Methodology for Calculating Energy Use in Residential Buildings

Prepared for

National Association of Home Builders

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Disclaimer

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Executive Summary

This white paper describes a method for determining energy usage in a representative single-family house for a specific energy code in a specific location. Energy usage is expressed in terms of electric (kWh) and natural gas (therm) usage. Beyond that, this paper also provides procedures to: 1) convert energy metric based on application (site, source or cost); 2) calculate percent energy savings between different editions of an energy code; 3) perform a regional (e.g., state, county) or national energy analysis; and 4) analyze energy impact or neutrality of code amendments.

The International Energy Conservation Code (IECC) minimum requirements are the primary basis for defining the *Standard Reference House.* However, there are many parameters not defined by the IECC which are necessary for a more detailed analysis. The Department of Energy's Building America (BA) program and the NAHB Research Center's Annual Builder Practices Survey (ABPS) have defined in detail many parameters representative of typical homes which are used to complement the IECC.

It is assumed that the 2006 edition of the IECC, the 2008 Building America Benchmark specifications, and the 2009 ABPS results are used as the baseline for comparative analyses; however, the methodology allows for other baselines. The methodology can be used to analyze energy usage for a variety of codes or for comparison of energy use from one code edition to another. For instance, a code-minimum compliant house designed to the 2006 IECC edition may be compared to the 2009 edition by modifying only the new requirements in the 2009 IECC. The differences in energy performance combined with the change(s) in first cost (not covered in this paper) may be used to assess cost effectiveness. The comparisons may also be used to document equivalence for alternative prescriptive designs to any referenced code, or calculate percent energy savings between code editions on a local, state, or national basis.

When determining energy usage beyond a single house in a single location, a methodology is needed to aggregate the effects of different foundations, wall types (mass or light-framed), heating fuel (electric or natural gas), and climate that are prevalent within a defined region (e.g., jurisdiction, state). The impact of these factors can be estimated by defining a representative house with specific characteristics and by estimating energy loads according to the climate for that region and house type. This aggregation methodology can be used for estimating impacts for regions that are inclusive of multiple climate zones and for different house design types, such as different foundation types (e.g., slab-on-grade, basement, or crawlspace). To determine and compare national average household energy consumption results from each climate zone must be weighted by housing starts.

This methodology is intended to be universally applicable and allow for customization by using locally relevant data. For local and regional applications of this methodology site-specific or region-specific data may be substituted for the listed national averages. Deviations from this methodology are acceptable; however, they must be noted when reporting energy use resulting from these procedures.

Background

With a strong push for energy efficiency in model building codes and proposed federal legislation, there is a need for a defined methodology by which household energy usage for a specific energy code can be determined. When developing an energy usage or energy savings methodology, the definition is neither obvious nor trivial. A well-documented approach is necessary to define a reasonable “measuring stick” by which energy usage can be accurately and consistently quantified and compared.

The purpose of this paper is to describe a repeatable methodology for determining energy usage for a residential building consistent with modern housing. The calculated annual energy usage of a Standard Reference House will be representative of a house in a specific region. The methodology also allows analysis of specific changes to the thermal characteristics in order to quantify energy consumption differences relative to the baseline.

Basis for Energy Evaluation Methodology

For an energy usage methodology to be clear and repeatable, it is necessary to define the geometry of a standard reference building and appropriate energy performance parameters. In addition, it must be understood that this a methodology to determine an energy usage baseline using the performance path for an average-sized, code-minimum home; the baseline must not to be confused with how any other code or a specific code change will affect the annual energy usage of a typical home. This distinction is important because many homes were constructed with features exceeding the minimum requirements and included features such as higher efficiency windows and tighter building envelopes than required.

There are many variables that are not controlled by the code which must be defined in order to perform consistent calculations. For example, the size of the residence and the location of the duct system are not specified within the code. Although this methodology specifies house size and construction assumptions, which are necessary to obtain consistent results, in most cases the results are not overly sensitive to keeping those assumptions constant. The *Standard Reference House* developed for this methodology represents typical energy usage for an average-dimensioned house built the year the code was published, following the minimum code requirements. This methodology can also be applied to determine the code’s impact on the average annual energy savings (e.g. comparing the 2006 IECC to the 2009 or 2012).

Some code changes introduce new requirements rather than just increasing existing requirements, which means they require a new baseline definition of additional inputs for the analysis. This step was needed for mandatory building tightness and duct tightness requirements, and the inclusion of lighting requirements introduced in the 2009 IECC.

There may be occasions where a new requirement may not be defined in either the 2006 IECC Performance Path or the Building America Benchmark (Hendron 2008). In these cases, credible research such as peer reviewed papers may be necessary in order to adjust the reference building.

