Predictions, Performance and Real World Results
What can we learn from 160,000 houses in Houston?

Shaun Hassel, Advanced Energy

RESNET 2010 National Conference
February, 24, 2010
Raleigh, NC

www.advancedenergy.org

Outline

- Assess programs with real world data – bill analysis
- Studies done to date
- Data Analysis, Results and Conclusions
- Where do we go from here?

Objectives

- Using actual consumption data, assess new construction programs in different markets to determine:
  - > Usage across different groups or programs
  - > Predicted vs Actual Savings
  - > Strategies that result in energy savings

Wisconsin ENERGY STAR Homes Study

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

- "Best" evaluation of ENERGY STAR Homes program
  - > 1999/2000 new ES homes and non ES homes

- Key Findings
  - > Gas Usage
    - ES Home = 928 th/yr (97 homes)
    - Non ES Home = 1024 th/yr (157 homes)
    - Savings = 96 th/yr, 9%
      - Savings attributed to tighter buildings
      - Lack of saving due to the presence of high efficiency furnaces
    - Both groups similar to state average use due to larger size

Wisconsin ENERGY STAR Homes Study

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

- Projected Usage
  - > HERS projections 10% high, attributed to duct leakage assumptions
  - > 56% of homes within ± 20%, 25% of homes within ± 10%
  - > But living area was nearly as good a predictor as the rating:
    - sq.ft. accounted for 50% of variation, REM projected accounted for 52%

New York ENERGY STAR Homes

- Part of NYSERDA-sponsored project to assess design options to reach HERS 90 (score)
  - > VEIC prime contractor
- Reviewed ratings data on 1,974 ES homes
  - > Upstate NY, built 2004 to late 2006
  - > Most Homes scored 87-89, 96 homes scored >90
- Assessed actual gas and electric usage to examine how real world performance varies

NY: Actual vs. Projected Heating Use

- REM-projected usage averaged: 1,190 total therms
  - > 881 heat vs. 804 actual
  - > 309 base vs. 265 actual
  - > REM over-predicted by ~10% on average
  - > Correlation pretty good, but house size drives much of the relationship

NY: Modeling Discrepancies

- 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 total projected load
  - > Slightly better than using just areas and CFM50
- REM estimates of duct losses and foundation losses had no discernible relation to measured gas usage
  - > Duct testing doesn't reduce heating usage (duh?)
- 2x6 walls don't seem to save as much as projected

NY: Electric Usage Results

- Usage averaged 11,040 kWh/yr (~$1,650/yr)
  - > 9,333 kWh baseload
  - > 829 kWh winter/heating load
  - > 878 summer/cooling loads
    - Homes with central AC used 990 kWh summer/cooling vs. 896 kWh projected cooling
    - But homes without Central AC used 814 kWh
- Electric usage is higher than average residential customer (~8,000 kWh/yr)
  - > house size and luxury

Energy Use of New Homes In Phoenix

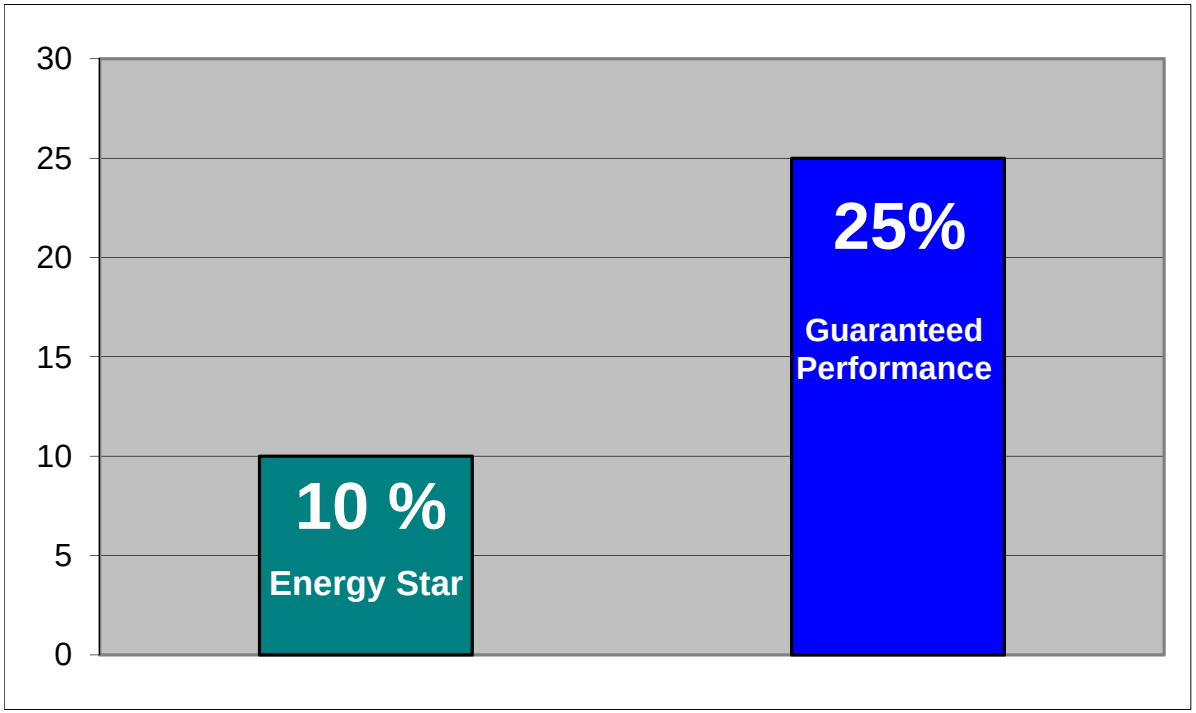
- Examined 7,165 homes built 1995 - 2004
  - > 3 primary efficiency categories:
    - 3,339 baseline homes
    - 2,998 ENERGY STAR homes
    - 828 Guaranteed Performance homes
  - > 6 major production builders
  - > Not a designed experiment, not a random sample

