May 2015 Progress Report

Unifying Home Asset & Operational Ratings: Adaptive Management via Open Data & Participation

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Description/Abstract: Recent environmental, social, and economic challenges are fostering a wave of interest in maximizing energy efficiency and conservation (EE+C) in existing U.S. homes. Long standing programs, ratings, and metrics are being reapplied into new stimulus initiatives such as the Recovery through Retrofit[1] program. Simultaneously, electric and gas utilities are expanding their demand side management (DSM) programs from weatherization and conventional technology replacement incentives to include conservation behavior campaigns with “recommendation algorithms” designed to assist in homeowner energy retrofit decision making. Furthermore, loan programs are emerging to address the financial barriers that commonly limit initiation of the necessary retrofits.

Collectively, these approaches most often project future home energy performance based on engineering models of the physical characteristics of homes (i.e., “asset ratings”). Yet to date, the marketplace is inadequately integrating historical household energy consumption patterns (i.e., “operational ratings”) into the decision tree to optimize retrofit program efficacy and consumer benefits. Moving toward the unification of asset and operational ratings is crucial for successful program management, proper monitoring/measurement/verification (MMV), loan risk assessment, and for the persistence of reduced home energy use over time. However, unification will not be easy. This research project combines qualitative and quantitative research methods in social science and building science using Florida case studies to evaluate the opportunities and constraints of asset and operational rating unification and the steps necessary to get there. Relationships between our project and the collaborative, transparent, and participatory nature of “open government” initiatives are also being explored.

The secondary supplemental research will expand on themes and insights gained through the first phase of this existing FESC project. Specifically, these insights suggest that even when adding operational data to building asset data, the reductionist approach to evaluating home energy performance by controlling for known variables may continue to offer an incomplete picture of the complexities of performance trends and the influence of unknown and/or misunderstood variables. Furthermore, the home improvement industry may need to consider the possibility that the magnitude of total energy consumption, while a worthwhile metric and with its net reduction a worthwhile goal, is also an incomplete indicator of home energy performance optimization.

Budget: Original = $24,000 over two years ($12,000 from 01/01/2011 to 12/31/2011 and $12,000 from 01/01/2012 to 12/31/2012). Supplemental = $32,000 over 18 months (from 04/01/2013 to 09/30/2014) to cover a portion of the salary (at a rate of $22.20/hour) and fringe benefits (at a rate of 26.9%) for Co-PI,

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[1] See, http://www.whitehouse.gov/assets/documents/Recovery_Through_Retrofit_Final_Report.pdf

Hal S. Knowles, III. This equates to 36% (14.6 hours, or effectively 2 weekdays) of this Co-PIs weekly salary and fringe for the 18 month period.

Universities: University of Florida, Queens College City University of New York

Summary of Progress Since October 2014

On March 10, 2015, Hal Knowles presented his research progress to date for the weekly UF School of Natural Resources and Environment (SNRE) Seminar for a group of students and faculty colleagues. A 5 minute summary presentation and associated poster for this progress to date has been submitted to the Florida Energy Systems Consortium (FESC) for inclusion in the 2015 FESC Workshop on May 20-21 in Orlando, Florida. The abstract for this conference submission offers a succinct summary for our research progress since October 2014. A full report of this research will be provided in the form of an October 2015 FESC Annual Report.

Presenter: Hal S. Knowles, III
Title**:** Home is Where the Heart is: Complexity, Pattern, & Meaning in Short Interval Residential Electric Smart Meter Data
Degree: Ph.D. Candidate in Interdisciplinary Ecology
Department: School of Natural Resources and Environment
Faculty Advisor: Dr. Mark Hostetler

Objectives: Since the 1970s, the major methods of home energy analysis have utilized linear-based engineering models of known building asset variables. While these methods provide useful feedback for the residential energy efficiency industry, their inputs and outputs are constrained by our limited knowledge of these variables and the associated flaws that may arise in our assumptions about their interaction. These constraints have shed light on the important role of occupant behavior on home energy consumption patterns. In response, an entirely new conservation behavior industry has grown around these knowledge gaps. Early attempts to integrate building asset and occupancy analyses suggest improved insights, as well as, new limitations to these linear models.

Are there ways for the home performance sector to accept and work with the inherent uncertainty in the interaction of these diverse and ever-changing building system and human behavioral variables? We believe there are and that the keys to these different, though complementary, ways of understanding may reside in the chaotic order of nonlinear dynamics and their application to the new data streams available through advanced metering infrastructure (AMI). Our FESC funded research evaluated the “complexity” of residential energy consumption patterns through the variability of their high-frequency electric meter readings over various time-series intervals.

Methods: Two data sets were analyzed: (1) 15-minute interval electric readings for approximately 350 homes and apartments in a random sample the JEA service territory of Jacksonville, Florida; and (2) hourly interval electric readings for 60 Florida homes in the Phased Deep Retrofits (PDR) program of the Building America – Partnership for Improved Residential Construction. First, normality testing was performed on the time series. Second, multifractal detrended fluctuation analysis (MFDFA) was performed on the original increments, shuffled surrogates, and phase randomized surrogates of these time series. Third, MFDFA was performed on the original and surrogate increments of various 15-minute interval weather time series and the disaggregated electric sub-meters of major home systems in the PDR (e.g., heat pump compressor, air handling unit, refrigerator, freezer, water heater, lighting circuit, home A/V system circuit, pool pump). Fourth, cluster analysis was used to segment and compare the multifractality of the homes and the weather.

Results: Home energy consumption is non-normal and non-stationary. The shape and magnitude of the MFDFA singularity spectra offer a proxy for the complexity of the house as a social-technological system with a mix of known and unknown variables. Sub-daily vs. supra-daily MFDFA singularity spectra suggest both weather and home energy consumption patterns may be driven by different dynamics within days versus across days.

Conclusions: Measuring complexity may provide new ways to differentially "diagnose" desirable and/or deviant electricity consumption patterns across nested scales from individual homes to entire utility grids. MFDFA and related nonlinear analyses of home energy consumptive use patterns may be useful in detecting under-performing homes, in diagnosing increased risk of building system failures, in improving smart grid supply and load balancing, and in evaluating the impacts of home energy improvements over time.

Appendix: A PDF format slide deck of the full March 10, 2015 presentation is attached herewith for supplementary details to this summary. Additionally, a 50 minute DVD with full video of the presentation will be sent to FESC via UF campus mail the first week of May 2015 in complement to the PDF slide deck.