Ultimately, all the building geometry, thermal requirements, and equipment performance must be analyzed using computer-based energy simulation software. Computer software quantifies the annual energy usage for the defined house. This methodology defines BEopt (currently version 0.9.5.2) as the evaluation software. BEopt was developed by the National Renewable Energy Laboratory (NREL) to both quantify building energy usage and optimize energy features for DOE's Building America Program, and is publically available at no charge. When the software is unable to do a direct analysis of a code change (e.g., skylights), or proposed change other analysis methodologies, such as related energy studies or alternate calculation software, must be used to quantify the impact.

Application of Methodology

This methodology allows quantification of energy use in a specific house or energy use comparisons between homes with different building component specifications. Evaluation of the energy performance based on the *standard reference house* in a single location or the results can be aggregated by weighting the building characteristics (walls, foundations), energy type (gas, electric), energy cost and/or housing distribution in different climate zones. By providing the appropriate diversity mix of the listed parameters, results can be obtained on a local, state or national basis.

Weighted Averaging

The use of weighted averaging is necessary to account for the diversity of wall materials, foundation configurations and climate conditions. Weighted averaging is applied both within and across climate zones. Within climate zones, weighting is applied to wall construction types for light-framed and mass walls and to foundation types (slab, crawlspaces, and basements) are applied. Once the savings within a climate zone are determined, a weighted calculation according to building starts (Briggs 2002) for each climate zone is performed in order to obtain a national average. If updated national or local weighting factors are available, they can be used as part of this methodology provided they are noted in the analysis.

Standard Reference House

Building configuration for the *Standard Reference House*, including shape, size, foundation, and wall materials, was primarily defined by the results of the 2008-2009 Annual Builder Practices Survey (ABPS) conducted by the NAHB Research Center. The ABPS is an annual national survey of builders that gauge national and regional building practices and material use. This survey represents a comprehensive source of general housing characteristics in the United States and contains information on building square footage, wall square footage, climate-based foundation type, climate-based wall construction type, and other residential construction characteristics. The parameters represent the average (mean) values from the survey for building areas and features not dictated by the 2006 IECC.

Building Surroundings

Although most homes have some shading from nearby foliage, overhangs, or other adjacent buildings, this methodology (consistent with the 2006 IECC) assumes no shading.

Building Envelope Parameters

The building thermal envelope requirements are those in the Equivalent U-factor prescriptive table (e.g. Table 402.1.3 in the 2006 IECC) for the baseline and modified requirements for later editions of the energy code.

House Geometry

The above-grade house geometry is the same for all climate zones. The *Standard Reference House* (Figure 1) is not intended to represent a house that has been or would be built; however, it does represent the relative averages for the components that affect energy consumption. This is appropriate for a methodology such as this with a goal to predict representative energy usage.

Table 1 reflects the data from the ABPS and the rounding adjustments used in order to make a "buildable" *Standard Reference House* model. The conditioned floor area (CFA) represents the above-grade floor area; models with conditioned basements will have larger conditioned areas. The listed wall areas do not include band (or rim) joist areas which are assumed to be one foot high and insulated when adjacent to conditioned space.

Table 1. Average Wall and Floor Square Footage

	Annual Builder Practices Survey (ABPS)	Standard Reference Model
1st Floor CFA	1,780	1,776
2nd Floor CFA	572	576
Total CFA (w/o Conditioned Basement)	2,352	2,352
Slab/Basement/Crawl Floor Area		1,776
Total CFA (with Conditioned Basement)		4,128
Attic Floor Area		1,776
1st Floor Wall Area	2,006	1,764
2nd Floor Wall Area	586	816
Total Above Grade Wall Area	2,592	2,580
Basement Wall Area (8ft wall height)		1,568
Crawlspace Wall Area (4ft wall height)		784
Window Area (18%/15%)		464/387

