Speeding the Audit and Rating Processes

Rethinking what data we really need

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Presented by: Michael Blasnik
M. Blasnik & Associates
mb@michaelblasnik.com

All models are wrong, but some are useful

G. P. Box

Everything should be made as simple as possible, but no simpler

Albert Einstein (paraphrased)

Why Collect Data about houses?

- To assess efficiency
  - Energy ratings, energy labels
  - assess compliance with standards
    - Energy Star, etc…
- To help figure out what to do
  - Audits / retrofits measure selection
    - Projections of savings
    - Details needed for work orders
  - comparing design options
- To manage work
  - Track what happened
  - Help evaluate impacts

Principles for Data Collection

- Only collect data that meets 3 conditions
  - can be collected with sufficient accuracy for the intended use
  - and can lead to more effective actions or more accurate conclusions than other approaches
  - and the value of the data is greater than the cost to collect it and analyze it

Should we insulate the uninsulated wall?
Hmmm, let's do some hourly simulations…

Energy Model Accuracy

- How does modeled energy use compare to actual?
- How much can we blame the occupants?
- How about the auditors / field people?
- Do differences between models and actual energy use vary systematic?
  - Are there particular features that are hard to model?
- Are the models revised based on measured data?

Energy Model "Testing"

BESTEST criteria (from DOE2, BLAST, SERIRES)

- Official software test allows for wide ranges of projected usage
  - Base case heating scenario can use from 50-80 MMBtu/yr
    - Even though inputs clearly defined, simplified house with constant infiltration and int. gains
  - Doesn't test using CFM50, many real issues
  - Does test bizarre buildings to assess physics calcs

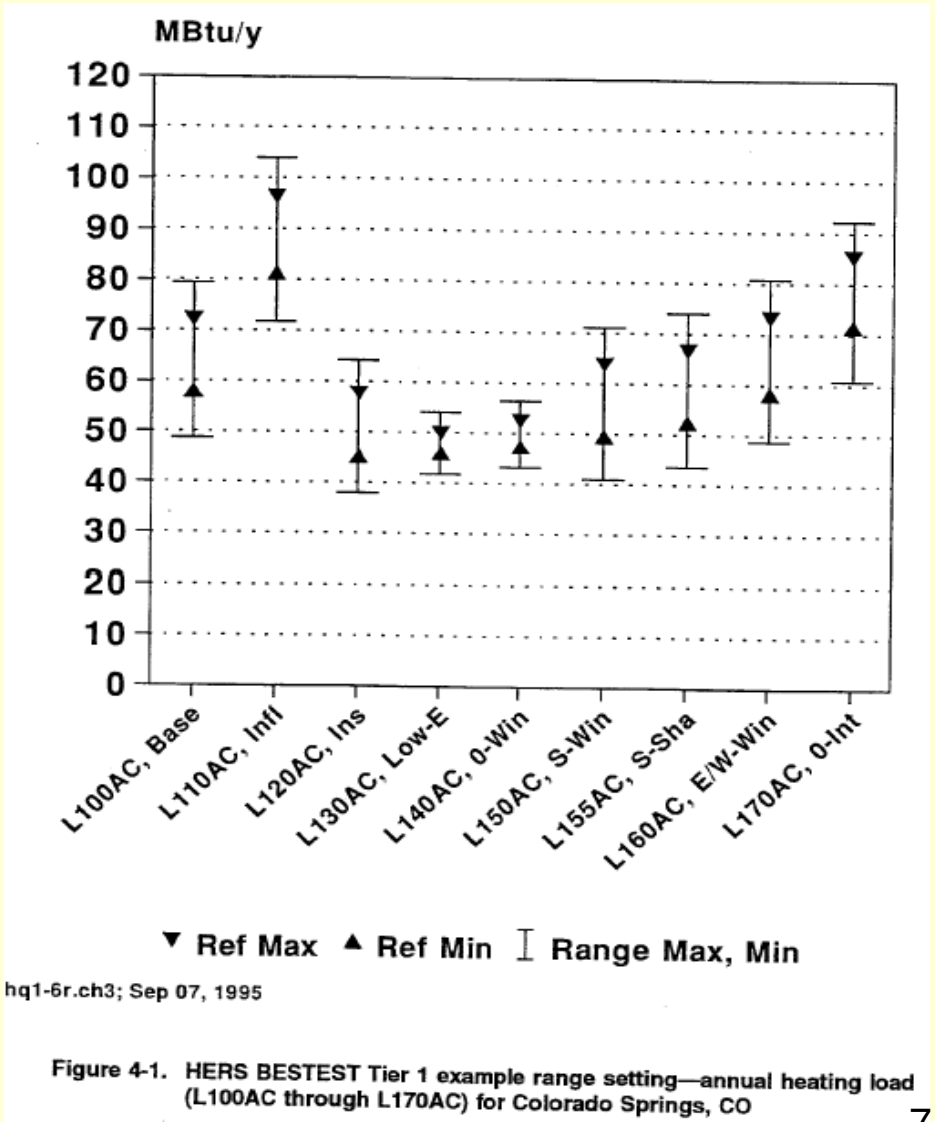
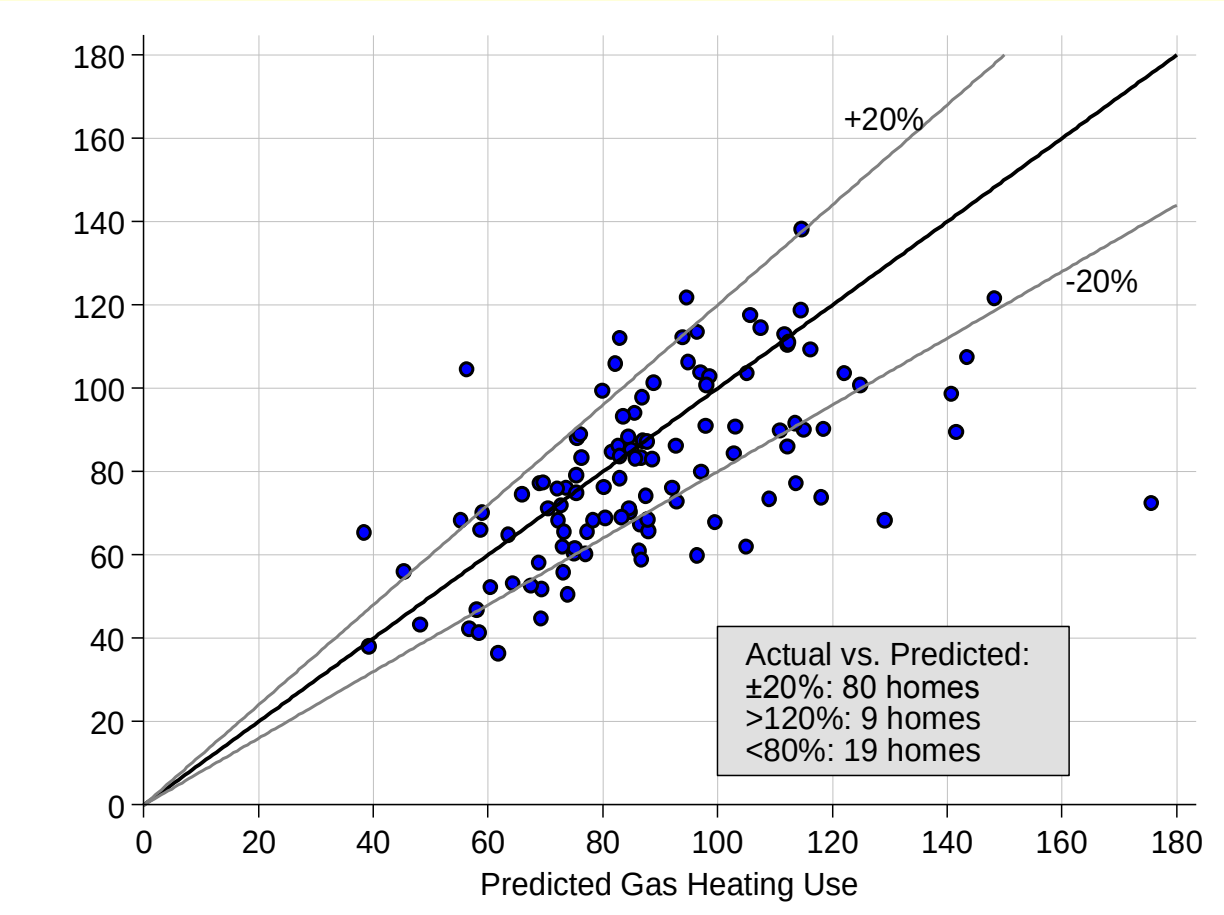


