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Experimental and data collection methods for a large-scale smart grid deployment: Methods and first results

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ABSTRACT

This paper has two objectives: 1) to describe the experimental and data collection methods for a large-scale smart grid deployment in Austin, Texas, and 2) to provide results based on those data. As of October 2012, the test bed was comprised of 1) 250 homes concentrated in a single neighborhood all built after 2007, and 2) 160 homes distributed throughout Austin with ages ranging from 10 to 92 years old. This experiment includes 200 electric monitoring systems (15-s resolution), 211 electric monitoring systems (1-min), 182 gas meters (2-cubic foot), and 51 water meters (1 gallon) and many of the monitored homes also have energy audits and homeowner surveys. The test bed also includes 185 rooftop PV (photovoltaic) installations and 50 electric vehicles in the same neighborhood. Data streams were automated and gathered at a supercomputing facility at UT-Austin yielding 250 GB (2.95×10^9 records) of data in the first year. This paper describes the baseline study and monitoring methods, characterizes the study participants, and provides some first results about residential energy use. These results include a negative correlation between energy use and knowledge about energy as well as a possible positive correlation between energy use and some rebates.

1. Introduction

1.1. Motivation and brief history

The electric utility industry is rapidly changing, especially in the area generally called the “smart grid” [1]. While the definition of smart grid varies, it usually refers to the integration of information, sensors, meters, automated controls, distributed generation, resource storage, and many other technologies relevant to the distribution grid of utilities. Though there is much speculation about the future of the smart grid, there are few controlled experiments providing rigorous field data on the deployment of these technologies.

A multi-institutional smart grid demonstration project in Austin, Texas is filling this knowledge gap by gathering and analyzing novel datasets that have the potential to be valuable for grid planning and understanding how customers will interface with new devices, information, and price signals. The project includes partners from the utility, academic, business, and environmental sectors and seeks to perform an unprecedented level of monitoring and analysis of the technologies and behaviors that are relevant to

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the future of the electric industry. The project is a public-private partnership between Pecan Street Inc. (a non-profit research and development organization), The University of Texas at Austin (including the Cockrell School of Engineering and the Texas Advanced Computing Center), Austin Energy (the local municipal electric utility), the Austin Chamber of Commerce, Austin Water Utility, and the Environmental Defense Fund (a non-profit environmental advocacy group).

1.2. Introduction to the research projects

This manuscript covers two related research projects: the Smart Grid Demonstration Project at Mueller (Mueller project) funded by the U.S. Department of Energy and the National Science Foundation and the Home Energy Research Project (Duke project) funded by the Doris Duke Charitable Foundation. The Mueller project was originally funded through the ARRA (American Recovery and Reinvestment Act) as a smart grid demonstration project in Austin – 1 of 99 projects funded by the act. The homes that are part of the Mueller (pronounced "Miller") project are located on the site of Austin's former municipal airport, close to central Austin. The homes that are part of the Duke project are located throughout the greater Austin area.

The homes selected to take part in these research projects received monitoring equipment that captures electricity use on less than or equal to 1 min intervals for the whole home and 6 to 22 subcircuits and major appliances. A subset of homes also received natural gas and water use monitoring equipment that measure whole-home consumption in 2 cubic foot and 1 gallon increments, respectfully. Fig. 1 shows a cartoon schematic of monitored systems in a home. Monitoring systems were selected to be passive and nearly invisible in the home to minimize homeowner awareness and interaction, so that the collected data would offer an undistorted baseline representation of energy use.

Participants in the Duke and Mueller projects received a free home energy audit overseen by project researchers, and will receive, at the conclusion of the multi-year study, a confidential and detailed report on the energy usage of their home and its major circuits and appliances for each season of the year. The initial year-long monitoring phase of the Mueller project was completed in February 2012 and preliminary research related to the project has already been published [2–4]. To date, published research has centered on the home energy audits and residential surveys undertaken at the outset of the Duke project. This manuscript intends to serve as the seminal methods paper for the baseline phase and for all future work.