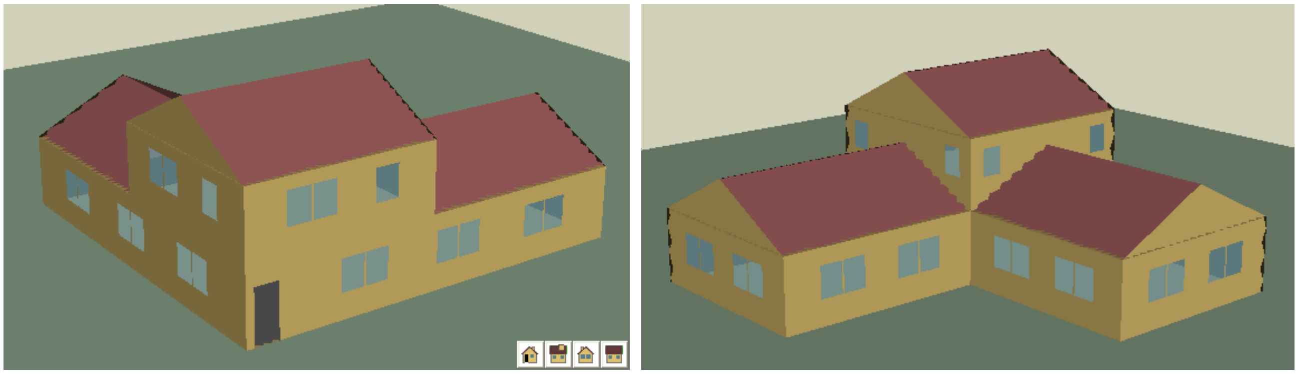

Figure 1. Simulation Model of Standard Reference House

House Shape

Most houses are irregular in shape (i.e., not rectangles). Consequently, houses have a higher ratio of wall to floor area as compared to a simple rectangle. The *Standard Reference House* shape incorporates average wall areas and floor areas along with assigning equal wall exposure in all cardinal directions into its design.

Above-Grade Wall Construction

The energy code has different insulation requirements for light-framed (i.e., wood and cold-formed steel studs) and mass (i.e., block, poured concrete, solid logs) walls. In addition, the percentage of each wall construction type (light-framed vs. mass) varies geographically (e.g., by climate zone, state, county, jurisdiction). Table 2 is provided to quantify the distribution of light-framed and mass walls for all climate zones was determined from the ABPS results. If the analysis is conducted for a specific geographic location (e.g., state), the distribution of wall types specific to that geographic location must be used.

Table 2. Wall Type Breakdown by Climate Zone

Climate Zone	Light-Framed Walls	Mass Walls
1	35%	65%
2	85%	15%
3	100%	0%
4	100%	0%
5	95%	5%
6	100%	0%
7 & 8	100%	0%

Note: results are rounded to nearest 5%.

Foundations

Similar to wall construction types, houses built over basements, crawlspaces, and slabs have varying energy code requirements. Typical foundation types are also strongly climate dependent. Table 3 is provided to quantify aggregate energy savings from code changes that apply to the various foundation types. Climate zone distributions of foundation type are based on ABPS results. For the purposes of this methodology, conditioned basements are treated as conditioned floor area. If the analysis is conducted for a specific geographic location (e.g., state), the distribution of foundation types specific to that geographic location must be used.

Table 3. Foundation Type by Climate Zone

Climate Zone	Conditioned Basement (%)	Conditioned Crawlspace (%)	Slab-on-Grade (%)	Unheated Basement (%)	Vented Crawlspace (%)
1 & 2	0	0	90	0	10
3	0	0	75	15	10
4	35	0	25	20	20
5	45	5	10	35	5
6, 7 & 8	75	5	5	10	5

Note: Results are rounded to nearest 5%.

Bedrooms

ABPS results indicate the average number of bedrooms in a newly-constructed house was 3.44. Since the BEopt software can only model whole numbers and assumes full occupancy in all bedrooms (2 people in the master bedroom), a rounded number of three bedrooms (4 occupants) is used in the *Standard Reference House* for this methodology.

Fuel Type

The space and water heating fuel type will have an impact on the magnitude of the energy savings. In order to properly include this factor, jurisdictions aggregating energy savings must include a distribution of fuel types for the analysis. Table 4 provides a breakdown of primary heating fuel sources for homes by climate zone. It is assumed that the same fuel type is used for both space and water heating.

Table 4. Heating Fuel Type by Climate Zone

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zones 7 & 8
Electric Heat	85%	70%	55%	35%	20%	5%	0%
Gas/Oil	15%	30%	45%	65%	80%	95%	100%

Note: Results are rounded to nearest 5%.

Energy Modeling Assumptions

Energy modeling parameters for the *Standard Reference House* are summarized in Tables 5 and 6. Table 5 includes specific modeling specifications; Table 6 includes the building envelope U-factors by climate zone taken directly from the IECC.

