HERS RATING OF DEEP ENERGY RETROFIT HOMES

PREDICTED AND MONITORED PERFORMANCE

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New directions for HERS

- Expand into existing home rating
  - Particularly applicable to deep retrofit where we expect large savings and a very efficient post-retrofit home
  - RESNET Existing home amendment adopted a year ago
- Unknown starting point for home may prove to be tricky
- Occupancy and conditioned floor area often change during retrofits – so what is the reference home???...

Implies we can only rate the finished project and not energy savings or changes in HERS Index?

RESNET Retrofit Savings Amendment

- Standardized Energy Savings compares Baseline Home to Improved Home
- Restricts pre-retrofit inputs
  - Forced air furnace AFUE cannot be less than 72%
  - 9 SEER air conditioner
  - Gas water heater EF 0.5
- 2nd refrigerator clause
- Includes site-to-source energy conversion
  - Fuel switching woes

Defining Deep Energy Retrofit (DER)

- Comprehensive upgrades to the building enclosure, heating, cooling and hot water equipment.
- Often incorporates appliance and lighting upgrades, plug load reductions, renewable energy and occupant conservation.

With Pre-Retrofit Energy Data

- % Reduction
  - >70%
- Absolute Reduction
  - Reduction > Average consumption in the region

Without Pre-Retrofit Energy Data

- Consumption Target
  - Affordable Comfort Thousand Home Challenge Option B
  - Zero Net-Energy
  - 50% less than regional average home
- Performance Target
  - HERS Score <50
  - Passive House or EnerPHit
  - 2012 IECC

How Well does HERS work for Deep Retrofits?

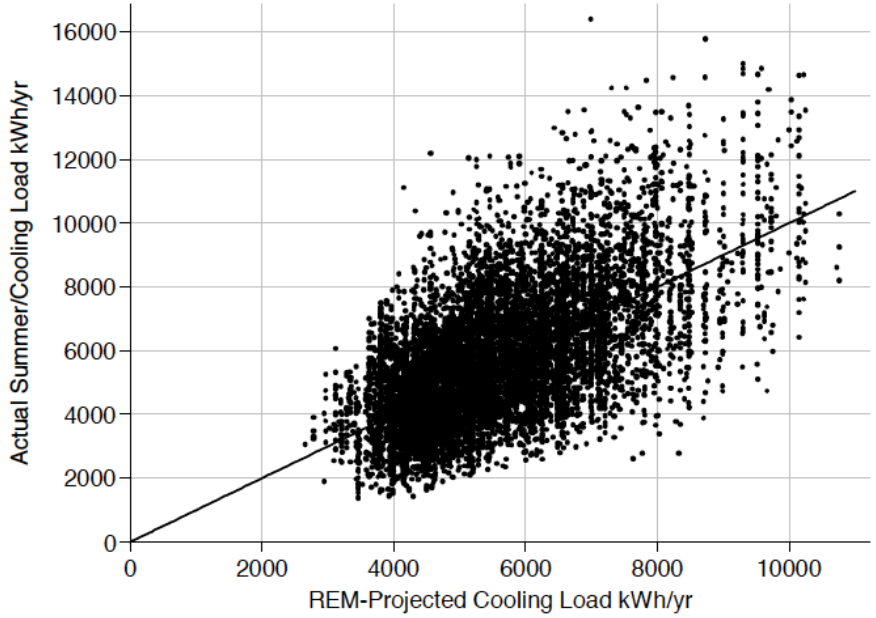
- Could HERS be a way of labeling deep retrofits?
  - Used as an end-point when we don't have pre-retrofit bills, or occupancy changes, or house size changes
  - Can it be used to compare new homes to retrofitted homes?
  - Can end-point HERS rating avoid issues with HERS ratings in older existing homes?
  - Setting targets for industry: utility programs, weatherization, home performance contractors, code bodies, etc.…
  - Future Energy Star, DOE Building America, LEED application to retrofitted homes
- What works in a HERS rating?
- What could be improved in a HERS rating?
- What presents problems in a HERS rating?

Issues for HERS in Assessing Deep Retrofits

- Larger homes require poorer envelopes and equipment performance than smaller homes to achieve the same score
- Asset rating versus Operational Rating
- Occupancy and behavior are not accounted for
- Rating ≠ Energy Use
  - HERS = Asset
  - Energy Use = Asset + Occupants

Past research evaluating accuracy of energy ratings

Figure 7: REM/Rate projected cooling loads versus actual cooling loads



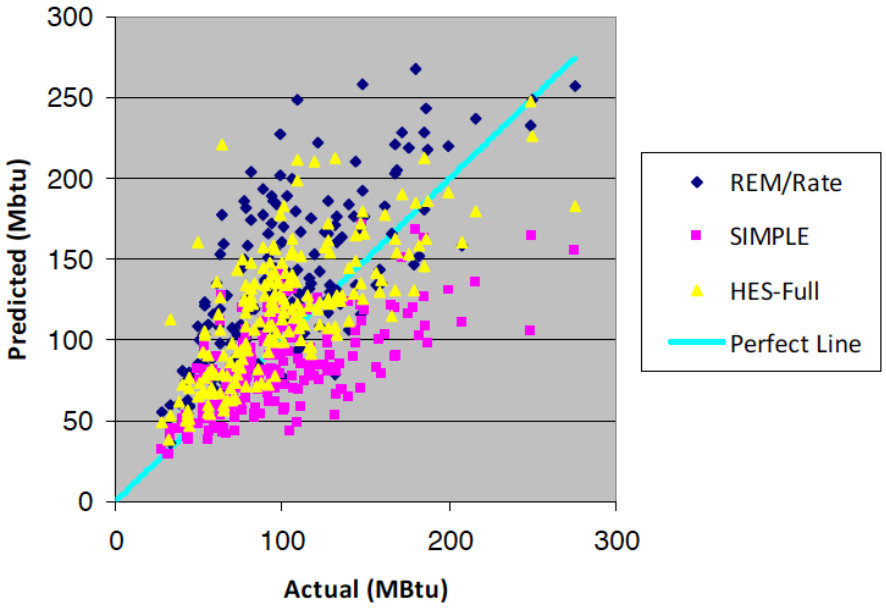


Figure 3.1 Predicted Total Energy Use vs. Weather Normalized Actual Energy Use (MBtu) (190 Homes)

Houston Home Energy Efficiency Study. 2009.
Hassel, Blasnik & Hannas

Energy Performance Score 2008 Pilot – Findings and Recommendations Report.
Earth Advantage Institute and CSG

Context for Evaluating accuracy of HERS

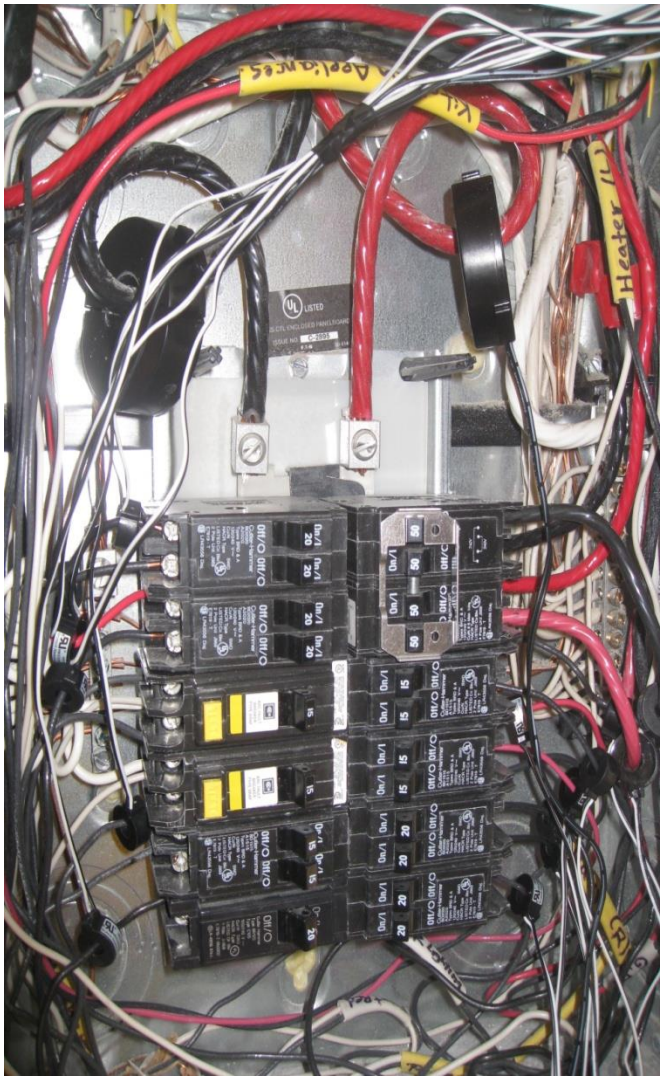
- Context
  - Identical side-by-side homes have ± 35% energy use due to occupancy effects
  - Weather changes energy use by ± 15%
  - Small errors over large groups: some studies only 1%
- Comparisons to actual energy use sensitive to thermostat settings
  - default assumption should be lower on average for heating and use nighttime setback
- Older homes often zoned
  - Core vs. exterior
  - Not all home heated

