A National Energy Savings Model of US Window Sales

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Purpose

The document describes a methodology to evaluate the space heating and cooling energy impacts of all windows sold in a given year to the residential market. Specifically, this model can be used to estimate the energy savings potentials of proposed revisions to the ENERGY STAR Residential Windows standards, and to quantify these savings. Proposed revised ENERGY STAR standards can be compared against each other, as well as to various baselines. Baselines include the existing standard as well as existing IECC prescriptive standards, and proposed IECC standards.

The model calculates energy savings from all windows sold to the single family residential market, for new and existing homes, in a year. The model does not address cost effectiveness or carbon impacts. The latter are not addressed because of the difficulty of assessing site-specific carbon impacts resulting from incremental increases in loads at varying times of day and energy flows across state lines.

Background

In the January 18, 2008 letter, DOE released proposed revisions to the ENERGY STAR Windows map, outlining a new five zone map which differed enough from the current four zone map that a detailed geographical analysis procedure needed to be developed.

To evaluate potential energy saving from the proposed revisions, we developed a procedure to compare standards/requirements based on various climate maps of the United States, specifically: the existing four-zone ENERGY STAR climate map, the eight-zone IECC climate map, and the new five-zone ENERGY STAR climate map. Because the only common denominator among these three maps is at the county level, this model analyzes energy savings at the county level. Aggregate savings are then summed over all counties in a given zone for the three cases above.

However, population totals are the only reliable county-level data. Other data essential to this analysis are documented at state or regional levels. We

created county level estimates of the following types of data down from state and regional data.

- window sales to new and existing homes (taken from census division estimates of annual window shipments from Ducker Surveys)
- house type: one-, two-story (from RECS)
- heating equipment penetration, by type and fuel: gas, electric heat pump or electric resistance (from RECS)
- cooling equipment penetration (from RECS)
- number of windows per single family home (from RECS)
    - We start with the number of windows sold and then convert window sales into equivalent homes. We then assume that an equivalent home is approximated well by a RESFEN home.

We also chose approximately 100 cities (TMY Weather tapes; see Appendix 1) from across the nation to represent the whole U.S. Each county in the US was then assigned to a nearby city judged to be representative of the local climate.

Methodology

The foundation of this study is a DOE-2 database of window energy use for typical new and typical existing one- and two-story houses (see Arasteh et. al., "RESFEN6 Modeling Assumptions for the 2008 Energy Star Window Analysis", April 2008) for approximately 50 window types, from single-glazed to highly insulating, for 100 climates throughout the U.S (represented by 100 cities as noted above). These prototypical new houses, termed "RESFEN6 houses," are representative new and existing single family houses; their standard characteristics are recently revised from RESFEN 3.1/5.0 characteristics.

We developed regression coefficients to fit these DOE-2 data so that heating and cooling energy could be expressed as a function of U-value and solar heat gain coefficient (SHGC). Infiltration was not considered in this calculation since it is assumed to be a constant among IECC standards and Energy STAR requirements. Total energy was evaluated as source energy using a site/source multiplier for electricity of 3.22.

After assigning a TMY city to each county, the model :

- for each county, determines heating and cooling per square foot of conditioned area for a typical new house based on proportional weighting of one- and two- story homes;
- for each county, determines heating and cooling per square foot of conditioned area for a typical existing house based on proportional weighting of one- and two- story homes;
- for each county, calculates window units sold to new and existing homes, working down from state/regional-level data;
- for each county, translates window units sold into equivalent number of new and existing RESFEN6 houses (based on RECS 2001 data on number of windows for a house in various census zones, these values vary regionally from 11 to 18 windows per home);
- for each county, calculates the energy impacts of proposed window standards scenario(s):
    - **Total county heating energy impacts** = (heating energy impact for typical RESFEN new house * number of new houses) + (heating energy impact for typical RESFEN Existing house * number of Existing houses); summed over the three heating equipment types (gas, electric resistance, electric HP);
    - **Total county cooling energy impacts** = (cooling energy impact for typical RESFEN new house * number of new houses) + (cooling energy impact for typical RESFEN Existing house * number of Existing houses);
    - These county level impacts can be based on:
        - a simple case where all the windows in a county are assumed to have the same U and SHGC properties, (termed the technical potential case), or, on
        - a case where the windows in a county are assumed to be made up of more than one type, with each type having a given penetration, the sum of all penetrations add up to 100%, (termed the penetration case).
- To develop the regional and national impacts, the model sums the effects of multiple counties over all counties in the "zone" from the previous step. A "zone" can be defined as an IECC zone, a current (4 zone) Energy STAR zone, or a proposed (5-zone) Energy STAR zone. The results at this stage of the model are interim results, called "RESFEN-based" or "Uncalibrated" since they assume all windows are placed in RESFEN6 houses, with no allowances for what RECS tells us about residential energy use in "real" houses.

- The model then develops RECS calibration factors for each county by comparing regional data (census zones) from the above step to RECS 2001 (EIA, 2003) estimates of actual heating and cooling. Separate calibration factors are developed for heating and cooling. These calibration factors include the following effects:
    - Fraction of homes which have cooling equipment
    - Fraction of homes which have heating equipment
    - All other differences between stock buildings and modeled buildings in order to align total simulated energy consumption for a census division with that estimated by RECS.
- These RECS calibration factors developed in the prior step are then applied (again, at a county level) to the total county heating energy impacts and the total county cooling energy impacts. A final set of regional and national energy impacts are then developed based on the use of these calibration factors. These final results are then termed "RECS-calibrated."