Figure 4-1. HERS BESTEST Tier 1 example range setting—annual heating load (L100AC through L170AC) for Colorado Springs, CO

NY ES New Homes
Actual vs. Projected Gas Heating Usage

- REM-Projected Usage 10% too high avg.
  - 1190 vs. 1069 actual
  - Heat: 881 vs. 804
  - Base: 309 vs. 265
- Typical error= 17%
- Correlation pretty good, but house size drives relationship



ON TEENAGERS, ADULT:

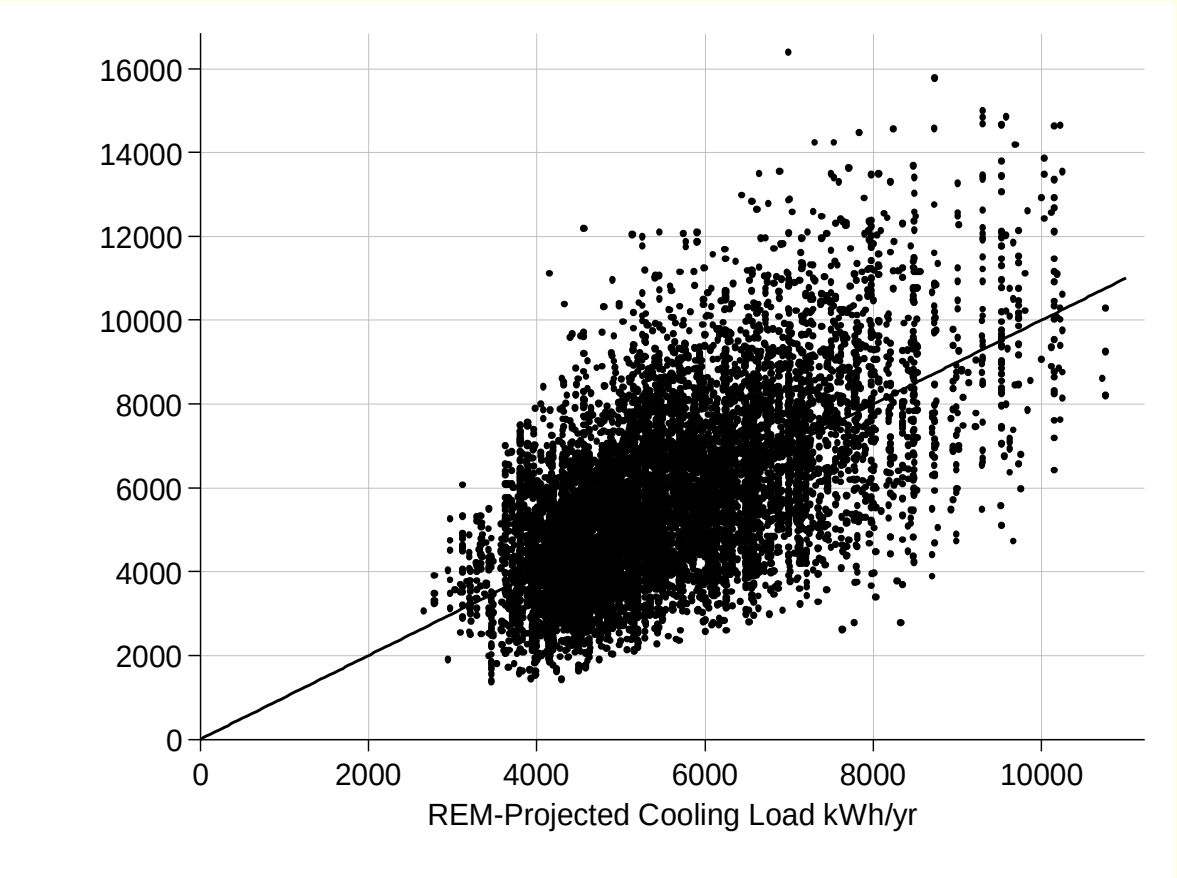
Statistics show that teen pregnancy drops off significantly after age 25.

