Validation of the Home Energy Saver Energy Calculation Methodology: Using Empirical Data to Improve Simulation

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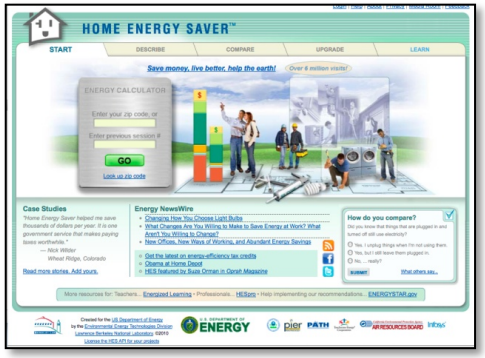
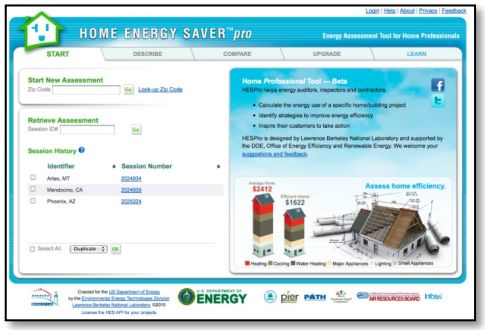
The Home Energy Saver

- First web-based residential energy analysis tool
- LBNL creates in early 1990s
- 7 million users
- Operational assessment (energy, cost, carbon)
- Hourly simulation using DOE-2.1E & documented methods
- Basis: Home Energy Scoring Tools
- APIs now used by 3rd-party developers

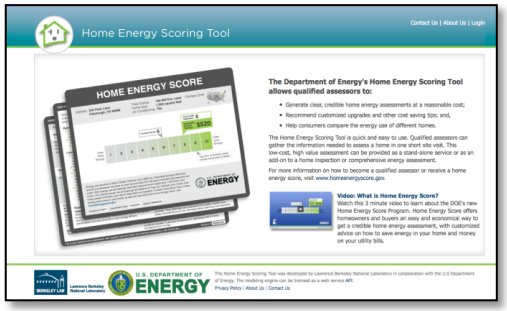
HESconsumer



HESpro

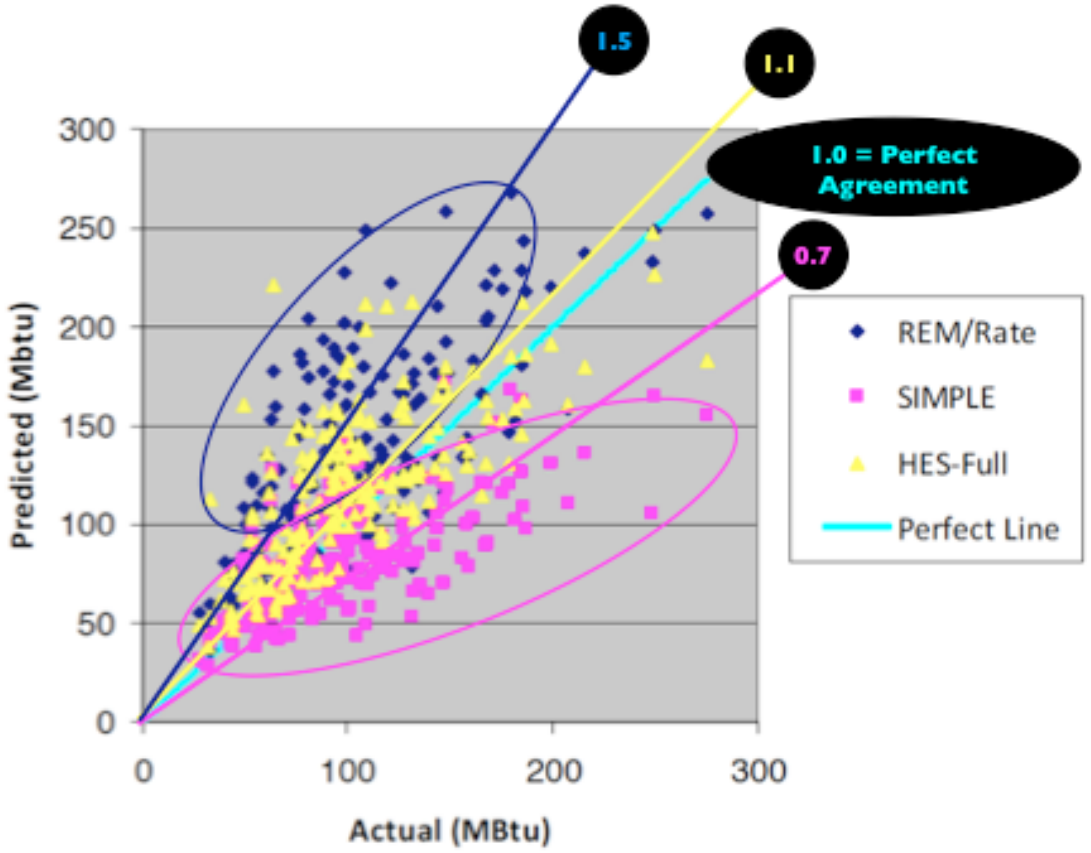


HEScore



Accuracy Misinterpretations

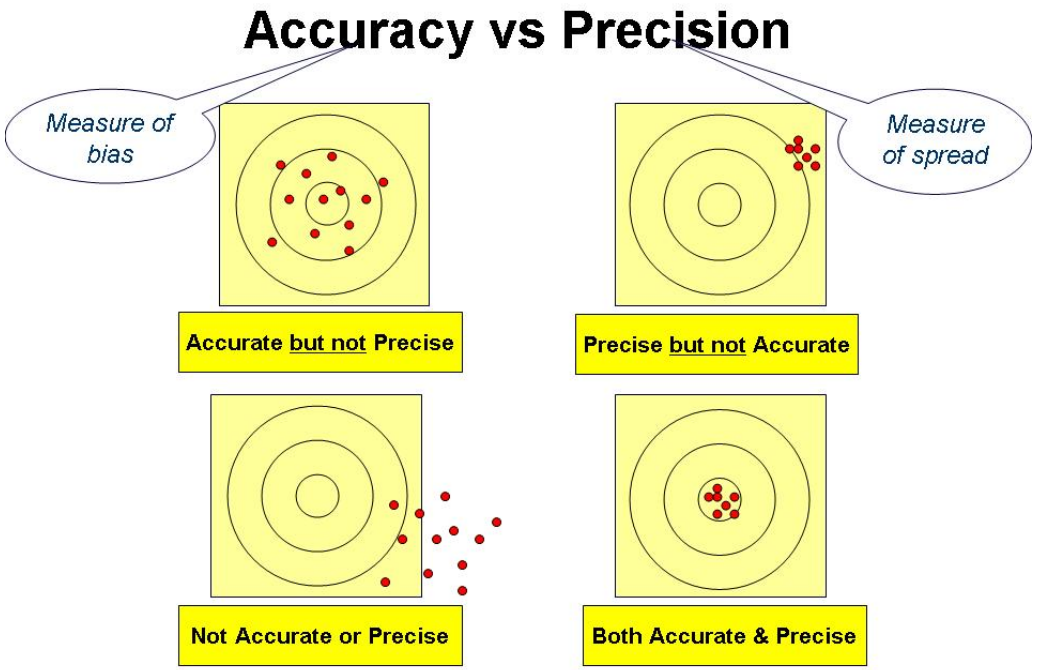
- Energy Trust of Oregon & CSG (2008) concluded that the tool in blue was more accurate than the tool in yellow
- Also concluded that more inputs do not make the analysis more accurate



Accuracy is Rarely Well-defined

Accuracy of What?

- Modeling
- Programming bugs
- Audit data
- Default values v. Operational
- User inputs/operator
- Measured data & weather



How is Accuracy Defined?

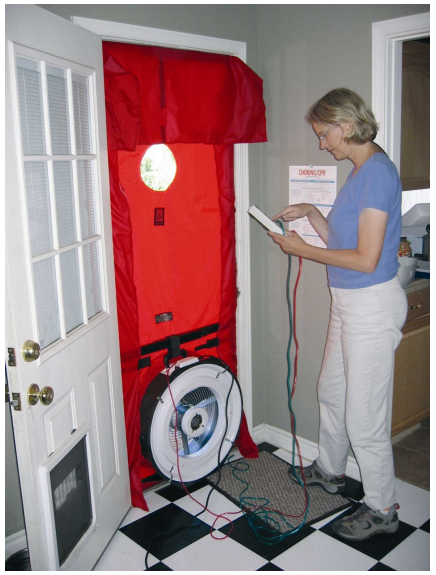
- Metrics
- Acceptable tolerance
- Operational vs. Asset

Why is Accuracy Assessment being Done?

