VIRGINIA DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT

2015 Code Change Cycle
Attachments from cdpVA for Non-Consensus Proposals to go with Book 2

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CB-901.3 cdpVA-15

Proponent : William Andrews (william.andrews@richmondgov.com)

2015 International Building Code

901.3 Modifications. Persons shall not remove or modify any *fire protection system* installed or maintained under the provisions of this code or the *International Fire Code* without approval by the *building official*. The building official shall notify the local fire official when approving installing, disabling, or removing a fire protection system.

Reason: Fire officials are responsible for applying the fire code on maintenance and periodic testing of the fire protection systems, plus local fire officials coordinate emergency responses to sites (including state). Local fire officials need to learn when a building official approve installing, disabling or removing fire alarms, sprinkler system, and other fire protection systems (including for renovation or demolition). The building official is the best source for properly authorizing substantial changes to fire protection systems, thus to notify local fire official. If code leaves responsibility on contractor and property owners, often their getting permits from the building official consider comply with code, resulting in fire official not notified. State and local building officials need to keep local fire official updated when approving substantial changes of fire protection systems within that fire official's emergency response area.

Cost Impact: No cost impact for construction. Minimal time and effort by building official's office to communicate information to the fire official.

Workgroup Recommendation

Workgroup 2 Recommendation Recommendation: Pending

Workgroup 2 Reason: This will return with collaborative efforts, Jaunna will work with Mr Andrews to tweak.

Workgroup 1 Recommendation Recommendation: Pending

Workgroup 1 Reason: Needs work. Proponent to come back with revised language based on workgroup feedback.

Board Decision

None

CB-901.3 cdpVA-15

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DBHDS SERVICES/BLDG CODE CATEGORIES

SERVICES	SERVICE DEFINITION	SERVICE SETTINGS	BLDG CODE CATEGORY	DBHDS LICENSE
Day support (center-based)	Structured programs of activity or training services for adults with an intellectual disability or a developmental disability. Day support services may provide opportunities for peer interaction and community integration and are designed to enhance the following: self-care and hygiene, eating, toileting, task learning, community resource utilization, environmental and behavioral skills, social skills, medication management, prevocational skills, and transportation skills.	Can be provided in a commercial structure, primary purpose and reimbursement are for treatment and/or training /educational purposes; Service settings: commercial structure, home, school, church, recreation centers such as Boys and girls club; size can vary.		Licenses the service
Day treatment, includes therapeutic day treatment for children and adolescents (after-school)	A treatment program that serves (i) children and adolescents through age 17 and under certain circumstances up to 21 with serious emotional disturbances, substance use, or co-occurring disorders or (ii) through age seven who are at risk of serious emotional disturbance, in order to combine psychotherapeutic interventions with education and mental health or substance abuse treatment. Services include: evaluation; medication education and management; opportunities to learn and use daily living skills and to enhance social and interpersonal skills; and individual, group, and family counseling.	Can be provided in a commercial structure, primary purpose and reimbursement are for treatment and/or training/and educational purposes; Service settings: commercial structure, school, church, recreation centers such as Boys and girls club; home; size can vary.		Licenses the service

DBHDS

Department of Behavioral Health and Developmental Services

ON-SITE REVIEW PREPARATION CHECKLIST

Note: A DBHDS License Will Not Be Issued Unless All Items Listed Have Been Completed

Provider Name ____

License Number_______________ **Date of Site Visit is scheduled for** ______________________

☐ 1. Staffing Schedule: including staff names, titles/credentials, all required training, and have oriented enough staff to begin service operation, (to include relief staff);
Additional requirements:
   - ☐ Resumes of applicable work experience and education,
   - ☐ Staff training completed in CPR, First Aid, Behavior Intervention, Emergency Preparedness and Infection Control and Medication Management, if applicable.

☐ 2. Criminal background checks and Central Registry (CPS) searches **must be initiated** for all staff that will begin work for **all services except children's residential**. Contact:
   - ☐ **Malinda Roberts** at 804/**786-6384** for all services except children's residential

   Central Registry (CPS) Contact:
   - ☐ **Betty Whittaker** at 804/**726-7567** or
   - ☐ **Kim Davis** at 804/**726-7549** for Central Registry Checks (CPS)

   Criminal background check and Central Registry (CPS) **results must be received** by the provider prior to scheduling staff to work for **children's residential facilities only**. Contact:
   - ☐ **Angela Pearson** at 804/**726-7099** for children's residential only

☐ 3. Licensing Policies and Procedures Approved;

☐ 4. Human Rights Policies and Procedures Approved;

☐ 5. Human Rights Affiliation (LHRC);

☐ 6. Proof of Insurance (general liability, professional liability, vehicular liability, & property damage)

☐ 7. Adequate Financial Backing for service provided (Updated/current)

☐ 8. Personnel: records must be complete and include evidence of completed applications for employment, evidence of required training and orientation, reference checks, and evidence of completed background investigations;

☐ 9. Client records, (a sample client record).

☐ 10. Ready to demonstrate your knowledge of and ability to implement your service description and policies and procedures, **-** random questions

☐ 11. Certificate of Occupancy;

☐ 12. Regulations regarding the physical plant are in compliance;

☐ 13. **Availability** of the **Final Policy Manual** (including all policies/forms) that was preliminarily approved. The licensing specialist will determine the final approval of the final policy manual.

CB-1023.5 cdpVA-15

Proponent : Kenney Payne, Representing AIA-VA (kpayne@moseleyarchitects.com)

2015 International Building Code

1023.5 Penetrations. Penetrations into or through *interior exit stairways* and *ramps* are prohibited except for *primary structural frame* other than columns and *secondary members*, equipment and ductwork necessary for independent ventilation or pressurization, sprinkler piping, standpipes, electrical raceway for fire department communication systems and electrical raceway serving the *interior exit stairway* and *ramp* and terminating at a steel box not exceeding 16 square inches (0.010 m^2). Such penetrations shall be protected in accordance with Section 714. There shall not be penetrations or communication openings, whether protected or not, between adjacent *interior exit stairways* and *ramps*.

> **Exception:** Membrane penetrations shall be permitted on the outside of the *interior exit stairway* and *ramp*. Such penetrations shall be protected in accordance with Section 714.3.2.

Reason: Structural framing is allowed to penetrate other rated assemblies, including rated corridor walls, exit passageways, shafts, and other fire barriers and rated construction (e.g., those elements governed by Chapter 6). As long as the penetrations are properly fire-stopped and/or installed and tested as required by Section 714, the level of safety should be equivalent to that of an exit passageway, corridor, or shaft. Otherwise, each stairway enclosure would be its own "mini-building" with structural framing starting and stopping and requiring duplicated structure within the enclosure as well as outside the enclosure. There is no code requirement for such enclosures to be constructed independent - only that they be enclosed with fire barriers.

This proposal would be consistent with what is allowed under 2015 IBC 713.8 for shaft enclosures: "Structural elements, such as beams or joists, where protected in accordance with Section 714 shall be permitted to penetrate a shaft enclosure."

Cost Impact: Allowing primary and secondary structural framing to penetrate such enclosures will result in COST SAVINGS because otherwise, the structure would need to be independent of each other and such enclosures would be required to be constructed almost like a fire wall is constructed.

Workgroup Recommendation

Workgroup 2 Recommendation Recommendation: Non-Consensus Final

Workgroup 2 Reason: Adkins opposes, Clements stated the stairwells are not designed to be structurally independent. Non consensus

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Board Decision

None

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U.S. DEPARTMENT OF ENERGY

Guide to the Changes between the 2009 and 2012 International Energy Conservation Code

TS Mapes
DR Conover

May 2012

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Pacific Northwest National Laboratory
Richland, Washington 99352

Acronyms

AAMA	American Architectural Manufacturers Association
ACCA	Air Conditioning Contractors of America
ACH	air changes per hour
AHAM	Association of Home Appliance Manufacturers
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AMCA	Air Movement and Control Association
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECP	Building Energy Codes Program
COP	coefficient of performance
CSA	Canadian Standards Association
CTI	Cooling Technology Institute
DASMA	Door and Access Systems Manufacturers Association
DOE	U.S. Department of Energy
EER	energy efficiency ratio
HVAC	Heating, ventilation, and air conditioning
IBC	International Building Code
ICC	International Code Council
IECC	International Energy Conservation Code
IEER	integrated energy efficiency ratio
IESNA	Illuminating Engineering Society
IMC	International Mechanical Code
IPLV	integrated part load value
IRC	International Residential Code
ISO	International Organization for Standardization
NFRC	National Fenestration Rating Council
NPLV	non-standard part load value
NR	no requirement
PF	performance factor
SEER	seasonal energy efficiency ratio
SHGC	solar heat gain coefficients
VAV	Variable air volume
VT	Visible transmittance
WDMA	Window & Door Manufacturers Association

Executive Summary

The International Code Council (ICC) published the 2012 International Energy Conservation Code® (IECC) in early 2012. The 2012 IECC is based on revisions, additions, and deletions to the 2009 IECC that were considered during the ICC code development process conducted in 2011. Solid vertical lines, arrows, or asterisks printed in the 2012 IECC indicate where revisions, deletions, or relocations of text respectively were made to 2009 IECC. Although these marginal markings indicate where changes have been made to the code, they do not provide any further guidance, leaving the reader to consult and compare the 2009 and 2012 IECC for more detail.

The U.S. Department of Energy (DOE) Building Energy Codes Program (BECP) created this guide to help those interested in energy codes compare where and how the 2009 and 2012 IECC documents differ. Key changes to the code are summarized on the following page(s). Additional changes are summarized in the table that follows.

This document is intended only as a cursory overview of the differences between the 2009 and the 2012 IECC. It does not provide the text of the codes, and should not be considered a stand-alone reference to code requirements. Readers are encouraged to refer to the 2009 and 2012 IECC texts for greater detail as needed. Revisions, additions and deletions between codes are noted in this document as R, A, or D, in the revision type column.

Please note that BECP made every effort to avoid language that inferred opinions or judgments of these provisions. Any interpretation of such judgment is purely coincidental and not the intent of the authors.

1.0 Key Changes

Key changes between the 2009 and 2012 IECC are provided below. A change may be considered key if it raises the level of stringency of the code, or if it has a positive impact on the implementation of, or compliance with, the code. The distinction between “key” and “not key” was made by the authors and is not intended to diminish the significance of any changes not noted.

1.1 All Building Types

- The IECC has been reformatted so that the provisions for residential and commercial buildings completely stand alone with their own separate administrative provisions, definitions, general provisions, climate zones, and reference standards.
- The provisions for both residential and commercial opaque thermal envelope components have been increased in stringency in most cases.

1.2 Commercial Buildings

- The table covering fenestration in commercial buildings has been simplified to define all fenestration as being fixed, operable, or an entrance door. The distinction between framing materials, thermal breaks, and curtain walls/storefronts with respect to thermal requirements has been removed. In some cases only residential criteria were modified. For example, solar heat gain coefficients (SHGC) were raised moderately for residential buildings but were not raised for commercial buildings. In addition, many of the U-factors applicable to skylights have been reduced.
- The allowable percentage of skylight area as a function of roof area has been increased from 3% to 5% of total roof area. Additionally, in certain building types (e.g., offices, convention centers over 10,000 ft^2 with ceilings more than 15 ft high), at least half of the floor area must be in a daylighting zone under skylights (with several exceptions allowed).
- Vertical fenestration area is now limited to 30% of above-grade wall area. The previous maximum of 40% is still allowed in Climate Zones 1-6, provided half of the conditioned floor is in a daylight zone, controls are installed, and the VT/SHGC ratio is at least 1.1.
- Visible transmittance is now used in several provisions for both vertical fenestration and skylights. In particular, a VT/SHGC ratio is one of three conditions used to increase the fenestration area maximum from 30% to 40%.
- Air barrier requirements have been added such that a continuous barrier is now needed throughout the building envelope in other than Climate Zones 1-3. The barrier must be sealed at all seams and joints, and lighting fixtures and other recesses must be treated to maintain that barrier.
- HVAC system piping insulation requirements have become more stringent. These requirements now also rely on pipe diameter and fluid temperature.
- Air system economizers are required in more climate zones and at a lower threshold (33K Btu/h instead of 54K Btu/h).
- A space-by-space method for determining allowable lighting power limits based on ASHRAE 90.1-10 was added.

- A new section on building commissioning has been added. It is now necessary for a *registered design professional* (or agency) to develop a mechanical system commissioning plan, and provide evidence of commissioning prior to the final mechanical inspection. HVAC air and water flow rates now must be balanced, and equipment, controls, and lighting must be performance tested.

1.3 Residential Buildings

- Added clarification that sunrooms enclosing conditioned spaces must meet the thermal envelope provisions of the 2012 IECC unless they are thermally isolated from the rest of the building.
- All residential buildings must be subjected to a blower door test to determine the air leakage rate and must not exceed the number of air changes per hour (ACH), either 5 or 3, prescribed as a function of climate zone.
- Hot water piping must now be insulated to at least R-3 with some exceptions.
- The minimum number of high-efficacy electrical lighting sources was changed from 50% of lamps in permanent fixtures to 75% of lamps in permanent fixtures or 75% of the permanent fixtures.

The following identifies changes between the 2009 and 2012 IECC by location. The first column shows section numbers of the 2009 IECC that contain changes. The second column lists the corresponding section number in the 2012 IECC. Note that the structure or format of the 2009 and 2012 IECC differ. The 2012 IECC has section numbers that are preceded by a "C" and an "R," indicating either commercial or residential provisions. Provisions for residential buildings are located in Chapter 4, and provisions for commercial buildings are located in Chapter 5 of the 2009 IECC.

Columns 3, 4, and 5 provide a description of new text in the 2012 IECC that was not in the 2009 IECC (addition), text that was in the 2009 IECC and is not in the 2012 IECC (deletion), and provisions that have been revised (revision) in the 2012 IECC. Section numbers in the 2009 IECC that are not included the first column or described elsewhere in the table remain unchanged other than being renumbered to be consistent with the new "C" and "R" designation.

2009 IECC	2012 IECC	CHANGES	REVISION TYPE
101.2 Scope	**C101.2 Scope** **R101.2 Scope**	The 2012 IECC separated the residential and commercial portions into two distinct, separate, stand-alone "codes." Both residential and commercial scopes were revised to include building sites in addition to systems and equipment associated with buildings and building sites.	R
101.3 Intent	**C101.3 Intent**	The intent of the 2009 IECC is "effective use of energy." The 2012 IECC adds "conservation of energy" and "over the useful life of the building" to that intent.	R
202 Definitions	**C202 Definitions**		
Building	Building	The 2012 IECC expanded the definition beyond the building to include mechanical, service water heating, electrical, and lighting systems that are on the building site and support the building.	R
—	Building commissioning	Newly defined term - Verifying and documenting that a building operates according to the owner's requirements and to minimum code requirements.	A
—	Building entrance	Newly defined term - Any portal with access to the building from the outside.	A
—	Building site	Newly defined term - A continuous area of land owned by a single entity.	A
Building thermal envelope	Building thermal envelope	Editorial clarification regarding boundaries between conditioned space and any exempt of unconditioned space.	R
—	Coefficient of performance (COP) - Cooling	Newly defined term - The ratio of heat removed to energy input for a complete refrigeration system or specific part of that system.	A
—	Coefficient of performance (COP) - Heating	Newly defined term - The ratio of heat delivered to energy input for a complete heating system or specific part of that system, including the compressor and auxiliary heat.	A
—	Continuous air barrier	Newly defined term - Building materials or assemblies that restrict air passage through the building envelope.	A
—	Demand recirculation water system	Newly defined term - A system that primes hot water piping with hot water upon demand.	A
Dwelling unit	[B] Dwelling unit	Added [B] in front of the definition to indicate that changes to the definition are under the IBC code change agenda and not the purview of the IECC Commercial Committee. (*Note - this change was not made in the IECC residential provisions.*)	R
—	Dynamic glazing	Newly defined term - A fenestration product capable of changing its performance properties, such as U-factor, SHGC, or VT.	A
—	Enclosed space	Newly defined term - A three-dimensional area surrounded by solid surfaces or operable devices (e.g., doors, windows).	A
Energy recovery ventilation	[M] Energy recovery ventilation	Added [M] in front of the definition to indicate that changes to the definition are under the IMC code change agenda and not the purview of the IECC Commercial Committee.	R
—	Equipment room	Newly defined term - Any room whose equipment, machinery, or pumps support the building.	A
—	Fenestration product, field-fabricated	Newly defined term - Frames, jambs, and other fenestration parts created from materials near the site that were not originally intended for that purpose (e.g., the use of excess lumber to create window frames). This does not, however, include site-built parts that were created in factories for the fenestration purpose and then assembled on site.	A
—	Fenestration product, site-built	Newly defined term - A fenestration product made from parts created in factories for the purpose of fenestration and assembled on site.	A
—	Furnace electricity ratio	Newly defined term - The ratio of furnace electricity use to total furnace energy use. $ER = 3.412E_{AE}/(1000E_F + 3.412E_{AE})$.	A
—	General lighting	Newly defined term - Lighting that remains at a uniform level over a given area. This does not include decorative lighting and task-specific lighting.	A
—	Integrated part load value (IPLV)	Newly defined term - Unlike EER or COP, which describe efficiency at full-load conditions, IPLV describes efficiency at various capacities.	A
—	Non-standard part load value (NPLV)	Newly defined term - Calculated part-load value that does not use the standard ARI rating conditions.	A
—	On-site renewable energy	Newly defined term - Any system located on site that provides energy from a renewable source (e.g., solar, wind, geothermal, tidal, biomass).	A
Residential building	Residential building	Added detached one and two-family dwellings and multiple one-family dwellings (e.g., townhouses).	R
Skylight	Skylight	Changed defining angle of skylights from at least 15 degrees from vertical to less than 60 degrees from horizontal.	R
Sleeping unit	[B] Sleeping unit	Added [B] in front of the definition to indicate that changes to the definition are under the IBC code change agenda and not the purview of the IECC Commercial Committee.	R
Storefront	Storefront	Added "with or without mulled windows and doors" to the end of the definition.	R
Ventilation	[M] Ventilation	Added [M] in front of the definition to indicate that changes to the definition are under the IMC code change agenda and not the purview of the IECC Commercial Committee. (*Note - this change was not made in the IECC residential provisions.*)	R
Ventilation air	[M] Ventilation air	Added [M] in front of the definition to indicate that changes to the definition are under the IMC code change agenda and not the purview of the IECC Commercial Committee. (*Note - this change was not made in the IECC residential provisions.*)	R
—	Visible transmittance	Newly defined term - A number from zero to one that describes the ratio of visible light to total incident light passing through a fenestration product.	A
303.1.3 Fenestration product rating	**C303.1.3 Fenestration product rating**	Expanded ratings to include VT for fenestration products whose SHGC ratings are determined by the NFRC 200.	R
Table 303.1.3(3) Default glazed fenestration SHGC	**Table C303.1.3(3) Default glazed fenestration SHGC and VT**	Added VT requirements to the table.	R

2009 IECC	2012 IECC	CHANGES	REVISION TYPE
501.1 Scope **501.2 Application**	**C401.1 Scope** **C401.2 Application**	Changed the caveats related to compliance. ANSI/ASHRAE/IES Standard 90.1-2010 remains a "deemed-to-comply" option. Alternatively, all commercial provisions of the IECC must be satisfied. However, the 2012 IECC has added three new provisions (**Section C406**), one of which must also be chosen. The total building performance compliance path remains, although instead of the proposed design having an annual energy cost less than the standard reference design building, that criterion has been reduced to 85% of the standard reference design building (although the provisions in 506.3 of the 2009 IECC have not been similarly changed in **Section C407.3** of the 2012 IECC).	R
—	**C401.2.1 Application to existing buildings**	Added a new subsection to provide that additions, alterations, and repairs to existing buildings meet either ASHRAE 90.1-10, or the envelope, HVAC, service water heating, and lighting provisions of the IECC.	A
502.1 General (Prescriptive)	**C402.1 General (Prescriptive)**	Added criteria to clarify that the building envelope was to meet either the insulation and fenestration criteria, or could use the U-factor alternative criteria in lieu of meeting the required R-values for insulation.	R
502.2 Specific insulation requirements (Prescriptive)	**C402.2 Specific insulation requirements (Prescriptive)**	Added provisions for the installation of continuous insulation board that contain a reference to the chapter on General Requirements covering installation of insulation and requiring multiple layers of insulation board to have the joints staggered unless the board manufacturer's installation instructions specifically cover installation of multiple layers of insulation board.	R
502.2.1 Roof assembly	**C402.2.1 Roof assembly**	Added provisions covering insulation of skylight curbs: the lesser of R-5 or the R-value of the roof insulation that is entirely above the roof deck unless the skylight curb is included as a component of the skylight assembly that is rated according to NFRC 100.	R
—	**C402.2.1.1 Roof solar reflectance and thermal emittance**	Added provisions addressing minimum solar reflectance and thermal emittance of roofs in Climate Zones 1-3 that have a slope less than 2 in 12 and a number of exceptions from those provisions for certain types of roof surfaces or those that are not exposed to solar radiation at certain times.	A
502.2.3 Above-grade walls	**C402.2.3 Thermal resistance of above-grade walls**	Editorial change in subsection title.	R
502.2.4 Below-grade walls	**C402.2.4 Thermal resistance of below-grade walls**	Editorial change in subsection title.	R
502.2.5 Floors over outdoor air or unconditioned space	**C402.2.5 Floors over outdoor air or unconditioned space**	Editorial change to criteria for mass floors from being "at least" to "not less than" stated weights.	R
502.2.6 Slabs on grade	**C402.2.6 Slabs on grade**	Added provisions to limit scope to slabs in contact with the ground and an exception to limit that coverage to those 24 in. or less below finished grade. Also added provisions that insulation extending away from the building must be protected by pavement or at least 10 in. of soil.	R
—	**C402.2.8 Insulation of radiant heating systems**	Added provisions to ensure that radiant heating systems for indoor space heating are insulated with at least R-3.5.	A
Table 502.1.2 Building envelope requirements opaque element, maximum U-factors	**Table C402.1.2 Opaque thermal envelope assembly requirements**	No row or column headings changed. Some requirements increased, some stayed the same, and none decreased in stringency. Added a footnote to allow values from ASHRAE 90.1-10 Appendix A to be used where the construction in question matches that covered in Appendix A.	R
Table 502.2(1) Building envelope requirements - Opaque assemblies	**Table C402.2 Opaque thermal envelope requirements**	No row or column headings changed. Some requirements increased in stringency, some remain unchanged, and none decreased in stringency. Changed the footnote referring to metal building assembly thermal properties from a table in the IECC to ASHRAE 90-1-10 Appendix A.	R
Table 502.2(2) Building envelope requirements - Opaque assemblies	—	Table deleted and replaced by reference to ASHRAE 90-1-10 Appendix A.	D
502.3 Fenestration (Prescriptive)	**C402.3 Fenestration (Prescriptive)**	Added reference to new provision that daylighting controls specified in **Section C402.3** must satisfy the lighting section of the 2012 IECC (**Section C405**).	R
C402.3.1 Maximum area	**C402.3.1 Maximum area**	The percentage limit of vertical fenestration area as a function of above-grade wall area has been reduced from 40% to 30% and the percentage limit of skylight area as a function of roof area remains unchanged at 3%. New provisions have been added that allow the 30% to increase to 40%, and the 3% to increase to 5%.	R
—	**C402.3.1.1 Increased vertical fenestration area with daylighting controls**	Added provisions that allow up to 40% fenestration area to above-grade wall area in Climate Zones 1-6 when at least 50% of the conditioned floor area is within a daylight zone that also has daylighting controls and the VT of the fenestration, when within the scope of NFRC 200, is at least 10% greater than the SHGC.	A
—	**C402.3.1.2 Increased skylight area with daylighting controls**	The percentage limit of skylight area as a function of roof area can be increased from over 3% to up to 5% when the daylight zone under the skylights has automatic daylighting controls.	A
—	**C402.3.2 Minimum skylight fenestration area**	Enclosed spaces greater than 10,000 ft² with ceilings higher than 15 ft that are being used for one of several special purposes (e.g., office, lobby, atrium) must have at least half of the floor area in a daylighting zone and have a minimum skylight area percentage based on skylight VT or effective aperture. Exceptions are made depending on climate zone, lighting power densities, blockage of direct sunlight on the roof, and areas where the daylight zone is more than 50% of the enclosed floor area.	A
—	**C402.3.2.1 Lighting controls in daylight zones under skylights**	All lighting in the daylighting zone must be controlled by multi-level controls that comply with **Section C405.2.2.3.3**. Exceptions are made depending on climate zone, lighting power densities, blockage of direct sunlight on the roof, and areas where the daylight zone is more than 50% of the enclosed floor area.	A
—	**C402.3.2.2 Haze factor**	Skylights in certain areas (e.g., office, storage, automotive service) must have a glazing material or diffuser that creates a haze factor greater than 90% according to ASTM D 1003. An exception is made for skylights using baffles or skylight geometry to exclude direct sunlight from entering the area.	A
502.3.3 Maximum U-factor and SHGC	**C402.3.3 Maximum U-factor and SHGC**	For windows and glass doors having different PF values, the option of using an area-weighted PF value has been removed. Each must be evaluated separately.	R
Table 502.3 Building envelope requirements - fenestration	**Table C402.3 Building envelope requirements -fenestration**	No column headings changed. Row headings are simplified and provide for vertical fenestration U-factor for fixed and operable fenestration and entrance doors, SHGC for any vertical fenestration, and U-factor and SHGC for any skylights. All U-factor and SHGC criteria were either reduced or remain the same except for the U-factor for some vertical fenestration in Climate Zone 6, which was increased.	R
—	**C402.3.3.1 SHGC adjustment**	Added new provisions to allow for the adjustment of maximum allowable fenestration SHGC values upwards based on projection factor and orientation of the fenestration.	A
—	**C402.3.3.2 Increased vertical fenestration and SHGC**	There will be an SHGC maximum of 0.40 for all windows that are entirely placed at least 6 ft above the finished floor in Climate Zones 1-3.	A
—	**C402.3.3.3 Increased skylight SHGC**	Skylights above daylighting zones that have automated control systems will have a maximum SHGC of 0.60 in Climate Zones 1-6.	A
—	**C402.3.3.4 Increased skylight U-factor**	Skylights above daylighting zones that have automated control systems will have a maximum U-factor of 0.90 in Climate Zones 1-3 and 0.75 in Climate Zones 4-8.	A

2009 IECC	2012 IECC	CHANGES	REVISION TYPE
—	**C402.3.3.5 Dynamic glazing**	For dynamic glazing, the SHGC used to comply with Section 402.3.3 will be the lowest rated by the manufacturer, and the VT/SHGC ratio will use the highest rating for each metric. Area-weighted averaging of dynamic glazing together with non-dynamic windows will not be permitted.	A
—	**C402.3.4 Area-weighted U-factor**	Area-weighted U-factors are only permitted for windows within the same product category (e.g., operable windows and fixed windows cannot be calculated together to find area-weighted averages).	A
502.4 Air leakage	**C402.4 Air leakage**	Revised the air leakage provisions by adding provisions for air barriers, adding more detail on air leakage associated with doors and access openings, and revised provisions associated with fenestration air leakage, vestibules, and recessed lighting.	R
—	**C402.4.1 Air barriers**	The thermal building envelope must provide a continuous air barrier either inside, outside, or within the envelope assemblies or any combination thereof. Specifics are given in the next several sections. Exception: Climate Zones 1-3.	A
—	**C402.4.1.1 Air barrier construction**	The continuous air barrier is expected to be: (1) across all joints and assemblies; (2) sealed at joints and changes of position or materials; and (3) compliant with **Section C404.2.8** where the barrier is penetrated (recessed light fixtures, etc.). However, buildings complying with **Section C402.4.1.2.3** are exempt from (1) and (3).	A
—	**C402.4.1.2 Air barrier compliance options**	Opaque building envelopes must meet the conditions of **Sections C402.4.1.2.1-C402.4.1.2.3**.	A
—	**C402.4.1.2.1 Materials**	A list of 15 materials (e.g., plywood, gypsum board) must be tested in accordance with ASTM E 2178 if they have an air leakage greater than 0.004 cfm/ft² under a pressure differential of 75 Pa.	A
—	**C402.4.1.2.2 Assemblies**	Material assemblies must be tested to ASTM E 2357, ASTM E 1677, and ASTM E 283 and display an average air leakage no greater than 0.04 cfm/ft² at a pressure differential of 75 Pa. Two particular assemblies–coated concrete masonry walls and a Portland cement/sand parge–need only comply to **Section C402.4.1.1**.	A
—	**C402.4.1.2.3 Building test**	The completed building envelope air leakage should not exceed 0.40 cfm/ft² for a pressure differential of 75 Pa in accordance with ASTM E 779 or an equivalent method approved by a code official.	A
502.4.1 Window and door assemblies **502.4.2 Curtain walls, storefront glazing and commercial entrance doors**	**C402.4.3 Air leakage of fenestration** **Table 402.4.3 Maximum air infiltration rate of fenestration assemblies**	Deleted the provisions from the 2009 IECC and replaced them with a table that lists the maximum allowable air infiltration rates for fenestration. All maximum air leakage rates are reduced except certain fenestration tested to AAMA/WDMA/CSA 101/I.S.2/A440 at 300 Pa can continue to have an air leakage rate of 0.30 cfm/ft². Also added air leakage limits for garage doors and rolling doors and added NFRC 400 as an acceptable test standard. Provisions allowing site-constructed windows and doors to be weather stripped and sealed in lieu of meeting the air infiltration rates were deleted.	R
502.4.3 Sealing of the building envelope	**C402.4.2 Air barrier penetrations**	Deleted the provisions from the 2009 IECC and replaced them with new provisions addressing sealing all paths of air leakage in the air barrier at both penetrations of and joints and seams in the air barrier.	R
502.4.4 Hot gas bypass limitation	**C403.4.7 Hot gas bypass limitations**	Provisions moved from Section 502 to **Section C403** and remain unchanged.	R
502.4.5 Outdoor air intakes and exhaust openings	**C402.4.4 Doors and access openings to shafts, chutes, stairways, and elevator lobbies**	These types of openings must meet Table 402.4.3 or be gasketed, weatherstripped, or sealed. Exception: Door openings required by the IBC to comply to IBC Section 715 or 715.4 or to UL 1784 need not comply with this section.	R
	C402.4.5 Air intakes, exhaust openings, stairways and shafts	These openings must have dampers and be in accordance with **Section C402.4.5.1** and **Section C402.4.5.2**.	R
	C402.4.5.1 Stairway and shaft vents	Must have Class I motorized dampers with a maximum leakage rate of 4 cfm/ft² at 249 Pa when tested to AMCA 500D. Controls must be installed that open the dampers when activated by a fire alarm system or when power to the dampers is interrupted.	R
	C402.4.5.2 Outdoor air intakes and exhausts	Must have Class I motorized dampers with a maximum leakage rate described in **Section C402.4.5.1**. Exceptions: Gravity dampers with a maximum leakage of 20 cfm/ft² at 249 Pa when tested to AMCA 500D are permitted when used for exhaust or relief dampers, in buildings less than three stories above grade, buildings in Climate Zones 1-3, or where design air intake/exhaust in <300 cfm. Dampers smaller than 24 in. may have a leakage up to 40 cfm/ft².	R
502.4.7 Vestibules	**C402.4.7 Vestibules**	Added a provision that the installation of a revolving door in an entrance does not eliminate the requirement for installation of a vestibule. Changed the scope of the requirement to provide a vestibule from doors separating conditioned space from the exterior to building entrances. Changed the exception for doors not intended to be used by the public or intended solely for employee use to doors not intended to be used as a building entrance. Added a new definition for building entrance.	R
—	**C402.4.8 Recessed lighting**	Editorial change to state the limitation of 2.0 cfm first and then the ASTM test standard instead of the reverse. No change in the "end state" technical requirements in the 2012 IECC.	A
503.2.1 Calculation of heating and cooling loads	**C403.2.1 Calculation of heating and cooling loads**	Added a sentence that the required design loads must account for building envelope, lighting, ventilation, and occupancy-related loads of the project.	R
503.2.2 Equipment and system sizing	**C403.2.2 Equipment and system sizing**	For clarification, heating and cooling equipment and systems capacity is defined as output capacity.	R
503.2.3 HVAC equipment performance requirements	**C403.2.3 HVAC equipment performance requirements**	Addition of plate-type liquid-to-liquid heat exchangers, which must meet the requirements of Table C403.2.3(9).	R
503.2.3 Exception	**C403.2.3.1 Water-cooled centrifugal chilling packages**	Two equations (Equations 4-3 and 4-4) are given for equipment not designed for operation at AHRI Standard 550/590 test conditions. These equations refer to Table 6.8.1C of the AHRI Standard and replace the earlier equations used in the 2009 IECC. These equations only apply to centrifugal chillers having (1) exit evaporative fluid temperature ≥36°F; (2) exit condenser fluid temperature ≤115°F; and (3) delta temperature for these two fluids ≥20°F and ≤80°F. Chillers designed to operate outside of these ranges need not comply.	R
Tables 503.2.3(1)-(7)	**Table C403.2.3(1)-(9)**	An additional column has been added titled "Heating Section Type," which differentiates electric resistance equipment from other types in some areas of the table. Some additional equipment types (e.g., through-the-wall, air-cooled) have been added, numerous quantitative changes have been made to the SEER requirements, and some test procedures have changed, but otherwise these tables have the same format as in the 2009 version. Two additional tables have been added for heat rejection and heat transfer equipment.	R

2009 IECC	2012 IECC	CHANGES	REVISION TYPE
Table 503.2.3(1) Minimum efficiency requirements: Electrically operated unitary air conditioners and condensing units	**Table C403.2.3(1) Minimum efficiency requirements: Electrically operated unitary air conditioners and condensing units**	Added a column covering the type of heating section provided with the air conditioner. Added provisions for small-duct high-velocity air-cooled equipment and condensing units over 135K Btu/h air, water or evaporatively cooled. Minimum efficiency for air-cooled air conditioners under 65K Bth/h and for through-the-wall air-cooled units not over 30K Btu/h did not change. Minimum energy efficiency ratios for air, water, or evaporatively cooled air conditioners changed in some instances, based on part because of the new distinction associated with the type of heating section and the addition in all cases of a minimum IEER as well.	R
Table 503.2.3(2) Unitary air conditioners and condensing units electrically operated minimum efficiency requirements	**Table C403.2.3(2) Minimum efficiency requirements: Electrically operated unitary and applied heat pumps**	Added a column covering the type of heating section provided with the heat pump that applies to the cooling mode of air-cooled heat pumps. Added heating and cooling mode provisions for single- (small) duct high-velocity air equipment. Efficiency for air-cooled cooling mode heat pumps remains unchanged or increased based on capacity and all now have a minimum IEER in addition to the previous energy efficiency requirements. Water-source cooling mode provisions are unchanged. Added a rating point and energy efficiency requirement (77F/13.4 EER) for groundwater source heat pumps in the cooling mode. Deleted cooling efficiency for ground source heat pumps. Added new classifications and efficiency requirements for the cooling and heating modes of water source water-to-water and groundwater-source brine-to-water equipment. Heating seasonal performance factor for heating mode of air-cooled under 65K Btu/h and through-the-wall heat pumps remain unchanged. COP for heating mode of air-cooled heat pumps at least 65K Btu/h remain unchanged for high-temperature rating condition but added a new low-temperature rating condition and COP requirement. Heating mode efficiency of water-source, groundwater-source, and ground-source heat pumps remain unchanged.	R
Table 503.2.3(3) Packaged terminal air conditioners and packaged terminal heat pumps	**Table C403.2.3(3) Minimum efficiency requirements: Electrically operated packaged terminal air conditioners, packaged terminal heat pumps, single package vertical air conditioners, single vertical heat pumps, room air conditioners and room air-conditioner heat pumps**	Added new minimum efficiencies for packaged terminal air conditioner and packaged terminal heat pump equipment listed in the 2009 IECC that are effective October 18, 2012. Until then, the same provisions in the 2009 IECC are retained. Also added provisions for single package vertical equipment and a number of room air conditioner types effective before October 18, 2012, and after that date as well based on input capacity and select test conditions.	R
Table 503.2.3(5) Boilers, gas and oil-fired minimum efficiency requirements	**Table C403.2.3(5) Minimum efficiency requirements: Gas and oil-fired boilers**	Revised the format of the table to focus first on type of boiler (hot water or steam) as opposed to fuel type. Combined oil-fired and boilers (residual) with all oil-fired boilers. The minimum efficiency (annual fuel utilization efficiency) remains unchanged for gas and oil-fired boilers under 300K Btu/h input. All others have been revised to either increase the stated thermal efficiency or combustion efficiency or change the metric from combustion to thermal efficiency and reduce the minimum efficiency.	R
Table 503.2.3(7) Water chilling packages efficiency requirements	**Table C403.2.3(7) Minimum efficiency requirements: Water chilling packages**	Changed the Path B values for air-cooled chillers from NR (no requirement) to NA (not applicable). The footnote in the 2009 IECC referring to chillers with leaving fluid temperatures below 40 °F was revised. It now states that the provisions after adjustment per the IECC do not apply to chillers with leaving temperatures less than 36 °F, positive displacement chillers with leaving temperatures less than 32 °F, and absorption chillers with leaving temperatures less than 40 °F.	R
—	**Table C403.2.3(8) Minimum efficiency requirements: Heat rejection equipment**	Added a new table covering heat-rejection equipment. Four types of cooling towers are provided with minimum performance requirements in terms of gpm/hp according to CTI ATC-105 and CTI STD-201 tests. Also air-cooled condensers must meet a performance requirement in terms of Btu/h* hp according to ARI 460 test.	A
—	**Table C403.2.3(9) Heat transfer equipment**	Added a new table covering plate-type liquid-to-liquid heat exchangers, referencing AHRI 400 and indicating there are no efficiency requirements.	A
—	**C403.2.3.2 Positive displacement (air- and water-cooled) chilling packages**	Equipment with leaving fluid temperatures >32 °F must meet Table C403.2(7) requirements when tested or certified to a referenced test procedure.	A
—	**C403.2.4.3.3 Automatic start capabilities**	Automatic start controls are required on all HVAC systems and must adjust the daily starting time to bring all occupied spaces to desired temperature immediately before scheduled occupancy.	A
503.2.5.1 Demand control ventilation	**C403.2.5.1 Demand control ventilation**	Demand control ventilation is now required where average occupancy load is 25 people per 1,000 ft². An additional exception has been made for ventilation used only for process loads.	R
503.2.6 Energy recovery ventilation system	**C403.2.6 Energy recovery ventilation system**	Table 403.2.6, “Energy Recovery Requirement,” has been created to define requirements for design supply air flow rates according to climate zone and percentage of outdoor air at full design rates. Systems that exceed these requirements must include an energy recovery system capable of changing the enthalpy of the outdoor air supply by at least 50% of the difference between outdoor air and return air enthalpies at design conditions. Where an air economizer is required, the energy recovery system must have a bypass or controls that permit the economizer to operate according to **Section C403.4**. Some changes have been made to Exceptions 3, 5, 6, and 7, and additional exceptions have been made for single exhaust locations that are below 75% of the design rate and for systems expected to operate less than 20 hours/week while complying with Table C403.2.6.	R
C503.2.7.1.3 High-pressure duct systems	**C403.2.7.1.3 High-pressure duct systems**	Equation 5-2, now called Equation 4-5, has changed to $CL=F/P^{0.65}$.	R
503.2.8 Piping insulation	**C403.2.8 Piping insulation**	Changes have been made to Exceptions 3, and 5, and an additional exception has been made for direct buried pipe conveying fluids $\leq$60 °F.	R
—	**C403.2.8.1 Protection of piping insulation**	Exposed piping insulation must be protected from damage from sunlight, moisture, maintenance, wind, and solar radiation. Adhesive tape is not allowed.	A
Table 503.2.8 Minimum pipe insulation	**Table C403.2.8 Minimum pipe insulation thickness**	This table’s format has been expanded to consider fluid operating temperature range (no longer differentiated by fluid type), conductivity, mean rating temperature, and nominal pipe size (diameter).	R
503.2.9 HVAC system completion	**C403.2.9 Mechanical systems commissioning and completion requirements**	All of Section 503.2.9 and its subsections have been moved to **Section C408.2**.	R
C403.2.10.1 Allowable fan floor horsepower	**503.2.10.1 Allowable fan floor horsepower**	Single-zone VAV systems must comply with the constant volume fan power limitation. Exception 3 for fans that exhaust air from fume hoods has been eliminated.	R
Table 5023.2.10.1(1) Fan power limitation	**Table C403.2.10.1(1) Fan power limitation**	Added a definition for the term CFM_D that us used in determining the value of the term A when using Option 2 for compliance with the fan power limitation provisions.	R
Table 503.2.10.1(2) Fan power limitation pressure drop adjustment	**Table C403.2.10.1(2) Fan power limitation pressure drop adjustment**	Several devices have been added (e.g., biosafety cabinet, coil runaround loop) and deductions have been eliminated, but the general format of this table is the same.	R
503.3 Simple HVAC systems and equipment	**C403.3 Simple HVAC systems and equipment**	Deleted the text indicating what the section does not apply to and referencing those named items to the section on complex HVAC systems.	R
503.3.1 Economizers	**C403.3.1 Economizers**	All cooling systems with a fan must have an economizer that meets the requirements stated in **Sections C403.3.1.1-C403.3.1.4**. Exceptions exist for several systems (e.g., systems operating <20 hours/week).	R

2009 IECC	2012 IECC	CHANGES	REVISION TYPE
Table 503.3.1(1) Economizer requirements	**Table C403.3.1(1) Economizer requirements**	Climate Zones 2A, 7, and 8 have been moved to the category that requires an economizer, and the minimum requirement has been raised to 54K Btu/h. The total capacity for all systems without economizers has been lowered to 300K Btu/h.	R
—	**C403.3.1.1 Air economizers**	Air economizers must comply with **Sections C403.1.1.1-C403.1.1.4**.	A
—	**C403.3.1.1.1 Design capacity**	Must be able to modulate up to 100% of the design supply air as outdoor air for cooling.	A
	C403.3.1.1.2 Control signal	Dampers must be able to be sequenced with cooling equipment and not only by mixed air temperature. An exception exists for systems controlled from space temperature (e.g., single-zone systems).	A
—	**C403.3.1.1.3 High-limit shutoff**	Must automatically reduce outdoor air intake to design minimum when it will no longer reduce energy usage. Table C403.3.1.1.3(1) shows the allowed and prohibited control types by climate zones, and Table C403.3.1.1.3(2) shows the settings required by device type and climate zone.	A
—	**Table C403.3.1.1.3(1) High-limit shutoff control options for air economizers**	Added provisions that vary by climate zone for control type acceptability in meeting the provisions requiring high-limit controls.	A
—	**Table C403.1.1.3(2) High-limit shutoff control setting for air economizers**	Added provisions that vary by device type and climate zone that address the high-limit settings at which the economizer must shut off.	A
—	**C403.3.1.1.4 Relief of excess outdoor air**	Systems must relieve excess outdoor air to avoid overpressurizing the building. The outlet must not recirculate air into the building.	A
503.4.1 Economizers	**C403.4.1 Economizers**	**Sections C403.4.1.1-C403.4.1.4** have been created for these requirements.	R
—	**C403.4.1.1 Design capacity**	Water economizers must be able to cool by indirect evaporation and provide up to 100% of the cooling load at outdoor temperatures of ≤50 °F dry bulb and ≤45 °F wet bulb. An exception exists for systems that cannot meet dehumidification requirements at these temperatures. For such systems, the requirements are ≤50 °F dry bulb and ≤45 °F wet bulb.	A
—	**C403.4.1.2 Maximum pressure drop**	Precooling coils and water-to-water heat exchangers in these systems need to have a water-side pressure drop of <15 ft or a secondary loop so that pressure drop is not seen by the circulating pumps in non-economizer mode.	A
—	**C403.4.1.3 Integrated economizer control**	Must be integrated with the mechanical system and able to provide partial cooling even when the mechanical system is needed. Exceptions exist for direct expansion systems that reduce outdoor air to prevent coil frosting if it is no greater than 25% of system capacity, and for direct expansion units rated less than 54K Btu/h that use nonintegrated controls, which preclude simultaneous use of the economizer and mechanical system.	A
—	**C403.4.1.4 Economizer heating system impact**	HVAC system design and controls must not increase heating energy use. An exception exists for VAV systems that cause zone-level heating to increase due to reduced supply air temperature.	A
503.4.2 Variable air volume (VAV) fan control	**C403.4.2 Variable air volume (VAV) fan control**	Requirements now apply to fans with motors ≥7.5 hp. The second requirement from 2009 may be replaced with a vane-axial fan with variable-pitch blades.	R
—	**C403.4.2.1 Static pressure sensor location**	Must be positioned so that the set point is no more than one-third of design static pressure, except for those with zone reset controls. Those downstream of duct splits must have a sensor in each branch.	A
503.4.2 Variable air volume (VAV) fan control (second paragraph)	**C403.4.2.2 Set points for direct digital control**	The static pressure set point must be reset based on the zone needing the most pressure.	R
502.4.4 Hot gas bypass limitation	**C403.4.7 Hot gas bypass limitations**	Moved (but did not change) the hot gas bypass requirements from the envelope section of the code to the HVAC section of the code.	R
504.5 Pipe insulation	**C404.5 Pipe insulation**	Heat-traced systems are now included in this section and must meet the manufacturer's installation instructions.	R
504.6 Hot water system controls	**C404.6 Hot water system controls**	Additional wording requiring ready access to operating controls.	R
504.7 Pools	**C404.7 Pools and inground permanently installed spas (Mandatory)**	This section, including the three **Subsections C404.7.1-C404.7.3**, remains unchanged except inground permanent spas have been added to the pool category, heaters pumps and motors with built-in timers are in compliance with these codes, the R-12 requirement for covers has been eliminated, and the exception for covers now applies to those receiving at least 70% of their energy from on-site.	R
504.7.1 Pool heaters	**C404.7.1 Heaters**	Change in title only from pool heaters to heaters, which according to **Section C404.7** would apply to pool heaters and inground permanently installed spas.	R
504.7.3 Pool covers	**C404.7.3 Covers**	Change in title from pool covers to covers, which according to **Section C404.7** would apply to pools and inground permanently installed spas. The R-12 cover requirement has been deleted. Changed the exception from 60% to 70% of site-recovered energy, added examples (heat pump or solar energy source) and added that the percentage contribution be assessed over an operating season.	R
505.1 General (Mandatory)	**C405.1 General (Mandatory)**	Exception to compliance now exists only for units with 75% of permanent light fixtures having high efficacy lighting.	R
—	**C405.2.1 Manual lighting controls**	Added a new section to refer to subsequent subsections that cover manual lighting controls.	A
505.2.2 Additional controls	**—**	Section has been moved and renumbered due to relocation of provisions previously covered in subsections under this section (light reduction controls and automatic lighting shutoff) in new subsections in the 2012 IECC). See **Section C405.2.2**.	D
505.2.2.1 Light reduction controls	**C405.2.1.2 Light reduction controls**	Exception to compliance has undergone several changes: areas with one luminaire must have at least 100W; equipment, electrical, and mechanical rooms have been added; and daylight spaces that comply with **Section C405.2.2.3.2** have been added.	R
505.2.2 Additional controls	**C405.2.2 Additional lighting controls**	Section reads the same as 505.2.2 in the 2009 IECC but now refers to code provisions associated with automatic time control devices, occupancy sensors, and daylight zone control. Exceptions to this section on additional lighting controls have been added and include sleeping units, spaces where patient care is directly provided, spaces where automatic shutoff would impact safety or security of occupants, and where lighting must be operated continuously.	A
502.2.2.2.1 Occupant override	**C405.2.2.1 Automatic time switch control devices**	Added new section on automatic time switch control devices and in part included the intent of 502.2.2.2.1 from the 2009 IECC. The new section indicates that all automatic control devices must be installed in all buildings other than for emergency egress lighting and lighting in spaces with occupancy sensors (new text in **Section C405.2.2.2**).	R
502.2.2.2.2 Holiday scheduling	**—**	Provisions on holiday scheduling deleted.	D
—	**C405.2.2.2 Occupancy sensors**	Occupancy sensors are required in several specifically named types of spaces (e.g., classrooms, lunch rooms). Controls must turn off lights in rooms that are unoccupied for 30 minutes and must be manual on or automatically turn lighting to no more than 50% power. An exception exists for spaces that are used for safety and security (e.g., corridors, stairways).	A

2009 IECC	2012 IECC	CHANGES	REVISION TYPE
505.2.2.3 Daylight zone control	**C405.2.2.3 Daylight zone control**	Lighting in daylight zones must be controlled separately from other areas and must conform to **Section C405.2.2.3.1** or **C405.2.2.3.2**. Daylight control zones must not be greater than 2,500 ft². Contiguous zones and zones under skylights still follow the 2009 IECC.	R
—	**C405.2.2.3.1 Manual daylighting controls**	Required in daylight zones unless automatic controls are installed according to **Section C405.2.2.3.2**.	A
—	**C405.2.2.3.2 Automatic daylighting controls**	Calibrating controls (set point) must be readily accessible. Daylighting controls must either: (1) reduce lighting to less than 35% of rated maximum power; or (2) incorporate stepped dimming such that at least one step 50-70% of design power and another step is no greater than 35% of maximum power.	A
—	**C405.2.2.3.3 Multi-level lighting controls**	Added provisions for multi-level lighting controls in daylight zones to ensure that, where such controls are provided to meet the daylight zone control provisions, the general lighting in the zone is separately controlled by one multi-level control that reduces space lighting power in response to daylighting. The control must also control the power draw of the general lighting to no more than 35% of rated power when the day-lit illuminance in the space is greater than the rated illuminance of the general lighting in the zone. The control must be located so calibration and set point controls are readily accessible and separate from the light sensor.	A
505.2.3 Sleeping unit controls	**C405.2.3 Specific application controls**	Added a new section to outline situations where additional lighting controls are required. The provisions for hotel and motel sleeping units in 505.2.3 is retained in principle as item 3 in **Section C405.2.3**. New situations include display and accent lighting, cases used for display case purposes, supplemental task lighting, lighting for non-visual applications, and lighting equipment that is for sale or demonstration.	R
505.5.2 Interior lighting power	**C405.5.2 Interior lighting power**	In addition to Table C405.5.2(1), used for the building area method, a second table has been created, Table C405.5.2(2) for a space-by-space method. The approach is similar, choosing the appropriate category, multiplying the given number by the floor area, and then taking the sum of all numbers. However, the second table allows for specific spaces within a building type (e.g., dining areas, lobbies within a hotel). Documented justification for the need for higher power in some areas is allowed according to the authority having jurisdiction. The original table has been changed slightly, but the general format remains the same.	R
Table 505.5.2 Interior lighting power allowances	**Table C405.5.2(1) Interior lighting power allowances: Building area method**	Footnote a to the table covering building area types and more specific building areas has been deleted and the current footnote b covering additional lighting power for retail areas has been moved so it does not apply to the building area method but instead to the space-by-space method.	R
—	**Table C405.5.2(2) Interior lighting power allowances: Space-by-space method**	Added a new table based on ASHRAE 90.1-10 for the new space-by-space compliance method added to the code. Retained footnote 'b' covering additional lighting power for retail areas from the building area method table and moved it to footnote 'a' of the space-by-space method table. Revised the footnote so the retail allowance starts at 500 watts instead of 1000 watts.	A
—	**C406 Additional efficiency package options**	An optional section now exists for superior performance regarding HVAC equipment, lighting, or on-site renewables.	A
—	**C406.2 Efficient HVAC performance Tables C406.2(1) through C406.2(7)**	Tables C406.2(1) through C406.2(7) will replace the tables used in **Section C403** only if the efficiencies here are superior to those listen in C403.	A
—	**C406.3 Efficient lighting system C406.3.1 Reduced lighting power density**	The numbers in Table C406.3 will be used in place of those in **Section C405**.	A
—	**C406.4 On-site renewable energy**	Minimum ratings of on-site systems must either provide 1.75 BTUs or 0.50 W/ft² of conditioned floor area, or at least 3% of the energy used for mechanical equipment, service hot water heating, and lighting.	A
—	**C408 System commissioning C408.1 General**	This entire section has been added to the previous code and applies to the commissioning of systems in **Sections C403** and **C405**.	A
—	**C408.2 Mechanical systems commissioning and completion requirements**	Before completion of the final inspection, documentation must be provided with evidence of mechanical systems commissioning. Exceptions exist for systems with a capacity of less than 480K Btu/h cooling and 600K Btu heating and for systems from **Section C403.3** that serve dwelling units in hotels, motels, etc.	A
—	**C408.2.1 Commissioning plan**	Must include: (1) a narrative description of each phase of the commissioning and personnel required; (2) a list of the equipment and appliances to be tested; (3) functions (e.g., calibrations) to be tested; (4) environmental conditions (e.g., seasonal) for testing; and (5) performance criteria.	A
—	**C408.2.2 Systems adjusting and balancing**	HVAC systems should be balanced and adjusted within product specification tolerances.	A
—	**C408.2.2.1 Air systems balancing**	Supply air outlets and zone terminals must have air balancing that meets IMC Chapter 6. Discharge dampers cannot be used with constant volume fans and VAV motors ≥10 hp. Must first minimize throttling losses then adjust fan speed to meet design conditions. An exception exists for fan motors ≤1 hp.	A
—	**C408.2.2.2 Hydronic systems balancing**	Hydronic heating and cooling coils must be used to measure flow, minimize throttle losses, and meet design flow conditions. Systems must either measure pressure across the pump or test ports at each side. Exceptions exist for pump motors ≤5 hp or where throttling is less than 5% of nameplate power, which is beyond a trimmed impeller.	A
—	**C408.2.3 Functional performance testing**	Testing is required for equipment, controls, and economizers according to **Sections C408.2.3.1-C408.2.3.3**.	A
—	**C408.2.3.1 Equipment**	Must demonstrate operation of components and system-to-system interfacing according to specifications during conditions of full load, partial load, and several emergency conditions (e.g., back up loads, alarms). An exception exists for equipment listed in **Section C403**, which do not require air economizers.	A
—	**C408.2.3.2 Controls**	HVAC controls must be tested and documented to be calibrated, adjusted, and operate according to specifications.	A
—	**C408.2.3.3 Economizers**	Must be tested to show operation in accordance with specifications.	A
—	**C408.2.4 Preliminary commissioning report**	Documented evidence of test procedures and results must be given to the building owner and must identify: (1) deficiencies that have not been corrected; (2) tests deferred due to climatic conditions; and (3) climatic conditions required for deferred tests.	A
—	**C408.2.4.1 Acceptance of report**	Before final mechanical inspection, a letter of receipt of the report must be given to the code official from the owner.	A
—	**C408.2.4.2 Copy of report**	The code official may require a copy of the code report.	A
—	**C408.2.5 Documentation requirements**	Construction documents must specify that the documents in this section be provided to the building owner within 90 days of the receipt of certificate of occupancy.	A
—	**C408.2.5.1 Drawings**	Must include the location and performance data for all equipment.	A
503.2.9.3 Manuals	**C408.2.5.2 Manuals**	The provisions for HVAC system manuals were deleted from the 2009 IECC and are now included in **Section C408.2.5.3** of the 2012 IECC, which applies to HVAC and electrical and lighting systems.	R
—	**C408.2.5.3 System balancing report**	A written report based on the findings from **Section C408.2.2**.	A
—	**C408.2.5.4 Final commissioning report**	Must include: (1) results of performance tests; (2) deficiencies found during testing and corrective measures proposed; and (3) performance test procedures used. An exception exists for test deferred due to climatic conditions.	A
—	**C408.3 Lighting system functional testing**	Controls for lighting systems must comply with **Section C408.3**.	A

