U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes

April 2012

Authors:
Todd Taylor
Nick Fernandez
Robert Lucas

Prepared by Pacific Northwest National Laboratory
for the U.S. Department of Energy Building Technologies Program

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161
ph: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

This document was printed on recycled paper.
(9/2003)

PNNL-21294

Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes

ZT Taylor
N Fernandez
RG Lucas

April 2012

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Contents

Figures

Tables

1.0 Introduction

The U.S. Department of Energy's (DOE's) Building Energy Codes Program has developed and established a methodology for evaluating the energy and economic performance of residential energy codes. This methodology serves two primary purposes. First, as DOE participates in the consensus processes of the International Code Council (ICC), the methodology described herein will be used by DOE to ensure that its proposals are both energy efficient and cost effective. Second, when a new version of the International Energy Conservation Code (IECC) is published, DOE will evaluate the new code as a whole to establish expected energy savings and cost effectiveness, which will help states and local jurisdictions interested in adopting the new codes. DOE's measure of cost-effectiveness balances longer-term energy savings against additions to initial costs through a life-cycle cost (LCC) perspective.

Evaluating cost effectiveness requires two primary steps—estimating the theoretical energy impact of a code change and assessing how that impact relates to the cost of implementing the change. The DOE methodology estimates the energy impact by simulating the effects of the code change(s) on typical new residential buildings, assuming both the old and new code provisions are implemented fully and correctly. The methodology does not estimate rates of code adoption or compliance. Cost effectiveness is defined primarily in terms of LCC evaluation, although the DOE methodology includes several metrics intended to be useful to states considering adopting new codes.

This document is arranged into three primary parts covering the following.

1. Estimating Energy Savings of Code Changes—by modeling changes to representative building types. The DOE methodology defines single- and multifamily prototype buildings, establishes typical construction and operating assumptions, and identifies climate locations to be used in estimating impacts in all climates zones and all states. The building prototypes include four foundation types and four heating equipment types to facilitate appropriate accounting for location-specific construction practices and fuel prices.

2. Estimating the Cost Effectiveness of Code Changes—by comparing energy cost savings to additions to first cost of the buildings. The methodology defines three metrics—LCC, simple payback period, and annual consumer cash flow—to be calculated; establishes sources for the economic parameters to be used in estimating those metrics; identifies a primary database of energy-efficiency measure costs; and defines three geopolitical levels at which those metrics will be reported (state, climate zone, national).

3. Aggregating Energy and Economic Results—across building types, foundation types, fuel/equipment types, and climate locations. The methodology establishes sources for weighting factors to be used in aggregating location-specific results to the three geopolitical levels.

2.0 Estimating Energy Savings of Code Changes

The first step in assessing the impact of a code change or a new code is estimating the energy savings of the associated changes. DOE will usually employ computer simulation analysis to estimate the energy impact of a code change (situations in which other analysis approaches might be preferred are discussed later). In some cases, DOE may rely on extant studies directly addressing the building elements involved in a proposed change if such can be identified. DOE intends to use the EnergyPlus™[1] software as the primary tool for its analyses. If necessary to more accurately capture the relevant impacts of a particular code change, DOE may supplement EnergyPlus with other software tools or performance databases. Such code changes will be addressed case by case.

Code changes affecting a particular climate zone will be simulated in representative weather locations. At least one location is chosen per climate zone in every U.S. state. DOE's methodology includes weighting factors based on recent housing starts data to allow the individual location results to be aggregated to climate-zone and national averages as needed. These methodologies, weighting factors, and other assumptions are described in the sections that follow.

2.1 Building Energy Use Simulation Assumptions and Methodology

The energy performance of most energy-efficiency measures can be estimated by computer simulation. Prototype buildings will be developed—one designed to comply with the baseline code and an otherwise identical building complying with the revised code. This comparison will be simulated in the relevant climate zones to estimate the overall energy impact of the new code. The inputs and assumptions used in the simulations are discussed in the following sections.

2.1.1 Energy Simulation Tool

DOE intends to use an hour-by-hour simulation tool to calculate annual energy consumption for relevant end uses. For most situations, the EnergyPlus software will be the tool of choice. EnergyPlus provides for a detailed hour-by-hour (or more frequent) simulation of a home's energy consumption throughout a full year, based on typical weather data for a location. It covers almost all aspects of residential envelopes; heating, ventilation, and air-conditioning (HVAC) equipment and systems; water heating equipment and systems; and lighting systems. Depending on how building energy codes evolve, it may be necessary to identify additional tools to estimate the impacts of more specialized changes.

DOE recognizes there are other tools that can produce credible energy estimates. DOE intends to use EnergyPlus as its primary tool, because it includes enhanced simulation capabilities, is under active development, and has the potential to include capabilities either unavailable or less sophisticated in other accepted simulation tools. EnergyPlus has capabilities for detailed simulation of the pressure-related interactions between duct leakage and air infiltration through the building envelope, enhanced capabilities for simulating residential attics and other unconditioned spaces, and the potential for analyzing detailed control strategies and specific hot water piping configurations.

[1] EnergyPlus. 2011."Going with the Flow: Designing High-Performance Building with EnergyPlus." http://www.energyplus.gov/

2.1.2 Prototypes

Simulations will be conducted for single-family and multifamily buildings. The prototypes used in the simulations are intended to represent, respectively, a typical new one- or two-family home or townhouse, and a low-rise multifamily building, such as an apartment, cooperative, or condominium. Four foundation types will be examined for all buildings: vented crawlspace, slab-on-grade, heated basement with wall insulation, and unheated basement with insulation in the floor above the basement. All buildings will be evaluated with central air conditioning and each of four heating system types: gas furnace, oil furnace, heat pump, and electric furnace. If new code provisions relate to other less frequently used foundations or equipment types, supplemental prototype configurations will be developed as necessary.

Prototypes will be configured to meet the provisions of each code's primary prescriptive manifestation. DOE will address any future codes that may not have such primary requirements (e.g., a purely performance code) and codes for which the primary prescriptive path does not represent the likely practical manifestation of the code on a case-by-case basis.

Table 2.1 shows the characteristics DOE intends to assume for the single-family prototype. Note that any of these characteristics may be modified if impacted by a code change. The single-family prototype is configured as a simple rectangular building and is illustrated by the line drawing in Figure 2.1.

Table 2.1. Single-Family Prototype Characteristics

Parameter	Assumption	Notes
Conditioned floor area	2,400 ft^2 (plus 1,200 ft^2 of conditioned basement, where applicable)	Characteristics of New Housing, U.S. Census Bureau
Footprint and height	30-ft-by-40 ft, two-story, 8.5-ft-high ceilings	
Area above unconditioned space	1,200 ft^2	Over a vented crawlspace or unconditioned basement
Area below roof/ceilings	1,200 ft^2, 70% with attic, 30% cathedral	
Perimeter length	140 ft	
Gross exterior wall area	2,380 ft^2	
Window area (relative to gross wall area)	Fifteen percent equally distributed to the four cardinal directions (or as required to evaluate glazing-specific code changes)	
Door area	42 ft^2	
Internal gains	91,436 Btu/day	2006 IECC, Section 404
Heating system	Natural gas furnace, heat pump, electric furnace, or oil-fired furnace	Efficiencies will be based on prevailing federal minimum manufacturing standards.
Cooling system	Central electric air conditioning	Efficiency will be based on prevailing federal minimum manufacturing standards.
Water heating	Natural gas, or as required to evaluate domestic hot water-specific code changes	

Btu = British thermal units.
IECC = International Energy Conservation Code.