- Much depends on purpose of the analysis and how results are to be used
- Accuracy assessments are most valuable when used during model development, *vs* after the fact

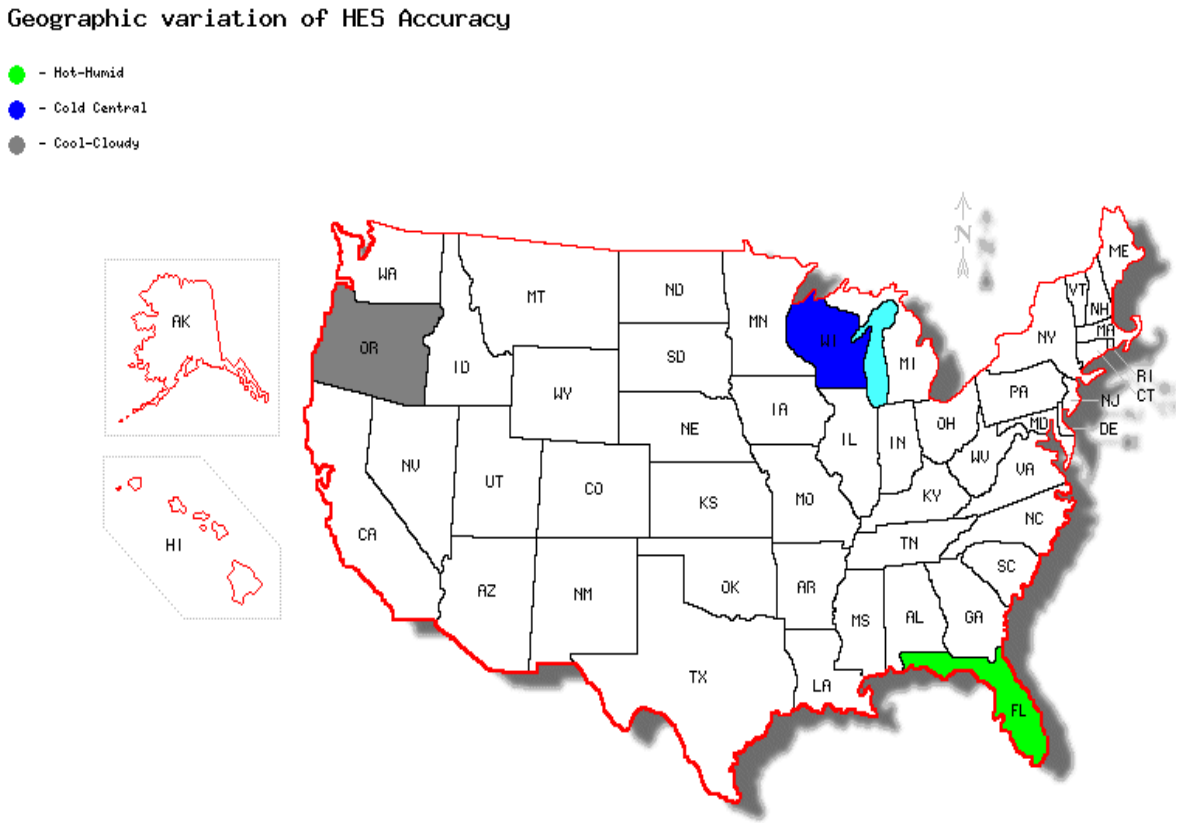
Asset vs. Operational Assessment

- Asset assessment (low information "drive-by" audit)
- Operational: classic on-site energy audit
- This study focuses on Operational analyses
  - see Bourassa et al. for accuracy results of the Asset-based derivative of HES => HEScore)



Model Accuracy Across Climates

- Operational analysis: 428 homes (QA'd down from 660)*
- Model results compared to actual energy data
- Three climates
  - Florida (Hot Humid)
  - Wisconsin (Cold)
  - Oregon (Cool/ Cloudy)
  - FSEC & NREL Data



* See https://sites.google.com/a/lbl.gov/hes-public/accuracy/decision-rules

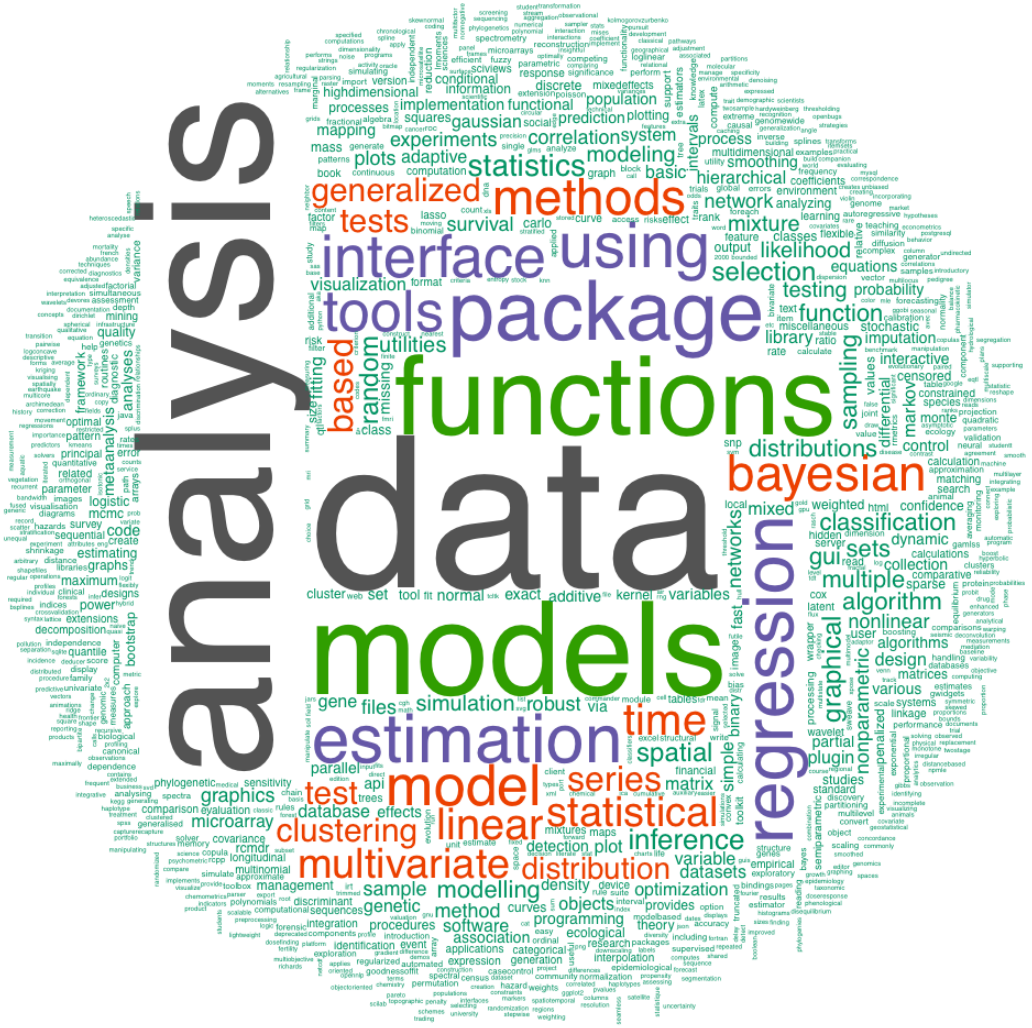
Four Scenarios of Input Detail

- "Defaults": fully defaulted except for weather [inputs: 1 required; 0 optional]
- "Asset: Visual" = non-intrusive, non-instrumented audit
  - Inputs: 18 required; 9 optional
- "Asset: Full" = Instrumented audit; more equipment & envelope characteristic data
  - Inputs: 26 required; 16 optional
- "Operational": = Asset:Full + behavioral inputs (interview)
  - Inputs: 28 required; 29 optional

* See https://sites.google.com/a/lbl.gov/hes-public/accuracy/decision-rules

Caveats

- Even “Operational” scenario was limited in rigor (lighting and misc. appliances poorly characterized in audits)
- Mapping good field-audit data to model inputs is challenging (e.g., duct locations and conditioned basements)
- Not all behavioral factors could be directly accommodated in the model (e.g., vacancy; zoned heating/cooling)



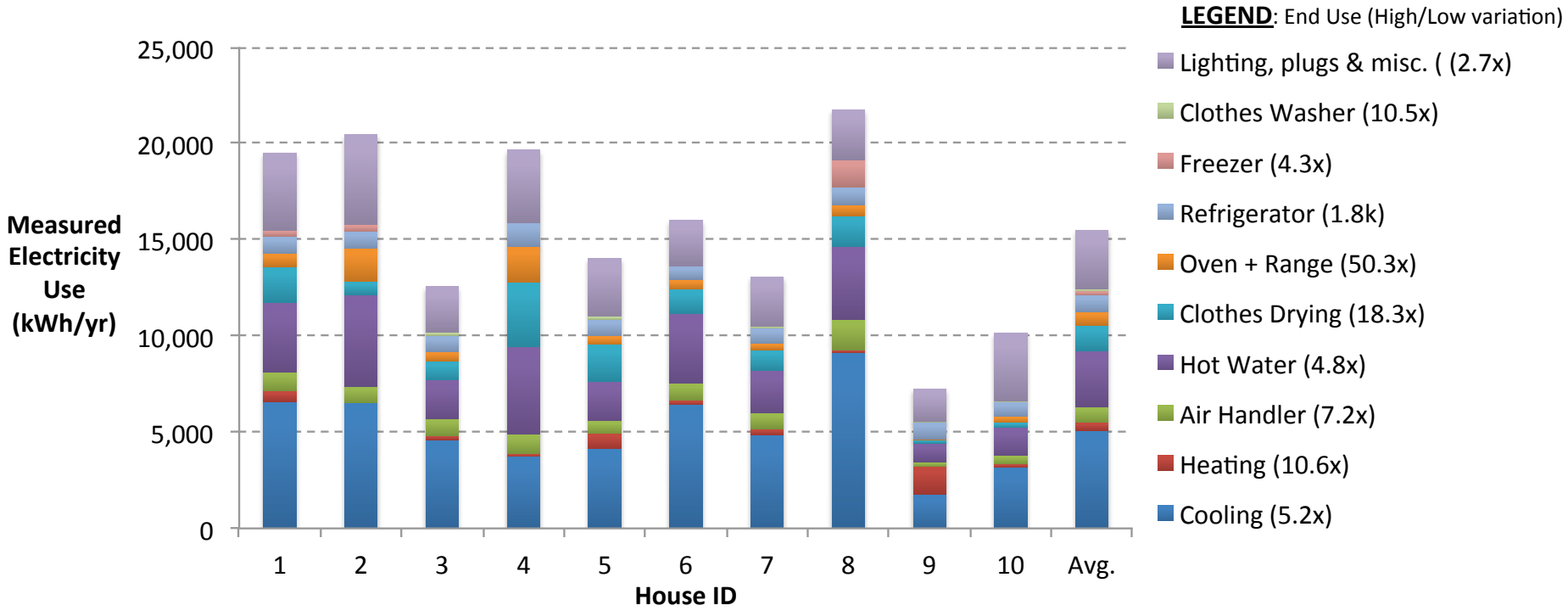
Sample Characteristics and HES Summary Results for the Four Cohorts of Homes