Mary Anne Tebedo, Republican state senator from Colorado Springs (contributed by Harry F. Pancec)

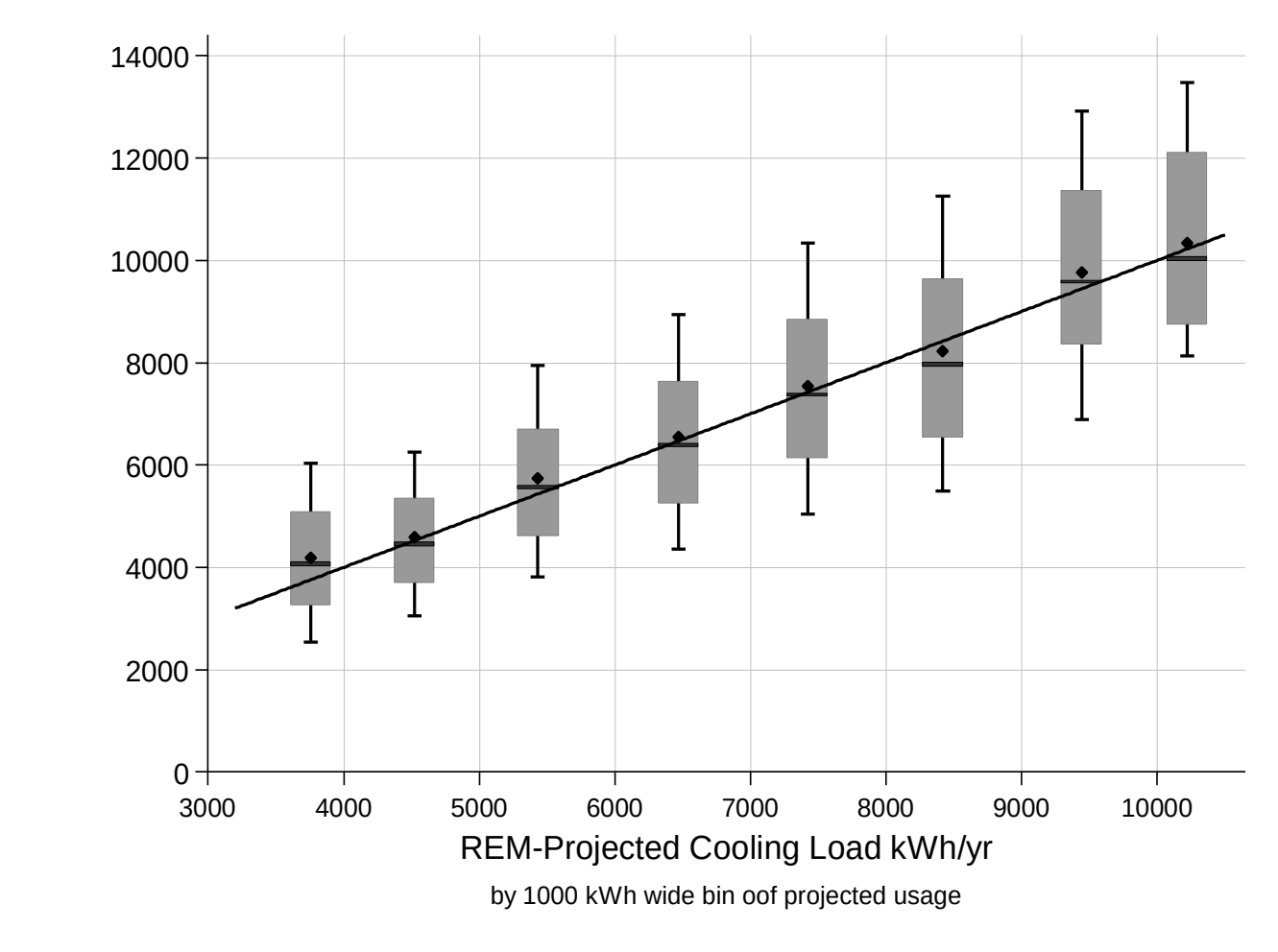
MONDAY DECEMBER 1999

Houston Energy Star Homes Study

- actual vs. predicted cooling
  - 10,258 homes
  - Lots of scatter
  - Averages close
    - REM= 5,506
    - Actual= 5,677
  - 17% Median diff
  - “actual” = billing data, includes seasonal loads
  - Models based on floor plan and max CFM50, CFM25
  - Model run with default occupancy