2009 IECC	2012 IECC	CHANGES	REVISION TYPE
–	**C408.3.1 Functional testing**	Must ensure that hardware and software function according to construction documents and manufacturer's instructions. Code official may require a third party to conduct testing and provide documentation. In areas with occupancy sensors, time switches, and other procedures must confirm: (1) placement; sensitivity, and time-out adjustments for sensors are acceptable; (2) time switches are programmed to turn lights off; and (3) placement and sensitivity for photo sensors reduce light based on usable daylight as specified.	A
Chapter 5 Referenced standards	**Chapter 6 Referenced standards**	Updates to editions of reference standards were made in AAMA, AHRI, AMCA, ANSI, ASHRAE, ASTM, CSA, ICC, IESNA, NFRC, and WDMA standards. New standards were listed for AHAM, AHRI, ASHRAE, ASTM, CTI, DASMA, DOE, and ISO. One standard was deleted from DOE.	R
401.2 Compliance	**R401.2 Compliance**	The language has been editorially changed from referencing specific section numbers to referencing provisions that are mandatory, prescriptive, and performance.	R
401.3 Certificate	**R401.3 Certificate (Mandatory)**	This section has now become mandatory. The certificate must be posted by the builder or design professional and air leakage testing from duct systems and building envelope are now required.	R
402.1 General (Prescriptive)	**R402.1 General (Prescriptive)**	Added specific text that the building thermal envelope must meet the criteria in the subsections to **Section R402.1**.	R
Table 402.1.1 Insulation and fenestration requirements by component	**Table R402.1.1 Insulation and fenestration requirements by component**	Some numbers and wording of footnotes have changed, but the format of the table is the same.	R
Table 402.1.3 Equivalent U-factors	**Table R402.1.3 Equivalent U-factors**	Some numbers and wording of footnotes have changed, but the format of the table is the same.	R
402.2 Specific insulation requirements (Prescriptive)	**R402.1 Specific insulation requirements (Prescriptive)**	Added specific text that clarifies that the insulation must meet the thermal envelope provisions as well as all the specific insulation requirements outlined in subsections to **Section R402.2**.	R
—	**R402.2.3 Eave baffle**	If an attic is vented and has air permeable insulation, it must have a baffle adjacent to soffit and eave vents that is no less in size than the vent itself and must extend over top of the insulation.	A
402.2.5 Steel-frame ceilings, walls, and floors	**R402.2.6 Steel-frame ceilings, walls, and floors**	Deleted the exception that allowed the recution of continuous insulation on steel-framed wall assemblies in Climate Zones 1 and 2.	R
Table 402.2.5 Steel-frame ceiling, wall, and floor insulation (R-value)	**Table R402.2.6 Steel-frame ceiling, wall, and floor insulation (R-value)**	Steel-framed walls have been divided into two categories, 16 in. O.C. and 24 in. O.C., having separate requirements for each. The rest of the table is unchanged.	R
—	**R402.2.12 Sunroom insulation**	Sunrooms enclosing conditioned spaces must comply with this code. For sunrooms with thermal isolation, the ceiling R-values need only be R-19 in Climate Zones 1-4 and R-24 in Climate Zones 5-8; wall R-values need only be R-13 in all climate zones.	A
402.3.5 Thermally isolated sunroom U-factor	**R402.3.5 Sunroom U-factor**	Sunrooms enclosing conditioned space must comply with this code. Exceptions exist in Climate Zones 4-8 such that the U-factor must be ≤0.45 and the skylight U-factor must be ≤0.75.	R
402.4 Air leakage (Mandatory)	**R402.4 Air leakage (Mandatory)**	The 2009 IECC had no text in this section. Text has been added to indicate that the provisions of all subsections to **Section R402.4** must be satisfied.	R
402.4.1 Building thermal envelope	**R402.4.1 Building thermal envelope**	The provisions of the code have been deleted, other than the requirement associated with dissimilar material expansion and contraction, and replaced with a reference to the provisions in the two subsections that address installation and testing.	R
Table 402.4.2 Air barrier and insulation inspection component criteria	**Table R402.4.1 Air barrier and insulation installation**	One category (common wall) has been added and several changes have been made to the criteria, including a footnote. All other formatting remains the same.	R
402.4.2.2 Visual inspection option	**R402.4.1.1 Installation**	The provisions of the code have been relocated. While the wording has been revised, the intent is to ensure application of the provisions in the table on air barrier and insulation installation. Unlike the 2009 IECC, these provisions must be satisfied in all cases (see **Section R402.4**).	R
402.4.2.1 Testing option	**R402.4.1.2 Testing**	This section is now mandatory. Air changes per hour must not exceed five in Climate Zones 1 and 2, and must not exceed three in all others. The conditions of testing have undergone slight modification but are essentially the same except that the condition that HVAC ducts not be sealed has been removed.	R
402.4.2.2 Visual option	—	This section has been removed.	D
402.4.3 Fireplaces	**R402.4.2 Fireplaces**	New wood-burning fireplaces now require tight-fitting flue dampers rather than gasketed doors.	R
402.4.5 Recessed lighting	**R402.4.4 Recessed lighting**	The wording has been edited to provide the air leakage rate limit first, followed by the test standard instead of the test standard first, followed by the air leakage rate limit.	R
403.2 Ducts	**403.2 Ducts**	The 2009 IECC had no text in this section. Text has been added to indicate that the provisions of all **Section R403.2** subsections must be satisfied.	R
403.2.2 Sealing (Mandatory)	**R403.2.2 Sealing (Mandatory)**	Exceptions have now been made such that (1) air-impermeable spray foam products are permitted without joint seals; (2) for inaccessible duct connections, three rivets will be spaced on the exposed joint; and (3) continuously welded and locking longitudinal joints and seams in ducts operating at 500 Pa do not require additional closure systems. Also, leakage must be ≤4 cfm/100 ft^2 of conditioned floor area for both the preconstruction and rough-in test and for the rough-in test the leakage is ≤3 cfm/100 ft^2 of conditioned floor area if the air handler is not installed. This test is not required if air handlers and ducts are entirely within conditioned space.	R
—	**R403.2.2.1 Sealed air handler**	Air handlers must have a manufacturer's air leakage of ≤2% of design air flow rate when tested to ASHRAE 193.	A
—	**R403.3.1 Protection of piping insulation**	Exposed insulation must be protected from damage (e.g., from sunlight, moisture, maintenance). Adhesive tape is not permitted.	A
—	**R403.4 Service hot water systems**	New provisions have been added to distinguish provisions for pipe insulation and circulating systems as applying to service hot water systems (see **Sections R403.4.1** and **R403.4.2**).	A
403.4 Circulating hot water systems (Mandatory)	**R403.4.1 Circulating how water systems (Mandatory)**	The provision concerning R-2 insulation has been deleted (**see Section R403.4.2**). The code now only addresses controls as covered in the previous code requirements.	R
—	**R403.4.2 Hot water pipe insulation (Prescriptive)**	R-3 insulation is required with hot water piping for the following piping: (1) ¾-in. diameter; (2) serving more than one dwelling unit; (3) from water heater to kitchen outlets; (4) outside conditioned space; (5) from water heater to distribution manifold; (6) under floor slab; (7) buried piping; (8) supply and return recirculation other than demand recirculation; and (9) having greater run lengths than the distance specified in Table R403.4.2.	A
—	**Table R403.4.2 Maximum run length**	A new table has been added providing pipe lengths as a function of pipe diameter over which R-3 pipe insulation is required unless the pipe's location or function is specifically listed in **Section R403.4.2**.	A

2009 IECC	2012 IECC	CHANGES	REVISION TYPE
403.5 Mechanical ventilation (Mandatory)	**R403.5 Mechanical ventilation (Mandatory)**	Must now meet the requirements of IRC or IMC or with other approved means of ventilation.	R
—	**R403.5.1 Whole-house mechanical ventilation system fan efficiency**	Must meet the requirements of Table 403.5.1. An exception exists for fans integral to tested and listed HVAC systems, which must have an electrically commutated motor.	A
—	**Table R403.5.1 Mechanical ventilation system fan efficiency**	Added new provisions (see **Section R403.5.1**) for minimum fan efficiency in cfm/watt by fan location (e.g., range, in-line, bathroom, utility room) as a function of minimum and maximum fan air flow rate.	A
403.6 Equipment sizing (Mandatory)	**R403.6 Equipment sizing (Mandatory)**	Must be done in accordance with ACCA Manual S based on loads calculated in Manual J or other approved methods.	R
403.9.3 Pool covers	**R403.9.3 Pool covers**	Minimum R-12 values are not required. An exception exists for pools receiving >70% of their energy from site-recovered sources.	R
404.1 Lighting (Prescriptive)	**R404.1 Lighting (Mandatory)**	This section is now mandatory. At least 75% of all fixtures must be high efficacy. An exception exists for low-voltage fixtures.	R
—	**R404.1.1 Lighting equipment (Mandatory)**	Fuel gas lighting may not have continuous pilot lights.	A
405.4 Documentation	**R405.4 Documentation**	Text has been included in the 2012 IECC to specifically refer to and require compliance with subsections to this section of the code.	R
405.5 Calculation procedure	**R405.5 Calculation procedure**	Text has been included in the 2012 IECC to specifically refer to and require compliance with subsections to this section of the code.	R
405.6 Calculation software tools	**R405.6 Calculation software tools**	Text has been included in the 2012 IECC to specifically refer to and require compliance with subsections to this section of the code.	R
405.6.1 Minimum capabilities	**R405.6.1 Minimum capabilities**	Calculation of whole-building sizing for heating and cooling equipment is now in accordance with the standard reference design in **Section R403.6**.	R
Table 405.5.2(1) Specifications for the standard reference and proposed designs	**Table 405.5.2(1) Specifications for the standard reference and proposed designs**	Revisions have been made to the table for interior shade fraction, the air-exchange rate, heating systems, cooling systems, and thermal distribution systems. Footnotes to the table have also been revised to reflect changes to the table.	R
Chapter 5 Referenced standards	**Chapter 6 Referenced standards**	Updates to editions of reference standards were made in AAMA, ASHRAE, CSA, ICC, NFRC, and WDMA standards. New standards were listed for ACCA and ASHRAE. Standards were deleted from ASHRAE and ASTM.	R

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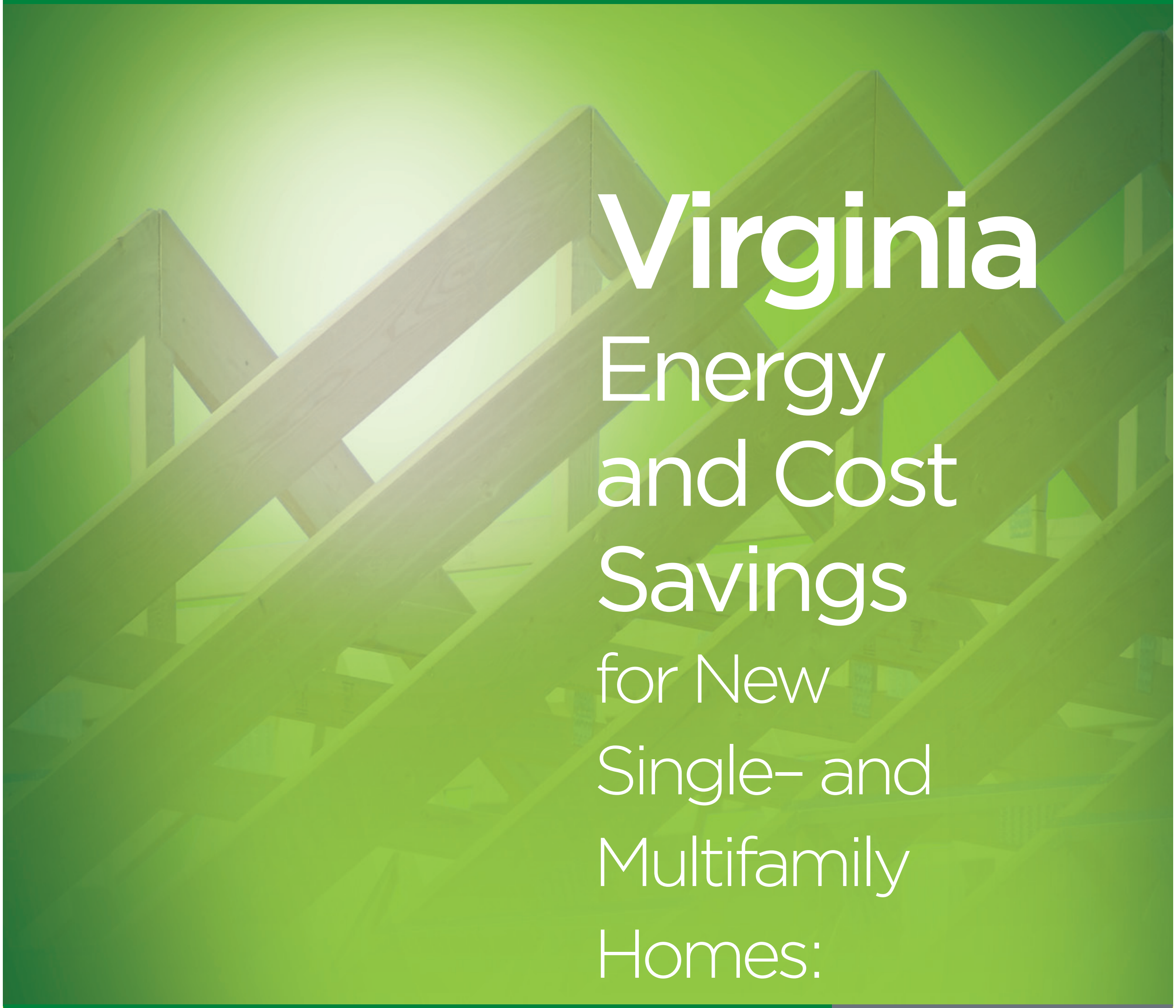


Virginia
Energy and Cost Savings for New Single– and Multifamily Homes:

2012 IECC as Compared to the **2009 Virginia Construction Code**

Building Energy Codes

Virginia Energy and Cost Savings for New Single- and Multifamily Homes: **2012 IECC** as Compared to the **2009 Virginia Construction Code**

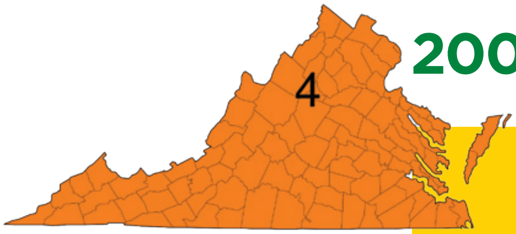


Figure 1. Virginia Climate Zones

The 2012 International Energy Conservation Code (IECC) yields positive benefits for Virginia homeowners.

Moving to the 2012 IECC from the current Virginia Construction Code is cost-effective over a 30-year life cycle. On average, Virginia homeowners will save $5,836 with the 2012 IECC.

Each year, the reduction to energy bills will significantly exceed increased mortgage costs. After accounting for up-front costs and additional costs financed in the mortgage, homeowners should see net positive cash flows (i.e., cumulative savings exceeding cumulative cash outlays) in 1 year for the 2012 IECC. Average annual energy savings are $388 for the 2012 IECC.

Highlights

Cost-effectiveness against a Virginia Construction Code baseline:

- Life-cycle cost savings, averaged across building types, are $5,836 for the 2012 IECC
- Simple payback period is 5.2 years for the 2012 IECC

Consumer savings compared to a Virginia Construction Code baseline:

- Households save an average of $388 per year on energy costs with the 2012 IECC
- Net annual consumer savings, including energy savings, mortgage cost increases, and other associated costs in the first year of ownership, average $272 for the 2012 IECC
- Energy costs, on average, are 27.4% lower for the 2012 IECC

Cost-Effectiveness

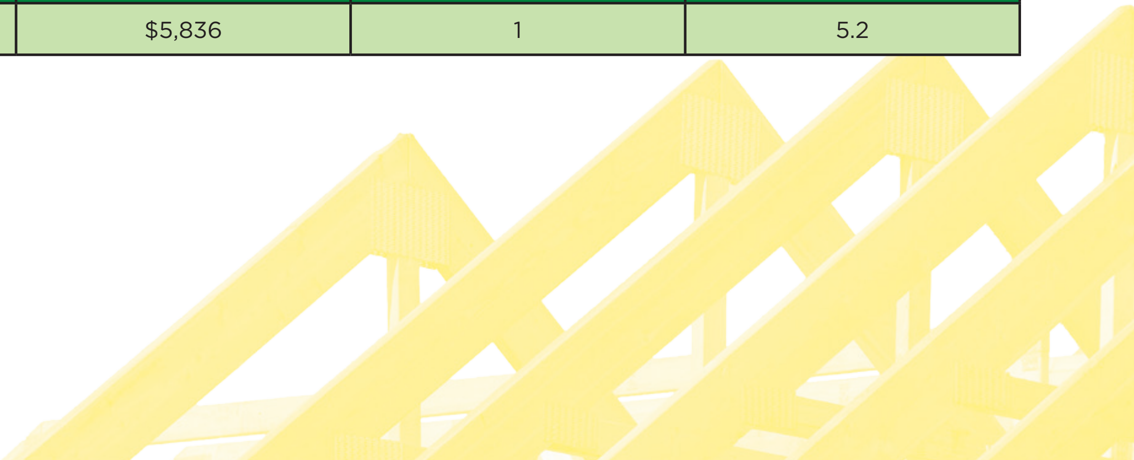
The U.S. Department of Energy (DOE) evaluates the energy codes based on three measures of cost-effectiveness:

- **Life-Cycle Cost:** Full accounting over a 30-year period of the cost savings, considering energy savings, the initial investment financed through increased mortgage costs, tax impacts, and residual values of energy efficiency measures
- **Cash Flow:** Net annual cost outlay (i.e., difference between annual energy cost savings and increased annual costs for mortgage payments, etc.)
- **Simple Paybac:** Number of years required for energy cost savings to exceed the incremental first costs of a new code

Life-cycle cost is the primary measure by which DOE assesses the cost-effectiveness of the IECC. These savings assume that initial costs are mortgaged, that homeowners take advantage of the mortgage interest deductions, and that long-lived efficiency measures retain a residual value after the 30-year analysis period. As shown in Table 1, life-cycle cost savings are $5,836 for the 2012 IECC compared to the Virginia Construction Code.

Table 1. Average Life-Cycle Cost Savings from Compliance with the 2012 IECC, Relative to the Virginia Construction Code

	Life-Cycle Cost Savings ($)	Net Positive Cash Flow (Years)	Simple Payback (Years)
2012 IECC	$5,836	1	5.2



Consumer Savings

Annual consumer cash flows impact the affordability of energy-efficient homes. Based on this analysis, Virginia homeowners, on average, should see average annual energy cost savings of $388 and achieve a net cumulative savings that accounts for an increased down payment in addition to energy costs, mortgage costs, and tax-related costs and benefits in 1 year when comparing the 2012 IECC to the 2009 Virginia Construction Code. Table 2 summarizes these results.

Table 2. Impacts to Consumers' Cash Flow from Compliance with the 2012 IECC Compared to the Virginia Construction Code

	Consumers' Cash Flow (Average)	2012 IECC
A	Down payment and other up-front costs	$215
B	Annual energy savings (year one)	$388
C	Annual mortgage increase	$117
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	-$1
E = [B-(C+D)]	Net annual cash flow savings (year one)	$272
F = [A/E]	Years to positive savings, including up-front cost impacts	1

The U.S. Department of Energy (DOE) provides estimates of energy and cost savings from code adoption:

- **National**: Energy cost savings (only)
- **Climate Zone**: Energy cost savings, life-cycle cost savings, and consumer cash flows
- **State**: Energy cost savings, life-cycle cost savings, consumer cash flows, and simple paybacks

For more information on how these estimates were developed, visit the DOE Building Energy Codes website: **www.energycodes.gov/development/residential**

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Technical Appendix A

Methodology

An overview of the methodology used to calculate these impacts is provided below. Further information as to how these estimates were developed is available at the U.S. Department of Energy's (DOE) Building Energy Codes website.[1]

Cost-Effectiveness

Pacific Northwest National Laboratory (PNNL) calculated three cost-effectiveness metrics in comparing the 2012 International Energy Conservation Code (IECC) to the 2009 Virginia Construction Code (referred to herein as the Virginia state code). These are:

- Life-Cycle Cost (LCC): Full accounting over a 30-year period of the cost savings, considering energy savings, the initial investment financed through increased mortgage costs, tax impacts, and residual values of energy efficiency measures
- Cash Flow: Net annual cost outlay (i.e., difference between annual energy cost savings and increased annual costs for mortgage payments, etc.)
- Simple Payback: Number of years required for energy cost savings to exceed the incremental first costs of a new code

LCC is a robust cost-benefit metric that sums the costs and benefits of a code change over a specified time period. LCC is a well-known approach to assessing cost-effectiveness. DOE uses LCC for determining the cost-effectiveness of code change proposals, and for the code as a whole, because it is the most straightforward approach to achieving the desired balance of short- and long-term perspectives.

The financial and economic parameters used for these calculations are as follows:

- New home mortgage parameters:
    - 5.0% mortgage interest rate (fixed rate)
    - Loan fees equal to 0.7% of the mortgage amount
    - 30-year loan term
    - 10% down payment
- Other rates and economic parameters:
    - 5% nominal discount rate (equal to mortgage rate)
    - 1.6% inflation rate
    - 25% marginal federal income tax and 5.75% marginal state income tax
    - 0.9% property tax
    - Insulation has 60-year life with linear depreciation resulting in a 50% residual value at the end of the 30-year period
    - Windows, duct sealing, and envelope sealing have a 30-year life and hence no residual value at the end of the analysis period
    - Light bulbs have a 6-year life and are replaced four times during the 30-year analysis period

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[1] www.energycodes.gov/development/residential

Energy and Economic Analysis

This analysis determined the energy savings and economic impacts of the 2012 IECC compared to the Virginia state code. Energy usage was modeled using DOE's EnergyPlus™ software for two building types:

1. Single-Family: A two-story home with a 30-ft by 40-ft rectangular shape, 2,400 ft^2 of floor area excluding the basement, and windows that cover 15% of the wall area, equally distributed on all sides of the house
2. Multifamily: A three-story building with 18 units (6 units per floor), each unit having conditioned floor area of 1,200 ft^2 and window area equal to approximately 10% of the conditioned floor area, equally distributed on all sides of the building

Each of these building types, single-family and apartment/condo in a multifamily building, has four unique foundation types:

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

Each building type also has four unique heating system types:

1. Natural gas
2. Heat pump
3. Electric resistance
4. Oil

This results in 16 unique scenarios (4 x 4) per building type.

PNNL incorporated the prescriptive requirements of the 2006, 2009, and 2012 IECC when modeling the impacts of changes to the code. Whenever possible, PNNL uses DOE's EnergyPlus model software to simulate changes to code requirements. However, in some cases, alternative methods are employed to estimate the effects of a given change. As an example, in order to give full consideration of the impacts of the 2012 IECC requirement for insulating hot water pipes (or shortening the pipe lengths), a separate estimate was developed for hot water pipe insulation requirements in the 2012 IECC, which results in a 10% savings in water heating energy use (Klein 2012).

Energy and economic impacts were determined separately for each unique scenario, including the single-family and multifamily buildings, the four unique foundation types, and the four unique heating system types. However, the cost-effectiveness results are reported as a single overall state average. To determine this average, first the results were combined across foundation types and heating system types for single-family and multifamily prototypes as shown in Table A.1 and Table A.2 (single-family and multifamily have the same shares for foundation types). For example, the primary heating system type in new residential units in Virginia is a heat pump. Therefore, the combined average energy usage calculations were proportionally weighted to account for the predominance of heat pump heating. Then single-family and multifamily results were combined to determine a state average weighted by housing starts from 2010 U.S. Census data as shown in Table A.3.

Table A.1. Heating Equipment Shares

Heating System	Percent Share Single-Family	Multifamily
Natural gas	19	24.2
Heat pump	78.9	74.9
Electric resistance	2	1.1
Oil	0.1	0

Table A.2. Foundation Type Shares

Foundation Type	Slab on Grade	Heated Basement	Unheated Basement	Crawlspace
Percent share	33.2	24.2	9.8	32.8

Table A.3. Construction by Building Type

Housing Starts Single-Family	Multifamily
13,820	1,948

Differences Between the 2006 IECC, the 2009 IECC, and the 2012 IECC

The Virginia state code is based on the 2009 IECC but does not require duct pressure testing. All versions of the IECC have requirements that apply uniformly to all climate zones, and other requirements that vary by climate zone. Highlights of the mandatory requirements across all buildings include:

- Building envelope must be caulked and sealed. The 2012 IECC adds a requirement that the building must be tested and a level of leakage that is no more than a maximum limit must be achieved.
- Ducts and air handlers must be sealed. Testing against specified maximum leakage rates is required in the 2012 IECC if any ducts pass outside the conditioned space (e.g., in attics, unheated basements). Supply and return ducts in attics, and all ducts in crawlspaces, unheated basements, garages, or otherwise outside the building envelope must be insulated.
- For both the Virginia state code and the 2012 IECC, a minimum percentage of the lighting bulbs or fixtures in the dwelling must be high-efficacy lighting.
- A certificate listing insulation levels and other energy efficiency measures must be posted on or near the electric service panel.

A comparison of significant IECC requirements is contained in Table A.4 and Table A.5. Of these, the most significant changes in the 2012 IECC compared to the Virginia state code are the requirements for pressure testing of the building envelope and ducts/air handlers, and for insulating service hot water pipes. The requirement for high-efficacy lamps, while significant, is somewhat abated by a superseding federal regulation banning the manufacture or import of less efficient lamps at common watt levels that takes effect in 2012 to 2014.

Table A.4. Comparison of Major Requirements That Do Not Vary by Climate Zone

Requirement	Virginia State Code	2012 IECC
Building envelope sealing	Caulked and sealed, verified by visual inspection against a more detailed checklist	Caulked and sealed, verified by visual inspection and a pressure test against a leakage requirement
Ducts and air handlers	Sealed, verified by visual inspection	Sealed, verified by visual inspection, and pressure tested against a specified leakage requirement, or all ducts must be inside building envelope
Supply ducts in attics	R-8	R-8
Return ducts in attics and all ducts in crawlspaces, unheated basements, garages, or otherwise outside the building envelope	R-6	R-6
Insulation on hot water pipes for service water heating systems	None	R-3 except where pipe run length is below a diameter-dependent threshold
Insulation on hot water pipes for hydronic (boiler) space heating systems	R-3	R-3
High-efficacy lamps (percent of lighting in the home)	50% of lamps	75% of lamps or 75% of fixtures
Certificate of insulation levels and other energy efficiency measures	Yes	Yes

Requirements such as insulation levels and fenestration (window, door, and skylights) U-factors can vary by the eight zones in the United States. Table A.5 shows these requirements. Virginia has one climate zone (Zone 4) as defined in the IECC.

Table A.5. Comparison of Major Requirements That Vary by Climate Zone

Climate Zone	IECC	Components										
		Ceiling (R-value)	Skylight (U-factor)	Fenestration (Windows and Doors)		Wood Frame Wall (R-value)	Mass Wall* (R-value)	Floor (R-value)	Basement Wall** (R-value)	Tested Max Air Leakage Rate (air changes per hour)	Slab*** (R-value and depth)	Crawl Space** (R-value)
				U-factor	SHGC							
1	**2009**	30	0.75	NR	0.3	13	3/4	13	NR	NR	NR	NR
	2012				0.25					5		
2	**2009**	30	0.75	0.65	0.3	13	4/6	13	NR	NR	NR	NR
	2012	38	0.65	0.4	0.25					5		
3	**2009**	30	0.65	0.5	0.3	13	5/8	19	5/13****	NR	NR	5/13
	2012	38	0.55	0.35	0.25	20	8/13			3		
4	**2009**	38	0.6	0.35	NR	13	5/10	19	10/13	NR	10, 2 ft	10/13
	2012	49	0.55		0.40	20	8/13			3		
5	**2009**	38	0.6	0.35	NR	20	13/17	30	10/13	NR	10, 2 ft	10/13
	2012	49	0.55	0.32			15/19		15/19	3		15/19
6	**2009**	49	0.6	0.35	NR	20	15/19	30	15/19	NR	10, 4 ft	10/13
	2012		0.55	0.32		20+5				3		15/19
7 and 8	**2009**	49	0.6	0.35	NR	21	19/21	38	15/19	NR	10, 4 ft	10/13
	2012		0.55	0.32		20+5				3		15/19

* The second number applies when more than half the insulation is on the interior side of the high mass material in the wall.

** The first number is for continuous insulation (e.g., a board or blanket directly on the foundation wall) and the second number is for cavity insulation (i.e., if there is a furred-out wall built against the foundation wall). Only one of these two has to be met.

*** The first number is R-value. The second value refers to the vertical depth of the insulation around the perimeter.

**** Basement wall insulation is not required in the warm-humid region of Zone 3 in the southeastern United States.

NR = not required

SHGC = solar heat gain coefficient

While exemptions or allowances in the code in are not included in this analysis, the code does allow for some of these depending on the compliance path. Examples include the following:

- One door and 15 ft^2 of window area are exempt
- Skylight U-factors are allowed to be higher than window U-factors
- Five hundred square feet or 20% of ceiling area of a cathedral ceiling, whichever is less, is allowed to have R-30 insulation in climate zones where more than R-30 is required for other ceilings

Incremental First Costs

Table A.6 shows the costs of implementing the prescriptive measures of the new code. Costs are provided for both the reference home and apartment/condo moving from the Virginia state code to the 2012 IECC. The costs derive from estimates assembled by Faithful + Gould (2012) and a number of other sources.[2] The original cost data were based on a national average. The costs are adjusted downwards by 11.3% (multiplied by 0.887) to reflect local construction costs based on location factors provided by Faithful + Gould (2011).

Table A.6. Total Construction Cost Increase for the 2012 IECC Compared to the Virginia State Code

2,400 ft^2 House	1,200 ft^2 Apartment/Condo
$2,138	$1,120

Results

Life-Cycle Cost

Table A.7 shows the LCC savings (discounted present value) of the 2012 IECC over the 30-year analysis period. These savings assume that initial costs are mortgaged, that homeowners take advantage of the mortgage interest tax deductions, and that efficiency measures retain a residual value at the end of the 30 years. As shown in Table A.7, life-cycle cost savings are $5,836 for the 2012 IECC.

Table A.7. Life-Cycle Cost Savings Compared to the Virginia State Code

	State Average
2012 IECC	$5,836

Cash Flow

Because most houses are financed, consumers will be very interested in the financial impacts of buying a home that complies with the 2012 IECC requirements compared to the Virginia state code. Mortgages spread the payment for the cost of a house over a long period of time (the simple payback fails to account for the impacts of mortgages). In this analysis, a 30-year fixed-rate mortgage was assumed. It was also assumed that homebuyers will deduct the interest portion of the payments from their income taxes.

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[2] The Faithful + Gould cost data and other cost data for energy efficiency measures are available on the "BC3" website at http://bc3.pnnl.gov/.

Table A.8 shows the impacts to consumers' cash flow resulting from the improvements in the 2012 IECC. Up-front costs include the down payment and loan fees. The annual values shown in the table are for the first year.

The savings from income tax deductions for the mortgage interest will slowly decrease over time while energy savings are expected to increase over time because of escalating energy prices. These tables also include increases in annual property taxes because of the higher assessed house values. The net annual cash flow includes energy costs, mortgage payments, mortgage tax deductions, and property taxes but not the up-front costs. The time to positive cash flow includes all costs and benefits, including the down payment and other up-front costs.

As shown in Table A.8, on average, there is a net positive cash flow to the consumer of $272 per year beginning in year one for the 2012 IECC. Positive cumulative savings, including payment of up-front costs, are achieved in 1 year.

Table A.8. Impacts to Consumers' Cash Flow from Compliance with the 2012 IECC Compared to the Virginia State Code

	Cost/Benefit	State Average
A	Down payment and other up-front costs	$215
B	Annual energy savings (year one)	$388
C	Annual mortgage increase	$117
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	-$1
E = [B-(C+D)]	Net annual cash flow savings (year one)	$272
F = [A/E]	Years to positive savings, including up-front cost impacts	1

Note: Item D includes mortgage interest deductions, mortgage insurance, and property taxes for the first year. Deductions can partially or completely offset insurance and tax costs. As such, the "net" result appears relatively small or is sometimes even negative.

Simple Payback

Table A.9 shows the simple payback period, which consists of the construction cost increase divided by first-year energy cost savings. This calculation yields the number of years required for the energy cost savings to pay back the initial investment. Simple payback does not consider financing of the initial costs through a mortgage or favored tax treatment of mortgages.

As Table A.9 shows, the simple payback period from moving to the 2012 IECC from the Virginia state code averages 5.2 years.

Table A.9. Simple Payback Period, Relative to the Virginia State Code (Years)

Code	State Average
2012 IECC	5.2

Energy Cost Savings

All fuel prices were obtained from the DOE Energy Information Administration and are recent residential prices specific to Virginia (DOE 2012a, 2012b, 2012c). For this analysis, natural gas fuel prices were set to $1.077/therm. Electricity prices were set to $0.098/kWh for space heating and $0.108/kWh for air conditioning. Oil prices were set to $23.7/MBtu. Energy prices are assumed to escalate at the rates published in DOE's *Annual Energy Outlook* (DOE 2012d).

Table A.10 shows the estimated annual energy costs, including heating, cooling, water heating, and lighting per home that result from meeting the requirements in the Virginia state code and 2012 IECC. Table A.11 shows the total energy cost savings as both a net dollar savings and as a percentage of the total energy use.[3] Results are averaged across home type (single- and multifamily), foundation type, and heating system type.

Table A.10. Annual Energy Costs for Virginia State Code and IECC 2012

	Virginia State Code					2012 IECC				
	Heating	Cooling	Water Heating	Lighting	Total	Heating	Cooling	Water Heating	Lighting	Total
State average	$579	$354	$323	$161	$1,417	$308	$295	$290	$136	$1,029

As can be seen from Table A.11, annual energy cost savings for the 2012 IECC compared to the Virginia state code average $388. On a percentage basis, energy cost savings are 27.4% with the 2012 IECC.

Table A.11. Total Energy Cost Savings Compared to the Virginia State Code

	2012 IECC	
	Savings ($/yr)	Percent Savings
State Average	**$388**	**27.4**

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[3] The percent savings is the annual energy cost savings for heating, cooling, water heating, and lighting divided by the total baseline annual energy cost for heating, cooling, water heating, and lighting.

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2012 IECC Cost Effectiveness Analysis

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National Association of Home Builders

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Disclaimer

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Objective

The objective of this analysis is to quantify the incremental construction cost, energy cost savings, and percent energy cost savings associated with constructing a house compliant with the 2012 IECC relative to a 2006 IECC baseline. A methodology established by the NAHB Research Center was used to determine the incremental energy cost savings. A cost effectiveness analysis was also performed using both the 2006 and 2009 IECC as a baseline to illustrate incremental paybacks in an analysis with different baselines.

Background

A strong push was made by many advocacy groups, including the U. S. Department of Energy (DOE), to increase the stringency of the 2012 International Energy Conservation Code (IECC) to achieve a 30 percent energy savings relative to the 2006 IECC. This effort resulted in a number of major changes which impact both energy savings and construction costs for residential construction.

Energy Evaluation Methodology

A methodology was developed by the NAHB Research Center (NAHB Research Center 2012-1) to calculate energy savings with 2006 IECC as the primary baseline. This methodology defines a *Standard Reference House*, including the building configuration and energy performance parameters. In addition, a calculation formula was included to determine a "percent energy savings" when comparing editions of the energy code. Energy performance parameters from the IECC were used where available. For parameters not defined in the IECC, DOE's Building America Benchmark (Hendron 2008) protocols were used.

Standard Reference House

The building geometry (Figure 1) used in this analysis is documented in the methodology paper and was developed using the NAHB Research Center's 2008 and 2009 Annual Builder Practices Survey (ABPS) results. The parameters represent the average (mean) values from the ABPS for building areas and features not dictated by the 2006 IECC. Table 1 lists floor, attic, wall, and window areas used in the *Standard Reference House*.

Table 1. Average Wall and Floor Square Footage

	Annual Builder Practices Survey (ABPS)	Standard Reference House
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

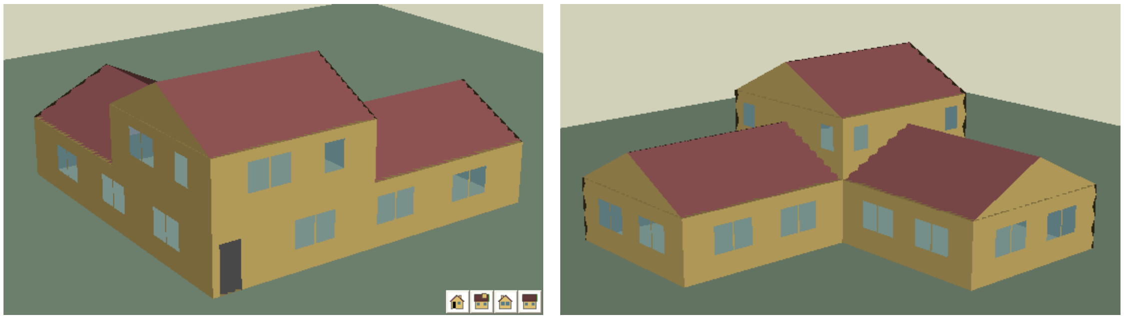

Figure 1: Simulation Model of Standard Reference House

Representative Cities

Eight cities (Table 2) representing each of the DOE Climate Zones (Figure 2) were selected to quantify energy savings for their respective climatae.

Table 2: 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

Note: HDD and CDD data from TMY3 Dataset

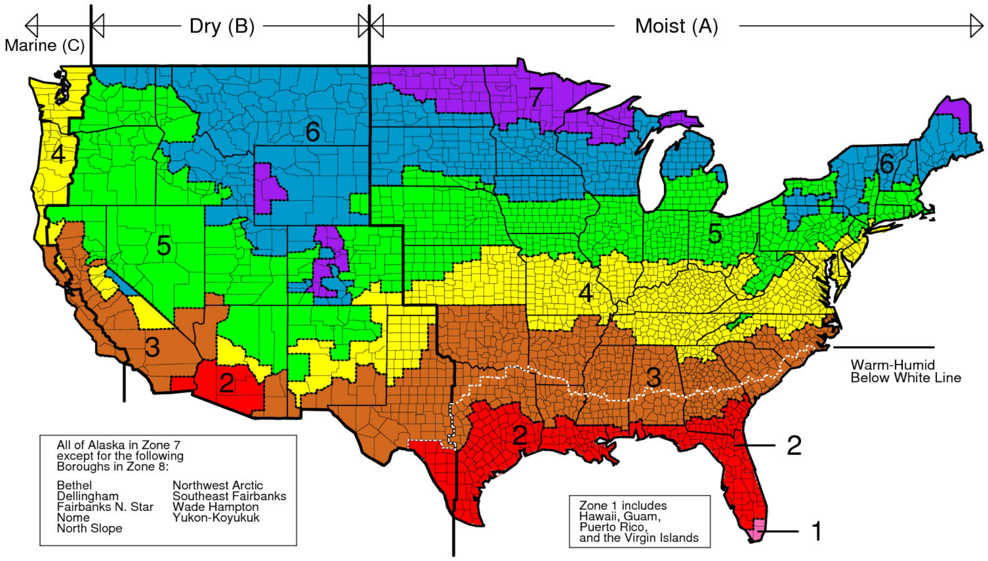

Figure 2: DOE Climate Zone Map

Weighted Averaging

Weighted averaging was applied both within and across climate zones. Within climate zones, wall construction factors for light-framed and mass walls, as well as various foundation types (slab, crawlspaces, and basements), were applied based on how new homes are constructed as determined by the NAHB Research Center's Annual Builder Practices Survey (ABPS). Once the savings within a climate zone were determined, a weighted calculation according to building starts (Briggs 2002) for each climate zone was performed in order to obtain a national average.

Changes and Cost Impacts of the 2012 IECC

A number of major changes were made from the 2006 IECC to the 2012 IECC. For the first time, performance testing for whole building tightness is now mandated in the IECC. Lighting requirements were added to the scope of the IECC in 2009 and further increased in 2012. The largest cost increases have been due to the changes in wall insulation requirements which affected six of the eight climate zones. Also added was a prescriptive requirement mandating insulation on the hot water pipes for specific locations and on all pipes exceeding specified lengths.

Appendix A includes the baseline 2006 IECC prescriptive table and Appendices B and C contain the 2009 and 2012 IECC prescriptive tables, respectively, with highlighted changes from the 2006 edition. Table 3 shows the incremental cost for changes made between the 2006 and 2012 IECC specified by climate zone. All costs listed below are based on a unit basis and totals for the *Standard Reference House*. Costs from the ASHRAE RP-1481 have been escalated for inflation using RS Means adjustment factors.

Construction Costs Associated with 2012 IECC Changes

Each climate zone has different requirements; consequently, the resulting incremental construction costs to comply with the 2012 IECC vary between climate zones. The cost increases (Table 4) range from a high of $8,871 in Climate Zone 3 to a low of $4,499 in Climate Zone 2, with a national weighted average cost increase of $7,034. Complete cost analysis details on the individual measures for each climate zone can be found in Appendix D.

Calculated Energy Usage

Table 4 summarizes the calculated energy usage for a house built to the minimum requirements of both the 2006 and 2012 IECC. The following nomenclature is used to categorize the energy use:

TEU_{2006} = Total Energy Usage using the 2006 IECC
TEU_{2012} = Total Energy Usage using the 2012 IECC
$HCWU_{2006}$ = Heating, Cooling, and Water heating energy Usage using the 2006 IECC

Energy cost savings are calculated using the Energy Information Administration's calendar year 2011 consumer price data for electricity ($0.118/kWh) and natural gas ($1.08/therm).

It is necessary to convert electric (kWh) and natural gas (Therm) energy usage into Btu's in order to determine the site and source energy usage. The site to source multipliers to obtain source Btu's are 3.365 for electricity and 1.092 for natural gas (Hendron 2008).

Table 3: Itemized 2012 IECC Incremental Construction Cost over 2006 IECC

Affected Climate Zone(s)	Item	Code Requirement		Cost			Source
		2006 IECC	2012 IECC	Unit Cost	Unit	Per House	
1,2	Air Sealing	N/R	5 ACH 50	$ 0.26	sq ft floor	$ 610	ASHRAE 1481 RP
3,4,5,6,7,8	Air Sealing	N/R	3 ACH 50	$ 0.41	sq ft floor	$ 955	ASHRAE 1481 RP
ALL	Blower Door Testing	N/R	Required	$ 165	per house	$ 165	Southface
2,3	Ceiling Insulation	R-30	R-38	$ 0.25	sq ft attic	$ 441	ASHRAE 1481 RP
4,5	Ceiling Insulation	R-38	R-49	$ 0.53	sq ft attic	$ 941	ASHRAE 1481 RP
ALL	High Efficacy Lighting	10% (base)	75%	$ 1.00	% cfl	$ 65	Local Survey
ALL	Duct Sealing	15% (base)	4cfm/100sf	$ 800	per house	$ 800	Building America
ALL	Duct Testing	N/R	Required	$ 165	per house	$ 165	Southface
7,8	Floor Insulation	R-30	R-38	$ 0.72	sq ft floor	$ 1,282	ASHRAE 1481 RP
1, 2	Mass Wall	R-3	R-4	$ 0.10	sq ft wall	$ 258	ASHRAE 1481 RP
5	Mass Wall	R-13	R-17	$ 0.41	sq ft wall	$ 1,060	ASHRAE 1481 RP
ALL	Mechanical Ventilation	N/R	Required	$ 382	per house	$ 382	Russell (2005)
ALL	Prog Thermostat	N/R	Required	$ 25	per house	$ 25	Local Survey
ALL	R-3 Plumbing	N/R	R-3	$ 1,034	per house	$ 1,034	NAHB RC (2010)
3,4	Wall- Above Grade	R-13	R-20	$ 1.33	sq ft AG wall	$ 3,433	ASHRAE 1481 RP
5	Wall- Above Grade	R-19	R-20	$ 0.20	sq ft AG wall	$ 516	ASHRAE 1481 RP
6	Wall- Above Grade	R-19	R-20+5	$ 1.52	sq ft AG wall	$ 3,927	ASHRAE 1481 RP
7,8	Wall- Above Grade	R-21	R-20+5	$ 1.32	sq ft AG wall	$ 3,403	ASHRAE 1481 RP
3 (northern 1/2)	Wall- Basement	N/R	R-10	$ 1.87	sq ft BM wall	$ 2,932	ASHRAE 1481 RP
5,6,7,8	Wall- Basement	R-10	R-15	$ 1.05	sq ft BM wall	$ 1,644	ASHRAE 1481 RP
5,6,7,8	Wall- Crawl Space	R-10	R-15	$ 1.05	sq ft CS wall	$ 822	ASHRAE 1481 RP
1	Window	U-1.2	U-0.5	$ 2.86	sq ft window	$ 1,108	ASHRAE 90.1 ENV
	SHGC	0.40	0.25				
2	Window	U-0.75	U-0.4	$ 2.00	sq ft window	$ 774	Paquette (2010)
	SHGC	0.40	0.25				
3	Window	U-0.65	U-0.35	$ 2.50	sq ft window	$ 968	Paquette (2010)
	SHGC	0.4	0.25				
4	Window	U-0.4	U-0.35	$ 0.50	sq ft window	$ 194	Paquette (2010)
	SHGC	NR	0.40				
5,6,7,8	Window	U-0.35	U-0.32	$ 0.45	sq ft window	$ 174	ASHRAE 90.1 ENV
	SHGC	NR	NR				

Table 4: 2012 IECC Incremental Construction Cost over 2006 IECC

Climate Zone/City	Incremental Construction Cost
1 Miami	$4,521
2 Phoenix	$4,499
3 Memphis	$8,871
4 Baltimore	$8,072
5 Chicago	$5,872
6 Helena	$8,734
7 Duluth	$8,403
8 Fairbanks	$8,403
National Weighted Average	**$7,034**

Table 5: Annual Energy Usage for House Built to the 2006 and 2012 IECC

Location		kWh	Therms	Site MBtu	Source MBtu	Energy Cost
Zone 1 Miami	TEU_{2006}	19,267	25	68.2	223.9	$ 2,300
	TEU_{2012}	15,296	24	54.6	178.2	$ 1,831
	HCWU_{2006}	10,919	23	39.6	127.9	$ 1,313
Zone 2 Phoenix	TEU_{2006}	20,782	118	82.7	251.5	$ 2,580
	TEU_{2012}	16,292	94	65.0	197.3	$ 2,024
	HCWU_{2006}	12,289	115	53.4	153.6	$ 1,574
Zone 3 Memphis	TEU_{2006}	18,855	440	108.3	264.5	$ 2,700
	TEU_{2012}	14,049	287	76.6	192.6	$ 1,967
	HCWU_{2006}	10,415	434	79.0	167.0	$ 1,698
Zone 4 Baltimore	TEU_{2006}	16,527	766	133.0	273.4	$ 2,777
	TEU_{2012}	13,302	537	99.1	211.4	$ 2,150
	HCWU_{2006}	7,340	757	100.8	167.0	$ 1,684
Zone 5 Chicago	TEU_{2006}	15,413	1,224	175.0	310.6	$ 3,141
	TEU_{2012}	12,436	875	129.9	238.3	$ 2,412
	HCWU_{2006}	6,051	1,222	142.9	202.9	$ 2,034
Zone 6 Helena	TEU_{2006}	12,316	1,496	191.6	304.7	$ 3,069
	TEU_{2012}	10,251	1,085	143.5	236.2	$ 2,382
	HCWU_{2006}	2,318	1,482	156.1	188.5	$ 1,874
Zone 7 Duluth	TEU_{2006}	11,238	2,271	265.4	377.0	$ 3,779
	TEU_{2012}	9,394	1,567	188.8	279.0	$ 2,801
	HCWU_{2006}	1,261	2,257	230.0	260.9	$ 2,586
Zone 8 Fairbanks	TEU_{2006}	11,432	2,999	338.9	458.8	$ 4,588
	TEU_{2012}	9,547	2,112	243.8	340.3	$ 3,408
	HCWU_{2006}	1,455	2,985	303.5	342.7	$ 3,396

		kWh	Therms	Site MBtu	Source MBtu	Cost
National Weighted Average	TEU_{2006}	17,499	715	131.2	279.0	$ 2,837
	TEU_{2012}	13,723	505	97.3	212.7	$ 2,164
	HCWU_{2006}	8,537	710	100.1	175.6	$ 1,774

Calculated Energy Savings

Energy savings are presented in three formats: 1) percent of site energy savings; 2) percent of source energy savings; and 3) percent of energy cost savings. Percent savings in Table 6 were calculated using a formula consistent with the PNNL/DOE presentation in various forums including the 2010 RESNET Conference (Taylor 2010):

$$\% \text{ Savings} = 100*(\text{TEU}_{2006} - \text{TEU}_{2012})/\text{HCWU}_{2006}$$

Table 6: 2012 IECC Energy Savings above the 2006 IECC

Climate Zone	Site Btu Savings	Source Btu Savings	Energy Cost Savings
1	34.5%	35.8%	35.8%
2	33.3%	35.3%	35.3%
3	40.1%	43.0%	43.1%
4	33.6%	37.1%	37.2%
5	31.6%	35.6%	35.8%
6	30.8%	36.3%	36.6%
7	33.3%	37.6%	37.8%
8	31.3%	34.6%	34.8%
National Weighted Average	**33.9%**	**37.8%**	**37.9%**

Cost Effectiveness

While various cost effectiveness evaluation criteria can be used, this analysis employs the simple payback method. The simple payback analysis is easy to understand and it does not make future assumptions such as general inflation rates, life expectancy of building components, or fuel escalation rates. Table 6 summarizes the energy cost savings, construction cost, and resulting simple payback for each climate zone by climate zone and a weighted national average.

The simple paybacks in Table 7 are based on an overall average for all changes in the 2012 IECC relative to a 2006 IECC baseline. Consequently, some changes result in shorter paybacks than the average simple payback and some in longer paybacks. This analysis did not calculate the individual payback period for each modification to the 2012 IECC.

Table 7: 2012 IECC Cost Effectiveness Relative to 2006 IECC

Climate Zone	Annual Energy Savings	Incremental Construction Cost	Simple Payback (yrs)
1	$470	$4,521	9.6
2	$556	$4,499	8.1
3	$732	$8,871	12.1
4	$627	$8,072	12.9
5	$728	$5,872	8.1
6	$687	$8,734	12.7
7	$978	$8,403	8.6
8	$1,180	$8,403	7.1
National Weighted Average	**$673**	**$7,034**	**10.4**

Cost Effectiveness Using a 2009 IECC Baseline

The above analysis focused on construction costs and energy reduction associated with the 2012 IECC relative to a 2006 IECC baseline; however, it is important to understand that cost effectiveness decreases as energy requirements become more stringent, presuming the codes advance in a rational manner. Decreasing cost effectiveness becomes evident when comparing a defined code edition to varying baselines.

An analysis was performed using the same methodology comparing the 2006 IECC to the 2009 IECC (NAHB Research Center 2012-2). When code comparison results of the 2009 IECC analysis are compared with this analysis; the resulting difference in both energy savings and incremental cost are listed in Table 8. A national average incremental simple payback of 13.3 years was calculated when going from the 2009 IECC to the 2012 IECC as compared to the 10.4 years when using the 2006 IECC baseline, thus decreasing the cost effectiveness when evaluating the payback over the latest code cycle.

Table 8: 2012 IECC Cost Effectiveness Relative to 2009 IECC

Climate Zone	Annual Energy Savings	Incremental Construction Cost	Simple Payback (yrs)
1	$206	$3,224	15.7
2	$294	$3,330	11.3
3	$470	$7,203	15.3
4	$410	$7,091	17.3
5	$505	$4,653	9.2
6	$397	$6,399	16.1
7	$609	$6,465	10.6
8	$725	$6,465	8.9
National Weighted Average	**$427**	**$5,668**	**13.3**

Conclusions

The energy savings calculation methodology used in this analysis provides detailed incremental construction cost, energy cost savings, percent energy savings, and a simple payback cost effectiveness analysis. The national average percent energy cost savings for the 2012 IECC over the 2006 IECC baseline is 37.9 percent (site energy savings 33.9 percent; source energy savings 37.8 percent). This result is significantly higher than many estimates which simply accept the 2012 IECC as 30 percent more efficient than the 2006 IECC.

The additional cost to construct to the 2012 IECC relative to the 2006 IECC is $7,034 with the majority of the increase ($5,668) associated with the changes between the 2009 and 2012 versions of the IECC.

Incremental simple payback from the 2006 to the 2012 IECC is 10.4 years; however, if the analysis only considers changes made from the 2009 edition of the IECC, the payback for adopting the 2012 IECC increases to 13.3 years.

