Energy Performance Scoring for Existing Homes & Households:

some issues...

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Energy Usage Projection Accuracy

Someone must have looked at this closely, right?

- How does energy usage projected by computer models compare to actual usage?
  - New Homes – so-so
  - Existing Homes – available data doesn't look good
- Can't we just blame the occupants? (NO)
  - Well, can we at least blame the auditors/raters? (NO)
- Do discrepancies vary with house characteristics? (YES)
  - Are there particular features that are hard to model? (YES)
- Are the models being revised based on latest methods and real world data? (RARELY)

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 internal gains
  - Doesn't test using CFM50 values, doesn't test many realistic circumstances

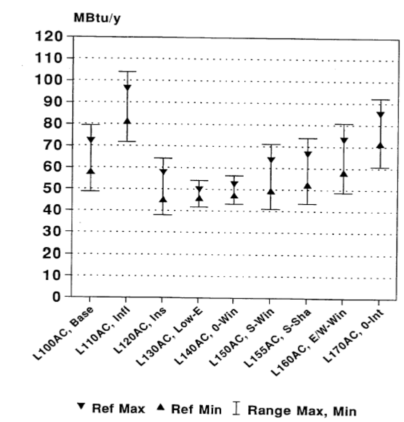


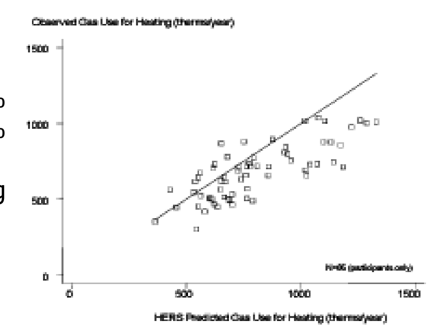
Figure 4-1. HERS BESTEST Tier 1 example range setting—annual heating load (L100AC through L170AC) for Colorado Springs, CO

Wisconsin HERS Study: New Homes

"Energy Savings from the Wisconsin Energy Star Homes Program", S. Pigg, ECW 211-1, Oct 2002

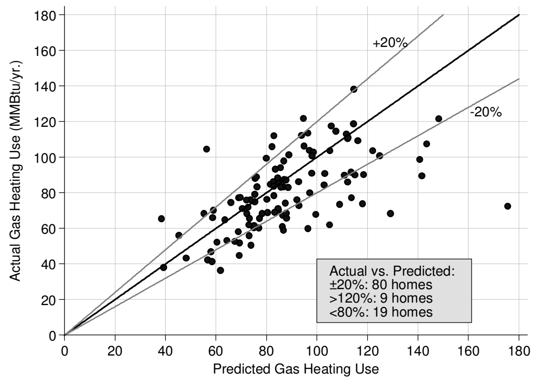
- HERS projections look pretty good
  - projections avg. 10% high
    - Duct leakage assumptions
  - Typical Difference=18%
  - 56% of homes within ± 20%
  - 25% of homes within ± 10%
- But floor area was almost as good a predictor as the rating
  - sq.ft. accounted for 50% of usage variation, HERS rating accounted for 52%

Figure 3, Observed versus predicted heating energy use.



NY ES New Homes (2004-2006) 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



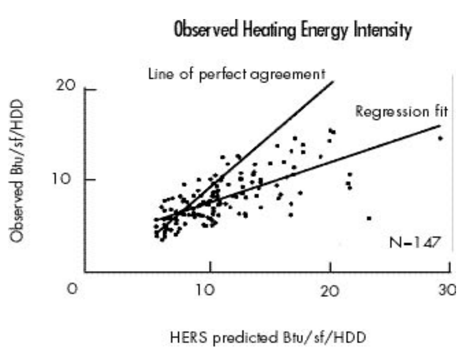
Modeled vs. Actual Heating Use NY ES Homes

- HERS Scores apparently not related to energy usage within 86-89 range
- REM estimates of heating loads from walls, infiltration, windows, and ceilings are correlated with actual usage
  - better predictor of usage than REM-projected total load
  - Slightly better than using just areas and CFM50
    - R-squared increased from 0.479 to 0.494
- REM estimates of duct losses and foundation losses had no discernible relation to measured gas usage
- Duct testing doesn't reduce heating usage (duh?)
  - just testing ducts boosts scores by avoiding default penalty

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

- Evaluations find real 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
  - Literature review found 44% avg. residential realization rate (Nadel & Keating 1991)
  - Problem not just thermal measures
    - OH electric baseload program 58%-68% of projected
    - NJ 2 studies found 60%-69%

Why Are Savings Overestimated?