Table 5. Modeling Specifications for Standard Reference House

Building Component	Specifications (Source)
Above-grade Walls and Rim Joists	Type: Wood Frame/Mass (per Table 1) (ABPS) U-factor: Per Table 402.1.3 (2006 IECC or Baseline) Gross area: Total 2,580 ft^2; 1,764 ft^2 first floor; 816 ft^2 second floor (ABPS) Solar absorptance / emittance = 0.75/0.90 (2006 IECC)
Basement and Crawlspace Walls	Type: Mass (ABPS) U-factor: Per Table 402.1.3 (2006 IECC or Baseline) Gross area: Per Table 3 (ABPS) w/insulation on interior side of walls when specified Height: Basement wall 8 ft high, 2 ft above grade; Crawlspace 4 ft high, 2 ft above grade (NAHBRC assumption)
Above-grade Floors	Type: Wood Frame/Slab (per Table 3) (ABPS) Gross area: 2,352 ft^2 first floor; 572 ft^2 second floor (ABPS)
Ceilings (adjacent to vented attics)	Type: Wood Frame U-factor: Per Table 402.1.3 (2006 IECC or Baseline) Gross area: 1,780 ft^2 (ABPS)
Roofs	Type: Composition Shingle on Wood Sheathing Pitch: 6/12 (Hendron 2008) Solar absorptance/emittance = 0.75/0.90 (2006 IECC)
Attics	Type: Vented with Aperture = 1 ft^2 per 300 ft^2 ceiling (2006 IECC)
Foundation	Type: Per Table 3 (APBS)
Doors	Area: 40 ft^2 (2006 IECC) Orientation: North (2006 IECC) U-factor: Same as fenestration per Table 402.1.3. (2006 IECC or Baseline)
Glazing	2006 IECC - Glazing area 18% of above-grade CFA (2006 IECC) (464 ft^2) 2009/2012 IECC - Glazing area 15% of above-grade CFA (2009 IECC, 2012 IECC) (387 ft^2) Orientation: Equally distributed to four cardinal compass orientations (N, E, S & W) (2006 IECC) U-factor: Per Table 402.1.3 (2006 IECC or Baseline) SHGC: Per Table 402.1.1, (for NR) SHGC = 0.40 shall be used (2006 IECC or Baseline) Interior shade fraction: Summer (all hours when cooling is required) = 0.70 (2006 IECC) Winter (all hours when heating is required) = 0.85 (2006 IECC) External shading: none (2006 IECC)
Skylights	2.4 ft^2 per house (ABPS)
Thermally Isolated Sunrooms	None (NAHBRC assumption)
Mechanical Ventilation	Annual vent fan energy use: kWh/yr = 0.03942 x CFA + 29.565 x (N_{br} + 1) (2006 IECC) where: CFA = conditioned floor area N_{br} = number of bedrooms
Internal Gains	Building America Benchmark (Hendron 2008)
Internal mass	An internal mass for furniture and contents of 8 lbs per square foot of floor area (2006 IECC)

Building Component	Specifications (Source)
Structural Mass	For masonry floor slabs, 80% of floor area covered by R-2 carpet and pad, and 20% of floor directly exposed to room air (2009 IECC) For masonry basement walls with insulation required by Table 402.1.3 located on the interior side of the wall (2006 IECC or Baseline) For all other walls, ceilings, floors: wood framed construction
Heating Systems	Fuel type: Natural Gas/Electric by climate zone per Table 4 (ABPS) Efficiencies: 78 AFUE/7.7 HSPF (2006/2009/2012 IECC), Prevailing federal minimum efficiency as of standard publish date (Future Codes) Capacity: Sized in accordance with Section M1401.3 of the IRC (2006 IECC)
Cooling Systems	Fuel type: Electric Efficiency: 13 SEER (2006/2009/2012 IECC), Prevailing federal minimum efficiency as of standard publish date (Future Codes) Capacity: Sized in accordance with Section M1401.3 of the IRC (2006 IECC)
Service Water Heating	Fuel type: Natural Gas/Electric by climate zone per Table 4 (ABPS) Efficiency: Gas = 59.4 EF, 0.78 RE (2006/2009/2012 IECC), Electric = 90.4 EF, 1.00 RE (2006/2009/2012 IECC), Prevailing federal minimum efficiency as of standard publish date (Future Codes) Tank Size: Gas = 40 Gallon (Hendron 2008) Electric = 50 Gallon (Hendron 2008) Daily hot water use (Hendron 2008) Tank temperature: 120°F (2006 IECC)
Thermal Distribution Systems	Duct location: Per Building America Benchmark (Hendron 2008) Insulation: From Section 404.3.2.1. (2006 IECC) Leakage rate: 2006 IECC: 10% flow leakage outside ducts; 5% flow leakage air handlers (Hendron 2008) 2009 IECC: 8 cfm/100 ft^2 for portions of building with ducts outside conditioned space (2009 IECC) 2012 IECC: 4 cfm/100 ft^2 for portions of building with ducts outside conditioned space (2012 IECC)
Thermostat	Type: Manual Cooling temperature set point = 76°F Heating temperature set point = 71°F (Hendron 2008)