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Appendix A: Prescriptive Requirements for 2006 IECC

2006 Internation Energy Conservation Code

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Glazed[b] Fenestration SHGC	Ceiling R-Value	Wood Frame Wall R-Value	Mass Wall R-Value	Floor R-Value	Basement[c] Wall R-Value	Slab[d] R-Value & Depth	Crawl[c] Space Wall R-Value
1	1.20	0.75	0.40	30	13	3	13	0	0	0
2	0.75	0.75	0.40	30	13	4	13	0	0	0
3	0.65	0.65	0.40[e]	30	13	5	19	0	0	5/13
4 Less Marine	0.40	0.60	NR	38	13	5	19	10/13	10/2	10/13
5 & 4 Marine	0.35	0.60	NR	38	19 or 13+5[g]	13	30[f]	10/13	10/2	10/13
6	0.35	0.60	NR	49	19 or 13+5[g]	15	30[f]	10/13	10/2	10/13
7 & 8	0.35	0.60	NR	49	21	19	30[f]	10/13	10/2	10/13

R-Values are mins. U-Factors are max. R19 permitted in 2x6 cavity

b Applies to all Fenestration
c First is continuous, second is framing cavity
d R-5 shall be added to slab edge for heated slabs
e No SHGC for Marine zones
f Or insulation to fill the framing cavity, R-19 minimum
g First is cavity, second is sheathing

Appendix B: Prescriptive Requirements for 2009 IECC

2009 Internation Energy Conservation Code

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Glazed[b,e] Fenestration SHGC	Ceiling R-Value	Wood Frame Wall R-Value	Mass Wall[i] R-Value	Floor R-Value	Basement[c] Wall R-Value	Slab[d] R-Value & Depth	Crawl[c] Space Wall R-Value
1	1.20	0.75	0.30	30	13	3/4	13	0	0	0
2	0.65[j]	0.75	0.30	30	13	4/6	13	0	0	0
3	0.50[j]	0.65	0.30	30	13	5/8	19	5/13[f]	0	5/13
4 Less Marine	0.35	0.60	NR	38	13	5/10	19	10/13	10/2	10/13
5 & 4 Marine	0.35	0.60	NR	38	20 or 13+5[h]	13/17	30[g]	10/13	10/2	10/13
6	0.35	0.60	NR	49	20 or 13+5[h]	15/19	30[g]	15/19	10/2	10/13
7 & 8	0.35	0.60	NR	49	21	19/21	38[g]	15/19	10/2	10/13

Highlighted cells represent modifications to the 2006 IECC

b Applies to all Fenestration
c First is continuous, second is framing cavity
d R-5 shall be added to slab edge for heated slabs
e No SHGC for Marine zones
f Not required in warm humid locations per table 301.1
g Or insulation to fill the framing cavity, R-19 minimum
h First is cavity, second is sheathing
i Second value applies when more than half the insulation is on the interior
j For impact Rated - U-Factors shall be 0.75 for zone 2 and 0.65 for 3

Appendix C: Prescriptive Requirements for 2012 IECC

2012 Internation Energy Conservation Code

Climate Zone	Fenestration U-Factor [b]	Skylight U-Factor [b]	Glazed [b,e] Fenestration SHGC	Ceiling R-Value	Wood Frame Wall R-Value	Mass Wall [i] R-Value	Floor R-Value	Basement [c] Wall R-Value	Slab [d] R-Value & Depth	Crawl [c] Space Wall R-Value
1	0.50	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5 [h]	8/13	19	5/13 [f]	0	5/13
4 Less Marine	0.35	0.55	0.40	49	20 or 13+5 [h]	8/13	19	10/13	10/2	10/13
5 & 4 Marine	0.32	0.55	NR	49	20 or 13+5 [h]	13/17	30 [g]	15/19	10/2	15/19
6	0.32	0.55	NR	49	20+5 or 13+10 [h]	15/20	30 [g]	15/19	10/4	15/19
7 & 8	0.32	0.55	NR	49	20+5 or 13+10 [h]	19/21	38 [g]	15/19	10/4	15/19

2009 Alteration
2012 Alteration

b Applies to all Fenestration
c First is continuous, second is framing cavity
d R-5 shall be added to slab edge for heated slabs
e No SHGC for Marine zones
f Not required in warm humid locations per table 301.1
g Or insulation to fill the framing cavity, R-19 minimum
h First is cavity, second is sheathing
i Second value applies when more than half the insulation is on the interior
~~j For impact Rated - U-Factors shall be 0.75 for zone 2 and 0.65 for 3~~

Appendix D: Itemized Climate-Specific Incremental Construction Costs 2006-2012 IECC

Climate Zone 1, Light Frame and Mass Walls

					Foundation Distribution					
Framed Walls	**Cost**		**Code Requirement**		**0%**	**0%**	**90%**	**0%**	**10%**	**Cost Source**
35%	**Unit Cost**	**Unit**	**2006 IECC**	**2012 IECC**	**Conditioned Basement**	**Conditioned Crawlspace**	**Slab on Grade**	**Unconditioned Basement**	**Vented Crawlspace**	
Window U-Facto	$ 2.86	sq ft window	1.20	0.50			$ 1,108		$ 1,108	ASHRAE 90.1 Env
SHGC			0.40	0.25						
Ceilings			0.035	0.035						
Frame Walls			0.082	0.082						
Mass Wall			N/A	N/A						
Floors			0.064	0.064						
Bsmt Walls			0.360	0.360						
Slab			0	0						
Crawl Wall			0.477	0.477						
CFL	$ 1.00	% cfl	10% (base)	75%			$ 65		$ 65	Local Survey
Ducts	$ 800	per house	15% (base)	4cfm/100sf			$ 800		$ 800	Building America
Blower Door	$ 165	per house	N/R	Required			$ 165		$ 165	Southface
Air Sealing	$ 0.26	sq ft floor	N/R	5 ACH 50			$ 610		$ 610	ASHRAE 1481 RP
Mechanical Ventilation	$ 382	per house	N/R	Required			$ 382		$ 382	Russell (2005)
Duct Blaster	$ 165	per house	N/R	Required			$ 165		$ 165	Southface
R-3 Plumbing	$ 1,034	per house	N/R	R-3			$ 1,034		$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required			$ 25		$ 25	Local Survey
Incremental Cost							**$ 4,354**		**$ 4,354**	**$ 4,354**

					Foundation Distribution					
Mass Walls	**Cost**		**Code Requirement**		**0%**	**0%**	**90%**	**0%**	**10%**	**Cost Source**
65%	**Unit Cost**	**Unit**	**2006 IECC**	**2012 IECC**	**Conditioned Basement**	**Conditioned Crawlspace**	**Slab on Grade**	**Unconditioned Basement**	**Vented Crawlspace**	
Window U-Facto	$ 2.86	sq ft window	1.20	0.50			$ 1,108		$ 1,108	ASHRAE 90.1 Env
SHGC			0.40	0.25						
Ceilings			0.035	0.035						
Frame Walls			N/A	N/A						
Mass Wall	$ 0.10	sq ft wall	R-3	R-4			$ 258		$ 258	ASHRAE 1481 RP
Floors			0.064	0.064						
Bsmt Walls			0.360	0.360						
Slab			0	0						
CFL	$ 1.00	% cfl	10% (base)	75%			$ 65		$ 65	Local Survey
Ducts	$ 800	per house	15% (base)	4cfm/100sf			$ 800		$ 800	Building America
Blower Door	$ 165	per house	N/R	Required			$ 165		$ 165	Southface
Air Sealing	$ 0.26	sq ft floor	N/R	5 ACH 50			$ 610		$ 610	ASHRAE 1481 RP
Mechanical Ventilation	$ 382	per house	N/R	Required			$ 382		$ 382	Russell (2005)
Duct Blaster	$ 165	per house	N/R	Required			$ 165		$ 165	Southface
R-3 Plumbing	$ 1,034		N/R	R-3			$ 1,034		$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required			$ 25		$ 25	Local Survey
Incremental Cost							**$ 4,612**		**$ 4,612**	**$ 4,612**

Climate Zone 1 Weighted Average Incremental Cost=	**$ 4,521**

Climate Zone 2, Light Frame and Mass Walls

					Foundation Distribution					
Framed Walls	**Cost**		**Code Requirement**		**0%**	**0%**	**90%**	**0%**	**10%**	**Cost Source**
85%	**Unit Cost**	**Unit**	**2006 IECC**	**2012 IECC**	**Conditioned Basement**	**Conditioned Crawlspace**	**Slab on Grade**	**Unconditioned Basement**	**Vented Crawlspace**	
Window U-Facto	$ 2.00	sq ft window	0.75	0.40			$ 774		$ 774	Paquette (2010)
SHGC			0.40	0.25						
Ceilings	$ 0.25	sq ft attic	0.035	0.030			$ 441		$ 441	ASHRAE 1481 RP
Frame Walls			0.082	0.082						
Mass Wall			N/A	N/A						
Floors			0.064	0.064						
Bsmt Walls			0.360	0.360						
Slab			0	0						
Crawl Wall			0.477	0.477						
CFL	$ 1.00	% cfl	10%	75%			$ 65		$ 65	Local Survey
Ducts	$ 800	per house	15.0%	4cfm/100sf			$ 800		$ 800	Building America
Blower Door	$ 165	per house	N/R	Required			$ 165		$ 165	Southface
Air Sealing	$ 0.26	sq ft floor	N/R	5 ACH 50			$ 610		$ 610	ASHRAE 1481 RP
Mechanical Ventilation	$ 382	per house	N/R	Required			$ 382		$ 382	Russell (2005)
Duct Blaster	$ 165	per house	N/R	Required			$ 165		$ 165	Southface
R-3 Plumbing	$ 1,034		N/R	R-3			$ 1,034		$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required			$ 25		$ 25	Local Survey
Incremental Cost							$ 4,460		$ 4,460	**$ 4,460**

					Foundation Distribution					
Mass Walls	**Cost**		**Code Requirement**		**0%**	**0%**	**90%**	**0%**	**10%**	**Cost Source**
15%	**Unit Cost**	**Unit**	**2006 IECC**	**2012 IECC**	**Conditioned Basement**	**Conditioned Crawlspace**	**Slab on Grade**	**Unconditioned Basement**	**Vented Crawlspace**	
Window U-Facto	$ 2.00	sq ft window	0.75	0.40			$ 774		$ 774	Paquette (2010)
SHGC			0.40	0.25						
Ceilings	$ 0.25	sq ft attic	0.035	0.030			$ 441		$ 441	ASHRAE 1481 RP
Frame Walls			N/A	N/A						
Mass Wall	$ 0.10	sq ft wall	R-3	R-4			$ 258		$ 258	ASHRAE 1481 RP
Floors			0.064	0.064						
Bsmt Walls			0.360	0.360						
Slab			0	0						
Crawl Wall			0.477	0.477						
CFL	$ 1.00	% cfl	10% (est)	75%			$ 65		$ 65	Local Survey
Ducts	$ 800	per house	15.0%	4cfm/100sf			$ 800		$ 800	Building America
Blower Door	$ 165	per house	N/R	Required			$ 165		$ 165	Southface
Air Sealing	$ 0.26	sq ft floor	N/R	5 ACH 50			$ 610		$ 610	ASHRAE 1481 RP
Mechanical Ventilation	$ 382	per house	N/R	Required			$ 382		$ 382	Russell (2005)
Duct Blaster	$ 165	per house	N/R	Required			$ 165		$ 165	Southface
R-3 Plumbing	$ 1,034	per house	N/R	R-3			$ 1,034		$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required			$ 25		$ 25	Local Survey
Incremental Cost							$ 4,718		$ 4,718	**$ 4,718**

Climate Zone 2 Weighted Average Incremental Cost=	**$ 4,499**

Climate Zones 3 and 4

					Foundation Distribution					
Framed Walls	**Cost**		**Code Requirement**		**0%**	**0%**	**75%**	**15%**	**10%**	**Cost Source**
100%	**Unit Cost**	**Unit**	**2006 IECC**	**2012 IECC**	**Conditioned Basement**	**Conditioned Crawlspace**	**Slab on Grade**	**Unconditioned Basement**	**Vented Crawlspace**	
Window U-Facto	$ 2.50	sq ft window	0.65	0.35			$ 968	$ 968	$ 968	Paquette (2010)
SHGC			0.40 e	0.25						
Ceilings	$ 0.25	sq ft attic	0.035	0.030			$ 441	$ 441	$ 441	ASHRAE 1481 RP
Frame Walls	$ 1.33	sq ft wall	0.082	0.057			$ 3,433	$ 3,433	$ 3,433	ASHRAE 1481 RP
Mass Wall			N/A	N/A						
Floors			0.047	0.047						
Bsmt Walls	$1.87	sq ft base wl	0.360	0.091				$ 2,932		ASHRAE 1481 RP
Slab			0	0						
Crawl Wall			0.136	0.136						
CFL	$ 1.00	% cfl	10% (base)	75%			$ 65	$ 65	$ 65	Local Survey
Ducts	$ 800	per house	15% (base)	4cfm/100sf			$ 800	$ 800	$ 800	Building America
Blower Door	$ 165	per house	N/R	Required			$ 165	$ 165	$ 165	Southface
Mechanical Ventilation	$ 382	per house	N/R	Required			$ 382	$ 382	$ 382	Russell (2005)
Air Sealing	$ 0.41	sq ft floor	N/R	3 ACH 50			$ 955	$ 955	$ 955	ASHRAE 1481 RP
Duct Blaster	$ 165	per house	N/R	Required			$ 165	$ 165	$ 165	Southface
R-3 Plumbing	$ 1,034	per house	N/R	R-3			$ 1,034	$ 1,034	$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required			$ 25	$ 25	$ 25	Local Survey
Incremental Cost							**$ 8,431**	**$ 11,363**	**$ 8,431**	**$ 8,871**

Climate Zone 3 Weighted Average Incremental Cost=	**$ 8,871**

					Foundation Distribution					
Framed Walls	**Cost**		**Code Requirement**		**35%**	**0%**	**25%**	**20%**	**20%**	**Cost Source**
100%	**Unit Cost**	**Unit**	**2006 IECC**	**2012 IECC**	**Conditioned Basement**	**Conditioned Crawlspace**	**Slab on Grade**	**Unconditioned Basement**	**Vented Crawlspace**	
Window U-Facto	$ 0.50	sq ft window	0.40	0.35	$ 194	$ 194	$ 194	$ 194	$ 194	Paquette (2010)
SHGC			N/R	0.40						
Ceilings	$ 0.53	sq ft attic	0.030	0.026	$ 941		$ 941	$ 941	$ 941	ASHRAE 1481 RP
Frame Walls	$ 1.33	sq ft wall	0.082	0.057	$ 3,433		$ 3,433	$ 3,433	$ 3,433	ASHRAE 1481 RP
Mass Wall			N/A	N/A						
Floors			0.047	0.047						
Bsmt Walls			0.059	0.059						
Slab			10\2	10\2						
Crawl Wall			0.065	0.065						
CFL	$ 1.00	% cfl	10% (base)	75%	$ 65		$ 65	$ 65	$ 65	Local Survey
Ducts	$ 800	per house	15% (base)	4cfm/100sf	NR		$ 800	$ 800	$ 800	Building America
Blower Door	$ 165	per house	N/R	Required	$ 165		$ 165	$ 165	$ 165	Southface
Mechanical Ventilation	$ 382	per house	N/R	Required	$ 382		$ 382	$ 382	$ 382	Russell (2005)
Air Sealing	$ 0.41	sq ft floor	N/R	3 ACH 50	$ 1,676		$ 955	$ 955	$ 955	ASHRAE 1481 RP
Duct Blaster	$ 165	per house	N/R	Required	NR		$ 165	$ 165	$ 165	Southface
R-3 Plumbing	$ 1,034		N/R	R-3	$ 1,034		$ 1,034	$ 1,034	$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required	$ 25		$ 25	$ 25	$ 25	Local Survey
Incremental Cost					**$ 7,913**		**$ 8,157**	**$ 8,157**	**$ 8,157**	**$ 8,072**

Climate Zone 4 Weighted Average Incremental Cost=	**$ 8,072**

Climate Zone 5, Light Frame and Mass Walls

					Foundation Distribution					
Framed Walls	**Cost**		**Code Requirement**		**45%**	**5%**	**10%**	**35%**	**5%**	**Cost Source**
95%	**Unit Cost**	**Unit**	**2006 IECC**	**2012 IECC**	**Conditioned Basement**	**Conditioned Crawlspace**	**Slab on Grade**	**Unconditioned Basement**	**Vented Crawlspace**	
Window U-Facto	$ 0.45	sq ft window	0.35	0.32	$ 174	$ 174	$ 174	$ 174	$ 174	ASHRAE 90.1 Env
SHGC			N/R	N/R						
Ceilings	$ 0.53	sq ft attic	0.030	0.026	$ 941	$ 941	$ 941	$ 941	$ 941	ASHRAE 1481 RP
Frame Walls	$ 0.20	sq ft wall	0.060	0.057	$ 516	$ 516	$ 516	$ 516	$ 516	ASHRAE 1481 RP
Mass Wall			N/A	N/A						
Floors			0.033	0.033						
Bsmt Walls	$ 1.05	sq ft base wl	0.059	0.050	$ 1,644					ASHRAE 1481 RP
Slab			10\2	10\2						
Crawl Wall	$ 1.05	sq ft base wl	0.065	0.055		$ 822				ASHRAE 1481 RP
CFL	$ 1.00	% cfl	10% (base)	75%	$ 65	$ 65	$ 65	$ 65	$ 65	Local Survey
Ducts	$ 800	per house	15% (base)	4cfm/100sf	NR	NR	$ 800	$ 800	$ 800	Building America
Blower Door	$ 165	per house	N/R	Required	$ 165	$ 165	$ 165	$ 165	$ 165	Southface
Mechanical Ventilation	$ 382	per house	N/R	Required	$ 382	$ 382	$ 382	$ 382	$ 382	Russell (2005)
Air Sealing	$ 0.41	sq ft floor	N/R	3 ACH 50	$ 1,676	$ 955	$ 955	$ 955	$ 955	ASHRAE 1481 RP
Duct Blaster	$ 165	per house	N/R	Required	NR	NR	$ 165	$ 165	$ 165	Southface
R-3 Plumbing	$ 1,034	per house	N/R	R-3	$ 1,034	$ 1,034	$ 1,034	$ 1,034	$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required	$ 25	$ 25	$ 25	$ 25	$ 25	Local Survey
Incremental Cost					**$ 6,621**	**$ 5,079**	**$ 5,221**	**$ 5,221**	**$ 5,221**	**$ 5,844**

					Foundation Distribution					
Mass Walls	**Cost**		**Code Requirement**		**45%**	**5%**	**10%**	**35%**	**5%**	**Cost Source**
5%	**Unit Cost**	**Unit**	**2006 IECC**	**2012 IECC**	**Conditioned Basement**	**Conditioned Crawlspace**	**Slab on Grade**	**Unconditioned Basement**	**Vented Crawlspace**	
Window U-Facto	$ 0.45	sq ft window	0.35	0.32	$ 174	$ 174	$ 174	$ 174	$ 174	ASHRAE 90.1 Env
SHGC			N/R	N/R						
Ceilings	$ 0.53	sq ft attic	0.030	0.026	$ 941	$ 941	$ 941	$ 941	$ 941	ASHRAE 1481 RP
Frame Walls	$ 0.20	sq ft wall	N/A	N/A						ASHRAE 1481 RP
Mass Wall	$ 0.41	per house	R-13	R-17	$ 1,060	$ 1,060	$ 1,060	$ 1,060	$ 1,060	ASHRAE 1481 RP
Floors			0.033	0.033						
Bsmt Walls	$ 1.05	sq ft base wl	0.059	0.050	$ 1,644					ASHRAE 1481 RP
Slab			10\2	10\2						
Crawl Wall	$ 1.05	sq ft base wl	0.065	0.055		$ 822				ASHRAE 1481 RP
CFL	$ 1.00	% cfl	10% (base)	75%	$ 65	$ 65	$ 65	$ 65	$ 65	Local Survey
Ducts	$ 800	per house	15% (base)	4cfm/100sf	NR	NR	$ 800	$ 800	$ 800	Building America
Blower Door	$ 165	per house	N/R	Required	$ 165	$ 165	$ 165	$ 165	$ 165	Southface
Mechanical Ventilation	$ 382	per house	N/R	Required	$ 382	$ 382	$ 382	$ 382	$ 382	Russell (2005)
Air Sealing	$ 0.41	sq ft floor	N/R	3 ACH 50	$ 1,676	$ 955	$ 955	$ 955	$ 955	ASHRAE 1481 RP
Duct Blaster	$ 165	per house	N/R	Required	NR	NR	$ 165	$ 165	$ 165	Southface
R-3 Plumbing	$ 1,034	per house	N/R	R-3	$ 1,034	$ 1,034	$ 1,034	$ 1,034	$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required	$ 25	$ 25	$ 25	$ 25	$ 25	Local Survey
Incremental Cost					**$ 7,166**	**$ 5,623**	**$ 5,766**	**$ 5,766**	**$ 5,766**	**$ 6,389**

Climate Zone 5 Weighted Average Incremental Cost=	**$ 5,872**

Climate Zones 6, 7 and 8

Framed Walls	Cost		Code Requirement		75%	5%	5%	10%	5%	Cost Source
100%	Unit Cost	Unit	2006 IECC	2012 IECC	Conditioned Basement	Conditioned Crawlspace	Slab on Grade	Unconditioned Basement	Vented Crawlspace	
Window U-Facto	$ 0.45	sq ft window	0.35	0.32	$ 174	$ 174	$ 174	$ 174	$ 174	ASHRAE 90.1 Env
SHGC			N/R	N/R						
Ceilings			0.026	0.026						
Frame Walls	$ 1.52	sq ft of wall	0.060	0.048	$ 3,927	$ 3,927	$ 3,927	$ 3,927	$ 3,927	ASHRAE 1481 RP
Mass Wall			N/A	N/A						
Floors			0.033	0.033						
Bsmt Walls	$ 1.05	sq ft base w	0.059	0.050	$ 1,644					
Slab			10\4	10\4						
Crawl Wall	$ 1.05	sq ft base w	0.065	0.055		$ 822				ASHRAE 1481 RP
CFL	$ 1.00	% cfl	10% (base)	75%	$ 65	$ 65	$ 65	$ 65	$ 65	Local Survey
Ducts	$ 800	per house	15% (base)	4cfm/100sf	NR	NR	$ 800	$ 800	$ 800	Building America
Blower Door	$ 165	per house	N/R	Required	$ 165	$ 165	$ 165	$ 165	$ 165	Southface
Mechanical Ventilation	$ 382	per house	N/R	Required	$ 382	$ 382	$ 382	$ 382	$ 382	Russell (2005)
Air Sealing	$ 0.41	sq ft floor	N/R	3 ACH 50	$ 1,676	$ 955	$ 955	$ 955	$ 955	ASHRAE 1481 RP
Duct Blaster	$ 165	per house	N/R	Required	NR	NR	$ 165	$ 165	$ 165	Southface
R-3 Plumbing	$ 1,034	per house	N/R	R-3	$ 1,034	$ 1,034	$ 1,034	$ 1,034	$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required	$ 25	$ 25	$ 25	$ 25	$ 25	Local Survey
Incremental Cost					**$ 9,091**	**$ 7,548**	**$ 7,691**	**$ 7,691**	**$ 7,691**	**$ 8,734**

Climate Zone 6 Weighted Average Incremental Cost=	$ 8,734

					Foundation Distribution					
Framed Walls	Cost		Code Requirement		75%	5%	5%	10%	5%	Cost Source
100%	Unit Cost	Unit	2006 IECC	2012 IECC	Conditioned Basement	Conditioned Crawlspace	Slab on Grade	Unconditioned Basement	Vented Crawlspace	
Window U-Facto	$ 0.45	sq ft window	0.35	0.32	$ 174	$ 174	$ 174	$ 174	$ 174	ASHRAE 90.1 Env
SHGC			N/R	N/R						
Ceilings			0.026	0.026						
Frame Walls	$ 1.32	sq ft of wall	0.057	0.048	$ 3,403	$ 3,403	$ 3,403	$ 3,403	$ 3,403	ASHRAE 1481 RP
Mass Wall			N/A	N/A						
Floors	$ 0.72	sq ft floor	0.033	0.028				$ 1,282	$ 1,282	ASHRAE 1481 RP
Bsmt Walls	$ 1.05	sq ft base w	0.059	0.050	$ 1,644					ASHRAE 1481 RP
Slab			10\4	10\4						
Crawl Wall	$ 1.05	sq ft base w	0.065	0.055		$ 822				ASHRAE 1481 RP
CFL	$ 1.00	% cfl	10% (base)	75%	$ 65	$ 65	$ 65	$ 65	$ 65	Local Survey
Ducts	$ 800	per house	15% (base)	4cfm/100sf	NR	NR	$ 800	$ 800	$ 800	Building America
Blower Door	$ 165	per house	N/R	Required	$ 165	$ 165	$ 165	$ 165	$ 165	Southface
Mechanical Ventilation	$ 382	per house	N/R	Required	$ 382	$ 382	$ 382	$ 382	$ 382	Russell (2005)
Air Sealing	$ 0.41	sq ft floor	N/R	3 ACH 50	$ 1,676	$ 955	$ 955	$ 955	$ 955	ASHRAE 1481 RP
Duct Blaster	$ 165	per house	N/R	Required	NR	NR	$ 165	$ 165	$ 165	Southface
R-3 Plumbing	$ 1,034	per house	N/R	R-3	$ 1,034	$ 1,034	$ 1,034	$ 1,034	$ 1,034	NAHB RC (2010)
Prog Thermostat	$ 25	per house	N/R	Required	$ 25	$ 25	$ 25	$ 25	$ 25	Local Survey
Incremental Cost					**$ 8,568**	**$ 7,025**	**$ 7,168**	**$ 8,449**	**$ 8,449**	**$ 8,403**

Climate Zones 7 & 8 Weighted Average Incremental Cost=	$ 8,403

U.S. DEPARTMENT OF
ENERGY

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under Contract DE-AC05-76RL01830

Cost-Effectiveness Analysis of the 2009 and 2012 IECC Residential Provisions – Technical Support Document

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R Lucas
S Goel

April 2013

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

This analysis was conducted by Pacific Northwest National Laboratory (PNNL) in support of the U.S. Department of Energy's (DOE) Building Energy Codes Program (BECP). DOE supports the development and adoption of energy efficient and cost-effective residential and commercial building energy codes. These codes set the minimum requirements for energy efficient building design and construction and ensure energy savings on a national level. This analysis focuses on one and two family dwellings, townhomes, and low-rise multifamily residential buildings. For these buildings, the basis of the energy codes is the International Energy Conservation Code (IECC). This report does not address commercial and high-rise residential buildings (four or more stories).

The IECC is developed and published on a three-year cycle, with a new version published at the end of each cycle. This analysis examines the 2006, 2009, and 2012 versions of the IECC as applied to individual states. Each version of the IECC includes provisions that increase energy-efficiency levels over its predecessor.

This report documents the analysis PNNL conducted to assess the cost effectiveness of the 2009 and 2012 IECC over the 2006 IECC at the state level. For each state, PNNL's analysis compares the newer version (or versions) of the IECC against an older version currently in use in the state. For states that have adopted the 2006 IECC or equivalent, the analysis evaluates the cost effectiveness of updating the state code to either the 2009 or 2012 IECC. For a state with a code already equivalent to the 2009 IECC, the analysis evaluates moving up to the 2012 IECC.

While some states adopt the IECC as published, other states amend the code. Still other states develop entirely unique state energy codes. Finally, some states have either no code at all or have a code based on a pre-2006 version of the IECC. PNNL conducted customized analyses for those states with amended IECC versions; assumed states with no code or an old code as using the 2006 IECC, and did not analyze state with custom codes.

DOE has established a methodology for determining energy savings and cost effectiveness of various building energy codes (Taylor et al. 2012). The methodology defines an analysis procedure including:

- Definitions of two building prototypes (single-family and multifamily)
- Identification of preferred calculation tools
- Climate locations
- Construction cost data sources
- Cost-effectiveness metrics and associated economic parameters
- Procedures for aggregating location-specific results to state, climate-zone, and national levels.

This technical support document provides additional detail and documents the specific assumptions used in applying the cost-effectiveness methodology.

The analysis is conducted using DOE's *EnergyPlus* simulation software. PNNL developed two prototype building models to represent the single-family and the multifamily buildings defined in the methodology. These two prototypes were then expanded to a suite of 32 energy models to represent four commonly used heating systems in homes (i.e., gas furnace, oil furnace, heat pump, and electric furnace) and four commonly used foundations (i.e., vented crawlspace, slab-on-grade, heated basement, and unheated basement). Different versions of the models are created to match the requirements of the 2006, 2009, and 2012 IECC for each location. The entire set is simulated across 119 locations to represent the different climate-zone and moisture regimes in each state across the country.

The annual energy consumption for space heating, cooling, domestic hot water heating, and lighting is extracted for each case. The energy use is converted to energy cost using fuel costs in the different states. Incremental first costs are calculated for each location for the energy provisions of the 2009 and 2012 IECC over the baseline code, as applicable, using the Building Component Cost Community (BC3) data repository.[1] These first costs are adjusted for variation in construction and material costs across the country using location multipliers developed by Faithful+Gould for PNNL.[2] The energy costs and first costs are aggregated based on new housing construction starts from the U.S. Census data[3], weights of the different foundation types from the Residential Energy Consumption Survey data[4], and heating system weights based on National Association of Home Builders data (NAHB 2009). Life cycle cost (LCC) analysis is then conducted for each case to assess cost effectiveness. DOE uses LCC as the primary measure of cost effectiveness.

Table ES.1 shows the final energy cost savings results of the analysis. Table ES.2 summarizes the LCC savings results for each state. These data show that construction based on the 2009 and 2012 IECC results in greater energy savings than construction based on the 2006 IECC and is cost effective for all states.

Table ES.1. National Weighted Energy Cost Savings

	2009 IECC	2012 IECC
National Energy Cost Savings over the 2006 IECC	10.8% ($ 168)	32.1% ($ 500)

Table ES.2. State Life Cycle Cost Savings over the 2006 IECC (2012 dollars)

	Life Cycle Cost Savings over the 2006 IECC ($)	
State	2009 IECC	2012 IECC
Alabama	2,117	6,182
Alaska	5,861	20,745
Arizona	3,245	6,550

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[1] http://bc3.pnnl.gov/wiki/index.php/Main_Page.

[2] http://bc3.pnnl.gov/wiki/images/7/7f/Location_Factors_Report.pdf.

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

[4] 2009 RECS Survey Data 'Structural and Geographic Characteristics' http://www.eia.gov/consumption/residential/data/2009/#undefined.

Table ES.2. (contd)

	Life Cycle Cost Savings over the 2006 IECC ($)	
State	2009 IECC	2012 IECC
Arkansas	1,948	6,679
California	1,192	2,136
Colorado	1,528	5,435
Connecticut	3,793	13,709
Delaware	4,316	14,778
District of Columbia	2,024	6,852
Florida	2,320	4,147
Georgia	2,210	6,415
Hawaii	5,150	14,238
Idaho	1,444	5,515
Illinois	1,784	6,506
Indiana	1,781	6,764
Iowa	2,823	10,416
Kansas	2,556	8,828
Kentucky	2,279	7,646
Louisiana	1,663	4,107
Maine	5,109	18,944
Maryland	3,473	11,688
Massachusetts	3,914	14,777
Michigan	3,363	12,346
Minnesota	3,196	11,817
Mississippi	2,022	5,400
Missouri	2,229	7,826
Montana	1,668	5,920
Nebraska	1,908	7,141
Nevada	2,543	7,352
New Hampshire	3,925	14,573
New Jersey	3,445	11,877
New Mexico	1,835	5,897
New York	3,870	13,677
North Carolina	1,844	5,911
North Dakota	2,353	8,719
Ohio	1,959	7,120
Oklahoma	2,526	8,621
Oregon	1,422	4,917
Pennsylvania	3,189	11,845
Rhode Island	4,043	15,074
South Carolina	2,215	6,650
South Dakota	2,583	9,514
Tennessee	1,809	6,102

Table ES.2. (contd)

State	Life Cycle Cost Savings over the 2006 IECC ($)	
	2009 IECC	2012 IECC
Texas	2,433	5,942
Utah	1,385	4,879
Vermont	5,133	18,861
Virginia	2,186	7,487
Washington	1,498	5,299
West Virginia	1,996	7,301
Wisconsin	3,056	11,272
Wyoming	1,809	6,441

Acronyms and Abbreviations

ACH50	50-Pa pressure differential
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BC3	Building Component Cost Community
BECP	Building Energy Codes Program
CFL	compact fluorescent lamp
CFM	cubic feet per minute
DOE	U.S. Department of Energy
ECPA	Energy Conservation and Production Act
EF	Energy Factor
ELA	effective leakage area
HVAC	heating, ventilation, and air conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
IES	Illuminating Engineering Society of North America
IMC	International Mechanical Code
IRC	International Residential Code
LCC	life cycle cost
PNNL	Pacific Northwest National Laboratory
SHGC	solar heat gain coefficient
TMY	Typical Meteorological Year
U-factor	effective thermal conductance
WFR	window-to-floor ratio
WHAM	Water Heater Analysis Model
WWR	window-to-wall ratio

Contents

Figures

Tables

1.0 Introduction

The U.S. Department of Energy (DOE) supports the development and adoption of building codes that promote energy efficiency. Title III of the Energy Conservation and Production Act (ECPA), as amended, mandates that DOE participate in the development of model building energy codes and assist states in adopting and implementing these codes. The designated residential model energy code is the International Energy Conservation Code (IECC) published by the International Code Council (ICC).

This report documents the methodology and assumptions used in a state-by-state analysis of two recent versions of the IECC (2009 and 2012) conducted by the Pacific Northwest National Laboratory (PNNL) in support of the DOE's Building Energy Codes Program (BECP). The analysis and associated methodology cover single-family detached homes and low-rise multifamily buildings.

1.1 Purpose of Analysis

The IECC is developed and published on a three-year cycle, with a new version published at the end of each cycle. This analysis examines the 2006, 2009, and 2012 versions of the IECC as applied to individual states. These versions are referred to as the 2006 IECC, the 2009 IECC, and the 2012 IECC in this report. Each version of the IECC includes provisions that increase energy-efficiency levels over its predecessor. For each state, PNNL's analysis compares the newer version (or versions) of the IECC against an older version currently in use in the state. For states that have adopted the 2006 IECC or an equivalent code, the analysis evaluates the cost effectiveness of updating the state code to either the 2009 or 2012 IECC. For a state with a code already equivalent to the 2009 IECC, the analysis evaluates energy efficiency-improvements that would be realized by adopting the 2012 IECC.

Not all states adopt the IECC directly. Some states adopt amended versions, some develop custom state codes, and some have either no code or an older code based on a pre-2006 IECC. PNNL conducted customized analyses for those states with amended versions of the IECC and assumed homes in states with no code or an older code are built to a level of energy efficiency equivalent to the 2006 IECC. PNNL did not analyze custom state codes that are not based on the IECC.

DOE has established a methodology for determining energy savings and cost effectiveness of various building energy codes (Taylor et al. 2012). The methodology, hereafter referred to as the cost-effectiveness methodology, is available for download from DOE's energy codes website.[1] The cost-effectiveness methodology defines an energy analysis procedure, including definitions of two building prototypes (single-family and multifamily), identification of preferred calculation tools, and selection of climate locations to be analyzed; establishes preferred construction cost data sources; defines cost-effectiveness metrics and associated economic parameters; and defines a procedure for aggregating location-specific results to state, climate-zone, and national levels. This technical support document provides additional detail and documents the specific assumptions used in applying the cost-effectiveness methodology.

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[1] http://www.energycodes.gov/development/residential/methodology.

1.2 Report Contents

This report documents the process of evaluating energy cost savings and cost effectiveness of newer versions of the IECC relative to an older version. Energy savings are computed using energy simulations of two base residential building prototypes—a single-family detached home and a low-rise multifamily building. These two prototypes are simulated using four different heating systems (i.e., gas furnace, heat pump, oil furnace, and electric furnace) and four different foundation types (i.e., vented crawlspace, slab-on-grade, heated basement, and unheated basement) to represent typical residential new-construction stock. These options result in an expanded set of 32 models that are simulated across 119 representative climate locations, yielding a set of 3808 building-energy models for each analyzed version of the IECC.

The energy savings results and the associated incremental costs for each case are aggregated to state, climate zones and national levels using U.S. Census data on new housing construction starts.[1] A cost-effectiveness analysis is carried out to determine three cost-effectiveness metrics—life-cycle cost (LCC), simple payback period, and consumer cash flow—for each analyzed version of the IECC.

This report is divided into three parts. Part one (Chapters 2 through 5) provides details on the energy modeling and assumptions. Part two (Chapters 6 and 7) details the incremental cost calculation for each location, economic calculations, and the aggregation scheme for generating state and national average energy cost savings and cost effectiveness results. Finally, part three (Chapter 8) summarizes state and national energy cost savings and cost effectiveness results. These final results also are published as a part of the individual state and national cost effectiveness reports.[2]

More details are provided in the appendices. Appendix A provides detailed modeling assumptions and prototype descriptions used in the energy simulations, including internal heat gains assumptions, and various schedules. Appendix B lays out the prescriptive code requirements of the 2006, 2009, and 2012 IECC. Finally, Appendix C describes prescriptive code requirements for states with amended versions of the IECC that are modeled in the customized state analyses.

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

[2] Residential IECC Cost Effectiveness Analysis and Results http://www.energycodes.gov/development/residential/iecc_analysis.

2.0 Process and Methodology

2.1 Analysis Overview

The 2009 and 2012 IECC include provisions that promote substantial improvements in energy efficiency compared to the 2006 IECC. The focus of this analysis is assessing the energy savings and cost effectiveness of the two newer versions of the IECC for typical single-family detached homes and low-rise multifamily buildings, and aggregating those results to appropriate state and/or national levels. The sequence of operations for a given state is described below:

1. Identify the relevant state code and any state-specific amendments. This establishes the baseline code for the state and determines whether both the 2009 and 2012 IECC will be analyzed (if the 2006 IECC is the baseline) or just the 2012 IECC (if the 2009 IECC is the baseline).
2. Assemble construction cost data for the building elements that have changed between the baseline code and the analyzed code(s). Apply regional adjustments to these national average costs so they represent the specific locations analyzed.
3. Simulate the energy differences (savings) between the baseline code and the newer code(s) for each of the climate locations.
4. Aggregate energy savings and incremental costs to state, climate-zone, and national levels and calculate cost-effectiveness metrics (e.g., LCC, payback period, consumer cash flow, etc.) for each new code.

Annual energy use for each case is simulated using DOE's EnergyPlus™ software, Version 5.0.[1] The cost-effectiveness methodology defines details of the single-family and multifamily prototype buildings such as typical constructions, mechanical systems, internal gains and operating assumptions. The building prototypes include four foundation types and four heating system types to appropriately account for location-specific construction practices and fuel usage. The energy results are aggregated across building types, foundation types, heating equipment types, and locations using weighting factors defined in the cost-effectiveness methodology to provide national, climate-zone-specific, and state-specific energy cost savings.

The cost effectiveness of code changes is determined using energy cost savings from the improvements in the code(s) and the associated incremental first cost of construction. Incremental first costs of energy efficient code changes are determined through several sources as detailed in subsequent chapters. Location-specific cost multipliers are used to account for regional variations in construction costs. Location-specific fuel prices are taken from the most recent state-specific residential fuel prices available from DOE's Energy Information Administration. .[2, 3, 4]

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[1] EnergyPlus at http://apps1.eere.energy.gov/buildings/energyplus.

[2] U.S. Department of Energy (DOE). 2012a. *Electric Power Monthly*. DOE/EIA-0226. Washington, D.C. http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

[3] U.S. Department of Energy (DOE). 2012b. *Natural Gas Monthly*. DOE/EIA-0130. Washington, D.C. http://www.eia.gov/oil_gas/natural_gas/data_publications/natural_gas_monthly/ngm.html

[4] U.S. Department of Energy (DOE). 2012c. *Petroleum Marketing Monthly*. DOE/EIA-0380. Washington, D.C. http://www.eia.gov/petroleum/marketing/monthly/

2.2 Climate Locations

The cost-effectiveness methodology details the selection of the climate locations used in this analysis. In each state, one representative climate location is chosen for each unique combination of climate zone - 1 through 8 and moisture regime - moist, dry, marine, and warm-humid. This results in 119 weather locations that are used in the analysis. Table 2.1 lists these locations.

To simulate energy use for each case, the latest Typical Meteorological Year weather files (TMY3)[1] are used with EnergyPlus. The TMY3 dataset contains 1020 locations nationwide, including Guam, Puerto Rico, and the U.S. Virgin Islands. However, a complete TMY3 file is not available for some state-climate zone combinations. In these cases, professional judgment is used to select a best representative TMY3 data location outside the state.

Table 2.1. Locations for Cost-Effectiveness Analysis

State	Climate Zone	Moisture Regime(a)	Location
Alabama	2	A, WH	Mobile
Alabama	3	A	Birmingham
Alabama	3	A, WH	Montgomery
Alaska	7		Anchorage
Alaska	8		Fairbanks
Arizona	2	B	Phoenix
Arizona	3	B	Kingman
Arizona	4	B	Prescott
Arizona	5	B	Winslow
Arkansas	3	A	Little Rock
Arkansas	3	A, WH	Shreveport (Louisiana)
Arkansas	4	A	Springfield (Missouri)
California	2	B	Tucson (Arizona)
California	3	B	Los Angeles
California	3	C	San Francisco
California	4	B	Sacramento
California	4	C	Arcata
California	5	B	Reno (NV)
California	6	B	Eagle
Colorado	4	B	Trinidad
Colorado	5	B	Colorado Springs
Colorado	6	B	Eagle County
Colorado	7		Gunnison County
Connecticut	5	A	Hartford-Bradley
Delaware	4	A	Wilmington

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[1] 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 2.1. (contd)

State	Climate Zone	Moisture Regime[(a)]	Location
District of Columbia	4	A	Baltimore (Maryland)
Florida	1	A, WH	Miami
Florida	2	A, WH	Tampa
Georgia	2	A, WH	Savannah
Georgia	3	A	Atlanta
Georgia	3	A, WH	Macon
Georgia	4	A	Chattanooga (Tennessee)
Hawaii	1	A	Honolulu
Idaho	5	B	Boise
Idaho	6	B	Pocatello
Illinois	4	A	St. Louis (Missouri)
Illinois	5	A	Peoria
Indiana	4	A	Evansville
Indiana	5	A	Indianapolis
Iowa	5	A	Des Moines
Iowa	6	A	Mason City
Kansas	4	A	Topeka
Kansas	5	A	Goodland
Kentucky	4	A	Lexington
Louisiana	2	A, WH	Baton Rouge
Louisiana	3	A	Monroe
Louisiana	3	A, WH	Shreveport
Maine	6	A	Portland
Maine	7		Caribou
Maryland	4	A	Baltimore
Maryland	5	A	Harrisburg (Pennsylvania)
Massachusetts	5	A	Boston-Logan
Michigan	5	A	Lansing
Michigan	6	A	Alpena County
Michigan	7		Sault Ste. Marie
Minnesota	6	A	Minneapolis-St. Paul.
Minnesota	7		Duluth
Mississippi	2	A, WH	Mobile (Alabama)
Mississippi	3	A	Tupelo
Mississippi	3	A, WH	Jackson
Missouri	4	A	St. Louis
Missouri	5	A	Kirksville
Montana	6	B	Helena
Nebraska	5	A	Omaha
Nevada	3	B	Las Vegas

Table 2.1. (contd)

State	Climate Zone	Moisture Regime[(a)]	Location
Nevada	5	B	Reno
New Hampshire	5	A	Manchester
New Hampshire	6	A	Concord
New Jersey	4	A	Newark
New Jersey	5	A	Allentown (Pennsylvania)
New Mexico	3	B	Lubbock (Texas)
New Mexico	4	B	Albuquerque
New Mexico	5	B	Winslow (Arizona)
New York	4	A	New York
New York	5	A	Albany
New York	6	A	Binghamton
North Carolina	3	A	Charlotte
North Carolina	3	A, WH	Wilmington
North Carolina	4	A	Raleigh
North Carolina	5	A	Elkins (West Virginia)
North Dakota	6	A	Bismarck
North Dakota	7		Minot
Ohio	4	A	Cincinnati (Kentucky)
Ohio	5	A	Columbus
Oklahoma	3	A	Oklahoma
Oklahoma	4	B	Amarillo (Texas)
Oregon	4	C	Portland
Oregon	5	B	Redmond
Pennsylvania	4	A	Philadelphia
Pennsylvania	5	A	Harrisburg.
Pennsylvania	6	A	Bradford
Rhode Island	5	A	Providence-
South Carolina	3	A	Columbia
South Carolina	3	A, WH	Charleston
South Dakota	5	A	Sioux City (Iowa)
South Dakota	6	A	Pierre
Tennessee	3	A	Memphis
Tennessee	4	A	Nashville
Texas	2	A, WH	Houston
Texas	2	B, WH	San Antonio
Texas	3	A	Wichita Falls
Texas	3	A, WH	Fort Worth-Alliance.
Texas	3	B	El Paso
Texas	4	B	Amarillo
Utah	3	B	Saint George
Utah	5	B	Salt Lake City
Utah	6	B	Vernal

Table 2.1. (contd)

State	Climate Zone	Moisture Regime[a]	Location
Vermont	6	A	Burlington
Virginia	4	A	Richmond
Washington	4	C	Seattle
Washington	5	B	Spokane
Washington	6	B	Kalispell (Montana)
West Virginia	4	A	Charleston
West Virginia	5	A	Elkins
Wisconsin	6	A	Madison
Wisconsin	7		Duluth (Minnesota)
Wyoming	5	B	Scottsbluff (Nebraska)
Wyoming	6	B	Cheyenne
Wyoming	7		Jackson Hole

(a) Moisture zone designations are defined as follows:
A = Moist
B = Dry
C = Marine
WH = Warm-Humid.

Climate zones 7 and 8 have no moisture designations in the code.

3.0 Energy Simulation Infrastructure

Energy savings estimates are generated using DOE's EnergyPlus, version 5.0, simulation software. The two prototype building models (i.e., single-family detached home and low-rise multifamily apartment building) are simulated with four heating systems and four foundation types, resulting in 32 separate models for each of three IECC versions. These 96 models are simulated in each of the 119 locations for a total of 11,424 EnergyPlus simulations for the entire national analysis.

The numerous input files (EnergyPlus Input Data Files—IDF) are generated using a PNNL in-house utility that combines a generic input data file template with a large table of input parameters. The generated files are executed in batch style on a Linux computer cluster and managed with the *Make*[1] utility to minimize the need for manual intervention to synchronize output files with input files. Custom post-processing scripts written in the Perl[2] language are used to automate the process of retrieving key values from the simulation outputs and forwarding them to a statistical analysis software package for calculating the cost-effectiveness metrics and aggregating results to appropriate levels.

The simulation input and output files are available for download from DOE's Energy Codes website at http://www.energycodes.gov/development/residential/iecc_models.

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[1] Make http://www.gnu.org/software/make/.

[2] Perl http://www.perl.org/.

4.0 Prototype Building Models

The single-family and multifamily prototype building models are intended to represent residential new-construction stock. The cost-effectiveness methodology defines the major elements that characterize these prototypes and the relevant code's primary prescriptive manifestation defines the prototypes' envelope efficiencies in each location of interest. Appendix A summarizes those characteristics along with numerous additional details required to assemble complete EnergyPlus input files for the various simulations. It also provides details on internal gains assumptions and calculations and includes schedules used in the energy simulations. Two electronic spreadsheets, known as scorecards[1] which contain key modeling assumptions and inputs for the two prototypes, are available on DOE's energy codes website.[2] All 11,424 EnergyPlus input files and associated output files from this analysis also are available for download on the same website.[2]

4.1 Building Geometry

The single-family prototype is configured as a 2400 ft^2, two-story detached home with one of four different foundation types. The house is divided into either two or three thermal zones based on the foundation type. All models contain a living space zone and an attic zone; an additional foundation zone is added for models with a crawlspace or basement foundation. Figure 4.1 shows a snapshot of the single-family model with a crawlspace extracted from OpenStudio[3], which is an EnergyPlus plug-in for the SketchUp[4] software.

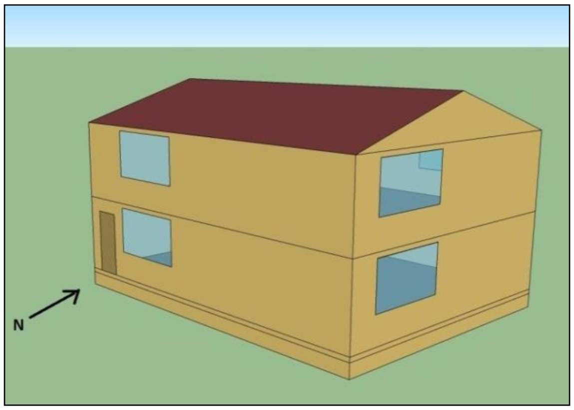

Figure 4.1. Image of the Single-Family Prototype

As depicted in Figure 4.2 and Figure 4.3, the multifamily prototype is configured as a three-story building with six dwelling units per floor, arranged in two rows with an open breezeway running through the middle. Each dwelling unit is modeled as a separate thermal zone. In addition to the resulting 18

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[1] The term *scorecard* was coined by the ASHRAE project committee for Standard 90.1 for summaries of commercial building simulation inputs. These scorecards summarize only inputs, not outputs or scores or any kind.

[2] http://www.energycodes.gov/development/residential/iecc_models.

[3] http://apps1.eere.energy.gov/buildings/energyplus/openstudio_suite.cfm.

[4] http://www.sketchup.com/.

thermal zones (one for each dwelling unit), the model has an attic zone and, for models with a crawlspace or basement, a foundation zone.

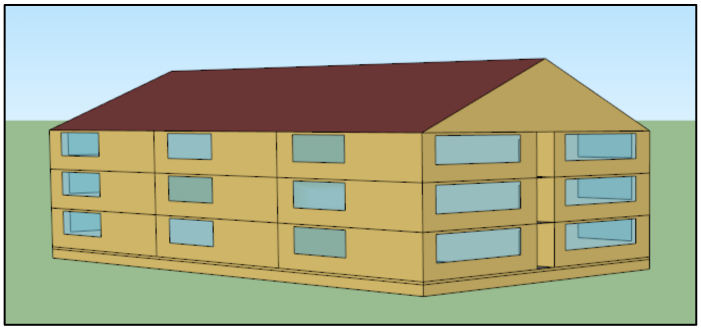

Figure 4.2. Image of the Multifamily Prototype

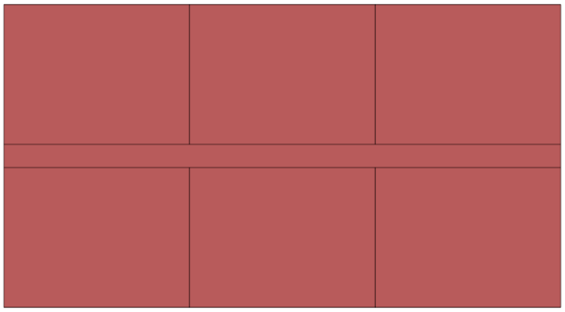

Figure 4.3. Plan View Showing Prototype Central Breezeway

4.2 Building Envelope

Both prototypes have gabled roofs with a 4:12 roof slope. Roof construction is assumed to be medium colored asphalt shingles with ceiling insulation placed entirely in the attic on the attic floor. For the multifamily prototype, ceiling insulation is assumed to be placed only on the ceilings at the top story exposed to unconditioned attic air. The attic is considered to be vented for both prototype buildings. The exterior walls are assumed to be wood-framed, with 2 × 4-in. studs spaced 16 in. on center or 2 × 6-in. studs spaced 24 in. on center depending on the thickness of wall insulation specified by the IECC. The floors are assumed to have wood joists spaced 24 in. on center. The ceiling, wall, and floor insulation levels are modeled according to the IECC code requirements for each code vintage.

Vertical fenestration for the single-family prototype is configured as a 15 percent window-to-floor ratio (WFR) distributed equally along all cardinal directions. The multifamily prototype is modeled with 23 percent window-to-wall ratio (WWR). However, the WWR calculation for the multi-family prototype does not include exterior walls facing the central breezeway. The WFR for the multifamily building prototype then is 10%.Vertical fenestration is modeled using the U-factor and solar heat gain coefficient (SHGC) requirements specified in each version of the IECC. The models do not account for external shading geometry. No skylights are assumed for either prototype.

Four foundation types are simulated in this analysis: 1) slab-on-grade, 2) crawlspace vented to the outdoors with insulation assumed to be placed entirely in the floor joists, 3) heated basement with the below grade walls insulated to the requirements of the IECC, and 4) unheated basement with the insulation placed entirely in the floor joists.

4.3 Internal Gains

The IECC provides limited guidance on specifying internal gains for the standard reference and proposed designs (Table 404.5.2(1) in the 2006 IECC). The table specifies equation 4.1 below for use in calculating total daily internal heat gains based on the conditioned floor area and the number of bedrooms of the home. Table 4.1 below summarizes the corresponding internal gains applicable to the single-family and multifamily prototypes.

$$\text{Internal Gains} = 17{,}900 + 23.8 \times \text{CFA} + 4104 \text{ x Nbr (Btu/day)} \tag{4.1}$$

where CFA is the conditioned floor area (ft^2) and Nbr is the number of bedrooms.

Table 4.1. Internal Gains for Single-Family and Multifamily Prototypes as Specified by the 2006 IECC

	CFA[a]	Nbr[b]	Internal Gains (Btu/Day)	Internal Gains (kBtu/year)
Single-family	2,400	3	87,332	31,876
Multifamily	1,200	2	54,668	19,954

(a) CFA = Conditioned floor area.
(b) Nbr = Number of bedrooms.

To facilitate evaluation of lighting and appliance changes in EnergyPlus, these daily totals are split into various end uses. This breakdown of appliance loads and corresponding appliance-use schedules (Appendix A, Section A.4) is developed to match, as closely as possible, the Building America research benchmark (Hendron and Engebrecht 2009). The approximate difference between the internal gains specified by the IECC and the sum of lighting and appliances from Building America, an IECC adjustment factor, is added as an additional miscellaneous load component. A breakdown of annual energy consumption and associated internal loads for major appliances and other equipment for the single-family and multifamily prototypes are shown in Table 4.2 and Table 4.3, respectively.

Table 4.2. Breakdown of Internal Gains for the Single-Family Prototype

			Internal Heat Gain (Fractions)			Internal Heat Gains (kWh/yr)		
Appliance	Power	Total Electricity (kWh/yr)	Fraction Sensible	Fraction Latent	Fraction Lost	2006 IECC	2009 IECC	2012 IECC
Refrigerator	91.09W	668.90	1.00	0.00	0.00	669	669	669
Clothes Washer	29.6 W	109.16	0.80	0.00	0.20	87	87	87
Clothes Dryer	222.11W	868.15	0.15	0.05	0.80	174	174	174
Dishwasher	68.33W	214.16	0.60	0.15	0.25	161	161	161
Range (electric/gas)	248.97W	604.90	0.40	0.30	0.30	423	423	423
Miscellaneous Plug Loads	0.228 W/sq.ft	3238.13	0.69	0.06	0.25	2429	2429	2429
Miscellaneous Electric Loads	182.5 W	1598.00	0.69	0.06	0.25	1199	1199	1199
IECC Adjustment Factor	0.0275 W/ft^2	390.56	0.69	0.06	0.25	293	293	293
Lighting			1.00	0.00	0.00	1635	1345	1164
Occupants	3 Occupants					2123	2123	2123
Totals					**kWh/yr**	**9192**	**8902**	**8721**
					kBtu/yr	**31,362**	**30,373**	**29,755**
					Btu/day	**85,924**	**83,213**	**81,522**

Table 4.3. Breakdown of Internal Gains for the Multifamily Prototype (per dwelling unit)

						Internal Heat Gains (kWh/yr)		
Appliance	Power	Total Electricity (kWh/yr)	Fraction Sensible	Fraction Latent	Fraction lost	2006 IECC	2009 IECC	2012 IECC
Refrigerator	91.09 W	668.90	1.00	0.00	0	669	669	669
Clothes Washer	29.6 W	109.16	0.80	0.00	0.2	87	87	87
Clothes Dryer	222.11 W	868.15	0.15	0.05	0.8	174	174	174
Dishwasher	68.33 W	214.16	0.60	0.15	0.25	161	161	161
Range (electric)	248.97 W	604.00	0.40	0.30	0.3	423	423	423
Miscellaneous Plug Loads	0.228 W/ft^2	1619.00	0.69	0.06	0.25	1214	1214	1214
Miscellaneous Electric Loads	121.88 W	1067.00	0.69	0.06	0.25	800	800	800
IECC Adjustment Factor	0.0275 W/ft^2	195.28	0.69	0.06	0.25	146	146	146
Lighting			1.00	0.00	0	493	405	351
Occupants	2 Occupants					1416	1416	1416
Total					**kWh/yr**	**5583**	**5495**	**5440**
					kBtu/yr	**19,049**	**18,748**	**18,562**
					Btu/day	**52,189**	**51,364**	**50,855**

4.4 Lighting

Lighting is modeled as hardwired, plug-in, exterior, and garage lighting. The baseline 2006 IECC lighting characteristics and energy consumption are based on the Building America Simulation Protocols (Hendron and Engebrecht 2010). The corresponding lighting energy use for the 2006 IECC is calculated using Building America's equations shown in **Error! Reference source not found.** based on conditioned floor area (CFA).

Table 4.4. Baseline Lighting Energy Use for the 2006 IECC

Type		Energy Use
Interior Hardwired	=	0.8 × (CFA x 0.542 + 334) kWh/yr
Interior Plug-in Lighting	=	0.2 × (CFA x 0.542 + 334) kWh/yr
Garage Lighting	=	Garage Area × 0.08 + 8 kWh/yr
Exterior Lighting	=	CFA × 0.145 kWh/yr

Building America assumes that 66 percent of all lamps are incandescent, 21 percent are compact fluorescent, and the remaining 13 percent are T-8 linear fluorescent in the baseline. The 2009 IECC and the 2012 IECC require 50 percent and 75 percent, respectively, of all lighting in permanently installed fixtures to be high efficacy. The lighting energy consumption for the 2009 and 2012 IECC is calculated using Building America's smart lamp replacement approach using fractions specified in Table 4.5 and equations 4.2, 4.3 and 4.4.

Interior Hardwired lighting energy = $Lhw \text{ x } \{[(Finc, HW + 0.34) + (FCFL, HW - 0.21) \text{ x } 0.27 + FLED, HW \text{ x } 0.30 + (FLF, HW - 0.13) \text{ x } 0.17] \text{ x } SAF \text{ x } 0.9 + 0.1 \text{ (kWh/yr)}$ (4.2)

Garage lighting energy = $LGAR \text{ x } \{[(Finc, GAR + 0.34) + (FCFL, GAR - 0.21) \text{ x } 0.27 + FLED, GAR \text{ x } 0.30 + (FLF, GAR - 0.13) \text{ x } 0.17] \text{ x } 0.9 + 0.1 \text{ (kWh/yr)}$ (4.3)

Exterior lighting energy = $LOUT \text{ x } \{[(Finc, OUT + 0.34) + (FCFL, OUT - 0.21) \text{ x } 0.27 + FLED, OUT \text{ x } 0.30 + (FLF, OUT - 0.13) \text{ x } 0.17] \text{ x } 0.9 + 0.1 \text{ (kWh/yr)}$ (4.4)

In those equations, LHW is the baseline hard-wired lighting energy, LGAR is the baseline garage lighting energy and LOUT is the baseline exterior lighting energy. Finc and FCFL are the fractions of fixture with incandescent lamps and fluorescent lamps, respectively.

Table 4.5. Lighting fixture type fractions for the 2006, 2009 and 2012 IECC

	2006 IECC	2009 IECC	2012 IECC
Fraction Incandescent	0.66	0.5	0.25
Fraction CFL	0.21	0.37	0.62
Fraction Linear Fluorescent	0.13	0.13	0.13

Based on the Building America Simulation Protocols, when estimating the energy savings of the 2009 and 2012 IECC, a 10-percent take back is included in the form of an increase in operating hours to account for operational differences when incandescent lamps are replaced with energy-efficient lamps.

4.5 Infiltration and Ventilation

4.5.1 Infiltration

The infiltration rates are handled differently in each of the three versions of the IECC. The 2006 IECC does not require a blower door test nor does it include a detailed sealing inspection checklist. A benchmark construction infiltration rate of eight air changes at a 50 Pa pressure differential (ACH50) was established for the 2006 IECC based on the lower end of envelope leakage rates for typical new construction presented by Sherman (2007).[1]

The 2009 IECC provides two paths for compliance with its infiltration requirements. One is a standard blower door test with a seven-ACH50 limit and the other is inspection against a detailed air sealing checklist. This analysis assumes either path results in the same effective infiltration rate, so a leakage rate of seven-ACH50 is assumed for the 2009 IECC.

The 2012 IECC allows a maximum of five-ACH50 in Climate Zones 1 and 2, and three-ACH50 in Climate Zones 3 through 8, as determined by a standard blower door test. EnergyPlus contains multiple modules that can be used to model infiltration. The EnergyPlus *ZoneInfiltration: EffectiveLeakageArea* model, based on work done by Sherman and Grimsrud for smaller residential type of buildings[2], was used in this analysis. This model uses the effective leakage area (ELA) derived from a standard blower door test to model infiltration loads on the zone.

The input to EnergyPlus is the ELA at a 4 Pa reference pressure differential. In contrast, a standard blower door test yields a leakage rate in air changes per hour at a 50-Pa pressure differential (ACH50). This value is converted to the EnergyPlus input using equations 4.5, 4.6, and 4.7 below.[3]

$$cfm50 = \frac{ACH50\ x\ Volume\ of\ the\ House}{60} \tag{4.5}$$

$$C_{ela} = \frac{cfm50}{50^{0.65}} \tag{4.6}$$

$$ELA = 0.2833 * C_{ela} * (4^{0.65}) \tag{4.7}$$

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[1] M. Sherman ‘Trends in US Ventilation’
http://www.aivc.org/medias/pdf/07_USA.pdf

[2] *EnergyPlus* Input Output Reference
http://apps1.eere.energy.gov/buildings/energyplus/pdfs/inputoutputreference.pdf

[3] P. Fairey ‘EnergyGauge Envelope Leakage and Infiltration Conversions’
http://www.energygauge.com/DOWNLOADS/EgUSA2802.pdf.

In those equations, $cfm50$ is the leakage flow-rate during the blower door test, C_{ela} is the leakage co-efficient, and ELA is the equivalent leakage area that is the input parameter to EnergyPlus. Table 4.6 lists the specific ELA values used in this analysis as input to EnergyPlus.

Table 4.6. Air Changes at 50 Pa and Effective Leakage Area by IECC Version

		Effective Leakage Area (in.^{2})	
Code	ACH50	Single-Family Prototype	Multifamily Prototype
2006 IECC	8	149.22	74.61
2009 IECC	7	130.57	65.28
2012 IECC Climate Zones 1-2	5	93.26	46.63
2012 IECC Climate Zones 3-8	3	55.96	27.98

4.5.2 Ventilation

The 2012 IECC sets mechanical ventilation requirements for one and two family dwelling units and townhomes based on the 2012 International Residential Code (IRC) and those for low-rise multifamily buildings based on the 2012 International Mechanical Code (IMC). The maximum five or three-ACH50 leakage requirements in the 2012 IECC, coupled with mechanical ventilation requirements of the 2012 IRC and the 2012 IMC, mandates mechanical ventilation for all homes built under the 2012 IECC.[1] The IRC allows the ventilation system to be either continuously operating with a lower required outdoor air flow-rate or intermittently operating with a higher required outdoor air flow-rate. The IMC requires ventilation air to be supplied continuously when the building is occupied.

For the single-family prototype, the minimum outdoor air flow-rates are based on conditioned floor area and number of bedrooms and are listed in table M1507.3.3(1) of the 2012 IRC. For the low-rise multifamily prototype, the minimum outdoor air flow-rates are based on occupant density and are listed in table 403.3 of the 2012 IMC. For the purpose of this analysis, a whole-house continuously operating ventilation system is assumed. Outdoor air flow rates required by the 2012 IRC and the 2012 IMC used in the simulations are summarized in Table 4.7.

Table 4.7. Outdoor Air Flow Rates Used in Simulations

Prototype	Outdoor Air Flow Rate used in Simulation (ft^3/min)
Single-Family	60
Multifamily	45

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[1] Section R303.4 of the 2012 IRC actually requires ventilation only when envelope leakage is less than five ACH50. Ventilation is not required for a home with a leakage rate of exactly five ACH50. This analysis assumes that such homes are rare and that all 2012 IECC-compliant homes will fall under the ventilation requirement.

There is growing consensus among building scientists that a ventilation system is necessary in new residential buildings regardless of the vintage of the building energy code in order to ensure a reliable supply of fresh air to maintain indoor air quality. Specific comments from the ASHRAE Standard 90.2 committee for analyses conducted in support of the development of standard 90.2 suggested assuming the same mechanical ventilation rates for the 2006 IECC, even though the 2006 IECC does not specifically require mechanical ventilation.[1] Therefore, for this analysis, the same mechanical ventilation system and outdoor air flow-rates are assumed in all analyzed code versions.

Ventilation is modeled using the EnergyPlus Zone: Ventilation model using the outdoor flow rates from Table 4.7 and a continuous ventilation fan operation schedule.

4.6 Heating, Ventilation, and Air-Conditioning Systems

All homes are assumed to have a central forced-air distribution system served by either a heat pump or an electric air-conditioner coupled with an electric, natural-gas, or oil furnace.

