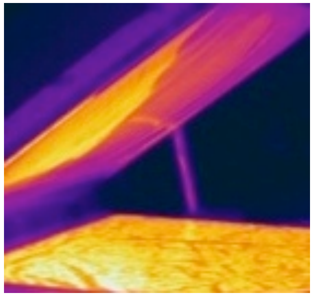
Using Communicating Thermostats to Automate, Customize, and Scale Home Energy Assessments



Better Buildings Summit

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- Fraunhofer Team:
  - Co-PI Michael Zeifman, Ph.D.
  - Amin Lazrak, Ph.D.
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  - Joana Abreu
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Project Motivation

- Space heating is the largest end use for homes in cold/very-cold climates
- Homes with poor/no insulation or inefficient heating systems have higher heating energy consumption
  - ~20-25 percent of homes
- Wall and/or attic insulation, air sealing, and HVAC system upgrades can significantly reduce space heating energy consumption
- Programs face high customer acquisition costs
- Slow market uptake of these proven measures
  - <1% of households/year in Massachusetts

Sources: DeMark Home Ontario. S. Edwards-Musa, Eversource Energy.

Project Objectives and Benefits

Project Objective: Develop a tool for utility energy efficiency (EE) programs that analyzes communicating thermostat (CT) data to automatically identify and quantify the benefit of targeted and customized retrofit opportunities

Customer and Utility Benefits:

- Increase the uptake of home energy assessments
- Increase deployment rate of the target energy conservation measures (ECMs)
- Decrease the cost of EE programs via targeting
- Reduce retrofit performance risks using home-level remote EM&V
- Increase customer engagement
- Increase the value proposition for CTs – projected ~25MM installed circa 2019

Ultimate Vision: CTs deployed in most homes identify high-impact opportunities to reduce HVAC energy consumption *and* ensure retrofit performance

Source: ACHRNews (2015).

Project Impact

Basic ECMs identified have significant energy savings potentials:

- Condensing Furnace or Boiler Retrofit: $165/year (avg. Mass. home)
- Attic and Wall Insulation: $165/year
- Air Sealing: $50-165/year
- *National Impact*: Consumer savings of **$4-5 billion per year**

Further savings from space cooling savings and deeper retrofits

Sources: DOE BTO (2012), Massachusetts TRM (2013), DOE/EIA (2017), DOE Building America (2010).

CTs provide insight into a home's thermal response.

What is actually happening:

Date	Time	System Setting	System Mode	Calendar Event	Program Mode	Cool Set Temp (F)	Heat Set Temp (F)	Current Temp (F)	Current Humidity (%RH)	Outdoor Temp (F)	Wind Speed (km/h)	Cool Stage 1 (sec)	Heat Stage 1 (sec)	Fan (sec)
3/29/2016	0:00:00	auto	heatOff		Sleep	82	63	70	39	43.8	16	0	0	0
3/29/2016	0:05:00	auto	heatOff		Sleep	82	63	69.9	39	43.8	16	0	0	0
3/29/2016	0:10:00	auto	heatOff		Sleep	82	63	69.8	40	43.8	16	0	0	0
3/29/2016	0:15:00	auto	heatOff		Sleep	82	63	69.8	40	43.8	16	0	0	0
3/29/2016	0:20:00	auto	heatOff		Sleep	82	63	69.8	40	43.8	16	0	0	0
3/29/2016	0:25:00	auto	heatOff		Sleep	82	63	69.7	40	43.8	16	0	0	0
3/29/2016	0:30:00	auto	heatOff		Sleep	82	63	69.6	40	42.7	22	0	0	0
3/29/2016	0:35:00	auto	heatOff		Sleep	82	63	69.4	40	42.7	22	0	0	0
3/29/2016	0:40:00	auto	heatOff		Sleep	82	63	69.3	40	42.7	22	0	0	0
3/29/2016	0:45:00	auto	heatOff		Sleep	82	63	69.1	40	42.7	22	0	0	0
3/29/2016	0:50:00	auto	heatOff		Sleep	82	63	69	40	42.7	22	0	0	0
3/29/2016	0:55:00	auto	heatOff		Sleep	82	63	68.9	40	42.7	22	0	0	0
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3/29/2016	1:20:00	auto	heatOff		Sleep	82	63	68.6	40	42.7	22	0	0	0
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3/29/2016	1:30:00	auto	heatOff		Sleep	82	63	68.5	40	42.6	19	0	0	0
3/29/2016	1:35:00	auto	heatOff		Sleep	82	63	68.4	40	42.6	19	0	0	0
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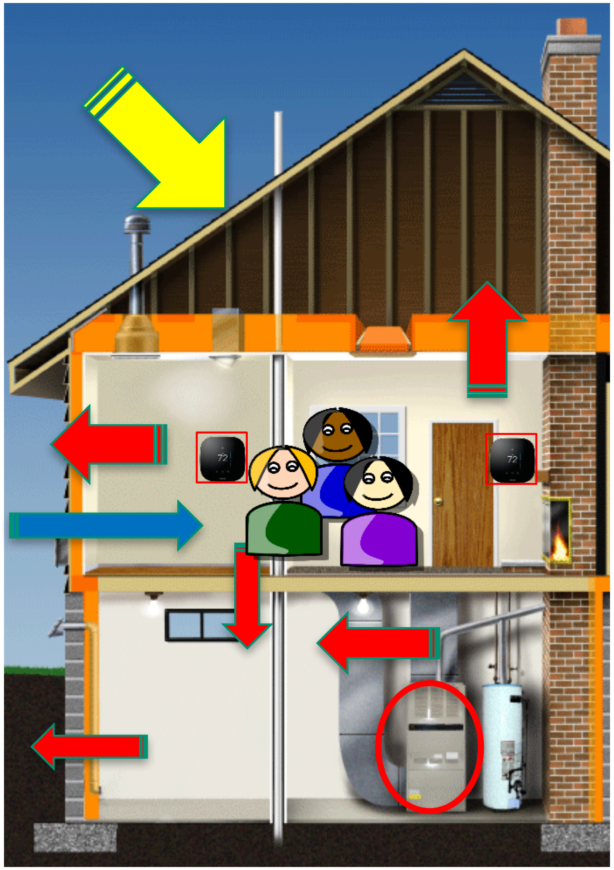
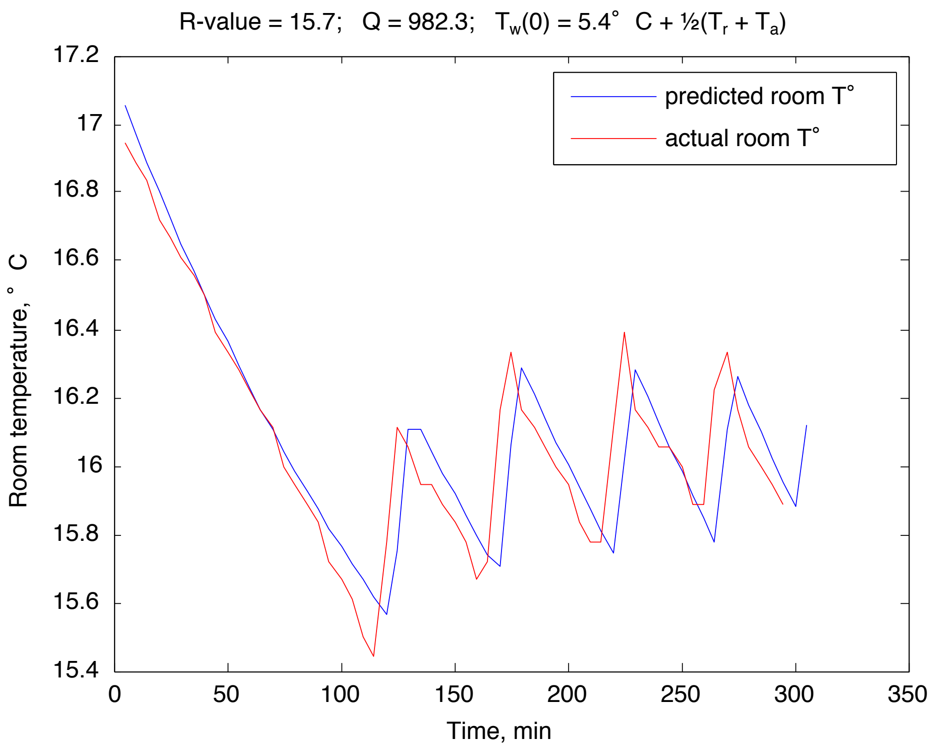
3/29/2016	1:45:00	auto	heatOff		Sleep	82	63	68.3	40	42.6	19	0	0	0
3/29/2016	1:50:00	auto	heatOff		Sleep	82	63	68.2	40	42.6	19	0	0	0
3/29/2016	1:55:00	auto	heatOff		Sleep	82	63	68.2	41	42.6	19	0	0	0
3/29/2016	2:00:00	auto	heatOff		Sleep	82	63	68.1	41	42.6	19	0	0	0