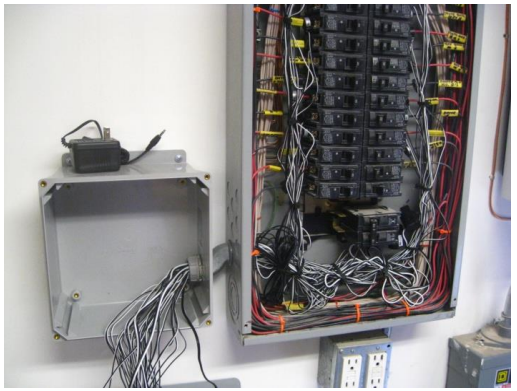
HERS in LBNL Deep Retrofit Study

- Measure energy use in eleven deeply retrofitted homes
  - Disaggregate end-uses to compare to HERS calculations
- Use diagnostics, site observations of lighting, appliances & water use and occupancy to generate HERS Index
  - only post-retrofit – no access pre-retrofit and few homes had occupancy information due to change in ownership

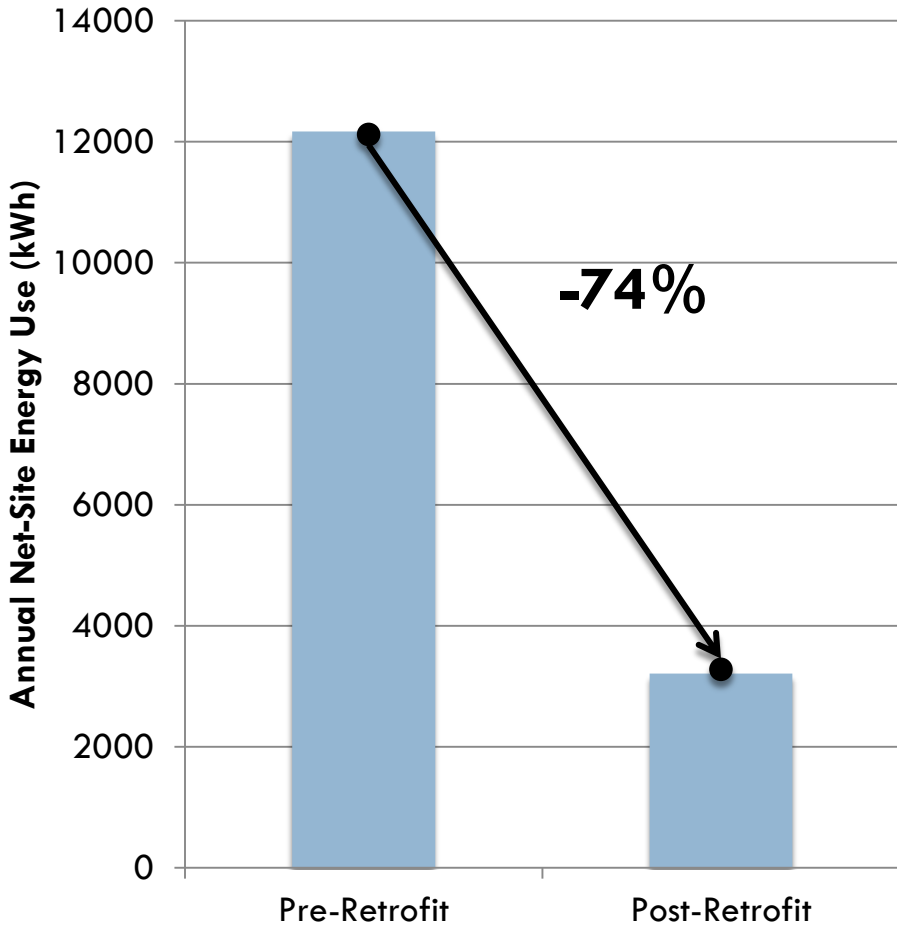
DER Locations

Monitoring Equipment





DEEP ENERGY REDUCTIONS ARE REAL



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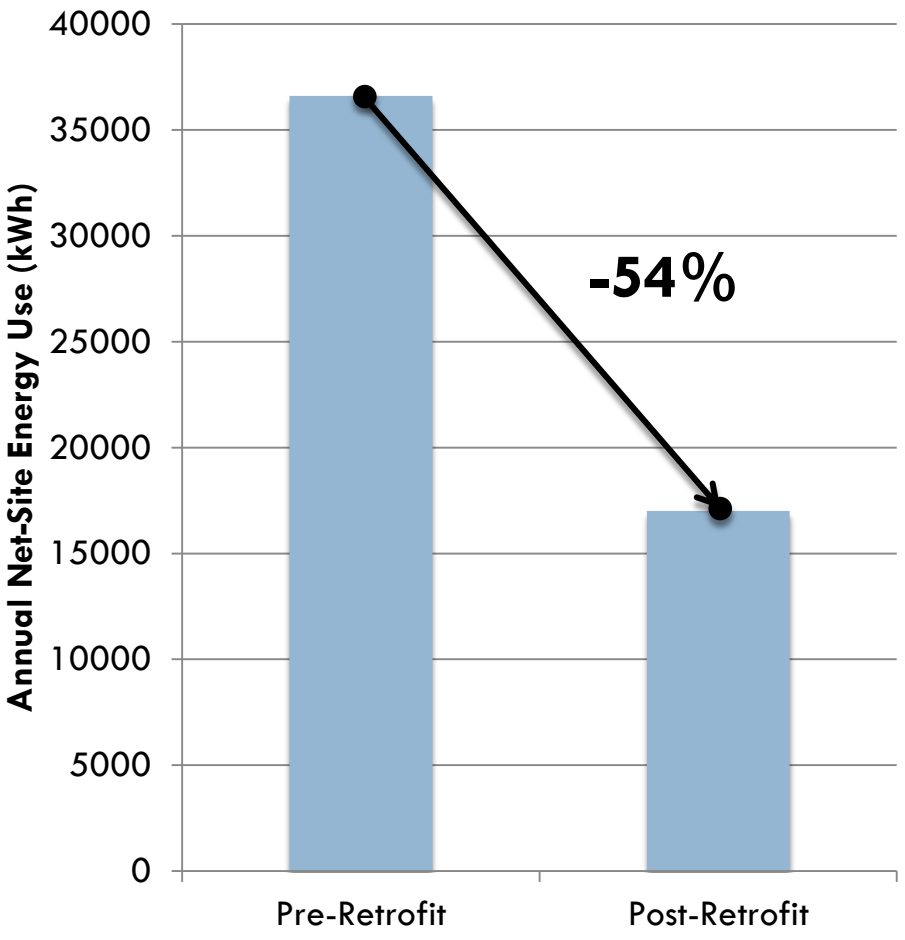
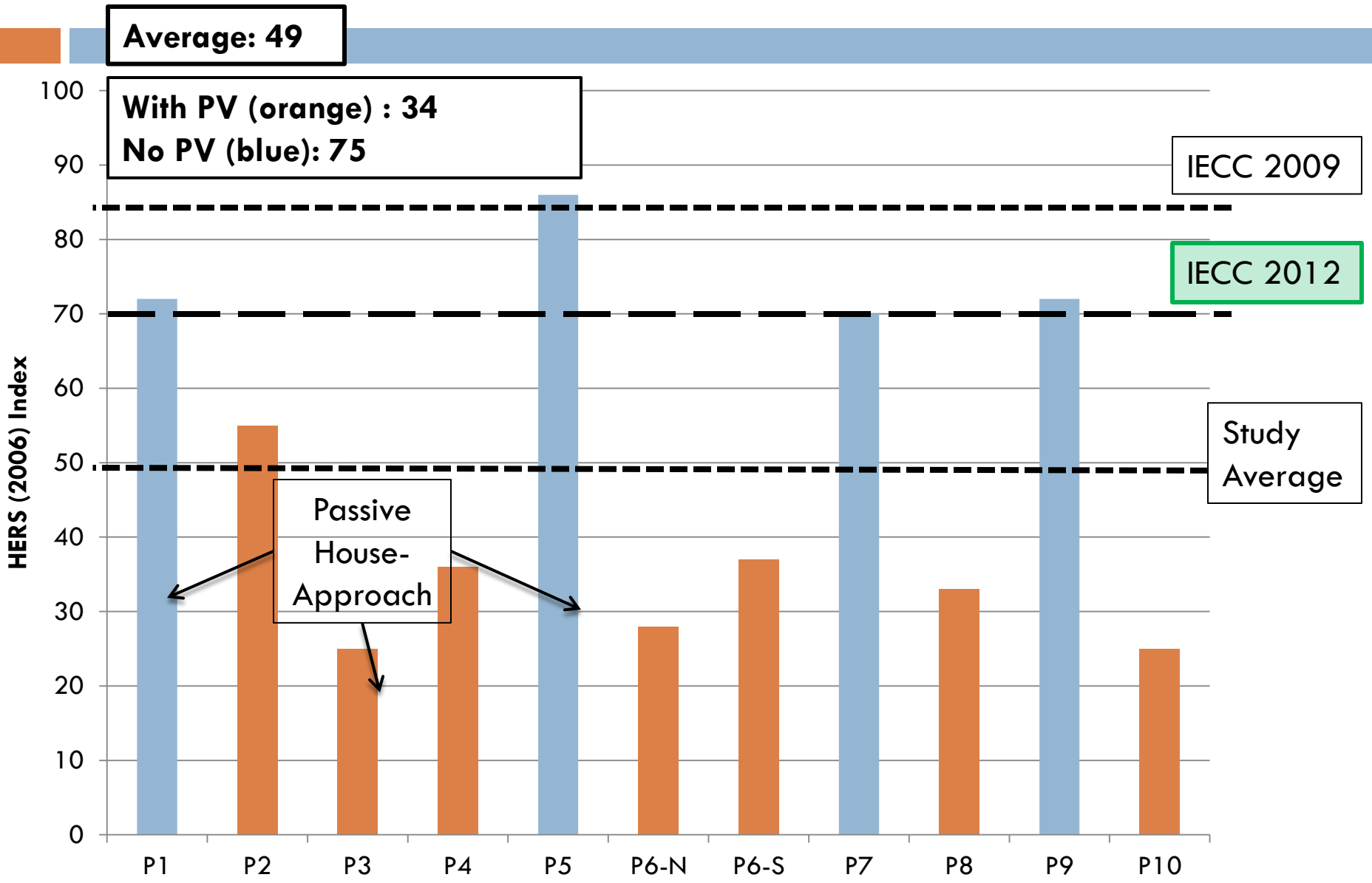