Table 6. Baseline 2006 IECC U-Factors

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Ceiling U-Factor	Light-Frame Wall U-Factor	Mass Wall U-Factor	Floor U-Factor	Basement Wall U-Factor	Crawlspace Wall U-Factor
1	1.2	0.75	0.035	0.082	0.197	0.064	0.360	0.477
2	0.75	0.75	0.035	0.082	0.165	0.064	0.360	0.477
3	0.65	0.65	0.035	0.082	0.141	0.047	0.360	0.136
4 (except Marine)	0.40	0.60	0.030	0.082	0.141	0.047	0.059	0.065
Marine 4 & 5	0.35	0.60	0.030	0.060	0.082	0.033	0.059	0.065
6	0.35	0.60	0.026	0.060	0.06	0.033	0.059	0.065
7 & 8	0.35	0.60	0.026	0.057	0.057	0.033	0.059	0.065

Space Heating and Cooling Systems

This methodology assumes that each house has a central forced-air HVAC system with electric cooling using a single-zone, split-system air conditioner. The heating system is natural gas fired or heat pump per Table 4. All systems are compliant with federal minimum efficiency standards effective at the time of the code publication[1]. The baseline efficiencies of the mechanical systems must be the same for all modeling scenarios (i.e., remain at 2006 IECC levels), unless federal mandate or future editions of the code require higher efficiencies, in which case energy savings attributable to mandatory use of the more efficient equipment will be reflected in the energy use calculations.

Thermostat Setting

The 2006 IECC provisions were based on thermostat setting of 68°F for heating and 78°F for cooling. Thermostat settings were changed in the 2009 IECC to 72°F for heating and 75°F for cooling. These changes are arbitrary (i.e., not based on actual thermostat settings) and are not a requirement. Therefore the Building America Benchmark settings that correspond with optimum seasonal temperature for human comfort (based on ASHRAE Standard 55) are used instead: Set point for heating = 71°F with no setback period; Set point for cooling = 76°F with no setup period.

Water Heating

The water heater modeling in the analysis includes either a 40-gallon natural gas (Hendron 2008) water heater with minimum efficiency (EF = 59.4; Federal minimum for 40-gallon gas heater) and a recovery efficiency of 0.78 or a 50-gallon electric water heater with a minimum efficiency (EF = 90.4; Federal minimum for a 50-gallon electric water heater) and a recovery efficiency of 1.00. The fuel type of the water heater is the same as that of the space heating fuel. The water heating set points are at 120°F and the daily hot water usage is per the Building America Benchmark (Hendron 2008).

Mechanical Ventilation

With the goal of improving indoor air quality, the performance path of the 2006 IECC essentially requires continuous mechanical ventilation in homes tested to a natural air exchange rate less than 0.35 ACH_{nat}. According to ASHRAE Standard 62.2, all homes should be ventilated to a specified rate based on conditioned square footage and number of bedrooms, regardless of the building's tightness. Consequently, this methodology will have mechanical ventilation based on the 2006 IECC reference code home at the rate proposed in ASHRAE 62.2 (54 CFM for houses without a conditioned basement) with no energy recovery, and the comparative code home ventilation rate will be the same unless future editions of the energy code change the requirement.

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[1] The 2006 IECC was published in February 2006, the prevailing federal minimum efficiencies at that time were 78 AFUE furnace; 7.7 HSPF heat pump; 13 SEER air conditioner. Heat pump and air conditioner efficiency increases took effect in January 2006.

Building Air Tightness

One of the most critical parameters changed since the 2006 IECC is building tightness. The 2006 IECC performance path assumes that the Specific Leakage Area (SLA) is 0.00036; however, there was no requirement included for building tightness testing. The metric was changed in the 2009 IECC to 7 Air Changes per Hour at a 50 Pascal pressure difference (7 ACH_{50}) as an option to a special inspection. While the 2009 testing requirements allow for slightly (about 3%) more air leakage than the 2006 performance level, it is not reasonable to assume a house built to the 2009 IECC is leakier than one built to the 2006 IECC.