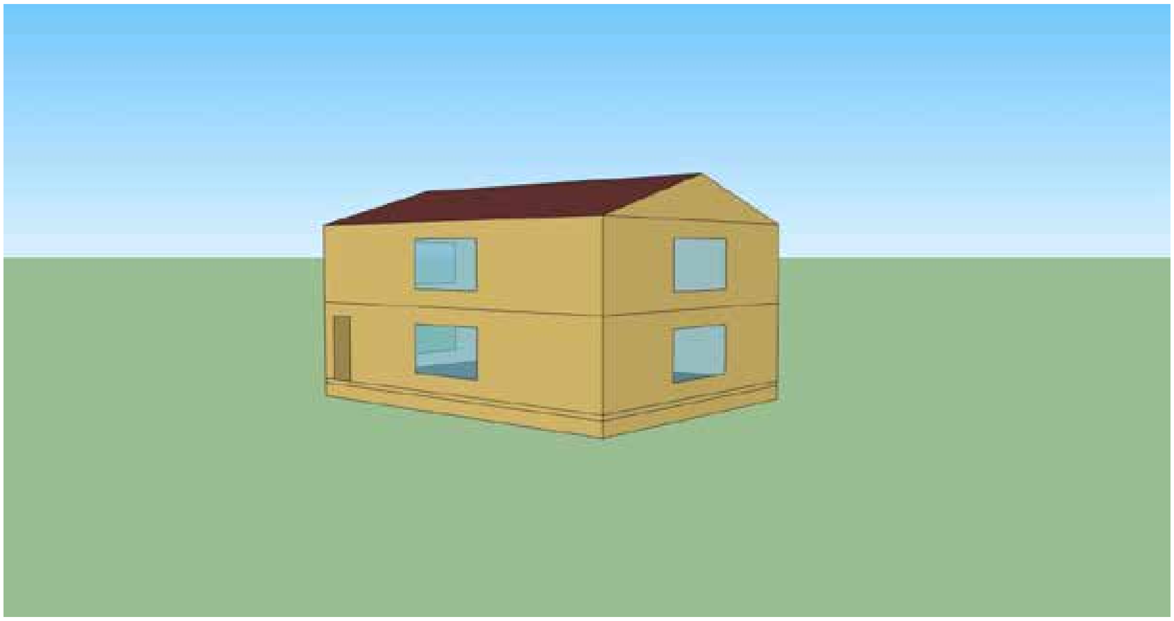

Figure 2.1. Single-Family Prototype

DOE will employ a three-story multifamily prototype having six dwelling units per floor, arranged in two rows with an open breezeway in between. The multifamily prototype characteristics to be used for DOE's analyses are shown in Table 2.2. The heating, cooling, and water-heating system characteristics are the same as for the single-family prototype (each dwelling unit is assumed to have its own separate heating and cooling equipment). The multifamily prototype is illustrated by the line drawing in Figure 2.2.

Table 2.2. Multifamily Prototype Characteristics

Parameter	Assumption	Notes
Conditioned floor area	1,200 ft^2 per unit, or 21,600 ft^2 total (plus 1,200 ft^2 of conditioned basement on ground-floor units, where applicable)	Characteristics of New Housing, U.S. Census Bureau
Footprint and height	Each unit is 40 ft wide by 30 ft deep, with 8.5-ft-high ceilings. The building footprint is 120 ft by 65 ft.	
Area above unconditioned space	1,200 ft^2 on ground-floor units	Over a vented crawlspace or unconditioned basement
Wall area adjacent to unconditioned space	None	No attached garages or similar
Area below roof/ceilings	1,200 ft^2, 70% with attic, 30% cathedral, on top-floor units	
Perimeter length	370 ft (total for the building), 10 ft of which borders the open breezeway	
Gross wall area	5,100 ft^2 per story, 2,040 ft^2 of which faces the open breezeway (15,300 ft^2 total)	
Window area (relative to gross wall area)	Fifteen percent (or as required to evaluate glazing-specific code changes)	
Door area	21 ft^2 per unit (378 ft^2 total)	Assumed to open into the breezeway
Internal gains	54,668 Btu/day per unit (984,024 Btu/day total)	2006 IECC, Section 404, assuming two bedrooms per unit
Heating system	Natural gas furnace, heat pump, electric furnace, or oil-fired furnace	Efficiency will be based on prevailing federal minimum manufacturing standards.
Cooling system	Central electric air conditioning	Efficiency will be based on prevailing federal minimum manufacturing standards.
Water heating	Natural gas, or as required to evaluate domestic hot water-specific code changes	

Btu = British thermal units.
IECC = International Energy Conservation Code.

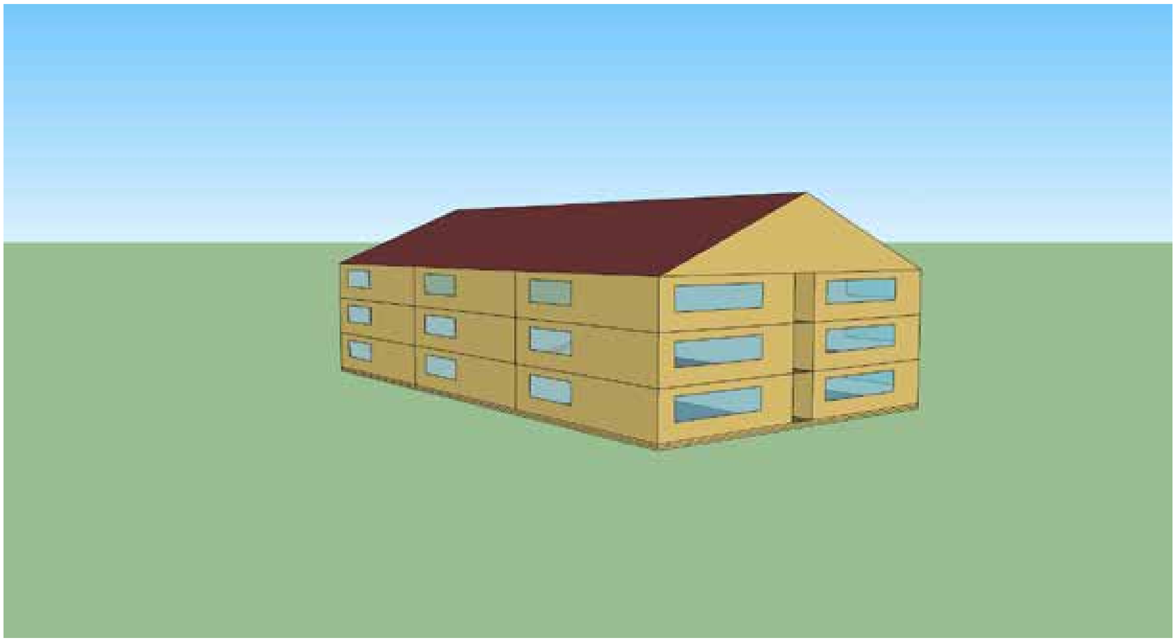

Figure 2.2. Multifamily Prototype

2.1.3 Default Assumptions

Some building components are not addressed by the code and many components may not change from one code to the next. For these components, inputs are identical in both pre- and post-revision simulations. While specific input values for these components are of secondary importance, it is important that they be reasonably typical of the construction types being evaluated. Assumptions and input values for these building components will be set to match shared code requirements (if such exist), shared standard reference design specifications from the codes' performance paths (if such exist), or to best estimates of typical practice. Typical practice assumptions will be taken from various sources, including prototypes and models used by DOE residential programs or other efficiency programs (e.g., Building America, Home Energy Rating System specifications).

2.1.4 Provisions Requiring Special Consideration

New code provisions that expand the code to include previously unaddressed building components may require special treatment. For example, editions of the IECC prior to 2009 had no duct testing requirement and hence analysis requires establishing a meaningful baseline leakage rate against which newer versions of the code can be compared. In these cases, rather than comparing one code to another, a new code must be compared to an unstated prior condition.[2] That prior condition can sometimes be based

---

[2] In DOE's proposal to add duct testing requirements to the 2009 IECC, energy savings was approximated based on findings from extant post-occupancy studies of duct leakage rather than by simulation. These studies included:

1. Hales D. 2001. *Washington State Energy Code Duct Leakage Study Report*. WSUCEEP01105, Washington State University Cooperative Extension Energy Program, Olympia, Washington. Available at: http://www.sos.wa.gov/library/docs/wsu/01_105Ductrptfinal_2008_004802.pdf . Accessed April 30, 2012.

on the average or typical pre-code level used by builders, but this can sometimes understate the energy savings of the new code requirement. Returning to the example of a new requirement for testing the duct leakage rate, consider Figure 2.3. The curve represents a hypothetical distribution of leakage rates prior to the code's regulation of leakage rates. Even if the new code requirement was set equal to or worse than the pre-change average rate, savings would accrue from houses that would have had higher leakage rates. Data to establish such a pre-code distribution is often unavailable, so DOE intends to evaluate scope expansions on a case-by-case basis to determine the most appropriate way to estimate energy savings given the data available.