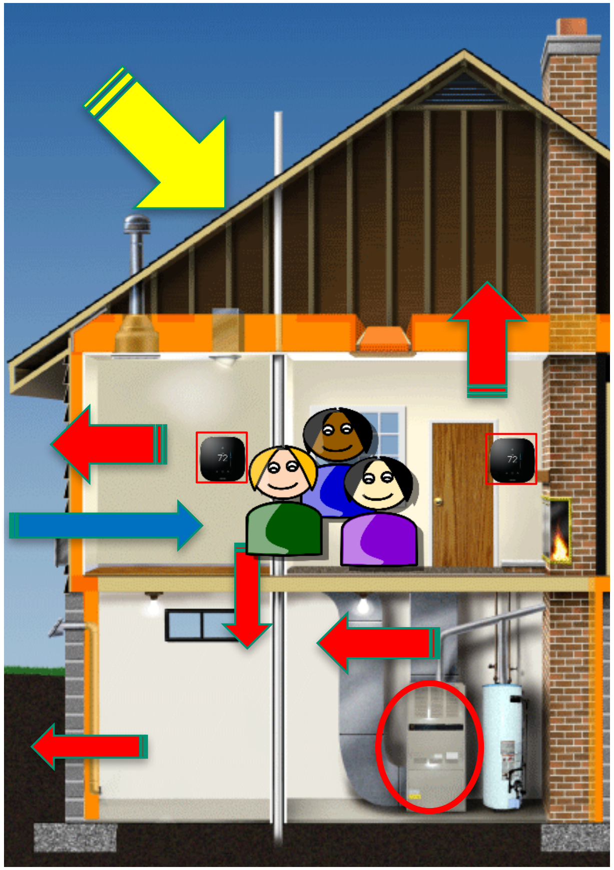


Sources: DOE, Ecobee, Fraunhofer CSE, Wikimedia Commons.

A home's thermal response reflects its characteristics.

Example of building parameter estimation by curve fitting using CT data from a single night





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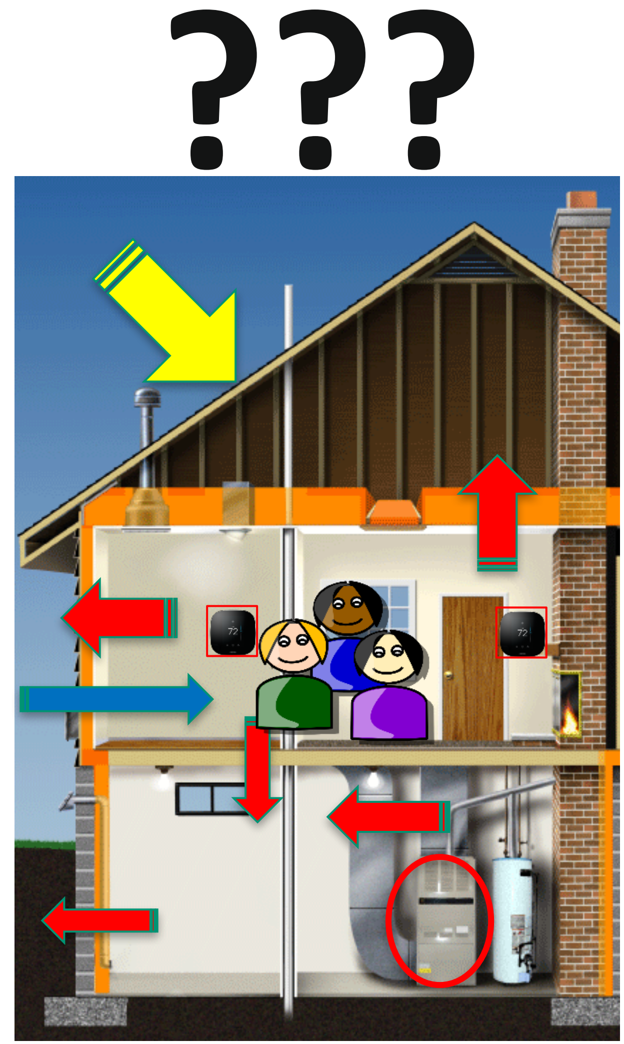
Key Challenges