	FL: Homestead	FL: Florida Power Corp	Wisconsin	Oregon
Sample	10 homes	171 homes	139 homes	108 homes
Defaults	-15%	-19%	4%	66%
Asset:: Visual	-17%	-7%	68%	56%
Asset::Full	-25%	-5%	7%	19%
Operational	0.5%	1.3%	na	-0.4%

"Scatter" of results (CV) was also minimized in each of the Operational cases

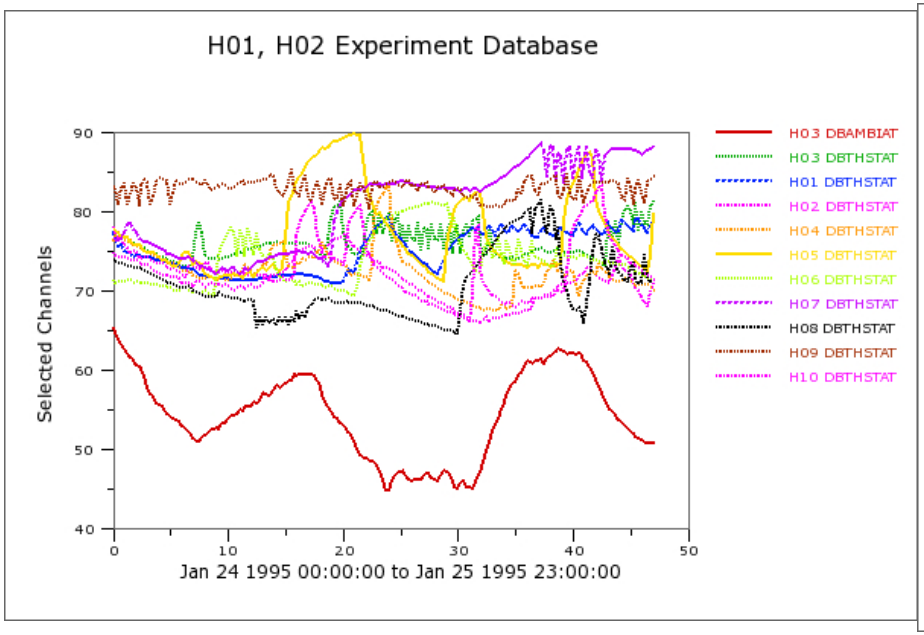
Homestead Cohort:
Virtually identical Homes & Efficiencies…
… but 3x Variation in Energy Use

- Even greater differences at end-use level
- End-use data extremely valuable for forensic accuracy assessment

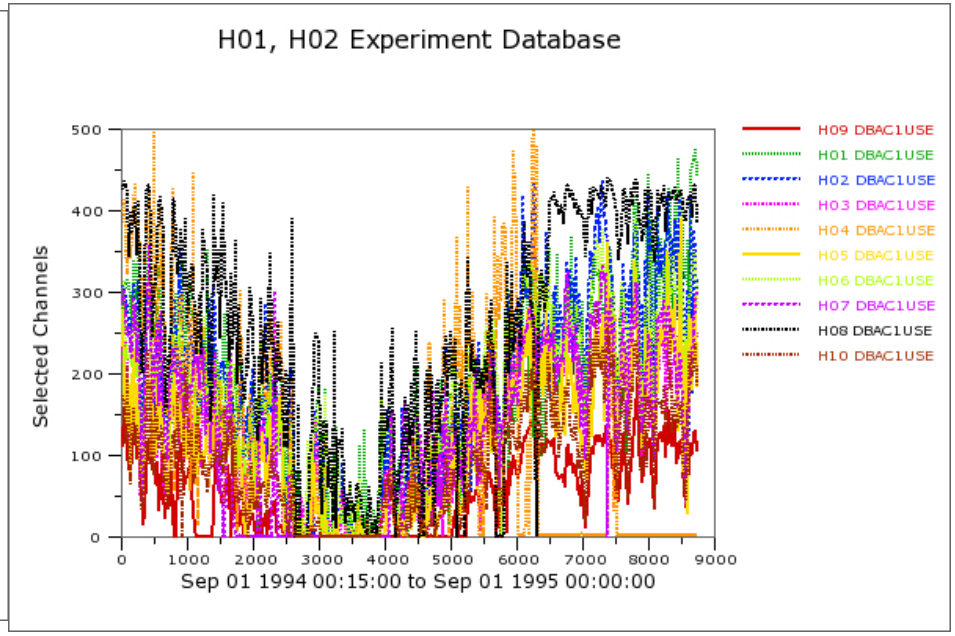


High-fidelity Interval Data for the Homestead Houses

Interior Temps: Jan. 24- 25th, 1995



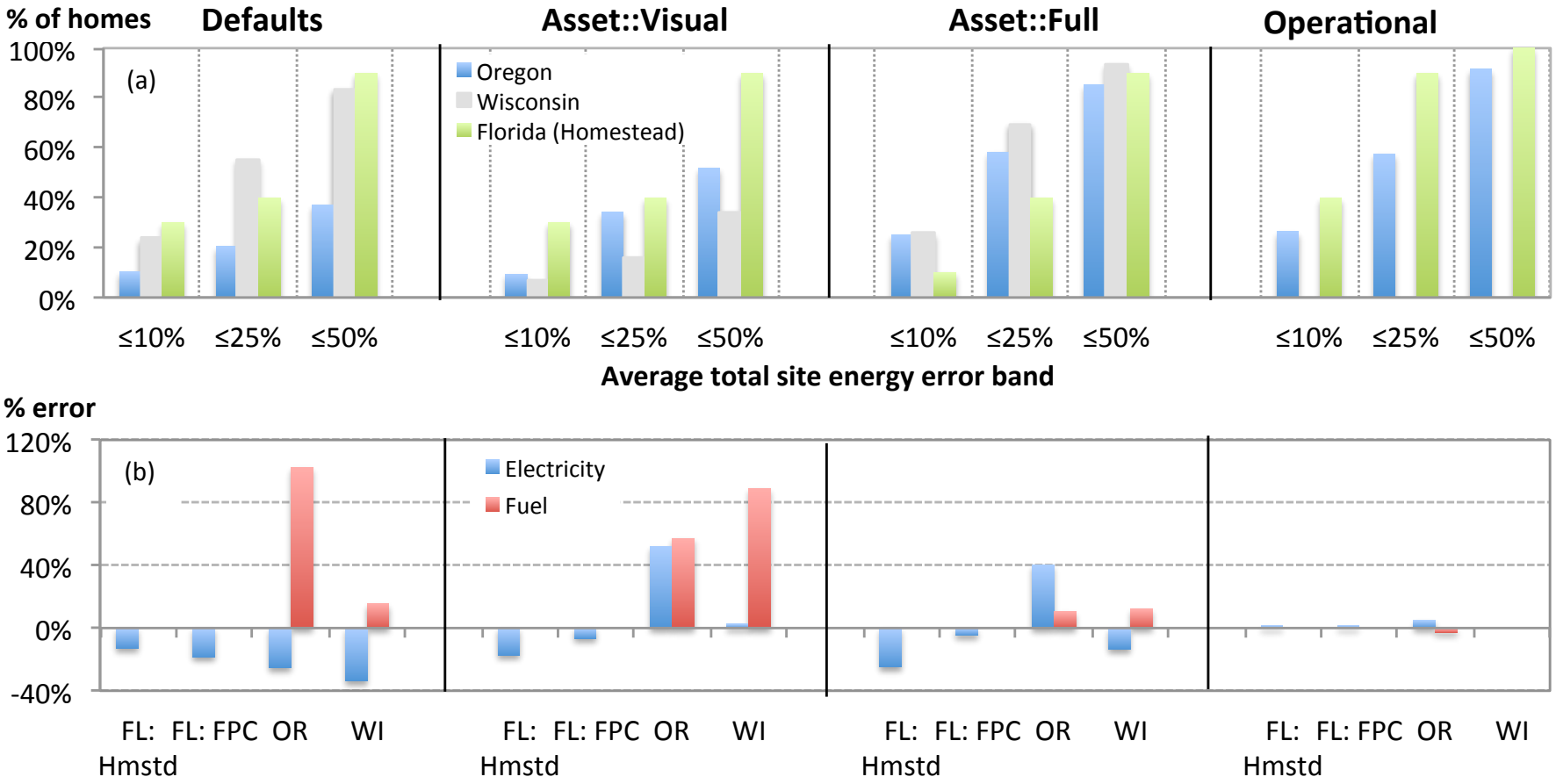
Heating Energy Use: Jan. 24th-25th, 1995



More at https://sites.google.com/a/lbl.gov/hes-public/accuracy/submetered-data

HES Accuracy by #Inputs (a) and Fuel (b)