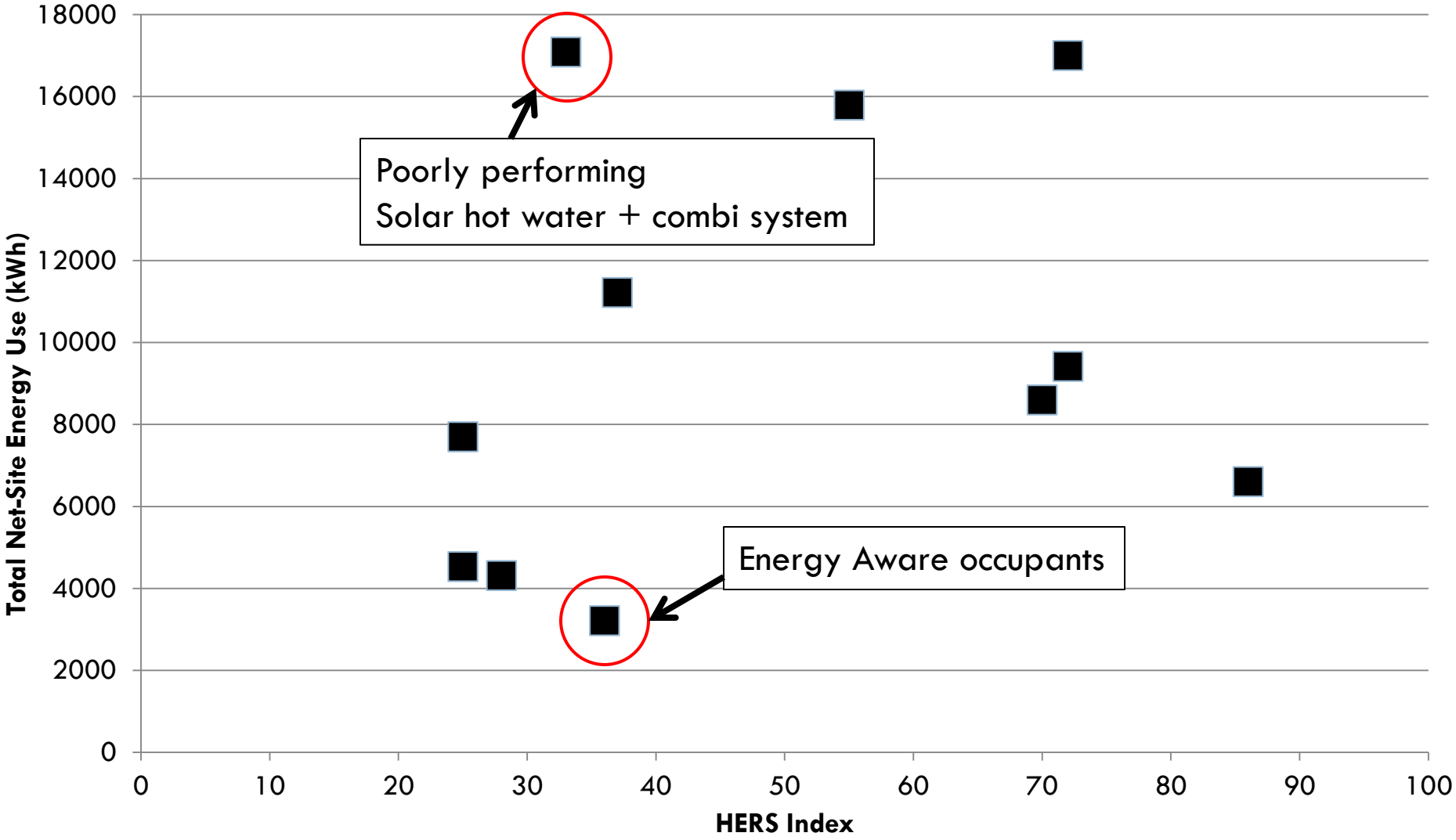
How we generated the HERS Ratings

- Drawings
  - Architectural and mechanical, where available
- Observation/Inspection
  - Number and type of appliances, hot water systems, lighting, number of occupants
- Diagnostics
  - Envelope/duct leakage and ventilation airflow
- Software
  - EnergyGauge USA