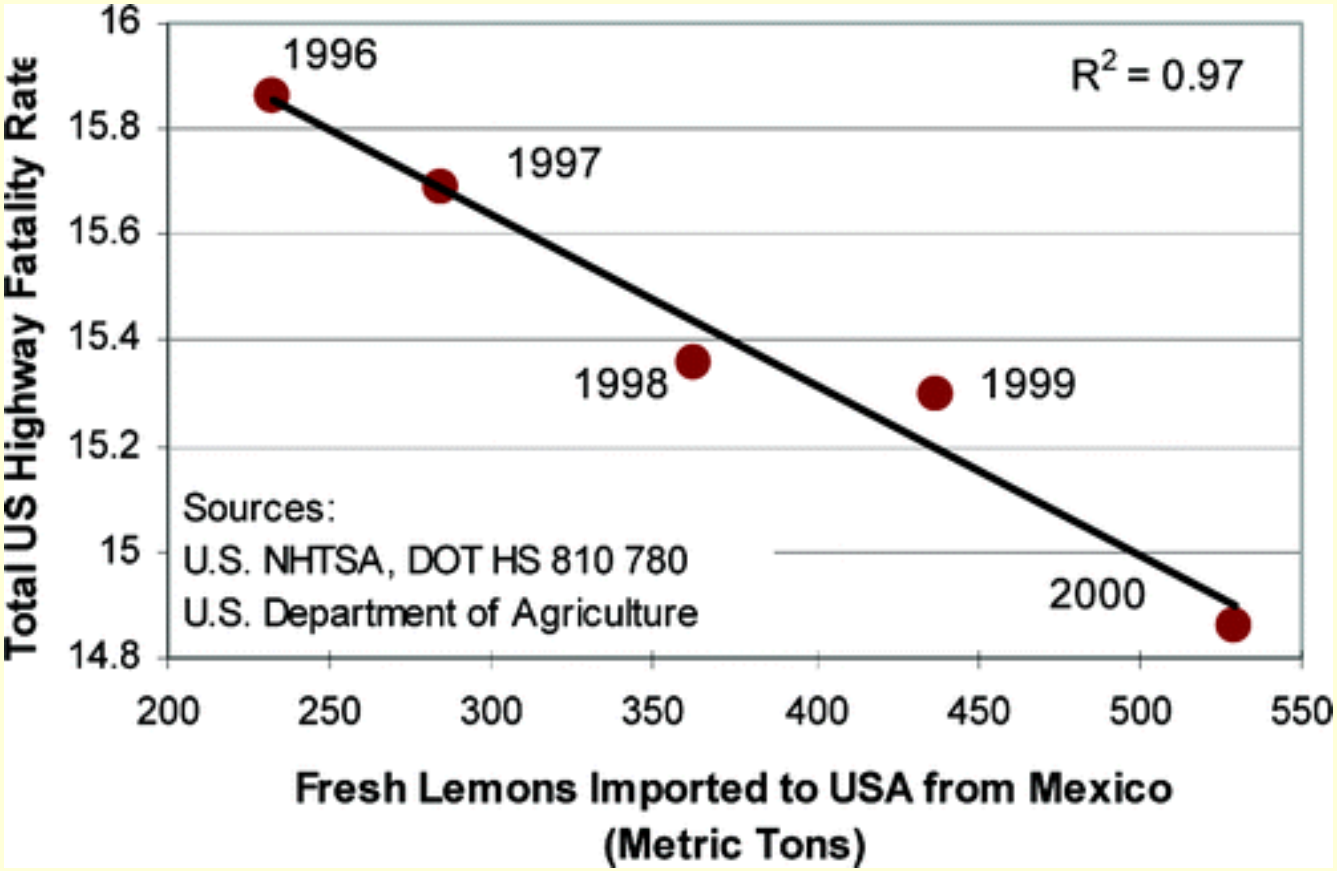


Houston Energy Star Homes Study



Combined projected loads into 1,000 kWh bins – agreement looks good

But remember…
correlation does not mean cause and effect…..

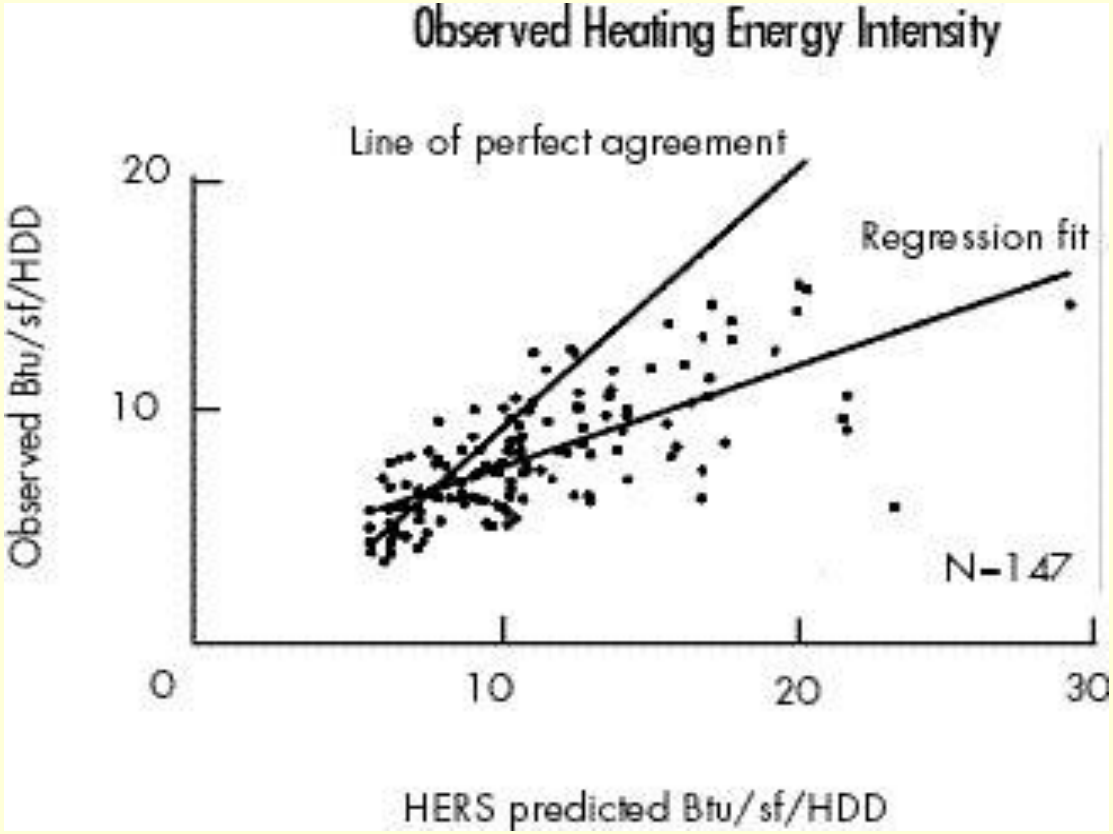


There is nothing so horrible in nature as to see a beautiful theory murdered by an ugly gang of facts - B. Franklin

Existing Homes: Wisconsin HERS Study

"A Rating Tale", S. Pigg, Home Energy Magazine Jan/Feb 2001

- Projected use 22% high on average
- "badly overestimated for inefficient homes"
  - Low scores too low: 50 should be 70!
  - High scores too high
- 90% of homes should have scored 74-84



Existing Homes
Retrofit Savings Predictions

- Evaluation studies show savings only 50%-70% of projected savings (realization rate)
  - NEAT Audit: 50%-60% of projected
    - NC (Sharp 1994) 13.9 of 24.4 MMBtu, 18 houses
    - NY (Gettings 1998): 53 of 105 MMBtu, 49 high users
    - IA (Dalhoff, 1997): 20.3 vs. 37.3 MMBtu, 42 homes
  - Problem not just thermal measures
    - OH electric baseload program 58%-68% of projected, NJ 60%-69%

Why Are Savings Overestimated?

- Damn Occupants!?
  - Easy scapegoat, but little evidence of takeback effect
    - Behavior should create noise, not bias, unless takeback occurs
  - Occupants do affect showerheads, CFLs, t-stats
- Poor Work Quality?
  - Potentially for high skill retrofits: insulation, air/duct sealing
- Models / Calculations are Poor
  - Projected savings too high, especially in inefficient homes
    - Pre-retrofit use is over-estimated dramatically while post-retrofit use is pretty close
  - Poor assumptions, biased inputs, bad algorithms