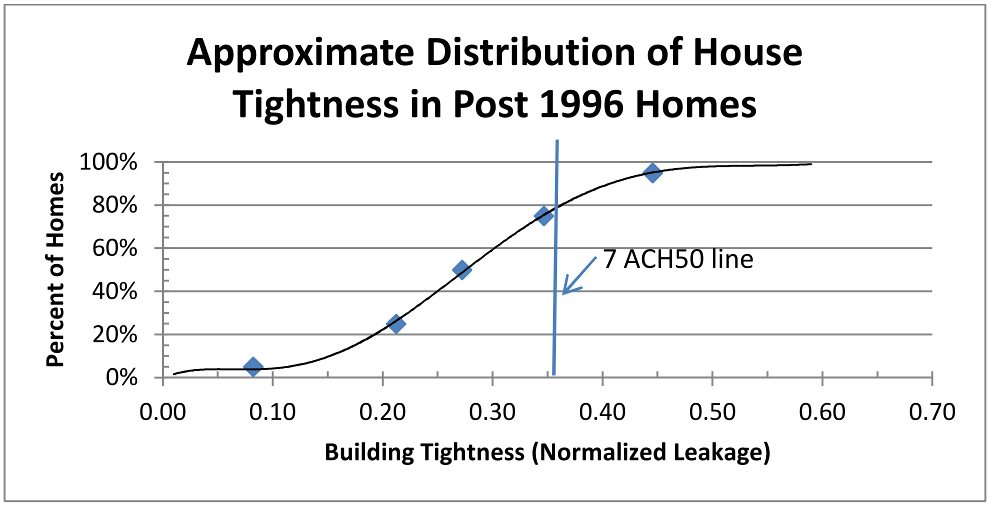

Figure 2. Building Tightness Cumulative Distribution

For the purpose of developing the 2006 IECC baseline for this methodology, tightness data from newly-constructed homes is used. The most recent national data available were published by Lawrence Berkley National Laboratory (Chen 2003) for homes built after 1996. These data show that roughly 75 percent of the homes constructed after 1996 are 7 ACH_{50} or tighter[2] (Figure 2). It is assumed that adoption and enforcement of the 2009 IECC will bring the remaining 25 percent of homes to (or below) 7 $ACH_{50.}$ Based on the shape of the distribution curve, one-quarter of the homes built to the 2009 IECC would become an average of 1 ACH_{50} tighter than homes built to the 2006 IECC. The 2012 IECC further reduces the air tightness to 5 ACH_{50} in climate zones 1 and 2, and 3 ACH_{50} in climate zones 3 through 8. The energy savings calculation uses 7 ACH_{50} when referring to the 2009 IECC.

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[2] The referenced study provides leakage rate distribution in Normalized Leakage, on a national basis, is approximately equivalent to the Natural Leakage rate. In addition, there is an approximate relationship between Natural Leakage and ACH_{50} where $ACH_{50}÷20≈$Natural Leakage.

Duct Leakage/Location

Duct tightness levels and location are in accordance with the Building America Benchmark. Assumed duct leakage will be 10 percent of air handler flow when all ducts are outside of conditioned space and 5 percent for air handlers outside conditioned space. This means that 85 percent of the conditioned air (energy) is assumed to make it into the house when HVAC systems are located entirely outside the building envelope. The 2009 IECC uses 8 CFM/100ft^2 of conditioned floor area when the ducts are outside of conditioned space; the 2012 IECC further reduced this to 4 CFM/100ft^2. Both the 2009 and 2012 IECC require duct tightness testing when ducts are outside conditioned space.

Table 7. Duct Location for Standard Reference House

Duct Type	Foundation Type	One-Story	Two-Story	Reference House
Supply duct location	Slab-on-grade	100% attic	65% attic, 35% conditioned space	76% attic, 24% conditioned space
	Crawlspace	100% crawl	65% attic, 35%, conditioned space	68% crawl, 21% attic, 11% conditioned space
	Basement	100% basement	65% basement, 35% conditioned space	76% basement, 24% conditioned space
Return duct and air handler location	Slab-on-grade	100% attic	100% attic	100% attic
	Crawlspace	100% crawl	100% crawl	100% crawl
	Basement	100% basement	100% basement	100% basement

Data on the tightness of duct systems is not nearly as complete or available as the building tightness data gathered by LBNL. With a lack of representative data, the assumption for this methodology is that ducts outside conditioned space for the 2006 IECC have a duct leakage of 15 percent of system air flow (Hendron 2008); the 2009 IECC has an air leakage to outside of 8 CFM/100ft2 for the total CFA; and the 2012 IECC has a leakage rate of 4 CFM/100ft2 for portions of the ducts located outside conditioned space. The Building America Benchmark (Hendron 2008) defines the duct location for homes based on the foundation type (Table 7). The Standard Reference House proportions the duct location based on the percentage of the house with the specific foundation type and number of stories.

Lighting

The 2006 IECC does not address lighting in its scope; consequently, there is no code-based reference for setting the high-efficacy lighting baseline or total annual lighting usage. In the 2009 IECC, a requirement for high-efficacy lighting was introduced for 50 percent of the hard-wired lamps. The 2006 baseline lighting usage for this methodology is set in accordance with the Building America Benchmark (Hendron 2008) with 10 percent of the interior hard-wired lighting as fluorescent and 90 percent as incandescent. By applying the Benchmark formulas to the Reference Standard House, a total baseline lighting energy usage is 1,869 kWh/yr for interior hard-wired lighting and 350 kWh/yr for exterior and garage lighting (which only includes lighting fixtures installed by the builder).