1.2.1. Mueller project

The Mueller redevelopment area is located at the former site of the Robert Mueller Municipal Airport (+30 17′ 47.66″, −97 41′ 55.83″) (see Fig. 2). The site contains 711 acres located approximately 1.5 miles from The University of Texas at Austin and 3 miles from downtown Austin. As of October 2012, the development had 750 single-family homes that were all built after 2007, and 643 apartments completed in 2011. The development is planned to eventually include 5700 households, comprised of single and multi-family units.

Planning for the Mueller Redevelopment Area (Mueller) began in 2000 [5], with construction beginning in 2007. Mueller was selected as the test bed for this research project because of its location, the relative uniformity of new homes, and the developer's requirement to build energy efficient homes and buildings. According to the website for Mueller, "Every single Mueller building, both residential, retail and commercial will meet standards for green building established by the Austin Energy Green Building Program and the U.S. Green Building Council's LEED certification" [6].

As of October 2012, 303 energy monitoring systems had been deployed in homes in Mueller. These homes are relatively new, most utilize gas for heating, and were built by a small number of builders. Also, 185 of the monitored homes have PV (photovoltaic) systems, totaling over 1.2 MW, which to the authors' knowledge is the highest residential PV density in the U.S. for retrofitted systems. A majority of these PV systems have both south and west facing arrays, the purpose of which will be discussed later in this manuscript. Over 70 homes within Mueller are expected to use EVs or PHEVs by 2013 (with Level 2 charging capability), again the highest residential concentration known to the authors in the U.S. As of October 2012, 50 homes had EVs or PHEVs.

1.2.2. Duke project

The Duke Project studies residential resource use in Austin's older housing stock, monitoring usage in homes more than 10 years

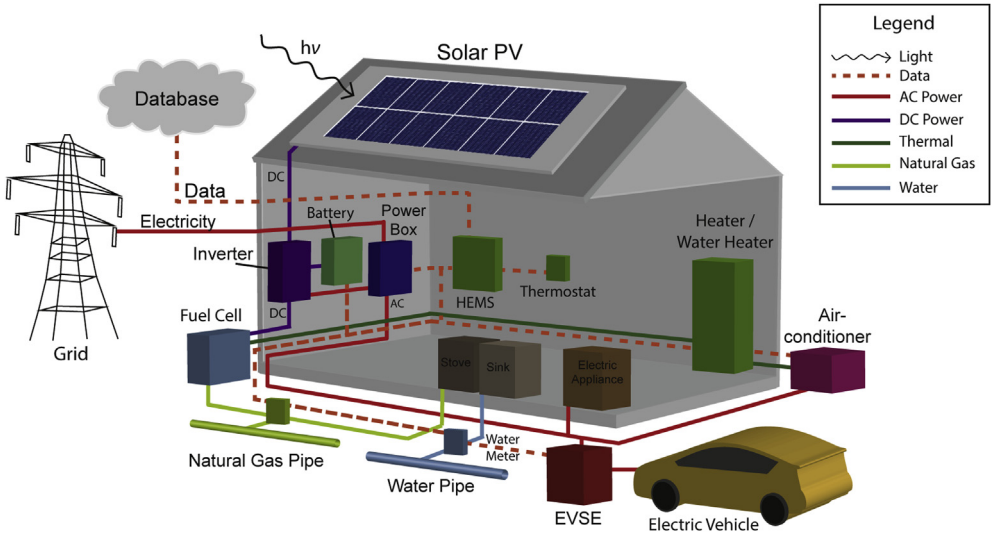

Fig. 1. A cartoon schematic of a house that is interacting with the electric, gas, and water grids in a dynamic way shows some of the flows and components. The information overlay allows for the HEMS (Home Energy Management Systems) to interact with all the appliances in the home, including large loads such as the air-conditioner and EVSE (electric vehicle supply equipment). Not every water, gas, or electric line is depicted.