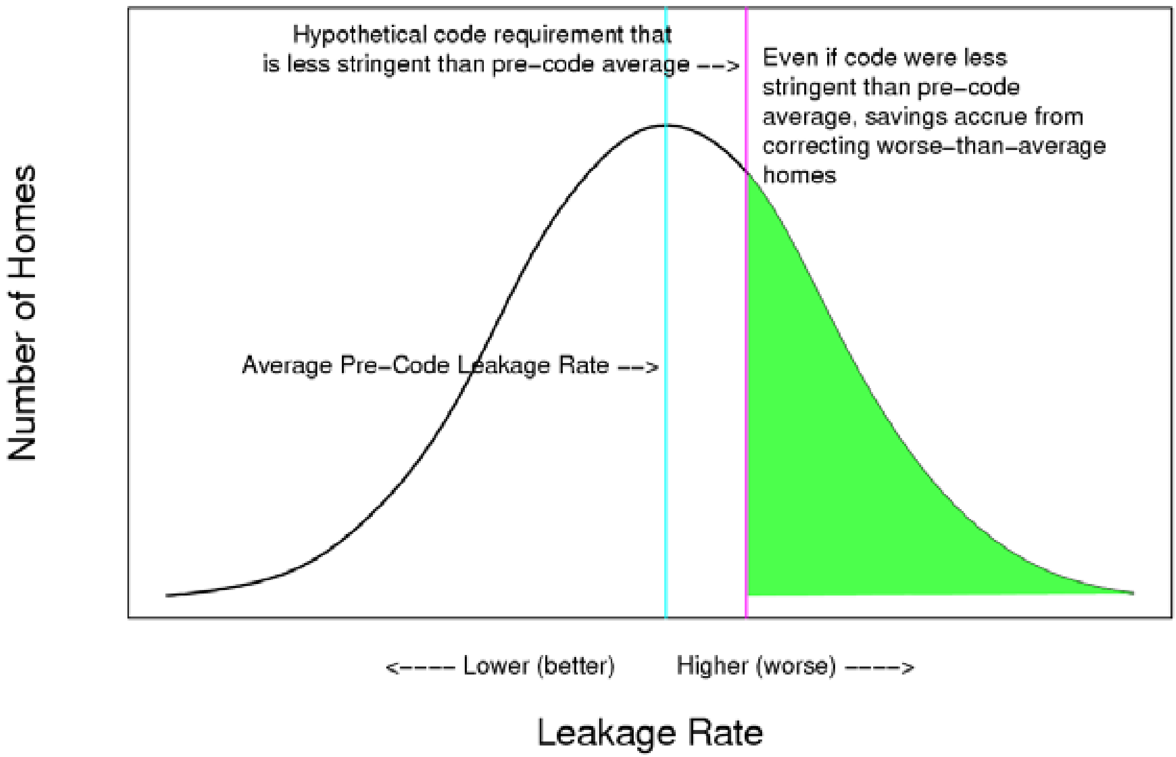

Figure 2.3. Illustration of Energy Savings from a Hypothetical Code Change that Improves the Worst-Performing Homes

---

2. Hales D, A Gordon, and M Lubliner. 2003. *Duct Leakage in New Washington State Residences: Findings and Conclusions.* KC-2003-1-3, *ASHRAE Transactions* 109(2):393-402.
3. Hammon RW and MP Modera. 1999. "Improving the Efficiency of Air Distribution Systems in New California Homes-Updated Report." Consol. Stockton, California.
4. Uniacke M. 2003. "Pressure-Testing Ductwork." *Journal of Light Construction*.
5. Sherman MH, IS Walker, and CP Wray. 2004. Instrumented Home Energy Rating and Commissioning Technical Reports. P500-04-012-A1**.** California Energy Commission through the Public Interest Energy Research Program, Sacramento, California.
6. Xenergy. 2001. Impact Analysis of the Massachusetts 1998 Residential Energy Code Revisions. Xenergy, Portland, Oregon. Available at: http://www.energycodes.gov/publications/research/documents/codes/Massachusetts_rpt.pdf . Accessed April 30, 2012.
7. Impacts of the 2009 IECC for Residential Buildings at State Level. 2009. Available at http://www.energycodes.gov/publications/techassist/IECC2009_Residential_Nationwide_Analysis.pdf.

3.0 Estimating the Cost Effectiveness of Code Changes

The intent of the DOE cost-effectiveness methodology is to determine whether code changes are economically justified from the perspective of a public policy that balances costs against energy savings over time. The DOE methodology accounts for the benefits of energy-efficient home construction that accrue to homeowners over 30 years. The methodology and assumptions are described in this section.

3.1 Economic Metrics to be Calculated

DOE intends to calculate three metrics in evaluating the economics of code change proposals and in assessing new editions of residential building energy codes:

1. LCC
2. Simple payback period
3. Cash flow

LCC is the primary metric DOE will use to evaluate whether a particular code change is cost effective. The payback period and cash flow analyses provide additional information that DOE believes is helpful to others participating in the code-change processes and to states and jurisdictions considering adoption of new codes. These metrics are discussed further in the following sections.

3.1.1 Life-Cycle Cost

LCC[3] is a robust cost-benefit metric that sums the costs and benefits of a code change over a specified time period. Any code change resulting in a net LCC less than or equal to zero (i.e., monetary benefits exceed costs) will be considered cost effective. The methodology considers only direct costs (and savings) to the consumer. Secondary or societal effects, such as reductions in carbon emissions, or externalities, such as impacts on manufacturers, are not considered. DOE will use LCC for determining the cost effectiveness of code change proposals, and for the code as a whole, as it is the most straightforward approach to achieving the desired balance of first costs and longer-term energy savings.

The key feature of LCC analysis is the summing of costs and benefits over multiple years, which requires cash flows in different years to be adjusted to a common year for comparison. This is done with a *discount rate* that accounts for changes in the value of money over time (i.e., the “time value” of money). Like most LCC implementations, DOE’s methodology sums cash flows in year-zero dollars (the present year), which allows the use of standard discounting formulas. Cash flows adjusted to year zero are termed *present values*. The procedure described herein combines concepts from two ASTM International standard practices, E917[4] and E1074.[5] The resultant procedure is both straightforward and

[3] LCC analysis is sometimes referred to as *net present value* analysis or *engineering economics*, and sometimes expressed in terms of *life-cycle savings*.
[4] ASTM International. “Practice for Measuring Life-Cycle Costs of Buildings and Building Systems.” 2010. E917, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. ASTM International, West Conshohocken, Pennsylvania.
[5] ASTM International. “Practice for Measuring Net Benefits and Net Savings for Investments in Buildings and Building Systems.” 2010. E1074, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. ASTM International, West Conshohocken, Pennsylvania.

comprehensive and is in accord with the methodology recommended and used by the National Institute of Standards and Technology.[6]

Present values can be calculated in either *nominal* or *real* terms. In a nominal analysis, all compounding rates (e.g., discount rate, mortgage interest rate, fuel price escalation rate) include the effect of general inflation, and cash flows in future years are assumed to rise with the general rate of inflation. An exception is mortgage payments, which remain constant from year to year regardless of inflation. In a real analysis, inflation is assumed to be zero, and all compounding rates are adjusted to remove the effect of inflation. The relationship between a nominal rate $R_{nominal}$ and a real rate R_{real} is expressed as a function of the inflation rate $R_{inflation}$:

$$(1 + R_{nominal}) = (1 + R_{real}) \times (1 + R_{inflation}) \tag{3.1}$$

Consequently:

$$R_{nominal} = (1 + R_{real}) \times \left(1 + R_{inflation}\right) - 1 \tag{3.2}$$

$$R_{real} = \left[\frac{(1+R_{nominal})}{(1+R_{inflation})}\right] - 1 \tag{3.3}$$

The two approaches are algebraically equivalent. DOE intends to conduct economic analyses of residential energy codes in nominal terms, because accounting for mortgage cash flows and associated income tax effects is more straightforward. Consumers are generally familiar with nominal rates, because, for example, mortgage interest rates are generally quoted in nominal terms.

