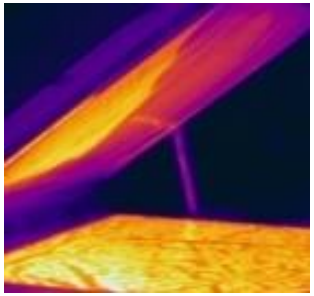
Using Communicating Thermostat Data to Automate and Scale Home Energy Performance Evaluations



EPRI Smart Thermostats and Customer Connected Devices Workshop

Session 3: Data Analytics from Connected Devices—Are the Benefits Worth the Cost?

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Motivation

- Space heating is the largest end use for homes in cold/very-cold climates
- Homes with poor/no insulation and/or high air leakage have higher heating energy consumption
- Programs face high customer acquisition costs
  - Pending LED “cliff” for home energy assessments
- Slower market uptake of these proven measures
  - Approximately <1% of households/year in Massachusetts

Sources: DeMark Home Ontario, DOE/PNNL, Mass RASS, DOE/EIA.

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Project Objectives

Develop a tool for utility EE programs that **analyzes communicating thermostat (CT) data** to **automatically identify** and **quantify the benefit** of **targeted outreach** identifying **customer-specific retrofit opportunities.**

Customer and Utility Benefits:

- Increase uptake of insulation and air sealing retrofits
- Decrease the cost of EE programs via targeting
- Reduce retrofit performance risks using remote EM&V
- Increase customer engagement

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

Technical Approach: Fitting CT data to a second-order grey-box model to estimate building physical parameters

$$C_r \frac{dT_r}{dt} = Q_{HVAC} + q_{int} + A_w/(R_w/2)(T_w - T_r) + q_{inf}$$ (indoor energy balance)

$$C_w \frac{dT_w}{dt} = A_w/(R_w/2)(T_r - T_w) + A_w/(R_w/2)(T_a - T_w) + q_{ext}$$ (enclosure energy balance)

$$q_{inf} = -\rho_{air} c_{p,air} (C_1 W^{2.6} + C_2 |T_a - T_r|^{1.3})^{0.5} (T_r - T_a)$$ (from I. Walker)

- *[green] = known, [red] = prediction needed for home assessment*
- T_r, T_w, T_a = indoor, wall and outdoor temperatures
- R_w and A_w = overall R-value and area of building envelope
- C_w and C_r = overall heat capacitance of the walls/internal space (=external/internal thermal mass)
- Q_{HVAC} = HVAC heat supply
- q_{int}/q_{ext}/q_{inf} = internal/external heat gains /infiltration heat loss
- W = wind speed

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We fit CT data to a model for each home's thermal response – this can be challenging!

???

- Ill-posed problem, i.e., different physical parameters can create similar building thermal responses
  - Separating conduction and infiltration
- Different HVAC systems have different response times and characteristics
- CT = point measurement of one zone
- Many homes have multiple CTs
- Thermal response "noise" from internal heat gains
- Varying CT data among vendors