Common Flaws with Projected Savings

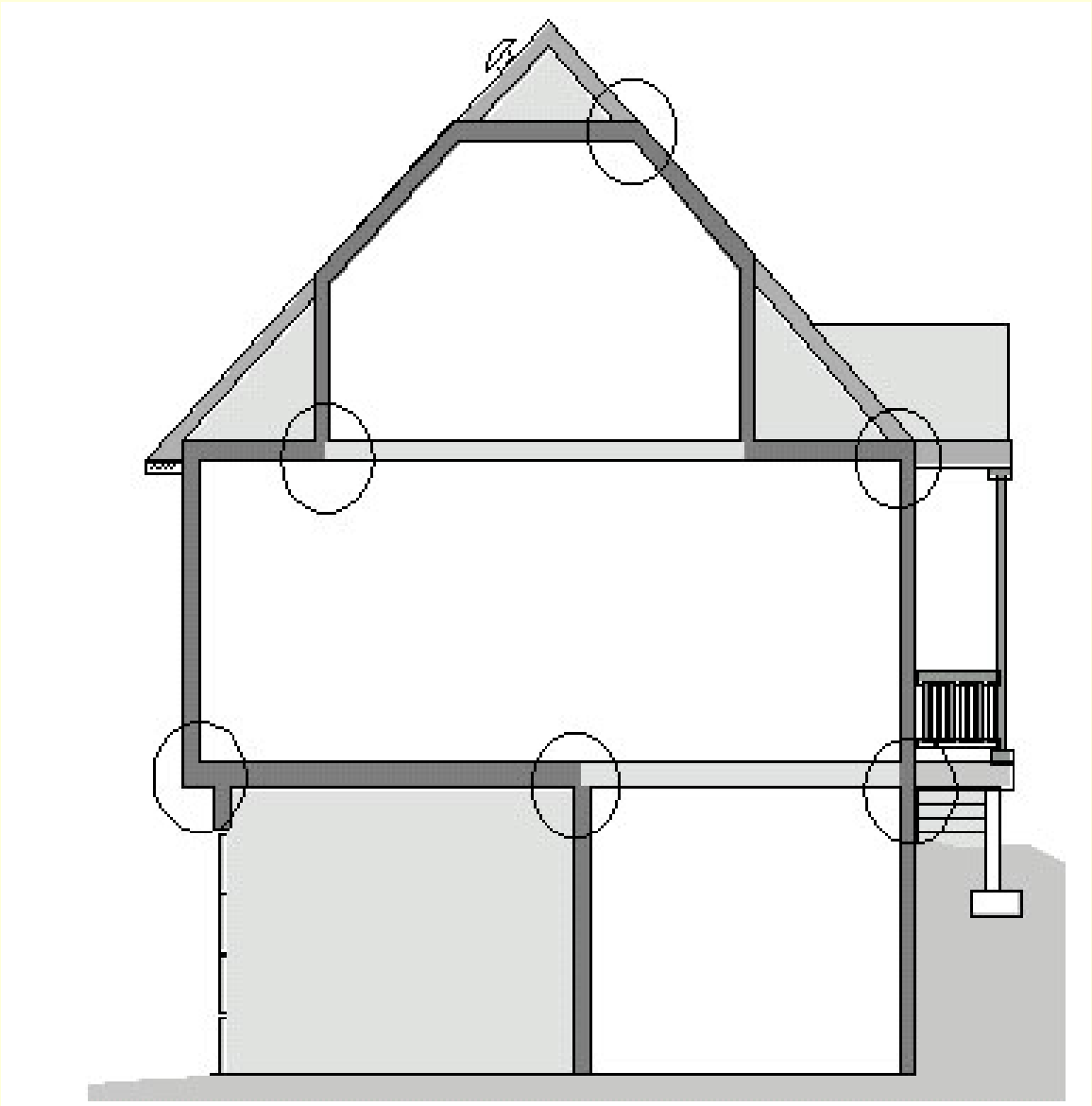
- Assume low existing efficiency
  - if you don't know a quantity, assume low performance
    - 60% furnaces, R-3.5 walls and attics, 5 gpm showerheads, etc.
- Make biased simplifications
  - underestimate thermal regain from basements and crawlspaces
    - large impact on floor insulation and duct sealing
  - ignore interactions between air flow and conduction in cavities
    - and directional nature of air flows in foundation and attic spaces
  - Measure what’s easy to measure, with too much precision…
  - ignore many little factors which nearly all lead to lower savings
- Don't bother with a "reality check"
  - don't look at actual usage or develop adjustments based on research and evaluation

Impacts of Energy Modeling Problems

- Older low efficiency homes
  - Many model problems lead to less heat loss than projected
    - large exfiltration through unvented attic reduces conduction
    - large infiltration into basement/crawl regains duct losses
    - infiltration model errors and heat recovery have big impact
    - framing factor higher and wall sheathing thicker in older homes
- Newer high efficiency homes
  - Lower leakage, higher R value reduce over-estimation
    - R-1 added to R-19 hardly matters, but added to R-4 it does
  - Flaws have bigger impact on remaining losses
    - Insulation flaws have big impact in high R assemblies
    - HVAC and duct flaws impact tight envelopes (room-to-room dPs)

Key Thermal Defect Junctures:

where do I enter this in the software?



Existing Homes: Earth Advantage EPS Pilot

"Energy Performance Score 2008 Pilot", for Energy Trust of OR, 2009

- Energy Labeling of Homes
  - Looking for simpler MPG-type rating for homes
- Tested 3 software tools on ~300 existing homes
  - REM/Rate – full HERS Rating (~100 inputs)
  - Home Energy Saver (LBL)
    - tested 2 variations: 24 data inputs, 185 data inputs
  - "SIMPLE" spreadsheet audit (32 inputs)
    - quickly designed to see if a simpler tool could achieve acceptable accuracy
    - only building dimension asked is conditioned floor area
- Compared projections to actual energy bills

Software Input Requirements Example: Windows

REM/Rate

- Area of each window
- Glazing and frame types
- Orientation
- Measurements of the geometry of overhangs

SIMPLE

- Glazing type
- General amount of window shading

Home Energy Saver (medium version)

- number of windows on each side of house

Home Energy Saver (long version)

- Total area of window on each side of home
- Window shades
- Glazing and frame types
- Depth of eaves
- Height of large shade trees and nearby buildings

“SIMPLE” audit inputs

House Characteristic	Current Home	Proposed Home
Finished floor area (sq.ft.)	2000	2000
Stories	2	2
Occupants	3	3
Heating Setpoint (°F)	68	68
Heating System Type	Std Gas 80%	**Condensing Gas**
Wall Insulation	Std Ins	Std Ins
Attic Insulation	Some Ins	**Std 10 inch**
Windows	Dbl/Sgl&Storm	Dbl/Sgl&Storm
Air Tightness	Average	Average
Foundation Type	Basement	Basement
Foundation Insulation	None	None
Heating is not forced air (0-1)	0	0
Ducts: % in Attic	0%	0%
Ducts: % in Basement	75%	75%
Duct Leakiness	Average	Average
Duct Insulation	None	None
Cooling Info		
AC SEER (none=0)	12	12
Cooling Setpoint	78	78
Window Shading	Typical	Typical
Cool Roof / Rad. Barrier rafters	Std Color	Std Color
Water Heating Info		
Water heater Type	Std Gas	Std Gas
Showering Use (flow, time)	Average	Average
Laundry	Average	**Low**
Other Hot Water	Average	Average
All Else Info		
Lighting Usage Intensity	Average	**Low**
Primary refrigerator	Average	Average
Extra Refrigerators / Freezers	None	None
Entertainment (TVs & PCs)	Average	Average
# Other Large Uses (500 kWh)	1	1
Plug & Other Loads	Average	Average
Clothes Dryer	Gas Avg Use	**Gas Low Use**
Cooking	Gas Avg Use	Gas Avg Use