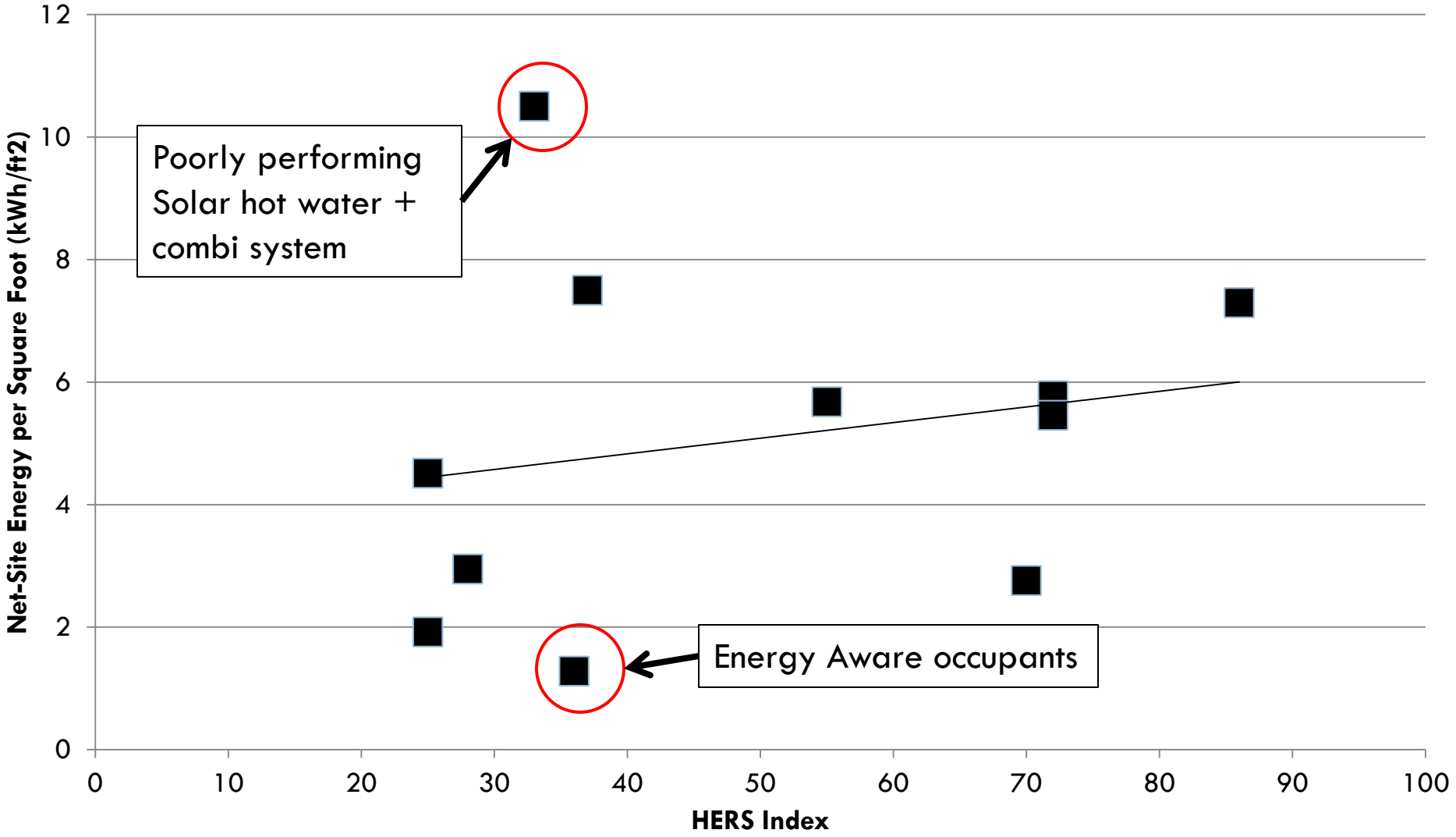
HERS Ratings for DERs



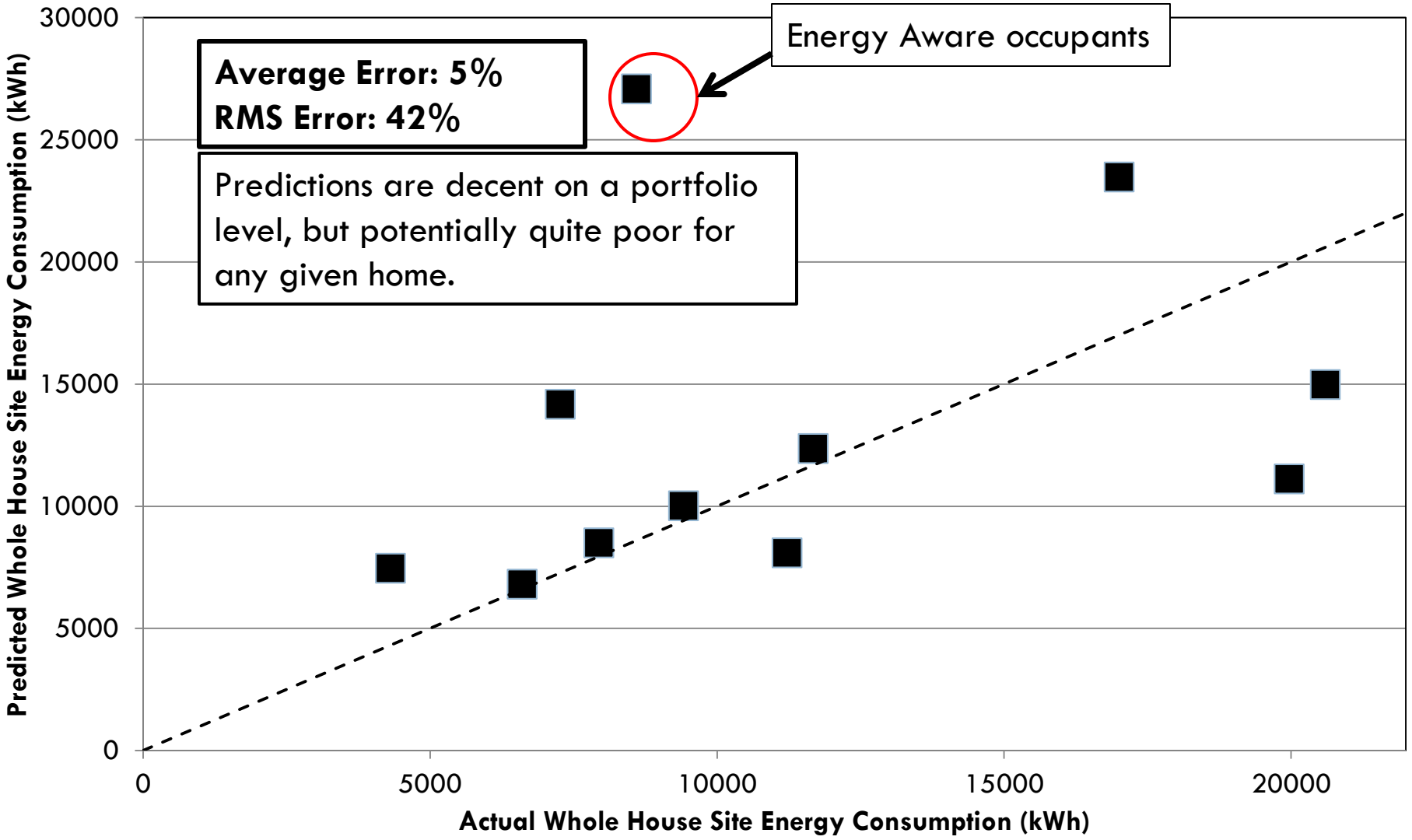
HERS Index & Site Energy



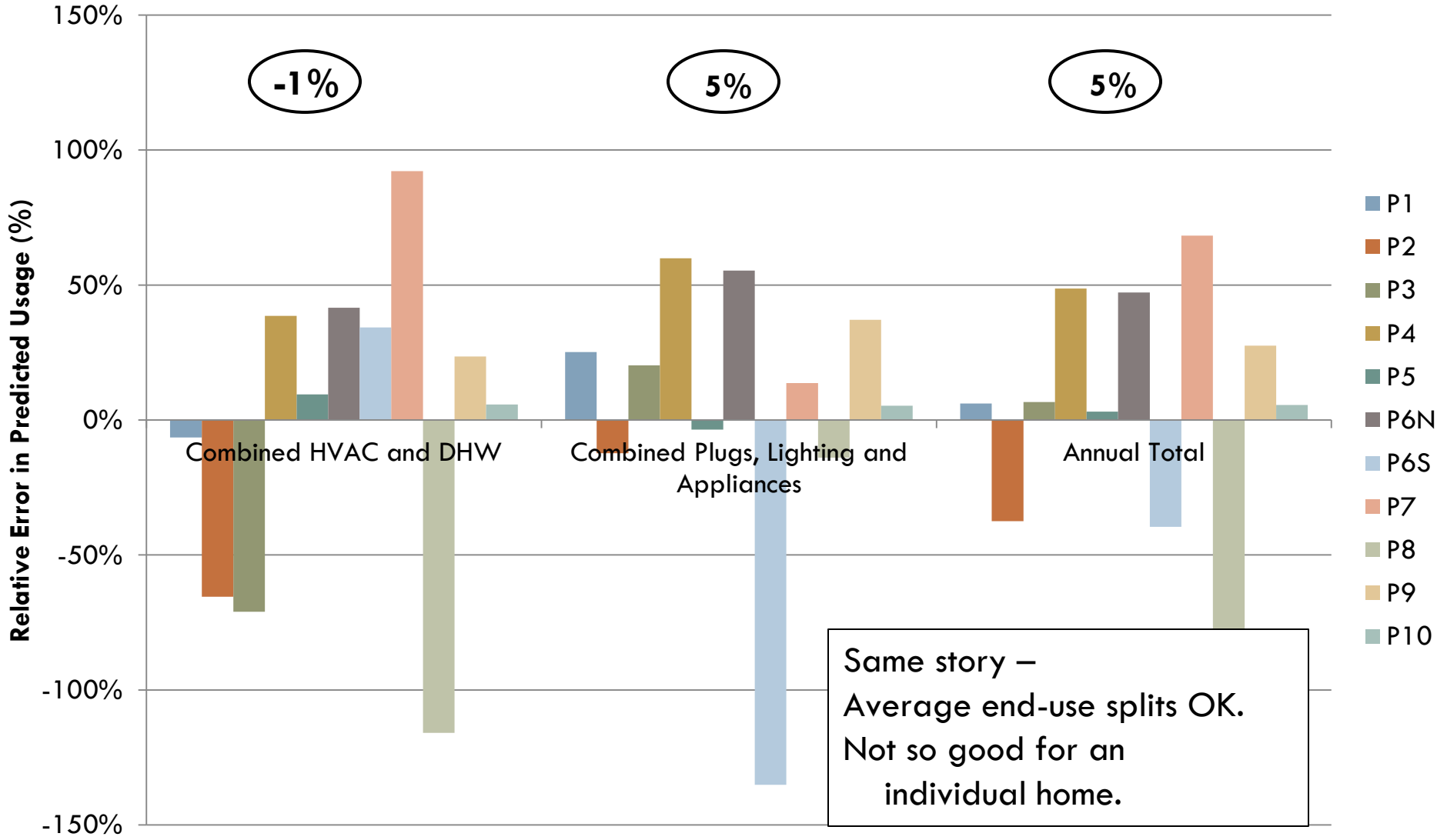
HERS Index & Normalized Energy Use (Gas + Electric)