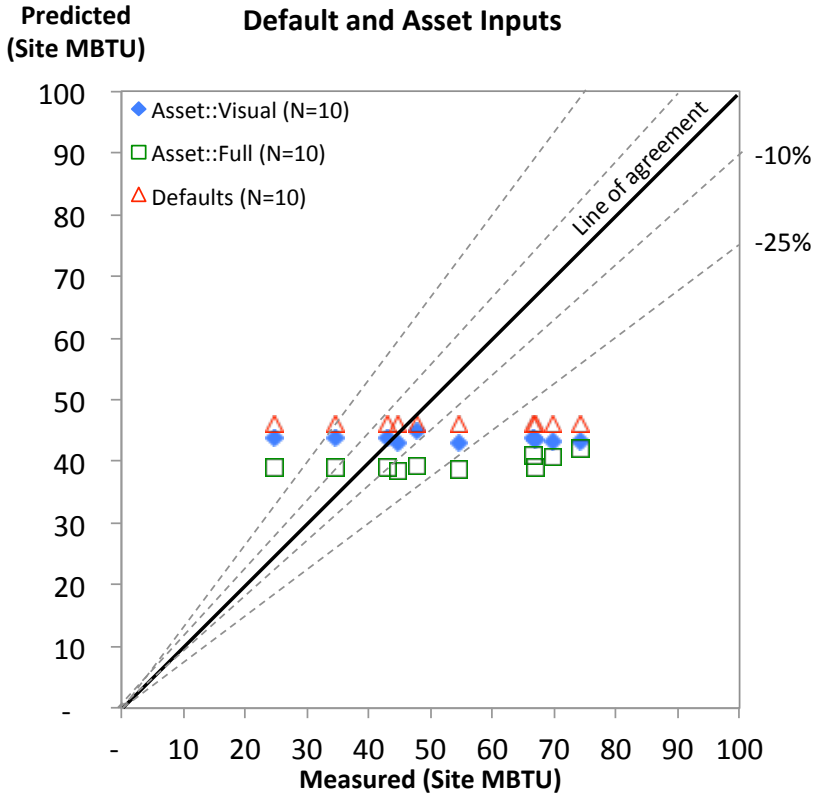
- More inputs <u>do</u> improve accuracy
- "Accuracy" can arise from offsetting errors

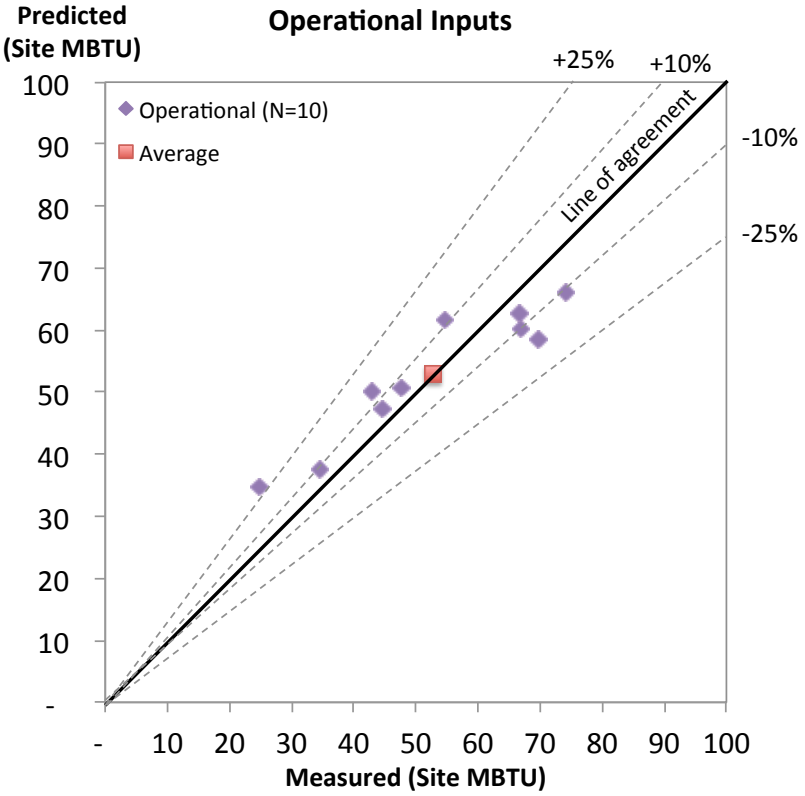


Note: Florida homes are all-electric

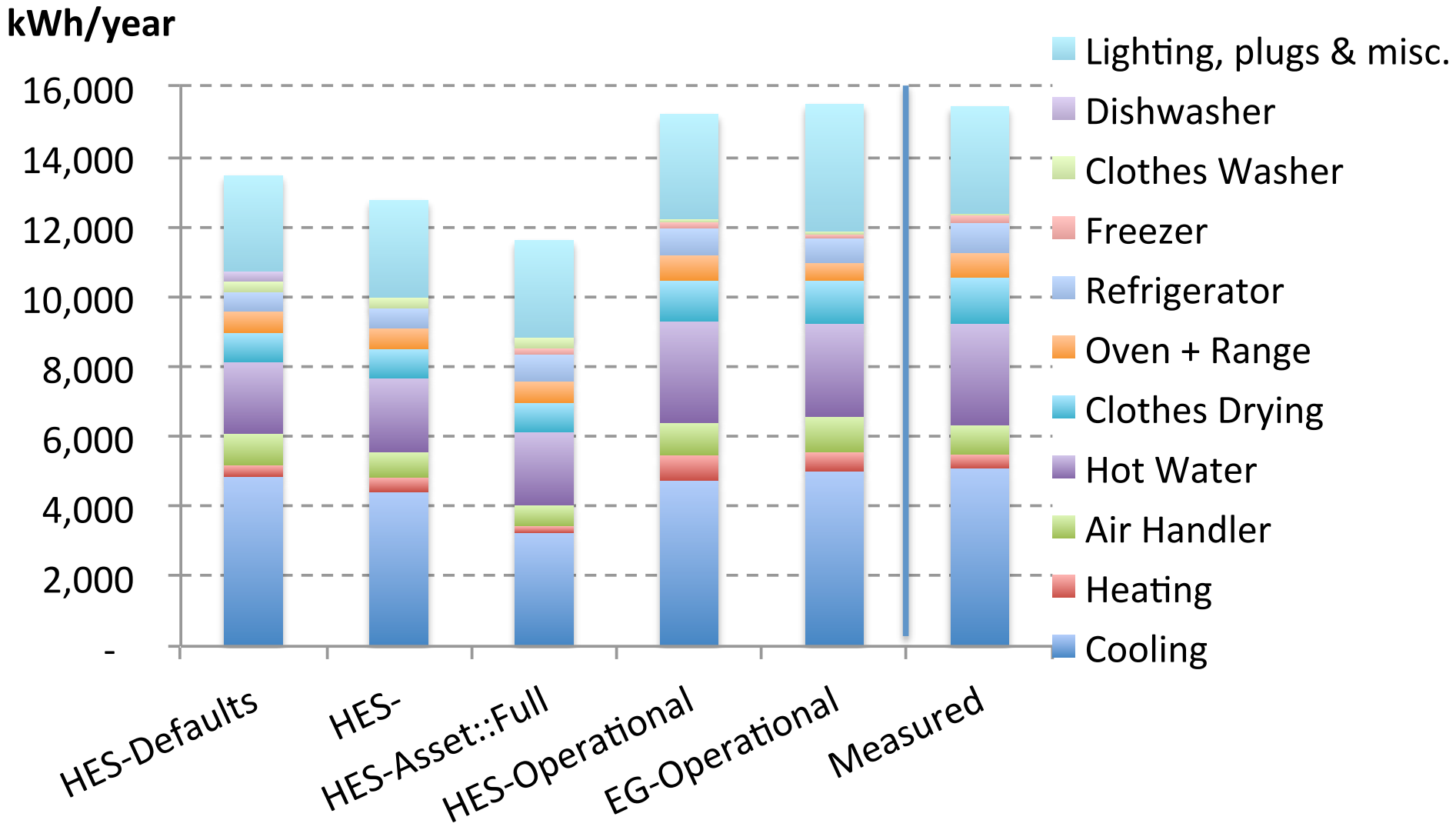
Measured *vs*. HES-predicted Annual Energy Use: Homestead Sample

- ***Asset*** analysis good on average; but often lousy for specific home
- ***Operational*** analysis accurate within 1%

