Technical Support for ENERGY STAR Windows Version 6.0 Specification Revision

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1. Purpose

The purpose of this document is to describe LBNL's national energy savings model for windows sales, the methodology used to estimate the energy savings potentials of several proposed residential windows standards, and in particular the revisions to the savings model specific to the upcoming ENERGY STAR residential windows specification. The focus is on describing the assumptions and changes to the model. We do not report results of the analysis; which will be discussed in EPA's Draft 1 Criteria and Analysis Report.

2. Background

In 2008, as part of the technical support for the then current ENERGY STAR specification, LBNL developed a procedure to compare energy impact arising from several standards and proposed requirements. These standards and proposals often divided the United States using differing climate maps, such as the previous four-zone ENERGY STAR climate map, the eight-zone IECC climate map, and the present revised Energy Star[1] climate map. Because the only common denominator among these maps is at the county level, the model analyzes energy savings at the county level, and aggregate savings are summed over all counties in a given zone for each standard or proposal considered. The model provides estimates of the space heating and cooling energy impacts of windows sold to the residential market in a given year. In addition to allowing multiple proposals for revised ENERGY STAR criteria to be compared against each other, the model also can include several baselines.

When the present ENERGY STAR criteria took effect in January 2010, the criteria for the next revision ("phase 2") were not finalized, but deferred to allow time for collecting additional data and performing additional analysis. In the framework document of June 14, 2011, ENERGY STAR announced the intention to undertake a criteria revision for windows, doors, and skylights with the intent that the final specification would take effect no earlier than Fall 2013. LBNL undertook to modify the national energy savings model to provide an evaluation framework for the revised specification.

3. Changes to the Model

This update uses the same basic framework and tools as the 2008 specification. We retained most of the previous assumptions and methods; the intent was to keep the methodology as similar as possible to the previous analysis so that the calculation of savings estimates would be as consistent as possible. The underlying modeling assumptions are based on RESFEN 6 (Apte and Arasteh 2006, Apte et al. 2008). This version the model incorporates new specifications for reference windows, updates market data, and allows for the evaluation of windows with a wider range of energy performance.

3.1 Reference Windows

The reference window specifications were developed in a manner very similar to the last criteria revision. The first reference window, used to represent low-end products and older code options, was a double-pane, clear glass, vinyl product with a U-factor of 0.45 and a solar heat gain

[1] The revised Energy Star map introduced in 2008 uses a four zones map in the specification, with different zones than in the original specification, but in the LBNL model the northern zone is sub-divided into three giving a 6 zone map, see the appendix for details.

coefficient (SHGC) of 0.55. With modifications to SHGC, the IECC 2009 prescriptive window criteria were used as the basis for the next set of reference criteria. During its product feasibility and product availability research, D&R International determined that the mean and median SHGC for both data sets was 0.22 (down from 0.30 in the 2008 analysis), so 0.27 was selected for the SHGC specification to be modeled as a conservative compromise between the 2008 SHGC and the current typical product performance. This process was repeated for the IECC 2012 reference window criteria selection with 0.27 again selected for the specification (except where code exceeds this level, i.e. 0.25 was selected for IECC zones 1-3) and the current (Version 5.0) ENERGY STAR criteria. The reference windows criteria and modeled levels are summarized in **Table 1**. Maps of the zones are in the appendix.