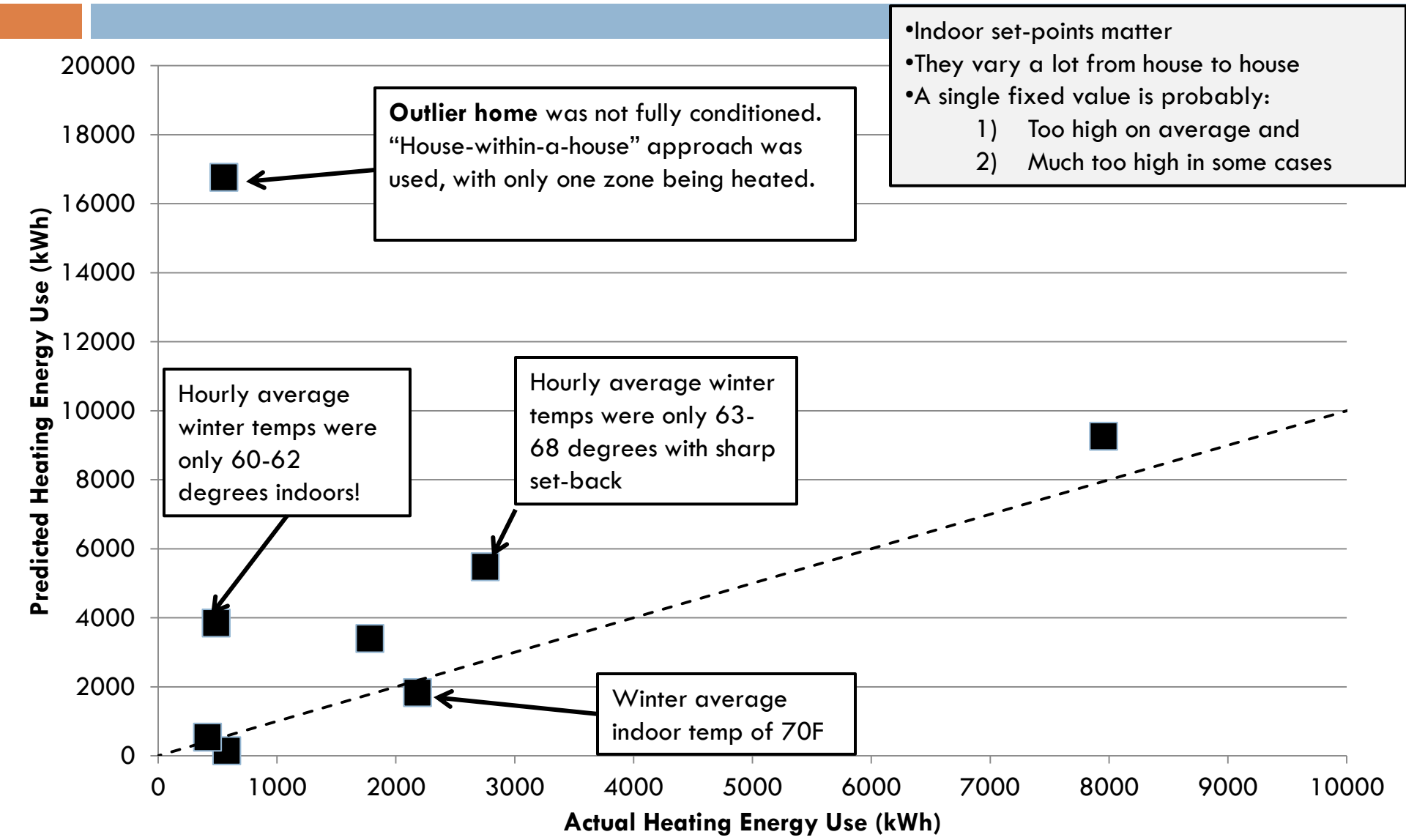
Total Energy Use Comparison



End-Use Energy Use – Where are the errors?