4.6.1 Operating Conditions

Thermostat set-points for all models are based on the 2012 IECC performance path specifications (Table R405.5.2(1) in the 2012 IECC). The relevant set-points, which apply to both the standard reference design and proposed design, are a heating set-point of 72°F without a setback period and a cooling set-point of 75°F without a setup period.

4.6.2 HVAC System Efficiency

None of the IECC versions specifies efficiency requirements for heating, ventilation, and air conditioning (HVAC) systems. A federal equipment standards rulemaking process governs minimum heating and cooling equipment efficiencies at the manufacturing level.[2] Federal minimum baseline efficiencies in effect as of May 2012 for residential central air conditioners, heat pumps and furnaces are assumed to apply for the purpose of this analysis (10 CFR 430[3]). Table 4.8 shows the heating and cooling equipment efficiencies used in the analysis.

Table 4.8. Heating and Cooling Equipment Efficiencies used in this Analysis.

Equipment Efficiencies				
Air Conditioner SEER[(a)]	Heat Pump SEER	Gas Furnace AFUE[(b)]	Oil Furnace AFUE	Heat Pump HSPF[(c)]
13	13	78%	78%	7.7

(a) SEER = Seasonal Energy Efficiency Ratio.
(b) AFUE = Annual Fuel Utilization Efficiency.
(c) HSPF = Heating Seasonal Performance Factor.

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[1] These comments were received during the web meeting held on March 22, 2012, for the development of the ASHRAE 90.2-2014 standard.

[2] Per the requirements of the National Appliance Energy Conservation Act of 1987 (NAECA), as amended.

[3] http://www.gpo.gov/fdsys/pkg/CFR-2011-title10-vol3/pdf/CFR-2011-title10-vol3-sec430-32.pdf.

4.6.3 Air Distribution System and Duct Leakage Rates

All models in the analysis are assumed to have a centralized supply and return duct system. The air distribution system is modeled using the EnergyPlus *Airflownetwork*. The model has capabilities for modeling wind and pressure-driven air flows through the building shell as well as detailed thermal gains and losses and leakages through the air-distribution system.

The 2006 IECC does not specify a maximum allowable duct leakage rate. Research done by Building America indicates that typical new homes with ducts in attics or crawlspaces lose about 25 to 40 percent of the heating or cooling energy that passes through the ducts. In EnergyPlus, duct leakage is defined as a ratio of the total supply air flow-rate. A conservative baseline duct leakage rate of 15 percent on the supply side and 15 percent on the return side for the 2006 IECC is assumed in this analysis, based on research done by Building America.[1] The ducts are assumed to be located in the unconditioned attic space and all the leakage is assumed to take place in this zone. The 2009 and 2012 IECC specify limits on duct leakage in terms of cubic feet per minute (CFM) per 100 ft^2 conditioned floor area at a 25-Pa pressure differential. This value is converted into a ratio of duct leakage CFM to the total supply CFM for input to EnergyPlus. The leakage is assumed to be equally distributed between the supply and return air sides. These leakage inputs are summarized in

Table **4.9**.

Table 4.9. Duct Leakage Rates

Energy Code	Maximum Allowed Duct Leakage Rate (CFM/100 ft^2 conditioned floor area at a 25-Pa pressure differential)	Duct Leakage Ratio (percent of total supply CFM)
2006 IECC	Not specified	15% supply and 15% return
2009 IECC	8	10% supply and 10% return
2012 IECC	4	4% supply and 4% return

Some modules within the EnergyPlus *Airflownetwork* were still under development at the time of this analysis, thus requiring a workaround to complete the simulations. The impacts of duct leakage on heating and cooling energy were simulated separately from other building elements and added to the energy results through post-processing. A separate suit of 11,424 models was created with the duct-leakage rates set to the 2006, 2009, and 2012 IECC levels, respectively, and the rest of the requirements were maintained at the 2006 IECC level. This approach allowed the impact of duct leakage on heating and cooling energy to be isolated and captured. This impact was then added to the energy use results from the 2009 and 2012 IECC models through post-processing.

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[1] Building America "Better Duct Systems for Home Heating and Cooling" http://www.nrel.gov/docs/fy05osti/30506.pdf.

4.7 Domestic Hot Water System

The domestic hot water system in all models is assumed to be a storage type water heater. For models that represent homes with fuel-fired furnaces as space-heating equipment, water heaters are modeled as gas-fired storage water heaters. For models that represent homes with electricity as the space heating fuel (electric furnace and heat pump), water heaters are assumed to be electric storage tank type water heaters.

The size of the storage tank is assumed to be 40 gal for gas-fired water heaters and 52 gal for electric water heaters. For the purpose of modeling, domestic hot water use is split into various end-uses such as baths, sinks, clothes washer, dishwasher, and showers using peak flow rates and schedules from the Building America House Simulation Protocols.

Commercially available residential size water heaters are rated in terms of an Energy Factor (EF). A federal rulemaking process determines minimum allowable EF values that depend on the equipment type and capacity (storage volume).[1] This analysis assumes EF values based on the federal rule in effect as of May 2012.

Table 4.10 summarizes the EF for gas-fired and electric water heaters used in this analysis.

Table 4.10. Water Heater Energy Factor used in the Analysis

Water Heater Type	Energy Factor
Gas fired storage type	0.594
Electric storage type	0.917

For modeling purposes, the EF has to be split into a burner thermal efficiency and standby losses. These calculations are carried out using equations from the Water Heater Analysis Model (WHAM) (Lutz et al. 1998). Table 4.11 summarizes thermal efficiency and shell losses for each case.

Table 4.11. Standby Losses and Burner Thermal Efficiencies for Water Heaters

Water Heater Type	Shell Losses-UA (Btu/hr-°F)	Burner Thermal Efficiency
Gas fired storage type	10.84	80%
Electric storage type	2.52	100%

The 2012 IECC specifies requirements for insulating hot water pipes for service water heating (faucets, showers, etc.). This insulation requirement did not exist in the 2006 or 2009 IECC. The savings from this requirement are variable, because they depend on system design and occupant behavior, and are not easy to capture with an energy model. Klein estimates the 2012 IECC requirements save from 10.2 to 27.4 percent of the overall hot water energy consumption for a typical household (Klein 2012). This analysis uses a conservative estimate of 10 percent hot water energy savings. These savings are applied to the simulated hot water energy consumption through post-processing.

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[1] http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_fedreg.pdf.

5.0 Energy Costs

5.1 Energy Use

EnergyPlus provides detailed end-use energy consumption estimates, potentially at high time resolution (monthly, hourly, or even sub-hourly). For this analysis, only annual end-use energy consumption, taken from the EnergyPlus 'table.csv' output report, is used. As specified in the cost-effectiveness methodology, energy savings for cost-effectiveness considerations are limited to heating, cooling, domestic hot water heating, and lighting to match the scope of the IECC.

5.2 Fuel Prices

Fuel prices and anticipated price escalation rates are needed to determine the energy cost savings from improved energy efficiency. This analysis uses the most recently available state-specific residential fuel prices from DOE's Energy Information Administration.[1, 2, 3] Electricity prices vary by the heating or cooling season. For air conditioning, electricity prices from the summer are used, and for electric space heating, winter electricity prices are used. Fuel price escalation rates are obtained from the most recent *Annual Energy Outlook* to account for projected changes in energy prices. This analysis assumes an average fuel escalation rate of 2.2%. Table 5.1 lists the state specific prices used for electricity, gas and oil.

Table 5.1. Fuel Prices by State

State	Electricity ($/kWh) (Heating)	Electricity ($/kWh) (Cooling)	Gas ($/Therm)	Oil ($/MBtu)
Alabama	0.106	0.109	1.329	23.7
Alaska	0.166	0.171	0.839	23.7
Arizona	0.099	0.117	1.306	23.7
Arkansas	0.08	0.092	0.924	23.7
California	0.149	0.156	0.943	23.7
Colorado	0.104	0.118	0.714	23.7
Connecticut	0.181	0.192	1.244	23.86
Delaware	0.133	0.142	1.365	23.7
District of Columbia	0.135	0.143	1.202	23.7
Florida	0.117	0.117	1.532	23.7
Georgia	0.098	0.109	1.249	23.7
Hawaii	0.301	0.284	4.72	23.7
Idaho	0.078	0.084	0.869	23.7
Illinois	0.108	0.122	0.717	23.7

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[1] U.S. Department of Energy (DOE). 2012a. *Electric Power Monthly*. DOE/EIA-0226. Washington, D.C. http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

[2] U.S. Department of Energy (DOE). 2012b. *Natural Gas Monthly*. DOE/EIA-0130. Washington, D.C. http://www.eia.gov/oil_gas/natural_gas/data_publications/natural_gas_monthly/ngm.html

[3] U.S. Department of Energy (DOE). 2012c. *Petroleum Marketing Monthly*. DOE/EIA-0380. Washington, D.C. http://www.eia.gov/petroleum/marketing/monthly/

Table 5.1. (contd)

State	Electricity ($/kWh) (Heating)	Electricity ($/kWh) (Cooling)	Gas ($/Therm)	Oil ($/MBtu)
Indiana	0.094	0.093	0.804	23.7
Iowa	0.096	0.11	0.802	23.7
Kansas	0.095	0.105	0.815	23.7
Kentucky	0.086	0.087	0.858	23.7
Louisiana	0.081	0.092	0.933	23.7
Maine	0.158	0.155	1.353	22.21
Maryland	0.134	0.151	1.039	23.7
Massachusetts	0.148	0.149	1.405	24.06
Michigan	0.123	0.131	0.971	23.7
Minnesota	0.103	0.108	0.833	23.7
Mississippi	0.098	0.102	0.848	23.7
Missouri	0.082	0.103	0.973	23.7
Montana	0.091	0.096	0.795	23.7
Nebraska	0.079	0.102	0.762	23.7
Nevada	0.118	0.122	0.977	23.7
New Hampshire	0.164	0.163	1.299	22.47
New Jersey	0.163	0.172	1.162	23.7
New Mexico	0.099	0.116	0.791	23.7
New York	0.175	0.192	1.177	23.87
North Carolina	0.097	0.103	0.992	23.7
North Dakota	0.073	0.094	0.685	23.7
Ohio	0.104	0.118	0.93	23.7
Oklahoma	0.082	0.095	0.724	23.7
Oregon	0.091	0.092	1.174	23.7
Pennsylvania	0.125	0.133	1.101	23.41
Rhode Island	0.158	0.162	1.369	24.47
South Carolina	0.107	0.106	1.018	23.7
South Dakota	0.083	0.097	0.749	23.7
Tennessee	0.095	0.095	0.862	23.7
Texas	0.11	0.12	0.814	23.7
Utah	0.083	0.094	0.843	23.7
Vermont	0.158	0.155	1.433	23.13
Virginia	0.098	0.108	1.077	23.7
Washington	0.08	0.083	1.142	23.7
West Virginia	0.088	0.089	0.988	23.7
Wisconsin	0.124	0.126	0.918	23.7
Wyoming	0.084	0.093	0.747	23.7

6.0 Construction Cost Calculation

6.1 Requirements by Climate Zone for Each Code Level

The 2009 and 2012 IECC have more stringent energy efficiency requirements than the 2006 IECC. Some of the requirements are constant across climate zones while some requirements vary. Table 6.1 summarizes the prescriptive requirements of the three versions of IECC analyzed in this study that vary by climate zone. Table 6.2 summarizes mandatory and prescriptive requirements that do not vary by climate zone.

6.2 Incremental Cost Calculation

The analysis compares the energy savings and cost effectiveness of the 2009 and 2012 IECC compared to the 2006 IECC. Cost effectiveness is calculated using incremental first cost and energy savings resulting from improvements in the code. The following sections detail incremental cost calculation for each component.

There are several existing studies on construction cost impacts for improved energy efficiency in residential new construction. Cost data sources consulted include but are not limited to:

- Construction cost data collected by Faithful+Gould in 2011 and 2012 under contract with PNNL[1]
- RS Means Residential Cost Data (RS Means 2011)
- ASHRAE Research Project 1481 (NAHB 2009).

All the costs used in this analysis are documented in the BC3 database.[2]

6.2.1 Duct Testing and Improved Duct Sealing

Section 403.2.2 of the 2009 and 2012 IECC require air distribution systems, where any of the ducts pass outside of the conditioned space (in attics, garages, etc.), to be pressure tested against specified maximum leakage rates. Testing is not required if all ducts and air handlers are inside the building envelope (for example in heated basements). All three versions of the IECC require all ducts to be sealed even if they are located inside the envelope. However, the 2006 IECC does not require ducts to be pressure tested for leakage. Thus, for the 2009 and 2012 IECC, there is an additional incremental cost for the pressure test (e.g., a duct blaster® test) and for additional sealing to achieve the required leakage rates.

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[1] Faithful+Gould "Prototype Estimate and Cost Data" http://bc3.pnnl.gov/wiki/images/f/fa/Residential_Report.pdf.

[2] http://bc3.pnnl.gov/wiki/index.php/Main_Page

Table 6.1. Prescriptive Code Requirements that Vary by Climate Zone

		Components										
				Fenestration (Windows and Doors)								
Climate Zone	IECC	Ceiling (R-value)	Skylight (U-factor)	U-factor	SHGC	Wood Frame Wall (R-value)	Mass Wall(a) (R-value)	Floor (R-value)	Basement Wall(b) (R-value)	Tested Max Air Leakage Rate (air changes per hour)	Slab(c) (R-value and depth)	Crawl Space(b) (R-value)
1	2006	30	0.75	NR	0.4	13	3/4	13	NR	NR	NR	NR
	2009				0.3					NR		
	2012				0.25					5		
2	2006	30	0.75	0.75	0.4	13	4/6	13	NR	NR	NR	NR
	2009	30	0.75	0.65	0.3					NR		
	2012	38	0.65	0.4	0.25					5		
3	2006	30	0.65	0.65	0.4	13	5/8	19	0	NR	NR	5/13
	2009	30	0.65	0.5	0.3	13	5/8		5/13(d)	NR		
	2012	38	0.55	0.35	0.25	20	8/13		5/13(d)	3		
4	2006	38	0.6	0.4	NR	13	5/13	19	10/13	NR	10, 2 ft	10/13
	2009	38	0.6	0.35		13	5/10		10/13	NR		10/13
	2012	49	0.55	0.35	0.4	20	8/13		10/13	3		10/13
5	2006	38	0.6	0.35	NR	19	13/19	30	10/13	NR	10, 2 ft	10/13
	2009	38	0.6	0.35		20	13/17		10/13	NR		10/13
	2012	49	0.55	0.32		20	15/19		15/19	3		15/19
6	2006	49	0.6	0.35	NR	19	10/13	30	10/13	NR	10, 4 ft	10/13
	2009		0.6	0.35		20	15/19		15/19	NR		10/13
	2012		0.55	0.32		20+5	15/19		15/19	3		15/19
7 and 8	2006	49	0.6	0.35	NR	21	19/21	30	10/13	NR	10, 4 ft	10/13
	2009		0.6	0.35		21		38	15/19	NR		10/13
	2012		0.55	0.32		20+5		38	15/19	3		15/19

(a) The second number applies when more than half the insulation is on the interior side of the high mass material in the wall.

(b) The first number is for continuous insulation (e.g., a board or blanket directly on the foundation wall) and the second number is for cavity insulation (i.e., if there is a furred-out wall built against the foundation wall). Only one of these two has to be met.

(c) The first number is R-value. The second value refers to the vertical depth of the insulation around the perimeter.

(d) Basement wall insulation is not required in the warm-humid region of Zone 3 in the southeastern United States.

IECC = International Energy Conservation Code.
NR = Not required.
SHGC = Solar heat gain coefficient.

Table 6.2. Major Code Requirements that do not vary by Climate Zone

Requirement	2006 IECC	2009 IECC	2012 IECC
Building envelope sealing	Caulked and sealed verified by visual inspection	Caulked and sealed verified by visual inspection against a more detailed checklist	Caulked and sealed verified by visual inspection and a pressure test against a stringent leakage requirement
Ducts and air handlers	Sealed verified by visual inspection	Sealed, verified by visual inspection, and pressure tested or all ducts must be inside building envelope	Sealed, verified by visual inspection, and pressure tested against a more stringent leakage requirement or all ducts must be inside building envelope
Supply ducts in attics	R-8	R-8	R-8
Return ducts in attics and all ducts in crawlspaces, unheated basements, garages, or otherwise outside the building envelope	R-8	R-6	R-6
Insulation on hot water pipes for service water heating systems	None	None	R-3 except where pipe run length is below a diameter-dependent threshold
Insulation on hot water pipes for hydronic (boiler) space heating systems	R-3	R-3	R-3
High-efficacy lamps (percent of lighting in the home)	None	50% of lamps	75% of lamps or 75% of fixtures
Certificate of insulation levels and other energy efficiency measures	Yes	Yes	Yes

Faithful+Gould reports a cost of $135 for duct testing when done as part of the construction process rather than as a one-off site visit test. Hammon and Modera (2009) estimate a cost of $131 to $163 for testing, and suggest costs will be even lower in a mature market. The *Journal of Light Construction* quotes a cost of $220 for testing (Uniacke 2003). An Appalachian State University study (Appalachian State University 2010) reports a cost of $175 to $250. It is important to note that the IECC allows the ducts to be tested by the HVAC contractor immediately after the ducts are installed. This should help keep both costs and construction timeline impacts to a minimum. A cost of $135 per duct blaster test is assumed in this analysis. Each dwelling unit within the multifamily building is assumed to have its own duct distribution system and thus a separate test would be conducted for each.

The second cost is the cost associated with further improvements in duct sealing to ensure the duct complies with the air leakage limits set in the code of interest. This is expected to be mostly labor costs. Hammon and Modera (1999) estimate a cost of $214 for materials and labor for improved duct sealing. The developers of Energy Star Home requirements estimated a cost of $0.10/ft^2 of conditioned home floor area for improved duct sealing (EPA 2011). This results in a cost of $240 for a 2400-ft^2 home and $120 for a 1200-ft^2 dwelling unit. A conservative estimate of $240 per home and $120 per dwelling unit is used in this analysis for single-family and multifamily buildings, respectively.

The total cost for duct testing and improved duct sealing for the 2009 IECC thus works out to be $375 for a typical new single-family home and $255 for a typical dwelling unit in a multifamily building, relative to the 2006 IECC. The 2012 IECC has lower allowable duct leakage rates compared to the 2009 IECC. An additional $100 is estimated for further improvements in duct sealing for the 2012 IECC, increasing the total sealing and testing cost to $475 for single-family homes and $355 for each dwelling unit within a multifamily building relative to the 2006 IECC.

6.2.2 Building Envelope Testing and Improved Envelope Sealing

Section 402.4.2 of the 2009 IECC provides two options for demonstrating envelope air tightness: a pressure test to verify that the leakage rate is below the specified leakage rate or a visual inspection option accompanied with a checklist (Table 402.4.2). This analysis assumes that either option would result in the same envelope leakage rate.

Section R402.4.1.2 of the 2012 IECC requires the building envelope to be pressure tested to verify that the leakage rate is at or below specified maximum leakage rates. Faithful+Gould reports a cost of $135 for envelope testing when done as part of the construction process rather than as a one-off site visit test. Similar to the duct blaster test for the multifamily prototype building, it is assumed that each dwelling unit will be tested for envelope leakage separately, thus costing $135 per dwelling unit.

The developers of Energy Star Home Requirements estimated a cost of $\$0.25/\text{ft}^2$ of home floor area for improved envelope sealing (EPA 2011). This is a cost of $600 for a 2400-$\text{ft}^2$ home and a cost of $300 for a 1200-$\text{ft}^2$ dwelling unit. This analysis assumes this to be the total cost of improved envelope sealing for 2012 IECC over 2006 IECC. The cost for improved envelope sealing for the 2009 IECC is calculated proportionally as $\$0.05/\text{ft}^2$ of home floor area. Thus, the cost of improved envelope sealing is $120 for the single-family prototype building and $60 for each dwelling unit in the multifamily prototype building for the 2009 IECC over the 2006 IECC.

The cost of pressure testing the envelope and improved sealing is assumed to be $735 for the single-family prototype and $435 for each dwelling unit in the multifamily prototype building for the 2012 IECC over the 2006 IECC.

6.2.3 Window Improvements (U-Factor and Solar Heat Gain Reduction)

The thermal performance of windows is described using two parameters: the effective heat transfer co-efficient (U-factor) and the Solar Heat Gain Coefficient (SHGC). The 2009 and 2012 IECC require varying degrees of improvement of these two parameters over the 2006 IECC across various climate zones. These prescriptive requirements are summarized along with other envelope requirements in Table 6.1. Table 6.3 also presents these requirements for windows in the three versions of the IECC. The single-family and multifamily building prototype models do not have skylights; hence, the requirements for skylights are not analyzed in this study.

It is challenging to assign a cost for the improvement in window U-factor and SHGC because these two parameters are properties of the window assembly as a whole and can be achieved with a wide variety of window products with a similarly wide range of costs. Although a variety of window products and technologies can be used to comply with the requirements of the 2006, 2009 and 2012 IECC, it is expected that the most common method will have the same basic features and will be used in all climate zones. The common use of a low-emissivity (i.e., low-E) coating has the effect of lowering both the U-factor and the SHGC. Thus, the same double-paned window with a low-E coating and a non-aluminum frame (typically wood or vinyl) often will meet both the low U-factor requirements in northern climate zones and the low SHGC requirements in southern climate zones.

Table 6.3. U-Factor and SHGC Requirements for Windows in the 2006, 2009, and 2012 IECC

Climate Zone	IECC	Skylight (U-Factor)	Fenestration (Windows and Doors)	
			U-Factor	SHGC
1	2006	0.75	NR	0.4
	2009			0.3
	2012			0.25
2	2006	0.75	0.75	0.4
	2009	0.75	0.65	0.3
	2012	0.65	0.4	0.25
3	2006	0.65	0.65	0.4
	2009	0.65	0.5	0.3
	2012	0.55	0.35	0.25
4	2006	0.6	0.4	NR
	2009	0.6	0.35	
	2012	0.55	0.35	0.4
5	2006	0.6	0.35	NR
	2009	0.6	0.35	
	2012	0.55	0.32	
6	2006	0.6	0.35	NR
	2009	0.6	0.35	
	2012	0.55	0.32	
7 and 8	2006	0.6	0.35	NR
	2009	0.6	0.35	
	2012	0.55	0.32	

Faithful+Gould report a cost separately for improving the U-factor and for improving the SHGC. The Faithful+Gould cost for SHGC improvement is used to cost the improvements in glazed fenestration requirements in climate zones 1 through 3. The reduction of SHGC from 0.40 to 0.30 costs \$2.77/ft^2 and the reduction of SHGC from 0.30 to 0.25 costs \$1.38/ft^2. Because the low-E coating technology commonly used to achieve lower SHGC also lowers the U-factor, no additional cost is assumed for the improvements to U-factor required by the 2009 and 2012 IECC in climate zones 1 through 3. The improvement of U-factor from 0.35 to 0.32 in climate zones 4 through 8 is assumed to cost \$0.18/ft^2 based on the Faithful+Gould cost estimate. The modest improvement in U-factor and SHGC in climate zone 4 required in the 2009 and 2012 IECC are assumed to have no incremental cost increase as most double-pane low-E windows will comply with the 2012 IECC requirements here.

6.2.4 Above-Grade Wall Insulation

Above grade walls in the single-family and multifamily building prototype models are assumed to be wood framed with fiberglass batt insulation. As such, all incremental cost calculations are carried out for fiberglass batt insulation. The 2009 IECC requires an increase of wall insulation from R-19 to R-20[1] in climate zones 5 and 6 compared to the 2006 IECC. Because fiberglass batts are not commonly manufactured at the R-20 level, the cost for R-21 batts is used. The incremental material cost of R-21 fiberglass batt insulation compared to R-19 was identified as $0.19/ft^2 from the Home Depot website.[2] A 10-percent markup is added to account for the installers profit (RS Means 2011). This results in an incremental cost of $0.21/ft^2 used in this analysis. The ASHRAE 90.2 database (NAHB 2009) reports a similar cost of $0.18/ft^2.

The 2012 IECC requires R-20 wall insulation in climate zones 3 and 4. This is an increase from R-13 in the 2006 and 2009 IECC. Wall insulation up to R-13 can be installed using 2×4-in. wood framing members. 2×4-in. framing members are assumed to be spaced 16 in. on-center. R-20 cavity insulation has a greater thickness than R-13 and necessitates using 2×6 wood framing members. As 2×6-in. framing allows for more structural stability, framing members are assumed to be spaced 24 in. on-center. RS Means indicates the change from 2×4-in. framing to 2×6-in. framing with larger spacing has zero cost. Based on data from RS Means, the incremental cost for R-19 fiberglass batts over R-13 batts is $0.06/ft^2. Thus, the total incremental cost for R-21 wall insulation over R-13 wall insulation is $0.27/ft^2.

The 2012 IECC requires R-20 cavity insulation plus R-5 continuous insulation in climate zones 6 through 8. The 2006 and 2009 IECC do not require R-5 continuous insulation in these zones. Faithful+Gould reports a cost of $0.79/ft^2 for a full layer of R-5 extruded polystyrene continuous insulation. This cost has been used here. The R-5 insulation is assumed to be in addition to structural sheathing such as oriented strand board (OSB) or plywood over the entire wall area. Alternative construction methods may allow the continuous insulation to replace some or all of the structural sheathing using bracing techniques such metal straps or using a combination of wood panel and insulating sheathing at corners of walls. This may allow lower construction costs, but may also modestly decrease energy efficiency. These alternatives are not analyzed here.

6.2.5 Basement Wall Insulation

The 2009 and 2012 IECC require basement walls to be insulated with either R-5 continuous insulation or R-13 cavity insulation in climate zone 3 above the “warm humid” line (e.g., northern Alabama and Mississippi) if the basement is conditioned. The 2006 IECC does not require basement wall insulation in this region. All versions of the IECC require basement wall insulation in climate zones 4 through 8.

This analysis has assumed R-13 fiberglass batt or blanket products would be most likely used to meet basement wall insulation requirements in the IECC. Basement wall insulation is only required if the basement is conditioned, and if the basement is conditioned it is most likely to be finished. Hence, this analysis assumes no additional cost for finishing a basement. Faithful+Gould estimates the installed cost kraft-faced R-13 fiberglass batt at $0.517/ft^2. Hence, an incremental cost of $0.51/ft^2 of basement wall area is assumed in this analysis for R-13 insulation.

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[1] The IECC permits the R-20 requirements to be met by R-13 cavity insulation plus R-5 continuous insulation.

[2] http://www.homedepot.com/. Last accessed February 27, 2012.

The 2009 IECC requires R-15 continuous or R-19 cavity insulation in basement walls in climate zones 6 through 8. The 2012 IECC extends this requirement to apply to climate zone 5 as well. This requirement also applies to crawlspace walls if the crawlspace is conditioned. The 2006 IECC only requires R-10 continuous or R-13 cavity insulation in these zones. Faithful+Gould estimate an incremental cost of $0.26/ft^2 of basement wall area for R-19 cavity insulation compared to R-13. This estimate includes the additional cost of switching from 2×4-in. to 2×6-in. framing and is used in this analysis.

6.2.6 Ceiling and Floor Insulation

The 2009 and 2012 IECC require improved ceiling and floor insulation over the 2006 IECC in certain cliamte zones. Faithful+Gould estimates an incremental cost of $0.24/ft^2 for R-38 floor insulation compared to R-30. For ceiling insulation, Faithful+Gould estimates an incremental cost of $0.28/ft^2 for R-38 insulation compared to R-30 and $0.28/ft^2 for R-49 compared to R-38. These costs are used in this analysis.

6.2.7 Lighting

The 2006 IECC does not contain any requirements for high- efficacy lamps. The 2009 and 2012 IECC require 50 percent and 75 percent, respectively, of lamps in permanently installed lighting fixtures to be high efficacy. Compact flourescent lamps (CFLs) will comply with the IECC high-efficacy lamp requirement. The high efficacy lighting requirements in the 2009 and 2012 IECC will become less relevant as the requirements of federal law, which will require improved efficiency in light bulbs sold in the United States, take effect in 2012 to 2014.

A study of 604 new single-family homes in the Pacific Northwest found that the average home has 49 light fixtures containing 77 bulbs (RLW Analytics 2007). The lighting energy use for the single-family and multifamily prototype building models is based on Building America house simulation protocols (Hendron and Engebrecht 2010). The protocols assume 16 percent of the lighting energy is plug-in. As the high-efficacy lighting requirement impacts permanently installed fixtures alone, the remaining 84 percent of lighting energy is assumed to be impacted by this requirement. This reduces the number of lamps impacted by the 2009 and 2012 IECC to 65 for the single-family home. Furthermore, the protocols assume 34 percent of all lighting in the *benchmark* home is already high efficacy. The benchmark home corresponds to the 2006 IECC case in this analysis. This translates to an estimate of 10 light bulbs being replaced with CFLs in the 2009 IECC cases and 27 bulbs in the 2012 IECC cases.

Faithful+Gould estimates standard incandescent bulbs cost $0.55 to $0.78 per bulb and CFL spiral lamps cost $3.87 or less per bulb. An incremental estimate of $3.00 per bulb is assumed in this analysis for high-efficiency lighting. These results in an incremental cost of $30 per house for the 2009 IECC and $81 per house for the 2012 IECC for high-efficacy lighting compared to incandescent lighting.

According to the Building America House Simulation Protocols, the lighting energy for the 1200-ft^2 dwelling unit in the multifamily prototype is 57 percent of the lighting energy of the 2400-ft^2 single-family prototype. The incremental lighting costs for multifamily are therefore scaled down to $14 per house for the 2009 IECC and $47 per house for the 2012 IECC.

6.2.8 Hot Water Pipe Insulation

The 2006 and 2009 IECC have no requirements for hot water pipe insulation for non-circulating service water heating systems. The 2012 IECC requires R-3 insulation on most hot water pipes for service water use. The Lowes website[1] reports a cost of $5.98 for 6 ft of R-3 pipe insulation, or about $1/ft. Assuming there are 200 ft of hot water pipe in a 2400-ft^2 home, the material cost would be $200.

Klein (2012) reports costs of $136.40 to $322.50 for R-3 insulation installed on hot water pipes in a new 2400-ft^2 home and $123.20 to $168.00 for pipe insulation in a 1200-ft^2 dwelling unit. A conservative estimate of $400 (materials and labor) in incremental costs for the single-family prototype and $200 for each dwelling unit in the multifamily prototype is used in this analysis for meeting the hot water piping insulation requirements in the 2012 IECC.

6.2.9 Total Incremental Construction Costs – 2006 to 2009 IECC

Table 6.4 and Table 6.5 summarize the incremental costs for the 2009 IECC over the 2006 IECC for the single-family and multifamily prototypes, respectively. Table 6.6 and Table 6.7 summarize the incremental costs for the 2012 IECC over the 2009 IECC for the single-family and multifamily prototypes, respectively.

6.3 Location Indices

The incremental construction costs are defined on a national average basis for each code improvement. Location multipliers for residential construction developed by Faithful+Gould are applied to the national average construction costs to derive the modified costs for a particular location.[2] The location factors take into urban/rural factors, and regional construction pricing factors. Table 6.8 indicates the location multipliers for each state.

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[1] Lowes http://www.lowes.com/. Last accessed February 28, 2012.

[2] Faithful+Gould Residential Energy Efficiency Measures: Location Factors http://bc3.pnnl.gov/wiki/images/7/7f/Location_Factors_Report.pdf.

Table 6.4. Incremental Costs for the 2009 IECC over the 2006 IECC for the Single-family Prototype

Climate Zone	Foundation Type	Duct Sealing and Testing	Improved Air Sealing	R-19 to R-20 Walls	Windows 0.30 SHGC and Lower U	Windows U-0.40 to 0.35	R-30 to R-38 Floors	R-19 Basement Wall Insulation	50% Energy Efficient Lighting	**Total**
1	All	$375	$120		$989				$30	**$1,514**
2	All	$375	$120		$989				$30	**$1,514**
3 – South	All	$375	$120		$989				$30	**$1,514**
3 – North	Heated basements	$375	$120		$989			$500	$30	**$2,014**
3 – North	All but heated basements	$375	$120		$989				$30	**$1,514**
4	All	$375	$120			$104			$30	**$629**
5	All	$375	$120	$414					$30	**$939**
6	Heated basements	$375	$120	$414				$255	$30	**$1,194**
6	All but heated basements	$375	$120	$414					$30	**$939**
7 and 8	Heated basements	$375	$120					$255	$30	**$780**
7 and 8	Floors over unconditioned spaces	$375	$120				$288		$30	**$813**
7 and 8	Slab on grade	$375	$120						$30	**$525**

Table 6.5. Incremental Costs for the 2009 IECC over the 2006 IECC for the Multifamily Prototype

Climate Zone	Foundation Type	Duct Sealing and Testing	Improved Air Sealing	R-19 to R-20 walls	Windows 0.30 SHGC and Lower U	Windows U-0.40 to 0.35	R-30 to R-38 Floors	R-19 Basement Wall Insulation	50% Energy Efficient Lighting	**Total**
1	All	$255	$60		$327				$18	**$660**
2	All	$255	$60		$327				$18	**$660**
3 – South	All	$255	$60		$327				$18	**$660**
3 – North	Heated basements	$255	$60		$327			$73	$18	**$733**
3 – North	All but heated basements	$255	$60		$327				$18	**$660**
4	All	$255	$60			$34			$18	**$367**
5	All	$255	$60	$149					$18	**$482**
6	Heated basements	$255	$60	$149				$37	$18	**$519**
6	All but heated basements	$255	$60	$149					$18	**$482**
7 and 8	Heated basements	$255	$60					$37	$18	**$370**
7 and 8	Floors over unconditioned spaces	$255	$60				$96		$18	**$429**
7 and 8	Slab on grade	$255	$60						$18	**$333**

Table 6.6. Incremental Costs for the 2012 IECC over the 2009 IECC for the Single-Family Prototype

Climate Zone	Foundation Type	Envelope Sealing	Blower Door Test	Windows - 0.25 SHGC and Lower U	Increased Ceiling Insulation	Increased Wall Insulation	Hot Water Pipe Insulation	Further Duct Sealing	75% Energy Efficient Lighting	R-19 Basement Wall Insulation	Total
1	All	$480	$135	$493			$400	$100	$51		**$1,659**
2	All	$480	$135	$493	$336		$400	$100	$51		**$1,995**
3	All	$480	$135	$493	$336	$533	$400	$100	$51		**$2,528**
4	All	$480	$135		$336	$533	$400	$100	$51		**$2,035**
5	Heated basement	$480	$135	$64	$336		$400	$100	$51	$255	**$1,821**
5	All but heated basement	$480	$135	$64	$336		$400	$100	$51		**$1,566**
6, 7 and 8	All	$480	$135	$64		$1,567	$400	$100	$51		**$2,797**

Table 6.7. Incremental Costs for the 2012 IECC over the 2009 IECC for the Multifamily Prototype

Climate Zone	Foundation Type	Envelope Sealing	Blower Door Test	Windows - 0.25 SHGC and Lower U	Increased Ceiling Insulation	Increased Wall Insulation	Hot Water Pipe Insulation	Further Duct Sealing	75% Energy Efficient Lighting	R-19 Basement Wall Insulation	Total
1	All	$240	$135	$163			$200	$100	$29		**$867**
2	All	$240	$135	$163	$112		$200	$100	$29		**$979**
3	All	$240	$135	$163	$112	$191	$200	$100	$29		**$1,170**
4	All	$240	$135		$112	$191	$200	$100	$29		**$1,007**
5	Heated basement	$240	$135	$21	$112		$200	$100	$29	$37	**$874**
5	All but heated basement	$240	$135	$21	$112		$200	$100	$29		**$837**
6, 7 and 8	All	$240	$135	$21		$562	$200	$100	$29		**$1,287**

Table 6.8. Construction Cost Multiplier by State

State	Multiplier
Alabama	0.842
Alaska	1.336
Arizona	0.928
Arkansas	0.839
California	1.142
Colorado	0.972
Connecticut	1.124
Delaware	1.053
District of Columbia	0.999
Florida	0.884
Georgia	0.882
Hawaii	1.288
Idaho	0.918
Illinois	1.069
Indiana	0.99
Iowa	0.946
Kansas	0.869
Kentucky	0.929
Louisiana	0.853
Maine	0.916
Maryland	0.956
Massachusetts	1.141
Michigan	0.989
Minnesota	1.06
Mississippi	0.833
Missouri	1.005
Montana	0.936
Nebraska	0.905
Nevada	1.063
New Hampshire	0.967
New Jersey	1.156
New Mexico	0.903
New York	1.093
North Carolina	0.838
North Dakota	0.888
Ohio	0.967
Oklahoma	0.852
Oregon	1.038
Pennsylvania	1.025
Rhode Island	1.082
South Carolina	0.808
South Dakota	0.829
Tennessee	0.863
Texas	0.837
Utah	0.883
Vermont	0.933

Table 6.8. (contd)

State	Multiplier
Virginia	0.887
Washington	1.034
West Virginia	0.979
Wisconsin	1.01
Wyoming	0.886

7.0 Cost-Effectiveness Calculations

7.1 Cost-Effectiveness Methodology

DOE supports the development and adoption of more efficient building energy codes that are cost effective. The cost-effectiveness methodology lays out the entire procedure for computing cost effectiveness of the codes analyzed in this study.

7.2 Calculation Structure

Three cost-effectiveness metrics are computed as defined in the cost-effectiveness methodology: 1) LCC, 2) simple payback, and 3) annual consumer cash flow. LCC is the primary metric used by DOE to assess the cost effectiveness of a code. Simple payback and cash flow details are provided to assist states in assessing new codes.

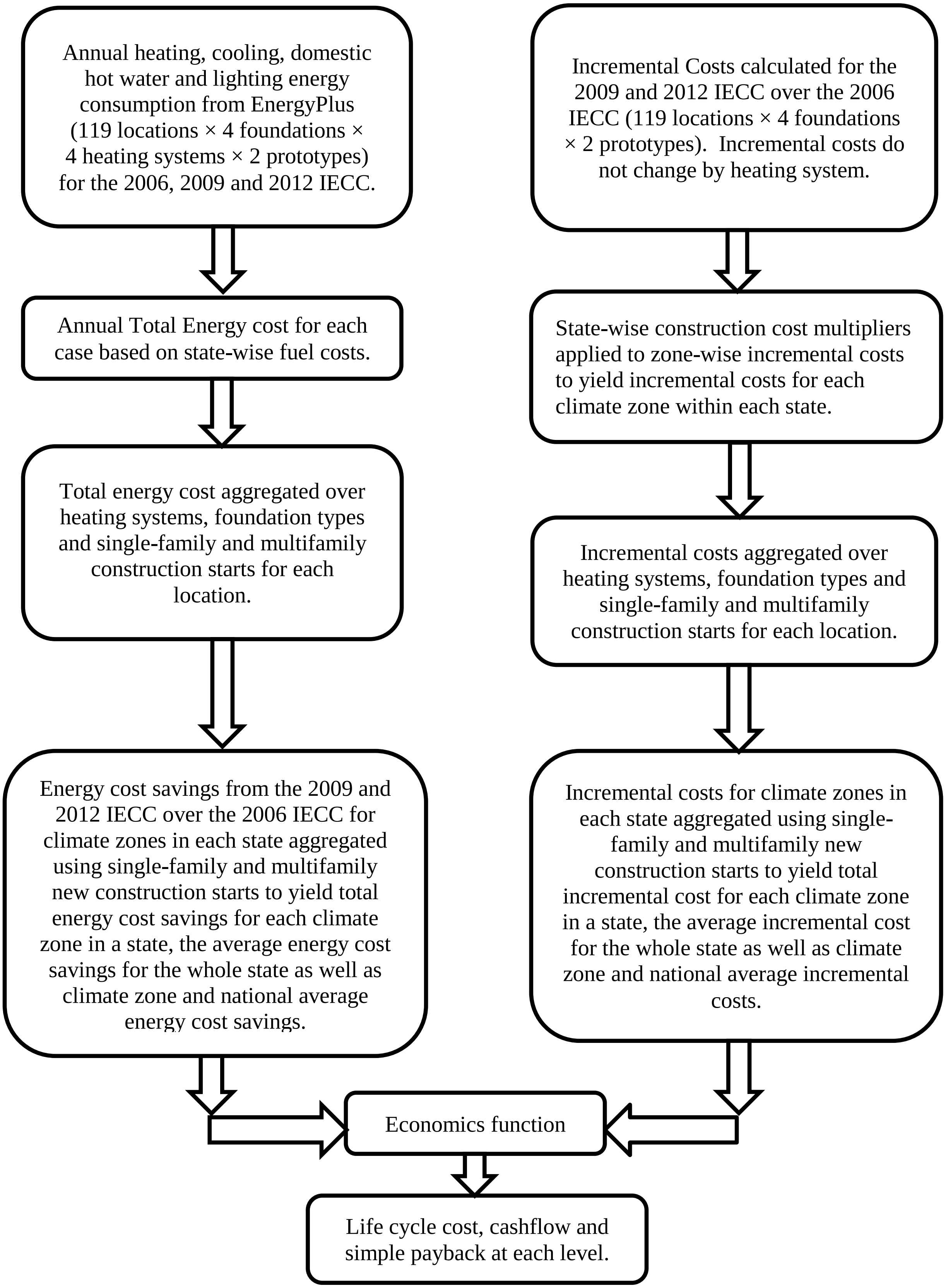
LCC is computed using the annual energy savings and the incremental first cost associated with the efficiency improvements of a code. The LCC calculation is an assessment of the net benefit of code changes in present value terms over a defined period of analysis. Annualized cash flows are a component of the LCC calculation, but are presented year by year without discounting to present value. They help in determining the number of years needed to achieve positive cash flow (i.e., how long before the annual cost savings outweigh the incremental mortgage payments). Simple payback is the simple calculation of the number of years it would take the annual energy savings to break even with the incremental first cost. It does not account for the time-value of money or any other mortgage calculations.

The economic parameters used in the economic calculations are defined in the cost-effectiveness methodology. These are summarized again in Table 7.1. The cost-effectiveness methodology provides more details on the reasoning behind the selection of each value.

7.3 Aggregation of Results

The economic results from the 11,424 energy models are aggregated to three levels: 1) state, 2) climate zone, and 3) national. The aggregated results are based on weighted averages of the individual results, in which weightings are defined by the relative prevalence of foundation types, heating system types, and building types (single-family vs. multifamily) at the three levels. Weighting factors are developed from multiple data sources as documented in the cost-effectiveness methodology.

Figure 7.1 provides a high level overview of the aggregation process. The weighting factors used in this analysis are further described in the following sections.



Annual heating, cooling, domestic hot water and lighting energy consumption from EnergyPlus (119 locations × 4 foundations × 4 heating systems × 2 prototypes) for the 2006, 2009 and 2012 IECC.

Annual Total Energy cost for each case based on state-wise fuel costs.

Total energy cost aggregated over heating systems, foundation types and single-family and multifamily construction starts for each location.

Energy cost savings from the 2009 and 2012 IECC over the 2006 IECC for climate zones in each state aggregated using single-family and multifamily new construction starts to yield total energy cost savings for each climate zone in a state, the average energy cost savings for the whole state as well as climate zone and national average energy cost savings.

Incremental Costs calculated for the 2009 and 2012 IECC over the 2006 IECC (119 locations × 4 foundations × 2 prototypes). Incremental costs do not change by heating system.

State-wise construction cost multipliers applied to zone-wise incremental costs to yield incremental costs for each climate zone within each state.

Incremental costs aggregated over heating systems, foundation types and single-family and multifamily construction starts for each location.

Incremental costs for climate zones in each state aggregated using single-family and multifamily new construction starts to yield total incremental cost for each climate zone in a state, the average incremental cost for the whole state as well as climate zone and national average incremental costs.

Life cycle cost, cashflow and simple payback at each level.

Figure 7.1. Overview of the Aggregation Process

Table 7.1. Economic Parameters Used in LCC Calculations

Parameter	Symbol	Current Estimate
Mortgage Interest Rate	R_{MI}	5%
Loan Term	T	30 years
Down Payment Rate	R_{DP}	10% of home price
Points and Loan Fees	R_{MF}	0.7% (non-deductible)
Discount Rate	R_d	5% (equal to Mortgage Interest Rate)
Period of Analysis	P	30 years
Property Tax Rate	R_{PT}	0.9% of home price/value
Income Tax Rate	R_{IT}	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 state average residential prices are based on current Energy Information Administration data and projections (as of the end of 2011; fuel price escalation rates are from the 2012Annual Energy Outlook. (An average nominal escalation rate of 2.2% is used in this analysis).	

7.3.1 Aggregation Across Foundation Types

Residential buildings typically have one of three foundation types: 1) basement, 2) crawlspace, or 3) slab-on-grade. The basement may be heated or unheated. Data from DOE's 2009 Residential Energy Consumption Survey[1] are used to establish foundation shares for both single-family and multifamily buildings. Table 7.2 details the foundation shares used in this analysis.

Table 7.2. Share of Foundation Types (percent)

State	Slab-on-Grade	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

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[1] 2009 RECS Survey Data 'Structural and Geographic Characteristics' http://www.eia.gov/consumption/residential/data/2009/#undefined

Table 7.2. (contd)

State	Slab-on Grade	Heated Basement	Unheated Basement	Crawlspace
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

7.3.2 Aggregation Across Heating System Types

The next level of aggregation is done by heating system shares. Heating system shares used in DOE’s analyses are taken from National Association of Home Builders survey data (NAHB 2009). The shares by heating system type for new construction in each census division for single-family and multifamily homes are shown in Table 7.3 and Table 7.4, respectively.

Table 7.3. Share of Heating Systems – Single-Family Home (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

Table 7.4. Share of Heating Systems – Multifamily Home (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[1]	30.2
Mountain	2.8	97.2	0	0
Pacific	14.9	84.2	0.2	0.8

7.3.3 Aggregation Across Building Types

Finally, new housing construction starts from the census data at the county level for 2010[2] are used to estimate single-family and multifamily shares within each climate location within each state. Table 7.5 shows the single-family and multifamily building new housing construction starts for each state - climate zone combination.

Table 7.5. New Housing Construction Starts from the 2010 Census Data

State	Climate Zone	Single Family Permits	Multifamily Permits
Alabama	2	1,577	94
Alabama	3	5,531	764
Alabama	3WH	1,594	798
Alaska	7	601	41
Alaska	8	65	0
Arizona	2	9,409	719
Arizona	3	696	28
Arizona	4	307	58
Arizona	5	343	88
Arkansas	3	3,454	1,512
Arkansas	3WH	51	5
Arkansas	4	1,143	119
California	2	102	0
California	3B	21,167	6,513
California	3C	3,585	3,416
California	4B	384	3

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[1] DOE believes there is either an error or an anomaly in the source table resulting in a large overstatement in oil heating use in the West South Central region. The value, 52.9 percent, 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.

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

Table 7.5 (contd)

State	Climate Zone	Single Family Permits	Multifamily Permits
California	4C	196	13
California	5	233	21
California	6	26	0
Colorado	4	23	1
Colorado	5	7,760	1,514
Colorado	6	462	8
Colorado	7	545	26
Connecticut	5	2,632	569
Delaware	4	2,673	258
District Of Columbia	4	177	364
Florida	1	2,045	1,680
Florida	2	27,995	3,909
Georgia	2	2,915	501
Georgia	3	9,245	931
Georgia	3WH	1,487	133
Georgia	4	1,132	44
Hawaii	1	2,203	515
Idaho	5	2,669	154
Idaho	6	899	169
Illinois	4	1,736	538
Illinois	5	5,888	2,757
Indiana	4	1,924	188
Indiana	5	7,849	2,135
Iowa	5	4,956	1,100
Iowa	6	996	62
Kansas	4	3,926	796
Kansas	5	48	22
Kentucky	4	5,983	1,296
Louisiana	2	7,723	481
Louisiana	3	20	1
Louisiana	3WH	2,467	251
Maine	6	2,636	89
Maine	7	75	8
Maryland	4	8,394	2,227
Maryland	5	95	0
Massachusetts	5	5,839	1,417
Michigan	5	6,041	830
Michigan	6	1,426	84
Michigan	7	236	12
Minnesota	6	5,440	1,839
Minnesota	7	1,613	117
Mississippi	2	1,765	351
Mississippi	3	1,769	91

Table 7.5 (contd)

State	Climate Zone	Single Family Permits	Multifamily Permits
Mississippi	3WH	893	96
Missouri	4	6,660	1,922
Missouri	5	241	42
Montana	6	1,322	387
Nebraska	5	3,779	1,139
Nevada	3	4,623	471
Nevada	5	738	128
New Hampshire	5	1,146	213
New Hampshire	6	744	128
New Jersey	4	5,024	1,873
New Jersey	5	2,354	824
New Mexico	3	953	130
New Mexico	4	1,282	115
New Mexico	5	927	46
New York	4	1,810	2,964
New York	5	5,702	987
New York	6	2,447	257
North Carolina	3	9,552	2,358
North Carolina	3WH	3,657	373
North Carolina	4	12,419	2,263
North Carolina	5	419	80
North Dakota	6	789	191
North Dakota	7	1,295	1,037
Ohio	4	953	213
Ohio	5	9,650	1,968
Oklahoma	3	6,864	824
Oklahoma	4	2	0
Oregon	4	4,435	852
Oregon	5	741	36
Pennsylvania	4	3,821	540
Pennsylvania	5	12,472	710
Pennsylvania	6	593	0
Rhode Island	5	727	91
South Carolina	3	7,979	574
South Carolina	3WH	4,712	287
South Dakota	5	171	28
South Dakota	6	2,015	505
Tennessee	3	1,463	576
Tennessee	4	10,167	2,559
Texas	2B	44,064	7,604
Texas	2A	870	56
Texas	3B	314	234
Texas	3A	15,908	3,887
Texas	3AWH	5,181	1,842

Table 7.5 (contd)

State	Climate Zone	Single Family Permits	Multifamily Permits
Texas	4B	636	280
Utah	3	873	11
Utah	5	5,084	857
Utah	6	9,26	398
Vermont	6	980	148
Virginia	4	13,820	1,948
Washington	4	10,550	2,464
Washington	5	3,889	845
Washington	6	263	3
West Virginia	4	1,139	150
West Virginia	5	657	237
Wisconsin	6	6,735	2,216
Wisconsin	7	952	15
Wyoming	5	18	4
Wyoming	6	1,366	388
Wyoming	7	162	24

8.0 Summary of Results

8.1 Energy Cost Savings

Table 8.1 through Table 8.3 summarize the combined energy cost savings of the single-family and multifamily prototypes for the 2009 and 2012 IECC compared to the 2006 IECC at the national, climate zone, and state levels. Table 8.4 through Table 8.6 summarize the combined energy cost savings for the 2012 IECC compared to the 2009 IECC. The savings calculation includes only space heating, space cooling, domestic water heating, and lighting energy costs.