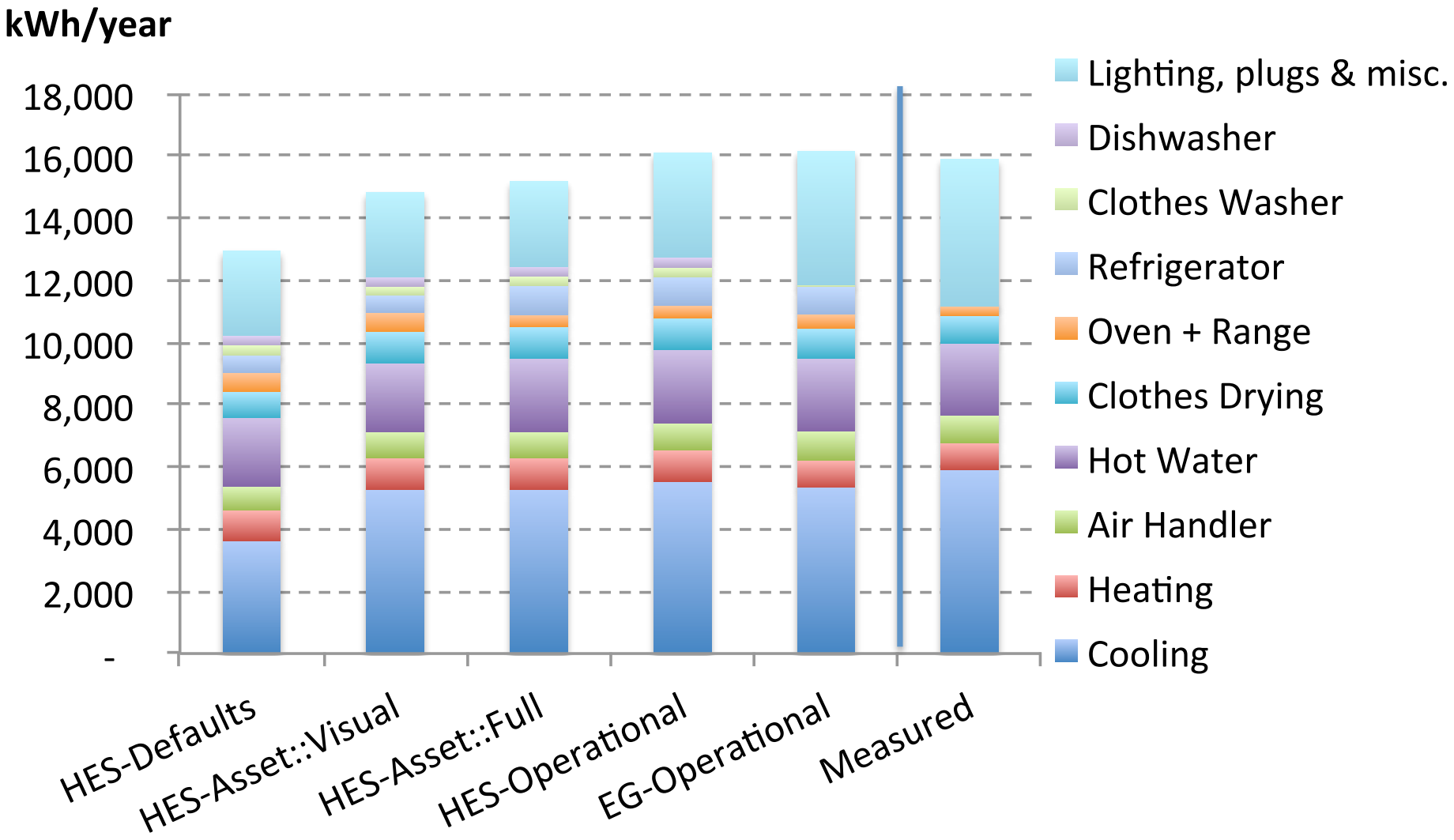




Results by End Use: Homestead Sample

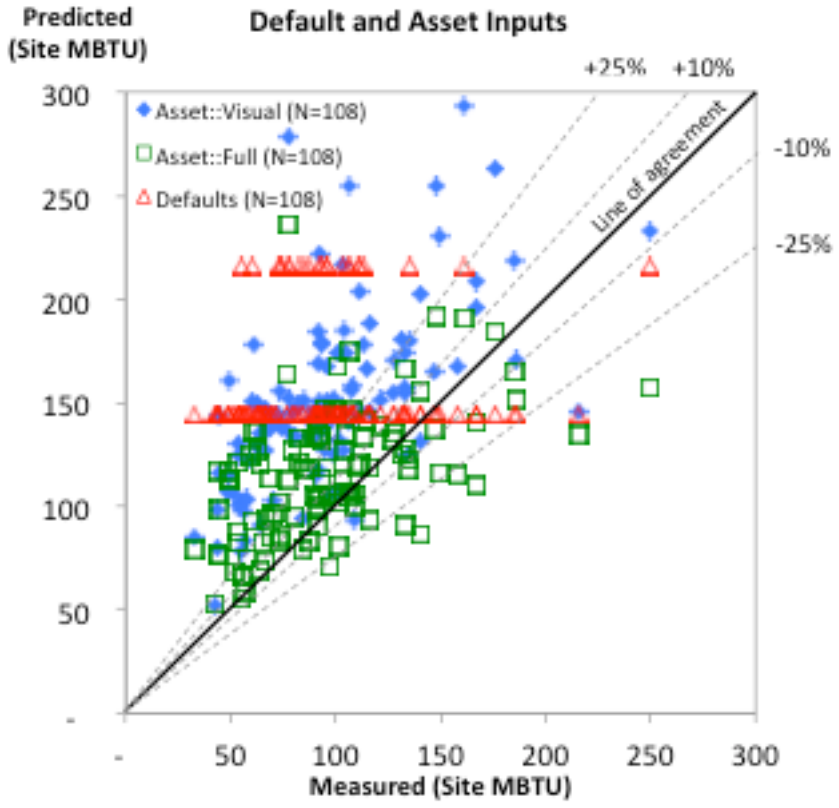


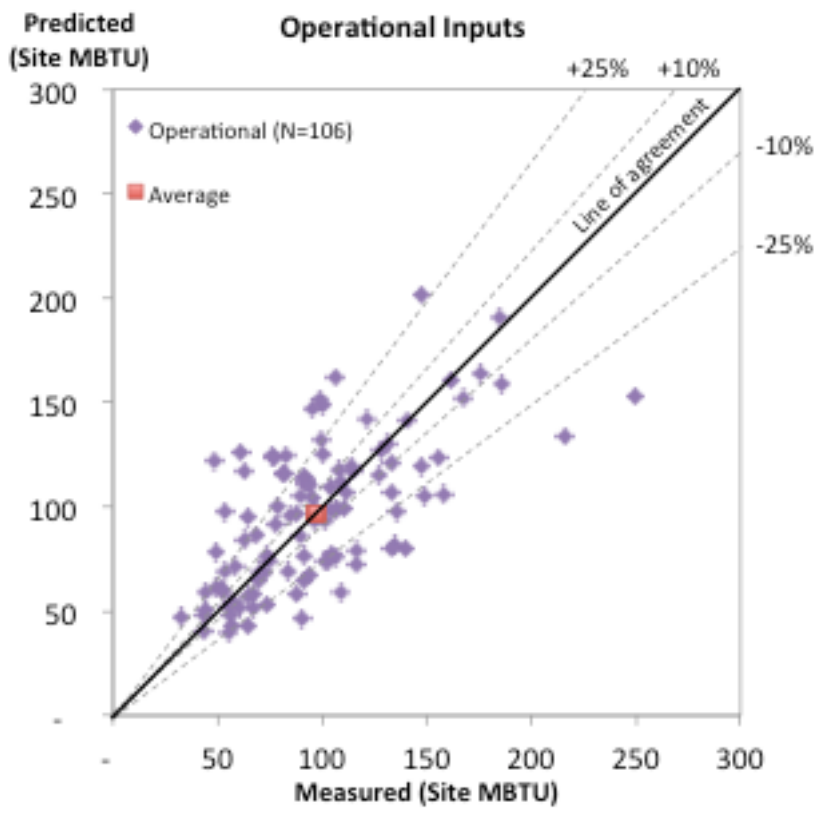
Results by End Use: Central Florida Large Sample



Measured vs. HES-predicted Annual Energy Use: Oregon Cohort

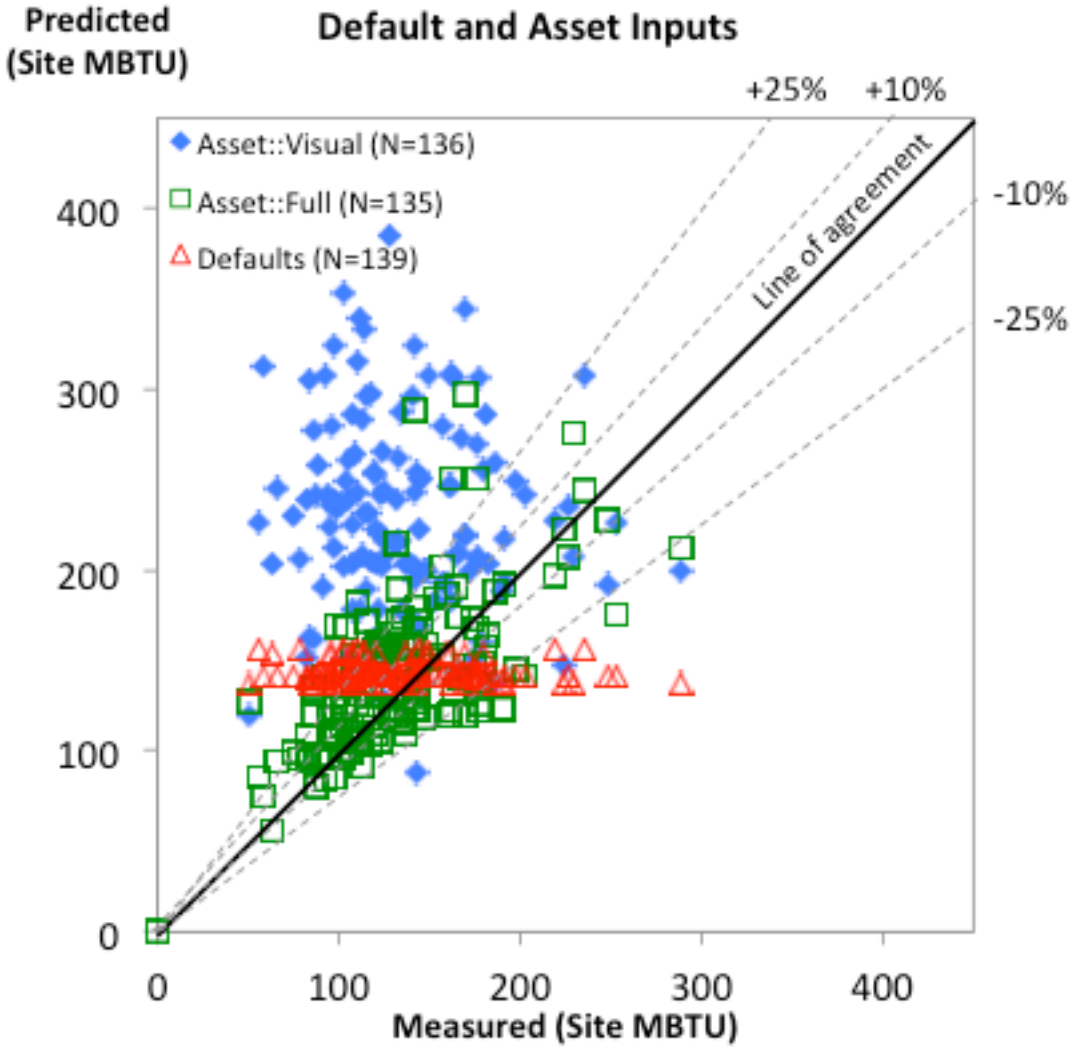
- Asset runs high, but improve with increased inputs
- Operational runs accurate to within 1%