EPS Pilot Findings
Total Energy Use

	REM/Rate	SIMPLE	HES-Mid	HES-Full
Mean Actual Use	101	101	101	101
Mean Predicted Use	133	84	157	119
Mean Error	32	-17	48	18
Mean Absolute Error	37	27	75	28
Median Absolute Error	31	21	66	23
Mean Absolute Percent Error	43.7%	25.1%	96.6%	33.4%
Median Absolute Percent Error	31.1%	24.0%	73.8%	21.8%
Percent of Homes with Accurate Prediction (less than +/- 25%)	43.2%	51.6%	19.5%	53.7%
Percent of Homes w/ Large Error in Prediction (larger than +/- 50%)	31.6%	7.9%	60.5%	21.6%

Table 3.5 Total Energy (MBtu) for 190-Home Sample

EPS Pilot Findings

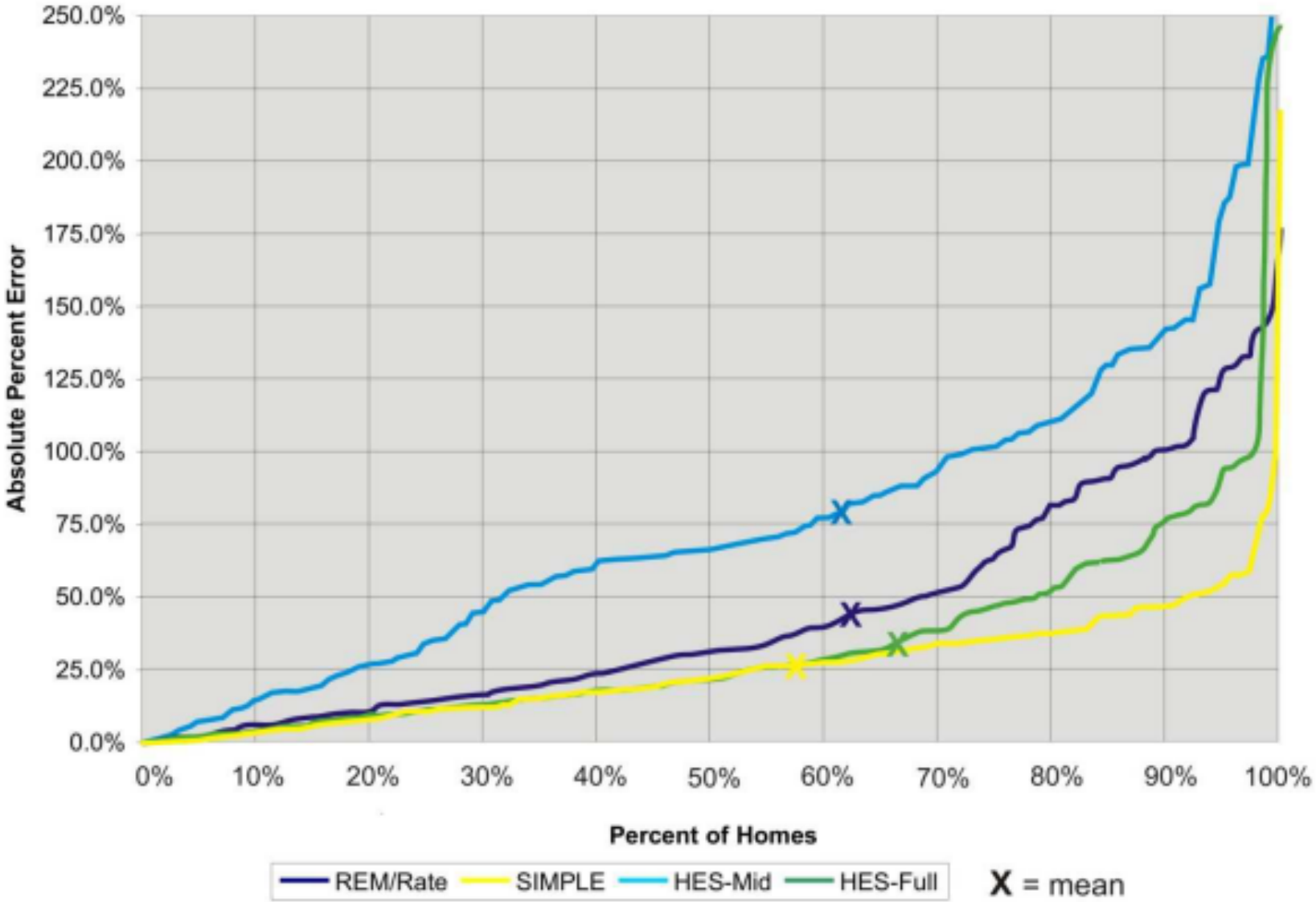


Figure 3.2 Comparison of Accuracy for Total Energy (MBtu) for 190-Home Sample

EPS Pilot Findings
Gas Use in Older Homes

	REM/Rate	SIMPLE	HES-Mid	HES-Full
Mean Actual Use	617	617	617	617
Mean Predicted Use	1089	643	1152	869
Mean Error	473	27	402	252
Mean Absolute Error	494	210	643	284
Median Absolute Error	430	182	578	198
Mean Absolute Percent Error	91.1%	35.8%	133.1%	52.3%
Median Absolute Percent Error	84.6%	30.9%	100.0%	41.2%
Percent of Homes with Accurate Prediction (less than +/- 25%)	22.0%	44.0%	13.2%	42.9%
Percent of Homes w/ Large Error in Prediction (larger than +/- 50%)	67.0%	23.1%	74.7%	42.9%

Table 3.9 Total Therms for Homes built before 1960 (86 Homes)