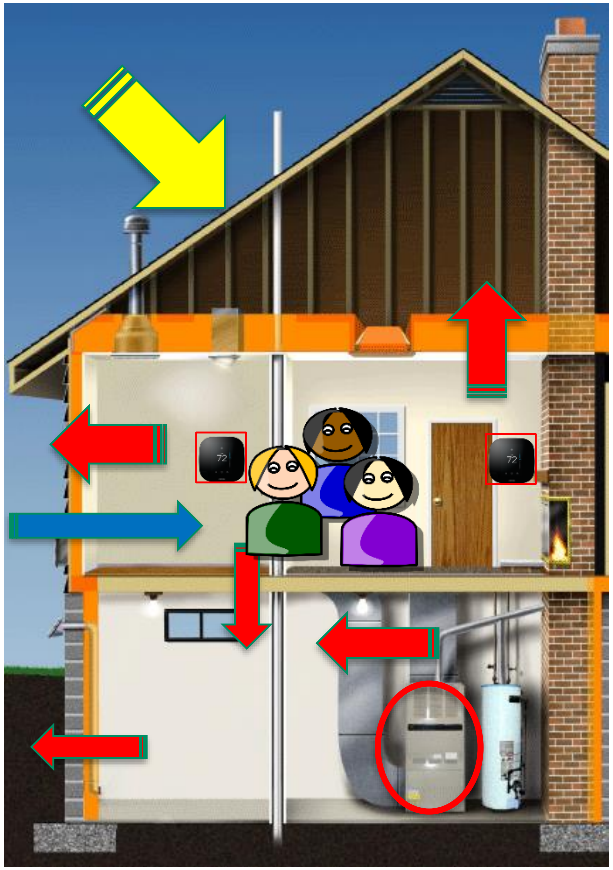

Image Source: DOE, ecobee.

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Field Data Collection

- Received complete data sets for >600 homes
  - Model Inputs:
    - CT data for at least one winter season
    - Gas bill data for 1+ year (coincides w/ CT data)
    - Home floorspace and number of stories
    - ZIP code
  - Ground Truth:
    - Home energy assessment data
    - Measures implemented (if any)

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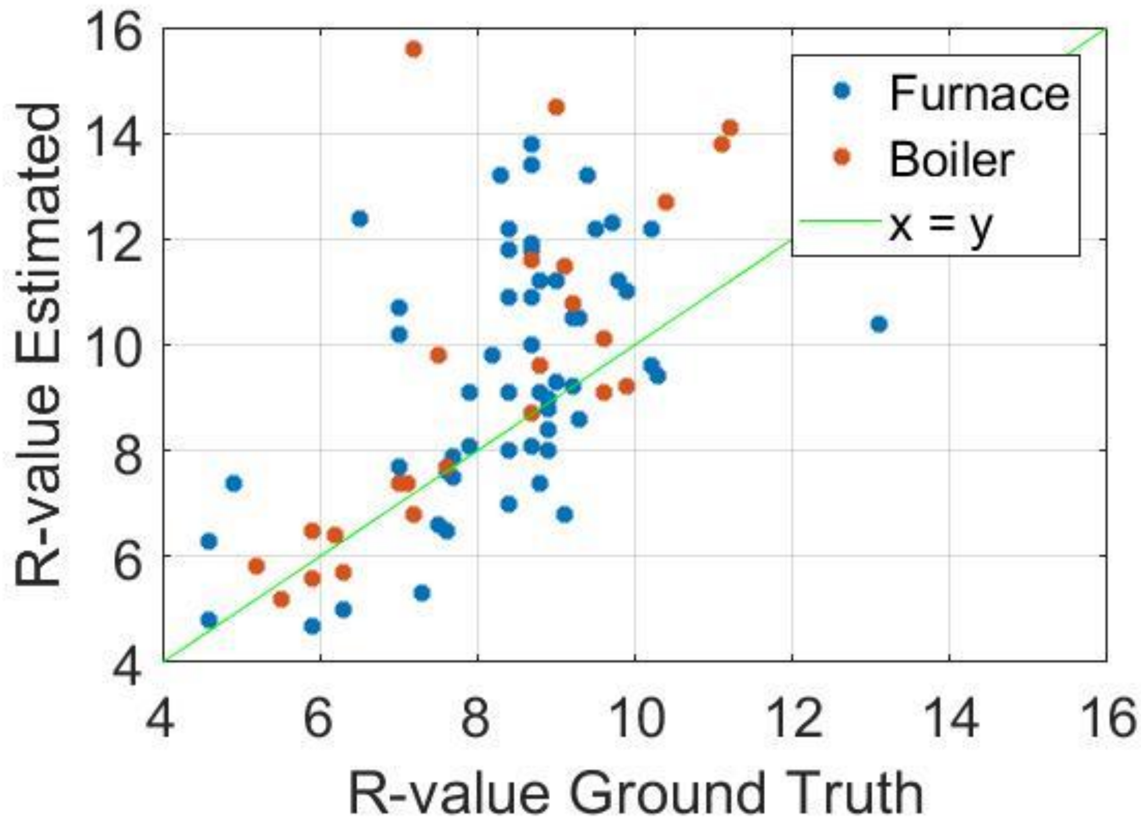
nationalgrid

