



Stanford Sensor and Energy Behavior Initiative

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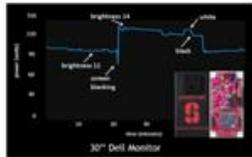
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<http://peec.stanford.edu/energybehavior>



Stanford Energy Behavior Initiative 

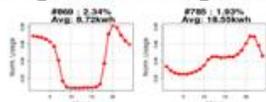
1. Communications network



2. Stanford platform

Category	Item	Description
Hardware	30" Dell Monitor	Energy monitoring device
Software	Stanford Platform	Energy management software
Services	Energy Audits	Professional energy audits
Partners	Energy Service Companies	Partners for energy efficiency improvements

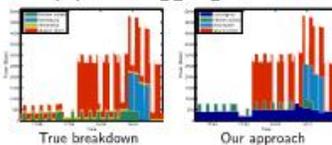
3. Segmentation algorithms



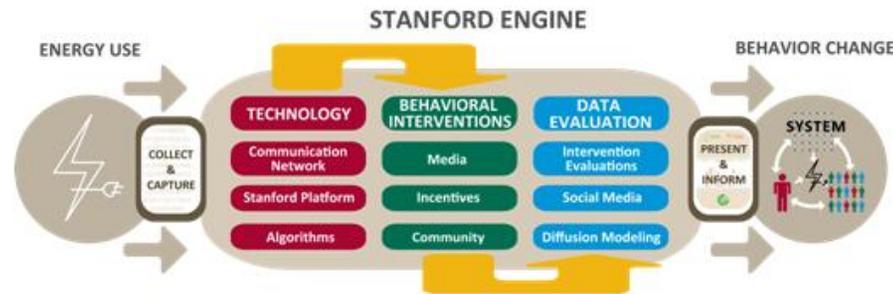
4. Learning & automation



5,6,7. Disaggregation



8,9. Target behaviors



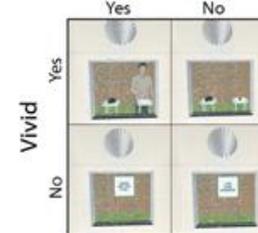
10. Social norms



11. Online game



12. Immersive reality



13. Facebook apps



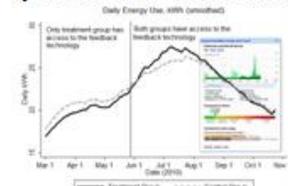
14. Appliance calculator



15. Raffle incentive



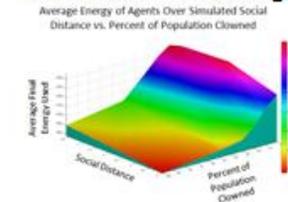
17. Google powermeter evaluation



18. Twitter explorer



19. Diffusion modeling



16. Community program



20. Integrative project

Proj. #	Project Name	Investigators & Partners	Deliverables (Publications for all projects can be found at http://peec.stanford.edu/energybehavior)
Technology			
1	Communication Network	– Levis, Kazandjieva (CS)	First, helped establish the first Internet standard for home area networks (HANs), which is being adopted by industrial consortia such as WirelessHART and ZigBee. Second, developed a wireless power plug meter that automatically joins a self-assembling, ad-hoc wireless mesh network; the deployed network of 200 meters allowed the team to publish detailed data at a scale orders of magnitude greater than other similar efforts, and is informing future energy standards for computing systems
2	Stanford Energy Services Platform (ESP)	– Armel, Reeves (PEEC) – Bonsai Development Corp.	Software platform that includes data collection services, a database, analytics, and graphical user interface templates for behavioral program deployment and experimentation at Stanford and beyond
Algorithms			
3	Segmentation Algorithms	– Fischer, Rajagopal, Albert, Kavousian (CEE) – Google, PG&E	Software to segment commercial and residential customers based on their smart meter data energy consumption patterns. This information can be strategically and cost-effectively used to target customers for energy savings; utility trial in planning phase
4	Learning and Automation	– Aghajan, Khalili, Chen (EE)	Software based on adaptive machine learning algorithms utilizing appliance and sensor data to improve TV and lighting automation on the dimensions of user activity, user preferences, and energy savings
5	Disaggregation Technical and Policy Survey Paper	– Armel (PEEC), Gupta, Shrimali, Albert – Bidgely, Venrock	Comprehensive survey paper assessing the benefits of disaggregation (i.e., the statistical separation of the whole building energy signal into appliance level energy use data), overview of state of the art algorithms and their performance, and smart meter data suitability for these algorithms; dissemination of findings through public forums and thousands of downloads
6	Residential Energy Disaggregation Dataset (REDD)	– Kolter, Chadwick, Armel, Flora (CS, PEEC) – Enmetric	Data set collected and made available for developers to improve, train, and test disaggregation algorithms; extensively used.
7	Disaggregation Algorithms	– Ng, Kolter (CS)	Disaggregation algorithms were developed using sparse coding methods to advance the state of the art