The net LCC of a code change is defined formally as the present value (*PV*) of all costs and benefits summed over the period of analysis.[7] Because it is defined in terms of costs, the net LCC of a code change must be zero or negative for the change to be considered cost effective, as shown in Equation 3.4.

$$LCC = PV(Costs) - PV(Benefits) \tag{3.4}$$

A future cash flow (positive or negative) is brought into the present (i.e., time zero) by assuming a discount rate (R_d or simply d). The discount rate is an annually compounding rate[8] by which future cash flows are discounted in value. It can be thought of as representing the minimum rate of return demanded of the investment in energy-saving measures. It is sometimes referred to as an alternative investment rate and chosen to approximate a homeowner's best alternative investment with risk similar to that of energy efficiency measures. Thus, the present value of a cash flow in year y (CF_y) is defined as:

$$PV = \frac{CF_y}{(1+d)^y} \tag{3.5}$$

---

[6] For a detailed discussion of LCC and related economic evaluation procedures specifically aimed at private sector analyses, see Ruegg and Petersen (Ruegg RT and SR Petersen. 1987. *Comprehensive Guide to Least-Cost Energy Decisions*, NBS Special Publication 709. National Bureau of Standards, Gaithersburg, Maryland).

[7] In this methodology, the term LCC is generally used to mean a *net* life-cycle cost because we are comparing the energy impacts of two scenarios rather than simply summing the total cost of ownership of a single scenario.

[8] The analysis can be done for other compounding periods (e.g., monthly), but for simplicity DOE uses annual periods for the subject analyses.

The present value of a stream of annual cash flows over the period of analysis, *N* years, is then the sum of all of those discrete cash flows:

$$PV = \sum_{y=0}^{N} \left[\frac{CF_y}{(1+d)^y}\right] \tag{3.6}$$

For an annualized stream of cash flows *A* that is the same from year to year, such as a mortgage payment with a term of *N* years, Equation 3.6 is equivalent to:

$$PV = A \times \left[\frac{(1+d)^N - 1}{d \times (1+d)^N}\right] \tag{3.7}$$

For an annualized stream of cash flows that is escalating with time, such as the energy cost savings (ES), that increases (or decreases) from year to year because of escalations in fuel prices, Equation 3.8 can be used (*e* is the fuel price escalation rate, *N* is the number of years):

$$PV = ES \times \left[\frac{1+e}{d-e}\right] \times \left[1 - \left(\frac{1+e}{1+d}\right)^N\right] \tag{3.8}$$

Or, if the escalation rate *e* is equal to the discount rate *d*:

$$PV = ES \times N \tag{3.9}$$

DOE intends to compute and publish annual cash flow impacts, as well as the net LCC at time zero. Equation 3.6 will generally be preferred to Equations 3.7 and 3.8, because it allows presentation and analysis of all the yearly cash flows during the LCC analysis period. Equations 3.7 and 3.8 are algebraically equivalent to 3.6, and useful when year-by-year cash flows are not needed.

The primary cash flows relevant to LCC analysis of energy code changes are detailed below.

- The *down payment cost* associated with the code changes is the down payment rate (R_{DP}) multiplied by the total cost of the code changes (*C*, or the "first cost") and is incurred at the onset (year zero):

$$down\ payment = R_{DP} \times C \tag{3.10}$$

- On top of the down payment is a *mortgage fee*, which represents the additional cost of obtaining credit due to the additional cost of efficiency measures. It is the cost of the code changes (*C*) multiplied by the mortgage fee rate (R_{MF}). The mortgage fee is not tax deductible. Some mortgages involve other up-front fees used to buy down the mortgage interest rate. These payments, often referred to as "points," are tax deductible because they are essentially prepaid interest on the loan. DOE's methodology assumes that all interest payments are accounted for in the mortgage interest rate, so there are no tax deductible up-front costs. The mortgage fee is calculated as:

$$mortgage\ fee = R_{MF} \times C \tag{3.11}$$

- *Property tax* occurs every year, beginning with year one and continuing through the analysis period *P*. It represents additional tax paid as a result of efficiency measures giving the home a higher value. It is the property tax rate (R_{PT}) multiplied by the cost of efficiency measures *C*, and further adjusted annually by a factor E_H representing the home price escalation rate. This assumes the initial tax appraisal of the house increases directly with the amount of the code-related cost increase, and that the year-to-year tax assessment increases in step with the escalating home price. The property tax cost in year *y* is calculated as:

$$property\ tax_y = R_{PT} \times C \times (1 + E_H)^y \tag{3.12}$$

- *Energy savings* occur every year, starting at year one and continuing through the analysis period *P*. They are equal to the modeled energy cost savings at year zero (ES_0), adjusted annually by a fuel price escalation factor E_F. The energy savings in year *y* are given by:

$$ES_y = ES_0 \times (1 + E_F)^y \tag{3.13}$$

- *Mortgage payments* occur every year throughout the mortgage term *T*, and are unchanging (i.e., unaffected by inflation). The annual mortgage payment is calculated dividing the additional loan amount by a standard uniform series present worth factor using the mortgage interest rate (R_{MI}) as the discounting factor. The additional loan amount is simply the initial cost of efficiency measures less the down payment. However, because mortgage interest rates are generally quoted as annual rates but used to calculate monthly payments, we calculate annual mortgage payments as 12 times a standard monthly payment. The annual mortgage payment is given by:

$$mortgage\ payment = \frac{(1 - R_{DP}) \times C \times 12}{\left[\frac{\left(1 + \frac{R_{MI}}{12}\right)^{12T} - 1}{\frac{R_{MI}}{12} \times \left(1 + \frac{R_{MI}}{12}\right)^{12T}}\right]} \tag{3.14}$$

- *Tax deductions* for mortgage interest payments and property tax payments begin in year one and continue through the end of the analysis period *P*. They are calculated as the marginal income tax rate (R_{IT}) multiplied by the sum of mortgage interest payments and property tax payments each year. Property tax payments are calculated as shown above. Mortgage interest payments are the mortgage interest rate (R_{MI}) multiplied by the loan balance each year. The loan balance is simply the present value (at year *y*) of the remaining stream of mortgage payments, discounted at the mortgage interest rate. Thus the tax deduction in year *y* is given by:

$$tax\ deduction_y = R_{IT} \times \left\{ \begin{matrix} property\ tax_y + \\ mortgage\ payment \times \left[\frac{(1 + R_{MI})^{T-y+1} - 1}{R_{MI} \times (1 + R_{MI})^{T-y+1}}\right] \end{matrix} \right\} \tag{3.15}$$

- The methodology accounts for *replacement costs* of efficiency measures that have an expected useful life *L* less than the analysis period. It is assumed that a failed measure is replaced with an identical measure at the same first cost, escalated per the home price escalation rate (E_H). For a measure *m* with a service life *L* that is less than the analysis period *P*, a replacement cost $RC_{m,y}$ is incurred at the end of any year when the service life expires. That is:

$$RC_{m,y} = \begin{cases} 0, & y \bmod L \neq 0 \\ (1 + E_H)^y \times FC_m, & y \bmod L = 0 \end{cases} \tag{3.16}$$

Where FC_m is the first cost of measure *m* and "*y* mod *L*" refers to the *modulo* operator, which gives the remainder after dividing *y* by *L*.

- Finally, there is a *residual value* for efficiency features with remaining useful life at the end of the analysis period. This is related to the replacement costs in that a feature replaced shortly before the end of the analysis period would have a higher residual value than one nearing the end of its service life. At the end of the analysis period P, the residual value of each efficiency measure is based on straight-line "depreciation" of its inflated first cost based on the number of years left in its useful life. That is, the residual value for measure m (RV_m) is a beneficial cash flow occurring at the end of year P and is given by:

$$RV_m = (1 + E_H)^P \times FC_m \times \left(\frac{P \bmod L}{L}\right) \tag{3.17}$$

Each of the cash flow components above is discounted to a time-zero present value and the results summed to compute the net LCC.