Table 1. Summary of Modeled Reference Windows

		Criteria Maxima		Model Inputs	
	Zone	U-factor	SHGC	U-factor	SHGC
Double Clear	N/A	N/A	N/A	0.45	0.55
IECC 2009	8	0.35	NR	0.35	0.27
	7	0.35	NR	0.35	0.27
	6	0.35	NR	0.35	0.27
Northern	5	0.35	NR	0.35	0.27
N-Central	4	0.35	NR	0.35	0.27
S-Central	3	0.50	0.30	0.50	0.27
Southern	2	0.65	0.30	0.65	0.27
	1	1.20	0.30	1.20	0.27
IECC 2012	8	0.32	NR	0.32	0.27
	7	0.32	NR	0.32	0.27
	6	0.32	NR	0.32	0.27
Northern	5	0.32	NR	0.32	0.27
N-Central	4	0.35	0.40	0.35	0.27
S-Central	3	0.35	0.25	0.35	0.25
Southern	2	0.40	0.25	0.40	0.25
	1	NR	0.25	1.20	0.25
ES Current	6	0.30	NR	0.30	0.27
(Phase 1)	5	0.30	NR	0.30	0.27
	4	0.30	NR	0.30	0.27
Trade-offs		0.31	0.35	N/A	N/A
Northern		0.32	0.40	N/A	N/A
N-Central	3	0.32	0.40	0.32	0.27
S-Central	2	0.35	0.30	0.35	0.27
Southern	1	0.60	0.27	0.60	0.27

Note to Table 1 – NR = “no requirement” for the zone.

To evaluate potential Version 6.0 ENERGY STAR criteria, several sets of reference window specifications were developed. The potential criteria selected for modeling included several complete criteria sets to evaluate overall programmatic impact potential and a number of individual U-factor and SHGC criteria across the zones to better understand trends in heating and

cooling loads at various levels. A discussion of the results of these analyses is provided in EPA's Draft 1 Criteria and Analysis Report. An abbreviated summary of performance criteria evaluated is provided in **Table 2**.

Table 2. Summary of Modeled Criteria Scenarios		
ENERGY STAR Climate Zone	U-Factor	SHGC
Northern	0.18-0.27	0.25-0.27
North-Central	0.22-0.30	0.27
South-Central	0.25-0.32	0.23-0.25
Southern	0.30-0.40	0.17-0.25

3.2 Market Penetration

We estimated market penetration rates for the existing specification and the specifications included in the analysis broken out by modified census regions and by new construction versus renovation/replacement. The modified census regions include the nine U.S. Census Divisions with California and Florida considered separately from their respective divisions. There were two forecast conditions: pre- and post-implementation of Version 6.0. Post-implementation accounted for possible lowered ENERGY STAR sales subsequent to the implementation of the new specification. Several post-implementation scenarios were considered with varying degrees of market share impact on ENERGY STAR product.

The method for estimating the market penetrations at various standard/specification levels was as follows:

- Building code requirements were reviewed at the state level and a window efficiency level was assigned for that state – either IECC 2003, 2006, 2009, 2012 (for the 2013 review year), or ENERGY STAR – corresponding to the minimum requirements for that state.
- Regional market shares by state are the population-weighted average of the state level assignments.
- For the existing 2010 analysis, the final regional IECC market shares were apportioned to new construction and to renovation/replacement categories in accordance with an estimated ratio of new construction to renovation/replacement from Ducker (2011a). The 2010 existing ENERGY STAR Market Share is from the Ducker Report of ENERGY STAR unit sales (Ducker, 2011b).
- For the 2013 forecast analysis, the final IECC projections were based on known or assumed code adoption plans by state. All states were assumed to establish a minimum model code equivalent to the IECC 2009 specification by 2013, however in order to account for transition periods and enforcement:
    - States with current model codes of IECC 2003 or earlier were projected to be at an IECC 2006 equivalent by 2013.
    - States with current model codes of IECC 2006 were projected to be at the expected IECC 2009 requirement.
    - For those states already having model codes of IECC 2009, only those with a history of active IECC adoptions were projected to adopt the IECC 2012 model code by 2013.
- ENERGY STAR market penetration projections were based on a logarithmic curve fitted to initial program market share (1999, 15%) and current market share (2010, 81%).

- Originally market penetrations were developed for IECC specifications 2003, 2006, 2009, and 2012. However, during the analysis – based on review of the CDP and the latest Ducker (2011a) reports – the market shares for IECC 2003, and 2006 were assigned to the standard reference window (vinyl frame, double pane, clear glazing).
- A reference window for single pane was also developed, but the market data indicated a very high penetration rate for at least double pane designs, so the single pane window was not included in the final analysis, though it will be used to calculate household savings.

3.3 Expansion of the Model

To better inform the evaluation of specification levels, we increased the number of new model specifications that could be compared from two to five; in addition, we expanded both the number and modeling details of the base cases.