Cooling Efficiency Results from 7141 Homes in Phoenix, AZ

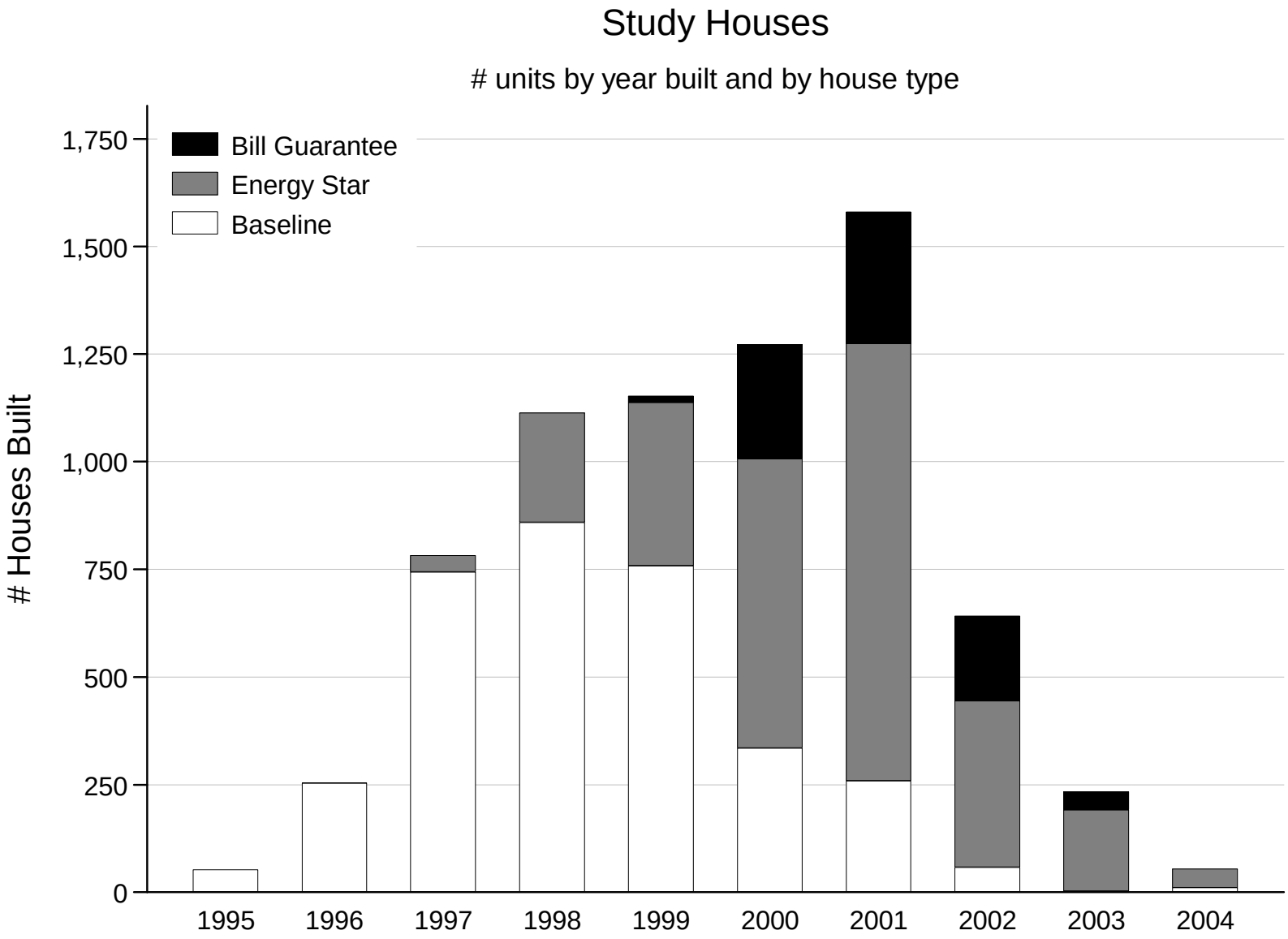
For cooling, **ENERGY STAR** homes were 10% more efficient than standard built homes.

Guaranteed performance homes were 25% more efficient than standard built homes.

Improvement In Cooling Efficiency Over A Comparable Standard Built Home



Production by category & year built



Baseline Homes: A moving target?

- ENERGY STAR compliance primarily involved SEER 12 and/or low-e windows
  - > Phoenix construction (slab, stucco) is already tight
- But…many new homes already met these standards
  - > 2 builders: all SEER 12 A/C and low-e windows
  - > All but 1 builder used all SEER 12 A/C
- As 2 efficient builders switched production to ENERGY STAR, Baseline homes became less efficient
- Overall, slightly more than half of the Baseline homes were potentially already ENERGY STAR

Regression Modeling of Electric Usage

- Some regression findings
  - > 1800 ft² home with gas heat and no pool: summer/cooling loads are estimated at 6,413 kWh for average Baseline, 6,493 kWh for EStar, and 5,409 kWh for GPerformance (16% savings over EStar)
  - > Compared to BaseReg, EStar use 10% less for summer/cooling and GPerformance use 25% less summer/cooling
  - > Swimming pools are estimated to use by about 4500 kWh/yr. with about 750 kWh as added summer/cooling load. This large end use may be worth addressing (pump sizing/scheduling?)

Houston Energy Efficiency Study

Using real world data evaluate the performance differences between baseline, ENERGY STAR® and Guaranteed Performance homes

Compare actual versus predicted performance, as well as identify construction techniques and products that deliver energy savings

Why Houston?