CT Provider	# Homes	Furnaces (Condensing)	Boilers (Condensing)
#1	366	125 (53)	192 (14)
#2	41	27 (12)	10 (1)
#3	232	148 (77)	53 (4)

Results for homes with one CT:

The algorithms effectively identify homes with insulation retrofit opportunities, for both furnaces and boilers.



Classification Accuracy (R>8 or ≤8) = 88%

n = 87

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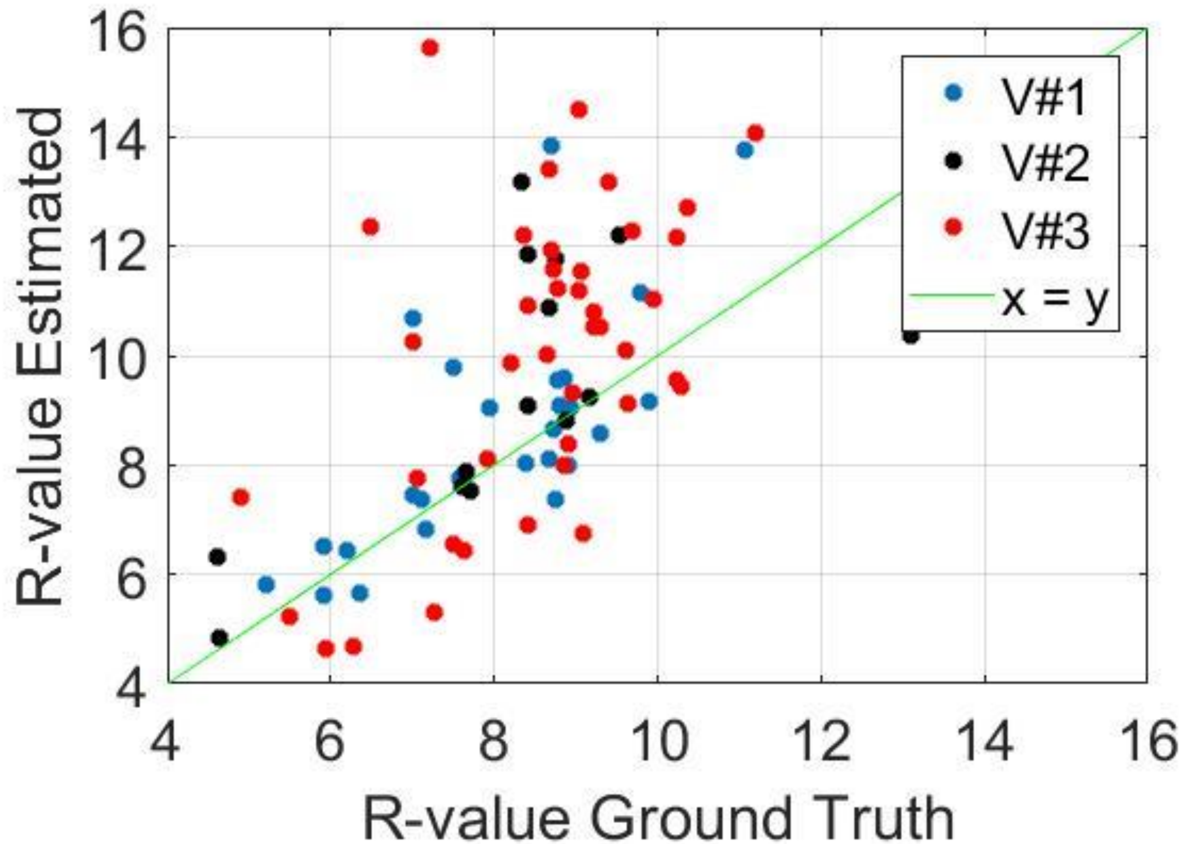
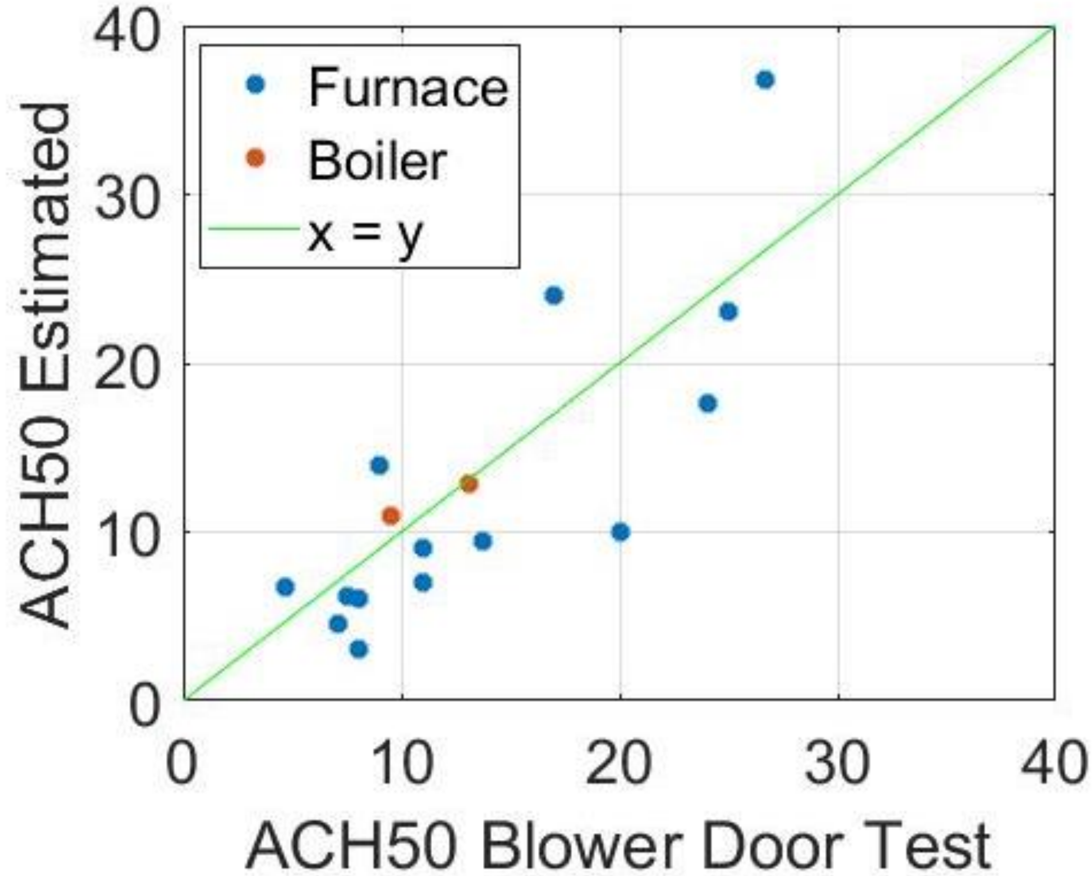
Classification accuracy does not appear to vary with CT vendor.



The algorithm accurately classifies ACH_{50}.