3.1.2 Simple Payback Period

The simple payback period is a straightforward metric including only the costs and benefits directly related to the implementation of energy-saving measures associated with a code change. It represents the number of years required for the energy savings to pay for the cost of the measures, without regard for changes in fuel prices, tax effects, measure replacements, resale values, etc. The payback period P, which has units of *years*, is defined as the marginal cost of compliance with a new code (C), divided by the annual marginal benefit from compliance (ES_0, the energy cost savings in year zero), as shown in Equation 3.18:

$$P = \frac{C}{ES_0} \tag{3.18}$$

The simple payback period is a metric useful for its ease of calculation and understandability. Because it focuses on the two primary characterizations of a code change—cost and energy performance—it allows an assessment of cost effectiveness easy to compare with other investment options and requires a minimum of input data. The simple payback period is used in many contexts, and is written into some state laws governing the adoption of new energy codes. However, because simple payback ignores many of the longer-term factors in the economic performance of an energy-efficiency investment, DOE does not use the payback period as a primary indicator of cost effectiveness for its own decision-making purposes.

3.1.3 Cash Flow Analysis

In the process of calculating LCC, year-by-year cash flows are computed. These can be useful in assessing a code change's impact on consumers and will be shown by DOE for the code changes it analyzes. The cash flow analysis simply shows each year's net cash flow (benefits minus costs) separately (in nominal dollars), including any time-zero cash flows, such as a down payment. Two aspects of cash flow analysis are of particular interest to consumers. First, the net annual cash flow shows how annual cost outlays are compensated by annual energy savings. This value ignores the mortgage down payment and other up-front costs, focusing instead on a new code's impact on consumers' ability to make monthly mortgage payments. Second, the number of years to positive cash flow shows the time required for cumulative energy savings to exceed cumulative costs, including both increased mortgage payments and the down payment and other up-front costs.

3.2 Economic Parameters and Other Assumptions

Calculating the metrics described in Section 3.1 requires defining various economic parameters. Table 3.1 shows the primary parameters of interest and how they apply to the three metrics. The actual current values are presented at the end of this section.

Table 3.1. Economic Parameters for Cost-Effectiveness Metrics

Parameter	Needed For
First costs Fuel prices	Payback Cash flow LCC
Fuel price escalation rates Mortgage parameters Inflation rate Tax rates (property, income) Period of analysis Residual value	Cash flow LCC
Discount rate	LCC

The actual values chosen for these parameters are considered by DOE to be representative of a typical home buyer with a 30-year mortgage. DOE will consult and cite authoritative sources to establish assumptions for each of these financial, economic, and fuel price parameters. Whenever possible, DOE will use sources discussed in the following sections. Where multiple sources for any parameter are identified, DOE will use those deemed best documented and reliable. Most economic parameters vary with time. DOE will periodically review its parameter estimates and update them to account for changing economic conditions, availability of updated data or projections from the selected sources, or identification of better data sources.

First Cost

A key step in assessing the cost effectiveness of a proposed code change or a newly revised code is estimating the first cost of the changed provision(s). The *first cost* of a code change refers to the marginal cost of implementing the change. For DOE's analyses, it refers to the retail cost (the cost to a home buyer) prior to amortizing that cost over multiple years through the home mortgage. It includes the price paid by the home buyer, including materials, labor, overhead, and profit, minus any tax rebates or other incentives generally available to home buyers when the new code takes effect.

DOE has collected energy-efficiency measure cost data from several sources and made them available on a public website "Building Component Cost Community (BC3) database"[9]. For each application of this cost-effectiveness analysis methodology, DOE will use first costs drawn from the BC3 database. Where costs differ among the sources or there are otherwise questions about the currency of any measure

[9] U.S. Department of Energy, Energy Efficiency & Renewable Energy. 2012. Building Component Cost Community (BC3) Database. Accessed April 27, 2012 at http://bc3.pnnl.gov

data, DOE will choose measure costs based on the specifics of the analysis (e.g., location, time period of interest), by seeking corroborating estimates from other sources (e.g., *RS Means Residential Cost Data*,[10] national home hardware suppliers such as Lowes and The Home Depot), and/or by consulting recent studies by others (DOE's own Building America[11] program, those generated from the ENERGY STAR[12] program, and buildings-oriented research publications such as American Society of Heating, Refrigerating and Air-Conditioning Engineers' [ASHRAE] Transactions).

DOE anticipates that as building energy codes advance and incorporate more energy features, the traditional cost sources may be insufficient for estimating the first costs of code changes. Where new technologies or techniques are involved, current cost data are often unreliable indicators of the long-term costs of such measures after taking into account economies of scale and builder/contractor learning curves. DOE will address such measures on a case-by-case basis, and document any cost adjustments along with the relevant analysis.

Mortgage Parameters

The majority of homes purchased are financed. The 2010 Characteristics of New Housing report from the Census Bureau reports that 91% of new homes were purchased using a loan while only 9% were purchased with cash. Accordingly, DOE calculates cost-effectiveness assuming the home buyer finances the purchase through a 30-year mortgage.

Mortgage Interest Rate(R_{MI})

DOE will use the current rate for each analysis. Currently, Freddie Mac reports that conventional 30-year real estate loans have averaged about 5% since the beginning of 2009 [13](though historical rates have been higher. The Federal Housing Finance Agency reports similar rates[14]. Thus DOE is currently using a mortgage rate of 5%.

Loan Term (T)

For real estate loans, 30 years is by far the most common term and is the value DOE uses in its analyses. According to Table 3-15 of the 2009 American Housing Survey (U.S. Census), approximately 75% of all home loans have a term between 28 and 32 years, with 30 being the median.

Down Payment (R_{DP})

The 2009 American Housing Survey reports a wide range of down payment amounts for loans for new homes (see Table 3.2). DOE assumes a down payment of 10%. Among the possible rates, this is probably most representative of first-time home buyers who have little significant equity to bring forward

---

[10] RSMeans Reed Construction Data. 2012. Accessed April 27, 2012 at http://www.rsmeans.com/
[11] U.S. Department of Energy, Energy Efficiency & Renewable Energy. 2012. Building America –Resources for Energy Efficient Homes. Accessed April 27, 2012 at http://www.buildingamerica.gov/.
[12] Energy Star. 2012. News Room. Available online at http://www.energystar.gov/
[13] Freddie Mac. 2012. 30-Year Fixed-Rate Mortgages Since 1971. Accessed April 27, 2012 at http://www.freddiemac.com/pmms/pmms30.htm.
[14] Federal Housing Finance Agency. Periodic Summary Table. Accessed April 27, 2012 at http://www.fhfa.gov/Default.aspx?Page=252.

from a previous home. It is among the more common ranges for down payments (13.6% of all mortgages have down payments in the 6-10% range).

Table 3.2. Down Payment - 2009 American Housing Survey, Table 3-14

Percent of Purchase Price	Percentage of Homes
No down payment	16.3
Less than 3 percent	6.4
3-5 percent	10.8
6-10 percent	13.6
11-15 percent	4.7
16-20 percent	12.2
21-40 percent	10.4
41-99 percent	6.1
Bought outright	6.9
Not reported	12.6

Points and Loan Fees (R_{MF})

Points represent an up-front payment to buy down the mortgage interest rate and are tax deductible. DOE assumes all interest is accounted for by the mortgage rate and so points are taken to be zero. The loan fee is likewise paid up front in addition to the down payment and varies from loan to loan. DOE assumes the loan fee to be 0.7% of the mortgage amount, based on recent data from Freddie Mac Weekly Primary Mortgage Market Survey[15]

Discount Rate (R_d)

The purpose of the discount rate is to reflect the time value of money. Because DOE's economic perspective is that of a homeowner, that time value is determined primarily by the owner's best alternative investment at similar risk to the energy features being considered—in this case a typical homeowner who holds a home throughout a 30-year mortgage term. DOE sets the discount rate equal to the mortgage interest rate in nominal terms. Because mortgage prepayment is an investment available to consumers who purchase homes using financing, the mortgage interest rate is a reasonable estimate of a consumer's alternative investment rate.