- Metropolitan Houston has become one of the largest markets in the country for new housing construction, with more than 350,000 new homes started since 2000
- Same 3 home types as Phoenix and LOTS of them
- Well established local high performance home infrastructure
- Different Climate than other studies: Hot and HUMID
- Fairly consolidated network of manufacturers and trades – but not as consolidated as Phoenix

Funding Partners

CenterPoint Energy

Advanced ENERGY

Blasnik and Associates

Study Methodology

- Methodology for Houston Evaluation Study
  - > Evaluate three house categories: baseline, ENERGY STAR & guaranteed performance
  - > Collect monthly electric and gas (when available) consumption data on all new hookups from 2002-2008
  - > Match usage data against building data collected from the ENERGY STAR homes database, appraisal data and Houston's largest home energy rating companies
  - > Compare annual consumption across house types and construction characteristics

House Types

- What constitutes a baseline home?
  - > Any non-program home in CenterPoint's Metro Houston territory
  - > Must meet local energy code at a *minimum*

House Types

ENERGY STAR

> Backed by the EPA

> More Energy Efficient than “Code”

- From 2002-2006, 30% better than a reference home built to the 1993 Model Energy Code
- From 2006-Present, 15% better than a reference home built to the 2006 IECC

> Third Party Certified

House Types

Typical ENERGY STAR Features:

- Higher SEER or AFUE
- Low-E Windows or Improved U-Values
- Duct Sealing and Testing
- Insulation QA
- Thermal Bypass Checklist, July 2006-Present

House Types

> Guaranteed performance specs are ENERGY STAR plus:

- More stringent building infiltration and duct leakage standards
- Right Sizing
- Air Barrier Framing and Insulation QC (2000 - Present)
- Ventilation
- Pressure Balancing
- Combustion Safety

Data Sources

Data	Source
ENERGY STAR Homes Program Tracking Data, Electric & Gas Usage	CenterPoint® Energy
County Property Assessor Data	Brazoria, Fort Bend, Harris and Montgomery Counties
REM/Rate Files and Building Testing Data	Houston HERS Raters
Weather Data	National Weather Service
Housing Market Data	Manufacturers, Installers and Distributors

Characterize the Houston Market

- Huge new residential construction market
- Different Climate: Hot and HUMID
- Consolidated: handful of key companies for each trade, many production builders, large home performance co's
- Huge developments: some with thousands of homes
- Adopted a residential energy code in summer 2001
- Major efforts around code training, ENERGY STAR, building science and consumer marketing outreach