n = 16

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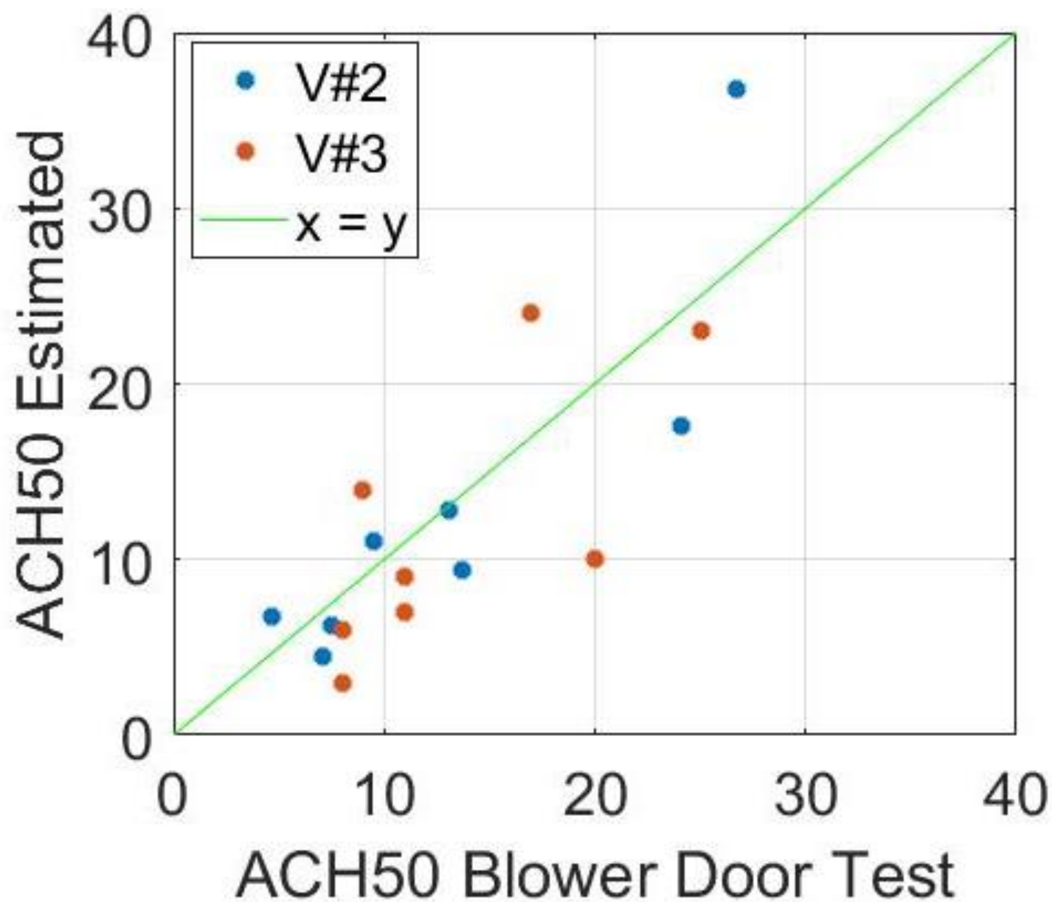
ACH_{50} accuracy does not appear to vary with CT vendor.



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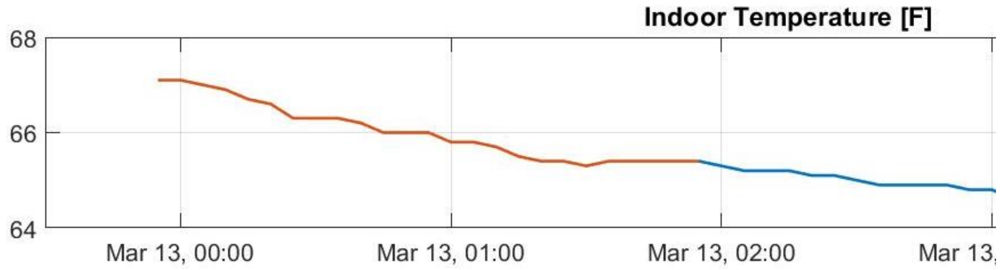
Time Constant Approach proposed by VEIC, Cornell