Applications of the Model to the 2008 Energy STAR standards

The above described model has been incorporated into an Excel spreadsheet for use at LBNL. Input to the model consists of the following data (separately for new and existing markets):

	Window Sales	Window Type 1	Window Type 2	…..	Window Type N
Zone 1		% penetration, U, SHGC			
Zone 2					
….					
Zone M (M=8 for IECC; 5 for Proposed E*, 4 for existing E*)					

The model produces results for total space residential heating and cooling energy for a given "standard". To look at differences between Window standards or scenarios, the differences between cases need to be obtained by simple subtraction.

The final results for energy savings for the proposed new standards are given in DOE's final August report by D&R. These savings are the RECS calibrated results. In general, the non-calibrated or RESFEN results over-predict heating (20%) and cooling (30%) at the national level; variations in regional levels are from -50% to 80% overprediction for heating and 0% to 150% overprediction for cooling. While we believe the RECS calibration factors at a national level, their application to smaller regions should not be taken for granted. This is due primarily to the fact that the underlying census and RECS data is presented at a census region/zone level – and these divisions do not correspond to window energy subdivisions. For example, data presented for the whole Mountain or Pacific census division is not necessarily equally applicable to all micro-climates in these regions. For this reason, the criteria developed are consistent with the trends from both the RESFEN and the RECS-calibrated results.

The results from the model were also used to develop U/SHGC trade-offs for the northern zones. These results are documented in the "Tradeoff Summary" sheet of the "LBNL Results…" Excel file at windows.lbl.gov/EStar2008. We looked at Energy STAR zones 5 and 4 separately. [The dependence of SHGC on total energy use in Zone 3 is inconsequential.] For zones 4 and 5, we determined tradeoffs for both the "RESFEN" cases and the "RECS-calibrated" case. For Zone 5, both these cases resulted in a similar tradeoff (a .05 increase in SHGC compensates for a .01 increase in U-factor). For zone 4, there was a significant difference in the tradeoff between the RESFEN and the RECS-Calibrated case due to the fact that RECS estimates much less cooling in Zone 4 than RESFEN. The proposed tradeoff in Zone 4 (a .08 increase in SHGC compensates for a .01 increase in U-factor) is an average of the RESFEN and RECS-Calibrated cases.

References

Apte, J. and D. Arasteh. *Window-Related Energy Consumption in the U.S. Residential and Commercial Building Stock*. Lawrence Berkeley National Laboratory. LBNL-60146. http://gaia.lbl.gov/btech/papers/60146.pdf

Energy Information Administration (EIA), 2003. Residential Energy Consumption Survey, 2001.

Appendix 1: Cities Modeled

City	State
BIRMINGHAM	Alabama
MOBILE	Alabama
ANCHORAGE	Alaska
FAIRBANKS	Alaska
FLAGSTAFF	Arizona
PHOENIX	Arizona
PRESCOTT	Arizona
TUCSON	Arizona
LITTLE_ROCK	Arkansas
ARCATA	California
BAKERSFIELD	California
DAGGETT	California
FRESNO	California
LOS_ANGELES	California
REDBLUFF	California
SACRAMENTO	California
SAN_DIEGO	California
SAN_FRANCISCO	California
BOULDER (Denver)	Colorado
GRAND_JUNCTION	Colorado
HARTFORD	Connecticut
WILMINGTON	Delaware
DAYTONA_BEACH	Florida
JACKSONVILLE	Florida
MIAMI	Florida
TALLAHASSEE	Florida
TAMPA	Florida
ATLANTA	Georgia
SAVANNAH	Georgia
HONOLULU	Hawaii
BOISE	Idaho
CHICAGO	Illinois
SPRINGFIELD	Illinois
INDIANAPOLIS	Indiana
DES_MOINES	Iowa
WICHITA	Kansas
LEXINGTON	Kentucky
LOUISVILLE	Kentucky
LAKE_CHARLES	Louisiana
NEW_ORLEANS	Louisiana
SHREVEPORT	Louisiana
PORTLAND	Maine
BALTIMORE	Maryland
BOSTON	Massachussets

DETROIT	Michigan
GRAND_RAPIDS	Michigan
HOUGHTON	Michigan
DULUTH	Minnesota
INTERNATIONAL_FALLS	Minnesota
MINNEAPOLIS	Minnesota
JACKSON	Mississippi
KANSAS_CITY	Missouri
ST._LOUIS	Missouri
BILLINGS	Montana
GREAT_FALLS	Montana
OMAHA	Nebraska
LAS_VEGAS	Nevada
RENO	Nevada
CONCORD	New Hampshire
ATLANTIC_CITY	New Jersey
ALBUQUERQUE	New Mexico
ALBANY	New York
BUFFALO	New York
NEW_YORK_CITY	New York
CHARLOTTE	North Carolina
RALEIGH	North Carolina
BISMARCK	North Dakota
CLEVELAND	Ohio
DAYTON	Ohio
OKLAHOMA_CITY	Oklahoma
MEDFORD	Oregon
PHILADELPHIA	Pennsylvania
PITTSBURGH	Pennsylvania
WILLIAMSPORT	Pennsylvania
PROVIDENCE	Rhode Island
CHARLESTON	South Carolina
GREENVILLE	South Carolina
PIERRE	South Dakota
MEMPHIS	Tennessee
NASHVILLE	Tennessee
AMARILLO	Texas
BROWNSVILLE	Texas
EL_PASO	Texas
FORT_WORTH	Texas
HOUSTON	Texas
LUBBOCK	Texas
SAN_ANTONIO	Texas
CEDAR_CITY	Utah
SALT_LAKE_CITY	Utah
BURLINGTON	Vermont
RICHMOND	Virginia
STERLING (DC)	Virginia

SEATTLE	Washington
SPOKANE	Washington
CHARLESTON	West Virginia
MADISON	Wisconsin
CHEYENNE	Wyoming