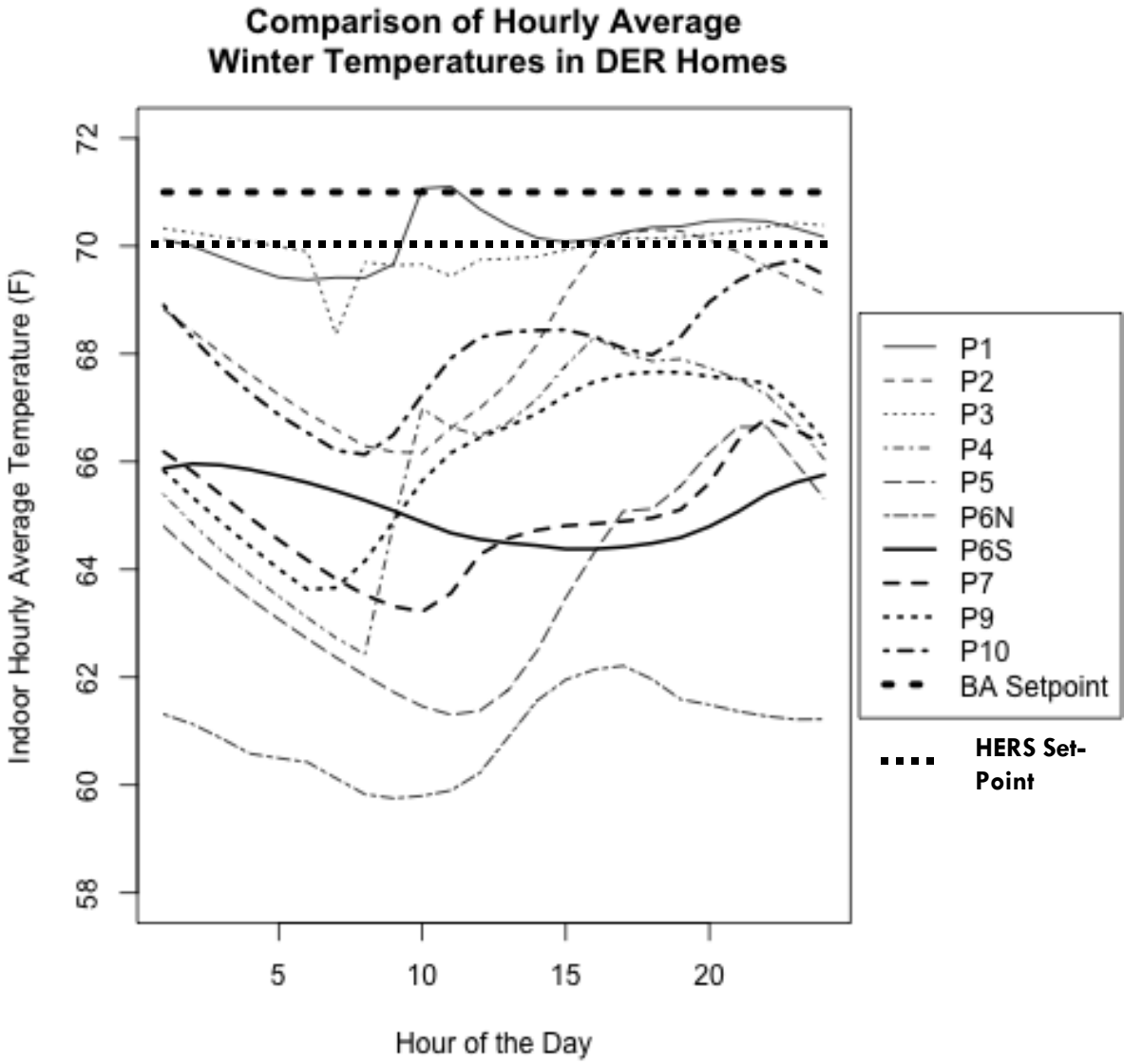


Heating Energy Comparisons

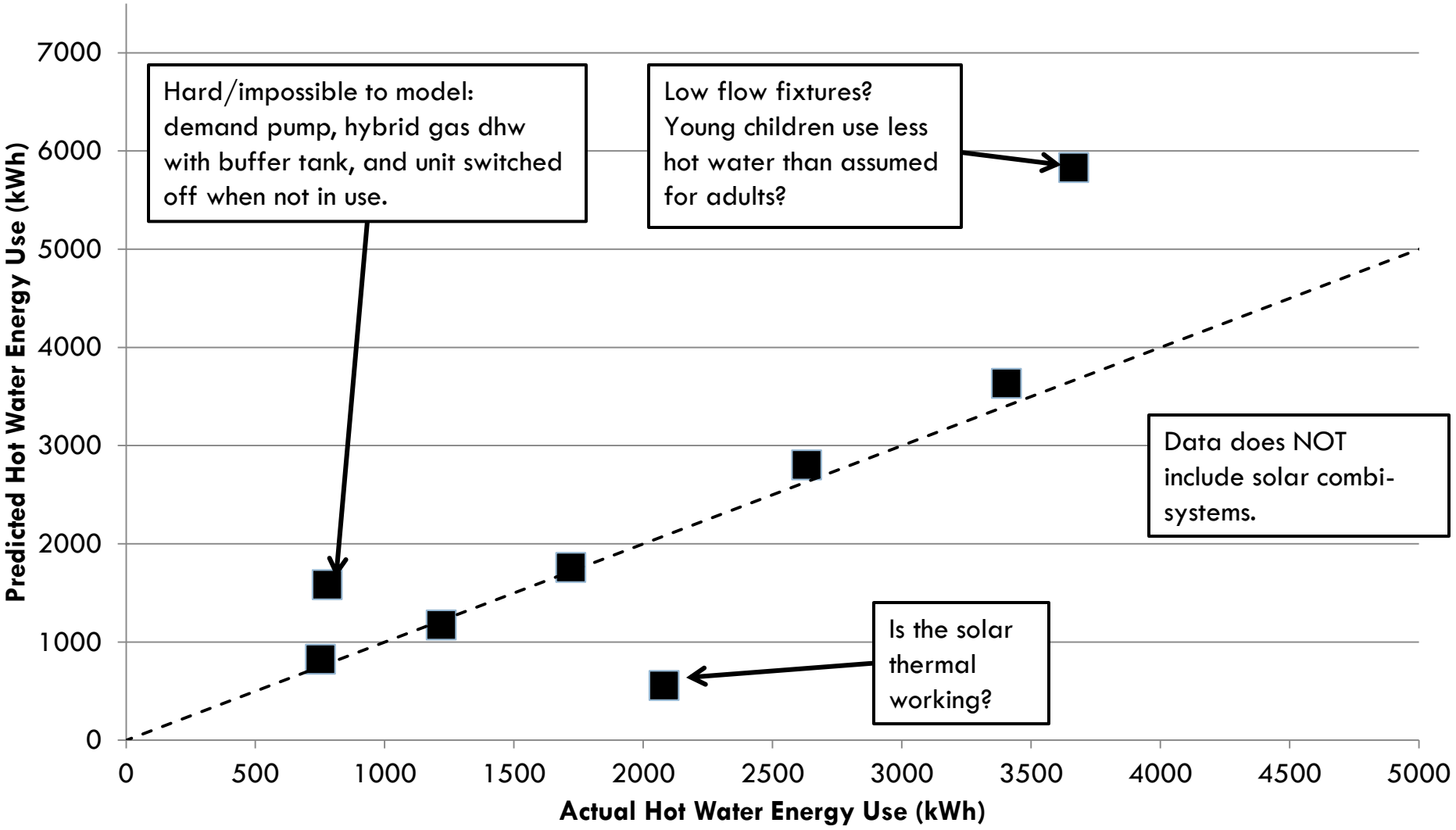


Challenges to Prediction of DER Performance— Occupant Driven Operation and Performance

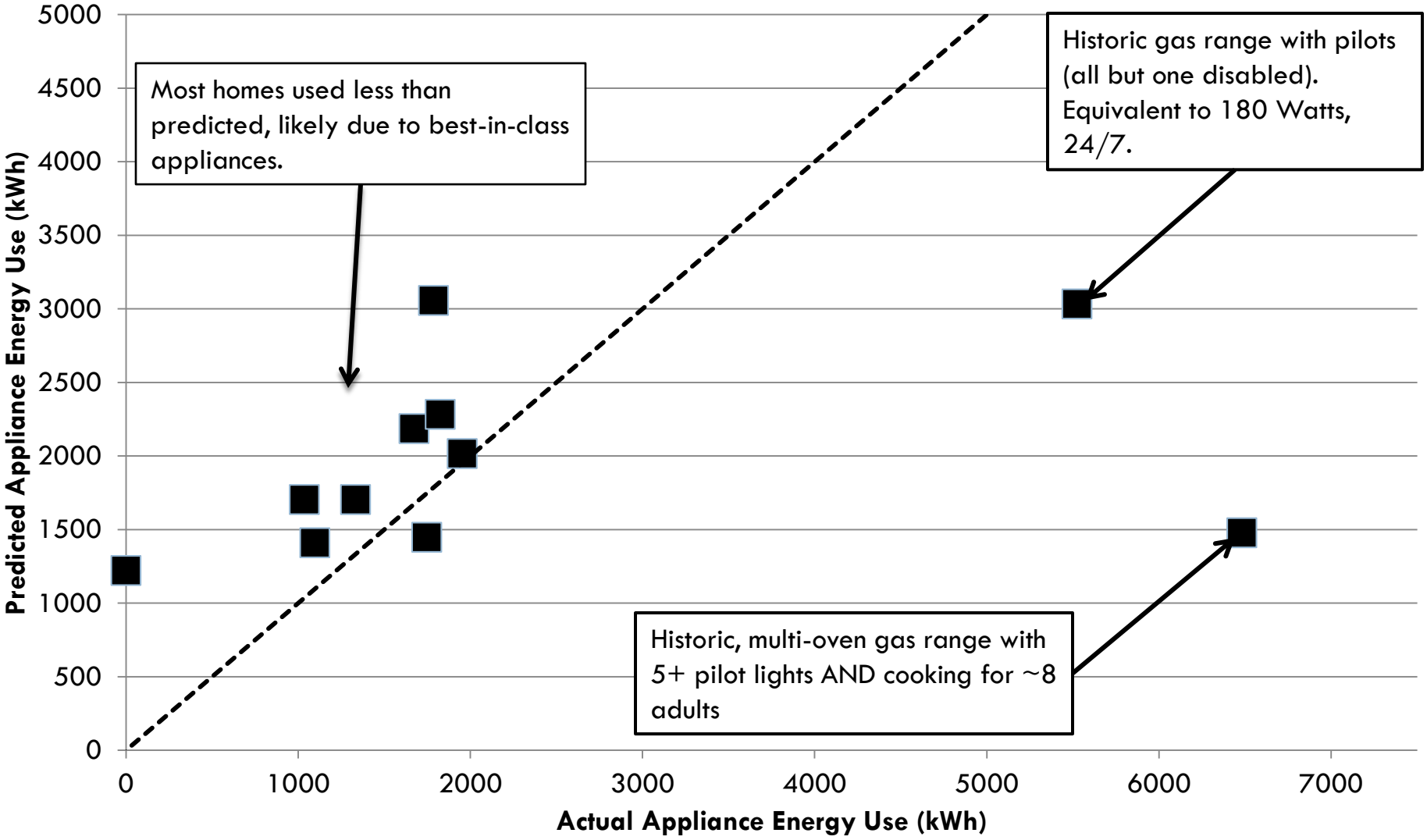
- Homes all provided indoor winter temperatures below the HERS set-point (70F)
- Nearly universal nighttime set-backs
- Occupant thermal preference?
- Occupant desire to reduce energy usage?
- Enhanced radiant environments?