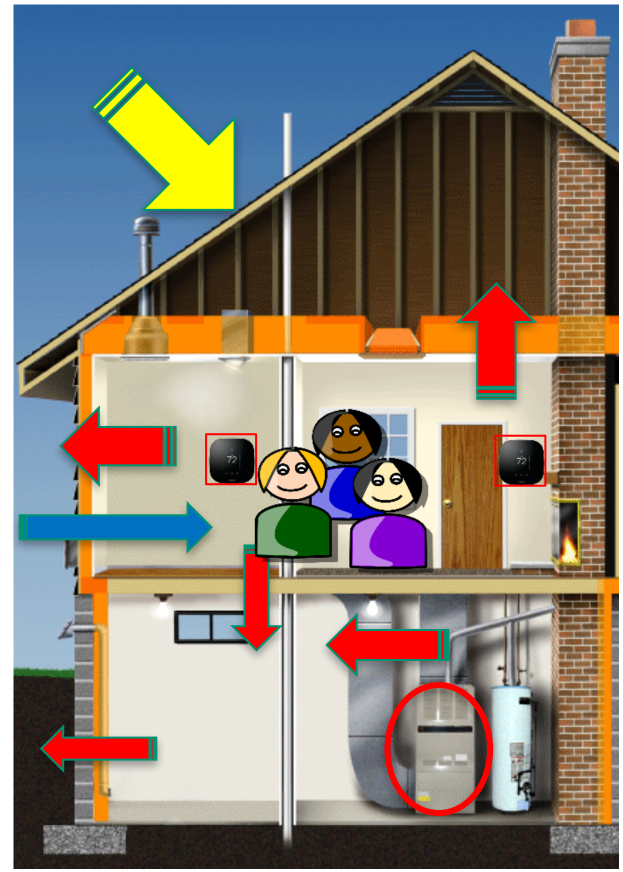


- Different physical parameters can create similar building thermal responses
- Different HVAC systems have different response times and characteristics
- Many homes have multiple CTs
- Thermal response “noise” from internal heat gains

Sources: DOE, Ecobee, Wikimedia Commons.

Project Approach: Overview

Analyze *real-world CT, interval, and home energy audit data* to successively refine home thermal response models to *accurately estimate home physical parameters* that correspond to the target ECMs *in increasingly complex situations*.



Sources: DOE, Ecobee, Wikimedia Commons.

Project Approach: Technical

Basic Approach:

1. Energy balances on the enclosure and indoor air
2. Fit real-world CT data sets to gray-box thermal models to determine the physical parameters
3. Compare physical parameters to thresholds indicative of retrofit opportunity

Approach to Overcoming the Technical Challenges: Data, Data, and More Data

Superior data quality and quantity enables a ***hybrid gray-box thermal modeling and machine-learning approach*** to develop and train algorithms

- CT and Home Energy Audit data for several hundred + homes
- Deep "ground truth" data from 80 homes with CTs
  - Home energy audit with blower door testing
  - Interval gas (hourly) and electric (5-minute) data

Source: Clearmeadows Community Association, DOE.

Scaling for Impact

1. Project Team: Two leading IOUs and innovative muni
   - Leverages data from existing CT programs
2. Project integrates randomized controlled trial (RCT) to validate key hypothesis of project:
3. Do targeted outreach and customized EE offers double the uptake of home energy audits and targeted ECMs?
4. Project Deliverables to Scale Impact
   - CT Data Specification
   - Best Practices Guide for EE Program Integration
   - Project completion in 2019
5. Near-term Outcome: Integrate with Eversource and National Grid EE programs
6. Target Future Outcomes:
   - CT data specification adopted by other utilities, EE programs, and EnergyStar
   - CT analytics used by other EE programs

Conclusions and Future Plans

Conclusions – Leverage data from HEMS technology to:

- Identify high-impact retrofits for largest residential end use
- Create customized retrofit offerings for individual homes to increase demand
- Validate retrofit performance
- Scale using through leading utility EE programs

Potential Extensions of Approach

- Expand to space heating with heat pumps
- Expand to space cooling applications
  - Deeper integration of electric interval data

Learn More:

- "Communicating Thermostats as a Tool for Home Energy Performance Assessment" – *Proc. 2017 IEEE Intl. Conf. on Consumer Electronics (ICCE).* Jan.
  - See: https://edas.info/p22259 .

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