The baselines for the previous 2008 analysis included only an assumed standard replacement window (vinyl frame, double pane, clear glass, U=0.45 SHGC=0.55) and a single IECC specification (2008 for the phase 1, 2009 for phase 2). The current, expanded analysis developed savings comparisons for two baselines (corresponding to 2010 existing and 2013 post-implementation) and each of five proposed model specifications. The new baselines include the standard replacement (initially three IECC cases), and existing ENERGY STAR with market shares for each as described in section 3.2 above.

The expanded model was extensively tested to ensure that it properly implemented the methods and data described above.

4. Methodology

The climate zone structure from the 2008 analysis was retained with climate maps corresponding to 2008 ENERGY STAR, current ENERGY STAR and IECC. As already noted, the common denominator among these three maps is at the county level, so the model analyzes energy usage at the county level. Aggregate consumptions are then summed over all counties in a given zone; savings are estimated by comparing the consumptions under the varying specification conditions.

The foundation for this work continues to be the DOE-2 database of window energy use for typical houses, new and existing and one- and two-story types for approximately 50 window types, from single-glazed to highly insulating (Apte and Arasteh, 2008). In addition, approximately 100 cities were selected from the set of cities for which there are National Oceanic and Atmospheric Administration's Typical Meteorological Year (TMY) data to represent the United States as a whole (see Apte and Arasteh, op. cit., Appendix 1 for specific assignments).

These prototypical houses, termed "RESFEN6 houses," are representative of new and existing single-family houses. For the 2008 specification, LBNL developed regression coefficients that fit the DOE-2 data and allow heating and cooling energy to be expressed as a function of U-factor and SHGC. These coefficients were retained in the current revision.

In brief, the model functions by:

- Assigning a representative TMY city to each county.
- Determining the heating and cooling area for new and existing homes in each county based on proportional weighting of one- and two- story homes.

- Calculating window units sold to new and existing homes, working down from state/regional-level data.
- Translating window units sold into equivalent number of new and existing RESFEN6 houses (based on RECS 2001[2] data on number of windows for a house in various census zones; these values vary regionally from 11 to 18 windows per home).
- Summing the total county heating and cooling energy impacts; heating is summed over three equipment types (gas, electric resistance, and electric heat pumps).
- Aggregating regional and national impacts; the model sums the effects of multiple counties over all counties in the "zone" from the previous step. These zones can be defined as an IECC zone, an old (2008) ENERGY STAR zone, or a current 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.
- Calibrating the results; the model includes RECS calibration factors for each county developed by comparing regional data (census divisions) from the above step to RECS 2001 (EIA, 2003) estimates of actual heating and cooling. Separate calibration factors are developed for heating and cooling. The 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.
- Applying these RECS calibration factors to the total county heating and 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, which are what were used in the analysis, are then termed "RECS-calibrated."

4.1 Major Housing Characteristics Assumptions

Table 3 lists the major assumptions in how homes are modeled in our analysis. For a full description of the RESFEN modeling assumptions see Arasteh et al (2008).

[2] The RECS 2001 data used in the original analysis both for this translation of units sold into equivalent homes and for the calibration was retained in this update, even though there had been a new release of the RECS survey, to maximize consistency.

Table 3 Housing Characteristics Assumptions		
Floor Area	1 Story Homes	2 Story Homes
New	1700 sq. ft.	2800 sq. ft.
Existing	1700 sq. ft.	2600 sq. ft.
House Type Construction is modeled as frame. Both 1- and 2-story houses are modeled in all climates. Energy impact based on the fractions of 1- and 2-story homes in each climate, for New and Existing.		
Foundation: Based on location, and National Association of Home Builders (NAHB) data. Basement, slab, and crawlspace foundation types are modeled		
Insulation:	New Homes	Existing Homes
	New is based on location using 2006 IECC requirements in Table 402.1.1 (except for fenestration).	Existing is modeled based on Ritschard et al. (1992).
Infiltration:	New	Existing
	SLA[3] = 0.00036	SLA = 0.00054

5. Summary and Limitations to the Analysis

The model calculates energy savings from all windows expected to be sold to the single-family residential market for new and existing homes in a year. The resulting savings estimates are "first year" program savings, and do not reflect further gains in market penetration in years following the introduction of the spec. The LBNL model described here does not attempt to address cost effectiveness or carbon impacts. EPA will present cost-effectiveness analysis in the Draft 1 Criteria and Analysis Report. Carbon impacts were not included in this analysis because of the difficulty of assessing site-specific carbon impacts resulting from incremental increases in loads at varying times of day as well as energy flows across state lines.