T_a = 14-16°F

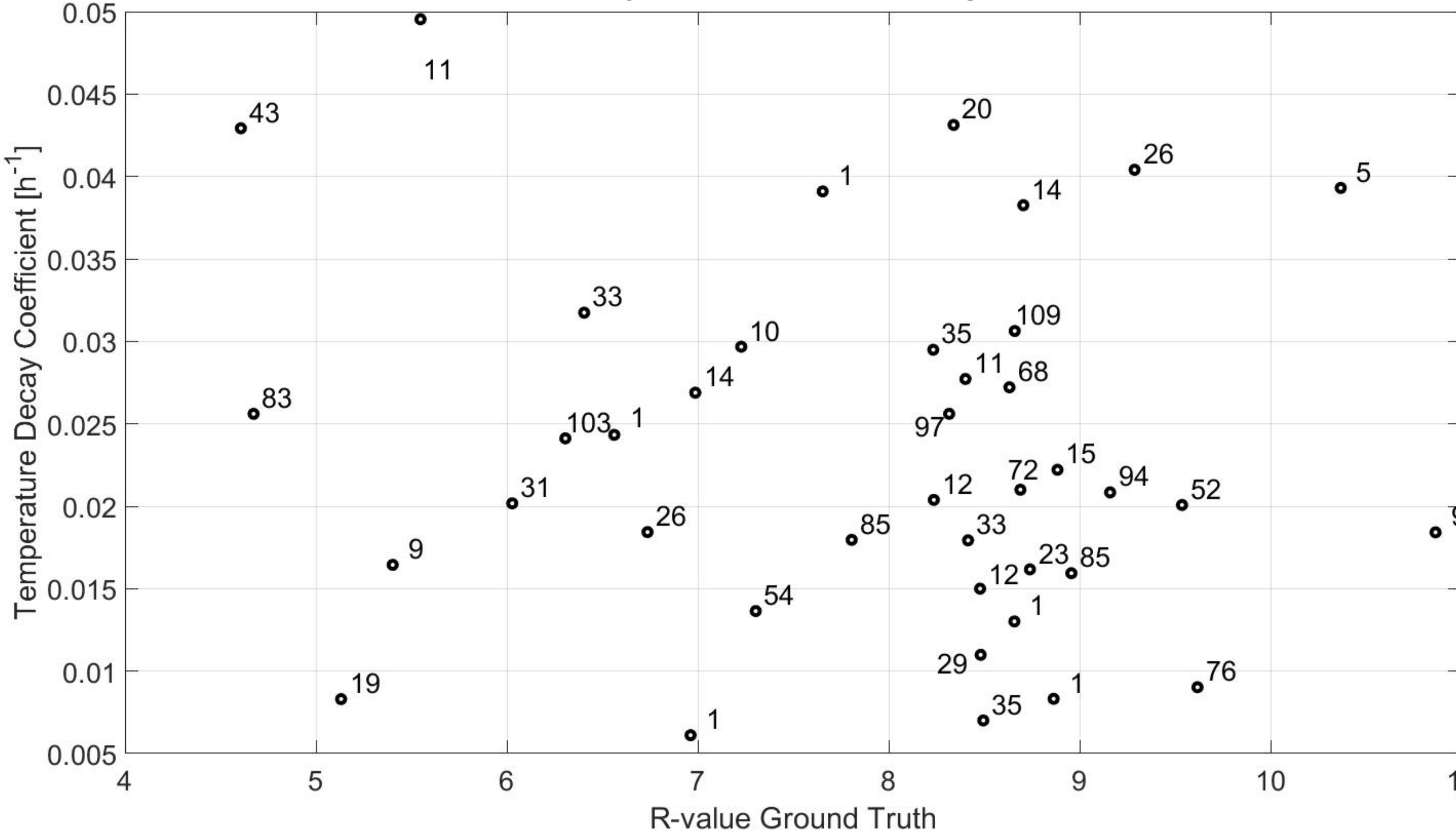
- $\alpha = \frac{1}{\tau} = \frac{-\log\left(\frac{(T_r(2) - T_{a,mean})}{(T_r(0) - T_{a,mean})}\right)}{2\ hours}$
- Calculated from midnight to 2AM time window
  - No heating for 1+hour before midnight and during time window
  - T_a varies by <2°C
  - T_r does not increase by >0.2°F
  - Mean T_a <40°F
- CT resolution = 0.1°F