EPS Pilot Conclusions

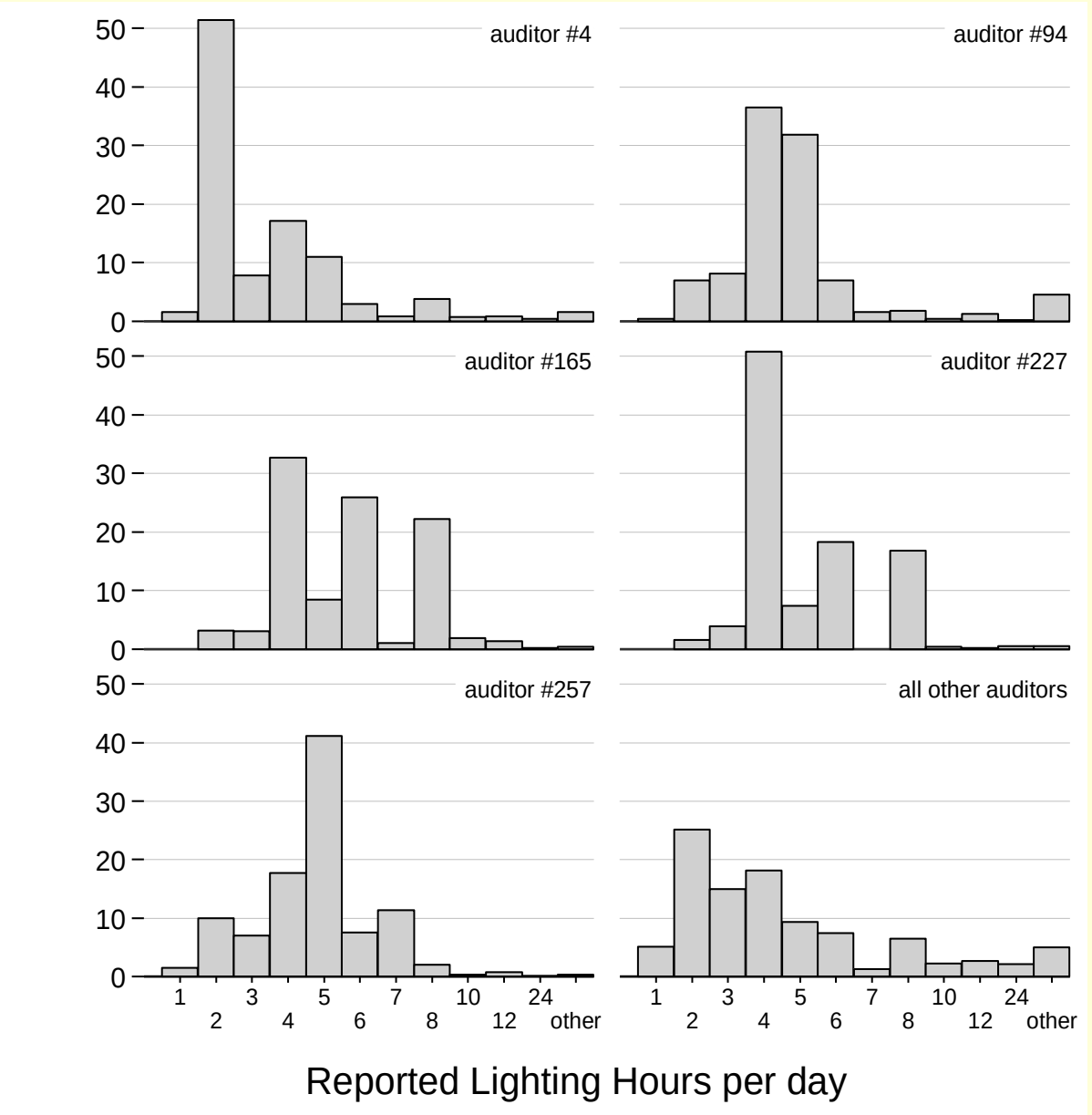
- None of the tools were very accurate
  - REM/Rate, a certified HERS tool, had average differences of 40% for electric and 60% for gas
  - REM and HES over-estimated gas use, by a lot in older homes
  - SIMPLE performed better in most situations
    - smallest average error, far fewer cases with large errors
    - even without asking window area or wall area or other details
- Major errors in standard software for estimating heating use in inefficient homes
  - Need to fix large biases – get the big stuff right before worrying too much about the little stuff
  - Collecting detailed data on some things and using complex models can give worse answers than making reasonable default assumptions and simpler models

Data Collection Accuracy
Don't Ask Don't Tell?

- Asking about something may be less accurate than assuming the answer
  - Example: hours of lighting use may be more a function of auditor bias/preference than any reality
  - Some questions people just can't answer accurately
    - How many hours per day do you use your oven, on average
  - Some questions make no sense
    - How many hours a day do you use your air conditioner in the summer?
  - Some questions have 'good" answer which becomes more common – TV watching, thermostat settings?

Lighting Hours of Use: reported values by auditor

- Reported hours varied by auditor
  - some liked 2 hours
  - some liked even numbers
  - some liked odd