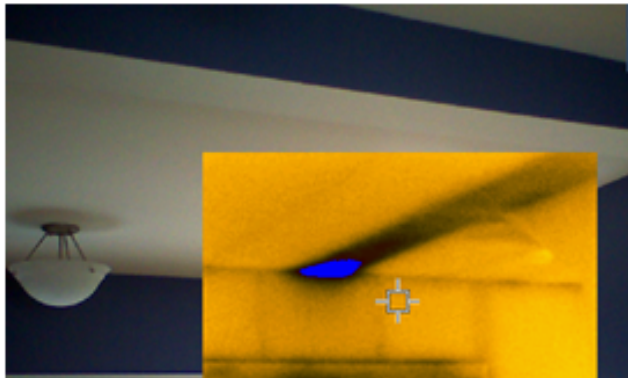
Measured vs. HES-predicted Defaults and Asset Annual Energy Use: Wisconsin

- Asset runs good with Full inputs
- Data did not support full operational analysis



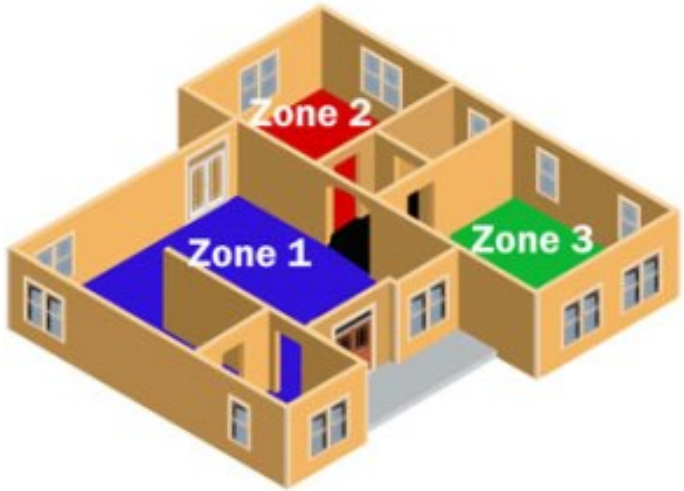
Value of Accuracy Assessment During Tool Development

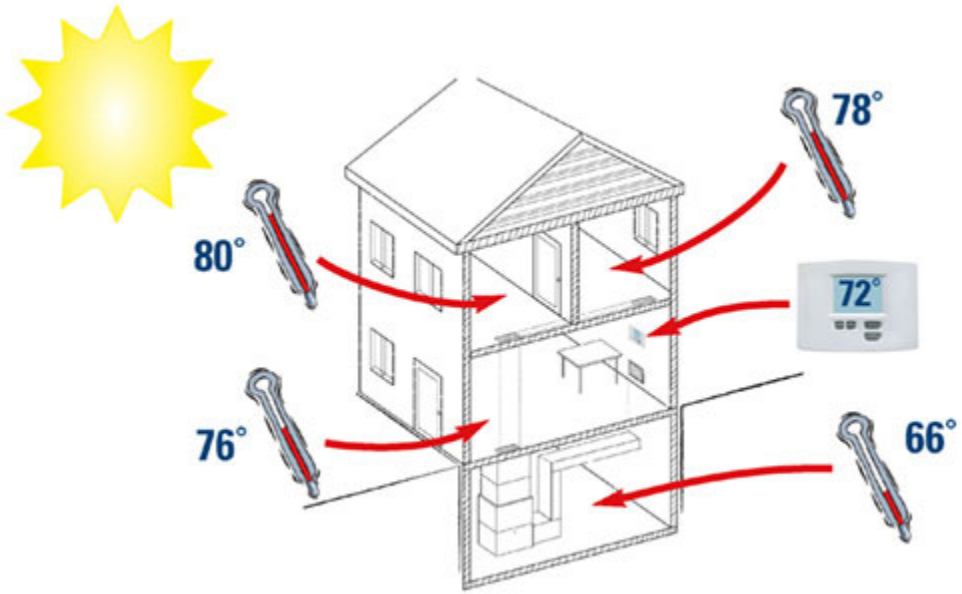
- Powerful: Compare measured data to model predictions vs. house/ equipment characteristics
- Identified bug in air handler/AC algorithm: results went from 75% under-prediction to 1% over-prediction in Florida home sample
- Identified need for updates to duct model, and inappropriate treatment of regain
- Identified and repaired inappropriate free heat from certain appliances (e.g. clothes dryer venting)
- Host of improvements/updates to defaults



Future Simulation Enhancements

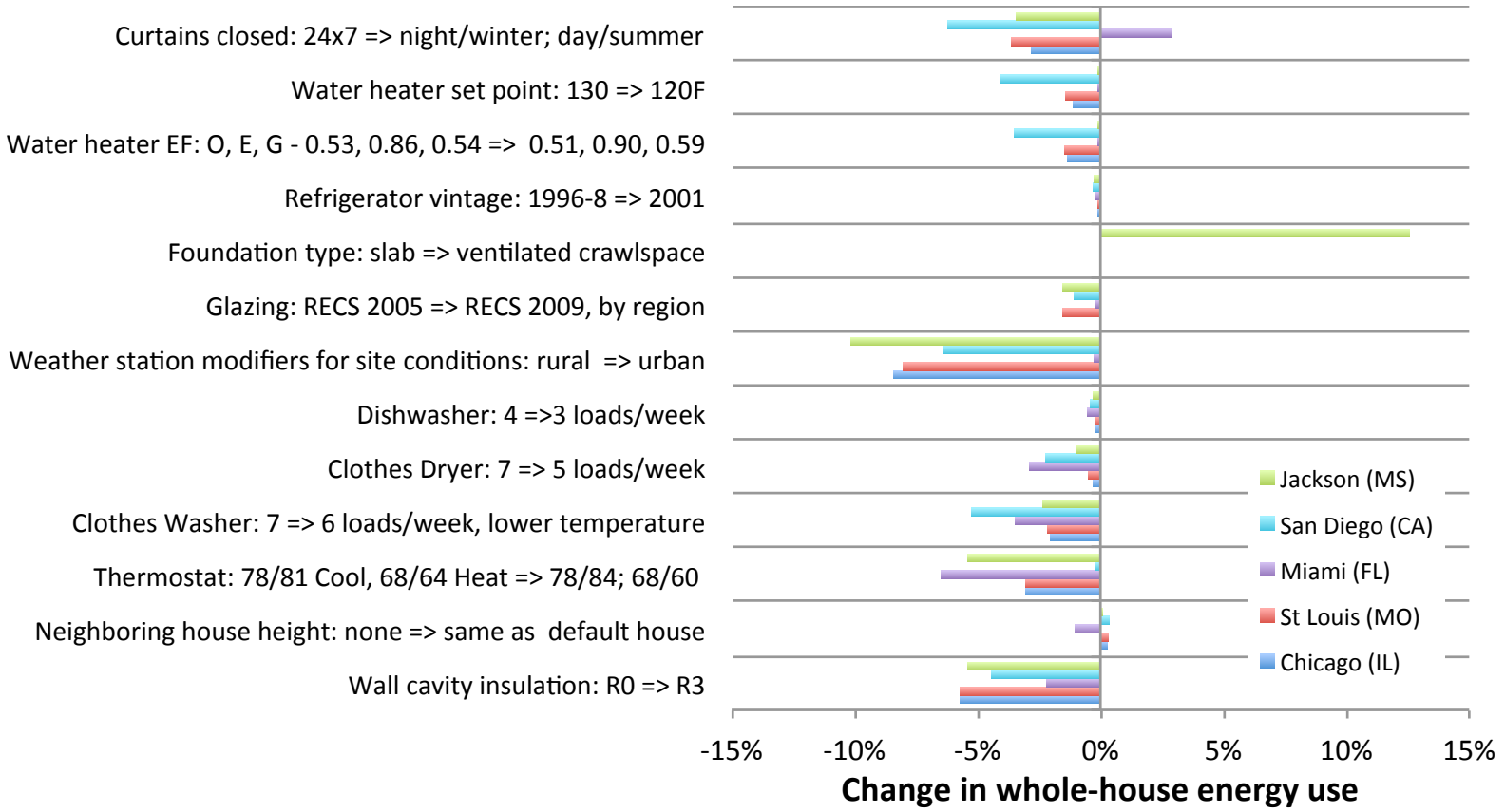
- Influence of partition walls: interior walls in poorly insulated homes provides significant increases in overall thermal resistance
- Zoning: GRI evaluation in 1980 revealed 30% reduction in heating from zoned vs. central
  - Hydronic & mini-splits
- Degree of basement conditioning
  - Known source of over-prediction
- Updates to duct model with treatment of regain
- Window heat transfer from curtains/insect screening (empirical & laboratory data)
- Heat Pump Water Heaters
- Mini-split heat pumps





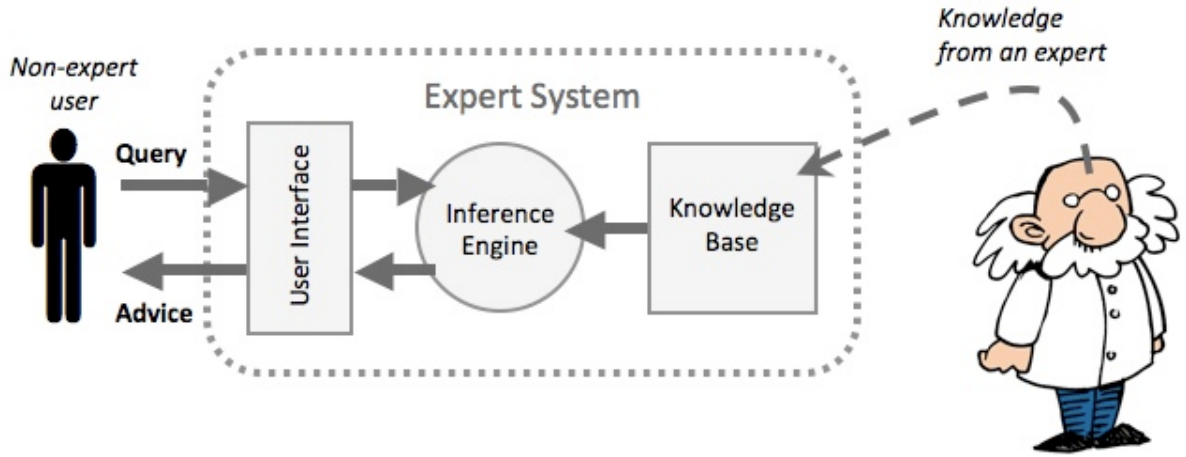
Defaults Assumptions are Important

- Sensitivity of HES-predicted whole-house Energy Use to old vs new default assumptions