Period of Analysis (P)

DOE's economic analysis is intended to examine the costs and benefits impacting all the consumers who live in the house. Energy-efficiency features generally last longer than the average length of home ownership, so a longer analysis period is used. Assuming a single owner keeps the house throughout the analysis period accounts for long-term energy benefits without requiring complex accounting for resale values at home turnover.

[15] Freddie Mac. 2012. Weekly Primary Mortgage Market Survey® (PMMS®). Accessed April 27, 2012 at http://www.freddiemac.com/pmms/.

DOE uses a 30-year period of analysis to capture long-term energy savings, and to match the typical mortgage term. Although 30 years is less than the overall life of the home, some efficiency measures, equipment in particular, require replacement during that period. It will be assumed that replacements are of equivalent efficiency and cost. The impact of the selection of any particular analysis term is ameliorated by the effect of the discount rate in aligning future costs and benefits with present values.

Property Tax Rate (R_{PT})

Property taxes vary widely within and among states. The median property tax rate reported by the 2007[16] American Housing Survey (U.S. Census Bureau 2007, Table 1A-7) for all homes is $9 per $1,000 in home value. Therefore, for purposes of code analysis, DOE assumes a property tax rate of 0.9%. For state-level analyses, state-specific rates will be used, as appropriate.

Income Tax Rate (R_{IT})

The marginal income tax rate paid by the homeowner determines the value of the mortgage tax deduction. The 2009 American Housing Survey[17] on "income characteristics" reports a median income of $70,200 for purchasers of new homes. The Internal Revenue Service Statistics of Income Tax Stats, Table 2.1 for 2008 (latest year available) reported that most tax payers in this income bracket itemize deductions (e.g., over 73% in this bracket took a deduction for cash contributions).[18] DOE accounts for income tax deductions for mortgage interest. A family earning $70,200 in 2011, with a married-filing-jointly filing status, would have a marginal tax rate of 25%, which is DOE's current assumption. Where state income taxes apply, rates will be taken from state sources or collections of state data, such as provided by the Federation of Tax Administrators.[19]

Inflation Rate (R_{INF})

The inflation rate R_{INF} is necessary only to give proper scale to the mortgage payments so that interest fractions can be estimated for tax deduction purposes. It does not affect the present values of cash flows, because all other rates are expressed in nominal terms (i.e., are already adjusted to match the inflation rate). The assumed inflation rate must be chosen to match the assumed mortgage interest rate (i.e., be estimated from a comparable time period). Estimates of the annual inflation rate are taken from the most recent Consumer Price Index (CPI) data published by the Bureau of Labor Statistics[20] At the time of writing, the most recent annualized CPI was reported to be 1.6%.

---

[16] The 2007 survey used as financial characteristics data is not available in the 2009 Survey.

[17] U.S. Census Bureau Current Housing Reports, Series H150/09. 2009. American Housing Survey for the United States. U.S. Government Printing Office, Washington, D.C. Available at http://www.census.gov/prod/2011pubs/h150-09.pdf.

[18] Internal Revenue Service. 2012. Tax Statistics - Produced by the Statistics of Income Division and Other Areas of the Internal Revenue Service. Accessed April 27, 2012 at http://www.irs.gov/taxstats/index.html (last updated April 10, 2012).

[19] Federation of Tax Administrators. Accessed April 27, 2012 at www.taxadmin.org (last updated April 26, 2012).

[20] Bureau of Labor Statistics. Consumer Price Indexes. Accessed April 27, 2012 at http://www.bls.gov/cpi/ (last updated March 2012).

Residual Value (*RV*)

The residual value of energy features is the value assumed to be returned to the home buyer upon sale of the home (after 30 years). As previously shown, it is calculated assuming straight-line depreciation of each measure's value against the useful life of that measure.

Home Price Escalation Rate *(E_H)*

DOE assumes that home prices have a real escalation rate of 0%. That is, the rate of home value appreciation is assumed to equal the general rate of inflation. While many homes do experience non-zero increases in value over time, the factors that influence future home prices (location, style, availability of land, etc.) are too varied and situation-specific to warrant direct accounting in this methodology.

Resale Value Fraction (R_R)

DOE will assume that energy-efficiency measures have a residual value calculated from strait-line depreciation based on an assumed useful life. Most measures are assumed to last for the life of the home, which is assumed to be 60 years. Measures that need replacement at some point during the 30-year analysis period will have a residual value based on the remaining life per Equation 3.17.

Fuel Prices

Fuel prices are needed to determine the energy cost savings from improved energy efficiency. Both current fuel prices and fuel price escalation rates are needed to establish estimated fuel prices in future years.

DOE will use the most recently available national average residential fuel prices from the DOE Energy Information Administration. If fuel prices from the most recent year(s) are deemed unusually high or low, DOE may consider using a longer-term average of past fuel prices. However, reported fuel price escalation rates (see below) may be tied to specific recent-year prices, so departures from the recent-year prices will be approached with caution. For air conditioning, fuel prices from the summer will be used, and for space heating, winter prices will be used. Fuel price escalation rates will be obtained from the most recent Annual Energy Outlook to account for projected changes in energy prices.

Table 3.3 summarizes the values discussed above.

Table 3.3. Summary of Current Economic Parameter Estimates

Parameter	Symbol	Current Estimate
Mortgage Interest Rate	I	5%
Loan Term	M_L	30 years
Down Payment Rate	R_D	10% of home price
Points and Loan Fees	R_M	0.7% (non-deductible)
Discount Rate	D	5% (equal to Mortgage Interest Rate)
Period of Analysis	L	30 years
Property Tax Rate	R_P	0.9% of home price/value
Income Tax Rate	R_I	25% federal, state values vary
Home Price Escalation Rate	E_H	Equal to Inflation Rate
Inflation Rate	R_{INF}	1.6% annual
Fuel Prices and Escalation Rates		Latest national average prices based on current Energy Information Administration data and projections[21] (as of July 2011, $0.12/kwh for electricity, $0.963/therm for natural gas); price escalation rates taken from latest Annual Energy Outlook.

[21] U.S. Department of Energy. 2011a. *Electric Power Monthly*. DOE/EIA-0226, Washington, D.C.
U.S. Department of Energy. 2011b. *Natural Gas Monthly*. DOE/EIA-0130, Washington, D.C.

4.0 Aggregating Energy and Economic Results

DOE will report its energy and cost analysis results at different levels:

1. State—Energy and cost-effectiveness assessments of a new code are often needed by states considering adoption of the code. For such purposes, DOE will report energy savings and cost effectiveness results aggregated to the individual state level. At this level, DOE will report all major analysis results, including energy savings, net LCC, annual cash flows, and simple payback periods.
2. Climate zone—DOE will aggregate its energy and economic analysis results to the climate zone level. The IECC's requirements vary by climate zone, so this is the natural aggregation for evaluation of proposed changes. At this level, DOE will report energy savings, net LCCs, and annual cash flows.
3. National—When assessing the overall impact of new codes, DOE will report results aggregated to a national average. At this level, only energy savings will be reported.

Aggregating to state, zone, and national levels involves a weighted averaging of results across several variables, including building type, foundation type, heating system/fuel type, and housing starts by climate location. Unless otherwise noted, the weighted averaging scheme assumes that those variables are independent, which means the weighting factors can be applied in arbitrary order. However, to facilitate reporting at the levels above, the weighting scheme is applied to climate location last. That is, energy simulation results (or computed LCCs) for a given location are first averaged across the foundation type, system type, and building type variables, then the weighted location-specific results are aggregated to the desired geographical regions. Because location weights are based on housing starts (permits) and those data differ between single-family and multifamily, the building-type weighting occurs after the foundation and system type weightings.