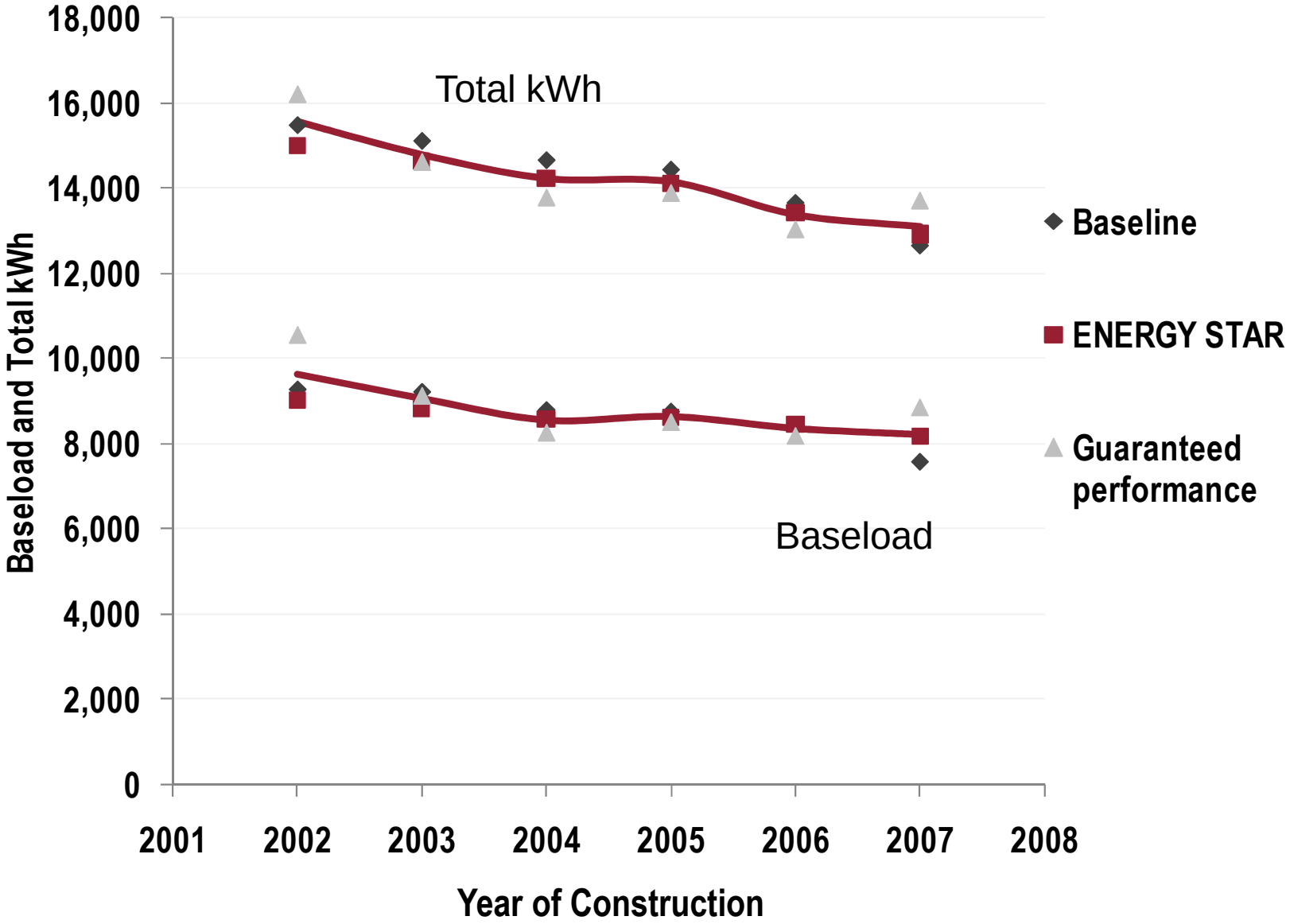
Electric Data: Usage Summaries

COMPOSITION OF DATA SET

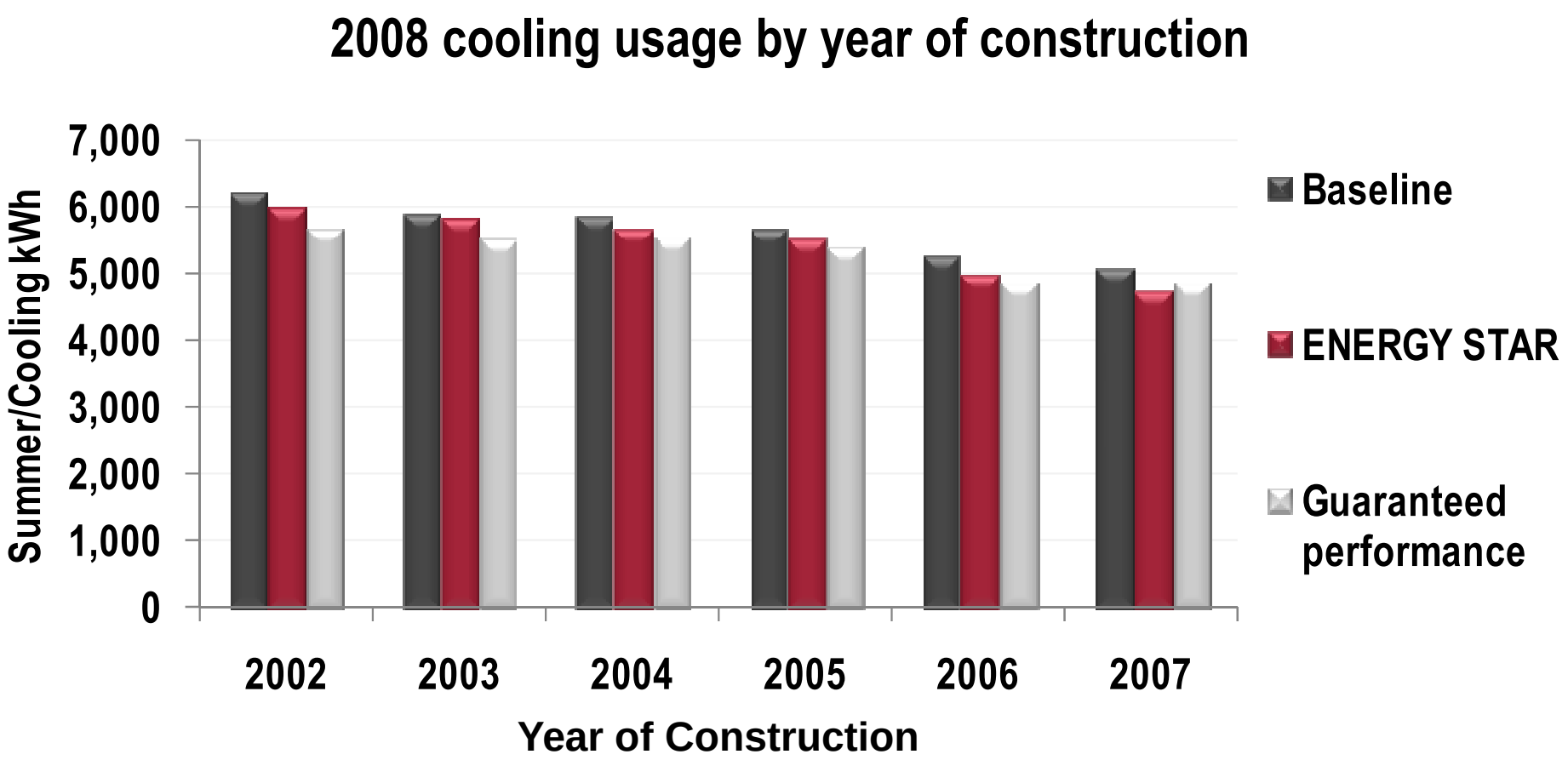
ENERGY STAR Homes database, utility usage data, property assessor data, REM/Rate files, field testing files, weather data, manufacturer and distributor data

Number of homes in study groups	Overall analysis	Electric usage analysis	Gas usage analysis
Baseline	70,828	40,981	10,815
ENERGY STAR	81,755	42,154	15,301
Guaranteed performance	6,115	2,795	659
Total	158,698	85,930	26,775

2008 kWh Usage



Data Analysis and Results



Overall Electric Usage

	Category			Difference vs. Base	
	Base	ES	GP	ES	GP
2008 Electric usage: unadjusted					
Summer/cooling	5,543	5,438	5,339	-105 ±27	-205 ±77
Baseload	8,511	8,533	8,849	22 ±60	338 ±175
Total kWh/yr	14,054	13,971	14,187	-83 ±77	134 ±222
2008 Electric usage: size adjusted					
Summer/cooling	5,770	5,471	5,394	-298 ±21	-375 ±60
Baseload	8,871	8,618	8,950	-253 ±53	79 ±157
Total kWh	14,641	14,089	14,344	-552 ±62	-297 ±183

- Baseload is bigger than cooling load in a hot climate like Houston – also responsible for about 20% of the cooling load

- Must find ways to reduce baseload if we want to achieve large overall savings

Data Analysis and Results

2008 difference in energy use from baseline homes (adjusted for size but not vintage)

	Percent Usage Difference vs. Baseline	
	ENERGY STAR	Guaranteed Performance
Summer/cooling kWh (2008)	5% less	6% less
Total kWh (2008)	4% less	2% less