Smart User Interface

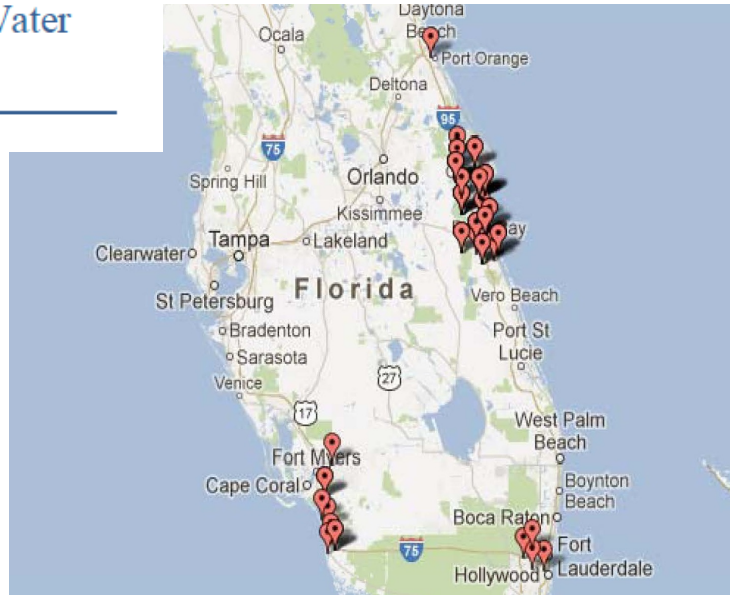
- Critical inputs for revised user interface
- What matters most? Big knobs?
  - Always big (e.g. thermostat/hot water use)
  - Infrequent but big (e.g. spas/pools)
- Empirical evidence (e.g. RECS)
- Parlay most powerful info from limited user attention span/patience



Unique New Test Data!
Phased Deep Retrofit Project

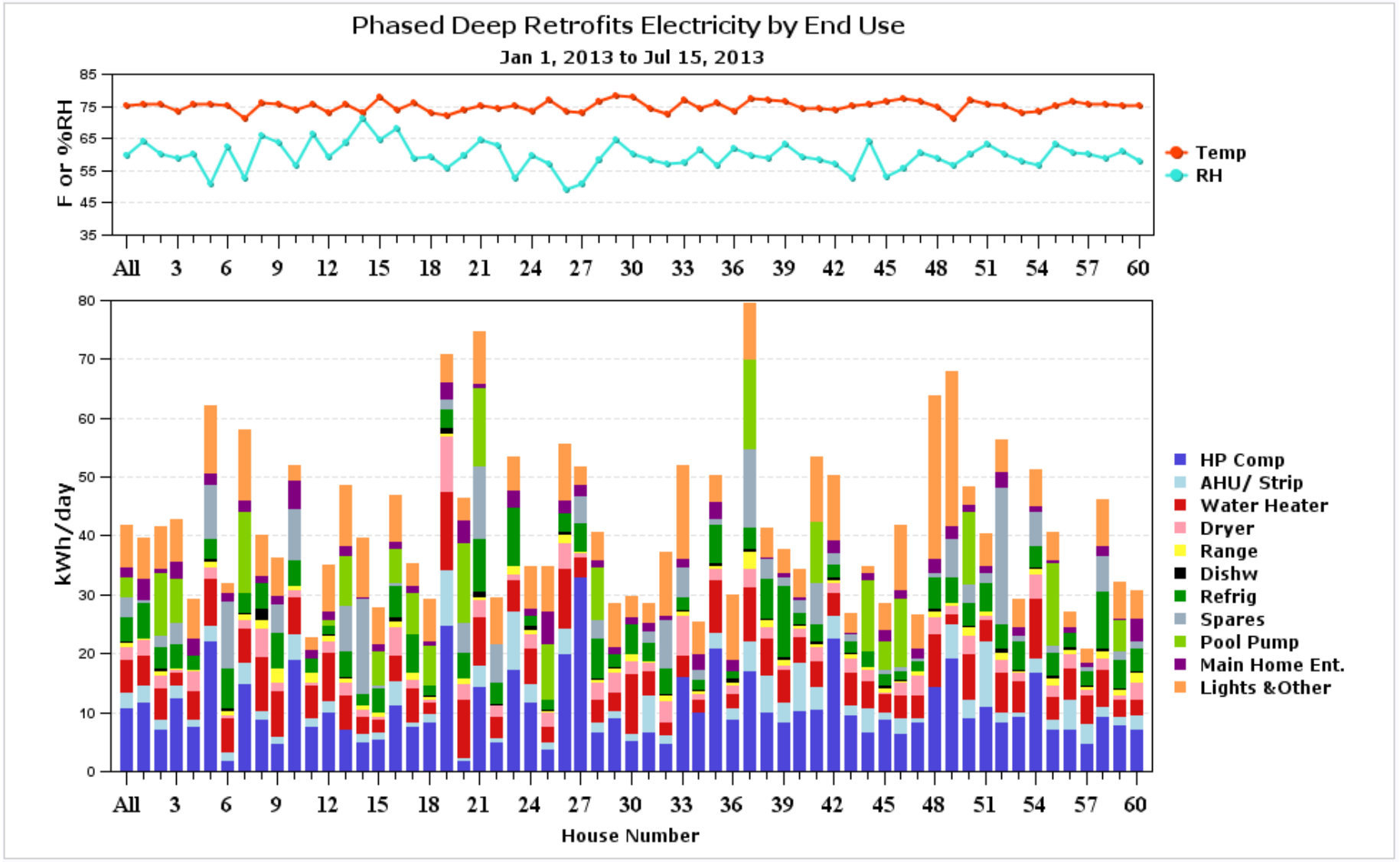
Table 1. Description of simple and deep retrofits

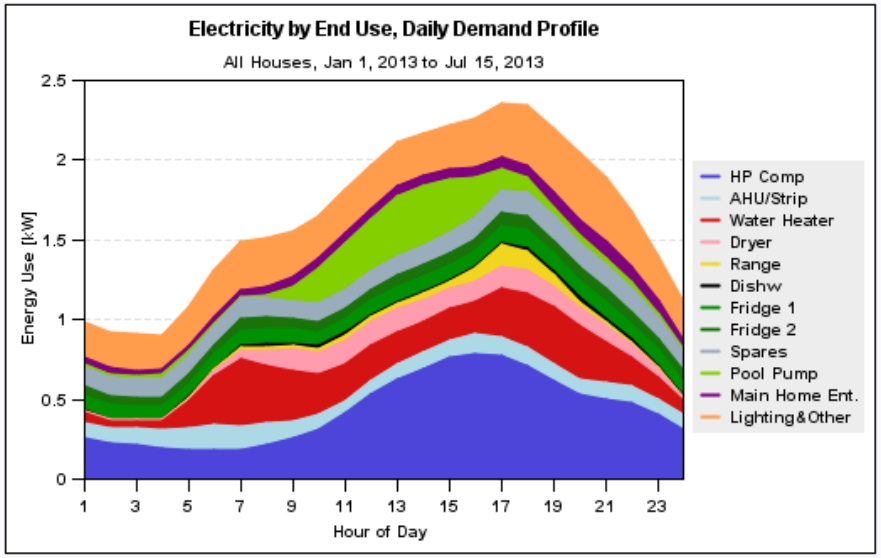
Phase I Simple Retrofits	Phase II Deep Retrofits
Hot Water Tank and Pipe Insulation	Upgrade to R-38 Ceiling Insulation
LED / CFL Lamps	Duct Testing and Sealing
Cleaning of Refrigerator Coils	Energy Star Refrigerator and Clothes Washer
Low Flow Showerheads	High Efficiency Heat Pump for Space Conditioning
Reduction of Pool Pump Hours	High Efficiency Pool Pump
Smart Power Strips for Home Offices and Entertainment Centers / Game Consoles	Heat Pump and/or Solar Water Heating



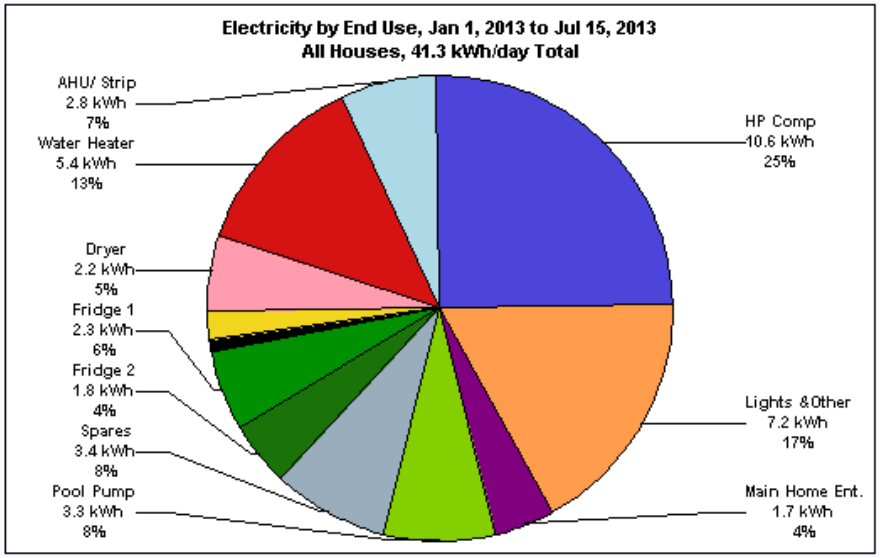
New Data: Extensive end-use metering from Phased Deep Retrofit project

- Jan – July 2013: 60 Florida all-electric S. Family homes
- Receiving shallow & deep retrofits
- Lighting, HPWH, AC retrofits, new dryers etc…
- Useful for additional HES testing/validation
- 18 channels
  - Whole house power down to the TV!
  - All major end uses
  - Interior temperature & humidity
  - Hourly data
- Created analysis system for graphic summary
  - Hourly time series; hourly load shape; daily averages
  - See long term, load shape trends and seasonal changes
  - By site; by groups, over discrete time intervals
- How can you make sense of 5.8 million data points?