Table 8.1. National Energy Cost Savings for the 2009 and 2012 IECC Compared to the 2006 IECC

	2009 IECC	2012 IECC
National Energy Cost Savings over the 2006 IECC	10.8% ($ 168)	32.1% ($ 500)

Table 8.2. Energy Cost Savings by Climate Zone for the 2009 and 2012 IECC Compared to the 2006 IECC

Climate Zone	Energy Cost Savings over the 2006 IECC			
	2009 IECC		2012 IECC	
	Savings (%)	Savings ($)	Savings (%)	Savings ($)
Zone 1	9.6	213	25.1	557
Zone 2	12.8	186	26.3	383
Zone 3	12.3	164	34	454
Zone 4	9.4	143	32.7	498
Zone 5	9.5	167	33	577
Zone 6	10	200	36.2	725
Zone 7	10	215	37.6	807
Zone 8	10.3	502	38.3	1862

Table 8.3. Energy Cost Savings by State and Climate Zone for the 2009 and 2012 IECC Compared to the 2006 IECC

State - Climate Zone	Energy Cost Savings over the 2006 IECC			
	2009 IECC		2012 IECC	
	Savings (%)	Savings ($)	Savings (%)	Savings ($)
Alabama-2AWH	11.9	173	26.1	380
Alabama-3A	11.9	177	34.3	509
Alabama-3AWH	11.1	139	31.5	395
Alabama	11.8	168	32.4	462
Alaska-7A	10.1	324	37.2	1190
Alaska-8A	10.3	502	38.3	1862
Alaska	10.1	340	37.3	1251
Arizona-2B	13.8	240	27.5	478
Arizona-3B	12.8	220	37.7	650
Arizona-4B	9.1	131	33	473
Arizona-5B	8.6	117	28.6	391

Table 8.3. (contd)

State - Climate Zone	Energy Cost Savings over the 2006 IECC			
	2009 IECC		2012 IECC	
	Savings (%)	Savings ($)	Savings (%)	Savings ($)
Arizona	13.5	231	28.3	486
Arkansas-3A	11.7	146	35.9	448
Arkansas-3AWH	11.7	149	34.8	441
Arkansas-4A	10	151	35.7	539
Arkansas	11.3	147	35.8	466
California-2B	14.3	294	28.1	578
California-3B	13.8	138	28.5	286
California-3C	12.3	116	35.2	331
California-4B	8.5	144	29.7	504
California-4C	9.2	119	29.8	385
California-5B	8.9	163	28.9	531
California-6B	9.4	219	34.3	799
California	13.4	135	29.8	301
Colorado-4B	9.9	141	34.1	486
Colorado-5B	9.3	116	30.3	377
Colorado-6B	9.6	146	33.7	514
Colorado-7B	9.4	148	34.3	540
Colorado	9.3	119	30.7	392
Connecticut-5A	9.6	237	32.7	811
Connecticut	9.6	237	32.7	811
Delaware-4A	10.3	249	35.8	865
Delaware	10.3	249	35.8	865
DistrictofColumbia-4A	8.7	125	29.9	429
District of Columbia	8.7	125	29.9	429
Florida-1AWH	9.3	115	25	309
Florida-2AWH	13.3	190	25.1	360
Florida	12.9	182	25.1	355
Georgia-2AWH	12.2	166	26.1	354
Georgia-3A	12.3	184	35.4	530
Georgia-3AWH	11.6	168	32.8	474
Georgia-4A	8.5	125	29.7	436
Georgia	12	175	32.9	481
Hawaii-1A	9.7	347	25.1	897
Hawaii	9.7	347	25.1	897
Idaho-5B	9.1	108	31.1	369
Idaho-6B	9.9	133	35.8	481
Idaho	9.3	114	32.4	399
Illinois-4A	9.5	136	32.6	466
Illinois-5A	9.3	129	31.3	437
Illinois	9.3	130	31.6	443
Indiana-4A	9.6	130	34	459
Indiana-5A	9.5	131	33	454
Indiana	9.5	130	33.1	454
Iowa-5A	9.8	172	33.8	595
Iowa-6A	10.3	234	38.1	865
Iowa	9.8	181	34.5	635
Kansas-4A	9.9	155	34.9	544
Kansas-5A	9.4	133	32.4	461
Kansas	10	155	34.9	543
Kentucky-4A	10.1	143	34.9	492
Kentucky	10.1	143	34.9	492

Table 8.3. (contd)

State - Climate Zone	Energy Cost Savings over the 2006 IECC			
	2009 IECC		2012 IECC	
	Savings (%)	Savings ($)	Savings (%)	Savings ($)
Louisiana-2AWH	12.2	149	26.9	330
Louisiana-3A	12	152	34.9	443
Louisiana-3AWH	11.8	151	34.8	444
Louisiana	12	149	28.9	358
Maine-6A	10.2	294	37.7	1086
Maine-7A	10.2	370	39.1	1423
Maine	10.2	297	37.7	1097
Maryland-4A	9.7	202	33.3	691
Maryland-5A	9.8	274	34	954
Maryland	9.8	203	33.3	694
Massachusetts-5A	10.1	243	35.9	864
Massachusetts	10.1	243	35.9	864
Michigan-5A	10	206	34.9	717
Michigan-6A	10.4	233	37.4	836
Michigan-7A	10.3	248	38.1	921
Michigan	10.1	212	35.5	744
Minnesota-6A	10	192	36.3	700
Minnesota-7A	10.3	260	38.8	983
Minnesota	10	205	36.9	754
Mississippi-2AWH	11.9	146	25.8	317
Mississippi-3A	12.5	186	35.2	524
Mississippi-3AWH	11.8	161	33.3	456
Mississippi	12.1	164	31.2	422
Missouri-4A	9.6	142	34.1	504
Missouri-5A	9.4	168	33.8	605
Missouri	9.6	143	34.1	507
Montana-6B	9.6	125	34.1	444
Montana	9.6	125	34.1	444
Nebraska-5A	9.3	133	32	458
Nebraska	9.3	133	32	458
Nevada-3B	13.5	219	36.3	590
Nevada-5B	8.9	126	29.5	419
Nevada	12.8	205	35.4	565
NewHampshire-5A	9.3	223	33.1	795
NewHampshire-6A	9.9	265	35.8	959
New Hampshire	9.5	239	34.2	859
NewJersey-4A	10.1	216	34.5	741
NewJersey-5A	9.5	201	32.1	681
New Jersey	9.9	211	33.8	722
NewMexico-3B	13.3	191	38	545
NewMexico-4B	9	112	31.3	388
NewMexico-5B	8.9	110	27.7	343
New Mexico	10.5	137	32.7	425
NewYork-4A	9.3	161	31.2	543
NewYork-5A	10	269	34.5	925
NewYork-6A	10.2	277	36.4	985
New York	9.9	234	34.1	808
NorthCarolina-3A	11.6	151	33.5	437
NorthCarolina-3AWH	11.6	152	32.7	429
NorthCarolina-4A	8.8	118	30	403
NorthCarolina-5A	9.2	153	32.2	537

Table 8.3. (contd)

State - Climate Zone	Energy Cost Savings over the 2006 IECC			
	2009 IECC		2012 IECC	
	Savings (%)	Savings ($)	Savings (%)	Savings ($)
North Carolina	10.2	136	31.7	422
NorthDakota-6A	10	169	36.6	620
NorthDakota-7A	9.5	141	36.1	535
North Dakota	9.6	149	36.2	560
Ohio-4A	10	159	35.1	556
Ohio-5A	9.3	136	31.3	460
Ohio	9.4	139	31.7	469
Oklahoma-3A	12.5	190	39	591
Oklahoma-4B	10.1	145	35.4	508
Oklahoma	12.5	190	39	591
Oregon-4C	8.7	100	30.2	346
Oregon-5B	9.6	153	33.7	534
Oregon	8.8	106	30.8	370
Pennsylvania-4A	10.1	192	35.3	671
Pennsylvania-5A	9.3	204	33.1	724
Pennsylvania-6A	10	250	37.3	931
Pennsylvania	9.5	203	33.8	718
RhodeIsland-5A	9.8	249	34.6	878
Rhode Island	9.8	249	34.6	878
SouthCarolina-3A	11.8	176	34	507
SouthCarolina-3AWH	11.8	166	32.3	456
South Carolina	11.8	173	33.4	488
SouthDakota-5A	10	173	35.6	617
SouthDakota-6A	10.1	168	36.4	609
South Dakota	10	168	36.4	609
Tennessee-3A	12.1	154	34.7	442
Tennessee-4A	8.9	118	31.1	410
Tennessee	9.4	123	31.6	415
Texas-2AWH	12.4	182	26.6	389
Texas-2BWH	12.9	207	27.1	434
Texas-3A	12.2	180	36.4	537
Texas-3AWH	12	192	35.7	571
Texas-3B	12.4	165	33.9	452
Texas-4B	9.8	152	34.2	529
Texas	12.3	183	29.7	442
Utah-3B	14.7	198	37	498
Utah-5B	8.8	103	29.7	349
Utah-6B	8.9	97	31.3	340
Utah	9.5	112	30.8	363
Vermont-6A	10.2	297	37.3	1089
Vermont	10.2	297	37.3	1089
Virginia-4A	9.1	138	31.9	482
Virginia	9.1	138	31.9	482
Washington-4C	9.1	97	31.8	339
Washington-5B	9.8	148	34.7	522
Washington-6B	9.7	175	36.6	662
Washington	9.4	112	32.9	392
WestVirginia-4A	9.5	141	33.7	501
WestVirginia-5A	8.9	126	31.8	450
West Virginia	9.3	135	32.9	480
Wisconsin-6A	9.7	189	35.4	688

Table 8.3. (contd)

State - Climate Zone	Energy Cost Savings over the 2006 IECC			
	2009 IECC		2012 IECC	
	Savings (%)	Savings ($)	Savings (%)	Savings ($)
Wisconsin-7A	10.4	274	38.9	1022
Wisconsin	9.8	197	35.8	720
Wyoming-5B	9.5	123	32.8	426
Wyoming-6B	10.3	129	36.7	458
Wyoming-7B	9.6	144	36.2	540
Wyoming	10.3	131	36.6	466

Table 8.4. National Energy Cost Savings for the 2012 IECC Compared to the 2009 IECC

	2012 IECC
National Energy Cost Savings over the 2009 IECC	23.9% ($ 332)

Table 8.5. Energy Cost Savings by Climate Zone for the 2012 IECC Compared to the 2009 IECC

Climate Zone	Energy Cost Savings of the 2012 IECC over the 2009 IECC	
	Savings (%)	Savings ($)
Zone 1	17.1	344
Zone 2	15.5	197
Zone 3	24.8	290
Zone 4	25.7	355
Zone 5	25.9	410
Zone 6	29.2	525
Zone 7	30.6	592
Zone 8	31.2	1360

Table 8.6. Energy Cost Savings by State and Climate Zone for the 2012 IECC Compared to the 2009 IECC

State – Climate Zone	Energy Cost Savings of the 2012 IECC over the 2009 IECC	
	Savings (%)	Savings ($)
Alabama-2AWH	16.1	207
Alabama-3A	25.4	332
Alabama-3AWH	22.9	256
Alabama	23.4	294
Alaska-7A	30.1	866
Alaska-8A	31.2	1360
Alaska	30.3	911
Arizona-2B	15.9	238
Arizona-3B	28.6	430
Arizona-4B	26.3	342
Arizona-5B	21.9	274

Table 8.6. (contd)

State – Climate Zone	Energy Cost Savings of the 2012 IECC over the 2009 IECC	
	Savings (%)	Savings ($)
Arizona	17.2	255
Arkansas-3A	27.4	302
Arkansas-3AWH	26.1	292
Arkansas-4A	28.6	388
Arkansas	27.6	319
California-2B	16.1	284
California-3B	17.1	148
California-3C	26.1	215
California-4B	23.2	360
California-4C	22.7	266
California-5B	21.9	368
California-6B	27.5	580
California	19	166
Colorado-4B	26.9	345
Colorado-5B	23.1	261
Colorado-6B	26.7	368
Colorado-7B	27.5	392
Colorado	23.6	273
Connecticut-5A	25.6	574
Connecticut	25.6	574
Delaware-4A	28.4	616
Delaware	28.4	616
DistrictofColumbia-4A	23.2	304
District of Columbia	23.2	304
Florida-1AWH	17.3	194
Florida-2AWH	13.7	170
Florida	14.1	173
Georgia-2AWH	15.8	188
Georgia-3A	26.3	346
Georgia-3AWH	24	306
Georgia-4A	23.2	311
Georgia	23.8	306
Hawaii-1A	17	550
Hawaii	17	550
Idaho-5B	24.2	261
Idaho-6B	28.8	348
Idaho	25.5	285
Illinois-4A	25.5	330
Illinois-5A	24.3	308
Illinois	24.6	313
Indiana-4A	27	329
Indiana-5A	25.9	323
Indiana	26.1	324
Iowa-5A	26.6	423
Iowa-6A	31	631
Iowa	27.4	454
Kansas-4A	27.7	389
Kansas-5A	25.5	328
Kansas	27.7	388

Table 8.6. (contd)

State – Climate Zone	Energy Cost Savings of the 2012 IECC over the 2009 IECC	
	Savings (%)	Savings ($)
Kentucky-4A	27.6	349
Kentucky	27.6	349
Louisiana-2AWH	16.8	181
Louisiana-3A	26.1	291
Louisiana-3AWH	26.1	293
Louisiana	19.2	209
Maine-6A	30.6	792
Maine-7A	32.3	1053
Maine	30.7	800
Maryland-4A	26.1	489
Maryland-5A	26.8	680
Maryland	26.1	491
Massachusetts-5A	28.7	621
Massachusetts	28.7	621
Michigan-5A	27.7	511
Michigan-6A	30.1	603
Michigan-7A	31	673
Michigan	28.3	532
Minnesota-6A	29.3	508
Minnesota-7A	31.8	723
Minnesota	29.9	549
Mississippi-2AWH	15.8	171
Mississippi-3A	26	338
Mississippi-3AWH	24.4	295
Mississippi	21.7	258
Missouri-4A	27.1	362
Missouri-5A	26.9	437
Missouri	27.1	364
Montana-6B	27.1	319
Montana	27.1	319
Nebraska-5A	25	325
Nebraska	25	325
Nevada-3B	26.4	371
Nevada-5B	22.6	293
Nevada	25.9	360
NewHampshire-5A	26.3	572
NewHampshire-6A	28.7	694
New Hampshire	27.3	620
NewJersey-4A	27.2	525
NewJersey-5A	25	480
New Jersey	26.5	511
NewMexico-3B	28.5	354
NewMexico-4B	24.5	276
NewMexico-5B	20.6	233
New Mexico	24.7	288
NewYork-4A	24.2	382
NewYork-5A	27.2	656
NewYork-6A	29.2	708
New York	26.9	574

Table 8.6. (contd)

State – Climate Zone	Energy Cost Savings of the 2012 IECC over the 2009 IECC	
	Savings (%)	Savings ($)
NorthCarolina-3A	24.8	286
NorthCarolina-3AWH	23.9	277
NorthCarolina-4A	23.3	285
NorthCarolina-5A	25.4	384
North Carolina	24	286
NorthDakota-6A	29.6	451
NorthDakota-7A	29.4	394
North Dakota	29.4	411
Ohio-4A	27.8	397
Ohio-5A	24.3	324
Ohio	24.6	330
Oklahoma-3A	30.3	401
Oklahoma-4B	28.2	363
Oklahoma	30.3	401
Oregon-4C	23.5	246
Oregon-5B	26.6	381
Oregon	24.1	264
Pennsylvania-4A	28	479
Pennsylvania-5A	26.2	520
Pennsylvania-6A	30.3	681
Pennsylvania	26.8	515
RhodeIsland-5A	27.5	629
Rhode Island	27.5	629
SouthCarolina-3A	25.2	331
SouthCarolina-3AWH	23.3	290
South Carolina	24.4	315
SouthDakota-5A	28.5	444
SouthDakota-6A	29.3	441
South Dakota	29.3	441
Tennessee-3A	25.7	288
Tennessee-4A	24.3	292
Tennessee	24.5	292
Texas-2AWH	16.2	207
Texas-2BWH	16.3	227
Texas-3A	27.6	357
Texas-3AWH	26.9	379
Texas-3B	24.5	287
Texas-4B	27	377
Texas	19.8	259
Utah-3B	26.1	300
Utah-5B	23	246
Utah-6B	24.6	243
Utah	23.5	251
Vermont-6A	30.2	792
Vermont	30.2	792
Virginia-4A	25.1	344
Virginia	25.1	344
Washington-4C	25	242
Washington-5B	27.6	374

Table 8.6. (contd)

State – Climate Zone	Energy Cost Savings of the 2012 IECC over the 2009 IECC	
	Savings (%)	Savings ($)
Washington-6B	29.8	487
Washington	25.9	280
WestVirginia-4A	26.7	360
WestVirginia-5A	25.2	324
West Virginia	26.1	345
Wisconsin-6A	28.4	499
Wisconsin-7A	31.8	748
Wisconsin	28.8	523
Wyoming-5B	25.7	303
Wyoming-6B	29.4	329
Wyoming-7B	29.4	396
Wyoming	29.4	335

8.2 Cost Effectiveness

Table 8.7 and Table 8.8 summarize the life cycle cost savings of the 2009 and 2012 IECC compared to the 2006 IECC at the climate zone and state levels. Table 8.9 summarizes the life cycle cost savings of the 2012 IECC compared to the 2009 IECC.

Table 8.7. Life Cycle Cost Savings by Climate Zone for the 2009 and 2012 IECC compared to the 2006 IECC (2012 dollars)

	Life Cycle Cost Savings over the 2006 IECC ($)	
Climate Zone	2009 IECC	2012 IECC
Zone 1	2,877	8,256
Zone 2	2,443	4,763
Zone 3	1,944	5,720
Zone 4	2,259	7,706
Zone 5	2,486	9,229
Zone 6	3,114	11,366
Zone 7	3,622	13,166
Zone 8	9,147	33,105

Table 8.8. Life Cycle Cost Savings by State and Climate Zone for the 2009 and 2012 IECC compared to the 2006 IECC (2012 dollars)

	Life Cycle Cost Savings over the 2006 IECC ($)	
State - Climate Zone	2009 IECC	2012 IECC
Alabama-2AWH	2,149	4,666

Table 8.8. (contd)

State - Climate Zone	Life Cycle Cost Savings over the 2006 IECC ($) 2009 IECC	2012 IECC
Alabama-3A	2,250	6,992
Alabama-3AWH	1,679	5,113
Alabama	2,117	6,182
Alaska-7A	5,537	19,525
Alaska-8A	9,124	32,986
Alaska	5,861	20,745
Arizona-2B	3,386	6,339
Arizona-3B	2,946	9,353
Arizona-4B	2,017	7,223
Arizona-5B	1,538	5,727
Arizona	3,245	6,550
Arkansas-3A	1,814	6,167
Arkansas-3AWH	1,707	5,627
Arkansas-4A	2,491	8,742
Arkansas	1,948	6,679
California-2B	4,109	7,557
California-3B	1,187	1,711
California-3C	994	3,259
California-4B	2,106	7,168
California-4C	1,622	4,832
California-5B	2,251	7,978
California-6B	3,355	12,100
California	1,192	2,136
Colorado-4B	2,162	7,233
Colorado-5B	1,469	5,246
Colorado-6B	1,963	6,820
Colorado-7B	2,261	7,641
Colorado	1,528	5,435
Connecticut-5A	3,793	13,709
Connecticut	3,793	13,709
Delaware-4A	4,316	14,778
Delaware	4,316	14,778
District of Columbia-4A	2,024	6,852
District of Columbia	2,024	6,852
Florida-1AWH	1,203	3,870
Florida-2AWH	2,453	4,141
Florida	2,320	4,147
Georgia-2AWH	2,024	4,167
Georgia-3A	2,326	7,222
Georgia-3AWH	2,012	6,095
Georgia-4A	1,900	6,471
Georgia	2,210	6,415
Hawaii-1A	5,150	14,238

Table 8.8. (contd)

State - Climate Zone	Life Cycle Cost Savings over the 2006 IECC ($)	
	2009 IECC	2012 IECC
Hawaii	5,150	14,238
Idaho-5B	1,322	5,116
Idaho-6B	1,821	6,629
Idaho	1,444	5,515
Illinois-4A	2,058	6,839
Illinois-5A	1,728	6,419
Illinois	1,784	6,506
Indiana-4A	1,934	6,685
Indiana-5A	1,782	6,804
Indiana	1,781	6,764
Iowa-5A	2,655	9,764
Iowa-6A	3,773	14,134
Iowa	2,823	10,416
Kansas-4A	2,571	8,850
Kansas-5A	1,979	7,371
Kansas	2,556	8,828
Kentucky-4A	2,279	7,646
Kentucky	2,279	7,646
Louisiana-2AWH	1,665	3,621
Louisiana-3A	1,708	5,508
Louisiana-3AWH	1,722	5,622
Louisiana	1,663	4,107
Maine-6A	5,054	18,719
Maine-7A	6,798	25,830
Maine	5,109	18,944
Maryland-4A	3,453	11,627
Maryland-5A	4,620	16,781
Maryland	3,473	11,688
Massachusetts-5A	3,914	14,777
Massachusetts	3,914	14,777
Michigan-5A	3,255	12,029
Michigan-6A	3,707	13,331
Michigan-7A	4,241	15,263
Michigan	3,363	12,346
Minnesota-6A	2,905	10,737
Minnesota-7A	4,448	16,385
Minnesota	3,196	11,817
Mississippi-2AWH	1,716	3,605
Mississippi-3A	2,393	7,196
Mississippi-3AWH	1,955	5,933
Mississippi	2,022	5,400
Missouri-4A	2,224	7,766
Missouri-5A	2,494	9,779
Missouri	2,229	7,826

Table 8.8. (contd)

	Life Cycle Cost Savings over the 2006 IECC ($)	
State - Climate Zone	2009 IECC	2012 IECC
Montana-6B	1,668	5,920
Montana	1,668	5,920
Nebraska-5A	1,908	7,141
Nebraska	1,908	7,141
Nevada-3B	2,720	7,616
Nevada-5B	1,565	5,846
Nevada	2,543	7,352
New Hampshire-5A	3,616	13,673
New Hampshire-6A	4,423	16,024
New Hampshire	3,925	14,573
New Jersey-4A	3,638	12,221
New Jersey-5A	3,078	11,094
New Jersey	3,445	11,877
NewMexico-3B	2,472	7,501
NewMexico-4B	1,631	5,483
NewMexico-5B	1,368	4,650
New Mexico	1,835	5,897
NewYork-4A	2,675	8,890
NewYork-5A	4,474	16,071
NewYork-6A	4,537	16,124
New York	3,870	13,677
NorthCarolina-3A	1,830	5,738
NorthCarolina-3AWH	1,769	5,399
NorthCarolina-4A	1,826	6,050
NorthCarolina-5A	2,354	8,878
North Carolina	1,844	5,911
NorthDakota-6A	2,545	9,518
NorthDakota-7A	2,283	8,416
North Dakota	2,353	8,719
Ohio-4A	2,561	8,834
Ohio-5A	1,887	6,939
Ohio	1,959	7,120
Oklahoma-3A	2,526	8,621
Oklahoma-4B	2,318	7,958
Oklahoma	2,526	8,621
Oregon-4C	1,341	4,428
Oregon-5B	2,139	8,217
Oregon	1,422	4,917
Pennsylvania-4A	3,187	10,923
Pennsylvania-5A	3,160	11,996
Pennsylvania-6A	4,009	15,015
Pennsylvania	3,189	11,845
RhodeIsland-5A	4,043	15,074
Rhode Island	4,043	15,074

Table 8.8. (contd)

State - Climate Zone	Life Cycle Cost Savings over the 2006 IECC ($) 2009 IECC	2012 IECC
SouthCarolina-3A	2,276	7,034
SouthCarolina-3AWH	2,071	5,999
South Carolina	2,215	6,650
SouthDakota-5A	2,734	10,369
SouthDakota-6A	2,583	9,473
South Dakota	2,583	9,514
Tennesse-3A	1,863	5,795
Tennesse-4A	1,804	6,114
Tennessee	1,809	6,102
Texas-2AWH	2,394	4,933
Texas-2BWH	2,821	5,705
Texas-3A	2,558	8,117
Texas-3AWH	2,637	8,363
Texas-3B	2,127	6,069
Texas-4B	2,536	8,705
Texas	2,433	5,942
Utah-3B	2,420	6,280
Utah-5B	1,278	4,863
Utah-6B	1,163	4,102
Utah	1,385	4,879
Vermont-6A	5,133	18,861
Vermont	5,133	18,861
Virginia-4A	2,186	7,487
Virginia	2,186	7,487
Washington-4C	1,255	4,223
Washington-5B	2,059	8,029
Washington-6B	2,502	9,533
Washington	1,498	5,299
WestVirginia-4A	2,184	7,627
WestVirginia-5A	1,729	6,852
West Virginia	1,996	7,301
Wisconsin-6A	2,883	10,652
Wisconsin-7A	4,731	17,223
Wisconsin	3,056	11,272
Wyoming-5B	1,675	6,404
Wyoming-6B	1,754	6,268
Wyoming-7B	2,238	7,977
Wyoming	1,809	6,441

Table 8.9. Life Cycle Cost Savings by State and Climate Zone for the 2012 IECC compared to the 2009 IECC (2012 dollars)

State - Climate Zone	Life Cycle Cost Savings over the 2009 IECC ($)
Alabama-2AWH	2447
Alabama-3A	4672
Alabama	3996
Alaska-7A	13922
Alaska-8A	23806
Alaska	14819
Arizona-2B	2926
Arizona-3B	6322
Arizona-4B	5146
Arizona-5B	4187
Arizona	3255
Arkansas-3A	4294
Arkansas-3AWH	3850
Arkansas-4A	6222
Arkansas	4680
California-2B	3377
California-3B	438
California-3C	2200
California-4B	4995
California-4C	3139
California-5B	5706
California-6B	8721
California	878
Colorado-4B	5019
Colorado-5B	3768
Colorado-6B	4833
Colorado-7B	5343
Colorado	3895
Connecticut-5A	9903
Connecticut	9903
Delaware-4A	10409
Delaware	10409
District of Columbia-4A	4796
District of Columbia	4796
Florida-1AWH	2641
Florida-2AWH	1639
Florida	1769
Georgia-2AWH	2088

Table 8.9 (contd)

State - Climate Zone	Life Cycle Cost Savings over the 2009 IECC ($)
Georgia-3A	4822
Georgia-3AWH	3998
Georgia-4A	4523
Georgia	4136
Hawaii-1A	9044
Hawaii	9044
Idaho-5B	3786
Idaho-6B	4798
Idaho	4057
Illinois-4A	4726
Illinois-5A	4687
Illinois	4704
Indiana-4A	4704
Indiana-5A	5032
Indiana	4966
Iowa-5A	7105
Iowa-6A	10349
Iowa	7573
Kansas-4A	6235
Kansas-5A	5403
Kansas	6234
Kentucky-4A	5321
Kentucky	5321
Louisiana-2AWH	1911
Louisiana-3A	3726
Louisiana-3AWH	3818
Louisiana	2386
Maine-6A	13639
Maine-7A	18995
Maine	13803
Maryland-4A	8127
Maryland-5A	12162
Maryland	8169
Massachusetts-5A	10848
Massachusetts	10848
Michigan-5A	8753
Michigan-6A	9591
Michigan-7A	10993
Michigan	8972
Minnesota-6A	7821

Table 8.9 (contd)

State - Climate Zone	Life Cycle Cost Savings over the 2009 IECC ($)
Minnesota-7A	11880
Minnesota	8592
Mississippi-2AWH	1847
Mississippi-3A	4723
Mississippi-3AWH	3908
Mississippi	3334
Missouri-4A	5496
Missouri-5A	7262
Missouri	5539
Montana-6B	4244
Montana	4244
Nebraska-5A	5224
Nebraska	5224
Nevada-3B	4806
Nevada-5B	4288
Nevada	4736
New Hampshire-5A	10054
New Hampshire-6A	11570
New Hampshire	10635
New Jersey-4A	8546
New Jersey-5A	8009
New Jersey	8393
New Mexico-3B	4954
New Mexico-4B	3803
New Mexico-5B	3293
New Mexico	4015
New York-4A	6175
New York-5A	11593
New York-6A	11543
New York	9777
North Carolina-3A	3846
North Carolina-3AWH	3546
North Carolina-4A	4189
North Carolina-5A	6521
North Carolina	4022
North Dakota-6A	6946
North Dakota-7A	6102
North Dakota	6345
Ohio-4A	6209
Ohio-5A	5044

Table 8.9 (contd)

State - Climate Zone	Life Cycle Cost Savings over the 2009 IECC ($)
Ohio	5151
Oklahoma-3A	6025
Oklahoma-4B	5593
Oklahoma	6025
Oregon-4C	3055
Oregon-5B	6076
Oregon	3450
Pennsylvania-4A	7697
Pennsylvania-5A	8844
Pennsylvania-6A	10990
Pennsylvania	8632
Rhode Island-5A	11011
Rhode Island	11011
South Carolina-3A	4690
South Carolina-3AWH	3842
South Carolina	4366
SouthDakota-5A	7634
South Dakota-6A	6862
South Dakota	6910
Tennessee-3A	3865
Tennessee-4A	4280
Tennessee	4217
Texas-2AWH	2505
Texas-2BWH	2828
Texas-3A	5485
Texas-3AWH	5662
Texas-3B	3886
Texas-4B	6118
Texas	3456
Utah-3B	3789
Utah-5B	3580
Utah-6B	2895
Utah	3479
Vermont-6A	13699
Vermont	13699
Virginia-4A	5255
Virginia	5255
Washington-4C	2922
Washington-5B	5983
Washington-6B	6999

Table 8.9 (contd)

State - Climate Zone	Life Cycle Cost Savings over the 2009 IECC ($)
Washington	3778
West Virginia-4A	5393
West Virginia-5A	5126
West Virginia	5270
Wisconsin-6A	7738
Wisconsin-7A	12445
Wisconsin	8186
Wyoming-5B	4722
Wyoming-6B	4475
Wyoming-7B	5702
Wyoming	4592

8.3 Cost-Effectiveness Reports

National and state IECC cost-effectiveness results from this analysis are published online and are available for download on the energy codes website.[1]

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[1] http://www.energycodes.gov/development/residential/iecc_analysis.

9.0 References

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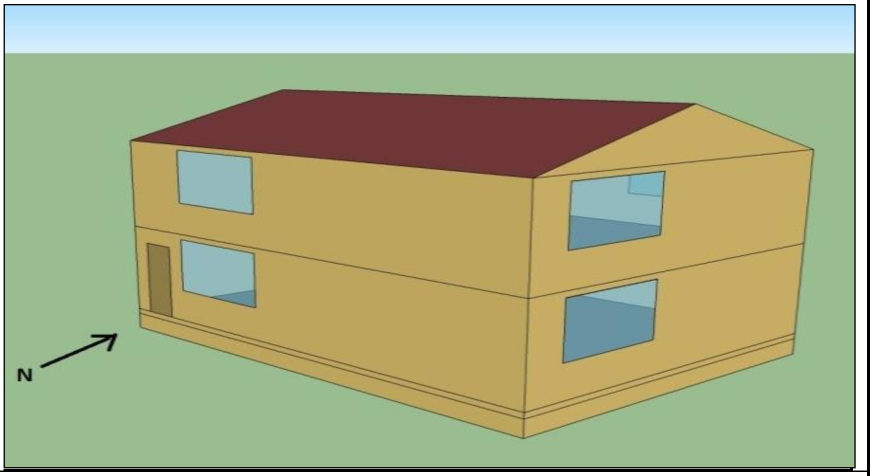
Appendix A

Building Energy Model Description

A.1 Single-Family Prototype Modeling Description

A.1

	Item	Description	Data Source
General			
	Vintage	New Construction	
	Locations	See under the ‘2.2 Climate Locations’	Reference: Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes
	Available fuel types	Natural Gas/Electricity/Fuel Oil	
	Building Type (Principal Building Function)	Residential	
	Building Prototype	Single-family Detached	
Form			
	Total Floor Area (sq. feet)	2,400 (30' x 40' x 2 stories)	Reference: Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes
	Building shape		
	Aspect Ratio	1.33	

	Item	Description	Data Source
	Number of Floors	2	
	Window Fraction (Window-to-Floor Ratio)	Average Total: 15.0% divided equally among all facades	Reference: Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes
	Window Locations	All facades	
	Shading Geometry	none	
	Orientation	Back of the house faces North (see image)	
	Thermal Zoning	The house is divided into three thermal zones: 'living space', 'attic' and 'crawlspace', 'heated basement', 'unheated basement' when applicable.	
	Floor to ceiling height	8.5’	
Architecture			
	Exterior walls		
	Construction	Wood-Frame Walls (2x4 16" O.C. or 2x6 24" O.C.) 1" Stucco + Building Paper Felt + Insulating Sheathing (if applicable) + 5/8" Oriented Strand Board + Wall Insulation + 1/2" Drywall	
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	IECC Requirements Residential; Walls, above grade, Wood Frame	IECC
	Dimensions	40' x 8'6" and 30' x 8'6"	
	Tilts and orientations	Vertical	
	Roof		
	Construction	Asphalt Shingles	
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	IECC Requirements Residential; Ceiling R value	IECC

	Item	Description	Data Source
	Tilts and orientations	Gabled Roof with a Slope of 4/12	
	Window		
	Dimensions	based on window fraction, location, floor area and aspect ratio	
	Glass-Type and frame	Hypothetical window with the exact U-factor and SHGC shown below	
	U-factor (Btu / h * ft^2 * °F)	IECC Requirements Residential; Glazing	IECC
	SHGC (all)		
	Skylight		
	Dimensions	Not Modeled	
	Glass-Type and frame	NA	
	U-factor (Btu / h * ft^2 * °F)		
	SHGC (all)		
	Visible transmittance		
	Foundation		
	Foundation Type	Four Foundation Types are Modeled- i. Slab-on Grade ii. Vented Crawlspace Depth 2' iii. Heated Basement - Depth 7' iv. Unheated Basement- Depth 7'	Reference: Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes
	Insulation level	IECC Requirements for floors, slabs and basement walls	IECC
	Dimensions	based on floor area and aspect ratio	
	Internal Mass	8 lbs/ft2 of floor area	IECC 2006 section 404

	Item	Description	Data Source
	Infiltration (ACH)	2006 IECC: 8 Air Changes/Hour at 50 Pa 2009 IECC: 7 Air Changes/Hour at 50 Pa 2012 IECC: 5 or 3 Air Changes/Hour at 50 Pa depending on climate zone	
HVAC			
	System Type		
	Heating type	Four Heating System Types are Modeled- i. Gas Furnace ii. Oil Furnace iii. Electric Furnace iv. Heat Pump	Reference: Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes
	Cooling type	Central DX Air-Conditioner/Heat Pump	
	HVAC Sizing		
	Cooling	autosized to design day	
	Heating	autosized to design day	
	HVAC Efficiency		
	Air Conditioning	SEER 13	Federal minimum efficiency
	Heating	AFUE 78% / HSPF 7.7	Federal minimum efficiency
	HVAC Control		
	Thermostat Setpoint	75°F Cooling/72°F Heating	
	Thermostat Setback	No setback	
	Supply air temperature	Maximum 110 F, Minimum 52 F	

	Item	Description	Data Source
	Ventilation	60 CFM Outdoor Air; Continuous Supply	2012 IRC
	Supply Fan		
	Fan schedules	See Appendix A.4	
	Supply Fan Total Efficiency (%)	Fan Efficiency 58%; Motor efficiency 65% (PSC motor)	Residential Furnaces aand Centralized Air Condtioners and Heat Pumps Direct Final Rule Technical Support Document.[1]
	Supply Fan Pressure Drop	1.6" w.g.	
	Domestic Hot Water		
	DHW type	Individual Residential Water Heater with Storage Tank	
	Fuel type	Natural Gas/Electricity	
	Thermal efficiency (%)	EF = 0.59 for Gas-fired Water Heaters EF = 0.917 for Electric Water Heaters	Federal minimum efficiency
	Tank Volume (gal)	40 for Gas-fired Water Heaters 52 for Electric Water Heaters	Reference: Building America Research Benchmark
	Water temperature set-point	120 F	
	Schedules	See Appendix A.4	
Internal Loads & Schedules			
	Lighting		
	Average interior power density (W/ft^2)	Living space: Lighting Power Density is 0.68 W/sq.ft for the 2006 IECC - See '4.4 Lighting' for the detailed calculations	Reference: 2010 Building America House Simulation Prototcols

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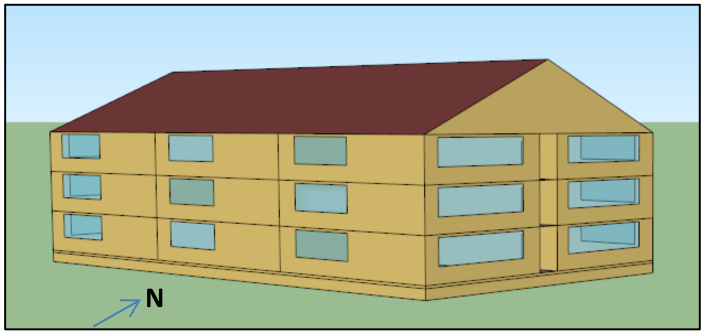
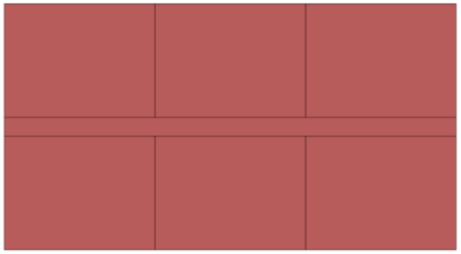
[1] Residential Furnaces and Central Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document – Chapter 7 'Energy Use Characterization' http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/hvac_ch_07_energy-use_2011-04-25.pdf

	Item	Description	Data Source
	Interior Lighting Schedule	See Appendix A.4	
	Internal Gains		
	Load (Btu/day)	17,900 + 23.8 x CFA + 4104 x Nbr See under '4.3 Internal Gains' for the detailed calculations	Reference: IECC 2006 and Building America Research Benchmark
	Internal gains Schedule(s)	See Appendix A.4	
	Occupancy		
	Number of people	3	
	Occupancy Schedule	See Appendix A.4	
	Exterior Lighting		
	Annual Energy (kWh)	348 for the 2006 IECC	Reference: 2010 Building America House Simulation Prototcols
	Exterior lighting Schedule	See Appendix A.4	
	Garage Lighting		
	Annual Energy (kWh)	40 for the 2006 IECC	Reference: 2010 Building America House Simulation Prototcols
	Garage Lighting Schedule	See Appendix A.4	

A.2 Multifamily Prototype Modeling Description

	Item	Description	Data Source
General			
	Vintage	New Construction	
	Location	See under ‘2.2 Climate Locations’	Reference: Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes
	Available Fuel Types	Natural Gas/Electricity/Fuel Oil	
	Building Type	Residential	
	Building Prototype	Low-rise Multifamily	
Form			
	Total Floor Area	Whole Building- 23,400 sq.ft Each Dwelling Unit - 1200 sq.ft	
	Building Shape		Reference: Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes
	Aspect Ratio	Whole Building- 1.85 Each Dwelling Unit - 1.33	
	Number of Floors	3	
	Number of Units per Floor	6	
	Orientation	Back of the house faces North (see image)	
	Dimensions	Whole Building - 120' x 65' x 25'6" Each Dwelling Unit - 40' x 30' x 8'6"	
	Conditioned Floor Area	Each Dwelling Unit- 1200 sq.ft	

	Item	Description	Data Source
	Window Area (Window-to- Exterior Wall Ratio)	23% WWR (Does not include breezeway walls)	
	Exterior Door Area	Each Dwelling Unit - 21 sq.ft Whole Building - 378 sq.ft	
	Shading Geometry	None	
	Thermal Zoning	Each floor has 6 dwelling units with a breezeway in the center. Each dwelling unit is modeled as a separate zone. The other thermal zones are: attic, breezeway and foundation (basements and crawlspace only)	
			
	Floor to ceiling height	8.5’	
Architecture			
	Exterior walls		
	Construction	Wood-Frame Walls (2x4 16" O.C. or 2x6 24" O.C.) 1" Stucco + Building Paper Felt + Insulating Sheathing (if applicable) + 5/8" Oriented Strand Board + Wall Insulation + 1/2" Drywall	
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	IECC Requirements Residential; Wood Frame Wall R-Value	IECC
	Dimensions	Each Dwelling Unit: 40' x 8'6" and 30' x 8'6"	
	Tilts and orientations	Vertical	
	Roof		

	Item	Description	Data Source
	Construction	Asphalt Shingles	
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	IECC Requirements Residential; Ceiling R value	IECC
	Tilts and orientations	Gabled Roof with a Slope of 4/12	
	Window		
	Dimensions	based on window fraction, location, glazing sill height, floor area and aspect ratio	
	Glass-Type and frame	Hypothetical window with the exact U-factor and SHGC shown below.	
	U-factor (Btu / h * ft^2 * °F)	IECC Requirements Fenestration U-Factor & SHGC	
	SHGC (all)		
	Skylight		
	Dimensions	Not Modeled	
	Glass-Type and frame	NA	
	U-factor (Btu / h * ft^2 * °F)		
	SHGC (all)		
	Visible transmittance		
	Foundation		
	Foundation Type	Four Foundation Types are Modeled- i. Slab-on Grade ii. Vented Crawlspace Depth 2' iii. Heated Basement - Depth 7' iv. Unheated Basement- Depth 7'	Reference: Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes
	Insulation level	IECC Requirements for floors, slabs and basement walls	
	Dimensions	based on floor area and aspect ratio	
	Internal Mass	8 lbs/ft2 of floor area	IECC 2006 section 404

	Item	Description	Data Source
	Infiltration (ACH)	2006 IECC: 8 Air Changes/Hour at 50 Pa 2009 IECC: 7 Air Changes/Hour at 50 Pa 2012 IECC: 5 or 3 Air Changes/Hour at 50 Pa depending on climate zone	
HVAC			
	System Type		
	Heating type	Four Heating System Types are Modeled- i. Gas Furnace ii. Oil Furnace iii. Electric Furnace iv. Heat Pump	
	Cooling type	Central DX Air-Conditioner/Heat Pump (1 per unit)	
	HVAC Sizing		
	Cooling	autosized to design day	
	Heating	autosized to design day	
	HVAC Efficiency		
	Air Conditioning	SEER 13	Federal Minimum Equipment Efficiency for Air Conditioners and Condensing Units
	Heating	AFUE 78% / HSPF 7.7	Federal Minimum Equipment Efficiency
	HVAC Control		
	Thermostat Setpoint	75°F Cooling/72°F Heating	
	Thermostat Setback	No setback	
	Supply air temperature	Maximum 110 F, Minimum 52 F	
	Ventilation	45 CFM Outdoor Air per dwelling unit; Continuous Supply	2012 International Mechanical Code (IMC)
	Supply Fan		
	Fan schedules	See Appendix A.4	

	Item	Description	Data Source
	Supply Fan Total Efficiency (%)	Fan efficiency 58%; Motor efficiency 65% (PSC motor)	Residential Furnaces and Centralized Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document[1]
	Supply Fan Pressure Drop	1.6" w.g.	
	Service Water Heating		
	SWH type	Individual Residential Water Heater with Storage Tank	
	Fuel type	Natural Gas / Electricity	
	Thermal efficiency (%)	EF = 0.59 for Gas-fired Water Heaters EF = 0.917 for Electric Water Heaters	Federal Minimum Equipment Efficiency
	Tank Volume (gal)	40	
	Water temperature set-point	120 F	
	Schedules	See Appendix A.4	
Internal Loads & Schedules			
	Lighting		
	Average power density (W/ft^2)	Dwelling unit units: Lighting Power Density is 0.82 W/sq.ft (For interior lighting) for the 2006 IECC See ’4.4 Lighting’ for the detailed calculations	2010 Building America House Simulation Prototcols
	Interior Lighting Schedule	See Appendix A.4	
	Internal Gains		
	Internal Gains (Btu/day per Dwelling Unit)	17,900 + 23.8 x CFA + 4104 x N_{br} See ’4.3 Internal Gains’ for the detailed calculations	

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[1] Residential Furnaces and Centralized Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document: Chapter 7 ‘Energy Use Characterization’ Residential Furnaces and Centralized Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document

	Item	**Description**	**Data Source**
	Internal Gains Schedule(s)	See under Appendix A.4	
	Occupancy		
	Average people	2	
	Occupancy Schedule	See Appendix A.4	
Misc.			
	Exterior Lighting		
	Annual energy (kWh)	174 for the 2006 IECC	
	Exterior Lighting Schedule	See Appendix A.4	
	Garage Lighting		
	Annual energy (kWh)	24 for the 2006 IECC	
	Garage Lighting Schedule	See Appendix A.4	

A.3 Internal Gains Assumptions

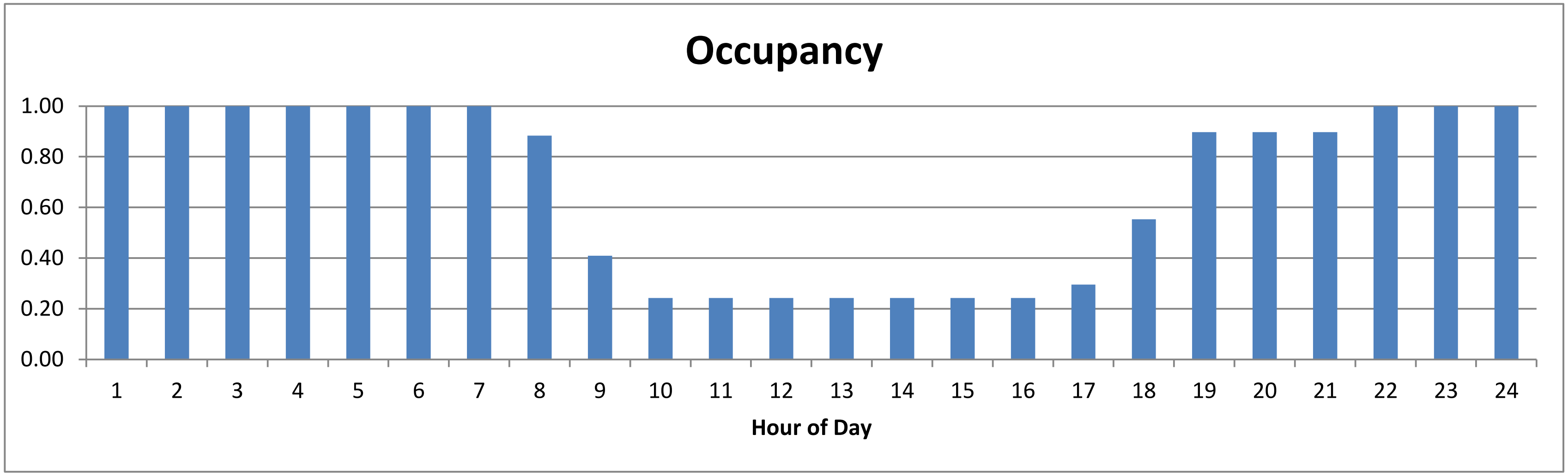
A.3.1 Total Internal Gains for the single-family prototype for the 2006, 2009 and 2012 IECC

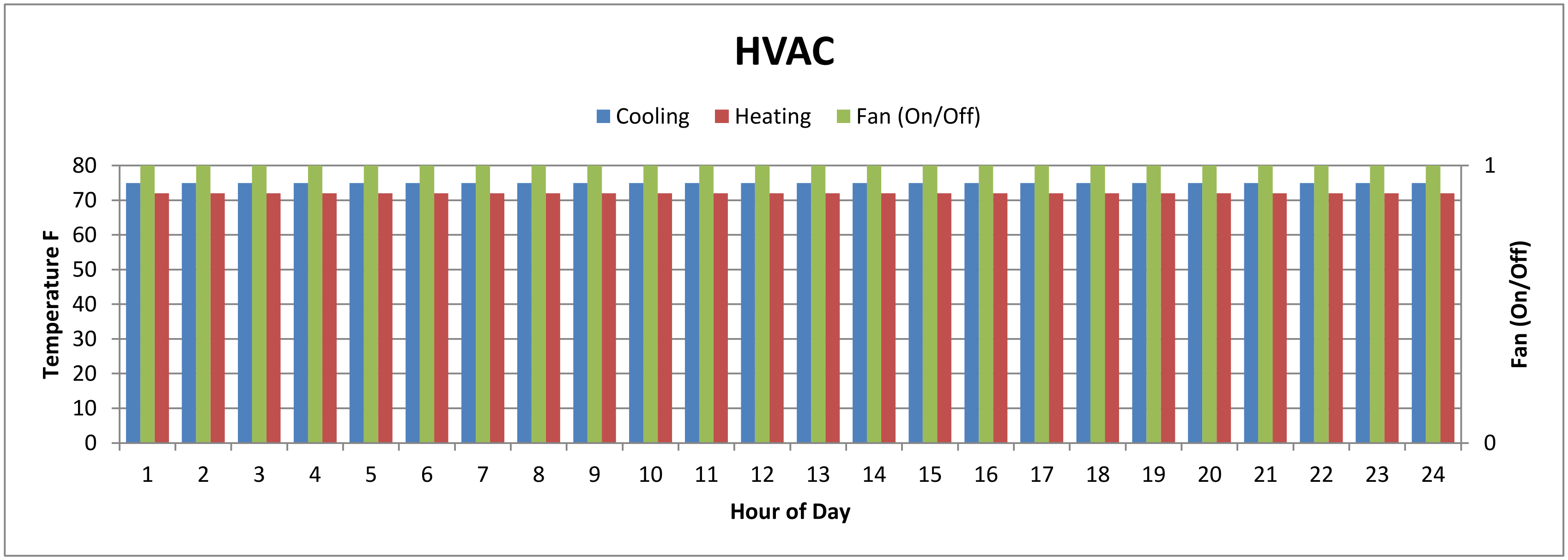
Appliance	Power	Total Electricity (kWh/yr)	Fraction Sensible	Fraction Latent	Fraction of electricity use not turned into heat	Internal Heat Gains (kWh/yr)		
						2006 IECC	**2009 IECC**	**2012 IECC**
Refrigerator	91.09 W	668.90	1.00	0.00	0.00	669	669	669
Clothes Washer	29.6 W	109.16	0.80	0.00	0.20	87	87	87
Clothes Dryer	222.11 W	868.15	0.15	0.05	0.80	174	174	174
Dishwasher	68.33 W	214.16	0.60	0.15	0.25	161	161	161
Range	248.97 W	604.90	0.40	0.30	0.30	423	423	423
Misc. Plug Load	0.228 W/sq.ft	3238.13	0.69	0.06	0.25	2429	2429	2429
Miscellaneous Electric Loads	182.5 W	1598.00	0.69	0.06	0.25	1199	1199	1199
IECC adjustment factor	0.0275 W/sq.ft	390.56	0.69	0.06	0.25	293	293	293
Lighting			1.00	0.00	0.00	1635	1345	1164
Occupants	3 Occupants					2123	2123	2123
Total					**kWh/yr**	**9192**	**8902**	**8721**
					kBtu/yr	**31362**	**30373**	**29755**
					Btu/day	**85924**	**83213**	**81522**

A.3.2 Total Internal Gains for the multifamily prototype for the 2006, 2009 and 2012 IECC (per dwelling unit)

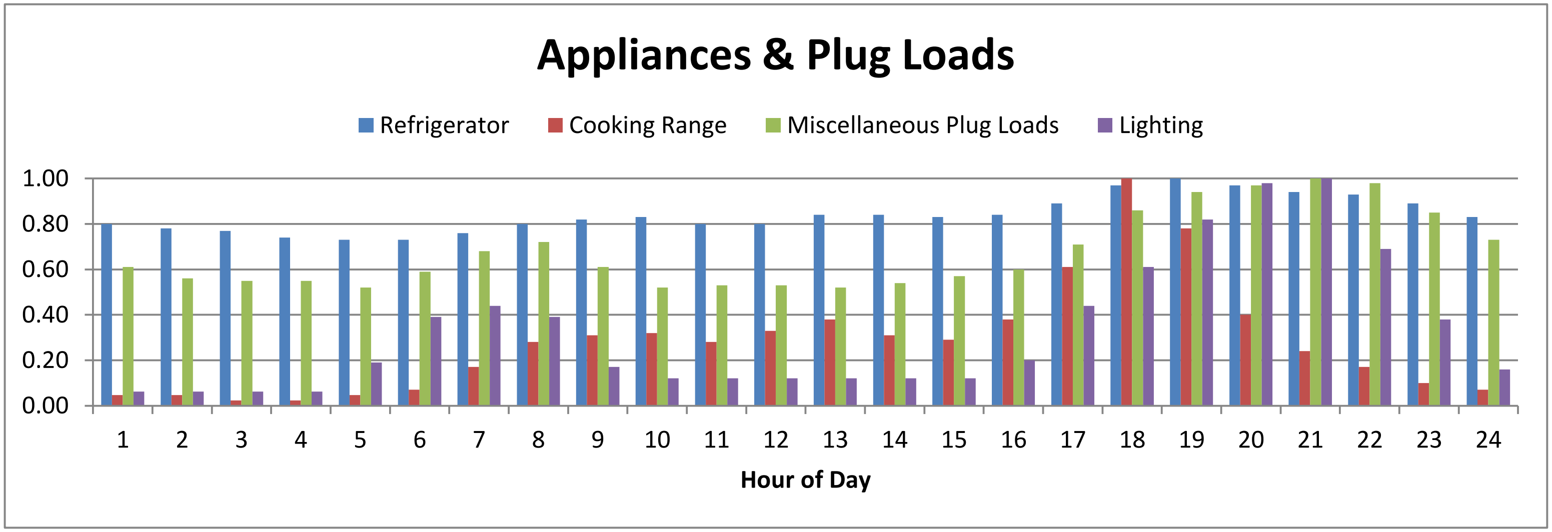
Appliance	Power	Total Electricity (kWh/yr)	Fraction Sensible	Fraction Latent	Fraction of electricity use not turned into heat	Internal Heat Gains (kWh/yr)		
						2006 IECC	**2009 IECC**	**2012 IECC**
Refrigerator	91.09 W	668.90	1.00	0.00	0	669	669	669
Clothes Washer	29.6 W	109.16	0.80	0.00	0.2	87	87	87
Clothes Dryer	222.11 W	868.15	0.15	0.05	0.8	174	174	174
Dishwasher	68.33 W	214.16	0.60	0.15	0.25	161	161	161
Range	248.97 W	604.00	0.40	0.30	0.3	423	423	423
Misc. Plug Load	0.228 W/sq.ft	1619.00	0.69	0.06	0.25	1214	1214	1214
Miscellaneous Electric Loads	121.88 W	1067.00	0.69	0.06	0.25	800	800	800
IECC adjustment factor	0.0275 W/sq.ft	195.28	0.69	0.06	0.25	146	146	146
Lighting			1.00	0.00	0	493	405	351
Occupants	2 Occupants					1416	1416	1416
Total					**kWh/yr**	**5582**	**5495**	**5440**
					kBtu/yr	**19046**	**18748**	**18562**
					Btu/Day	**52181**	**51364**	**50855**

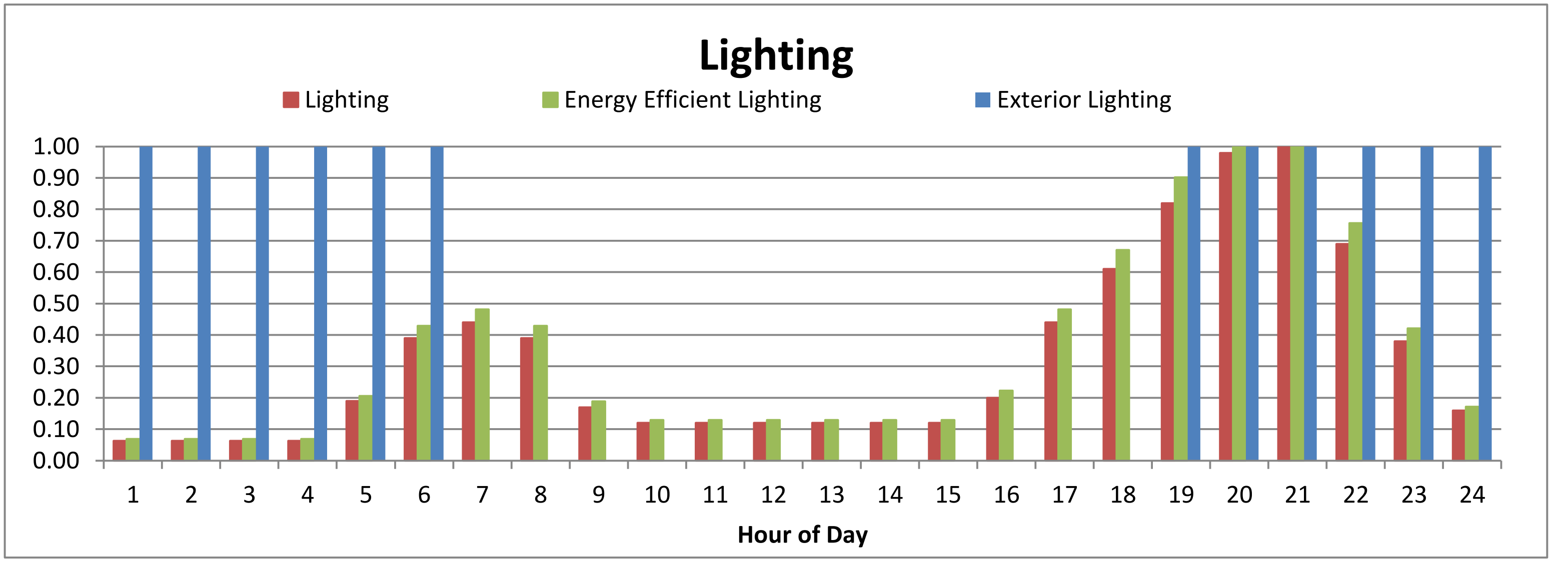
A.4 Schedules





A.16


Appliances & Plug Loads
Refrigerator
Cooking Range
Miscellaneous Plug Loads
Lighting
1.00
0.80
0.60
0.40
0.20
0.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Hour of Day


Lighting
Lighting
Energy Efficient Lighting
Exterior Lighting
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
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3
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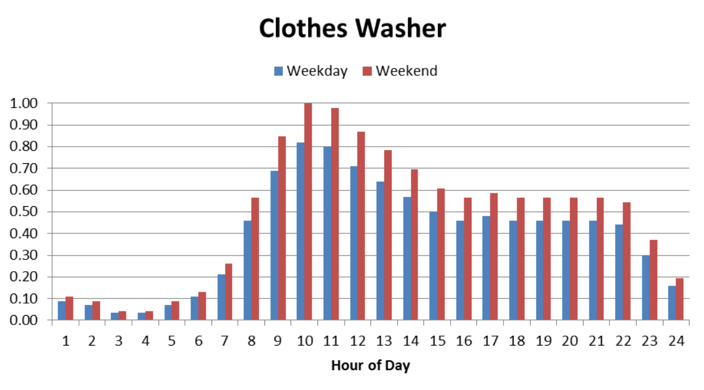
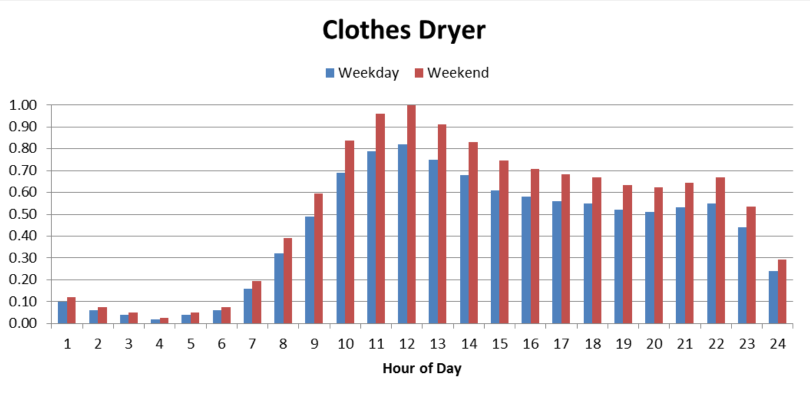
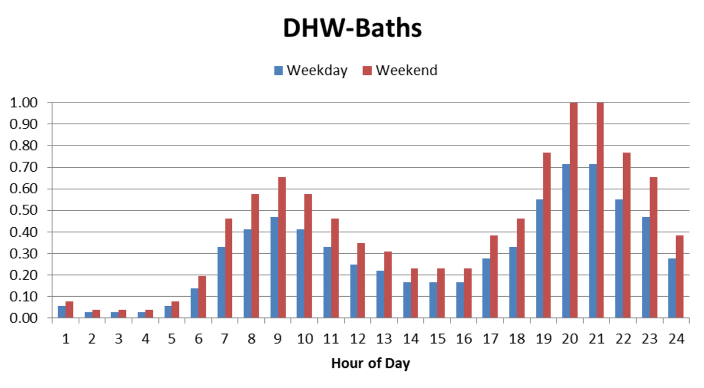
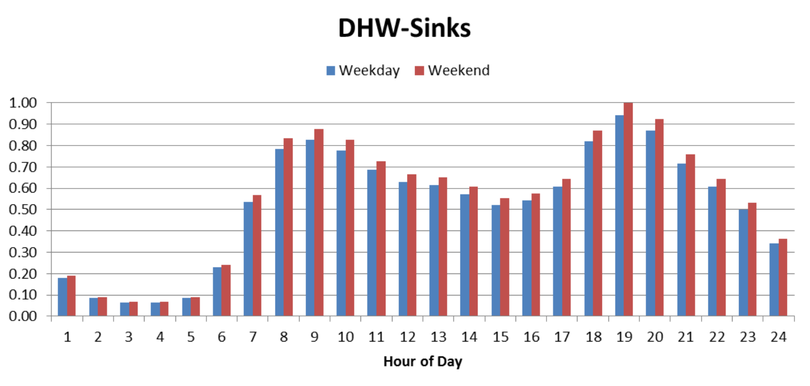
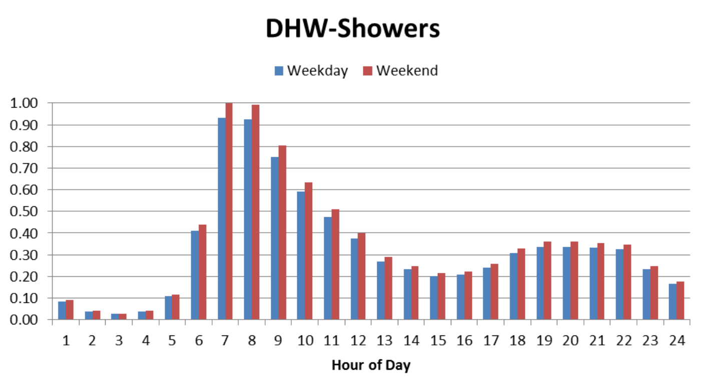
Hour of Day


Clothes Washer


Clothes Dryer


DHW-Baths


DHW-Sinks


DHW-Showers

Appendix B

Major Prescriptive Code Requirements for the 2006 IECC, the 2009 IECC, and the 2012 IECC

Table B.1.

		Components										
				Fenestration (Windows and Doors)								
Climate Zone	IECC	Ceiling (R-value)	Skylight (U-factor)	U-factor	SHGC	Wood Frame Wall (R-value)	Mass Wall(a) (R-value)	Floor (R-value)	Basement Wall(b) (R-value)	Tested Max Air Leakage Rate (air changes per hour)	Slab(c) (R-value and depth)	Crawl Space(b) (R-value)
1	2006	30	0.75	NR	0.4	13	3/4	13	NR	NR	NR	NR
	2009				0.3					NR		
	2012				0.25					5		
2	2006	30	0.75	0.75	0.4	13	4/6	13	NR	NR	NR	NR
	2009	30	0.75	0.65	0.3					NR		
	2012	38	0.65	0.4	0.25					5		
3	2006	30	0.65	0.65	0.4	13	5/8	19	0	NR	NR	5/13
	2009	30	0.65	0.5	0.3	13	5/8		5/13(d)	NR		
	2012	38	0.55	0.35	0.25	20	8/13		5/13(d)	3		
4	2006	38	0.6	0.4	NR	13	5/13	19	10/13	NR	10, 2 ft	10/13
	2009	38	0.6	0.35		13	5/10		10/13	NR		10/13
	2012	49	0.55	0.35	0.4	20	8/13		10/13	3		10/13
5	2006	38	0.6	0.35	NR	19	13/19	30	10/13	NR	10, 2 ft	10/13
	2009	38	0.6	0.35		20	13/17		10/13	NR		10/13
	2012	49	0.55	0.32		20	15/19		15/19	3		15/19
6	2006	49	0.6	0.35	NR	19	10/13	30	10/13	NR	10, 4 ft	10/13
	2009		0.6	0.35		20	15/19		15/19	NR		10/13
	2012		0.55	0.32		20+5	15/19		15/19	3		15/19
7 and 8	2006	49	0.6	0.35	NR	21	19/21	30	10/13	NR	10, 4 ft	10/13
	2009		0.6	0.35		21		38	15/19	NR		10/13
	2012		0.55	0.32		20+5		38	15/19	3		15/19

(a) The second number applies when more than half the insulation is on the interior side of the high mass material in the wall.