Construction Practices Across Groups

	RESNET Reference	Estimated Baseline	ENERGY STAR
Wall R-value	13	14	14
Roof/ceiling R-value	30	30	30
Normalized leakage, nL	0.57 **(0.48)**	?	0.40 **(0.39)**
Glazing U-factor, effective	0.75	0.54	0.54 **(0.52)**
SHGC	0.40	0.36	0.36
Percentage window area	18%	14%	14%
R-value return ducts	4	6	6
R-value supply ducts	8	6	6
Default distribution efficiency	0.80	?	~0.88
Furnace AFUE	78%	80%	80%
Air Conditioner SEER	10 **(13)**	11.5+ **(13.5)**	12.6 **(13.7)**
DHW, gas efficiency	0.54 **(0.59)**	0.54 **(0.59)**	0.59 **(0.60)**
DHW, electric efficiency	0.86 **(0.91)**	0.86 **(0.91)**	0.91

Note: changes in 2006 shown in brackets (2004 for DHW)

Data Analysis and Results

REM/RATE™ ANALYSIS
Predicted versus actual usage

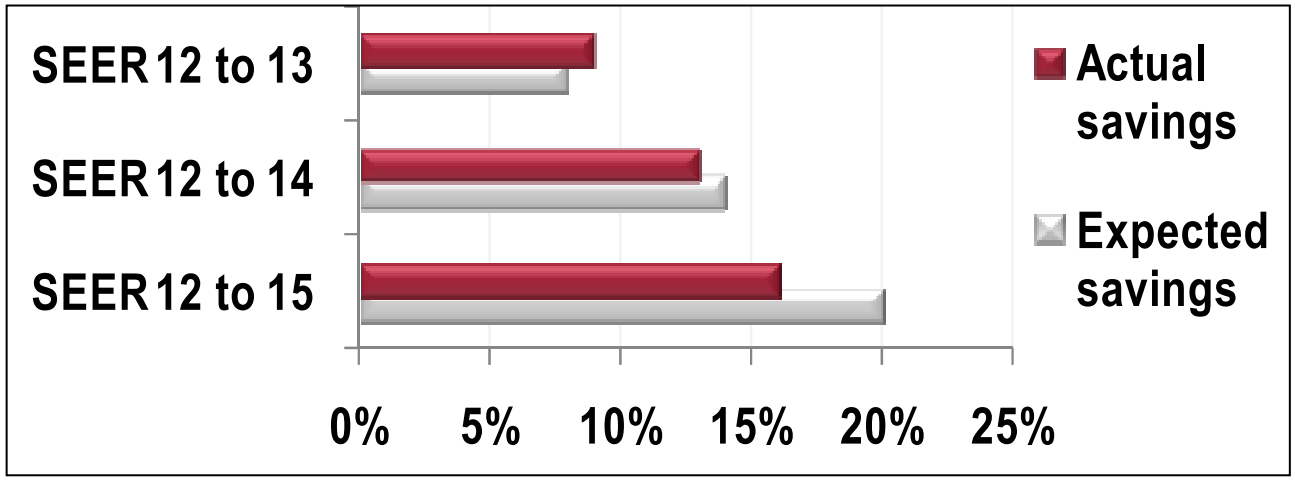
Cooling load projections and usage	
Average load [kWh/yr]	
REM/Rate	5,506
Billing data	5,677
Difference	171 [3%]
% Homes where REM/Rate within…	
...10% of billing data	28%
...25% of billing data	64%
...50% of billing data	91%
Correlations with billing data	
REM/Rate	0.62
Floor area, shell area	0.67

Regression Modeling of ES Homes

- Regression analysis used to assess how house data relates to summer/cooling usage
  - > 16,374 ES Homes with matching REM data
    - 3,254 with duct and shell field test data too
- Explored a variety of questions using multiple modeling approaches
- Report on relationships that appear solid

Regression Modeling Findings (1)

- A/C SEER Savings vs. SEER12
  - > SEER 13: 583 kWh, 9% (8% expected)
  - > SEER 14: 787 kWh, 13% (14% expected)
  - > SEER 15: 984 kWh, 16% (20% expected)



  - > SEER changes account for 2/3 of ES Homes load reduction from 2005 to 2007

Regression Modeling Findings (2)

- Building Shell Leakage
  - > Summer/cooling ~ 0.4 kWh per CFM50
  - > Infiltration Loads: 734 kWh/yr of cooling (14%) in average 1924 CFM50 home
- Duct Leakage
  - > Summer/cooling ~ 2-2.5 kWh/CFM25 duct
  - > Duct leakage loads: 174 kWh of cooling (3%) in average 87 CFM25 home

Regression Modeling Findings (3)

- Radiant Barrier Roof Sheathing
  - > Reduces loads about .09 kWh/ft², equals about 180 kWh (3%) per home
- Baseload Electric Impact on Summer/Cooling Loads
  - > strongly related to summer/cooling loads at 0.13 kWh cooling per annual kWh baseload
    - About 1150 kWh -- 20% of cooling load is removing baseload heat
- Baseload Electric Loads
  - > related to house size (floor or shell) and assessed value of home
  - > Baseload kWh/yr ~ 2900 + 1.8 * floor area + 6.5 * Assessed Value ($1000s)