4.1 Aggregation across Foundation Types

Residential buildings typically have one of three foundation types: basement, crawlspace, or slab-on-grade. The 2010 Census data indicates that 52% of new single-family homes have slab-on-grade, 30% have a basement, and 18% have a crawlspace. For DOE's analyses, basements are divided into two categories: heated and unheated. Therefore, four foundation configurations are examined:

1. Crawlspace
2. Slab on grade
3. Heated basement
4. Unheated basement

National Association of Home Builders (NAHB) survey data provide a breakdown on foundation types in new housing by nine Census divisions. However, there are considerable differences in the use of foundation types within these Census divisions. As a primary example, the NAHB data indicate that homes in the South Atlantic division have a significant number of basements. However, it is well known that basements are very rare in warm/wet climates, like Florida, and most homes with basements are likely in the relatively colder states in the South Atlantic division, such as West Virginia and Maryland.

Therefore, data from DOE's 2009 Residential Energy Consumption Survey (RECS) will be used to establish foundation shares. The advantage of the RECS database is that it provides data for 27 regions, with each region consisting of either a single state or a combination of a few states. The disadvantage of RECS is that it covers existing housing of all vintages, including both older and newer buildings. However, the RECS data suggest the type of foundation used by region has been relatively stable over time.

Table 4.1 shows the assumptions about foundation type used in the aggregation of results. These percentages will be used for both single-family and multifamily.

Table 4.1. Foundation Type Shares (percent) by State

State	Slab	Heated Basement	Unheated Basement	Crawlspace
Connecticut, Rhode Island, Vermont, New Hampshire, Maine	16.8	23.8	45.5	13.9
Massachusetts	15.8	21.2	51.9	11.2
New York	20.4	25.9	41.7	12
New Jersey	26.9	18.3	30.6	24.2
Pennsylvania	28.9	24.6	32.8	13.7
Illinois	22.5	39.4	14.1	24.1
Ohio and Indiana	27.5	29.9	21.2	21.4
Michigan	15.7	36.2	27.3	20.8
Wisconsin	14.9	45	29.7	10.4
Minnesota, Iowa, North Dakota, South Dakota	22.1	46.9	15.5	15.5
Kansas and Nebraska	29.8	32.7	14.9	22.5
Missouri	24.8	36.4	20.8	17.9
Virginia	33.2	24.2	9.8	32.8
Maryland, Delaware, and West Virginia	28	30.7	18.3	23
Georgia	57.1	6.6	9.7	26.7
North Carolina and South Carolina	38.7	2.3	4.1	54.9
Florida	87.7	0	0.4	11.8
Alabama, Mississippi, Kentucky	44.1	8.6	10.6	36.7
Tennessee	35.3	7.2	9	48.4
Arkansas, Louisiana, and Oklahoma	66.9	0.6	2.9	29.7
Texas	79.6	0.3	0.4	19.8
Colorado	30.7	28.2	9.9	31.2
Utah, Wyoming, Montana, Idaho	26.7	36.6	11	25.6
Arizona	90.7	0.6	3.1	5.6
Nevada and New Mexico	86.1	2.5	0.8	10.7
California	59	1.2	4.9	34.9
Washington, Oregon, Alaska, Hawaii	37	8.9	3.1	51

4.2 Aggregation across Heating Equipment and Fuel Types

Residential buildings have a variety of different of space heating equipment types. According to U.S. Census data for new construction in 2010, the most common types of heating fuels in homes are natural gas (including liquid petroleum gas) with a 54% share, electricity with a 43% share, and oil with a 1% share (Census Characteristics of New Housing[22] Heating systems types are 56% warm-air furnace, 38% heat pump, and 2% hot water or steam. Ninety percent of the heat pumps are electric, 10% are gas.

Four combinations of HVAC equipment and fuel are examined:

1. Natural gas with a forced air furnace
2. Liquefied petroleum gas/propane with a forced air furnace
3. Electric resistance with a forced air furnace
4. Electric heat pump with forced air distribution

Central electric air conditioning is assumed for all geographic locations and all four heating types. According to Census data, 88% of single-family homes and 93% of new multifamily units built in 2010 had central air conditioning installed [23]

Heating system shares used in DOE's analyses are taken from NAHB survey data (NAHB 2009). The NAHB data provide more detail than the Census data (9 regions compared to 4 regions for the Census data). NAHB surveyed 1,400 homebuilders throughout the United States. The percent shares by heating type for new construction in each Census division are shown in Table 4.2 and Table 4.3.

Table 4.2. Heating System Shares by Census Division, Single Family (percent)

Census Division	Electric Heat Pump	Gas Heating	Oil Heating	Electric Furnace
New England	10.8	57	31.1	1.1
Middle Atlantic	24.5	69.2	4.6	1.7
East North Central	22.5	76.2	0.5	0.7
West North Central	39.6	56.7	0.2	3.4
South Atlantic	78.9	19	0.1	2
East South Central	68.9	28.9	0	2.1
West South Central	37.5	48.1	0	14.5
Mountain	19.4	77.8	0.2	2.6
Pacific	34	62.9	0.2	2.9

[22] United States Census Bureau. Characteristics of New Single-Family Houses Completed. Accessed April 27, 2012 at http://www.census.gov/construction/chars/completed.html.
[23] United States Census Bureau. Characteristics of Units in New Multifamily Buildings Completed. Accessed April 27, 2012 at http://www.census.gov/construction/chars/mfu.html.

Table 4.3. Heating System Shares by Census Division, Multifamily (percent)

Census Division	Electric Heat Pump	Gas Heating	Oil Heating	Electric Furnace
New England	3	66	30.4	0.7
Middle Atlantic	39.5	49.6	6.1	4.9
East North Central	3.3	96.5	0.1	0.1
West North Central	24.8	68	3	4.3
South Atlantic	74.9	24.2	0	1.1
East South Central	94.1	1.8	0	4.1
West South Central	6.9	10.1	52.9[24]	30.2
Mountain	2.8	97.2	0	0
Pacific	14.9	84.2	0.2	0.8

4.3 Aggregation across Building Type (Single-family and Multifamily) and Climate Zone

To facilitate climate-specific energy estimates, DOE will be using a number of weather locations that give reasonable climate coverage at both the climate-zone and state level. One weather location per climate zone in each state is used, including all unique combinations of the zone (temperature-oriented zone designation in the IECC), moisture regime (moist, dry, marine), and warm-humid designation (equivalent to ASHRAE's definition of warm-humid climates). This results in 119 weather locations to be used in the DOE analyses.

Census building permit data at the county level for 2010[25] will be used to estimate single-family and multifamily shares and to give appropriate weight to each climate location within a state and/or larger code zone.

4.3.1 Estimate of Low-Rise Multifamily Construction

The IECC's residential provisions limit multifamily buildings to structures that are three stories or less above grade. High-rise multifamily buildings are considered commercial buildings within the IECC and are not considered in this analysis. As building permit data do not differentiate high-rise from low-rise, Census data (Characteristics of New Housing[26]), will be used to estimate the number of housing units in structures with three stories or less. These data indicate that recent construction trends have favored high-rise multifamily buildings. In the late 1990s, less than 10% of new multifamily dwelling units were in buildings of four or more stories. In new buildings in 2010, 51% of multifamily units were in buildings of four or more stories. Therefore, a 5-year average of the Census data (2006-2010) was used to estimate the proportion of multifamily units that are in low-rise buildings. Table 4.4 shows the

---

[24] DOE believes there is an error in the source table resulting in a large overstatement in Oil Heating use in the West South Central region. The value, 52.9%, is set to zero and the shares for the other fuel/equipment types are renormalized to sum to 100% for purposes of DOE's analyses.
[25] United States Census Bureau. Building Permits. Accessed April 27, 2012 at http://censtats.census.gov/bldg/bldgprmt.shtml.
[26] United States Census Bureau. Characteristics of Units in New Multifamily Buildings Completed. Accessed April 27, 2012 at http://www.census.gov/construction/chars/mfu.html.

percentage of building permits that are assumed to fall under the scope of residential buildings in the IECC. These estimates are assumed to hold for each state in the specified region.