Hot Water Energy Comparisons



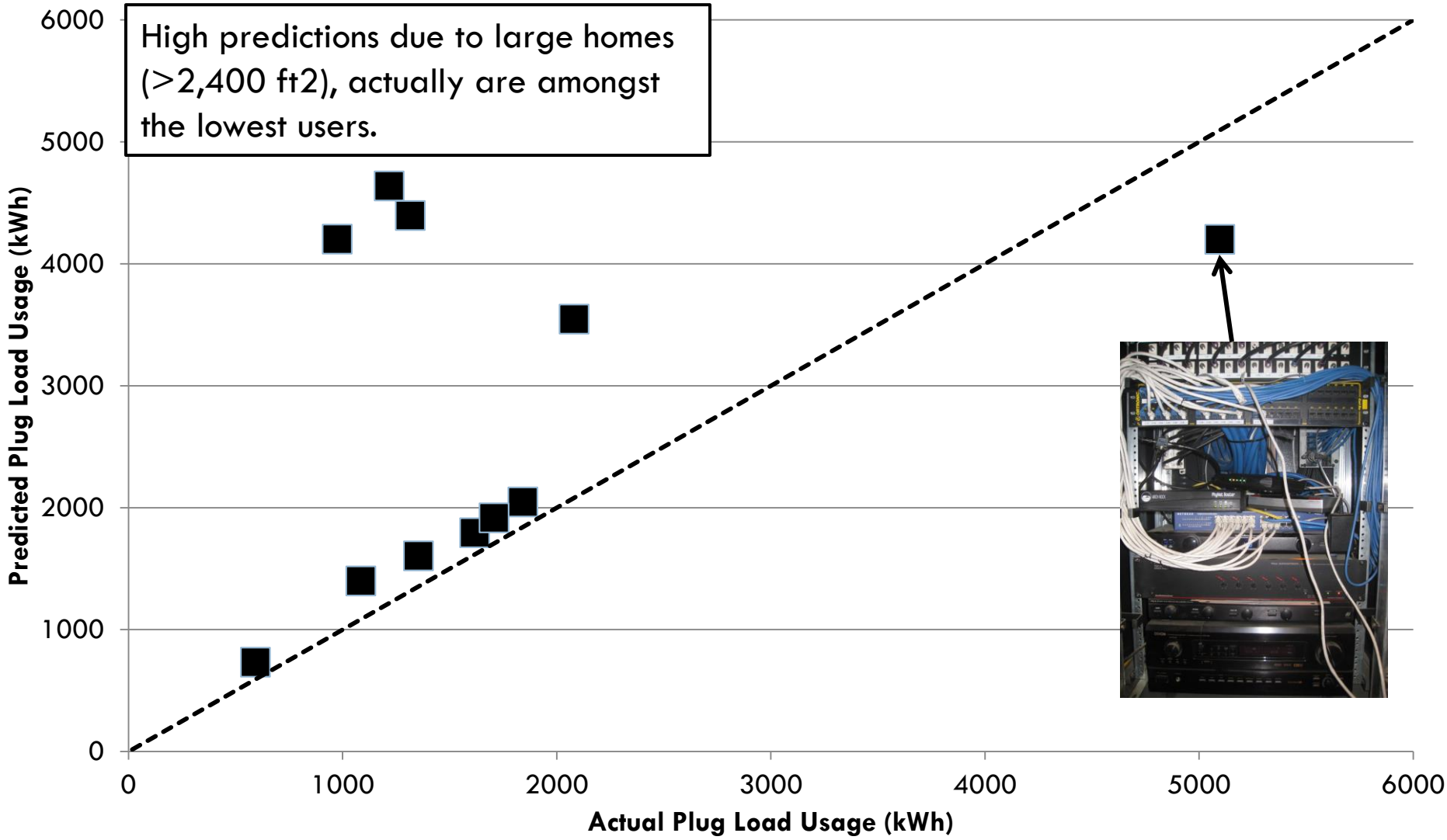
Appliance Energy Comparisons



Lighting Energy Comparisons

Most homes used more lighting energy. Might be due to increases in decorative and outdoor lighting.

Plug Load Energy Comparisons

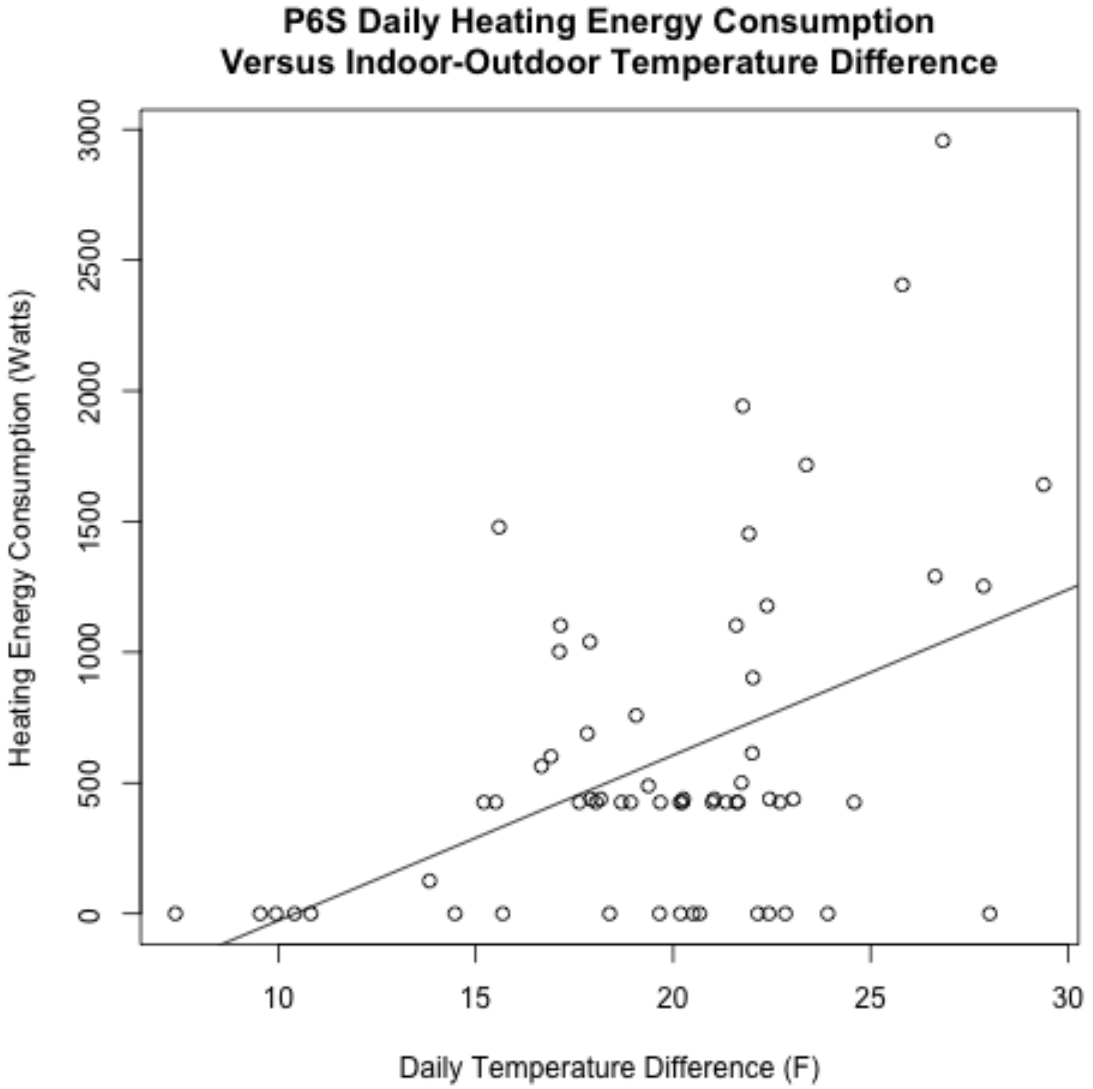


Challenges to Predictions of DER Performance

- Works well on average – but poorly for a single home (same as non-DER studies)
  - DER Specific:
    - Operation and performance are strongly occupant driven
    - Limited ability of software to handle complex and novel building systems/assemblies
    - Reduced sensitivity to envelope loads makes rating more sensitive to other loads
    - Need a better way to estimate plug loads?
- Unknown pre-retrofit conditions for Pre-Post HERS comparisons