Gas Usage Findings

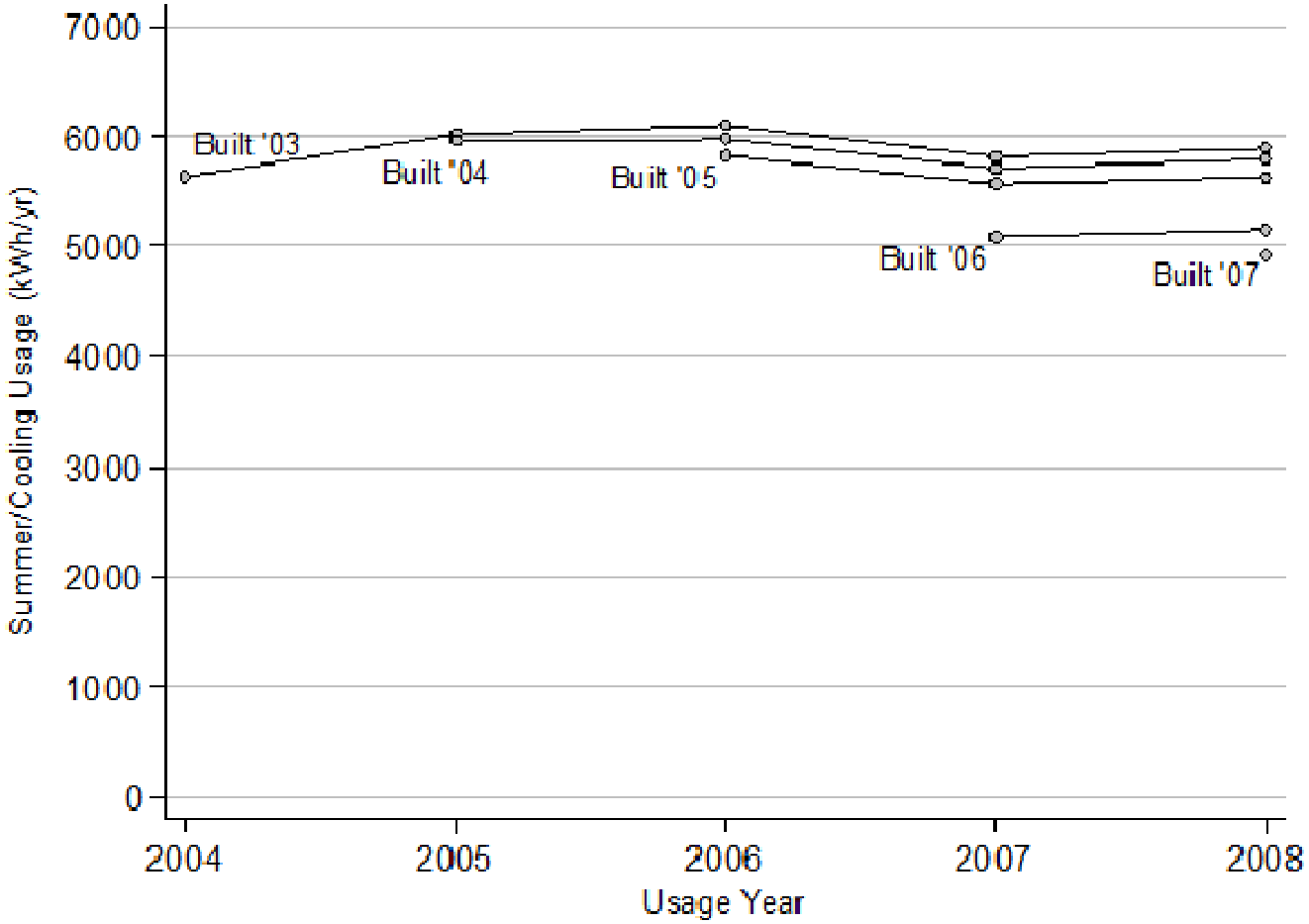
	Category			Difference vs. Base	
	Base	ES	GP	ES	GP
Number of homes	10,815	15,301	659		
Floor area	2,353	2,446	2,412	93 ±19	59 ±60
Envelope area (above grade)	4,134	4,255	4,239	121 ±22	104 ±71
One-story home	61%	60%	43%	-2%	-18%
Gas usage: unadjusted					
Winter/heating	264	258	238	-6 ±3	-26 ±10
Baseload	174	165	162	-10 ±2	-12 ±7
Total therms/yr	438	423	400	-16 ±4	-38 ±13
Gas usage: size adjusted					
Winter/heating	274	259	243	-15 ±2	-31 ±8
Baseload	184	168	167	-16 ±2	-17 ±6
Total therms/yr	458	427	410	-30 ±3	-48 ±10

Usage Trends Over Time: Cooling

Could differences between home vintages be an occupancy effect?

Maybe cooling use increases over time for a home?