(b) The first number is for continuous insulation (e.g., a board or blanket directly on the foundation wall) and the second number is for cavity insulation (i.e., if there is a furred-out wall built against the foundation wall). Only one of these two has to be met.

(c) The first number is R-value. The second value refers to the vertical depth of the insulation around the perimeter.

(d) Basement wall insulation is not required in the warm-humid region of Zone 3 in the southeastern United States.

IECC = International Energy Conservation Code.
NR = Not required.
SHGC = Solar heat gain coefficient.

Appendix C

Custom State Requirements and Analyses

Appendix C

Custom State Requirements and Analyses

C.1 Introduction

Not at all states adopt the International Energy Conservation Code (IECC) without any modifications. Some states adopt modified versions of the IECC. Pacific Northwest National Laboratory conducted customized state analyses for the District of Columbia, Georgia, Michigan, Minnesota, Montana, Oklahoma, Virginia, Vermont, and Wisconsin to account for changes that these states made to the IECC in their existing code. This section describes the customizations analyzed for each state. The EnergyPlus models and output files and the state cost-effectiveness reports for all the above states are available for download on the energy codes website.[1, 2]

C.2 District of Columbia

The District of Columbia Energy Conservation Code is an amended version of the 2009 IECC with the following changes:

- The DC Energy Conservation Code requires R-18 above-grade wall insulation. The DC Energy Conservation Code requires R-49 ceiling insulation, which is more stringent than the 2012 IECC ceiling insulation requirements.
- The DC Energy Conservation Code requires R-2 hot water piping insulation.

C.3 Georgia

Georgia has three climate zones (climate zones 2, 3, and 4) as defined by the IECC. The Georgia State Code is an amended version of the 2009 IECC. This analysis assesses the cost effectiveness of the 2012 IECC over the Georgia state energy code. Table C.1 below summarizes prescriptive requirements of the Georgia code that contain differences to the 2009 IECC.

Table C.1. Residential Prescriptive Code Requirements for the State of Georgia

Climate Zone	Fenestration U-Factor (Btu/hr-ft^2-F)	Fenestration SHGC	Slab Insulation R-value and Insulation Depth
2	0.5	0.3	0
3	0.5	0.3	0
4	0.35	0.3	0

---

[1] EnergyPlus models and output files – http://www.energycodes.gov/development/residential/iecc_models.

[2] State Cost-effectiveness Reports – http://www.energycodes.gov/development/residential/iecc_analysis.

Additionally, the Georgia code does not explicitly mention the exception for basement wall insulation in warm-humid climates. Thus, the analysis assumes that basement wall insulation is required by the state code in the representative warm-humid location of Macon. Georgia also does not allow the use of electric resistance as the primary heating source. To address this prohibition, electric resistance heating is not analyzed for Georgia and the weights for electric resistance heat are reassigned proportionally to natural gas heating and heat pumps during the aggregation process.

C.4 Michigan

Michigan has three climate zones (climate zones 5, 6, and 7) as defined by the IECC. The Michigan Uniform Energy Code is based on the 2009 IECC but does not require duct pressure testing. This analysis assesses the cost effectiveness of the 2012 IECC over the Michigan state energy code by accounting for the savings and incremental costs for duct sealing requirements in 2012 IECC.

C.5 Minnesota

Minnesota has two climate zones (climate zones 6 and 7) as defined by the IECC. The Minnesota State code is similar to the 2006 IECC but it requires R-38 ceiling insulation in climate zone 6 and R-44 in climate zone 7. It also requires R-19 above grade wall insulation in climate zone 7. The 2006 IECC has more stringent ceiling and above grade wall insulation requirements than the Minnesota state code. This analysis assesses the cost effectiveness of the 2009 and 2012 IECC over the Minnesota state code.

There is some evidence that the typical envelope leakage rates achieved by builders in Minnesota are lower than the assumed 8 50-Pa pressure differential (ACH50) for the 2006 IECC. A proposed code change (RE-12) to the 1322 Advisory Committee for the State of Minnesota in 2012 from the Builders Association of Minnesota reports that recently built homes in Minnesota had an average air leakage of 1.7 ACH50, substantially better than required by any version of the IECC. Additional analysis is conducted assuming 1.7 ACH50 rate for the current Minnesota state code, the 2009 IECC, and the 2012 IECC.

C.6 Montana

Montana has only one climate zone (climate zone 6) as defined by the IECC. The Montana State energy code is based on the 2009 IECC with some minor modifications. It requires a fenestration U-factor of 0.33 Btu/hr-ft^2-F and R-21 above grade wall insulation. These requirements are more stringent than the fenestration and above grade wall insulation requirements in the 2009 IECC. This analysis assesses the cost effectiveness of the 2012 IECC over the Montana State energy code.

C.7 Oklahoma

Oklahoma has two climate zones (climate zone 3 and 4) as defined by the IECC. Oklahoma has adopted the 2009 International Residential Code (IRC). The 2009 IRC requires a glazed fenestration solar heat gain coefficient (SHGC) of 0.35 in climate zone 3. This glazed fenestration SHGC requirement for climate zone 3 is 0.30 in the 2009 IECC. This analysis assesses the cost effectiveness of the 2012 IECC over the Oklahoma state energy code.

C.8 Virginia

Virginia has only one climate zone (climate zone 4) as defined by the IECC. The Virginia state code is based on the 2009 IECC but does not require duct pressure testing. This analysis assesses the cost effectiveness of the 2012 IECC over the Virginia state energy code by assuming no savings and no incremental costs from duct sealing requirement in 2009 IECC.

C.9 Vermont

Vermont has only one climate zone (climate zone 6) as defined by the IECC. The Vermont state energy code is based on the 2009 IECC with a number of modifications. The Vermont Energy Code has four packages in the "Fast Track" compliance method. This analysis assesses the cost effectiveness of the 2012 IECC over package 1 of the Vermont State Energy Code, which has many of the same prescriptive requirements as the 2009 IECC but with a few differences. This analysis accounts for the following modifications to the 2009 IECC:

- The fenestration U-factor requirement in the Vermont Energy Code is 0.32 instead of the 2009 IECC requirement of 0.35.
- Slab perimeter insulation is required to be R-15 instead of the IECC's R-10.
- The maximum allowable duct leakage rates are lower than allowed by the 2009 IECC.

The Vermont code requires mechanical ventilation with fan capacity dependent on whether the system is flow tested. If the flow-rate is verified by testing, the Vermont code would require a 60-cubic feet per minute (cfm) fan for the three-bedroom home analyzed here. An untested system would have to be rated at 100 cfm. This analysis assumes 60 cfm ventilation rate for the Vermont code for a single-family home and 45 cfm for the multifamily building because it results in conservatively low estimates of energy savings and cost effectiveness for the 2012 IECC. The 2012 IECC also requires mechanical ventilation and the same ventilation rates are assumed for the 2012 IECC as for the state code.

The Vermont Energy Code has other differences from the IECC, such as special requirements for log homes and combustion safety requirements. Additionally, the fast track methods cannot be used if the glazing area is greater than 20% of the wall area. These differences are not examined in this analysis.

C.10 Wisconsin

Wisconsin has two climate zones (climate zone 6 and 7) as defined by the IECC. The Wisconsin State energy code is equivalent to the 2006 IECC with the following modifications:

- The 2006 IECC requires U-0.35 glazed fenestration whereas the Wisconsin state code requires U-0.30 glazed fenestration.
- The 2006 IECC requires R-10 basement walls whereas the Wisconsin state code requires R-15 basement walls.
- The 2006 IECC requires R-19 above-grade walls in Zone 6 and R-21 in Zone 7 whereas the Wisconsin state code requires R-21 above-grade walls for the entire state

This analysis assesses the cost effectiveness of the 2009 and 2012 IECC over the Wisconsin State Energy Code.

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www.pnl.gov

Virginia's2012 residential energy code - and estimated comparison to the n

Estimates are *very* rough - based solely on my experience modeling and testing h

Andrew Grigsby, MS, LEED AP, HERS Rater, BPI Building Analyst and Envelope Professional
andrew.grigsby@commonwealthsustainability.com 804-252-1486

Many of these strategies have synergistic effects. Considering them independently creates inaccuracies.
Numbers shown are averages; all houses are built differently and operated differently.

#	2012 IECC Measure (zone 4)	Section	2012 USBC	2012 USBC as compared to 2009 USBC
1	Insulate most hot water pipes	R403.4.2	Insulate some hot water pipes (not required: pipe between water heater and kitchen; runs of ½" pipe more than 20' long; etc.)	improved compared to 2009 USBC, does not reach 2012 IECC standard
2	Increase attic insulation to from R38 to R49	R402.1.1	Keep at 38	no improvement
3	Require duct leakage testing	R403.2.2.2	Allow visual inspection	no improvement
4	Require total duct leakage no more than 4% either at post-construction or rough-in – down from 8% and 6%	R403.2.2.1	6% total leakage at post-construction; 5% total leakage at rough-in	improved compared to 2009 USBC, does not reach 2012 IECC standard
5	Require blower door test	R402.4.1.2.2	Allow visual inspection	no improvement
6	Require no more than 3ACH – down from 7ACH in 2009 IECC	R402.4.1.3	Set at 5ACH	improved compared to 2009 USBC, does not reach 2012 IECC standard
7	Require min. 75% high efficiency lighting	R404.1	Require 50% (same as 2009)	no improvement
8	Improve skylight U-Factor from .6 to .55 and fenestration SHGC from NR to ≤0.40.	R402.1.3	Approved	meets IECC 2012 goal
9	"Knee walls shall be sealed"	R402.4.1.1	Approved	meets IECC 2012 goal
10	Increase wall insulation from R13 to R20 or 13+5	R402.1.1	Increase to R15 or 13+1, cavities in corners and headers shall include R3, min.	barely improved compared to 2009 USBC, does not reach 2012 IECC standard. This is the first upgrade in wall insulation requirments in 25+ years
11	Mass wall insulation from 5/10 to 8/13	R402.1.3	Approved	meets IECC 2012 goal

12	Replacement windows must meet current standard (.35/.4)		No requirement	no improvement
13	Performance Path glazing area assumption: 15% where proposed design is ≥15%; “as proposed” where proposed design is <15%	R405.5.2(1)	15% glazing assumption, regardless of proposed design	**less** stringent than 2009 code
14	All access doors from conditioned to unconditioned space insulated to same R-Value as surrounding area	R402.2.4	Vertical attic access doors can be R-5. Pull down attic stairs can be R-5 with 75% insulated.	improved compared to 2009 USBC, does not reach 2012 IECC standard

Estimated **total % efficiency improvement**

PNNL staff estimate that the 2012 IECC obtains 25% energy cost sa

http://www.energycodes.gov/sites/default/files/d

odel code

omes in Virginia.

estimated efficiency gain, 2012 USBC compared to 2009	*estimated* efficiency gain: 2012 IECC compared to 2009 IECC	Comments
1.0%	2.0%	
0.0%	1.0%	
0.0%	3.0%	
1.0%	2.0%	Impossible to verify % without performing duct leakag
0.0%	3.0%	
1.0%	2.0%	Impossible to verify ACH without performing blower d
0.0%	1.5%	
1.0%	1.0%	
1.0%	1.0%	
1.0%	2.5%	
1.0%	1.0%	

0.0%	2.0%
-0.5%	0.5%
0.5%	1.0%
7.0%	**23.5%**
2012 USBC	2012 IECC

avings compared to the 2009 IECC for Virginia, see
ocuments/State_CostEffectiveness_TSD_Final.pdf

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TOPICAL FIRE REPORT SERIES Volume 14, Issue 13 / March 2014

Residential Building Electrical Fires (2009-2011)

These topical reports are designed to explore facets of the U.S. fire problem as depicted through data collected in the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS). Each topical report briefly addresses the nature of the specific fire or fire-related topic, highlights important findings from the data, and may suggest other resources to consider for further information. Also included are recent examples of fire incidents that demonstrate some of the issues addressed in the report or that put the report topic in context.

Findings

- **An estimated 25,900 residential building electrical fires were reported to fire departments within the United States each year. These fires caused an estimated 280 deaths, 1,125 injuries and $1.1 billion in property loss.**
- **Residential building electrical fires resulted in greater dollar loss per fire than residential building nonelectrical fires.**
- **Residential building electrical fires occurred most often in one- and two-family dwellings (84 percent).**
- **Residential building electrical fires occurred most often in the colder months of January and December (at 11 percent each month).**
- **In 79 percent of residential building electrical fires, the fire spread beyond the object where the fire started.**
- **The leading items most often first ignited in residential building electrical fires were electrical wire, cable insulation (30 percent) and structural member or framing (19 percent).**
- **The leading factors contributing to the ignition of residential building electrical fires were other electrical failure, malfunction (41 percent), unspecified short-circuit arc (25 percent), and short-circuit arc from defective, worn insulation (12 percent).**
- **Smoke alarms were present in 50 percent and automatic extinguishing systems were present in 2 percent of electrical fires that occurred in occupied residential buildings.**

Electricity is a basic part of residential life in the U.S. It provides the energy for most powered items in a contemporary home, from lights to heating systems to televisions. Today it is hard to imagine a residence without electricity. It is a part of our homes and our activities that most of us take for granted. We rarely think how powerful electricity is.

Yet, using electricity can have dangerous consequences. Electrical fires occur frequently throughout the U.S., causing injury, claiming lives, and resulting in large losses of property.[1] From 2009 to 2011, an estimated 25,900 residential building electrical fires were reported by U.S. fire departments annually.[2, 3] These fires caused an estimated 280 deaths, 1,125 injuries and $1.1 billion in property damage.[4] Residential building electrical fires continue to be a part of the residential fire problem and accounted for 7 percent of all residential building fires.[5] The term electrical fires is defined as those fires that include electrical distribution, wiring, transformers, meter boxes, power switching gear, outlets, cords, plugs, surge protectors, electric fences, lighting fixtures, and electrical arcing as the source of heat.[6]

This topical report addresses the characteristics of electrical fires in residential buildings as reported to the National Fire Incident Reporting System (NFIRS) from 2009 to 2011.[7] The NFIRS data are used for the analyses presented throughout the report. For the purpose of the report, the terms "residential fires," "electrical fires," and "nonelectrical fires" are synonymous with "residential building fires," "residential building electrical fires" and "residential building nonelectrical fires" respectively. "Electrical fires" is used throughout the body of this report; the findings, tables, charts, headings and endnotes reflect the full category, "residential building electrical fires."

The Residential Building Electrical Fire Problem

Although electrical fires declined by 14 percent from 2007 to 2011,[8] electrical malfunction was the third leading cause of residential fires during these five years.[9] Electrical fires are fires that involve the flow of electric current or static electricity[10] and are caused by electrical system failures, appliance defects, incorrectly installed wiring, misuse and poor maintenance of electrical appliances, and overloaded circuits and extension cords.[11] These electrical fires can be unique. For example, electrical fires that start in walls can smolder for some time and cause smoke to not be seen immediately and detection to be delayed. By the time smoke is seen and fire is detected, the flames may have already spread behind and within walls.[12] As a result, electrical fires have the potential to spread further and cause more damage and injuries. In addition, electrical fires can be particularly tricky to put out. Since they involve electricity, and water conducts electricity, using water to put out the fire can cause electrocution unless power is reliably disconnected.

Over the last 30 years, our homes have been dramatically transformed by electrical devices. Today's electrical demands can overburden the electrical system in a home,[13] putting it at a higher risk of an electrical fire. This may be particularly true for homes more than 40 years old that have older wiring and electrical systems and devices. There is also the likelihood that older homes may not comply with more modern electric code requirements, which puts them at an elevated risk of hazardous conditions that could lead to an electrical fire.[14] Eventually, given enough time, any home can be at risk of an electrical fire as wire insulation ages, connections loosen, receptacles and switches come loose or wear out, and oil and dirt cause electrical components to overheat.[15]

Type of Fire

Building fires are divided into two classes of severity in NFIRS: "confined fires," which are fires confined to certain types of equipment or objects, and "nonconfined fires," which are not. Confined building fires are small fire incidents that are limited in extent, staying within pots, fireplaces or certain other noncombustible containers.[16] Confined fires rarely result in serious injury or large content loss and are expected to have no significant accompanying property loss due to flame damage.[17] Of the two classes of severity, nonconfined fires accounted for almost all of the electrical fires (Table 1). Because there were so few confined electrical fires, the subsequent analyses in this report include all electrical fires and do not distinguish between confined and nonconfined fires.

Table 1. Residential Building Electrical Fires by Type of Incident (2009-2011)

Incident Type	Percent
Nonconfined fires	99.83
Confined fires	0.17
Trash or rubbish, contained	0.13
Incinerator overload or malfunction, fire confined	0.04
Total	100.00

Source: NFIRS 5.0.

Loss Measures

Table 2 presents losses, averaged over the three-year period of 2009 to 2011, of reported electrical and nonelectrical residential fires.[18] Electrical fires caused a similar number of fatalities and injuries per thousand fires as did nonelectrical fires (Table 2). Electrical fires, however, resulted in greater dollar loss (70 percent higher) per fire than nonelectrical fires. The increase in dollar loss per fire may ultimately be due to challenges in the detection and location of some electrical fires.

Table 2. Loss Measures for Residential Building Electrical and Nonelectrical Fires (Three-year Average, 2009-2011)

Measure	Residential Building Electrical Fires	Residential Building Nonelectrical Fires
Average Loss:		
Fatalities/1,000 fires	5.5	5.4
Injuries/1,000 fires	31.7	29.1
Dollar loss/fire	$25,140	$14,820

Source: NFIRS 5.0.

Notes: 1. Average loss for fatalities and injuries is computed per 1,000 fires. Average dollar loss is computed **per fire** and is rounded to the nearest $10.
2. When calculating the average dollar loss per fire for 2009-2011, the 2009 and 2010 dollar-loss values were adjusted to their equivalent 2011 dollar-loss values to account for inflation.

Property Use

Residential buildings are divided into three major property types: one- and two-family residential buildings, multifamily residential buildings, and other residential buildings. One- and two-family residential buildings include detached single-family residences, manufactured homes, mobile homes not in transit, and duplexes. Multifamily residential buildings include apartments, condominiums and town houses. Other residential buildings include all other types of residences, such as hotels or motels, long-term care facilities, dormitories, and sorority or fraternity housing.

One- and two-family residential buildings accounted for 84 percent of electrical fires reported to NFIRS (Table 3). By comparison, one- and two-family residential buildings accounted for 64 percent of nonelectrical fires, more in line with the occurrence of one- and two-family residential building fires overall (65 percent).[19] Multifamily residential buildings accounted for only 12 percent of electrical fires while they accounted for 29 percent of nonelectrical fires. Finally, all other residential buildings accounted for 4 percent of electrical fires while they accounted for 6 percent of nonelectrical fires. One explanation for the lower percentage of electrical fires in multifamily and other dwellings may be that more stringent building and fire codes that require regular fire and safety inspections (which include the inspection of wiring and electrical components) are often imposed on these types of residential buildings. In addition, multifamily dwellings and other residential buildings may more often be professionally maintained.

Table 3. Residential Building Electrical and Nonelectrical Fires by Property Use (2009-2011)

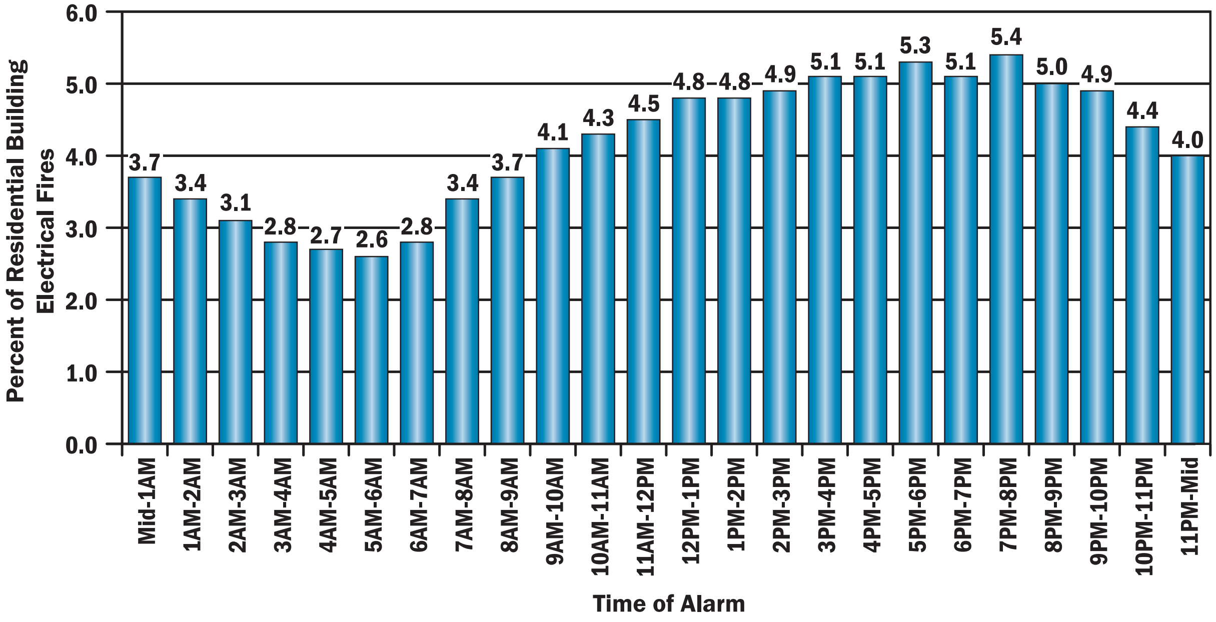
Property Type	Percent of Residential Building Electrical Fires	Percent of Residential Building Nonelectrical Fires
One- and Two-Family	83.7	64.3
Multifamily	12.1	29.3
Other	4.2	6.4
Total	100.0	100.0

Source: NFIRS 5.0.

When Residential Building Electrical Fires Occur

As shown in Figure 1, electrical fires occurred most frequently in the late afternoon to early evening hours.[20] They gradually declined throughout the late evening and early morning hours reaching the lowest point from 5 to 6 a.m. Beginning at 6 a.m., fire incidence started to increase until the peak hours were reached.

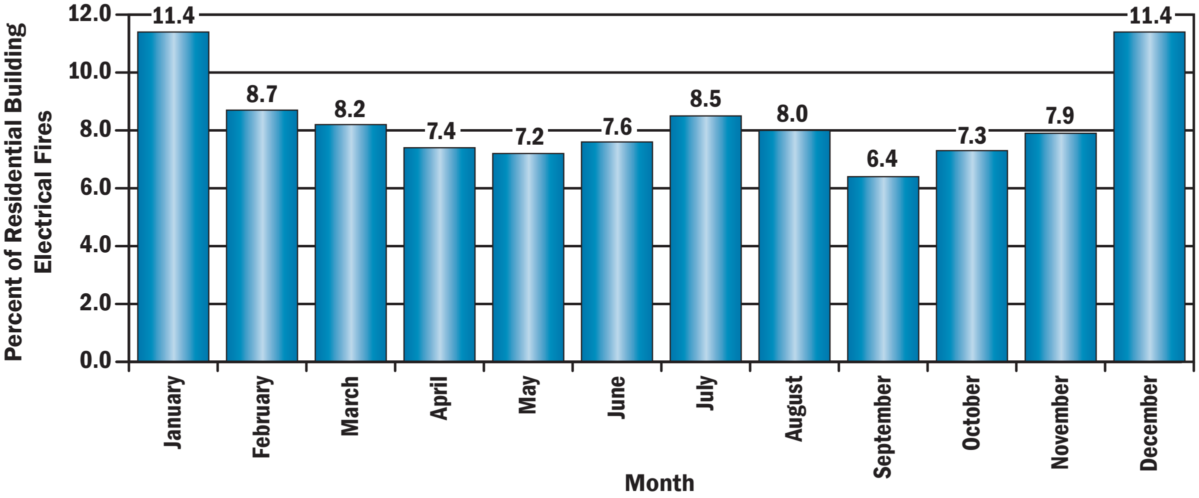
Figure 1. Residential Building Electrical Fires by Time of Alarm (2009-2011)



Source: NFIRS 5.0.
Note: Total does not add up to 100 percent due to rounding.

Figure 2 illustrates that electrical fire incidence was highest during the months of December and January, each at 11 percent. This is not surprising as cooler weather in these months typically results in more indoor activities which leads to an increase in lighting, heating and appliance use. In addition, low humidity within a home is most likely to occur in winter, particularly when a house is being heated,[21] which results in wood studs and framing drying out and being somewhat more easily ignited by an arcing current or electrical overheating. The lowest incidence of electrical fires occurred in September at 6 percent.

Figure 2. Residential Building Electrical Fires by Month (2009-2011)

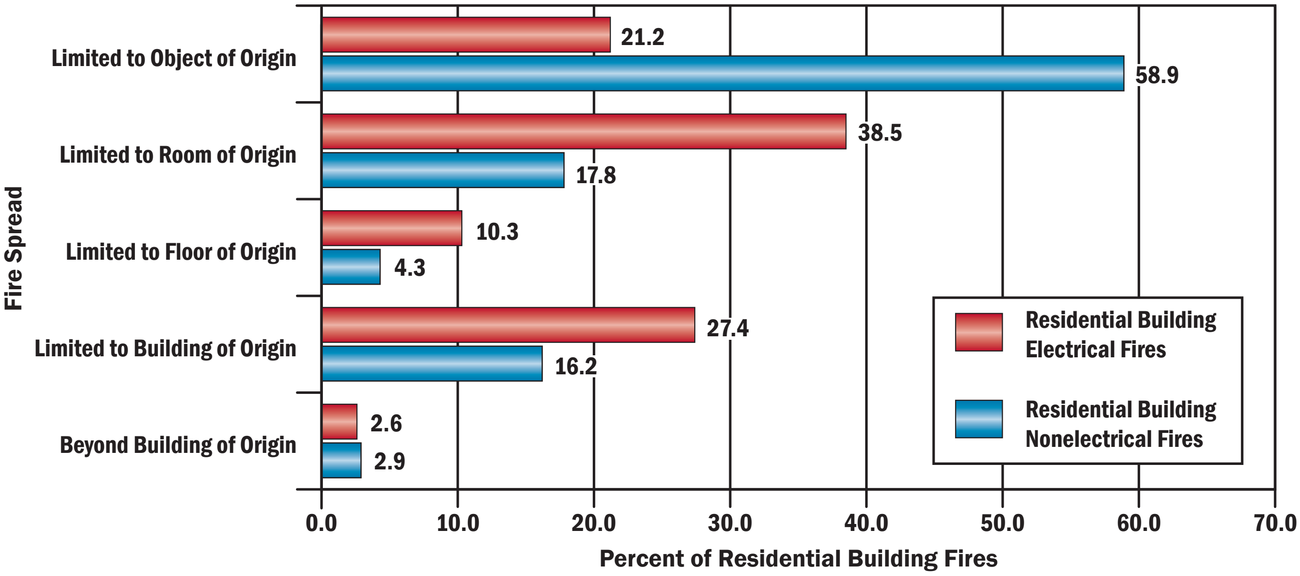


Source: NFIRS 5.0.

Fire Spread in Residential Building Electrical Fires

While 59 percent of nonelectrical fires were limited to the object of origin, only 21 percent of electrical fires were limited to the object of origin (Figure 3). Of the remaining 79 percent of electrical fires that spread beyond the object of origin, 39 percent were limited to the room of origin, 10 percent were limited to the floor of origin, and 27 percent were limited to the building of origin. An additional 3 percent of electrical fires spread beyond the building of origin. The larger fire spread may be partly due to challenges in the detection of some electrical fires (i.e., fires within walls) as previously discussed.

Figure 3. Extent of Fire Spread in Residential Building Electrical and Nonelectrical Fires (2009-2011)



Source: NFIRS 5.0.
Note: Total for residential building nonelectrical fires does not add up to 100 percent due to rounding.

Where Residential Building Electrical Fires Start (Area of Fire Origin)

Five areas in the home — bedrooms (15 percent); attics or vacant crawl spaces (13 percent); walls or concealed wall spaces (9 percent); cooking areas and kitchens (8 percent); and common rooms or lounge areas (7 percent) — accounted for 52 percent of electrical fires (Table 4).

Table 4. Leading Areas of Fire Origin in Residential Building Electrical Fires (2009-2011)

Area of Origin	Percent of Residential Building Electrical Fires (Unknowns Apportioned)
Bedrooms	15.3
Attic: vacant, crawl space above top story	13.4
Wall assembly, concealed wall space	8.6
Cooking area, kitchen	8.4
Common room, den, family room, living room, lounge	6.7

Source: NFIRS 5.0.

How Residential Building Electrical Fires Start (Heat Source)

The "heat from powered equipment" category accounted for the majority (89 percent) of all electrical fires (Table 5). Within this category, electrical arcing accounted for 82 percent, heat from other powered equipment accounted for 3 percent, radiated or conducted heat from operating equipment also accounted for 3 percent, and sparks, embers or flames from operating equipment accounted for 1 percent of all electrical fires. The "hot or smoldering object" category accounted for an additional 6 percent of electrical fires, while the heat source for the remaining 6 percent of electrical fires fell into other categories.

Table 5. Sources of Heat in Residential Building Electrical Fires by Major Category (2009-2011)

Heat Source Category	Percent of Residential Building Electrical Fires (Unknowns Apportioned)
Heat from powered equipment	88.6
Hot or smoldering object	5.8
All other heat source categories	5.7

Source: NFIRS 5.0.
Note: Total does not add up to 100 percent due to rounding.

What Ignites First in Residential Building Electrical Fires

Electrical wire, cable insulation (30 percent) and structural member or framing (19 percent) were the specific items most often first ignited in electrical fires (Table 6). Although less prominent, thermal, acoustical insulation (7 percent), interior wall covering (6 percent), exterior sidewall covering, surface or finish and other types of structural component or finish were also leading items first ignited (each at 5 percent).

Table 6. Leading Items First Ignited in Residential Building Electrical Fires (2009-2011)

Item First Ignited	Percent of Residential Building Electrical Fires (Unknowns Apportioned)
Electrical wire, cable insulation	29.8
Structural member or framing	18.5
Thermal, acoustical insulation within wall, partition, or floor/ceiling	7.3
Interior wall covering	6.3
Exterior sidewall covering, surface, finish	5.1
Other structural component or finish	4.6

Source: NFIRS 5.0.

Factors Contributing to Ignition in Residential Building Electrical Fires

Table 7 shows the categories of factors contributing to ignition in electrical fires. As expected, the leading category, by far, was "electrical failure, malfunction" (90 percent). In this category, other electrical failure, malfunction (41 percent), unspecified short-circuit arc (25 percent), and short-circuit arc from defective, worn insulation (12 percent) were the specific factors that accounted for 78 percent of electrical fires.

The "mechanical failure, malfunction" category was a contributing factor in 6 percent of electrical fires. The leading specific factor contributing to ignition in this category was other mechanical failure, malfunction at 4 percent.

Table 7. Factors Contributing to Ignition for Residential Building Electrical Fires by Major Category (Where Factors Contributing to Ignition are Specified, 2009-2011)

Factors Contributing to Ignition Category	Percent of Residential Building Electrical Fires
Electrical failure, malfunction	89.5
Mechanical failure, malfunction	6.1
Misuse of material or product	4.3
Operational deficiency	3.7
Design, manufacture, installation deficiency	1.3
Natural condition	1.0
Other factors contributing to ignition	0.9
Fire spread or control	0.2

Source: NFIRS 5.0.

Notes: 1. Includes only incidents where factors that contributed to the ignition of the fire were specified.

2. Multiple factors contributing to fire ignition may be noted for each incident; total will exceed 100 percent.

Equipment Involved in Ignition in Residential Building Electrical Fires

Three types of equipment played a leading role in the ignition of 39 percent of all residential electrical fires. These leading types of equipment involved in ignition, as shown in Table 8, were other electrical wiring (22 percent), outlets and receptacles (10 percent), and electrical branch circuits (8 percent).[22] Of interest, extension cords, panel (fuse) boards, and other lamps and lighting were also leading types of equipment involved in ignition (each at 5 percent).

Table 8. Leading Equipment Involved in Ignition of Residential Building Electrical Fires (2009-2011)

Equipment Involved in Ignition	Percent of Residential Building Electrical Fires
Electrical wiring, other	21.8
Outlet, receptacle	9.6
Electrical branch circuit	7.7

Source: NFIRS 5.0.

Alerting/Suppression Systems in Residential Building Electrical Fires

Technologies to detect and extinguish fires have been a major contributor to the drop in fire fatalities and injuries over the past 35 years. Smoke alarms, which aim to detect smoldering fires before they break into open flame or produce large volumes of smoke, are now present in the majority of residential buildings. In addition, the use of residential sprinklers is widely supported by the fire service and is gaining support within residential communities.

Smoke alarm data presented in Tables 9 and 10 are the raw counts from the NFIRS dataset and are not scaled to national estimates of smoke alarms in residential buildings where electrical fires occurred. In addition, NFIRS does not allow for the determination of the type of smoke alarm — that is, if the smoke alarm was photoelectric or ionization — or the location of the smoke alarm with respect to the area of fire origin. The data presented in Table 11 are also the raw counts from the NFIRS dataset and are not scaled to national estimates of automatic extinguishing systems (AESs) in residential buildings where electrical fires occurred.

Smoke Alarm Data

Overall, smoke alarms were present in 48 percent of residences where electrical fires occurred and were known to have operated in 24 percent of the fires. By comparison, smoke alarms were present in 41 percent of nonconfined, nonelectrical fires and operated in 25 percent. In 26 percent of electrical fires, no smoke alarms were present. In another 25 percent of these fires, firefighters were unable to determine if a smoke alarm was present (Table 9).

Table 9. NFIRS Smoke Alarm Presence in Residential Building Electrical Fires (2009-2011)

Presence of Smoke Alarms	Count	Percent
Present	22,487	48.4
None present	12,103	26.0
Undetermined	11,824	25.4
Null/Blank	57	0.1
Total incidents	46,471	100.0

Source: NFIRS 5.0.

Notes: 1. The data presented in this table are raw data counts from the NFIRS dataset. They do not represent national estimates of smoke alarms in residential building electrical fires. They are presented for informational purposes.
2. Total does not add up to 100 percent due to rounding.

While 7 percent of electrical fires occurred in residential buildings that are **not** currently or routinely occupied, these buildings — which are under construction, undergoing major renovation, vacant and the like — are unlikely to have alerting and suppression systems that are in place and, if in place, that operate. In fact, only 13 percent of all electrical fires in unoccupied residential buildings were reported as having smoke alarms that operated. In addition, AESs were reported as present in only 1 percent of electrical fires in residential buildings that were not routinely occupied. As a result, the detailed analyses in the next sections focus on electrical fires in occupied residential buildings only.[23]

Smoke Alarms in Occupied Residential Building Electrical Fires

Smoke alarms were reported as present in 50 percent of electrical fires in occupied residential buildings and were known to have operated in 25 percent of the fires (Table 10). Smoke alarms were known to be absent in 25 percent of electrical fires in occupied residential buildings. Firefighters were unable to determine if a smoke alarm was present in another 25 percent of these fires.

When operational status is considered, the percentage of smoke alarms reported as present (50 percent) consisted of:

- Present and operated — 25 percent.
- Present, but did not operate — 17 percent (fire too small, 10 percent; alarm failed to operate, 8 percent).[24]
- Present, but operational status unknown — 8 percent.

When the subset of incidents where smoke alarms were reported as present was analyzed separately, smoke alarms were reported to have operated in 51 percent of the incidents. The alarms failed to operate in 15 percent of the incidents. In 19 percent of the subset, the fire was too small to activate the alarm. The operational status of the alarm was undetermined in an additional 15 percent of the incidents.

Table 10. NFIRS Smoke Alarm Data for Occupied Residential Building Electrical Fires (2009-2011)

Presence of Smoke Alarms	Smoke Alarm Operational Status	Smoke Alarm Effectiveness	Count	Percent
Present	Fire too small to activate smoke alarm		4,080	9.5
	Smoke alarm operated	Smoke alarm alerted occupants, occupants responded	7,678	17.8
		Smoke alarm alerted occupants, occupants failed to respond	274	0.6
		No occupants	1,515	3.5
		Smoke alarm failed to alert occupants	362	0.8
		Undetermined	1,038	2.4
	Smoke alarm failed to operate		3,251	7.5
	Undetermined		3,270	7.6
None present			10,664	24.8
Undetermined			10,930	25.4
Total incidents			43,062	100.0

Source: NFIRS 5.0.

Notes: 1. The data presented in this table are raw data counts from the NFIRS dataset. They do not represent national estimates of smoke alarms in occupied residential building electrical fires. They are presented for informational purposes.
2. Total does not add up to 100 percent due to rounding.

Automatic Extinguishment System Data

Overall, full or partial AESs, mainly sprinklers, were present in just 2 percent of occupied residential buildings where electrical fires occurred (Table 11). The lack of suppression equipment (sprinklers) in homes experiencing electrical fires is not unexpected as sprinklers are largely absent nationwide in residential buildings.[25]

Table 11. NFIRS Automatic Extinguishing System Data for Occupied Residential Building Electrical Fires (2009-2011)

Presence of Automatic Extinguishing Systems	Count	Percent
AES present	914	2.1
Partial system present	36	0.1
AES not present	39,777	92.4
Unknown	2,335	5.4
Total incidents	43,062	100.0

Source: NFIRS 5.0.

Note: The data presented in this table are raw data counts from the NFIRS dataset. They do not represent national estimates of AESs in occupied residential building electrical fires. They are presented for informational purposes.

Examples

The following are some recent examples of electrical fires reported by the media:

- October 2013: A family of four was displaced when a midday fire destroyed their home in Ravena, New York. The intense blaze, which was blowing out windows as fire crews arrived on-scene, took about an hour to get under control. Fire investigators determined the fire was caused by an electrical problem that originated in the cellar. There were no injuries reported as the occupants of the residence were not at home when the fire started.[26]
- October 2013: Six units in a Louisville, Kentucky, apartment complex were damaged by a fire caused by an electrical malfunction involving an old air conditioning unit. The air conditioning unit was located in between the ceiling of the second floor unit and the floor of the unit above it. The fire then spread through the walls between the apartments. All six units that were damaged were considered a total loss. No injuries were reported as a result of the fire.[27]
- October 2013: Firefighters extinguished a late night fire in Belleville, New Jersey, which resulted in a residence being deemed uninhabitable. The cause of the blaze was determined to be electrical. An oil-filled space heater was pushed to a higher setting resulting in the overloading of the home's electrical junction box. No injuries were reported.[28]
- October 2013: A late morning electrical fire broke out at a residential high-rise building in La Jolla, California, injuring two people. The fire started while two electricians were working in the electrical room when, for unknown reasons, the electrical panel exploded. One of the workers was severely burned while the second worker sustained minor burns. No other injuries were reported. In addition, while the electrical fire caused some smoke and damage, the structure of the building, which houses approximately 200 residents, was not affected.[29]

Preventing Electrical Fires

Residential electrical fires can be prevented by understanding basic electrical safety principles and following certain prevention and preparation strategies as identified by the Electrical Safety Foundation International:

- **Understand the basics of your home's electrical system** (above or below ground power lines, electric meter, electrical service panel, wiring system, outlets, switches and appliances).
- **Install advanced electrical safety technologies** (Arc Fault Circuit Interrupters (AFCIs), Ground Fault Circuit Interrupters (GFCIs) and Tamper Resistant Receptacles).
- **Properly maintain your electrical system and components by**:
  - Ensuring all residential work is performed by a qualified, licensed electrician and complies with codes and standards.
  - Testing electrical safety devices (AFCIs, GFCIs, smoke alarms, etc.) on a monthly basis.
  - Properly labeling electrical panel circuits.
  - Replacing fuses or circuit breakers with the correct size and amperage.
  - Keeping your electrical panel accessible.
  - Getting a professional electrical system inspection if your home:
    - Is 40 years or older.
    - Is previously owned.

  - Has undergone a major renovation.
  - Has been outfitted with major new appliances in the last 10 years.
- **Identify and correct potential electrical hazards.**
- **Install smoke alarms according to current recommendations and test monthly.**
- **Prepare and practice a fire escape plan that includes two ways out of each room.**[30]

For additional electrical home fire prevention tips and information, please visit the U.S. Fire Administration's (USFA's) electrical fire safety Web page at http://www.usfa.fema.gov/citizens/home_fire_prev/electrical.shtm.

NFIRS Data Specifications for Residential Building Electrical Fires

Data for this report were extracted from the NFIRS annual Public Data Release files for 2009, 2010 and 2011. Only version 5.0 data was extracted.

Residential building electrical fires were defined using the following criteria:

- Aid Types 3 (mutual aid given) and 4 (automatic aid given) were excluded to avoid double counting of incidents.
- Incident Types 111 to 123 (excluding Incident Type 112):

Incident Type	Description
111	Building fire
113	Cooking fire, confined to container
114	Chimney or flue fire, confined to chimney or flue
115	Incinerator overload or malfunction, fire confined
116	Fuel burner/boiler malfunction, fire confined
117	Commercial compactor fire, confined to rubbish
118	Trash or rubbish fire, contained
120	Fire in mobile property used as a fixed structure, other
121	Fire in mobile home used as fixed residence
122	Fire in motor home, camper, recreational vehicle
123	Fire in portable building, fixed location

Note: Incident Types 113 to 118 do not specify if the structure is a building.

- Property Use Series 400 which consists of the following:

Property Use	Description
400	Residential, other
419	One- or two-family dwelling, detached, manufactured home, mobile home not in transit, duplex
429	Multifamily dwelling
439	Boarding/Rooming house, residential hotels
449	Hotel/Motel, commercial
459	Residential board and care
460	Dormitory-type residence, other
462	Sorority house, fraternity house
464	Barracks, dormitory

- Structure Type:
  - For Incident Types 113 to 118:
    - 1—Enclosed building.
    - 2—Fixed portable or mobile structure, and Structure Type not specified (null entry).
  - For Incident Types 111 and 120 to 123:
    - 1—Enclosed building.
    - 2—Fixed portable or mobile structure.
- The USFA Structure Fire Cause Methodology was used to determine residential building electrical malfunction fire incidents (i.e., cause code = '06').[31]

The analyses contained in this report reflect the current methodologies used by the USFA. USFA is committed to providing the best and most current information on the U.S. fire problem and continually examines its data and methodology to fulfill this goal. Because of this commitment, data collection strategies and methodological changes are possible and do occur. As a result, analyses and estimates of the fire problem may change slightly over time. Previous analyses and estimates on specific issues (or similar issues) may have used different methodologies or data definitions and may not be directly comparable to the current ones.

To request additional information or to comment on this report, visit https://apps.usfa.fema.gov/feedback/.

Notes:

[1] "Residential Building Electrical Fires," Topical Fire Report Series, U.S. Fire Administration (USFA), March 2008, Volume 8, Issue 2, http://www.usfa.fema.gov/downloads/pdf/statistics/v8i2.pdf.

[2] Residential buildings include, but are not limited to, one- or two-family dwellings, multifamily dwellings, boarding houses or residential hotels, commercial hotels, college dormitories, and sorority/fraternity houses.

[3] In National Fire Incident Reporting System (NFIRS) version 5.0, a structure is a constructed item of which a building is one type. In previous versions of NFIRS, the term "residential structure" commonly referred to buildings where people live. To coincide with this concept, the definition of a residential structure fire for NFIRS 5.0 has, therefore, changed to include only those fires where the NFIRS 5.0 Structure Type is 1 or 2 (enclosed building and fixed portable or mobile structure) with a residential property use. Such structures are referred to as "residential buildings" to distinguish these buildings from other structures on residential properties that may include fences, sheds and other uninhabitable structures. In addition, confined fire incidents that have a residential property use but do not have a structure type specified are presumed to be buildings. Nonconfined fire incidents that have a residential property use without a structure type specified are considered to be invalid incidents (structure type is a required field) and are not included.

[4] National estimates are based on 2009-2011 native version 5.0 data from the NFIRS, residential structure fire-loss estimates from the National Fire Protection Association's (NFPA's) annual surveys of fire loss, and the USFA's residential building fire-loss estimates: http://www.usfa.fema.gov/statistics/estimates/index.shtm. Electrical fires and losses in residential buildings are determined by USFA's Structure Fire Cause Methodology. From 2009 to 2011, the fire cause was unknown for 18.1 percent of fires, 47.0 percent of deaths, 25.2 percent of injuries, and 38.0 percent of property damage in residential buildings. In computing national estimates, fires and losses with unknown causes are not ignored. The approach taken by USFA is to compute "adjusted" percentages using only those incidents for which causal data were provided. This calculation, in effect, distributes the fires and losses for which the cause data are unknown in the same proportion as the fires and losses for which the causes are known. These adjusted percentages are then scaled up to reflect results from NFPA's annual surveys of fire loss. Further information on USFA's residential building fire-loss estimates is found in the "National Estimates Methodology for Building Fires and Losses," August 2012, http://www.usfa.fema.gov/downloads/pdf/statistics/national_estimate_methodology.pdf. For information on NFPA's survey methodology, see NFPA's report on "Fire Loss in the United States": http://www.nfpa.org/~/media/Files /Research/NFPA%20reports/Overall%20Fire%20Statistics/osfireloss.pdf. In this residential building electrical fires topical report, estimates of fires are rounded to the nearest 100, deaths to the nearest five, injuries to the nearest 25, and losses to the nearest 100 million dollars.

[5] "Residential Building Fires (2009-2011)," Topical Fire Report Series, U.S. Fire Administration, May 2013, Volume 14, Issue 4, http://www.usfa.fema.gov/downloads/pdf/statistics/v14i4.pdf.

[6] The term "electrical fires" is an abbreviated form of the original term "electrical malfunction fires" as defined by USFA's Structure Fire Cause Methodology. The cause definitions can be found at http://www.usfa.fema.gov/fireservice/nfirs/tools/fire_cause_category_matrix.shtm.

[7] Participation in NFIRS is voluntary, however, some states do require their departments to participate in the state system. Additionally, if a fire department is a recipient of a Fire Act Grant, participation is required. From 2009 to 2011, 70 percent of NFPA's annual average estimated 1,356,500 fires to which fire departments responded were captured in NFIRS. Thus, NFIRS is not representative of all fire incidents in the U.S. and is not a "complete" census of fire incidents. Although NFIRS does not represent 100 percent of the incidents reported to fire departments each year, the enormous dataset exhibits stability from one year to the next, without radical changes. Results based on the full dataset are generally similar to those based on part of the data.

[8] "Residential Building Electrical Malfunction Fire Trends (2007-2011)," USFA Fire Estimate Summary, U.S. Fire Administration, February 2013, http://www.usfa.fema.gov/downloads/pdf/statistics/res_bldg_electrical_fire_trends.pdf.

[9] "Residential Building Fire Causes (2007-2011)," USFA Fire Estimate Summary, U.S. Fire Administration, February 2013, http://www.usfa.fema.gov/downloads/pdf/statistics/res_bldg_fire_causes.pdf.

[10] Babrauskas, Vytenis, 2008. Research on Electrical Fires: The State of the Art. "Fire Safety Science" 9: 3-18. doi:10.3801/IAFSS.FSS.9-3, http://www.iafss.org/publications/fss/9/3# (accessed Nov. 19, 2013).

[11] "Common causes of home electrical fires," vancouverelectricianblog.com, Feb. 4, 2011, http://www.vancouverelectricianblog.com/common-home-electrical-fires/ (accessed Nov. 4, 2013).

[12] Mike Holmes, "Dangers of electrical fires: Ditch DIY when fixing faulty wiring," canada.com, Aug. 7, 2012, http://www.canada.com/news/Dangers+electrical+fires/7051750/story.html (accessed Nov. 4, 2013).

[13] "Arc Fault Circuit Interrupters," Arc Fault Circuit Interrupter (ARCI) Fact Sheet, Electrical Safety Foundation International, 2011, http://esfi.org/index.cfm/page/Arc-Fault-Circuit-Interrupter-(AFCI)-Fact-Sheet/cdid/11865/pid/10272 (accessed Nov. 19, 2013).

[14] "Residential Electrical System Aging Research Project," The Code Authority, Underwriters Laboratories, Issue 2, 2008, http://www.ul.com/global/documents/offerings/perspectives/regulators/technical/ul_ResidentialElectricalSystemResearch.pdf (accessed Nov. 19, 2013).

[15] Mike Holmes, "Dangers of electrical fires: Ditch DIY when fixing faulty wiring," canada.com, Aug. 7, 2012, http://www.canada.com/news/Dangers+electrical+fires/7051750/story.html (accessed Nov. 4, 2013).

[16] In NFIRS, confined fires are defined by Incident Type Codes 113 to 118.

[17] NFIRS distinguishes between "content" and "property" loss. Content loss includes losses to the contents of a structure due to damage by fire, smoke, water and overhaul. Property loss includes losses to the structure itself or to the property itself. Total loss is the sum of the content loss and the property loss. For confined fires, the expectation is that the fire did not spread beyond the container (or rubbish for Incident Type Code 118), and hence, there was no property damage (damage to the structure itself) from the flames. There could be, however, property damage as a result of smoke, water and overhaul.

[18] The average fire death and fire injury loss rates computed from the national estimates do not agree with average fire death and fire injury loss rates computed from NFIRS data alone. The fire death rate computed from national estimates is (1,000*(280/25,900)) = 10.8 deaths per 1,000 residential building electrical fires and the fire injury rate is (1,000*(1,125/25,900)) = 43.4 injuries per 1,000 residential building electrical fires.

[19] "One- and Two-Family Residential Building Fires (2009-2011)," Topical Fire Report Series, U.S. Fire Administration, September 2013, Volume 14, Issue 10, http://www.usfa.fema.gov/downloads/pdf/statistics/v14i10.pdf.

[20] For the purposes of this report, the time of the fire alarm is used as an approximation for the general time the fire started. However, in NFIRS, it is the time the fire was reported to the fire department.

[21] "Humidity," science.howstuffworks.com, http://science.howstuffworks.com/dictionary/meteorological-terms/humidity-info.htm (accessed Nov. 21, 2013).

[22] The three leading types of equipment involved in ignition do not add up to 39 percent due to rounding.

[23] The term "occupied" implies that the building is operational or in normal use. This includes residences that are unoccupied for a brief period of time such as when household members are away at work, school or on vacation.

[24] Total percentage of smoke alarms that were present but did not operate does not equal 17 percent due to rounding.

[25] "Residential Building Fires (2009-2011)," Topical Fire Report Series, U.S. Fire Administration, May 2013, Volume 14, Issue 4, http://www.usfa.fema.gov/downloads/pdf/statistics/v14i4.pdf.

[26] Paul Nelson, "Chief: Electrical fire destroys Ravena home," timesunion.com, Oct. 30, 2013, http://www.timesunion.com/local/article/Chief-Electrical-fire-destroys-Ravena-home-4941277.php (accessed Nov. 1, 2013).

[27] Brittany Gonzalez, "Fire chief: Electrical malfunction causes fire at Legacy Apartments," whas11.com, Oct. 29, 2013, http://www.whas11.com/news/local/Fire-chief-Electrical-malfunction-causes-fire-at-Legacy-Apartments-229736551.html (accessed Nov. 1, 2013).

[28] Roman Uschak, "Electrical fire damages Belleville home," northjersey.com, Oct. 25, 2013, http://www.northjersey.com/news/229306611_Electrical_fire_damages_Belleville_home.html (accessed Nov. 1, 2013).

[29] Monica Garske and Chris Chan, "2 injured in La Jolla high-rise fire," nbcsandiego.com, Oct. 2, 2013, http://www.nbcsandiego.com/news/local/Electrical-Fire-La-Jolla-High-Rise-Coast-Blvd-226010051.html (accessed Nov. 1, 2013).

[30] "Electrical Fire Safety," Electrical Fire Safety Presentation, Electrical Safety Foundation International, Fire Prevention Week 2012, http://esfi.org/index.cfm/page/Electrical-Fire-Safety-Presentation-Fire-Prevention-Week-2012/cdid/12666/pid/10272 (accessed Nov. 19, 2013).

[31] The USFA Structure Fire Cause Methodology is designed for structure fires of which building fires are a subset. The cause definitions can be found at http://www.usfa.fema.gov/fireservice/nfirs/tools/fire_cause_category_matrix.shtm.

Topical Fire Report Series *Volume 16, Issue 4 / June 2015*

One- and Two-Family Residential Building Fires (2011-2013)

These topical reports are designed to explore facets of the U.S. fire problem as depicted through data collected in the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS). Each topical report briefly addresses the nature of the specific fire or fire-related topic, highlights important findings from the data, and may suggest other resources to consider for further information. Also included are recent examples of fire incidents that demonstrate some of the issues addressed in the report or that put the report topic in context.

Findings

- **An estimated 241,700 one- and two-family residential building fires were reported to fire departments within the United States each year and caused an estimated 2,025 deaths, 8,400 injuries, and 5.4 billion dollars in property loss.**
- **One- and two-family residential building fires accounted for 65 percent of all residential building fires, representing the largest subgroup of residential building fires.**
- **Cooking, at 35 percent, was the leading reported cause of one- and two-family residential building fires reported to the fire service. Of these cooking fires, 87 percent were small, confined fires with limited damage.**
- **In 52 percent of nonconfined one- and two-family residential building fires, the fire extended beyond the room of fire origin. The leading reported causes of these larger fires were other unintentional, careless actions (16 percent); electrical malfunctions (14 percent); intentional actions (12 percent); and open flames (11 percent).**
- **One- and two-family residential building fire incidence was higher in the cooler months, peaking in January at 11 percent.**
- **Smoke alarms were not present in 23 percent of nonconfined fires in occupied one- and two-family residential buildings. This is a high percentage when compared to the 3 percent of households lacking smoke alarms nationally.**
- **Automatic extinguishing systems (AESs) were present in only 1 percent of nonconfined fires in occupied one- and two-family residential buildings.**

From 2011 to 2013, fire departments responded to an estimated 241,700 fires in one- and two-family residences each year across the nation.[1, 2] These fires resulted in an annual average of 2,025 deaths, 8,400 injuries, and 5.4 billion dollars in property loss. One- and two-family residential building fires accounted for 65 percent of all residential building fires and dominated the overall residential building fire profile. One- and two-family residential buildings include detached dwellings, manufactured homes, mobile homes not in transit, and duplexes.

From 2011 to 2013, 67 percent of all fire deaths in the nation occurred in one- and two-family dwellings. Because these fatalities occurred throughout the year and all over the country, they often did not make national headlines. Nevertheless, fire deaths in one- and two-family dwellings accounted for far more deaths in most years than all natural disasters combined.[3]

Most one- and two-family residential building fires (61 percent) were larger, nonconfined fires; they were not contained in pots, stoves, garbage containers or other types of noncombustible containers that confine them. Fires in all other types of residential buildings, by contrast, were mostly small and "confined" to noncombustible containers (68 percent).

One- and two-family residential building fires also differed from all other residential building fires in their cause profiles. While cooking accounted for 35 percent of all one- and two-family residential building fires, cooking played a much larger role in all other types of residential building fires, accounting for 69 percent of fires. However, heating and electrical malfunctions, such as short circuits, arcing and the like, played a larger role in one- and two-family residential building fires than in all other types of residential building fires.

This current topical report is an update to the "One- and Two-Family Residential Building Fires (2010-2012)" (Volume 15, Issue 3) topical report, which was released in September 2014. As part of a series of topical reports that address fires in the major residential building types, the remainder of this report addresses the characteristics of one- and two-family residential building fires as reported to the National Fire Incident Reporting System (NFIRS). The focus is on fires reported from 2011 to 2013, the data most currently available at the time of the analysis.[4] This data is useful by itself and as a point of comparison with other residential building categories. Comparisons to multifamily residential building fires noted throughout the report are based on analyses from the "Multifamily Residential Building Fires (2011-2013)" (Volume 16, Issue 5) topical report.[5]

For the purpose of this report, the terms "residential fires" and "one- and two-family fires" are synonymous with "residential building fires" and "one- and two-family residential building fires," respectively. "One- and two-family fires" is used throughout the body of this report; the findings, tables, charts, headings and endnotes reflect the full category, "one- and two-family residential building fires."

Type of Fire

Building fires are divided into two classes of severity in NFIRS: "confined fires," which are fires confined to certain types of equipment or objects, and "nonconfined fires," which are fires that are not confined to certain types of equipment or objects. Confined building fires are small fire incidents that are limited in extent, staying within pots, fireplaces or certain other noncombustible containers.[6] Confined fires rarely result in serious injury or large content loss, and they are expected to have no significant accompanying property loss due to flame damage.[7] Of the two classes of severity, nonconfined fires accounted for 61 percent of one- and two-family fires. The smaller, confined fires accounted for the remaining 39 percent of one- and two-family fires. Cooking fires were the predominant type of confined fires in one- and two-family dwellings, as they were in most residential occupancies (Table 1).

Table 1. One- and Two-Family Residential Building Fires by Type of Incident (2011-2013)

Incident Type	Percent
Nonconfined fires	60.9
Confined fires	39.1
Cooking fire, confined to container	24.3
Chimney or flue fire, confined to chimney or flue	7.8
Incinerator overload or malfunction, fire confined	0.2
Fuel burner/boiler malfunction, fire confined	2.5
Commercial compactor fire, confined to rubbish	0.0
Trash or rubbish fire, contained	4.3
Total	100.0

Source: NFIRS 5.0.

Loss Measures

Table 2 presents losses, averaged over the three-year period from 2011 to 2013, of reported one- and two-family fires and all other residential fires.[8] The average number of fatalities per 1,000 fires and average dollar loss per fire for one- and two-family fires were about two times as high as the same loss measures for all other residential building fires. In addition, all of the average loss measures associated with nonconfined one- and two-family fires were notably higher than the same loss measures for confined one- and two-family fires. This can be expected, however, as nonconfined fires are generally larger fires that often result in serious injuries and more content loss.