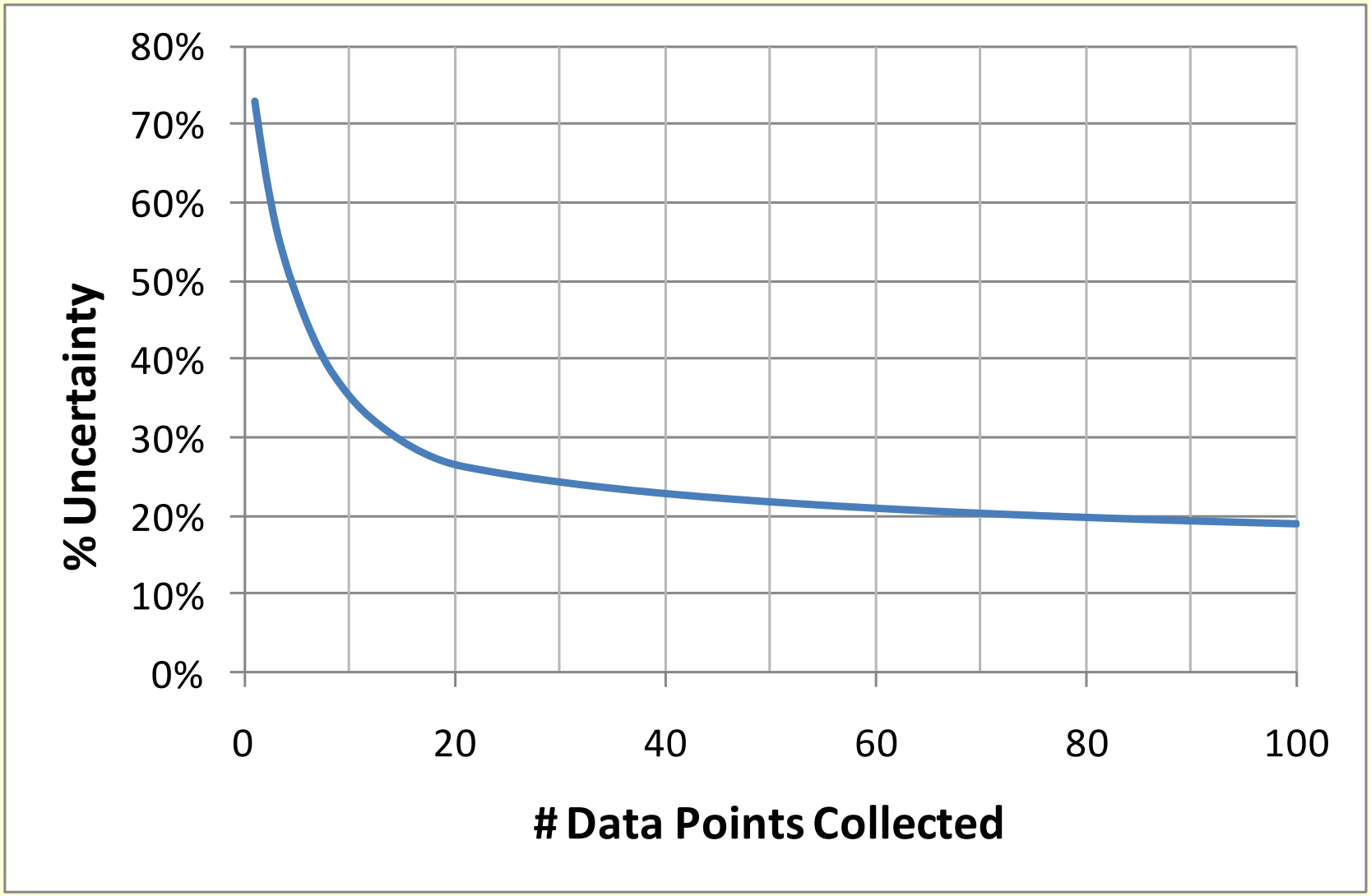


Always Check Your Data

Fundamental Modeling Problems

- Houses are complicated and some sources of uncertainty are hard to reduce
  - Foundation heat loss
    - soil conductivity / ground temperature, waste heat regain
  - Infiltration
    - known errors unfixed, wind unknown, leak distribution?
  - Wall and Attic Heat Loss
    - framing factor, insulation quality; air leakage interactions
  - Window Loss/Gain
    - shading, screens, old storms, air film
  - HVAC Performance
    - duct efficiency and regain, AC charge and air flow impacts

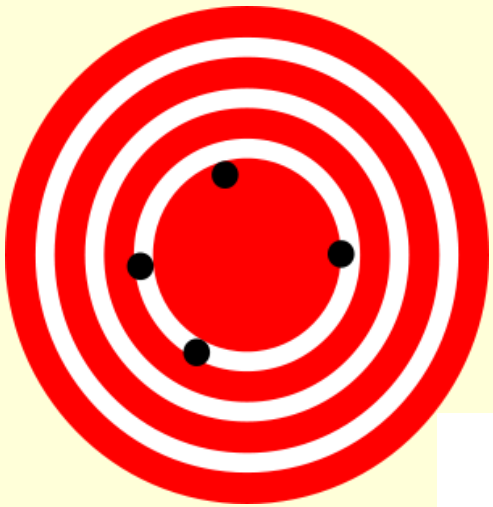
Value of data / limits of accuracy



Accuracy vs. Precision

bias vs. variance

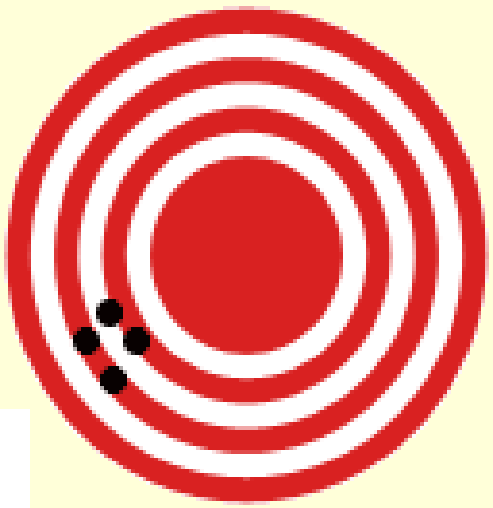
Accurate, not precise

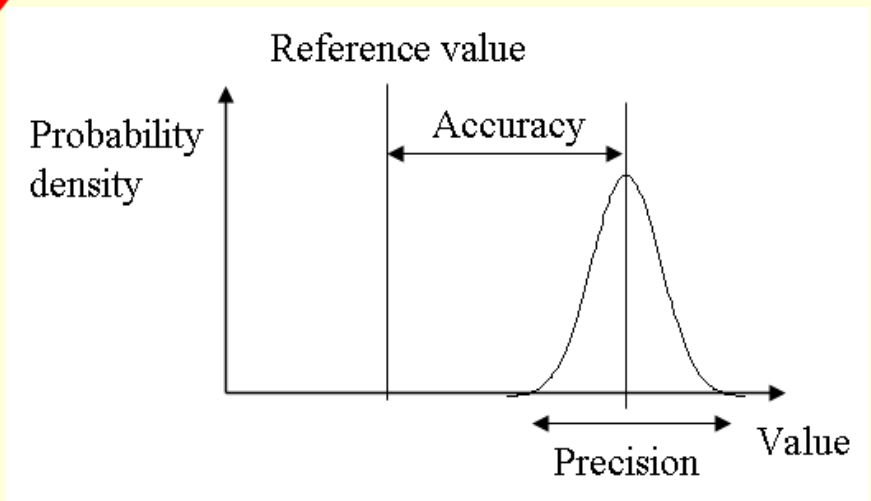


Accurate = Unbiased
Precise = Low Variability

Bias is worse because large samples don't help

Precise, not Accurate





It's better to be approximately right than precisely wrong!

Computerized Audit Tools

- In Most Homes…
  - Computers aren't needed to figure out what to do
    - Modeling has many uncertain inputs and shaky assumptions and algorithms
    - Measured savings often much lower than predicted
    - Rough estimates can work as well or better in many cases
  - Computers are great for
    - Tracking what happened when, managing things
    - Producing nice reports
    - Selling the job

Back to Basics: Saving Energy

- Lack of Efficiency Measures - install them
  - Insulate walls and attics
- Inefficient Stuff - replace
  - Heating system, refrigerator
- Extra Stuff - unplug it / remove it / turn it off / control it
  - 2nd fridge, freezer, humidifier, all night outdoor lighting
  - Harder: swimming pool, aquarium, grow lights
- Defects - find and fix
  - High air leakage rate with lots of attic bypasses
  - Thermal/Pressure Boundary Issues
    - split level, kneewall, porch, balloon framing
  - Hot water leaks
- Behavior - educate
  - Thermostat settings, lack of setback
  - Leave stuff on 24 hours/day: lights, computers, TVs, fans, furnace fan

You don’t need to be good at math to figure out what to do