Internal gains

In an occupied home, people, appliances, lighting, and plug loads create internal heat gains. The IECC (2006, 2009 & 2012) defines internal gains with a simple formula based on the number of bedrooms and conditioned floor area. This method was adequate when the code did not directly impact the internal gains; however, with the addition of lighting to the scope of the code, significant reductions to the internal gains will occur resulting in increased heating requirements and reduced cooling loads. The Building America Benchmark (Hendron 2008) addresses this issue, so the Benchmark internal gain values are used in the annual energy calculations.

Window Area

Window area would typically be considered part of the building geometry, but it evolved into an energy performance parameter when the baseline window percentage changed from the 2006 to the 2009 IECC. The window percentage is similar to a prescriptive requirement in that if the specified window percentage is exceeded when using the performance path, the additional energy usage needs to be made up somewhere else. The 2006 IECC reference design home has an 18 percent glazing area to CFA. The window percentage was reduced in the 2009 IECC to 15 percent and was promoted as an energy savings proposal. For this methodology, the 2006 code home uses 18 percent glazing per square foot of above-grade CFA and the 2009 code home uses 15 percent glazing per square foot of above-grade CFA and the energy savings are recognized by this methodology (basement conditioned floor area not included in the *Standard Reference House* when calculating window area).

Basic Results (kWh/Therm)

With the building geometry and energy parameters provided, typical energy usage can be quantified at any specific location. The results from this portion of the methodology will be in annual consumption of electricity (kWh) and natural gas (therm).

If a specific location has specific building characteristics that significantly differ from those above (e.g., foundation types, heating fuel used) then the distribution can be altered, but the changes must be noted when energy usage numbers are being reported and this methodology is being cited.

Calculating National Results

If nationally-based conclusions are to be drawn from the analysis, additional parameters need to be defined, including representative weather locations and climate zone housing start distribution

Representative Weather Locations

Eight cities representing all of the DOE Climate Zones (Table 8 and Figure 3) have been selected to quantify energy savings. By having all climate zones represented, any climate-specific changes made in the energy code will be captured in the analysis.

Table 8. Representative Climate Zone Cities

Climate Zone	Moisture Region	State	City	HDD(65)	CDD(65)
1	Moist	Florida	Miami	120	4,396
2	Dry	Arizona	Phoenix	977	4,790
3	Moist	Tennessee	Memphis	2,851	2,221
4	Moist	Maryland	Baltimore	4,460	1,314
5	Moist	Illinois	Chicago	6,174	911
6	Dry	Montana	Helena	7,474	353
7	N/A	Minnesota	Duluth	9,371	185
8	N/A	Alaska	Fairbanks	12,818	49

Energy simulations must use historical weather information from the Typical Meteorological Year (TMY3) dataset. The Heating Degree Days (HDD) and Cooling Degree Days (CDD) are measures of the intensity of the heating and cooling seasons for a particular location. The climate zones are assigned on the basis of HDD and CDD.

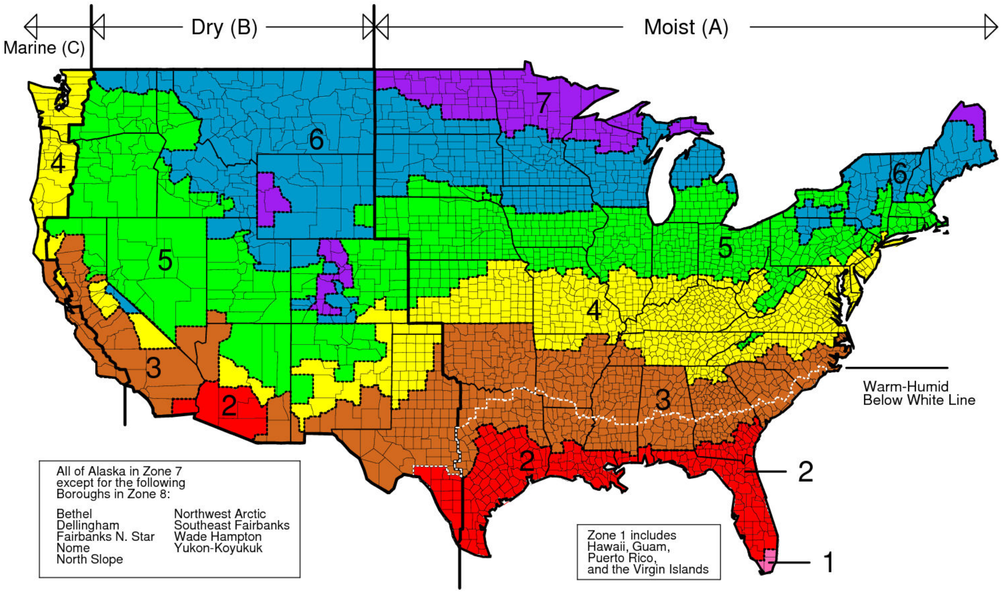

Figure 3. DOE Climate Zone Map

Building Starts by Climate Zones

In order to get a national average energy savings, each climate zone must be evaluated for energy savings and then weighted according to building starts in each. This methodology uses the latest information available (Briggs 2002) on building starts by climate zone (Table 9).