Table 2. Loss Measures for One- and Two-Family Residential Building Fires (Three-Year Average, 2011-2013)

Measure	One- and Two-Family Residential Building Fires	Confined One- and Two-Family Residential Building Fires	Nonconfined One- and Two-Family Residential Building Fires	Residential Building Fires (Excluding One- and Two-Family)
Average Loss				
Fatalities/1,000 fires	6.7	0.0	11.0	3.1
Injuries/1,000 fires	27.9	7.1	41.3	29.0
Dollar loss/fire	$18,680	$210	$30,550	$10,390

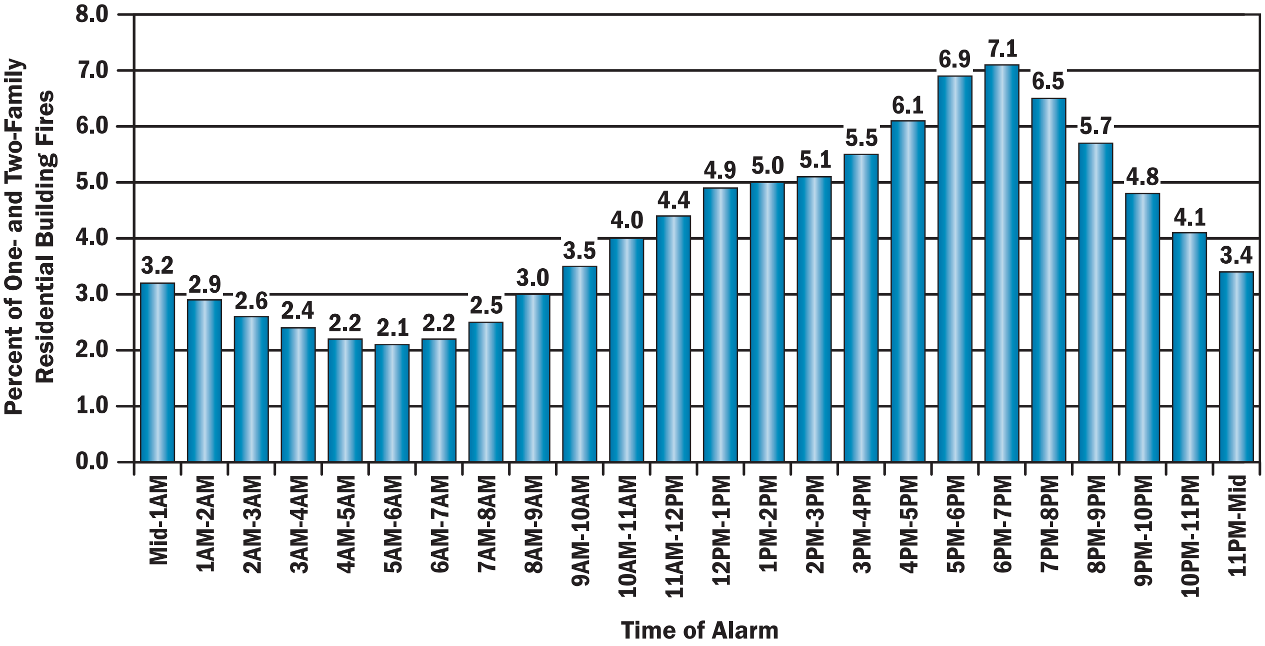
Source: NFIRS 5.0.

Notes: 1. Average loss for fatalities and injuries is computed per 1,000 fires; average dollar loss is computed **per fire** and rounded to the nearest $10.
2. The 2011 and 2012 dollar-loss values were adjusted to 2013 dollars.

When One- and Two-Family Residential Building Fires Occur

As shown in Figure 1, one- and two-family fires occurred most frequently in the early evening hours, peaking during the dinner hours from 5 to 8 p.m., when cooking fire incidence was high.[9, 10] Cooking fires, discussed later in the Causes of One- and Two-Family Residential Building Fires section, accounted for 35 percent of one- and two-family fires. Fires then declined throughout the night, reaching the lowest point during the early morning hours from 4 to 7 a.m.

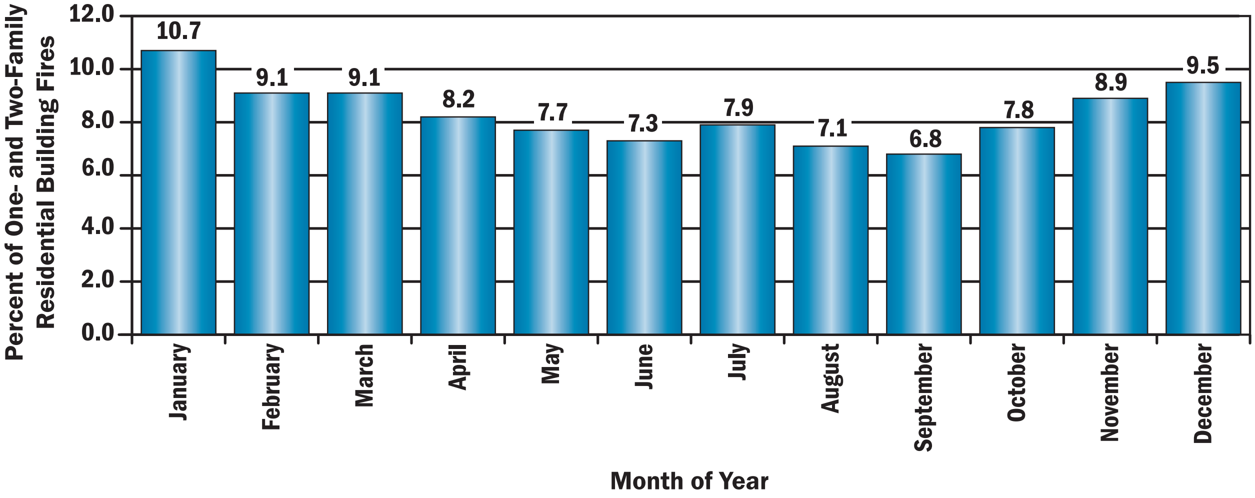
Figure 1. One- and Two-Family Residential Building Fires by Time of Alarm (2011-2013)



Source: NFIRS 5.0.
Note: Total does not add up to 100 percent due to rounding.

Figure 2 illustrates that one- and two-family fire incidence was higher in the cooler months, peaking in January at 11 percent. Winter peaks are often explained by the increase in heating fires. The increase in fires in the cooler months may also be the result of more indoor activities in general, as well as more indoor seasonal and holiday activities. During the spring and summer months, the fire incidence generally declined, reaching a low in September.

Figure 2. One- and Two-Family Residential Building Fires by Month (2011-2013)



Source: NFIRS 5.0.
Note: Total does not add up to 100 percent due to rounding.

Causes of One- and Two-Family Residential Building Fires

Cooking was the leading reported cause of one- and two-family fires and accounted for 35 percent of all one- and two-family fires, as shown in Table 3.[11] Of these cooking fires, 87 percent were small, confined fires with limited damage.

Heating, at 16 percent, was the second leading reported cause of one- and two-family fires. The next four causes combined accounted for 28 percent of one- and two-family fires: fires caused by electrical malfunctions, such as short circuits and wiring problems (8 percent); other unintentional, careless actions, a miscellaneous group (8 percent); open flames that resulted from candles, matches and the like (6 percent); and intentional actions (6 percent).[12]

Table 3. Leading Causes of One- and Two-Family Residential Building Fires (2011-2013)

Cause	Percent (Unknowns Apportioned)
Cooking	35.0
Heating	16.2
Electrical malfunction	8.4
Other unintentional, careless	7.6
Open flame	5.8
Intentional	5.8

Source: NFIRS 5.0.

There was a striking difference between one- and two-family and all other residential occupancies in the prevalence of cooking as a fire cause. While cooking accounted for 35 percent of one- and two-family fires, it accounted for 72 percent of multifamily residential building fires and 59 percent of other residential building fires. The most persuasive explanation for this difference may be that the smaller, confined fires in one- and two-family dwellings are not reported as often to fire departments. They are small and contained, and they often do not cause much damage. In addition, if it is activated, only the residents hear the smoke alarm. However, these same confined fires in multifamily residences may be reported if someone else in the complex hears the alarm or smells the smoke. Alternatively, if it is a newer complex, the alarms will be connected to the building alarm system, and the fire department may automatically be called.

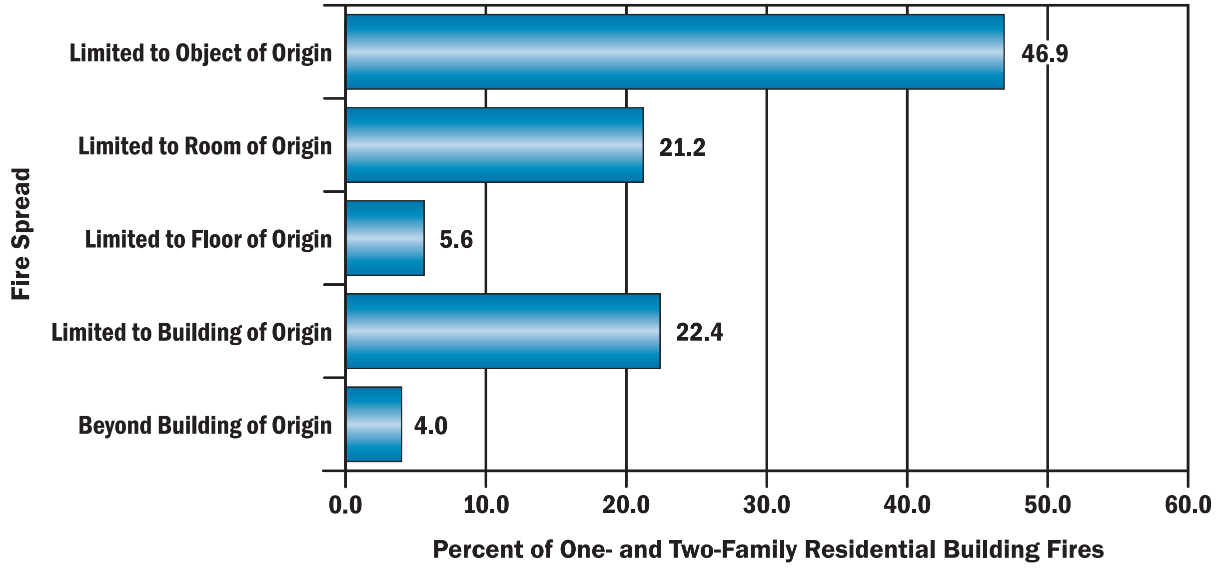
Heating and electrical malfunctions played a larger role in one- and two-family fires than in multifamily fires. One reason for this may be that many one- and two-family residential buildings have fireplaces, chimneys and fireplace-related equipment that most other types of residential properties do not have.[13]

A strong relationship between housing age and the rate of electrical fires has been observed, with housing over 40 years old having the strongest association with electrical distribution fires.[14, 15] As of 2013, the median age of one- and two-family housing was over 35 years. With more than half of the housing stock older than 35 years, electrical issues become an increasingly larger player in residential fires.[16] In addition, a 2008 study concluded that there are three major areas in older properties that contribute to compromised electrical systems: the effects of aging on the wiring itself, misuse and abuse of the electrical components, and noncode-compliant installations.[17] Codes, including the National Electrical Code®, are comprehensive and standard in nearly every community. “Noncode” improvements or changes, however, are difficult to track and, therefore, difficult to enforce.

Fire Spread in One- and Two-Family Residential Building Fires

In 47 percent of one- and two-family fires, the fire was limited to the object of origin (Figure 3). Included in these fires are those coded as “confined fires” in NFIRS. Additionally, 32 percent of the fires extended beyond the room of origin.

Figure 3. Extent of Fire Spread in One- and Two-Family Residential Building Fires (2011-2013)



Source: NFIRS 5.0.
Note: Total does not add up to 100 percent due to rounding.

Confined Fires

NFIRS allows abbreviated reporting for smaller, confined fires, and many details of these fires are not required to be reported. It is important to note that not all fires where the extent of fire spread is limited to the object of origin are counted as NFIRS confined fires.[18] For example, a fire in which the fire spread is limited to a mattress or clothes dryer is not defined as a "confined fire" in NFIRS because of the greater potential for spread. Unlike fires in pots or chimneys, there is no container to stop the fire, even though the fire did not spread beyond the object of origin.

As previously discussed, however, it is known that confined fires accounted for 39 percent of all one- and two-family fires. Cooking fires — those cooking fires confined to a pot or the oven, for example — accounted for 62 percent of these confined fires (Table 1).

In addition, the number of confined one- and two-family fires was greatest from 5 to 8 p.m.; these fires accounted for 52 percent of the one- and two-family fires in this time period. Moreover, confined cooking fires accounted for 66 percent of the confined fires and 34 percent of all fires in one- and two-family buildings that occurred from 5 to 8 p.m.

Confined one- and two-family fires peaked in January, then declined through the spring and summer, reaching the lowest incidence in August.

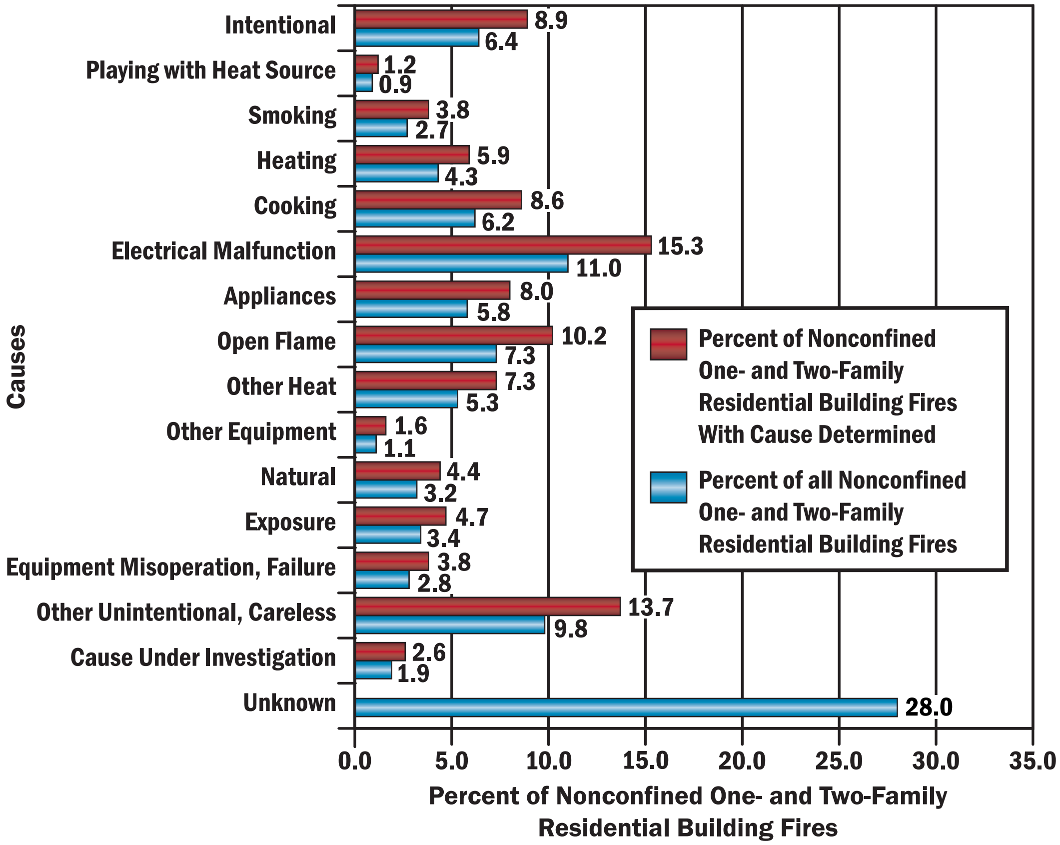
Nonconfined Fires

This section addresses nonconfined one- and two-family fires — the larger and more serious fires that are not confined to noncombustible containers — where more detailed fire data are available, as they are required to be reported in NFIRS.

Causes of Nonconfined One- and Two-Family Residential Building Fires

While cooking was the leading reported cause of one- and two-family fires overall, it only accounted for 9 percent of all nonconfined one- and two-family fires (Figure 4). At 15 percent, electrical malfunction was the leading reported cause of nonconfined one- and two-family fires. The second and third leading reported causes of nonconfined one- and two-family fires were other unintentional, careless actions (14 percent) and open flames (10 percent).

Figure 4. Causes of Nonconfined One- and Two-Family Residential Building Fires (2011-2013)



Source: NFIRS 5.0.

Notes: 1. Causes are listed in order of the U.S. Fire Administration (USFA) Structure Fire Cause Hierarchy for ease of comparison of fire causes across different aspects of the fire problem. Fires are assigned to one of 16 cause groupings using a hierarchy of definitions, approximately as shown in the chart above. A fire is included in the highest category into which it fits. If it does not fit the top category, then the second one is considered, and if not that one, the third and so on. For example, if the fire is judged to be intentionally set and a match was used to ignite it, it is classified as intentional and not open flame because intentional is higher in the hierarchy.

2. Total percent of all nonconfined one- and two-family residential building fires does not add up to 100 percent due to rounding.

Where Nonconfined One- and Two-Family Residential Building Fires Start (Area of Fire Origin)

Nonconfined one- and two-family fires most often started in cooking areas and kitchens (18 percent), as shown in Table 4. Bedrooms (13 percent) and common rooms, living rooms or lounge areas (7 percent) were the next most common areas of fire origin in the home. Smaller but not minor percentages of fires started in attics and vacant spaces (6 percent); exterior wall surfaces (6 percent); laundry areas (5 percent); and vehicle storage areas, such as garages and carports (5 percent).

Note that these areas of origin do not include areas associated with confined fires. Cooking was the leading reported cause of all one- and two-family fires at 35 percent, and it is not surprising that kitchens were the leading area of fire origin. The percentages were not identical between cooking and kitchen fires because some cooking fires started outside the kitchen, some areas of origin for cooking fires were not reported (as in most confined cooking fires), and some kitchen fires were not due to cooking. In fact, only 42 percent of nonconfined one- and two-family fires that started in the kitchen were cooking fires. Other unintentional, careless actions accounted for 14 percent, and appliances, such as freezers and refrigerators, accounted for an additional 9 percent of nonconfined one- and two-family fires that started in the kitchen.

Table 4. Leading Areas of Fire Origin in Nonconfined One- and Two-Family Residential Building Fires (2011-2013)

Areas of Fire Origin	Percent (Unknowns Apportioned)
Cooking area, kitchen	18.3
Bedrooms	12.7
Common room, den, family room, living room, lounge	6.7
Attic, vacant spaces	5.7
Exterior wall surfaces	5.5
Laundry area	5.1
Vehicle storage area: garage, carport	5.0

Source: NFIRS 5.0.

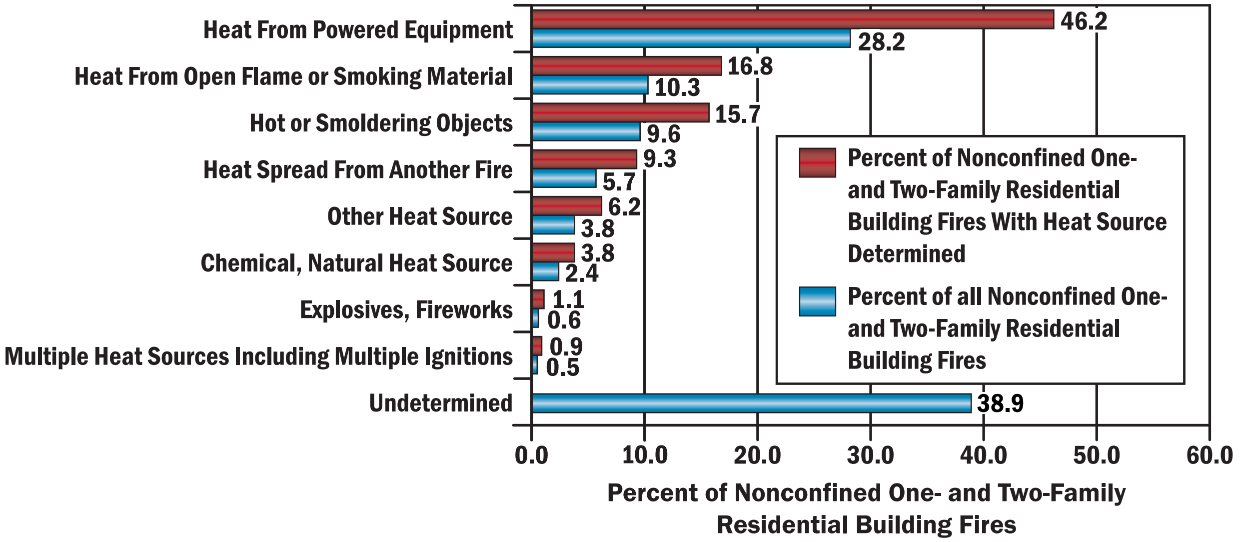
How Nonconfined One- and Two-Family Residential Building Fires Start (Heat Source)

Figure 5 shows sources of heat categories for nonconfined one- and two-family fires. Heat from powered equipment accounted for 46 percent of nonconfined one- and two-family fires. This category includes electrical arcing (16 percent); radiated or conducted heat from operating equipment (13 percent); heat from other powered equipment (12 percent); and spark, ember or flame from operating equipment (5 percent).

Heat from open flame or smoking materials accounted for 17 percent of nonconfined one- and two-family fires. This category includes such items as miscellaneous open flame or smoking materials (4 percent), cigarettes (4 percent), lighters and matches (combined, 4 percent), and candles (3 percent).

The third largest category pertained to hot or smoldering objects (16 percent). This category includes miscellaneous hot or smoldering objects (7 percent) and hot embers or ashes (7 percent).

Figure 5. Sources of Heat in Nonconfined One- and Two-Family Residential Building Fires by Major Category (2011-2013)



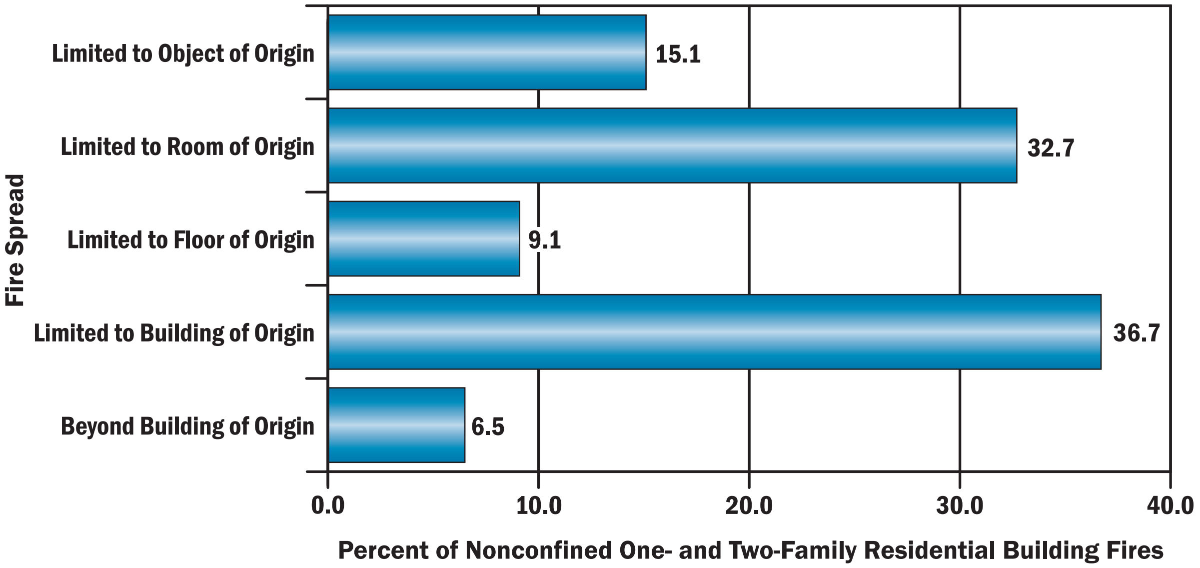
Source: NFIRS 5.0.

Fire Spread in Nonconfined One- and Two-Family Residential Building Fires

Figure 6 shows the extent of fire spread in nonconfined one- and two-family fires. In 48 percent of the nonconfined fires, the fire was limited to the object or room of fire origin — in 33 percent of nonconfined fires, the fire was limited to the room of origin; in another 15 percent of fires, the fire was limited to the object of origin.

In 52 percent of nonconfined one- and two-family fires, the fire extended beyond the room of origin. The leading reported causes of these larger fires were other unintentional, careless actions (16 percent); electrical malfunctions (14 percent); intentional actions (12 percent); and open flames (11 percent).

Figure 6. Extent of Fire Spread in Nonconfined One- and Two-Family Residential Building Fires (2011-2013)



Source: NFIRS 5.0.
Note: Total does not add up to 100 percent due to rounding.

Factors Contributing to Ignition in Nonconfined One- and Two-Family Residential Building Fires

Table 5 shows the categories of factors contributing to ignition in nonconfined one- and two-family fires. The leading category was the misuse of material or product (36 percent). In this category, the leading specific factors contributing to ignition were a heat source too close to combustible materials (13 percent of all nonconfined one- and two-family fires) and abandoned or discarded materials, such as matches or cigarettes (10 percent of all nonconfined one- and two-family fires).

Electrical failures and malfunctions contributed to 23 percent of nonconfined one- and two-family fires. Operational deficiency was the third leading category at 14 percent. Unattended equipment was the leading factor in the operational deficiency category and accounted for 7 percent of all nonconfined one- and two-family fires.

Table 5. Factors Contributing to Ignition for Nonconfined One- and Two-Family Residential Building Fires by Major Category (Where Factors Contributing to Ignition Are Specified, 2011-2013)

Factors Contributing to Ignition Category	**Percent of Nonconfined One- and Two-Family** Residential Building Fires (Unknowns Apportioned)
Misuse of material or product	35.6
Electrical failure, malfunction	22.9
Operational deficiency	14.0
Fire spread or control	11.9
Mechanical failure, malfunction	7.1
Other factors contributing to ignition	6.3
Natural condition	4.7
Design, manufacture, installation deficiency	2.4

Source: NFIRS 5.0.

Notes: 1. Includes only incidents where factors that contributed to the ignition of the fire were specified.
2. Multiple factors contributing to fire ignition may be noted for each incident; the total will exceed 100 percent.

Alerting/Suppression Systems in One- and Two-Family Residential Building Fires

Technologies to detect and extinguish fires have been major contributors to the drop in fire fatalities and injuries over the past 35 years. Smoke alarms are now present in the majority of residential buildings. In addition, the use of residential sprinklers is widely supported by the fire service and is gaining support within residential communities.

Smoke alarm data is available for both confined and nonconfined fires, although for confined fires, the data is very limited in scope. As different levels of data are reported on smoke alarms in confined and nonconfined fires, the analyses are performed separately. Note that the data presented in Tables 6 to 8 are the raw counts from the NFIRS dataset and are not scaled to national estimates of smoke alarms in one- and two-family fires. In addition, NFIRS does not allow for the determination of the type of smoke alarm — that is, if the smoke alarm was photoelectric or ionization — or the location of the smoke alarm with respect to the area of fire origin.

Smoke Alarms in Nonconfined Fires

Overall, smoke alarms were reported as present in 38 percent of nonconfined one- and two-family fires (Table 6). In 29 percent of nonconfined one- and two-family fires, there were no smoke alarms present. In another 33 percent of these fires, firefighters were unable to determine if a smoke alarm was present. Thus, smoke alarms were potentially missing in between 29 and 62 percent of fires with the ability to spread and possibly result in fatalities.

Table 6. Presence of Smoke Alarms in Nonconfined One- and Two-Family Residential Building Fires (2011-2013)

Presence of Smoke Alarms	Percent
Present	38.1
None present	29.2
Undetermined	32.7
Total	100.0

Source: NFIRS 5.0.

While 19 percent of all nonconfined one- and two-family fires occurred in residential buildings that are **not** currently or routinely occupied, these occupancies — buildings under construction, undergoing major renovation, vacant and the like — are unlikely to have alerting and suppression systems that are in place and, if in place, that are operational. In fact, only 6 percent of nonconfined fires in unoccupied one- and two-family residential buildings were reported as having smoke alarms that operated. As a result, the detailed smoke alarm analyses in the next section focus on nonconfined fires in occupied one- and two-family residential buildings only.

Smoke Alarms in Nonconfined Fires in Occupied One- and Two-Family Residential Buildings

Smoke alarms were reported as present in 44 percent of nonconfined fires in occupied one- and two-family residential buildings (Table 7). In 23 percent of nonconfined fires in occupied one- and two-family residential buildings, there were no smoke alarms present. In another 33 percent of these fires, firefighters were unable to determine if a smoke alarm was present. Unfortunately, in almost half (49 percent) of the fires where the presence of a smoke alarm was undetermined, either the flames involved the building of origin or spread beyond it. These fires were so large and destructive that it is unlikely the presence of a smoke alarm could be determined.

When smoke alarms were present (44 percent) and the alarm operational status is considered, the percentage of smoke alarms reported as present consisted of:

- Present and operated — 25 percent.
- Present but did not operate — 11 percent (alarm failed to operate, 6 percent; fire too small, 6 percent).[19]
- Present but operational status unknown — 7 percent.[20]

When the subset of incidents where smoke alarms were reported as present was analyzed separately as a whole, smoke alarms were reported to have operated in 57 percent of these incidents. The alarms failed to operate in 13 percent of these incidents, and the fire was too small to activate the alarm in another 13 percent. The operational status of the alarm was undetermined in an additional 17 percent of these incidents.

Nationally, only 3 percent of households lack smoke alarms.[21] Here, at least 23 percent of nonconfined fires in occupied one- and two-family residential buildings had no smoke alarms present — and perhaps more if fires without information on smoke alarms were also taken into account.[22] A large proportion of reported fires without smoke alarms may reflect the effectiveness of the alarms themselves: Smoke alarms do not prevent fires, but they may prevent a fire from being reported if it is detected at an early stage and extinguished before the fire department becomes involved. Alternatively, fires in homes without smoke alarms may **not** be detected at an early stage, causing them to grow large, require fire department intervention, and thus be reported.[23]

Properly installed and maintained smoke alarms provide an early warning signal to household members in the event that a fire occurs. Smoke alarms help save lives and property. USFA continues to partner with other government agencies and fire service entities to improve and develop new smoke alarm technologies. More information on smoke alarm technologies, performance, disposal and storage, training bulletins, and public education and outreach materials can be found at http://www.usfa.fema.gov/prevention/technology/smoke_fire_alarms.html.

Table 7. NFIRS Smoke Alarm Data for Nonconfined Fires in Occupied One- and Two-Family Residential Buildings (2011-2013)

Presence of Smoke Alarms	Smoke Alarm Operational Status	Smoke Alarm Effectiveness	Count	Percent
Present	Fire too small to activate smoke alarm		14,572	5.8
	Smoke alarm operated	Smoke alarm alerted occupants, occupants responded	44,558	17.8
		Smoke alarm alerted occupants, occupants failed to respond	1,609	0.6
		No occupants	8,566	3.4
		Smoke alarm failed to alert occupants	1,752	0.7
		Undetermined	6,707	2.7
	Smoke alarm failed to operate		14,167	5.7
	Undetermined		18,558	7.4
None present			57,946	23.1
Undetermined			81,874	32.7
Total incidents			250,309	100.0

Source: NFIRS 5.0.

Notes: 1. The data presented in this table are raw data counts from the NFIRS dataset summed (not averaged) from 2011-2013. They do not represent national estimates of smoke alarms in nonconfined fires in occupied one- and two-family residential buildings. They are presented for informational purposes.
2. Total does not add up to 100 percent due to rounding.

Smoke Alarms in Confined Fires

Less information about smoke alarm status is collected for confined fires, but the data still give important insights about the effectiveness of alerting occupants in these types of fires. The analyses presented here do not differentiate between occupied and unoccupied residential buildings, as this data detail is not required when reporting confined fires in NFIRS. However, an assumption may be made that confined fires are fires in occupied housing, as these types of fires are unlikely to be reported in residential buildings that are not occupied.

Smoke alarms alerted occupants in 34 percent of the reported confined one- and two-family fires (Table 8). In other words, in about one-third of fires in these types of homes, residents received a warning from a smoke alarm. The data suggest that smoke alarms may alert residents to confined fires, as the early alerting allowed the occupants to extinguish the fires, or the fires self-extinguished. If this is the case, it is an example of the contribution to life safety and the ability to rapidly respond to fires in early stages that smoke alarms afford. Details on smoke alarm effectiveness for confined fires are needed to pursue this analysis further.

Occupants were not alerted by smoke alarms in 22 percent of confined one- and two-family fires.[24] In 44 percent of these confined fires, the smoke alarm effectiveness was unknown.

Table 8. NFIRS Smoke Alarm Data for Confined One-and Two-Family Residential Building Fires (2011-2013)

Smoke Alarm Effectiveness	Count	Percent
Smoke alarm alerted occupants	66,141	33.5
Smoke alarm did not alert occupants	43,415	22.0
Unknown	87,632	44.4
Null/Blank	1	0.0
Total incidents	197,189	100.0

Source: NFIRS 5.0.

Notes: 1. The data presented in this table are raw data counts from the NFIRS dataset summed (not averaged) from 2011-2013. They do not represent national estimates of smoke alarms in confined one- and two-family residential building fires. They are presented for informational purposes.
2. Total does not add up to 100 percent due to rounding.

Automatic Extinguishing Systems in Nonconfined Fires in Occupied One- and Two-Family Residential Buildings

AES data is available for both confined and nonconfined fires, although for confined fires, the data is also very limited in scope. In confined residential building fires, an AES was present in only 1 percent of reported incidents.[25] In addition, the following AES analyses focus on nonconfined fires in occupied one- and two-family buildings only, as even fewer AESs are present in unoccupied housing.

Residential sprinklers are the primary AES in one- and two-family residences and are not yet widely installed. In fact, full or partial AESs were reported as present in only 1 percent of nonconfined fires in occupied one- and two-family buildings (Table 9). This was the lowest reported presence of sprinklers in nonconfined fires in any occupied residential occupancy.

Residential sprinkler systems help to reduce the risk of civilian and firefighter casualties, homeowner insurance premiums, and uninsured property losses. Yet many residences are unequipped with AESs that are often installed in hotels and businesses. Sprinklers are required by code in hotels and many multifamily residences. There are major movements in the U.S. fire service to require or facilitate use of sprinklers in all new homes, which could improve the use of residential sprinklers in the future. At present, however, they are largely absent in residences nationwide.[26]

USFA and fire service officials across the nation are working to promote and advance residential fire sprinklers. More information on costs and benefits, performance, training bulletins, and public education and outreach materials regarding residential sprinklers can be found at http://www.usfa.fema.gov/prevention/technology/home_fire_sprinklers.html. Additionally, USFA's position statement on residential sprinklers is available at http://www.usfa.fema.gov/about/sprinklers_position.html.

Table 9. NFIRS Automatic Extinguishing System Data for Nonconfined Fires in Occupied One- and Two-Family Residential Buildings (2011-2013)

Automatic Extinguishing System Presence	Count	Percent
Automatic extinguishing system present	2,855	1.1
Partial system present	103	0.0
Automatic extinguishing system not present	225,984	90.3
Unknown	21,367	8.5
Total incidents	250,309	100.0

Source: NFIRS 5.0.

Notes: 1. The data presented in this table are raw data counts from the NFIRS dataset summed (not averaged) from 2011-2013. They do not represent national estimates of AESs in nonconfined fires in occupied one- and two-family residential buildings. They are presented for informational purposes.

2. Total does not add up to 100 percent due to rounding.

Examples

The following are some recent examples of one- and two-family fires reported by the media:

- April 2015: A lightning strike caused a late night house fire in San Antonio, Texas. Upon arrival, the San Antonio Fire Department encountered flames coming out of the second-story roof but were able to eventually control the fire. The family of three who lived in the home escaped without injury. The entire second-story roof of the home, however, was destroyed, with damages estimated at $110,000.[27]

- April 2015: A faulty portable space heater caused a two-story house fire in Cecil County, Maryland, that injured one resident and one firefighter. The young resident, who reported the afternoon fire, suffered minor burns. The firefighter, who was first to arrive at the scene, was seriously burned while entering the home after initial reports falsely indicated that someone was still trapped inside. For treatment of their injuries, the resident was transported to a local hospital and the firefighter was transported to a burn center. The fire started in a second-floor bedroom. Damage to the home was estimated at $95,000, and although smoke alarms were present inside of the home, they did not activate.[28]

- April 2015: A man and his grandmother were killed in a Revloc, Pennsylvania, duplex fire. Upon arrival, fire crews found much of the building engulfed in flames. Witnesses reported that the 24-year-old man re-entered the house in an attempt to save the 65-year-old woman. While others in the duplex were able to safely escape, the man and his grandmother became trapped and died from smoke and gas inhalation. Their bodies were later recovered. It was reported that a wood burner may have started the fire.[29]

NFIRS Data Specifications for One- and Two-Family Residential Building Fires

Data for this report were extracted from the NFIRS annual Public Data Release files for 2011, 2012 and 2013. Only Version 5.0 data were extracted.

One- and two-family fires were defined using the following criteria:

- Aid Types 3 (mutual aid given) and 4 (automatic aid given) were excluded to avoid double counting of incidents.

- Incident Types 111 to 123 (excluding Incident Type 112):

Incident Type	Description
111	Building fire
113	Cooking fire, confined to container
114	Chimney or flue fire, confined to chimney or flue
115	Incinerator overload or malfunction, fire confined
116	Fuel burner/boiler malfunction, fire confined
117	Commercial compactor fire, confined to rubbish
118	Trash or rubbish fire, contained
120	Fire in mobile property used as a fixed structure, other
121	Fire in mobile home used as fixed residence
122	Fire in motor home, camper, recreational vehicle
123	Fire in portable building, fixed location

Note: Incident Types 113 to 118 do not specify if the structure is a building.

- Property Use 419:

Property Use	Description
419	One- or two-family dwelling, detached, manufactured home, mobile home not in transit, duplex

- Structure Type:
    - For Incident Types 113 to 118:
        - 1—Enclosed building, or
        - 2—Fixed portable or mobile structure, or
        - Structure Type not specified (null entry).
    - For Incident Types 111 and 120 to 123:
        - 1—Enclosed building, or
        - 2—Fixed portable or mobile structure.

The analyses contained in this report reflect the current methodologies used by USFA. USFA is committed to providing the best and most currently available information on the U.S. fire problem and continually examines its data and methodology to fulfill this goal. Because of this commitment, data collection strategies and methodological changes are possible and do occur. As a result, analyses and estimates of the fire problem may change slightly over time. Previous analyses and estimates on specific issues (or similar issues) may have used different methodologies or data definitions and may not be directly comparable to the current ones.

Information regarding USFA's national estimates for residential building fires as well as the data sources used to derive the estimates can be found in the document, "Data Sources and National Estimates Methodology Overview for the U.S. Fire Administration's Topical Fire Report Series (Volume 16)," http://www.usfa.fema.gov/downloads/pdf/statistics/data_sources_and_national_estimates_methodology_vol16.pdf. This document also addresses the specific NFIRS data elements analyzed in the topical reports, as well as "unknown" data entries and missing data.

To request additional information or to comment on this report, visit http://www.usfa.fema.gov/contact.html.

Notes:

[1] National estimates are based on 2011-2013 native Version 5.0 data from NFIRS, residential structure fire loss estimates from the National Fire Protection Association's (NFPA's) annual surveys of fire loss, and USFA's residential building fire loss estimates: http://www.usfa.fema.gov/data/statistics/order_download_data.html. Further information on USFA's residential building fire loss estimates can be found in the "National Estimates Methodology for Building Fires and Losses," August 2012, http://www.usfa.fema.gov/downloads/pdf/statistics/national_estimate_methodology.pdf. For information on NFPA's survey methodology, see NFPA's report on fire loss in the U.S.: http://www.nfpa.org/~/media/Files/Research/NFPA%20reports/Overall%20Fire%20Statistics/osfireloss.pdf. In this topical report, fires are rounded to the nearest 100, deaths to the nearest five, injuries to the nearest 25, and dollar loss to the nearest $100 million.

[2] In NFIRS Version 5.0, a structure is a constructed item of which a building is one type. In previous versions of NFIRS, the term "residential structure" commonly referred to buildings where people live. To coincide with this concept, the definition of a residential structure fire for NFIRS 5.0 has, therefore, changed to include only those fires where the NFIRS 5.0 Structure Type is 1 or 2 (enclosed building and fixed portable or mobile structure) with a residential property use. Such structures are referred to as "residential buildings" to distinguish these buildings from other structures on residential properties that may include fences, sheds and other uninhabitable structures. In addition, confined fire incidents that have a residential property use but do not have a Structure Type specified are presumed to occur in buildings. Nonconfined fire incidents that have a residential property use without a Structure Type specified are considered to be invalid incidents (Structure Type is a required field) and are not included.

[3] National Oceanic and Atmospheric Administration's National Weather Service, Summary of Natural Hazard Statistics for 2013 in the U.S. (http://www.nws.noaa.gov/om/hazstats/sum13.pdf).

[4] Fire department participation in NFIRS is voluntary; however, some states do require their departments to participate in the state system. Additionally, if a fire department is a recipient of a Fire Act Grant, participation is required. From 2011 to 2013, 68 percent of NFPA's annual average estimated 1,334,800 fires to which fire departments responded were captured in NFIRS. Thus, NFIRS is not representative of all fire incidents in the U.S. and is not a "complete" census of fire incidents. Although NFIRS does not represent 100 percent of the incidents reported to fire departments each year, the enormous dataset exhibits stability from one year to the next, without radical changes. Results based on the full dataset are generally similar to those based on part of the data.

[5] Multifamily residential buildings include structures such as apartments, town houses, row houses, condominiums, and other tenement properties.

[6] In NFIRS, confined fires are defined by Incident Type codes 113-118.

[7] NFIRS distinguishes between "content" and "property" loss. Content loss includes losses to the contents of a structure due to damage by fire, smoke, water and overhaul. Property loss includes losses to the structure itself or to the property itself. Total loss is the sum of the content loss and the property loss. For confined fires, the expectation is that the fire did not spread beyond the container (or rubbish for Incident Type code 118), and hence, there was no property damage (damage to the structure itself) from the flames. However, there could be property damage as a result of smoke, water and overhaul.

[8] The average fire death and fire injury loss rates computed from the national estimates do not agree with average fire death and fire injury loss rates computed from NFIRS data alone. The fire death rate computed from national estimates is (1,000*(2,025/241,700)) = 8.4 deaths per 1,000 one- and two-family residential building fires, and the fire injury rate is (1,000*(8,400/241,700)) = 34.8 injuries per 1,000 one- and two-family residential building fires.

[9] For the purposes of this report, the time of the fire alarm is used as an approximation for the general time at which the fire started. However, in NFIRS, it is the time at which the fire was reported to the fire department.

[10] USFA, "Cooking Fires in Residential Buildings (2008-2010)," Volume 13, Issue 12, January 2013, http://www.usfa.fema.gov/downloads/pdf/statistics/v13i12.pdf.

[11] The USFA Structure Fire Cause Methodology was used to determine the cause of one- and two-family residential building fires. The cause methodology and definitions can be found in the document "National Fire Incident Reporting System Version 5.0 Fire Data Analysis Guidelines and Issues," July 2011, http://www.usfa.fema.gov/downloads/pdf/nfirs/nfirs_data_analysis_guidelines_issues.pdf.

[12] Fires caused by intentional actions include, but are not limited to, fires that are deemed to be arson. Intentional fires are those fires that are deliberately set and include fires that result from the deliberate misuse of a heat source and fires of an incendiary nature (arson) that require fire service intervention. For information and statistics on arson fires only, refer to the Uniform Crime Reporting Program arson statistics from the U.S. Department of Justice, FBI, Criminal Justice Information Services Division, http://www.fbi.gov/about-us/cjis/ucr/ucr.

[13] The American Housing Survey does not indicate the number of fireplaces, chimneys and fireplace-related equipment per se. It does collect data on fireplaces, etc., as the primary heating unit, which applies to this analysis. U.S. Department of Housing and Urban Development (HUD) and U.S. Census Bureau, 2013 American Housing Survey, "General Characteristics by Units in Structure-All Occupied Units (National)," Table C-12-AO, http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=AHS_2013_C12AO&prodType=table (accessed April 14, 2015).

[14] Smith, Linda E. and Dennis McCoskrie, "What Causes Wiring Fires in Residences?" Fire Journal, January/February 1990.

[15] Dini, David A., "Residential Electrical System Aging Research Project," Fire Protection Research Foundation, Quincy, Massachusetts, July 1, 2008, http://www.nfpa.org/research/fire-protection-research-foundation/reports-and-proceedings/electrical-safety/aging-electrical-system-performance (accessed May 5, 2015).

[16] The American Housing Survey does not have a category for one- and two-family residences that conforms to the definition used by NFIRS. Housing age given here is an estimate based on the information presented for single-family attached and detached housing. HUD and U.S. Census Bureau, 2013 American Housing Survey, "General Characteristics by Units in Structure-All Occupied Units (National)," Table C-12-AO, http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=AHS_2013_C12AO&prodType=table (accessed April 14, 2015).

[17] Dini, David A., "Residential Electrical System Aging Research Project," Fire Protection Research Foundation, Quincy, Massachusetts, July 1, 2008, http://www.nfpa.org/research/fire-protection-research-foundation/reports-and-proceedings/electrical-safety/aging-electrical-system-performance (accessed May 5, 2015).

[18] As noted previously, in NFIRS, confined building fires are small fire incidents that are limited in scope, are confined to specific noncombustible containers, rarely result in serious injury or large content loss, and are expected to have no significant accompanying property loss due to flame damage. In NFIRS, confined fires are defined by Incident Type codes 113-118.

[19] Total does not add up to 11 percent due to rounding.

[20] Total does not add up to 44 percent due to rounding.

[21] Greene, Michael and Craig Andres, "2004-2005 National Sample Survey of Unreported Residential Fires," Division of Hazard Analysis, Directorate for Epidemiology, U.S. Consumer Product Safety Commission, July 2009.

[22] Here, **at least** 23 percent of nonconfined fires in occupied one- and two-family residential buildings had no smoke alarms present — the 23 percent that were known to not have smoke alarms and some portion (or as many as all) of the fires where the smoke alarm presence was undetermined.

[23] The "2004-2005 National Sample Survey of Unreported Residential Fires," however, suggests that this may not be the case. It is observed that "if this conjecture is true, it would suggest that the percentage decrease in fire department-attended fires would have been greater than unattended fires in the 20 year period between the surveys."

[24] In confined fires, the entry "smoke alarm did not alert occupants" can mean no smoke alarm was present; the smoke alarm was present but did not operate; the smoke alarm was present and operated, but the occupant/s was already aware of the fire; or there were no occupants present at the time of the fire.

[25] As confined fire codes are designed to capture fires contained to noncombustible containers, it is not recommended to code a fire incident as a small-, low- or no-loss confined fire incident if the AES operated and contained the fire as a result. The preferred method is to code the fire as a standard fire incident with fire spread confined to the object of origin and provide the relevant information on AES presence and operation.

[26] HUD and U.S. Census Bureau, 2011 American Housing Survey, "Health and Safety Characteristics-All Occupied Units (National)," Table S-01-AO, http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=AHS_2011_S01AO&prodType=table (accessed May 5, 2015).

[27] "Lightning Sparks House Fire," www.kens5.com, April 13, 2015, http://www.kens5.com/story/news/local/2015/04/13/lightning-sparks-house-fire/25700497/ (accessed April 13, 2015).

[28] Brown, Robin, "2 Injured in House Fire," www.delawareonline.com, April 12, 2105, http://www.delawareonline.com/story/news/local/2015/04/12/injured-house-fire/25691967/ (accessed April 13, 2015).

[29] "Man, Grandmother Die in House Fire as He Tries to Save Her," www.nytimes.com, April 4, 2015, http://www.nytimes.com/aponline/2015/04/04/us/ap-us-fatal-duplex-fire.html?_r=0 (accessed May 5, 2015).

TOPICAL FIRE REPORT SERIES
Volume 16, Issue 1 / June 2015

Residential Building Fires (2011–2013)

These topical reports are designed to explore facets of the U.S. fire problem as depicted through data collected in the U.S. Fire Administration's National Fire Incident Reporting System. Each topical report briefly addresses the nature of the specific fire or fire-related topic, highlights important findings from the data, and may suggest other resources to consider for further information. Also included are recent examples of fire incidents that demonstrate some of the issues addressed in the report or that put the report topic in context.

Findings

- **An estimated 372,900 residential building fires were reported to fire departments within the United States each year and caused an estimated 2,530 deaths, 13,125 injuries and $7 billion in property loss.**
- **Cooking, at 48 percent, was the leading reported cause of residential building fires. Nearly all residential building cooking fires were small, confined fires (91 percent).**
- **Residential building fire incidence was higher in the cooler months, peaking in January at 10 percent.**
- **Residential building fires occurred most frequently in the early evening hours, peaking during the dinner hours from 5 to 8 p.m., when cooking fire incidence is high.**
- **Nonconfined residential building fires most often started in cooking areas and kitchens (21 percent).**
- **In 49 percent of nonconfined residential building fires, the fire extended beyond the room of origin. The leading reported causes of these larger fires were unintentional or careless actions (16 percent), electrical malfunctions (13 percent), intentional actions (12 percent), and open flames (11 percent).**
- **The leading reported factor contributing to ignition category was misuse of material or product (38 percent).**
- **Smoke alarms were not present in 22 percent of nonconfined fires in occupied residential buildings. This is a high percentage when compared to the 3 percent of households lacking smoke alarms nationally. Additionally, automatic extinguishing systems (AESs) were present in only 4 percent of nonconfined fires in occupied residential buildings.**

From 2011 to 2013, fire departments responded to an estimated 372,900 fires in residential buildings each year across the nation.[1, 2] These fires resulted in an annual average of 2,530 deaths, 13,125 injuries and $7 billion in property loss.

The residential building portion of the fire problem is of great national importance, as it accounts for the vast majority of civilian casualties. National estimates for 2011-2013 show that 83 percent of all fire deaths and 79 percent of all fire injuries occurred in residential buildings. In addition, residential building fires accounted for over half (58 percent) of the total dollar loss from all fires.[3]

The term "residential buildings" includes what are commonly referred to as "homes," whether they are one- or two-family dwellings or multifamily buildings. It also includes manufactured housing, hotels and motels, residential hotels, dormitories, assisted living facilities, and halfway houses — residences for formerly institutionalized individuals (patients with mental disabilities or drug addictions, or those formerly incarcerated) that are designed to facilitate their readjustment to private life. The term "residential buildings" does not include institutions such as prisons, nursing homes, juvenile care facilities, or hospitals, even though people may reside in these facilities for short or long periods of time.

As part of a series of topical reports that address fires in types of residential buildings, this report addresses the characteristics of all residential building fires, as reported to the National Fire Incident Reporting System (NFIRS). The focus is on fires reported from 2011 to 2013, the most recent data available at the time of the analysis.[4] NFIRS data is used for the analyses throughout this report.

For the purpose of this report, the term "residential fires" is synonymous with "residential building fires." "Residential fires" is used throughout the body of this report; the findings, tables, charts, headings and endnotes reflect the full category, "residential building fires."

U.S. Department of Homeland Security • U.S. Fire Administration
National Fire Data Center • Emmitsburg, Maryland 21727
www.usfa.fema.gov/data/statistics

Type of Fire

Building fires are divided into two classes of severity in NFIRS: "confined fires," which are fires confined to certain types of equipment or objects, and "nonconfined fires," which are fires that are not confined to certain types of equipment or objects. Confined building fires are small fire incidents that are limited in extent, staying within pots, fireplaces or certain other noncombustible containers.[5] Confined fires rarely result in serious injury or large content loss and are expected to have no significant accompanying property loss due to flame damage.[6] Of the two classes of severity, nonconfined fires accounted for 51 percent of residential fires. The smaller, confined fires accounted for the remaining 49 percent of residential fires. Cooking fires were the predominant type of confined fires in residential buildings (Table 1).

Table 1. Residential Building Fires by Type of Incident (2011-2013)

Incident Type	Percent
Nonconfined fires	50.7
Confined fires	49.3
Cooking fire, confined to container	36.1
Chimney or flue fire, confined to chimney or flue	5.5
Incinerator overload or malfunction, fire confined	0.2
Fuel burner/boiler malfunction, fire confined	2.6
Commercial compactor fire, confined to rubbish	0.2
Trash or rubbish fire, contained	4.6
Total	100.0

Source: NFIRS 5.0.
Note: Confined fire incident type percentages do not add up to the total confined fires percentage due to rounding.

Loss Measures

Table 2 presents losses, averaged over the three-year period from 2011-2013, of reported residential and nonresidential building fires.[7] The average number of fatalities and injuries per 1,000 residential fires was notably higher than the same loss measures for nonresidential building fires.

Table 2. Loss Measures for Residential and Nonresidential Building Fires (Three-Year Average, 2011-2013)

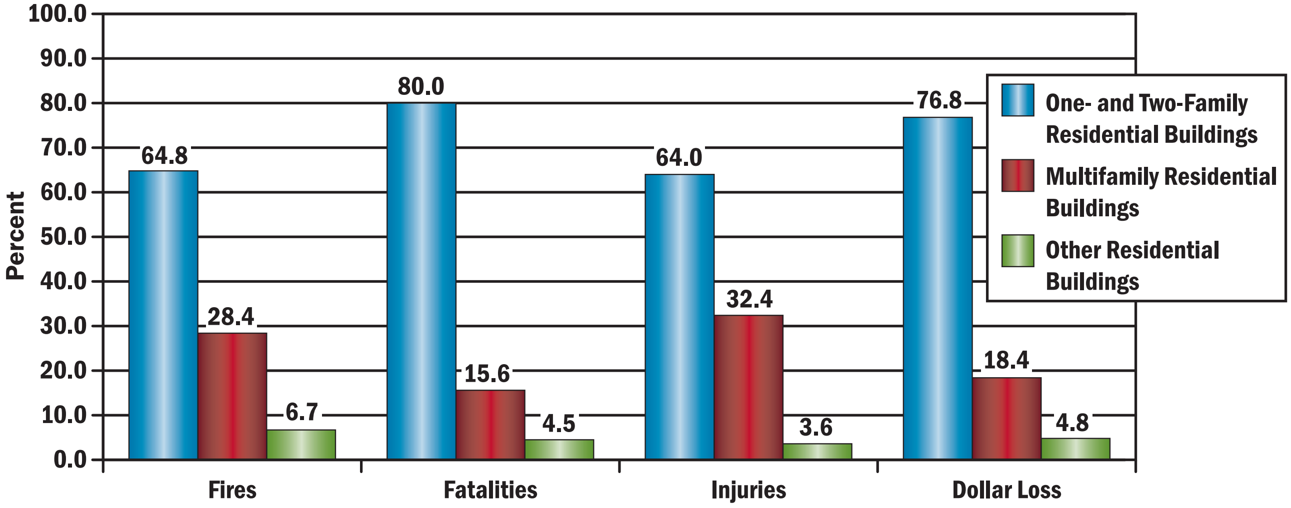
Measure	Residential Building Fires	**Confined** Residential Building Fires	**Nonconfined** Residential Building Fires	Nonresidential Building Fires
Average Loss				
Fatalities/1,000 fires	5.5	0.0	10.7	1.0
Injuries/1,000 fires	28.3	7.7	48.3	9.5
Dollar loss/fire	$15,770	$190	$30,900	$29,710

Source: NFIRS 5.0.
Notes: 1. Average loss for fatalities and injuries is computed per 1,000 fires. Average dollar loss is computed **per fire** and rounded to the nearest $10.
2. One death in confined residential building fires was reported to NFIRS in 2011; the resulting loss of 0.0 fatalities per 1,000 fires only reflects data reported to NFIRS.
3. The 2011 and 2012 dollar-loss values were adjusted to 2013 dollars.

Property Use

Figure 1 presents the percentage distribution of fire losses by property use (i.e., one- and two-family residential buildings, multifamily residential buildings, and other residential buildings).[8] Consistent with the fact that the majority of residential fires took place in one- and two-family residential buildings (65 percent), the percentages of fatalities (80 percent), injuries (64 percent) and dollar loss (77 percent) were also highest in these types of residences. One explanation for the higher percentages of fires and subsequent losses in one- and two-family dwellings may be that more stringent building and fire codes, which require detection and suppression systems, as well as regular fire inspections, are imposed on multifamily dwellings and other residential buildings. In addition, multifamily dwellings and other residential buildings may more often be professionally maintained.

Figure 1. Fire Losses by Property Use (2011-2013)



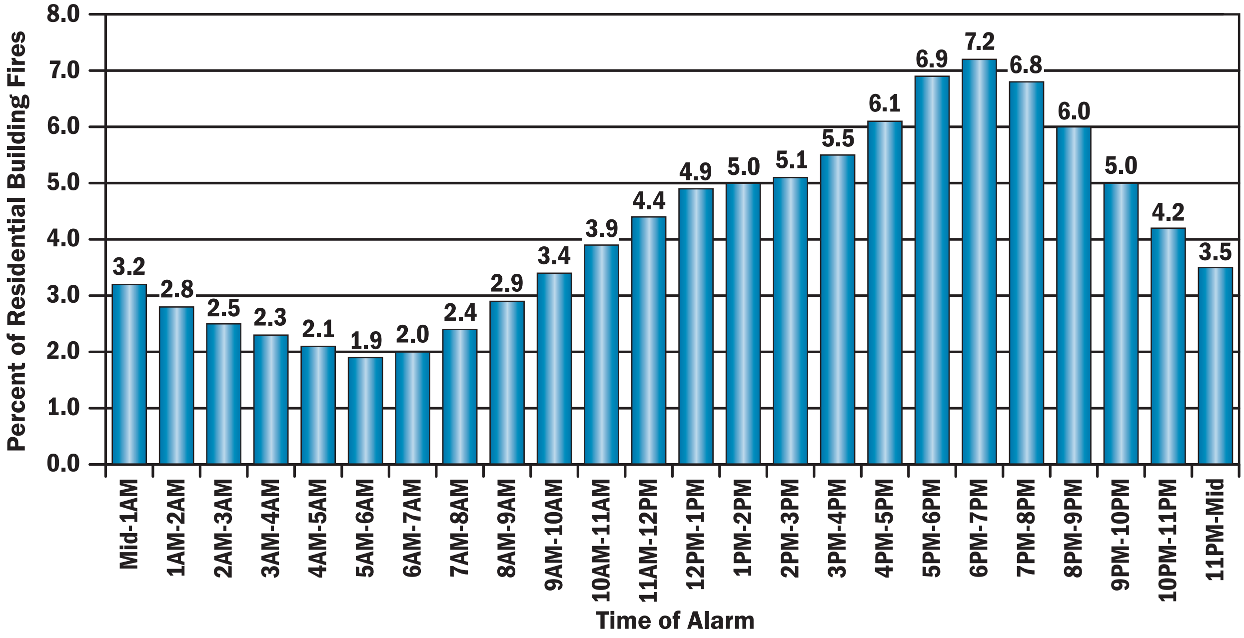
Source: NFIRS 5.0.

