- Favorite professional website or blog

Who has visited this website prior to today?

Describe how you came to learn about the site and how you may have used it prior to today?

Guide remaining semi-structured questions via Website Use Scenarios section.

Research Study Debriefing

At the conclusion of the focus group roundtable discussion, study debrief the participants about how the data collected from the study will be used, what they can do with this new information, and how they can continue to support our efforts should they so desire.

- Review how the study data will be used.
- Discuss how participants can translate this new information into action.
- Provide free "take-away" materials for participants, including the following:
    a. A one-page (front and back) quick reference guide for GRU energy efficiency rebates and programs. (Note: Donated by GRU)
    b. Two compact fluorescent light bulbs. (Note: Donated by GRU)
    c. Handbook –"Options for Clean Energy Financing Programs: Scalable Solutions for Florida's Local Governments." (Note: Donated by the University of Florida Program for Resource Efficient Communities)
        i. http://buildgreen.ufl.edu/FloridaGuide_order.pdf
- Ask participants if the research team may contact them again in the future should we desire additional feedback from ongoing website improvements and after their more long-term home use of the website.

FEDERAL FINANCIAL REPORT

(Follow form instructions)

1. Federal Agency and Organizational Element to Which Report is Submitted US Department of Energy Office of Science (SBIR)	2. Federal Grant or Other Identifying Number Assigned by Federal Agency (To report multiple grants, use FFR Attachment) DE-SC0004609	Page 1 of pages

3. Recipient Organization (Name and complete address including Zip code)
Accelerated Data Works, INC., 2831-A NW 41st Street, Gainesville, FL 32606-6690

4a. DUNS Number	4b. EIN	5. Recipient Account Number or Identifying Number (To report multiple grants, use FFR Attachment)	6. Report Type	7. Basis of Accounting
14375781	65-0765335		☐ Quarterly ☐ Semi-Annual ☐ Annual ☑ Final	☑ Cash ☐ Accrual

8. Project/Grant Period (Month, Day, Year)		9. Reporting Period End Date (Month, Day, Year)
From: 7/1/2010	To: 3/18/2011	3/18/2011

10. **Transactions**	Cumulative
(Use lines a-c for single or multiple grant reporting)	
Federal Cash (To report multiple grants, also use FFR Attachment):	
a. Cash Receipts	99588
b. Cash Disbursements	99588
c. Cash on Hand (line a minus b)	0
(Use lines d-o for single grant reporting)	
Federal Expenditures and Unobligated Balance:	
d. Total Federal funds authorized	99588
e. Federal share of expenditures	99588
f. Federal share of unliquidated obligations	0
g. Total Federal share (sum of lines e and f)	99588
h. Unobligated balance of Federal funds (line d minus g)	0
Recipient Share:	
i. Total recipient share required	79745
j. Recipient share of expenditures	90280
k. Remaining recipient share to be provided (line i minus j)	0
Program Income:	
l. Total Federal program income earned	5000
m. Program income expended in accordance with the deduction alternative	0
n. Program income expended in accordance with the addition alternative	5000
o. Unexpended program income (line l minus line m or line n)	0

11. Indirect Expense	a. Type	b. Rate	c. Period From	Period To	d. Base	e. Amount Charged	f. Federal Share
	Pre-Determined	94%	1/1/2009	12/31/2009	37481	35232	35172
				g. Totals:	37481	35232	35172

12. Remarks: Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation:

13. Certification: By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate, and the expenditures, disbursements and cash receipts are for the purposes and intent set forth in the award documents. I am aware that any false, fictitious, or fraudulent information may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)

a. Typed or Printed Name and Title of Authorized Certifying Official Brett C. Tambling, President of Operations	c. Telephone (Area code, number, and extension) 352-335-6500, x101 d. Email Address brett@acceleration.net
b. Signature of Authorized Certifying Official	e. Date Report Submitted (Month, Day, Year) 03/22/2011
	14. Agency use only:

Standard Form 425 - Revised 6/28/2010
OMB Approval Number: 0348-0061
Expiration Date: 10/31/2011