References: Goldman et al. (2014), Chong and George (2016)

Time Constant Approach: We did not find a meaningful correlation between Tau and the whole-home R-values

Number of time windows averaged to calculate α values shown

α



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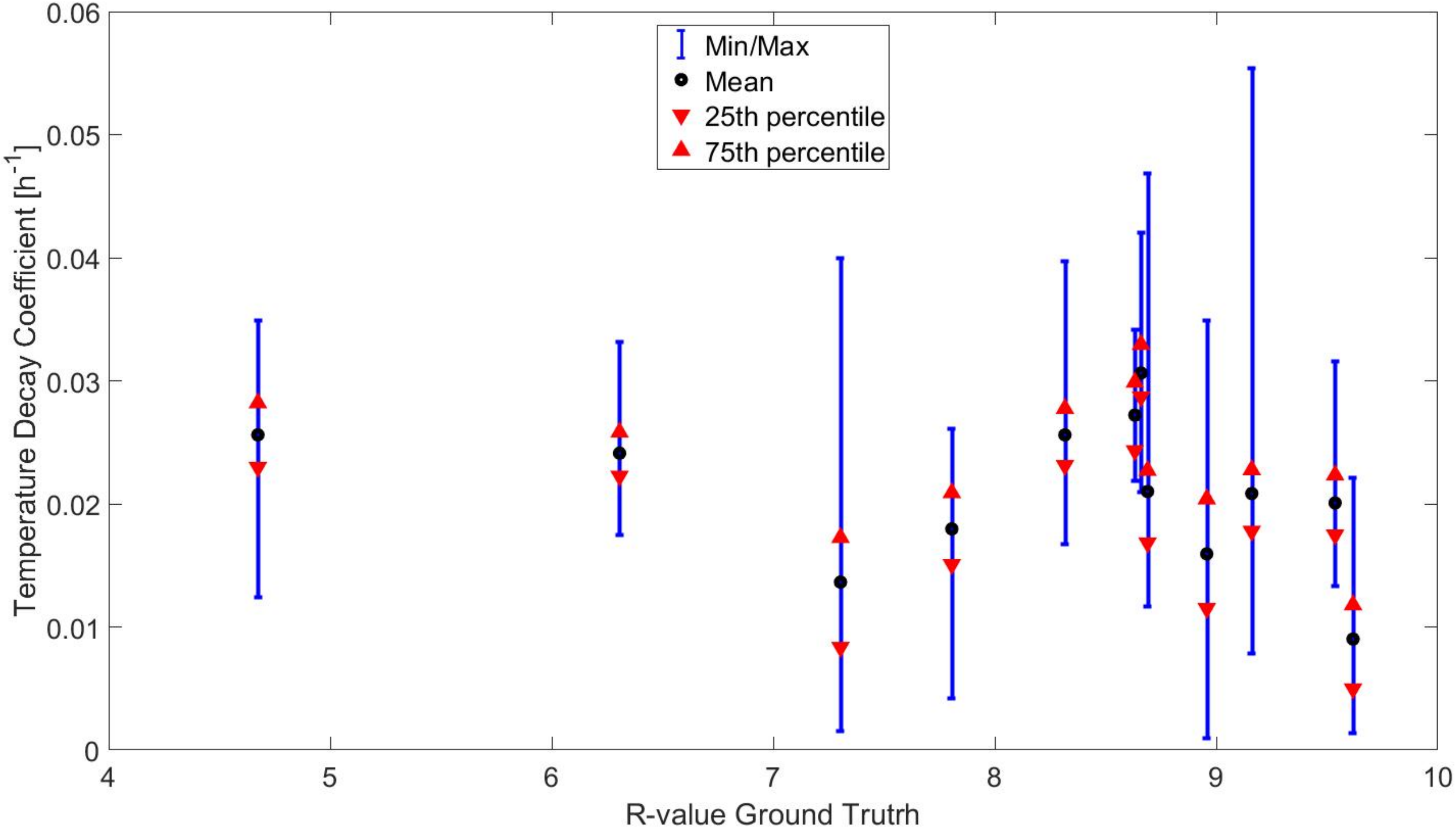
Time Constant Approach: α/τ can show appreciable variability.