Notes: 1. Total percentages of fires and fatalities do not add up to 100 percent due to rounding.
2. The 2011 and 2012 dollar-loss values were adjusted to 2013 dollars.

When Residential Building Fires Occur

As shown in Figure 2, residential fires occurred most frequently in the early evening hours, peaking during the dinner hours from 5 to 8 p.m., when cooking fire incidence is high.[9], [10] Cooking fires, discussed later in the Causes of Residential Building Fires section, accounted for 48 percent of residential fires. Fires then declined throughout the night, reaching the lowest point during the early to mid-morning hours (4 to 7 a.m.).

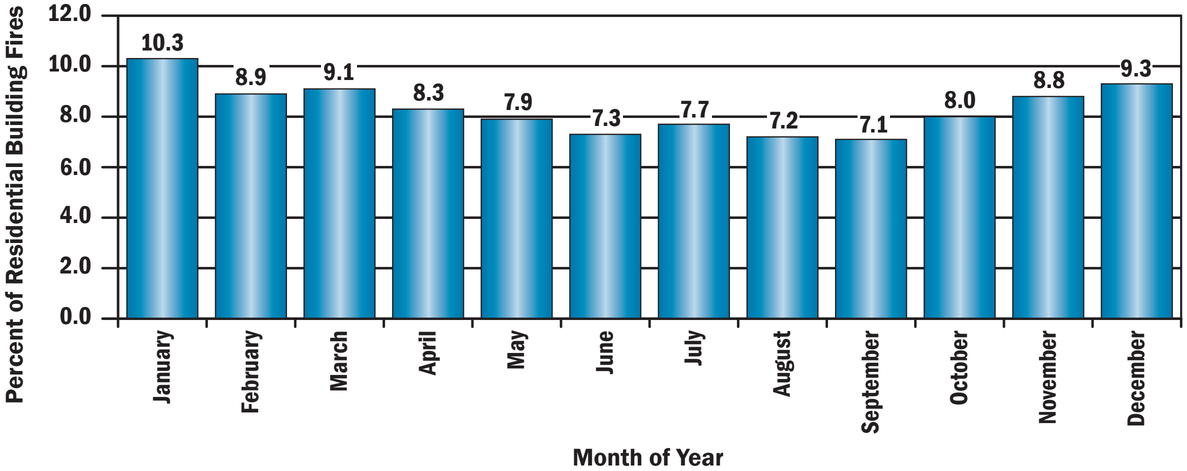
Figure 2. Residential Building Fires by Time of Alarm (2011-2013)



Source: NFIRS 5.0.

Figure 3 illustrates that residential fire incidence was higher in the cooler months, peaking in January at 10 percent. The increase in fires in the cooler months may be explained by the increase in heating fires. In addition, the increase may also be due to more indoor activities in general, as well as more indoor seasonal and holiday activities. During the spring and summer months, fire incidence declined steadily, reaching a low in September.

Figure 3. Residential Building Fires by Month (2011-2013)



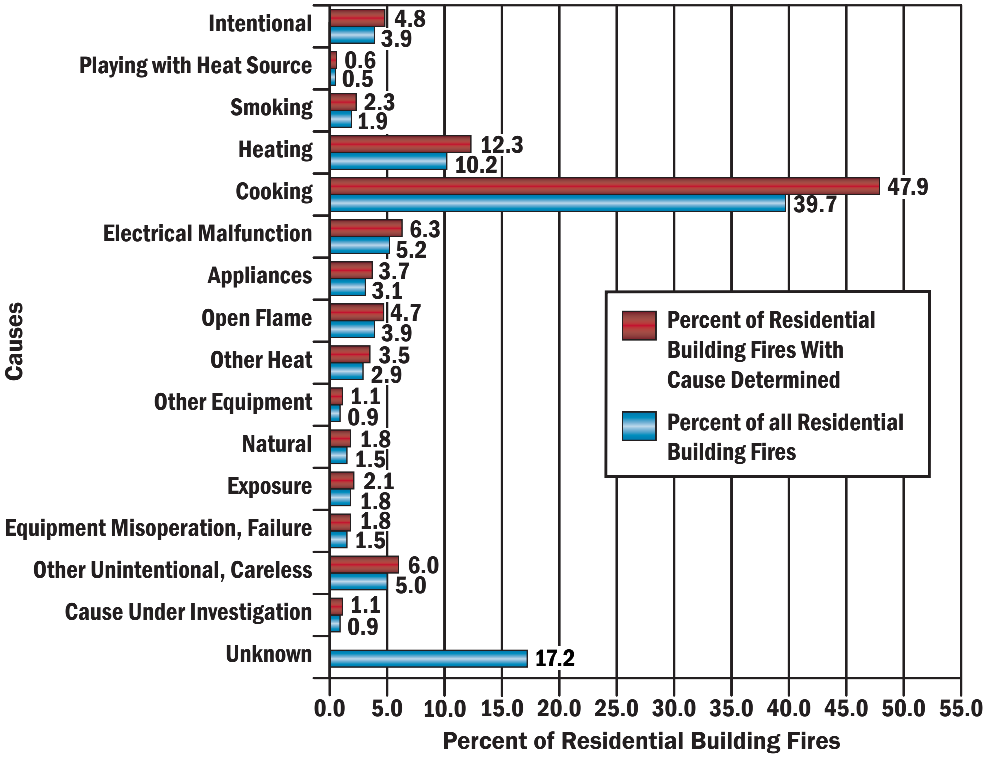
Source: NFIRS 5.0.
Note: Total does not add up to 100 percent due to rounding.

Causes of Residential Building Fires

Cooking was the leading reported cause and accounted for 48 percent of all residential fires, as shown in Figure 4.[11] Nearly all of these cooking fires (91 percent) were small, confined fires with limited damage.

The next five reported causes combined accounted for 34 percent of residential fires: fires caused by heating (12 percent); electrical malfunctions, such as short circuits and wiring problems (6 percent); other unintentional or careless actions, a miscellaneous group (6 percent); intentional actions (5 percent);[12] and open flames that resulted from candles, matches and the like (5 percent).

Figure 4. Causes of Residential Building Fires (2011-2013)



Source: NFIRS 5.0.
Notes: 1. Causes are listed in order of the U.S. Fire Administration (USFA) Structure Fire Cause Hierarchy for ease of comparison of fire causes across different aspects of the fire problem. Fires are assigned to one of 16 cause groupings using a hierarchy of definitions, approximately as shown in the chart above. A fire is included in the highest category into which it fits. If it does not fit the top category, then the second one is considered, and if not that one, the third and so on. For example, if the fire is judged to be intentionally set and a match was used to ignite it, it is classified as intentional and not open flame because intentional is higher in the hierarchy.
2. Total percent of all residential building fires does not add up to 100 percent due to rounding.

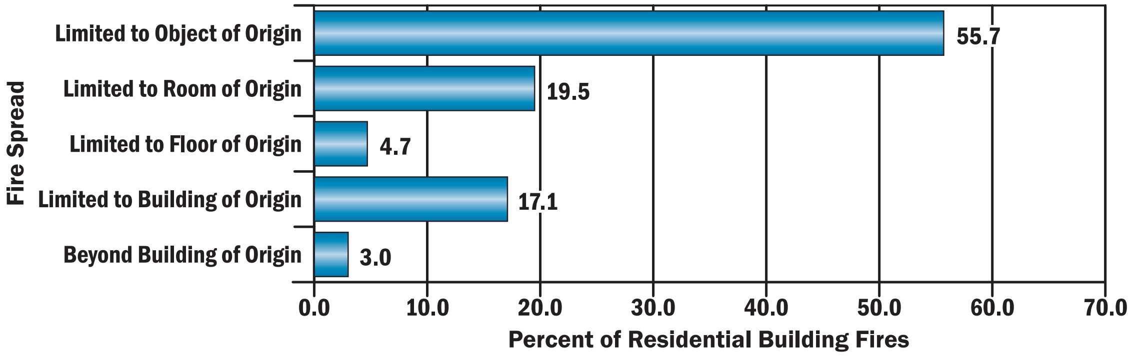
However, when looking at the different types of property use (i.e., one- and two-family, multifamily, and other residential buildings), there are striking differences in the prevalence of cooking as a reported fire cause. Cooking accounted for 72 percent of multifamily residential building fires and 59 percent of other residential building fires but only 35 percent of one- and two-family building fires. The most persuasive explanation for this difference may be that the smaller confined fires in one- and two-family dwellings are not reported as often to fire departments. They are small and contained, and they do not cause much damage. In addition, only the residents hear the smoke alarm if it is activated. However, these same confined fires in multifamily residences may be reported — if someone else in the complex hears the alarm or smells the fire. Alternatively, if it is a newer complex, the alarms are connected to the building alarm system, and the fire department may automatically be called.

Heating and electrical malfunctions played a larger role in one- and two-family fires than in multifamily fires. One reason for this may be that many one- and two-family residential buildings have fireplaces, chimneys and fireplace-related equipment that most other types of residential properties do not have.[13] This heating equipment difference may also be the explanation for the increase in confined chimney and flue fires (a component of heating fires) seen in one- and two-family fires (8 percent) as compared to multifamily fires (less than 1 percent).

Fire Spread in Residential Building Fires

As shown in Figure 5, 56 percent of residential fires were limited to the object of origin. Included in these fires were those coded as “confined fires” in NFIRS. In addition, 25 percent of fires extended beyond the room of origin.

Figure 5. Extent of Fire Spread in Residential Building Fires (2011-2013)



Source: NFIRS 5.0.

Confined Fires

NFIRS allows abbreviated reporting for confined fires, and many reporting details of these fires are not required, nor are they reported. (Not all fires confined to the object of origin are counted as confined fires.)[14] As previously discussed, however, it is known that confined fires accounted for 49 percent of all residential fires. Confined cooking fires — those cooking fires confined to a pot or the oven, for example — accounted for the majority of these confined fires (Table 1).

In addition, the number of confined residential fires was greatest from 5 to 8 p.m. These fires accounted for 60 percent of all residential fires occurring in this time period. Moreover, confined cooking fires accounted for 76 percent of the confined fires and 46 percent of all fires in residential buildings that occurred between 5 and 8 p.m.

Confined residential fires peaked in January, then steadily declined until reaching the lowest incidence in July.

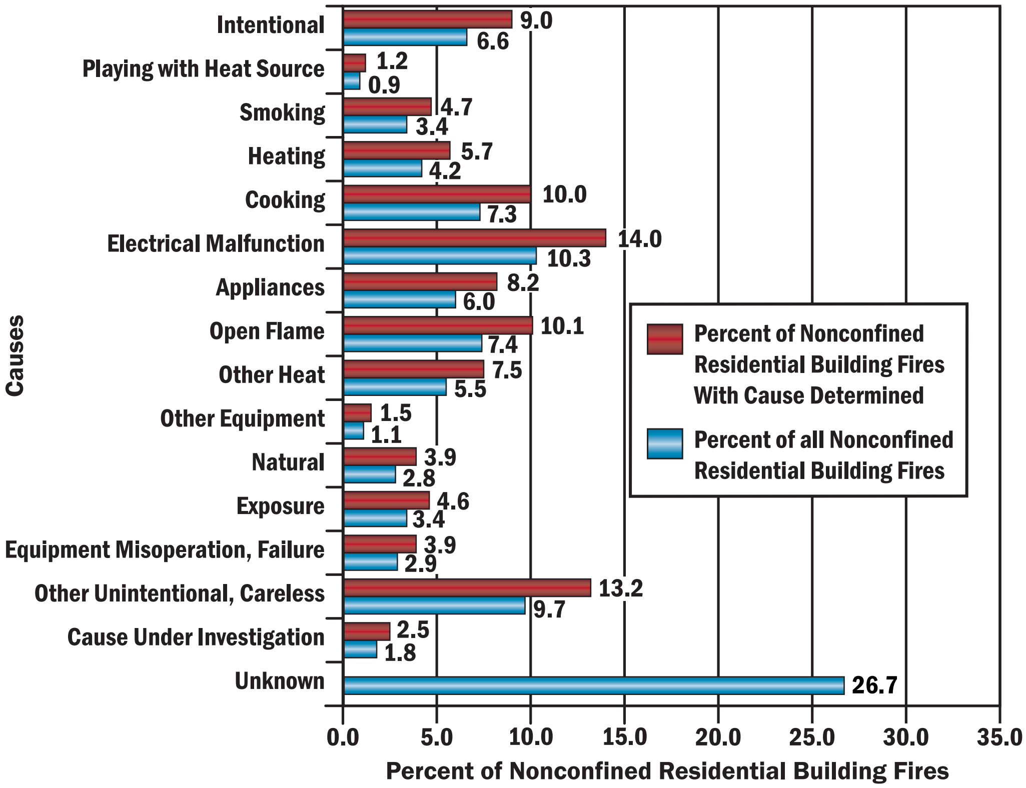
Nonconfined Fires

The next sections of this topical report address nonconfined residential fires — the larger and more serious fires — where more detailed fire data are available, as they are required to be reported in NFIRS.

Causes of Nonconfined Residential Building Fires

While cooking was the leading reported cause of residential fires overall, it only accounted for 10 percent of all nonconfined residential fires. At 14 percent, electrical malfunction was the leading reported cause of nonconfined residential fires. The second leading reported cause of these fires was carelessness or other unintentional actions at 13 percent (Figure 6).

Figure 6. Causes of Nonconfined Residential Building Fires (2011-2013)



Source: NFIRS 5.0.

Note: Causes are listed in order of the USFA Structure Fire Cause Hierarchy for ease of comparison of fire causes across different aspects of the fire problem. Fires are assigned to one of 16 cause groupings using a hierarchy of definitions, approximately as shown in the chart above. A fire is included in the highest category into which it fits. If it does not fit the top category, then the second one is considered, and if not that one, the third and so on. For example, if the fire is judged to be intentionally set and a match was used to ignite it, it is classified as intentional and not open flame because intentional is higher in the hierarchy.

Where Nonconfined Residential Building Fires Start (Area of Fire Origin)

Nonconfined residential fires most often started in cooking areas and kitchens (21 percent), as shown in Table 3. Bedrooms (13 percent) and common rooms, living rooms or lounge areas (7 percent) were the next most common areas of fire origin in the home. Smaller but not minor percentages of fires started in laundry areas (5 percent), vacant spaces and attics (5 percent), and exterior wall surfaces (5 percent). Also of interest, 4 percent of nonconfined residential fires started in garages and carports.

Note that these areas of origin do not include areas associated with confined fires. Cooking was the leading reported cause of all residential fires at 48 percent, and it is not surprising that kitchens were the leading area of fire origin. The percentages were not identical between cooking and kitchen fires because some cooking fires started outside the kitchen, some areas of origin for cooking fires were not reported (as is the case in most confined cooking fires), and some kitchen fires did not start due to cooking. In fact, only 44 percent of nonconfined residential fires that started in the kitchen were cooking fires. Other unintentional or careless actions accounted for 14 percent, appliances such as freezers and refrigerators accounted for 9 percent, and other heat from sources such as flames/torches or hot materials accounted for an additional 8 percent of kitchen fires.

Table 3. Leading Areas of Fire Origin in Nonconfined Residential Building Fires (2011-2013)

Areas of Fire Origin	Percent (Unknowns Apportioned)
Cooking area, kitchen	20.7
Bedrooms	12.8
Common room, den, family room, living room, lounge	6.6

Source: NFIRS 5.0.

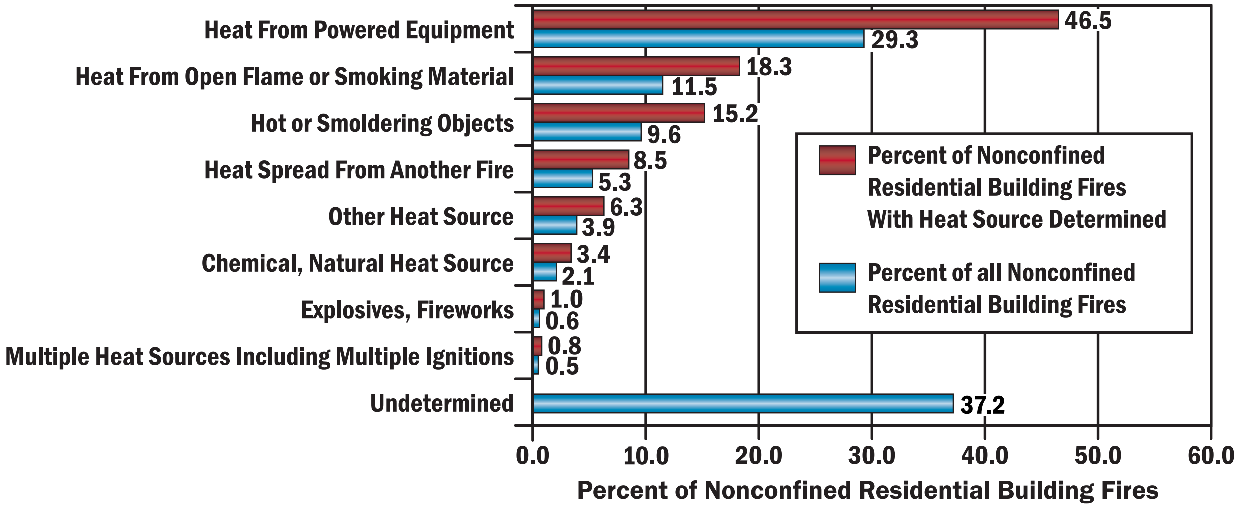
How Nonconfined Residential Building Fires Start (Heat Source)

Figure 7 shows sources of heat categories for nonconfined residential fires. Heat from powered equipment accounted for 47 percent of nonconfined residential fires. This category includes electrical arcing (15 percent); radiated or conducted heat from operating equipment (14 percent); heat from other powered equipment (13 percent); and spark, ember or flame from operating equipment (5 percent).

Heat from open flame or smoking materials accounted for 18 percent of nonconfined residential fires. This category includes such items as cigarettes (5 percent), other miscellaneous open flame or smoking materials (4 percent), lighters and matches (combined, 4 percent), and candles (3 percent).

The third largest category pertains to hot or smoldering objects (15 percent). This category includes miscellaneous hot or smoldering objects (7 percent) and hot embers or ashes (6 percent).

Figure 7. Sources of Heat in Nonconfined Residential Building Fires by Major Category (2011-2013)



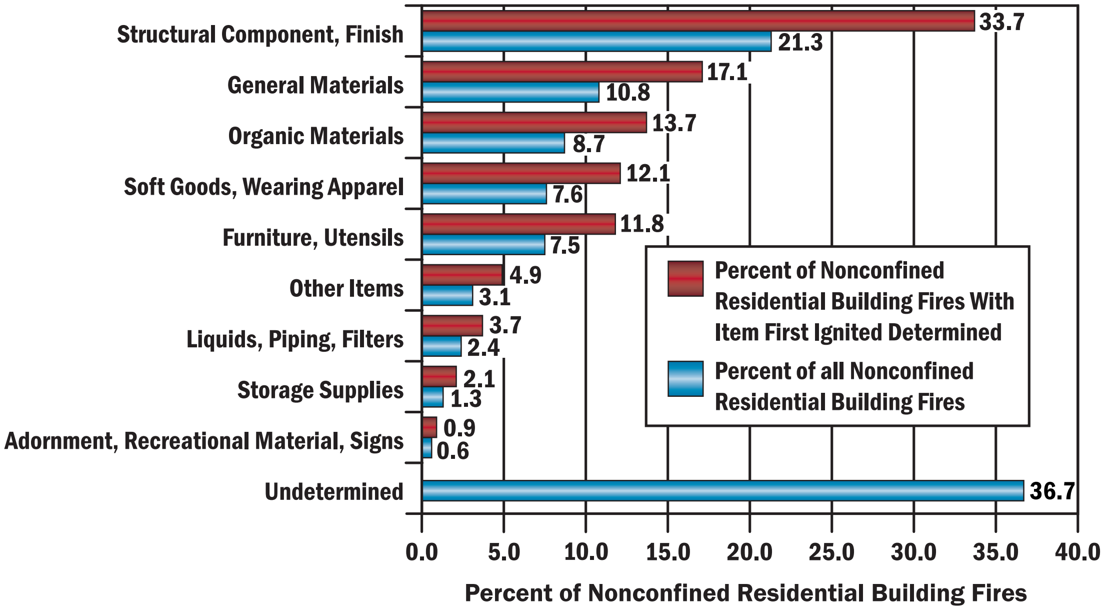
Source: NFIRS 5.0.

What Ignites First in Nonconfined Residential Building Fires

As shown in Figure 8, 34 percent of the items first ignited in nonconfined residential fires where the item is determined fell under the "structural component, finish" category. This category includes structural members or framing and exterior sidewall coverings. The second leading category of items first ignited in nonconfined residential fires was "general materials," which accounted for 17 percent of these fires. "General materials" includes items such as electrical wire, cable insulation, and trash or rubbish. The next three leading categories of nonconfined residential fires were "organic materials" at 14 percent, plus "soft goods, wearing apparel" and "furniture, utensils," each at 12 percent. These categories include items such as cooking materials, clothing, bedding, and upholstered sofas and chairs.

Cooking materials (11 percent); structural member and framing (10 percent); electrical wire, cable insulation (8 percent); and exterior sidewall covering (7 percent) were the specific items most often first ignited in nonconfined residential fires.

Figure 8. Item First Ignited in Nonconfined Residential Building Fires by Major Category (2011-2013)



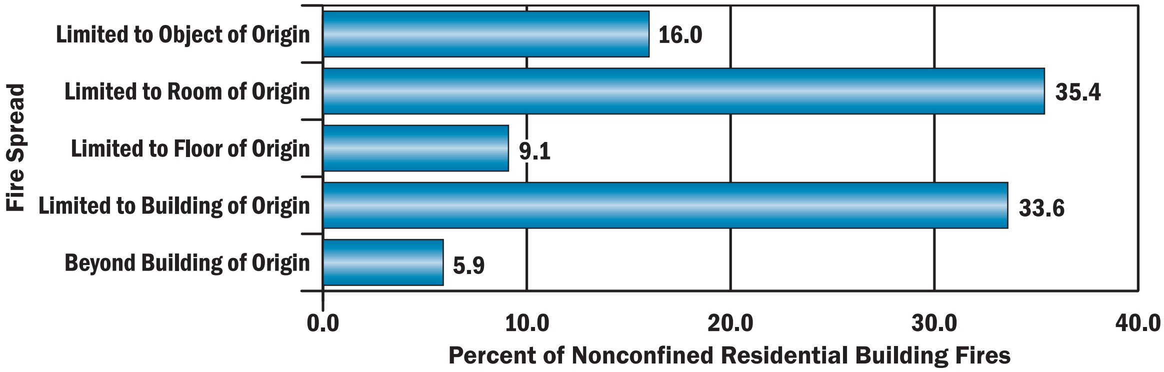
Source: NFIRS 5.0.

Fire Spread in Nonconfined Residential Building Fires

Figure 9 shows the extent of fire spread in nonconfined residential fires. In 51 percent of nonconfined fires, the fire was limited to the object or room of fire origin — in 35 percent of nonconfined fires, the fire was limited to the room of origin; in another 16 percent of fires, the fire was limited to the object of origin. (Note that a fire limited to a sofa or bed is not defined as a "confined fire" because of the greater potential for spread. Unlike fires in pots or chimneys, there is no container to stop the fire, even though the fire did not spread beyond the object of origin.)

In 49 percent of nonconfined residential fires, the fire extended beyond the room of origin. The leading reported causes of these larger fires were unintentional or careless actions (16 percent), electrical malfunctions (13 percent), intentional actions (12 percent), and open flames (11 percent).

Figure 9. Extent of Fire Spread in Nonconfined Residential Building Fires (2011-2013)



Source: NFIRS 5.0.

Factors Contributing to Ignition in Nonconfined Residential Building Fires

Table 4 shows the categories of factors contributing to ignition in nonconfined residential fires. The leading category was the misuse of material or product (38 percent). In this category, the leading specific factors contributing to ignition were a heat source too close to combustible materials (13 percent) and abandoned or discarded materials, such as matches or cigarettes (11 percent).

Electrical failures and malfunctions contributed to 21 percent of nonconfined residential fires. Operational deficiency was the third leading category at 15 percent. Unattended equipment was the leading factor in the operational deficiency category and accounted for 8 percent of all nonconfined residential fires.

Table 4. Factors Contributing to Ignition for Nonconfined Residential Building Fires by Major Category (Where Factors Contributing to Ignition Are Specified, 2011-2013)

Factors Contributing to Ignition Category	**Percent of Nonconfined Residential Building Fires** (Unknowns Apportioned)
Misuse of material or product	38.2
Electrical failure, malfunction	21.2
Operational deficiency	15.3
Fire spread or control	11.1
Mechanical failure, malfunction	6.9
Other factors contributing to ignition	6.4
Natural condition	4.1
Design, manufacture, installation deficiency	2.1

Source: NFIRS 5.0.

Notes: 1. Includes only incidents where factors that contributed to the ignition of the fire were specified.
2. Multiple factors contributing to fire ignition may be noted for each incident; the total will exceed 100 percent.

Alerting/Suppression Systems in Residential Building Fires

Technologies to detect and extinguish fires have been major contributors to the drop in fire fatalities and injuries over the past 35 years. Smoke alarms are now present in the majority of residential buildings. In addition, the use of residential sprinklers is widely supported by the fire service and is gaining support within residential communities.

Smoke alarm data is available for both confined and nonconfined fires, although for confined fires, the data is very limited in scope. Since different levels of data are reported on smoke alarms in confined and nonconfined fires, the analyses are performed separately. Note that the data presented in Tables 5 to 7 are the raw counts from the NFIRS dataset and are not scaled to national estimates of smoke alarms in residential fires. In addition, NFIRS does not allow for the determination of the type of smoke alarm (i.e., photoelectric or ionization) or the location of the smoke alarm with respect to the area of fire origin.

Smoke Alarms in Nonconfined Fires

Overall, smoke alarms were reported as present in 42 percent of nonconfined residential fires (Table 5). In 28 percent of nonconfined residential fires, there were no smoke alarms present. In another 30 percent of these fires, firefighters were unable to determine if a smoke alarm was present. Thus, smoke alarms were potentially missing in between 28 and 58 percent of fires with the ability to spread and possibly result in fatalities.

Table 5. Presence of Smoke Alarms in Nonconfined Residential Building Fires (2011-2013)

Presence of Smoke Alarms	Percent
Present	42.3
None present	27.5
Undetermined	30.2
Total	100.0

Source: NFIRS 5.0.

While 17 percent of all nonconfined residential fires occurred in residential buildings that are not currently or routinely occupied, these buildings — which are under construction, undergoing major renovation, vacant and the like — are unlikely to have alerting and suppression systems that are in place and, if in place, that are operational. In fact, only 6 percent of all nonconfined fires in unoccupied residential buildings were reported as having smoke alarms that operated. As a result, the detailed smoke alarm analyses in the next section focus on nonconfined fires in occupied residential buildings only.

Smoke Alarms in Nonconfined Fires in Occupied Residential Buildings

Smoke alarms were reported as present in 48 percent of nonconfined fires in occupied residential buildings (Table 6). In 22 percent of nonconfined fires in occupied residential buildings, there were no smoke alarms present. In another 30 percent of these fires, firefighters were unable to determine if a smoke alarm was present; unfortunately, in 47 percent of fires where the presence of a smoke alarm was undetermined, either the flames involved the building of origin or spread beyond it. The fires were so large and destructive that it is unlikely the presence of a smoke alarm could be determined.

When smoke alarms were present (48 percent) and the alarm operational status is considered, the percentage of smoke alarms reported as present consisted of:

- Present and operated — 28 percent.
- Present but did not operate — 12 percent (alarm failed to operate, 6 percent; fire too small, 6 percent).
- Present but operational status unknown — 8 percent.

When the subset of incidents where smoke alarms were reported as present was analyzed separately as a whole, smoke alarms were reported to have operated in 59 percent of the incidents and failed to operate in 12 percent. In another 13 percent of this subset, the fire was too small to activate the alarm. The operational status of the alarm was undetermined in 16 percent of these incidents.

Nationally, only 3 percent of households lack smoke alarms.[15] At least 22 percent of nonconfined fires in occupied residential buildings had no smoke alarms present — and perhaps more if fires without information on smoke alarms could be factored in.[16] A large proportion of reported fires without smoke alarms may reflect the effectiveness of the alarms themselves: Smoke alarms do not prevent fires, but they may prevent a fire from being reported if it is detected at an early stage and extinguished before the fire department becomes involved. Alternatively, fires in homes without smoke alarms may **not** be detected at an early stage, causing them to grow large, require fire department intervention, and thus be reported.[17]

Properly installed and maintained smoke alarms provide an early warning signal to household members in the event a fire occurs. Smoke alarms help save lives and property. The USFA continues to partner with other government agencies and fire service entities to improve and develop new smoke alarm technologies. More information on smoke alarm technologies, performance, disposal and storage, training bulletins, and public education and outreach materials can be found at http://www.usfa.fema.gov/prevention/technology/smoke_fire_alarms.html.

Table 6. NFIRS Smoke Alarm Data for Nonconfined Fires in Occupied Residential Buildings (2011-2013)

Presence of Smoke Alarms	Smoke Alarm Operational Status	Smoke Alarm Effectiveness	Count	Percent
Present	Fire too small to activate smoke alarm		20,321	6.2
	Smoke alarm operated	Smoke alarm alerted occupants, occupants responded	67,168	20.5
		Smoke alarm alerted occupants, occupants failed to respond	3,077	0.9
		No occupants	11,132	3.4
		Smoke alarm failed to alert occupants	2,271	0.7
		Undetermined	9,402	2.9
	Smoke alarm failed to operate		19,385	5.9
	Undetermined		25,836	7.9
	Null/Blank		2	0.0
None present			71,957	21.9
Undetermined			97,795	29.8
Total incidents			328,346	100.0

Source: NFIRS 5.0.

Notes: 1. The data presented in this table are raw data counts from the NFIRS dataset summed (not averaged) from 2011-2013. They do not represent national estimates of smoke alarms in nonconfined fires in occupied residential buildings. They are presented for informational purposes.
2. Total does not add up to 100 percent due to rounding.

Smoke Alarms in Confined Fires

Less information about smoke alarm status is collected for confined fires, but the data still give important insights about the effectiveness of alerting occupants in these types of fires. The analyses presented here do not differentiate between occupied and unoccupied residential buildings, as this data detail is not required when reporting confined fires in NFIRS. However, an assumption may be made that confined fires are fires in occupied housing, as these types of fires are unlikely to be reported in residential buildings that are not occupied.

Smoke alarms alerted occupants in 44 percent of the reported confined residential fires (Table 7). In other words, residents received a warning from a smoke alarm in over two-fifths of these fires. The data suggest that smoke alarms may alert residents to confined fires, as the early alerting allowed the occupants to extinguish the fires, or the fires self-extinguished. If this is the case, it is an example of the contribution to overall safety and the ability to rapidly respond to fires in early stages that smoke alarms afford. Details on smoke alarm effectiveness for confined fires are needed to pursue this analysis further.

Occupants were not alerted by smoke alarms in 18 percent of confined residential fires.[18] In 38 percent of these confined fires, the smoke alarm effectiveness was unknown.

Table 7. NFIRS Smoke Alarm Data for Confined Residential Building Fires (2011-2013)

Smoke Alarm Effectiveness	Count	Percent
Smoke alarm alerted occupants	169,171	44.1
Smoke alarm did not alert occupants	68,539	17.9
Unknown	145,676	38.0
Null/Blank	1	0.0
Total incidents	383,387	100.0

Source: NFIRS 5.0.

Note: The data presented in this table are raw data counts from the NFIRS dataset summed (not averaged) from 2011-2013. They do not represent national estimates of smoke alarms in confined residential building fires. They are presented for informational purposes.

Automatic Extinguishing Systems in Nonconfined Fires in Occupied Residential Buildings

AES data are available for both confined and nonconfined fires, although for confined fires, the data is also very limited in scope. In confined residential building fires, an AES was present in 1 percent of reported incidents.[19] In addition, the following AES analyses focus on nonconfined fires in occupied residential buildings only, as even fewer AESs are present in unoccupied housing.

Residential sprinklers are the primary AES in residences but are not yet widely installed. In fact, AESs were reported as present in only 4 percent of nonconfined fires in occupied residential buildings (Table 8).

Residential sprinkler systems help to reduce the risk of civilian and firefighter casualties, homeowner insurance premiums, and uninsured property losses. Yet many residences are unequipped with AESs that are often installed in hotels and businesses. Sprinklers are required by code in hotels and many multifamily residences. There are major movements in the U.S. fire service to require or facilitate use of sprinklers in all new homes, which could improve the use of residential sprinklers in the future. At present, however, they are largely absent in residences nationwide.[20]

The USFA and fire service officials across the nation are working to promote and advance residential fire sprinklers. More information on costs and benefits, performance, training bulletins, and public education and outreach materials regarding residential sprinklers can be found at http://www.usfa.fema.gov/prevention/technology/home_fire_sprinklers.html. Additionally, USFA's position statement on residential sprinklers is available at http://www.usfa.fema.gov/about/sprinklers_position.html.

Table 8. NFIRS Automatic Extinguishing System Data for Nonconfined Fires in Occupied Residential Building Fires (2011-2013)

Automatic Extinguishing System Presence	Count	Percent
Automatic extinguishing system present	12,878	3.9
Partial system present	516	0.2
Automatic extinguishing system not present	288,178	87.8
Unknown	26,774	8.2
Total incidents	328,346	100.0

Source: NFIRS 5.0.

Notes: 1. The data presented in this table are raw data counts from the NFIRS dataset summed (not averaged) from 2011-2013. They do not represent national estimates of AESs in nonconfined fires in occupied residential buildings. They are presented for informational purposes.

2. Total does not add up to 100 percent due to rounding.

Examples

The following are recent examples of residential fires reported by the media:

- March 2015: A child playing with a cigarette lighter accidentally set fire to a house in Raleigh, North Carolina, at about 8:30 a.m. Upon arrival, the Raleigh Fire Department found smoke and heavy fire coming out of the roof and second floor of the two-story home. Four people were displaced as a result of the fire, which caused damage to an estimated 60 percent of the home. No injuries were reported.[21]
- March 2015: Montgomery County Fire and Rescue firefighters knocked down a chimney fire that was on the first and second floors of a home in Germantown, Maryland. Although no one was injured, the accidental fire displaced four people and one dog. Damages were estimated at $100,000.[22]
- March 2015: An early morning fire in Brooklyn, New York, tragically took the lives of seven siblings ages 5 to 16. Shortly after midnight, flames originated from a large hot plate that was warming food on a first-floor kitchen counter. Meanwhile, in upstairs bedrooms that were connected to the kitchen by an open stairwell, the seven children, their mother and an additional sibling, age 15, slept. Officials believe the fire smoldered in the kitchen unnoticed for a while. When the fire reached the stairwell, however, it shot upstairs and trapped the seven children in their bedrooms. The mother and surviving sibling were able to escape but sustained burns and smoke inhalation. After firefighters arrived and brought the fire under control, they rescued the seven trapped children, some of whom were badly burned, but could not resuscitate any of them. This fire was New York City's deadliest since 2007.[23]

NFIRS Data Specifications for Residential Building Fires

Data for this report were extracted from the NFIRS annual Public Data Release files for 2011, 2012 and 2013. Only Version 5.0 data were extracted.

Residential building fires were defined using the following criteria:

- Aid Types 3 (mutual aid given) and 4 (automatic aid given) were excluded to avoid double counting of incidents.
- Incident Types 111 to 123 (excluding Incident Type 112):

Incident Type	Description
111	Building fire
113	Cooking fire, confined to container
114	Chimney or flue fire, confined to chimney or flue
115	Incinerator overload or malfunction, fire confined
116	Fuel burner/boiler malfunction, fire confined
117	Commercial compactor fire, confined to rubbish
118	Trash or rubbish fire, contained
120	Fire in mobile property used as a fixed structure, other
121	Fire in mobile home used as fixed residence
122	Fire in motor home, camper, recreational vehicle
123	Fire in portable building, fixed location

Note: Incident Types 113 to 118 do not specify if the structure is a building.

- Property Use Series 400, which consists of the following:

Property Use	Description
400	Residential, other
419	One- or two-family dwelling, detached, manufactured home, mobile home not in transit, duplex
429	Multifamily dwelling
439	Boarding/Rooming house, residential hotels
449	Hotel/Motel, commercial
459	Residential board and care
460	Dormitory-type residence, other
462	Sorority house, fraternity house
464	Barracks, dormitory

- Structure Type:
  - For Incident Types 113 to 118:
    - 1—Enclosed building, or
    - 2—Fixed portable or mobile structure, or
    - Structure Type not specified (null entry).
  - For Incident Types 111 and 120 to 123:
    - 1—Enclosed building, or
    - 2—Fixed portable or mobile structure.

The analyses contained in this report reflect the current methodologies used by USFA. USFA is committed to providing the best and most currently available information on the U.S. fire problem and continually examines its data and methodology to fulfill this goal. Because of this commitment, data collection strategies and methodological changes are possible and do occur. As a result, analyses and estimates of the fire problem may change slightly over time. Previous analyses and estimates on specific issues (or similar issues) may have used different methodologies or data definitions and may not be directly comparable to the current ones.

Information regarding USFA's national estimates for residential building fires as well as the data sources used to derive the estimates can be found in the document, "Data Sources and National Estimates Methodology Overview for the U.S. Fire Administration's Topical Fire Report Series (Volume 16)," http://www.usfa.fema.gov/downloads/pdf/statistics/data_sources_and_national_estimates_methodology_vol16.pdf. This document also addresses the specific NFIRS data elements analyzed in the topical reports, as well as "unknown" data entries and missing data.

To request additional information or to comment on this report, visit http://www.usfa.fema.gov/contact.html.

Notes:

[1] National estimates are based on 2011-2013 native Version 5.0 data from NFIRS, residential structure fire loss estimates from the National Fire Protection Association's (NFPA's) annual surveys of fire loss, and USFA's residential building fire loss estimates: http://www.usfa.fema.gov/data/statistics/order_download_data.html. Further information on USFA's residential building fire loss estimates can be found in the "National Estimates Methodology for Building Fires and Losses," August 2012, http://www.usfa.fema.gov/downloads/pdf/statistics/national_estimate_methodology.pdf. For information on NFPA's survey methodology, see NFPA's report on fire loss in the U.S.: http://www.nfpa.org/~/media/Files/Research/NFPA%20reports/Overall%20Fire%20Statistics/osfireloss.pdf. In this topical report, fires are rounded to the nearest 100, deaths to the nearest five, injuries to the nearest 25, and dollar loss to the nearest $100 million.

[2] In NFIRS Version 5.0, a structure is a constructed item of which a building is one type. In previous versions of NFIRS, the term "residential structure" commonly referred to buildings where people live. To coincide with this concept, the definition of a residential structure fire for NFIRS 5.0 has, therefore, changed to include only those fires where the NFIRS 5.0 Structure Type is 1 or 2 (enclosed building and fixed portable or mobile structure) with a residential property use. Such structures are referred to as "residential buildings" to distinguish these buildings from other structures on residential properties that may include fences, sheds and other uninhabitable structures. In addition, confined fire incidents that have a residential property use but do not have a Structure Type specified are presumed to occur in buildings. Nonconfined fire incidents that have a residential property use without a Structure Type specified are considered to be invalid incidents (Structure Type is a required field) and are not included.

[3] The percentages shown here are derived from the national estimates of residential building fires as explained in Endnote 1 and the summary data resulting from NFPA's annual fire loss surveys (Karter, Jr., Michael, J., "Fire Loss in the United States During 2013," NFPA, September 2014; "Fire Loss in the United States During 2012," NFPA, September 2013; "Fire Loss in the United States During 2011," NFPA, September 2012).

[4] Fire department participation in NFIRS is voluntary; however, some states do require their departments to participate in the state system. Additionally, if a fire department is a recipient of a Fire Act Grant, participation is required. From 2011 to 2013, 68 percent of NFPA's annual average estimated 1,334,800 fires to which fire departments responded were captured in NFIRS. Thus, NFIRS is not representative of all fire incidents in the U.S. and is not a "complete" census of fire incidents. Although NFIRS does not represent 100 percent of the incidents reported to fire departments each year, the enormous dataset exhibits stability from one year to the next, without radical changes. Results based on the full dataset are generally similar to those based on part of the data.

[5] In NFIRS, confined fires are defined by Incident Type codes 113-118.

[6] NFIRS distinguishes between "content" and "property" loss. Content loss includes losses to the contents of a structure due to damage by fire, smoke, water and overhaul. Property loss includes losses to the structure itself or to the property itself. Total loss is the sum of the content loss and the property loss. For confined fires, the expectation is that the fire did not spread beyond the container (or rubbish for Incident Type code 118), and hence, there was no property damage (damage to the structure itself) from the flames. However, there could be property damage as a result of smoke, water and overhaul.

[7] The average fire death and fire injury loss rates computed from the national estimates do not agree with average fire death and fire injury loss rates computed from NFIRS data alone. The fire death rate computed from national estimates is (1,000*(2,530/372,900)) = 6.8 deaths per 1,000 residential building fires, and the fire injury rate is (1,000*(13,125/372,900)) = 35.2 injuries per 1,000 residential building fires.

[8] "One- and two-family residential buildings" include detached dwellings, manufactured homes, mobile homes not in transit, and duplexes. "Multifamily residential buildings" include apartments, town houses, row houses, condominiums, and other tenement properties. "Other residential buildings" include boarding/rooming houses, hotels/motels, residential board and care facilities, dormitory-type residences, sorority/fraternity houses, and barracks.

[9] For the purposes of this report, the time of the fire alarm is used as an approximation for the general time at which the fire started. However, in NFIRS, it is the time at which the fire was reported to the fire department.

[10] USFA, "Cooking Fires in Residential Buildings (2008-2010)," Volume 13, Issue 12, January 2013, http://www.usfa.fema.gov/downloads/pdf/statistics/v13i12.pdf.

[11] The USFA Structure Fire Cause Methodology was used to determine the cause of residential building fires. The cause methodology and definitions can be found in the document "National Fire Incident Reporting System Version 5.0 Fire Data Analysis Guidelines and Issues," July 2011, http://www.usfa.fema.gov/downloads/pdf/nfirs/nfirs_data_analysis_guidelines_issues.pdf.

[12] Fires caused by intentional actions include, but are not limited to, fires that are deemed to be arson. Intentional fires are those fires that are deliberately set and include fires that result from the deliberate misuse of a heat source and fires of an incendiary nature (arson) that require fire service intervention. For information and statistics on arson fires only, refer to the Uniform Crime Reporting Program arson statistics from the U.S. Department of Justice, FBI, Criminal Justice Information Services Division, http://www.fbi.gov/about-us/cjis/ucr/ucr.

[13] The American Housing Survey does not indicate the number of fireplaces, chimneys and fireplace-related equipment per se. It does collect data on fireplaces, etc., as the primary heating unit, which applies to this analysis. U.S. Department of Housing and Urban Development (HUD) and U.S. Census Bureau, 2013 American Housing Survey, "General Characteristics by Units in Structure-All Occupied Units (National)," Table C-12-AO, http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=AHS_2013_C12AO&prodType=table (accessed April 14, 2015).

[14] As noted previously, confined building fires are small fire incidents that are limited in scope, are confined to noncombustible containers, rarely result in serious injury or large content loss, and are expected to have no significant accompanying property loss due to flame damage. In NFIRS, confined fires are defined by Incident Type codes 113-118.

[15] Greene, Michael and Craig Andres, "2004-2005 National Sample Survey of Unreported Residential Fires," Division of Hazard Analysis, Directorate for Epidemiology, U.S. Consumer Product Safety Commission, July 2009.

[16] Here, **at least** 22 percent of nonconfined fires in occupied residential buildings had no smoke alarms present — the 22 percent that were known to not have smoke alarms and some portion (or as many as all) of the fires where the smoke alarm presence was undetermined.

[17] The "2004-2005 National Sample Survey of Unreported Residential Fires," however, suggests that this may not be the case. It is observed that "if this conjecture is true, it would suggest that the percentage decrease in fire department-attended fires would have been greater than unattended fires in the 20 year period between the surveys."

[18] In confined fires, the entry "smoke alarm did not alert occupants" can mean no smoke alarm was present; the smoke alarm was present but did not operate; the smoke alarm was present and operated, but the occupant/s was already aware of the fire; or there were no occupants present at the time of the fire.

[19] As confined fires codes are designed to capture fires contained to noncombustible containers, it is not recommended to code a fire incident as a small-, low- or no-loss confined fire incident if the AES operated and contained the fire as a result. The preferred method is to code the fire as a standard fire incident with fire spread confined to the object of origin and provide the relevant information on AES presence and operation.

[20] HUD and U.S. Census Bureau, 2011 American Housing Survey, "Health and Safety Characteristics-All Occupied Units (National)," Table S-01-AO, http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=AHS_2011_S01AO&prodType=table (accessed April 14, 2015).

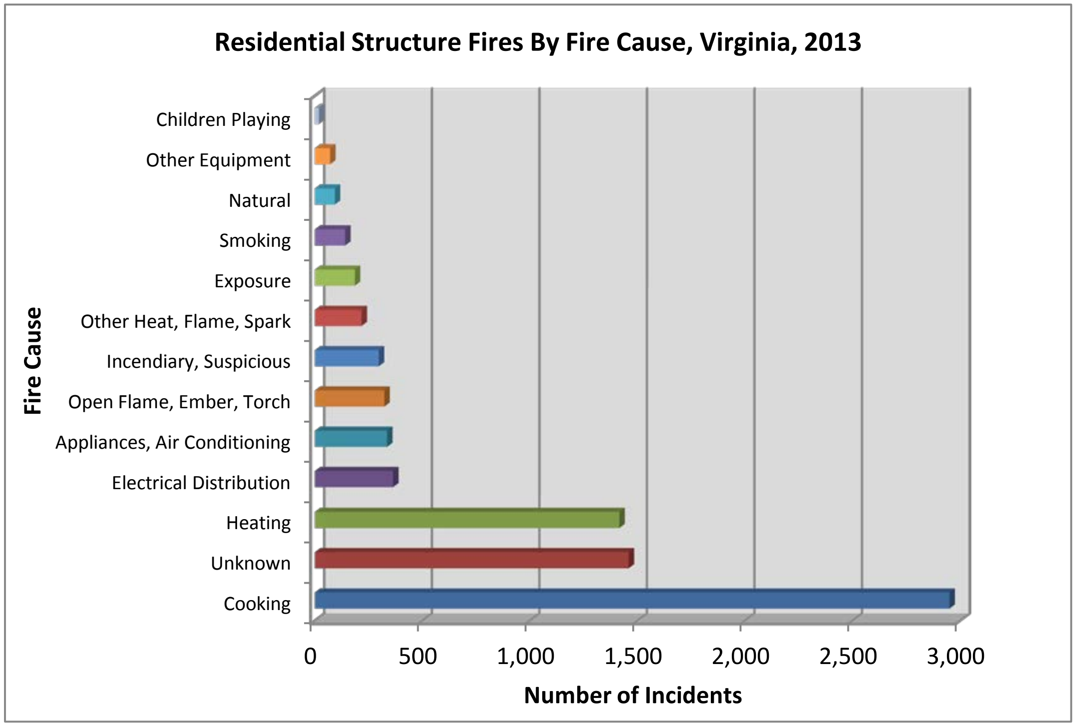
[21] "Playing With a Cigarette Lighter, Child Sparks House Fire in Raleigh," www.wncn.com, March 29, 2015, http://wncn.com/2015/03/29/playing-with-a-cigarette-lighter-child-sparks-house-fire-in-raleigh/ (accessed April 14, 2015).

[22] "4 People, 1 Dog Displaced in Germantown House Fire," www.wusa9.com, March 28, 2015, http://www.wusa9.com/story/news/local/maryland/2015/03/28/germantown-house-fire-4-displaced/70615024/ (accessed March 30, 2015).

[23] Mueller, Benjamin and Nate Schweber, "Brooklyn Fire Kills 7 Children, City's Worst Toll Since 2007," www.nytimes.com, March 21, 2015, http://www.nytimes.com/2015/03/22/nyregion/7-children-die-in-brooklyn-fire.html?_r=0 (accessed March 30, 2015).

Residential Structure Fire Causes Summary, Virginia, 2013

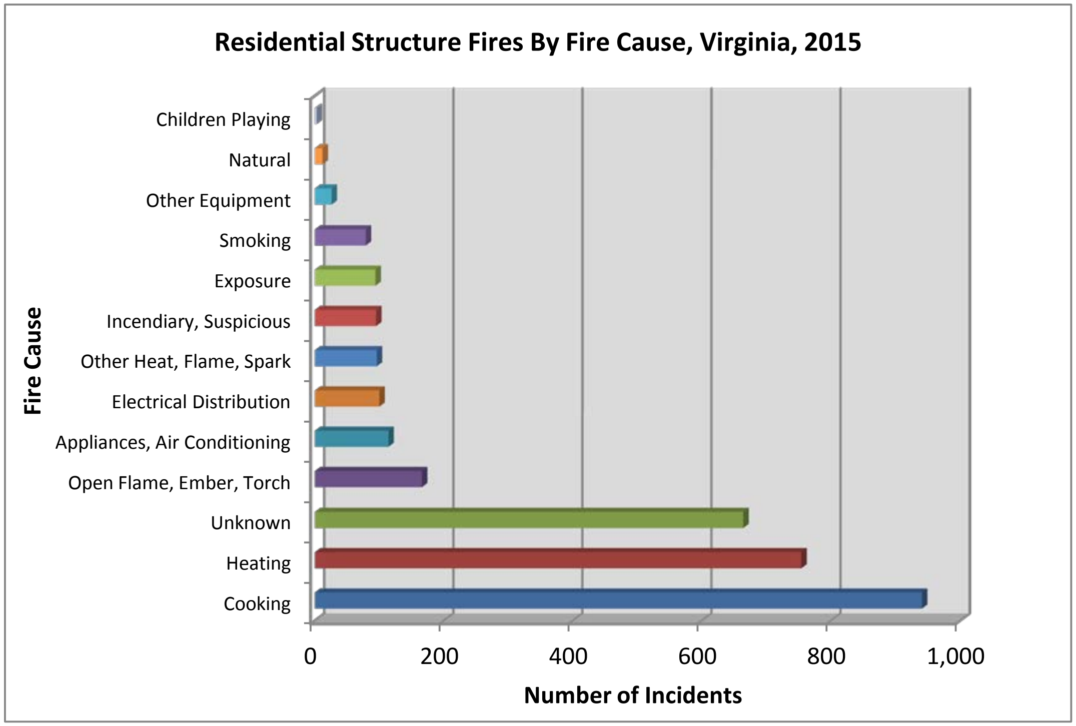
Fire Cause Category	Total	Percent	Total Fire Dollar Loss	Civilian Fire Injuries	Civilian Fire Deaths	Fire Service Injuries	Fire Service Deaths
Incendiary, Suspicious	297	3.77%	$9,811,807	20	11	13	0
Children Playing	19	0.24%	$524,451	0	0	3	0
Smoking	141	1.79%	$3,818,507	12	0	7	0
Heating	1,416	17.99%	$9,141,760	20	1	8	0
Cooking	2,951	37.48%	$10,873,659	127	3	6	0
Electrical Distribution	364	4.62%	$11,882,880	19	6	15	0
Appliances, Air Conditioning	336	4.27%	$6,099,085	15	0	5	0
Open Flame, Ember, Torch	323	4.10%	$6,984,850	20	2	5	0
Other Heat, Flame, Spark	217	2.76%	$5,097,103	12	2	7	0
Other Equipment	71	0.90%	$1,823,250	2	0	0	0
Natural	93	1.18%	$3,446,868	2	0	2	0
Exposure	186	2.36%	$18,959,397	9	0	8	0
Unknown	1,459	18.53%	$57,913,874	59	26	60	0
Grand Total	**7,873**	**100.00%**	**$146,377,491**	**317**	**51**	**139**	**0**



Note: Numbers are compiled from incidents reported to the Virginia Fire Incident Reporting System (VFIRS) for 2013 as of 3/12/2014.

Residential Structure Fire Causes Summary, Virginia, 2015

Fire Cause Category	Total	Percent	Total Fire Dollar Loss	Civilian Fire Injuries	Civilian Fire Deaths	Fire Service Injuries	Fire Service Deaths
Incendiary, Suspicious	95	3.02%	$4,765,401	8	1	5	0
Children Playing	3	0.10%	$7,000	0	0	0	0
Smoking	79	2.51%	$4,250,837	4	0	0	0
Heating	754	23.98%	$3,352,665	9	0	9	0
Cooking	941	29.93%	$6,072,928	47	4	5	0
Electrical Distribution	100	3.18%	$6,889,176	2	0	3	0
Appliances, Air Conditioning	114	3.63%	$4,453,698	6	0	4	0
Open Flame, Ember, Torch	166	5.28%	$5,173,117	5	4	5	0
Other Heat, Flame, Spark	96	3.05%	$3,150,349	4	2	0	0
Other Equipment	26	0.83%	$839,453	1	0	0	0
Natural	12	0.38%	$251,850	0	0	0	0
Exposure	94	2.99%	$1,990,737	2	0	0	0
Unknown	664	21.12%	$37,396,960	46	9	17	0
Grand Total	**3,144**	**100.00%**	**$78,594,171**	**134**	**20**	**48**	**0**



Note: Numbers are compiled from incidents reported to the Virginia Fire Incident Reporting System (VFIRS) for 2015 as of 7/7/2015. Data for 2015 is considered preliminary since we are continuously receiving new and updated reports from fire departments.

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CTM-506.5.2 cdpVA-15

Proponent : Shawn Strausbaugh, Representing VPMIA & VBCOA PMG code change committee (sstrausbaugh@arlingtonva.us)

2012 Virginia Mechanical Code

SECTION 202 DEFINITIONS

Pollution Control Unit **POLLUTION CONTROL UNIT** Manufactured equipment that is installed in a grease exhaust duct system for the purpose of extracting smoke, grease particles, and odors from the exhaust flow by means of a series of filters.

506.5.2 **Pollution Control Unit** **506.5.2 Pollution Control Units.** The installation of pollution control units shall be in accordance with the manufacturer's installation instructions and all of the following:

1. Pollution control units shall be listed and labeled in accordance with UL 1978.
2. Fans serving pollution control units shall be listed and labeled in accordance with with UL 762.
3. Pollution control units shall be mounted and secured in accordance with the manufacturer's installation instructions and the International Building Code.
4. Pollution control units located indoors shall be listed and labeled for such use. Where enclosed duct systems, as required by Section 506.3.11, are connected to a pollution control unit, such unit shall be located in a room or space having the same fire-resistance rating as the duct enclosure. Access shall be provided for servicing and cleaning of the unit. The space or enclosure shall be ventilated in accordance with the manufacturer's installation instructions.
5. A clearance of not less than 18 inches (457 mm) shall be maintained between the pollution control unit and combustible material.
6. Roof mounted pollution control units shall be listed for exterior installation and shall be mounted not less than 18 inches (457 mm) above the roof.
7. Exhaust outlets for pollution control units shall be in accordance with Section 506.3.13.
8. An airflow differential pressure control shall be provided to monitor the pressure drop across the filter sections of a pollution control unit. When the airflow is reduced below the design velocity, the airflow differential pressure control shall activate a visual alarm located in the area where cooking operations occur.
9. Pollution control units shall be provided with a factory installed fire suppression

system.

10. Service space shall be provided in accordance with the manufacturer's instructions for the pollution control unit and the requirements of Section 306.

11. Wash down drains shall discharge through a grease interceptor and shall be sized for the flow. Drains, shall be sealed with a trap or other approved means to prevent air bypass. Where a trap is utilized it shall have a seal depth that accounts for the system pressurization and evaporation between cleanings.

12. Protection from freezing shall be provided for the water supply and fire suppression systems where such systems are subject to freezing.

13. Duct connections to pollution control units shall be in accordance with Section 506.3.2.3. Where water splash or carryover can occur in the transition duct as a result of a washing operation, the transition duct shall slope downward toward the cabinet drain pan for a length not less than 18 inches (457 mm). Ducts shall transition to the full size of the units inlet and outlet openings.

14. Extra heavy duty appliance exhaust systems shall not be connected to pollution control units except where such units are specifically designed and listed for use with solid fuels.

15. Pollution control units shall be maintained in accordance with the manufacturer's instructions.

Reason: Pollution Control Units have been manufactured by numerous companies for several years. The desire to limit the amount of smoke, grease, and other particulate at the exhaust outlets of commercial cooking appliances has driven the use of these units as numerous entities are requiring these types of units to be installed. These unit and there minimum construction and installation standards need to be addressed in the mechanical code.

Cost Impact: Will increase the cost of construction

The cost of construction of these specific units may be increased by manufacturers if their current unit did not meet the minimum requirements per this new section. As we do not represent manufacturers it is difficult to substantiate if this proposed change will have such a cost increase or not.

Workgroup Recommendation

Workgroup 4 Recommendation Recommendation: Pending

Workgroup 4 Reason: Strausbaugh spoke on his proposal-was approved at the national level and will be in the 2018 IMC. Toalson speaks about cost impact? Strausbaugh stated this is not required to be installed-Toalson asked again for cost-Strausbaugh stated cost is no factor. Revels asking why the proposal is being brought in but not other 2018 changes. Cindy stated it is an issue that needs to be addressed-Greg disagrees with bringing this into the 2015.

Board Decision

None

CTM-506.5.2 cdpVA-15