Table 9. Building Starts (Briggs 2002)

Climate Zone	% Building Starts
1	2
2	19
3	27
4	19
5	27
6	6
7 & 8	0.3

Combining Electricity and Natural Gas

There are three primary methods by which electric and gas consumption can be combined: energy cost ($); site energy (Btu); or source energy (Btu).

Utility Rates/Energy Type (cost metric)

The IECC uses annual energy cost to determine code compliance in the performance approach making it a surrogate for actual energy use. In addition, energy commodity cost captures the market value for energy. Developing an energy cost also defines a cost basis to determine cost effectiveness.

In order to convert energy use into dollars, there must be a defined basis by which electricity and natural gas can be converted into dollars. Since the release of the 2006 IECC, there have been constant fluctuations in the utility rates of both natural gas and electricity; consequently, this methodology requires that utility rates be updated annually. For example, at the time of publication of this report, the latest annual (2011) prices from the DOE Energy Information Administration are $0.118/kWh for electricity and $1.08/therm for natural gas.

Energy Consumed at the Meter (site energy metric)

Annual energy use calculated from the computer simulations results in electric (kWh) and natural gas (therm) consumed at the utility meter located at the building site. In order to quantify the total energy consumption at the site, the kWh and therms must be converted into a common unit (Btu).

Equation 1: Site Energy Conversion Equation:

$$\text{Site MBtu} = \text{kWh}*3.412+\text{therms}/10$$

Where: MBtu = 1,000,000 Btu

Source Btu's (source energy metric)

Source energy includes site energy as well as the total amount of primary fuel required to generate and deliver energy to the site. The Building America (Hendron 2008) program has developed conversions with the following equation:

Equation 2: Site to Source Conversion Equation:

$$\text{Source MBtu}=\text{kWh}*3.412*M_e/1000+\text{therms}*M_g/10+\text{MBtu}*M_o$$

Where: $M_e = 3.365$ *= site to source multiplier for electricity (Hendron 2008)*
$M_g = 1.092$ *= site to source multiplier for natural gas (Hendron 2008)*
M_o *= site to source multiplier for all other fuels (Hendron 2008)*

Note: The IECC conversion factors for M_e and M_g differ from the Building America factors.

Percent Savings Calculation

A number of methods for calculating percent energy savings have been used in various programs which creates the potential for confusion when referencing a percent savings number. For instance, the federal 50 percent energy savings tax credit was only based on heating and cooling energy. The 2006 IECC performance calculation considered heating, cooling, and water heating energy. Energy Star (since 2006) has used total energy for its rating calculation, which includes lighting, appliances, and plug loads in addition to heating, cooling, and water heating energy. To further complicate the calculation, the scope of the 2009 IECC was expanded with the addition of lighting requirements.

This methodology will base the energy savings percentage on heating, cooling and water heating energy (Equation 3); however, future additions to the scope of the code (i.e. lighting) will not impact the denominator. The numerator represents the total energy savings when comparing the "new" code to the 2006 IECC (or other baseline code), so changes in scope will include associated energy savings in the numerator.

Equation 3: Percent Energy Savings Calculation[3]

$$\%\ \text{Savings} = 100*(\text{TEU}_{2006} - \text{TEU}_{\text{new code}})/\text{HCW}_{2006}$$

Where: TEU_{2006} *= Total Energy Usage using the 2006 IECC*
$TEU_{new\ code}$ *= Total Energy Usage with all new code changes*
HCW_{2006} *= Heating, Cooling, and Water heating energy usage using the 2006 IECC*

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[3] This formula is consistent with PNNL/DOE presentation in various forums including the 2010 RESNET Conference (Taylor 2010).

Energy usage can be expressed using any of the three options: site energy (Btu), source energy (Btu), or energy cost ($). When referencing a percent savings, the method of calculation should be specified.

Because it is not reasonable to burden the savings percentage with items which are not within the scope of the baseline code, the denominator does not include lighting, appliances, or plug load energy. For example, if a 50 percent reduction in a home’s total energy use was required, and the heating, cooling, and water heating amounted to 55 percent of the total household energy use (scope of the 2006 IECC), then the heating, cooling, and water heating would have to be reduced by 90 percent to get to the 50 percent reduction target. Since this is not possible without on-site generation, this methodology uses the savings percentage on the scope of the 2006 IECC code (i.e., heating, cooling, and water heating energy) as the baseline reference.

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