Challenges to Prediction of DER Performance— Occupant Driven Operation and Performance

- Most DER homes show inconsistent relationships between heating system energy and temperature difference
- Homes are not simply thermostat controlled
- Internal and solar gains could also cause this, or "heat when home" strategies



Challenges to Prediction of DER Performance—Occupant Driven Operation and Performance

- P7 represents an extreme example of occupant driven, hard-to-model circumstances
- Kitchen zone was insulated and airtightened with respect to inside and outside
- This zone was kept reasonably comfortable, while rest of home drifted with minimal input from zone heating systems
- This project was tailored to meet the needs and patterns of usage of the actual occupants
- It was conceived as a strictly operational project and was successful as a result

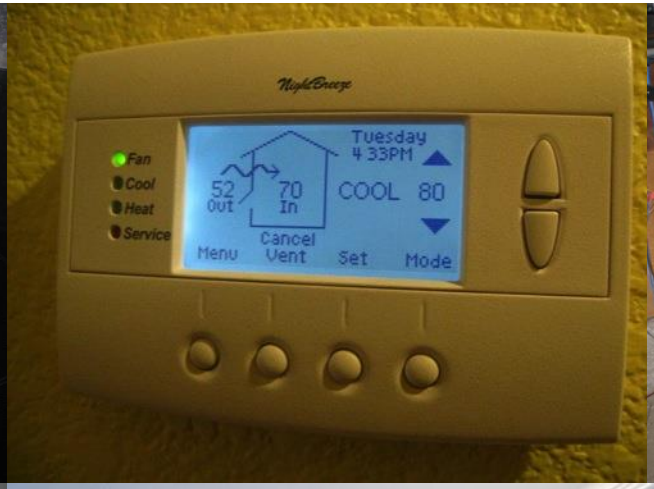
Challenges to Prediction of DER Performance—Complex and Novel Systems

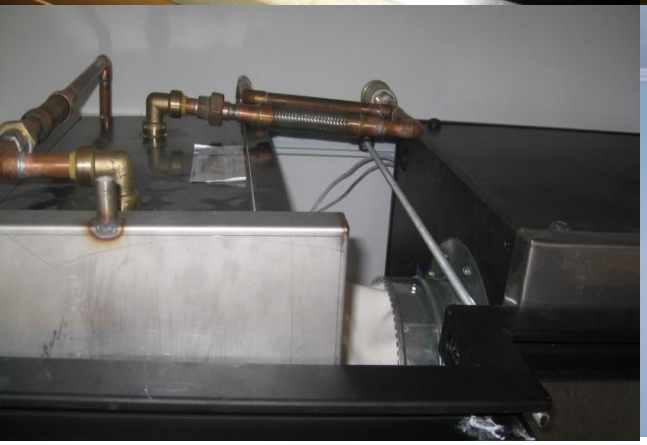




Top row, from left: Evaporatively cooled condenser, Large natural ventilation stack, chilled and hot water storage tanks, solar combi boiler.
Bottom row, from left: Air-to-water heat pump, air handler with integrated ERV.

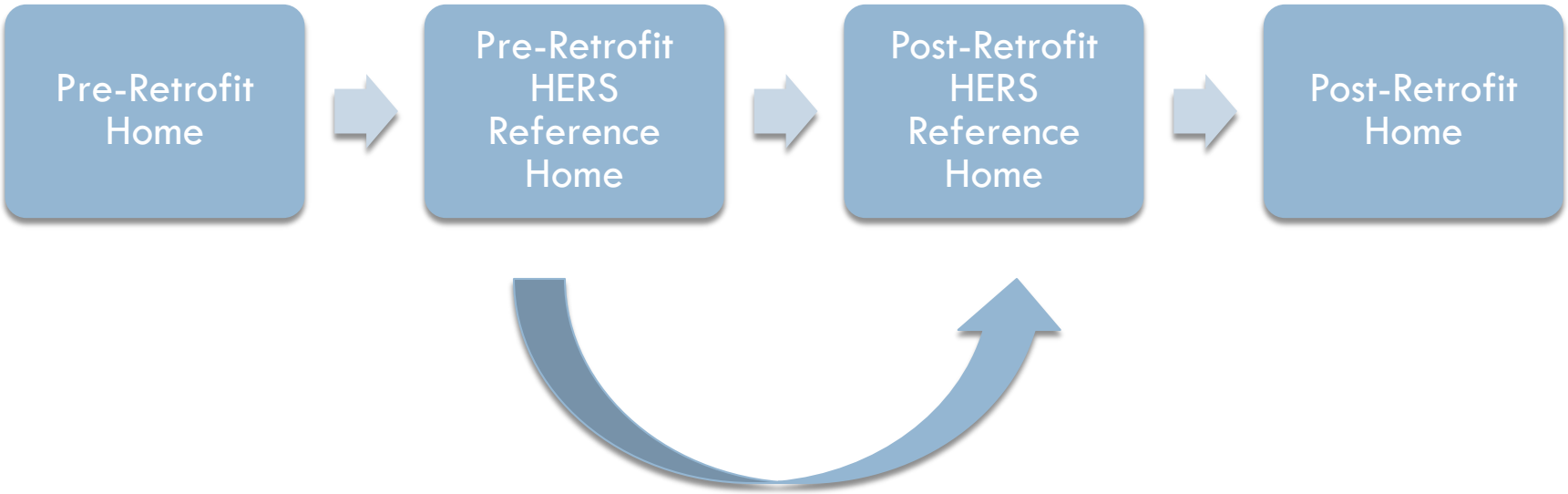
Challenges to Prediction of DER Performance—Complex and Novel Systems





Top row, from left: Induction cooktop, Nightbreeze ventilative cooling controller, pumped grey water system for toilet flushing. *Bottom row, from left*: Solar heated hydronic heat exhcanger in ERV supply duct, mini-split heat pump.

Another Application of HERS in DER—Change in HERS Score



The problem is when these two are different homes

10 DER Reported by FSEC—Similar Reference Homes

- Ten homes in foreclosure retrofitted as affordable housing DER
- **Targeted HERS 70 for DER**
- **Pre-retrofit average of 132**
- Present before and after HERS Indices
- % reduction in HERS Index is similar to, but not the same as the projected annual energy use reductions (36% versus 31%)
- Homes did not change floor area

Table 3 Post-Retrofit Projected Energy Use and Savings Results for ten completed renovations

Year Built	Test-In HERS Index	Test-Out HERS Index	Test-Out ACH50	Test-Out qn,out	Annual Energy Use Savings
1987	156	78	5.39	0.04	**48%**
1967	165	73	8.12	0.02	**44%**
1981	151	79	5.38	0.11	**43%**
1963	177	81	7.24	0.04	**41%**
1978	143	92	16.80	0.08	**34%**
1995	99	67	5.51	0.40	**33%**
1993	109	79	3.82	0.02	**22%**
1981	112	87	7.65	0.09	**22%**
1983	116	86	4.37	0.02	**17%**
1995	98	86	6.07	0.03	**9%**

Source: McIlvaine et al., 2010. Exploring Cost-Effective High Performance Residential Retrofits for Affordable Housing in the Hot Humid Climate *(FSEC-PF-448-10)*

Pre- and Post-Retrofit HERS Indexes Run Into Trouble When…

- 7 of 11 projects change square footage
- 10 of 11 projects change occupancy in some way
- 4 of 11 projects fuel switch from gas to electricity
- 4 of 11 projects change window areas
- Changing reference homes will leave you scratching your head, and will distort energy outcomes

Challenges to Prediction Pre-Post HERS comparisons —Unknown Pre-Retrofit Conditions

- What do we have to compare the post-retrofit home to???
  - We were unable to access pre-retrofit plan documents in 8 of 11 homes
  - Most project teams did not document or measure pre-retrofit conditions
  - 10 of 11 project homes experienced changes in occupancy from pre- to post-retrofit
  - We do not know internal conditions—set-points, thermostat schedules, water heater temp, etc.

General Conclusions for using HERS in DERs

- What works in a HERS rating?
  - Good results over a population (OK for utility/government programs)
  - Good results for predicable technologies, e.g., PV & hot water
- What could be improved in a HERS rating?
  - Better temperature settings
    - Change reference home to have nighttime setback
    - Include zoning (i.e., deliberately not conditioning the whole house the same)
  - Estimates of plug loads
- What presents problems in a HERS rating?
  - Limited to rating asset
  - Unusual/novel technologies
  - Pre-post can be a big struggle when reference home changes

Thank You & Contact Info

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