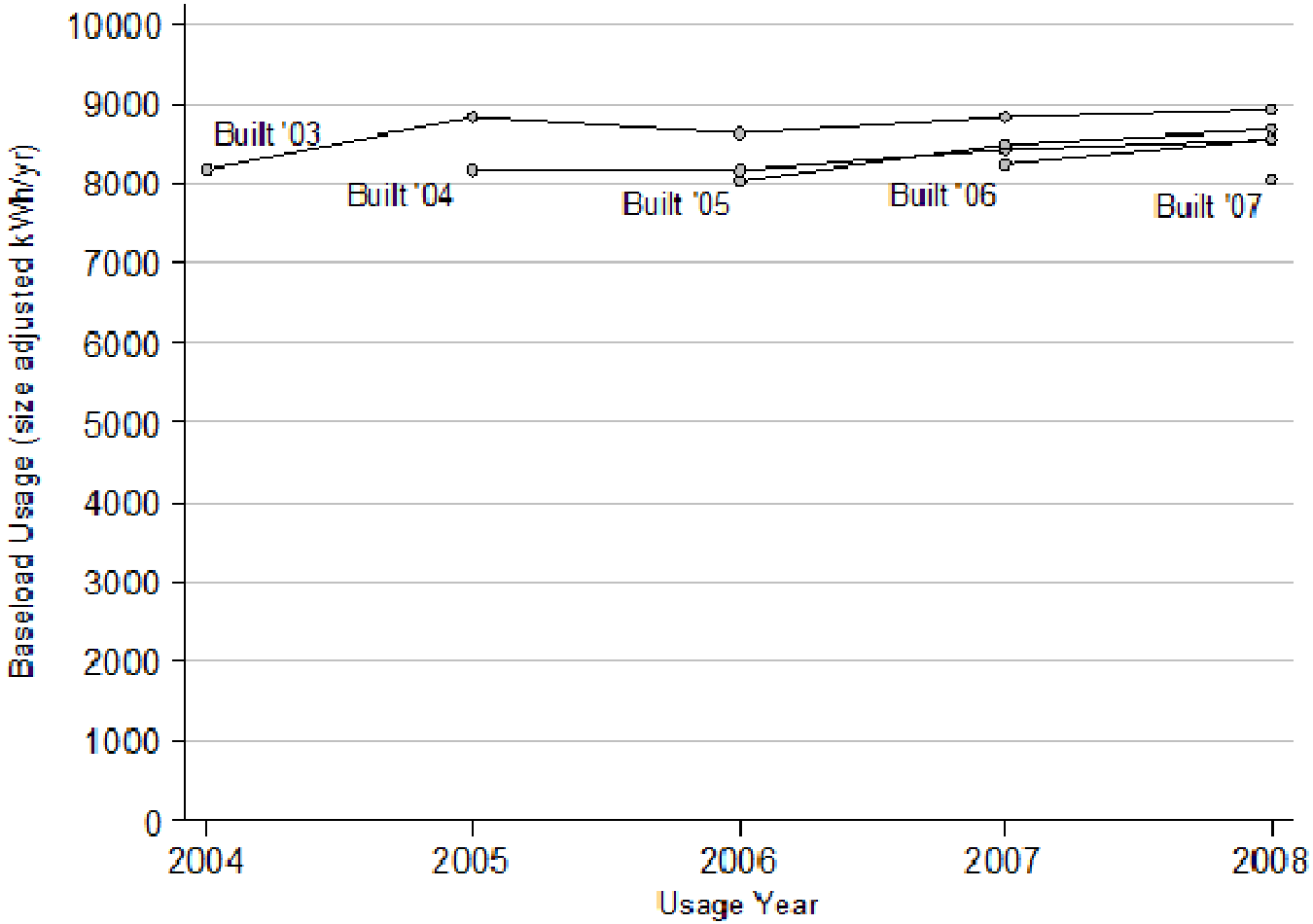
Not in these homes...



Usage Trends Over Time: Baseload

Baseload does increase some over time...

so comparing across years may be less useful

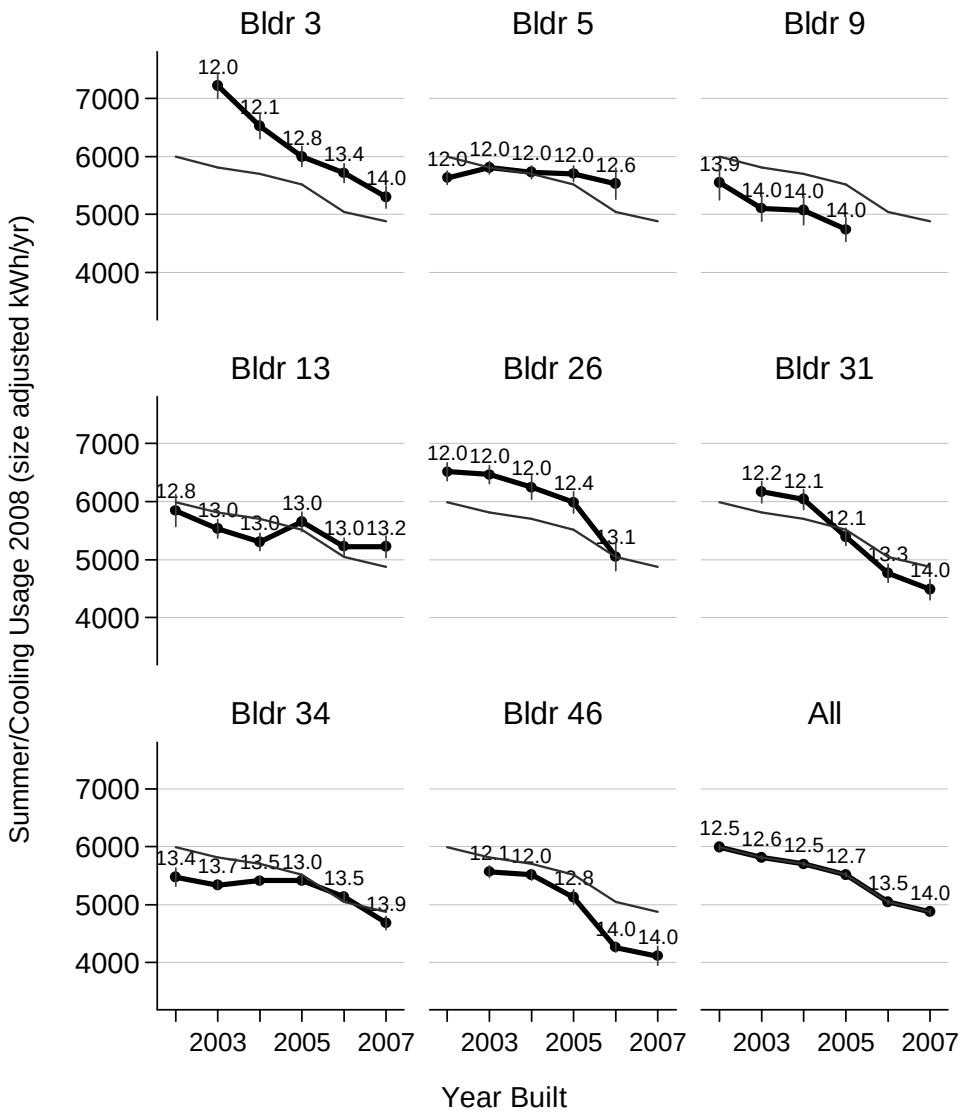


Builder Effects

Graph of Cooling Use vs. Year Built by builder

Labeled with avg SEER

Builders with largest cooling declines over time showed large AC SEER increases



Conclusions

- ENERGY STAR homes perform very close to the predictions of the models, but baseline homes perform much better than the reference homes defined by the HERS standard.