Table 4.4. Proportion of Multifamily Dwelling Units with Three or Fewer Stories

Census Region	Percentage of multifamily dwelling units that are three stories or less
Northeast	44
Midwest	70
South	65
West	55

4.3.2 State-Level Aggregations

Forty-one of the 50 U.S. states contain more than one IECC climate zone within their borders. To determine average impacts of the IECC within each state, the share of residential construction within each climate zone must be identified for states containing more than one zone. Census building permit data at the county level for 2010 will be used to determine these shares.[27]

4.3.3 Representative Weather Locations

Table 4.5 shows the single-family and multifamily building permit data by climate zone for each state, along with the weather location used to represent the associated climate zone. The EnergyPlus building energy simulations are run using the latest Typical Meteorological Year weather files (TMY3).[28] There are 1,020 locations nationwide with TMY3 weather data, including Guam, Puerto Rico, and the U.S. Virgin Islands. Nonetheless, there are a few state/zone combinations that do not contain a TMY3 weather file. In these cases, a best representative TMY3 data location outside the state is chosen.

[27] United States Census Bureau. Building Permits. Accessed April 27, 2012 at http://censtats.census.gov/bldg/bldgprmt.shtml.

[28] National Solar Radiation Data Base. 1991-2005 Update: Typical Meteorological Year 3. Accessed April 27, 2012 at http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

Table 4.5. Housing Permits and Weather Data by Climate Zone in Each State

State	Climate Zone[29]	TMY3 Location	Single-Family Permits	Multifamily Permits
Alabama	2A	Mobile	1577	94
Alabama	3A	Montgomery	5531	764
Alabama	3A,WH	Birmingham	1594	798
Alaska	7	Anchorage	601	41
Alaska	8	Fairbanks	65	0
Arizona	2B	Phoenix	9409	719
Arizona	3B	Kingman	696	28
Arizona	4B	Prescott	307	58
Arizona	5B	Flagstaff	343	88
Arkansas	3A	Little Rock	3454	1512
Arkansas	3A,WH	Shreveport	51	5
Arkansas	4A	Springfield	1143	119
California	2B	Tucson	102	0
California	3B	Los Angeles	21167	6513
California	3C	San Francisco	3585	3416
California	4B	Sacramento	384	3
California	4C	Arcata	196	13
California	5B	Reno	233	21
California	6B	Eagle	26	0
Colorado	4B	Trinidad	23	1
Colorado	5B	Colorado Springs	7760	1514
Colorado	6B	Eagle	462	8
Colorado	7	Gunnison	545	26
Connecticut	5A	Hartford	2632	569
Delaware	4A	Wilmington	2673	258
District of Columbia	4A	Baltimore	177	364
Florida	1A	Miami	2045	1680
Florida	2A	Tampa	27995	3909
Georgia	2A	Savannah	2915	501
Georgia	3A	Atlanta	9245	931
Georgia	3A,WH	Macon	1487	133
Georgia	4A	Chattanooga	1132	44
Hawaii	1A	Honolulu	2203	515
Idaho	5B	Boise	2669	154
Idaho	6B	Pocatello	899	169
Illinois	4A	St Louis	1736	538
Illinois	5A	Peoria	5888	2757
Indiana	4A	Evansville	1924	188

[29] The suffixes A, B, and C represent moisture regimes moist, dry, and marine, respectively. “WH” indicates the zone/regime is a warm humid location.

State	Climate Zone[29]	TMY3 Location	Single-Family Permits	Multifamily Permits
Indiana	5A	Indianapolis	7849	2135
Iowa	5A	Des Moines	4956	1100
Iowa	6A	Mason City	996	62
Kansas	4A	Topeka	3926	796
Kansas	5A	Goodland	48	22
Kentucky	4A	Lexington	5983	1296
Louisiana	2A	Baton Rouge	7723	481
Louisiana	3A	Monroe	20	1
Louisiana	3A,WH	Shreveport	2467	251
Maine	6A	Portland	2636	89
Maine	7	Caribou	75	8
Maryland	4A	Baltimore	8394	2227
Maryland	5A	Harrisburg	95	0
Massachusetts	5A	Boston	5839	1417
Michigan	5A	Lansing	6041	830
Michigan	6A	Alpena	1426	84
Michigan	7	Sault Ste Marie	236	12
Minnesota	6A	Minneapolis-St Paul	5440	1839
Minnesota	7	Duluth	1613	117
Mississippi	2A	Mobile	1765	351
Mississippi	3A	Jackson	1769	91
Mississippi	3A,WH	Tupelo	893	96
Missouri	4A	St. Louis	6660	1922
Missouri	5A	Kirksville	241	42
Montana	6B	Helena	1322	387
Nebraska	5B	Omaha	3779	1139
Nevada	3B	Las Vegas	4623	471
Nevada	5B	Reno	738	128
New Hampshire	5A	Manchester	1146	213
New Hampshire	6A	Concord	744	128
New Jersey	4A	Newark	5024	1873
New Jersey	5A	Allentown	2354	824
New Mexico	3B	Lubbock	953	130
New Mexico	4B	Albuquerque	1282	115
New Mexico	5B	Flagstaff	927	46
New York	4A	New York City	1810	2964
New York	5A	Albany	5702	987
New York	6A	Binghamton	2447	257
North Carolina	3A	Wilmington	9552	2358
North Carolina	3A,WH	Charlotte	3657	373
North Carolina	4A	Raleigh-Durham	12419	2263
North Carolina	5A	Elkins WV	419	80
North Dakota	6A	Bismarck	789	191

State	Climate Zone[29]	TMY3 Location	Single-Family Permits	Multifamily Permits
North Dakota	7	Minot	1295	1037
Ohio	4A	Cincinnati	953	213
Ohio	5A	Columbus	9650	1968
Oklahoma	3A	Oklahoma City	6864	824
Oklahoma	4B	Amarillo	2	0
Oregon	4C	Portland	4435	852
Oregon	5	Redmond	741	36
Pennsylvania	4B	Philadelphia	3821	540
Pennsylvania	5A	Harrisburg	12472	710
Pennsylvania	6A	Bradford	593	0
Rhode Island	5A	Providence	727	91
South Carolina	3A	Charleston	7979	574
South Carolina	3A,WH	Columbia	4712	287
South Dakota	5A	Sioux City	171	28
South Dakota	6A	Pierre	2015	505
Tennessee	3A	Memphis	1463	576
Tennessee	4A	Nashville	10167	2559
Texas	2B	Houston	44064	7604
Texas	2A	San Antonio	870	56
Texas	3B	Fort Worth	314	234
Texas	3A	Wichita Falls	15908	3887
Texas	3A,WH	El Paso	5181	1842
Texas	4B	Amarillo	636	280
Utah	3B	Saint George	873	11
Utah	5B	Salt Lake City	5084	857
Utah	6B	Vernal	926	398
Vermont	6A	Burlington	980	148
Virginia	4A	Richmond	13820	1948
Washington	4C	Seattle	10550	2464
Washington	5B	Spokane	3889	845
Washington	6B	Kalispell	263	3
West Virginia	4A	Charleston	1139	150
West Virginia	5A	Elkins	657	237
Wisconsin	6A	Madison	6735	2216
Wisconsin	7	Duluth	952	15
Wyoming	5B	Scottsbluff	18	4
Wyoming	6B	Cheyenne	1366	388
Wyoming	7	Jackson Hole	162	24

5.0 Conclusion

The U.S. Department of Energy (DOE) established this methodology to document the process for evaluating the energy and economic performance of residential energy codes. DOE's measure of cost-effectiveness balances longer-term energy savings against additions to initial costs through a life-cycle cost perspective. As DOE participates in code development processes, the method serves to ensure DOE proposals are both energy efficient and cost-effective. In addition, DOE will use this approach to evaluate recently published codes, which will help states and local jurisdictions better understand the impacts of updating residential energy codes.

The U.S. Department of Energy's Building Energy Codes Program is an information resource on national model energy codes. We work with other government agencies, state and local jurisdictions, national code organizations, and industry to promote stronger building energy codes and help states adopt, implement, and enforce those codes.

BECP Website
www.energycodes.gov

BECP Technical Support
techsupport@becp.gov
www.energycodes.gov/support/helpdesk.php

EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov/informationcenter

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

PNNL-21294 • April 2012

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post-consumer waste.