Sociotechnical Systems to Enable Smart & Connected Energy-Aware Residential Communities #1737591 (IRG – 1, FY2017)

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Communities Partners : Garry Hobbs (BWI), Jacob Sipe (IHCDA), Evan Thie (NAHA), Alex Bazan (CoSB)

Project Challenge

Challenge

High energy burden for low-income communities

ihcda — *Launches **Moving Forward program***

BWI — *Builds sustainable **housing communities***

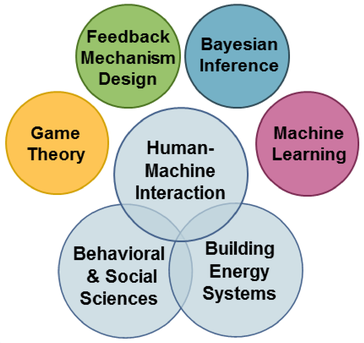
PURDUE UNIVERSITY — *Conducts **sociotechnical** research*

Vision

Develop new S&C technology to engage residents in understanding and reducing their home energy use while increasing their environmental awareness and improving their quality of life.

Intellectual Merit

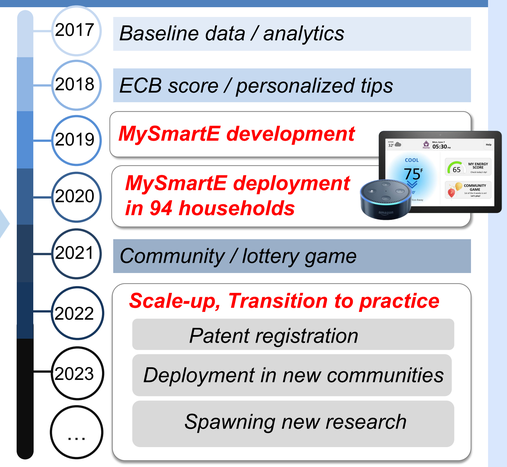
Integrative research



Fundamental advances

- ***Physics-informed machine learning for energy model identification***
- ***Learning and normative energy-feedback***
- ***Social game and mechanism design***
- ***Human decision modeling***

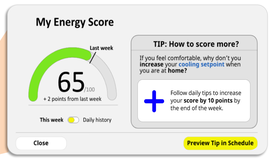
Milestones



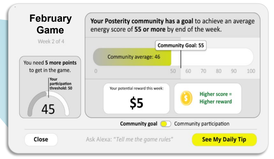
Major Outcomes

Technological Innovations

MySmartE App



Personalized eco-feedback



Collaborative community game

Non-provisional Patent (2023-KARA-69985-02)

- *Novel energy conservation behavior score*
- *Algorithm for delivering personalized actionable recommendations*
- *Energy game for a multitude of households with social proof information*

Industry partners

Purdue OTC

- Product licensing
- Start-up venture

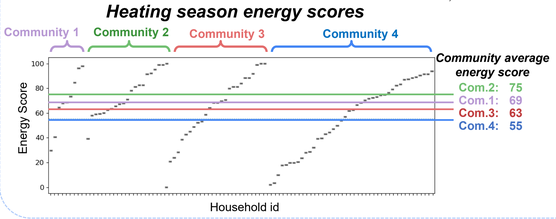
- Smart Home Hub Vendors
- HVAC
- Controls & IoT
- utility providers

Scaling Up & Community Engagement

Pilot communities across IN

- 250 Households
- 7 Locations
- 8 Construction types (single-family/multi-unit, new/old/retrofitted, heating/cooling type, etc)
- Different population demographics (low-/moderate-income, workforce)

Heating season energy scores



Bringing together diverse community stakeholders

- **Housing authorities/agencies**: IHCDA, FWHA, BHA, HASB, HANA,
- **Municipalities**: CoSB, CoIN
- **Utility providers/associations**: NPPD, TipMont REMC, IEA
- **Housing developers**: BWI, NRP
- **Community action groups**: INCAA, OVO
- **Resident community advocate groups**: BIC, JBNC, Flanner House
- **Non-profit organizations**: Hoosier Uplands
- **Real Estate**: TM1 Properties

What they liked:

- ❑ Resident engagement app (ECB metric, gamification, social proof)

Needs

- ❑ Data-sharing framework
- ❑ Systematic solution for evaluating behavioral changes and impact of MySmartE

Scalability Research

Community decision preference learning

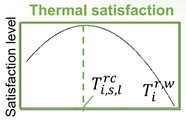
Household decision-model

❑ **Decision variables:** $T_i^{r,w}$ (*room air temperature*)

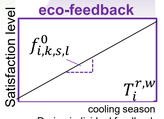
$$U_{i,s,l}^{H}(T_i^{r,w}) = U_{i,s,l}^{C}(T_i^{r,w}) + U_{i,s,l}^{IF}(T_i^{r,w}) + U_{i,s}^{CG}(T_i^{r,w}) + U_{i,s}^{LT}(T_i^{r,w})$$

s: season
l: weather intensity

Thermal satisfaction



Personalized eco-feedback



Collaborative social game

$\gamma_{i,s}^{0} \cdot I \cdot (\alpha_i^w / \alpha_{min}^w)(\bar{\alpha}^w - \alpha_{goal}^w)$

Reward — Threshold achievement — Goal achievement

Competitive lottery game

$\chi_{i,s}^{0} \cdot I \cdot p_i(t_i^w)$

Reward — Probability of winning

$U_{i,s,l}^{IF}$, $U_{i,s}^{CG}$, and $U_{i,s}^{LT}$ exists depending on the experiment type

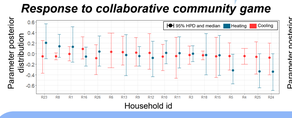
Utility maximization

$$T_i^{r,w*} = \arg\max_{T_i^{r,w}} U_{i,s,l}^{H}(T_i^{r,w})$$

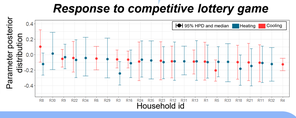
Hierarchical Bayesian model calibration

Parameter learning

Response to collaborative community game



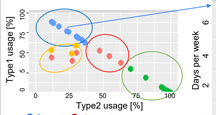
Response to competitive lottery game



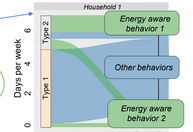
Community decision preference learning

Behavioral analysis

Classification of MySmartE interactions



Energy-aware interactions



Impact evaluation metric

- Energy burden
- Energy Equity
- Economic development

Broader Impact

- Develop new smart home energy management system that works with a tablet and Amazon Alexa.
- Empower affordable housing residents with smart technology to reduce their energy bills.
- Enable government (cities/states, housing authorities) and industry stakeholders (community developers, utility providers) to design and monitor new energy efficiency programs.

Future Goal

Translation into practice

Community

Housing agencies/municipalities
- Program monitoring and resident education

Housing real estate
- Energy savings and interventions for portfolio management

Industry partners

Smart Home Ecosystem (HVAC/Controls/IoT)
- Behavioral and hardware data streaming
- Data pattern analysis

Utility companies
- Behavioral energy efficiency and demand response programs

What's Next

Deployment Across the U.S – National model

Translation into Practice