- Why? Because the reference home rarely if ever actually got built. And some the assumptions about “typical” homes established by the standards may be incorrect.

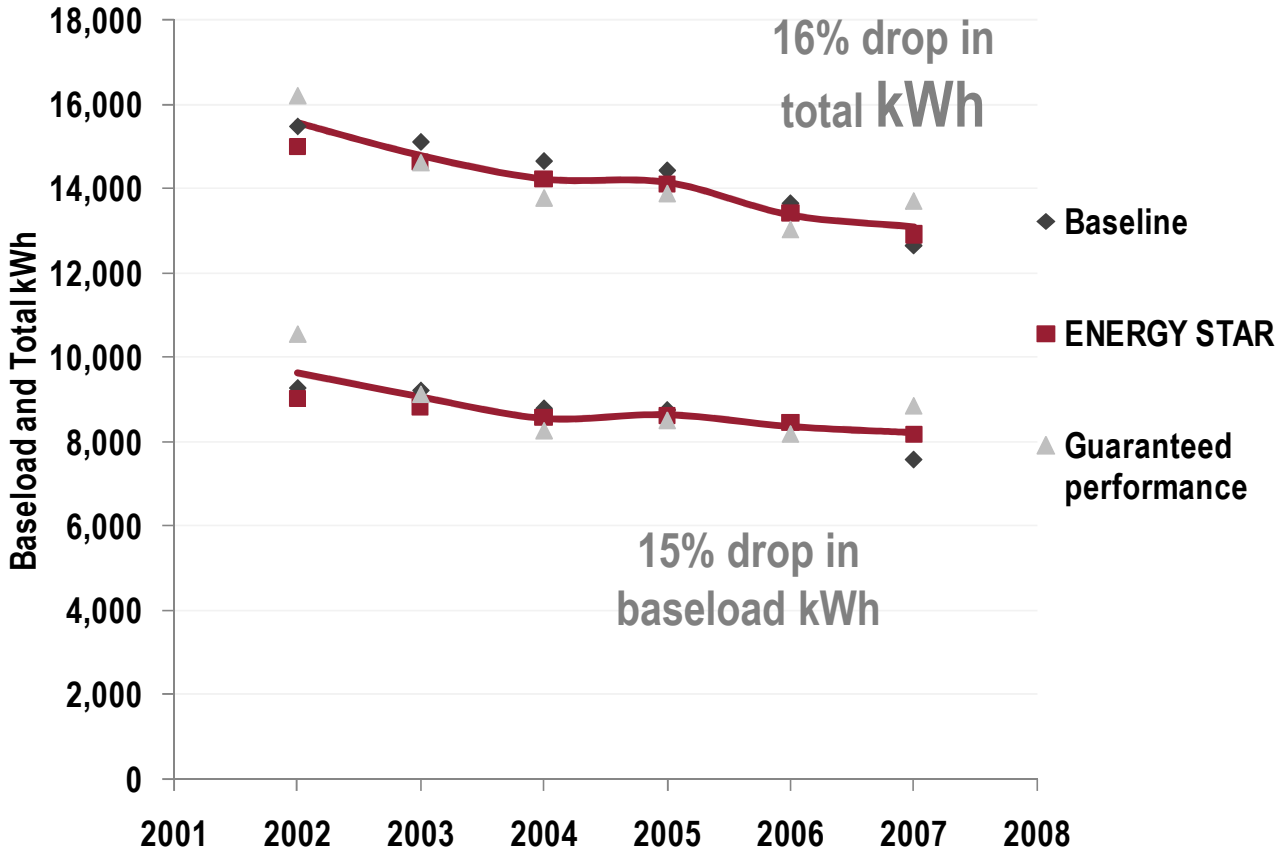
Conclusions

- As a result, savings between program homes and Baseline homes in Houston are small

	Percent Usage Difference vs. Baseline	
	ENERGY STAR	Guaranteed Performance
Summer/cooling kWh (2008)	5% less	6% less
Total kWh (2008)	4% less	2% less

Conclusions

- All New Homes in Houston Are More Efficient



Conclusions

Why only 3-5%lower use in ENERGY STAR?

> 2001 IECC went into effect in Texas September 2002

- SHGC <0.4 windows (30% cooling savings vs. std 0.73 SHGC)
- R-8 ducts with mastic seal on all seams if outside conditioned space
  - R-6 ducts acceptable if AC SEER 14
- Seal recess can lights
- R-19 attics (everyone used R-30)

> 2006 federal SEER minimum standard increased

- 11% drop in baseline home cooling after SEER-13 standard; shows that they weren't SEER-10 before

Conclusions

Spillover effects of ENERGY STAR?

> Duct testing, adoption of mastic for duct sealing & training

> Building tightness standards, air barrier framing practices

Positive spillover effects would reduce observed "savings" when they should increase impact estimates

Lessons Learned

- WHAT DOES HOUSTON TELL US?

Lessons Learned

- ENERGY STAR may have helped facilitate code compliance in Houston

- Most builders in Houston are working with a home performance contractor – either to build to a program or to comply with the code.

Lessons Learned

- Billing analysis can provide accurate measurement of program results and clarifies what specs provide savings

  > Also allows you to benchmark current building practices and develop standards that fit your marketplace

Where do we go from here?

- We need to clarify our models and assumptions
- Is there a need for increasing the ENERGY STAR standards?
- What is the relationship between ENERGY STAR and other high performance home program's to codes and construction markets?

Where do we go from here?

- What else can we learn from Houston?
  - > Are ENERGY STAR houses holding their value?
  - > Differences within groups of program homes?
  - > Are there more energy “hogs” in any particular group?
- How does this play out in different markets and climates?
- Are consumers happier with these homes?
- What else?

THANKS

Shaun Hassel
503-477-0469
shassel@advancedenergy.org

Advanced ENERGY

www.advancedenergy.org