Homes with 50+ α values calculated

α



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CT Data – Lessons Learned

- Ease of obtaining CT data varies among vendors
- Data field vary among CT vendors
  - Developing CT Data Specification
- Missing or unreported heating system runtime data not uncommon
  - Noted in prior work

Sources: Building36, ecobee, Honeywell.

Conclusions and Looking Forward

- For homes with 1 CT, we can accurately:
  - Estimate ACH_{50}
  - Classify whole-home R-value
  - Separate insulation from air sealing opportunities

- Next:
  - Extend algorithms to homes with multiple CTs
  - Evaluate ability to predict energy savings from target retrofits
  - Perform Randomized Controlled Trial (RCT) to test hypothesis: Does targeted, customized outreach increase rate of HEAs conducted *and* ECM implementation?
  - Finalize recommendations for scale-up: CT Data Specification, Best Practices Guide for Utility Program Integration

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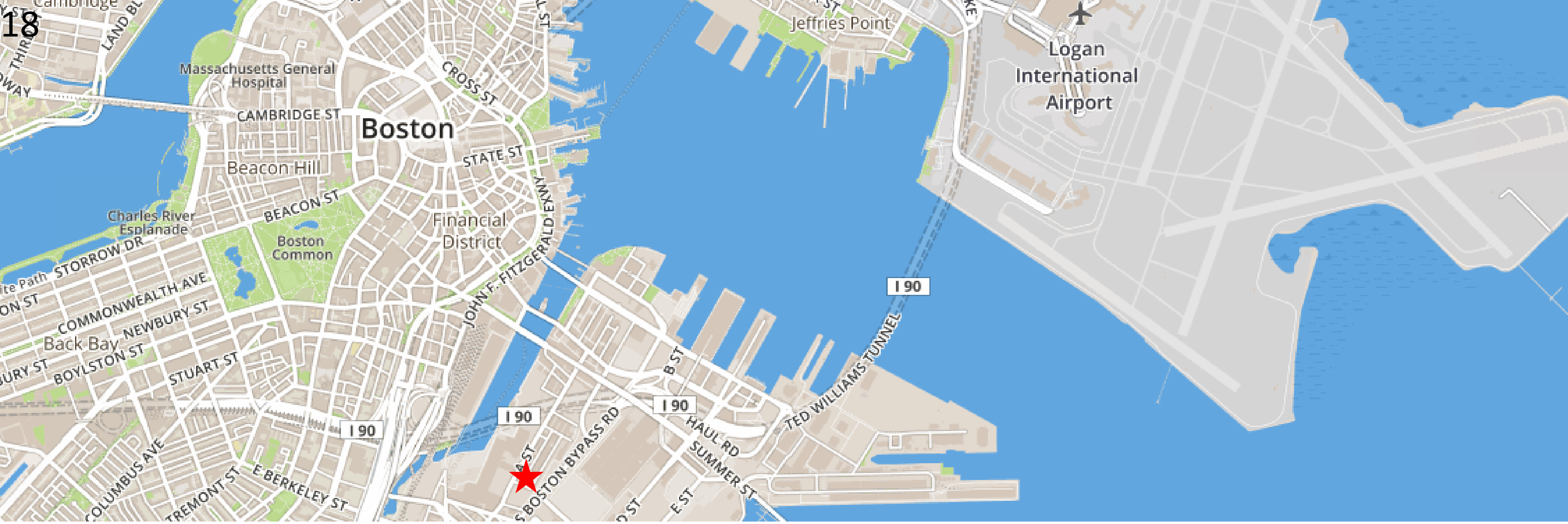

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