Behavioral Interventions			
Target Behaviors			
8	Energy Behavior Taxonomy	– Flora, Boudet, Roumpani, Armel (PEEC)	Database of 250 energy saving actions, their attributes and impact, and barriers. Implementation in Bidgely Inc.'s online recommendation system
9	Identification of Innovative Energy Behaviors	– Armel, Cornelius, Ardoin, Plano, Bridgeland, Morton, Chang, Allen (PEEC)	Opportunity map identifying energy reducing practices and technical insights from other cultures and time periods, quantifying their potential energy saving impacts across U.S. climate zones, if adapted for developed nations
Media Interventions			
10	Social Norms	– Walton, Sparkman, Clark, Paunesku, Armel, Luo, Flora (Psy) – Home Energy Analytics, City of Mountain View	Web application that helps consumers track energy use and receive tips; 800+ users, embedded experiments showed the effectiveness of thematically organized tips and collective action framing
11	Online Game	– Reeves, Cummings, Scarborough (Comm) – Kuma Games	Online game utilizing real world energy data, social competition, and retraining of habits through reinforcement ; laboratory and field studies suggested changes in energy saving behaviors and consumption.
12	Immersive Reality	– Bailenson, Bailey, Flora, Armel, Voelker, Reeves (Comm) – DraftFCB	Experimental evaluation of the utility of an immersive virtual environment in promoting energy saving behaviors, with results suggesting that vivid visualizations of energy consumption (e.g., amount of coal instead of KWh) may be more important than the personalization afforded by avatars.
13	Facebook Applications	– Banerjee, Flora, Sahoo, Bhansali, Greenspan, Khakwana, Liptsey-Rahe, Madres, Manley, Omer, Rajendra, Scalamnini, Wong, Stehly, Voelker (ME/Design)	Three Facebook applications to motivate energy reductions and online experimental evaluations of these

Policy Interventions			
14	Appliance Calculator	– McClure, Houde, Armel (Psy)	Online appliance calculator application; 60,000 users via Google Ads, embedded experiments evaluated the effectiveness of information and framing tools for guiding the purchase of energy efficient appliances and electronics, e.g., selection of 10-20% more energy efficient refrigerators from default sort order (manipulations informed in part by a study with Sears)
15	Raffle Incentive	– Prabhakar, Merugu, Pluntke, Gomes, D. Mandayam, Yue, Atikoglu, Albert, Fukumoto, Liu, Wischik, Rama (EE) – National University of Singapore, Land Transport Authority of Singapore	Online software developed for a raffle-like incentive program to motivate energy savings; 21,000 users, ~10% of trips were shifted off peak to reduce congestion and associated fuel waste
Community Intervention			
16	Community Program	– Robinson, Ardoin, Boudet, Flora, Armel (School of Med & Education) – Girl Scouts, People Power	Girl Scout “GLEE” curricula; 30 troop study, showed significant changes in self-reported home energy saving actions for both girls and their parents
Data Evaluation and Modeling			
17	Google Powermeter Evaluation	– Houde, Sudarshan, Todd, Flora, Armel (MS&E) – Google	Field trial and evaluation of Google PowerMeter impact using analysis tools from economics; 1000+ participants, 6% energy savings in the first two months (much longer persistence has been reported in other studies with different conditions). The study provides a benchmark, and illustrates experimental and analysis methods
18	Twitter Explorer	– Russell, Rubens, Flora (Comm) – University of Electro-Communications, Tokyo	Twitter Explorer, a software tool for collecting all tweets containing any of ~150 energy or climate change words, as well as an analysis of the online social “conversation” about energy efficiency for over a year of data
19	Diffusion Modeling	– Shrager (Symbolic Systems)	Simulation tool to predict diffusion in behavioral interventions based on parameters such as time, behavioral technique used, and social network distance and type. More sophisticated tools could eventually lessen time and cost of developing interventions