- Damn Occupants!?
  - Easy scapegoat, but little evidence of takeback effect, especially for major thermal measures (Nadel, 1993)
  - Behavior can affect individual homes, but shouldn't bias overall results
  - Occupant's do impact measure removal: showerheads, CFLs, T-stats
- Poor Work Quality?
  - Potential factor for measures requiring higher skill levels: insulation, air sealing, duct sealing, and HVAC work can be done poorly
- Models / Calculations are Poor
  - Biggest reason for shortfall: projected savings too high
    - Studies found main problem with estimating pre-retrofit usage – models of older, leaky, poorly insulated homes over-state usage by a lot
  - Poor assumptions and biased inputs
  - Bad algorithms that never get tested and/or never get fixed

Common Flaws with Projected Savings

- Assume low existing efficiency
  - if you don't know a quantity, assume low performance
    - 60% furnaces, R-3 or R-4 uninsulated walls and attics, 5 gpm showerheads, etc.
- Make biased simplifications
  - underestimate thermal regain from basements and crawlspaces
    - very large impact on floor insulation and duct sealing projections
  - ignore interactions between air flow and conduction in cavities
    - and directional nature of air flows in foundation and attic spaces
  - ignore many little factors which nearly all lead to lower savings
- Don't bother with a "reality check"
  - don't look at actual usage
  - don't apply "fudge" factors developed from research and evaluation

Fundamental Energy Modeling Problems

- Houses are complicated
  - Models collect data on what's easily measured and modeled, but more important factors often still unknown:
    - Foundation heat loss
      - soil conductivity; waste heat from ducts, appliances, etc; directional infiltration (stack effect); crawlspace ventilation
    - Air Leakage
      - model mistakes unfixed; real wind speeds; are all homes "well-shielded"?; leak distribution
    - Wall and Attic Heat Loss
      - framing factors; insulation quality; air leakage interactions
    - Window Loss/Gain
      - shading, screens; old storm windows
    - HVAC Performance
      - duct efficiency and regain, AC charge and air flow impacts

Impacts of Energy Modeling Problems

- Older low efficiency homes
  - many poorly modeled factors lead to less heat loss than projected
    - large exfiltration through poorly vented attic reduces conductive loss through poorly insulated ceiling
    - large infiltration into basement (or crawlspace) picks up duct losses and brings back into home due to stack effect
    - infiltration model over-estimation of wind effects and ignoring heat recovery leads has biggest impacts in leaky homes
    - wall framing factor higher and sheathing thicker in older (pre-plywood) homes
- Newer high efficiency homes
  - Higher R values and tighter envelopes reduce impacts of most sources of over-estimation
    - adding R-1 to an R-19 wall doesn't affect heat loss nearly as much as adding R-1 to and R-4 wall
  - Flaws have bigger impact and usage may be under-estimated
    - Insulation / thermal envelope flaws can dramatically increase losses from high R assemblies (infra-red scan...)
    - HVAC system installation flaws and duct system interactions with tight envelopes (room-to-room dPs) can lead to degraded performance

Modeling Solutions?

- Need to refine models on a regular basis
  - incorporate latest research findings
  - adjust assumptions (fudge factors) as needed to make results consistent with available measured data
  - but there's little incentive to do this now
- Accept Imperfection (serenity prayer?)
  - we can do much better than current models, but modeling flaws are inevitable given such a complicated system with so many unknown inputs.

Other Rating/Scoring Issues: What's average?

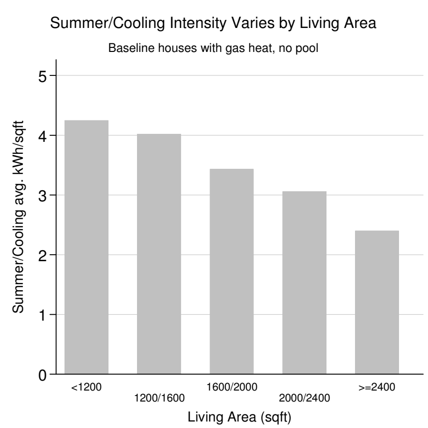
	Baseline Homes				
	All	BaseES	BaseReg	Energy Star	Guarantee Bill
Gas No Pool: # homes	877	537	340	1195	560
Living Area	1735	1878	1509	1967	2112
Total Use	14,107	14,228	13,915	15,831	14,904
Baseload	7,797	7,827	7,750	8,936	8,996
Summer/Cooling	6,064	6,054	6,080	6,736	5,694
Total kWh/ft²	8.36	7.71	9.39	8.22	7.27
Summer/Cooling /ft²	**3.60**	**3.26**	**4.16**	**3.50**	**2.80**
Baseload /ft²	4.62	4.27	5.18	4.64	4.37

- Phoenix ES Home study found many non-Energy Star homes had comparable specs: higher SEER AC, solar control windows, decent insulation, tight shell
- Resulted in Mixed Cooling Intensity Differences
  - Energy Star homes slightly lower kWh/ft² than average Baseline
  - Energy Star equivalent Baseline homes (BaseES) used less than (non-ES) BaseReg

Other Scoring Issues: House Size

the Problem with Btu/ft² or kWh/ft²

- Common way to compare homes of different sizes
  - But does it solve the problem or create a new one?
- Graph shows kWh/ft² is lower for larger homes (Phoenix ESH study)
  - Building shell and window areas don't double if floor area doubles
  - Also true for baseload
- kWh/ft² is a poor way to correct for house size!
  - Makes large houses look better
  - Should use shell area instead of floor area



Occupant Effects?

- Analyzed occupant effects by comparing the usage of homes with moves vs. no moves (Phoenix ESH study)
  - Total and summer/cooling use in 2000 vs. 2004 for 1,289 movers and 1,384 stayers
    - Summer/Cooling usage averaged 5% lower in 2004 for both movers and stayers
    - The typical (median) change in usage between 2000 to 2004 was 14% for stayers and 21% for movers, implying that occupancy changes are typically responsible for less than a 10% change in use
    - More movers experienced large changes in usage compared to stayers – 1 in 4 movers showed a usage change of 40% or more, but only 1 in 10 stayers showed that large a change.