Phased Deep Retrofits Electricity by End Use
Jan 1, 2013 to Jul 15, 2013
F or %RH
85
75
65
55
45
35
All 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60
Temp
RH
kWh/day
80
70
60
50
40
30
20
10
0
All 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60
House Number
HP Comp
AHU/ Strip
Water Heater
Dryer
Range
Dishw
Refrig
Spares
Pool Pump
Main Home Ent.
Lights &Other



Expand Download

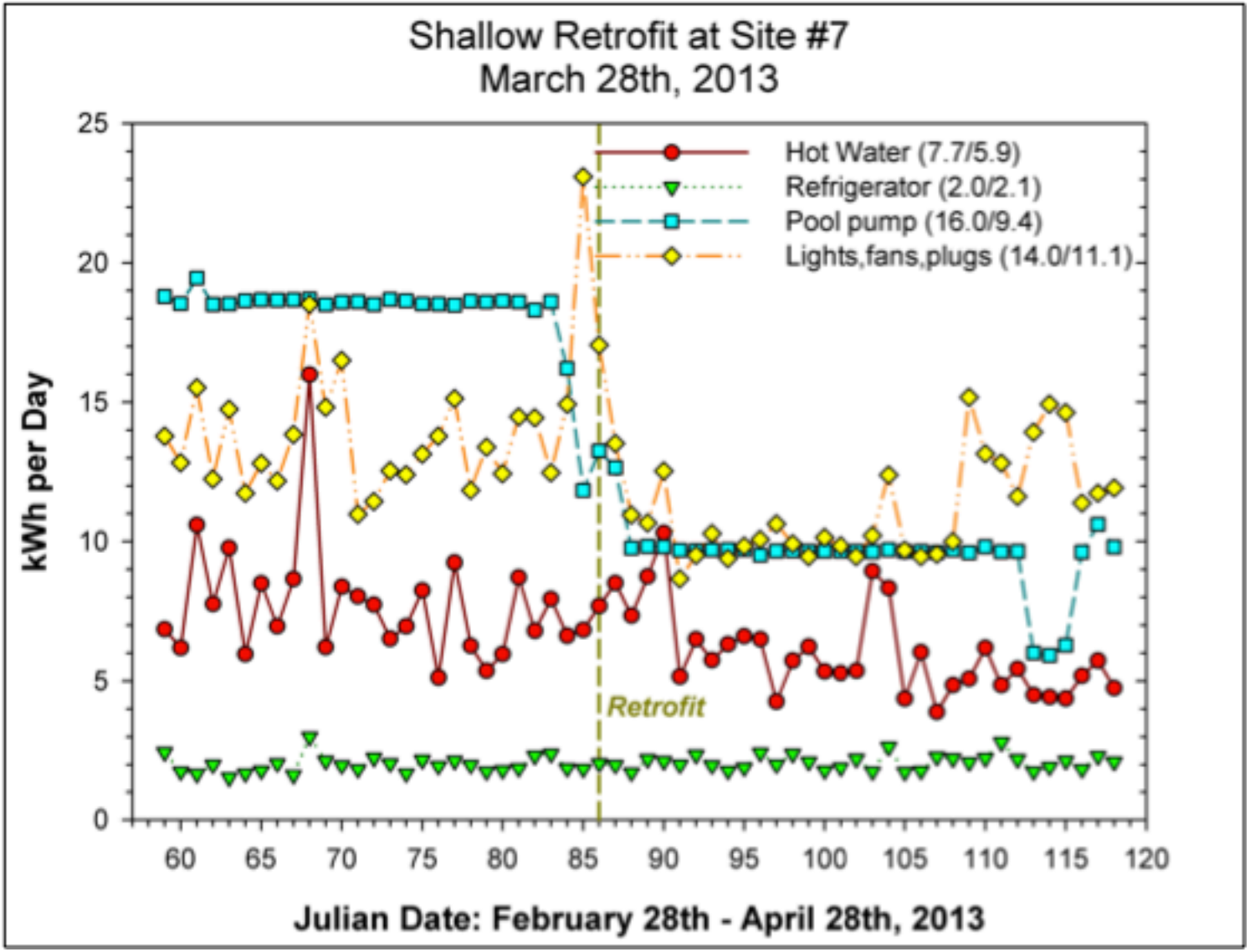


Expand

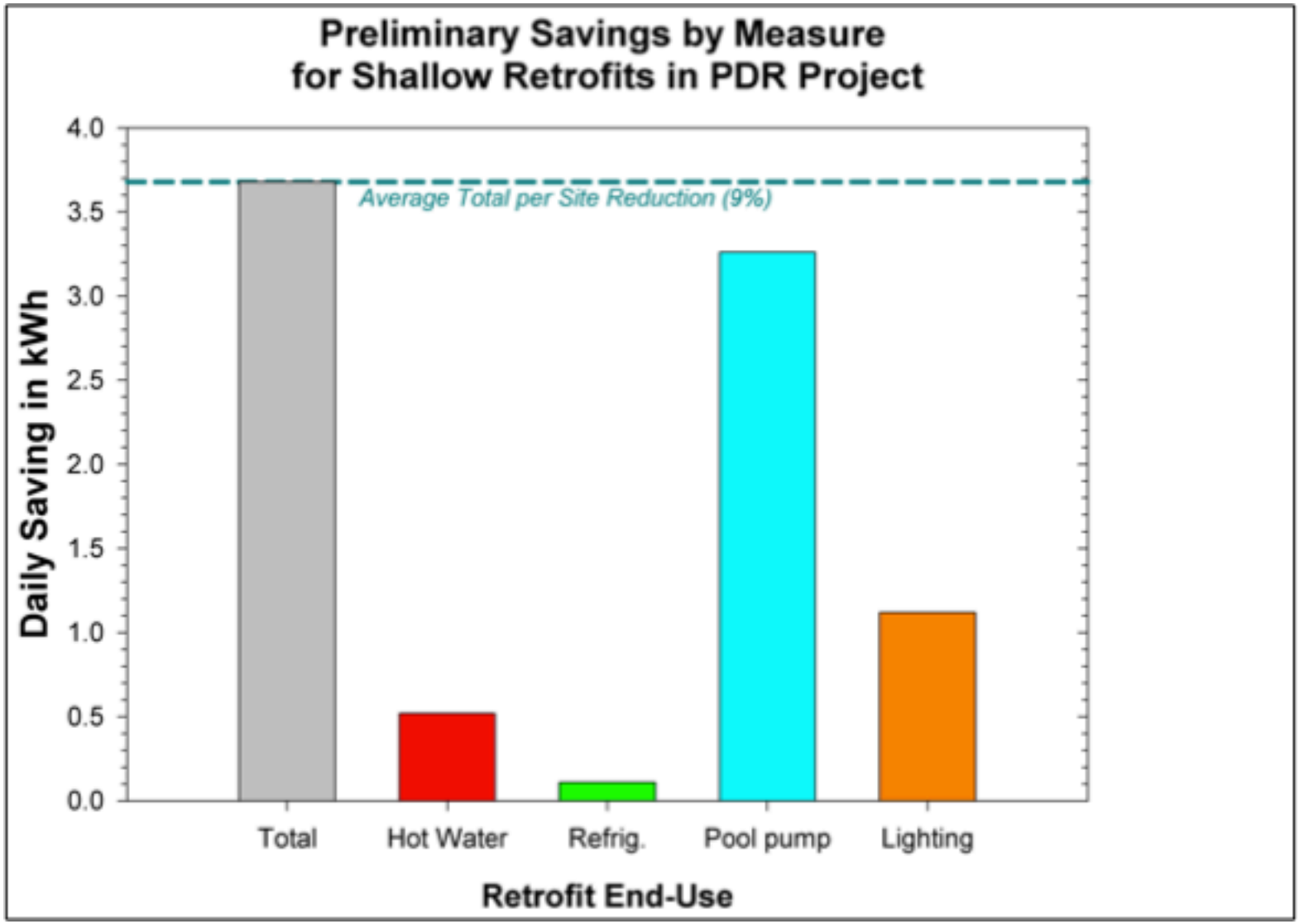
Homes that have pools show pool pumping to be another very large electrical load – 5.2 kWh/day.

The main television and entertainment center, seldom considered from an energy-efficiency perspective, was found to use a large amount of energy (approximately 750 kWh/year).

Example of a Shallow Retrofit…



Overall Shallow Savings…



HES Accuracy: Take-aways

- ***HES Pro: Operational factors brings accuracy to < 1% of actual bills***
  - minimizes variance relative to asset analyses
  - Accuracy found excellent at the end-use level
  - Repeatability results in large samples in varied climates
- ***Operational factors have as great an effect on accuracy as do physical characteristics***
- How you run the house matters at least as much as the house construction and equipment. Major conclusion!
- Deficiencies or gaps in audit data erode perceived accuracy
  - Lighting and miscellaneous energy use are important
- Accuracy assessments (prediction vs. data) aid model development
  - Errors often offset one-another; can give false illusion of accuracy
  - Embrace new end-use data sources such as PDR project
- Building simulation community now capturing important nuances (e.g. basement thermal performance)
- Improved modeling of lighting/miscellaneous energy and zoning are important to further improvements in accuracy