[3] SLA = Standard Leakage Area = Effective leakage area / conditioned floor area.

6. References

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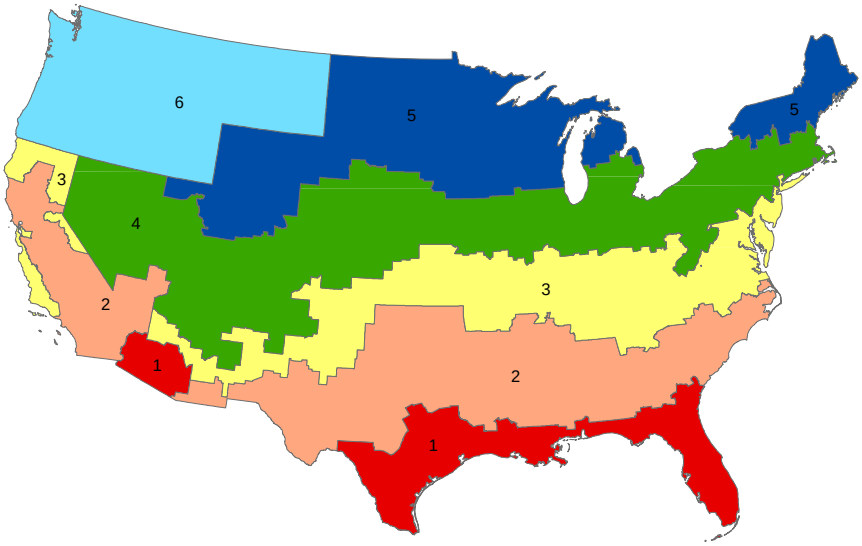
Appendix

Figure 1. Map of Energy Star Zones used in this analysis.



Note: Zones 4, 5, and 6 comprise the current ENERGY STAR Northern Zone.

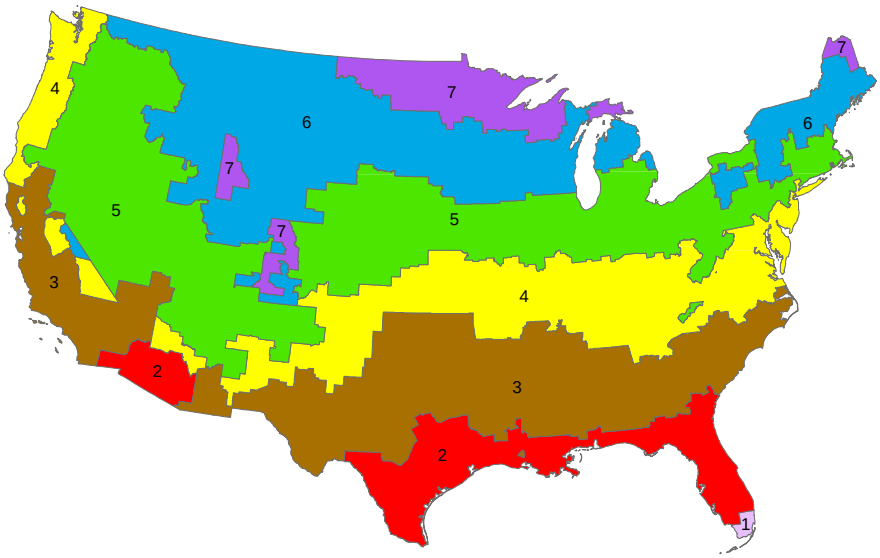



Figure 2. Map of IECC Zones used in this Analysis