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TABLE OF CONTENTS

Executive Summary4

 Project Objectives4

 Introduction4

 Summary of Findings4

Energy Code Inquiries5

 State Example: Massachusetts’ Technical Support Inquiries7

Common Residential Energy Code Inquiries.....7

 Air Leakage and Air Barrier Requirements9

 Energy Impacts11

 Relationship to the IECC11

 Literature Review.....11

 Duct and Duct Testing Requirements13

 Energy Impacts15

 Relationship to the IECC15

 Literature Review.....16

 Building Envelope Insulation Requirements17

 Energy Impacts20

 Relationship to the IECC20

 Literature Review20

 Mechanical Ventilation Requirements23

 Energy Impacts24

 Relationship to the IECC24

 Literature Review.....25

Conclusion.....26

Appendix A. List of Residential Energy Code Inquiries26

EXECUTIVE SUMMARY

Project Objectives

This project is a team effort led by the FSEC Energy Research Center to determine and evaluate gaps in building practices associated with the International Energy Conservation Code® (IECC®). The IECC has multiple pathways to compliance, and little data are available on whether these compliance pathways are internally consistent or whether they are equitable from an energy and cost effectiveness perspective. The goals of the project are to produce:

- Empirical energy and cost data on the differences in residential code compliance methods

- An inventory of compliance issues, technology gaps, potential energy and cost impacts associated with each compliance method, and

- Specifications for electronic tools that meet the needs of jurisdictions and third-party providers in the code permitting and compliance verification process.

Introduction

This is a report on Task 3, Code Gaps and Issues Identification, in which the International Code Council (ICC) conducted a study to identify code issues that impact or impede implementation or are perceived to limit effectiveness of each compliance path. The team gathered information on energy code issues from the following sources:

- State helpdesks or frequently asked questions (FAQs) available online

- ICC's membership requests for technical opinions

- The U.S. Department of Energy's (DOE) Building Energy Code Program (BECP) helpdesk

Code inquiries were sorted by building type and building system; commercial inquiries were excluded from the analysis. The team assumed that topics with the greatest number of inquiries across the different sources represented key issues with the IECC, or the state-adopted amended version of the IECC (energy code). The team also conducted an in-depth literature review of online sources available on these topics to determine if adequate resources were readily available to individuals experiencing difficulty with the residential provisions.

Following is a synthesis of findings, literature review results, and technical solutions currently available. The team identified the relationship between common code questions, instances where the code may provide barriers to emerging technologies and implementation issues, potential energy impacts, and applicable compliance paths. Information from this report will support the FSEC team in assessing the energy implications for each compliance implementation and verification issue for each climate zone using simulation analysis. Each issue will be evaluated for its code performance or enforcement effectiveness impact.

Summary of Findings

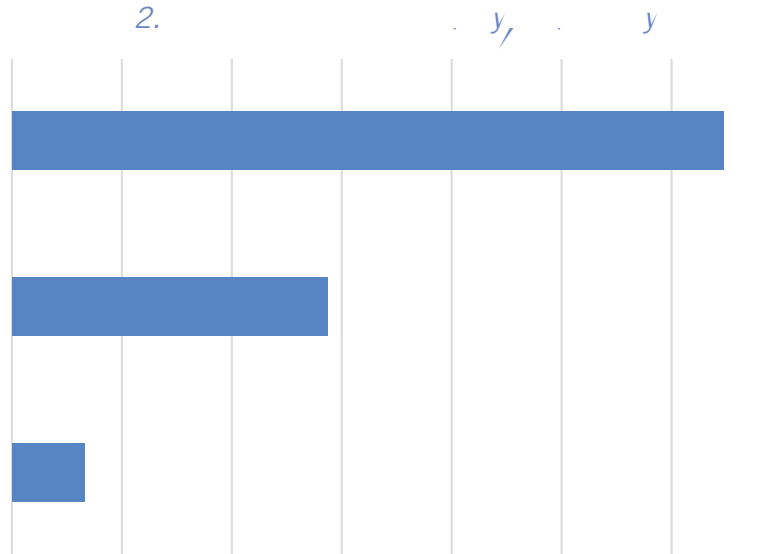
Residential-specific queries accounted for 29 percent of collected energy code questions. This study did not find queries associated with gaps, broken code or issues that may be creating a barrier to implementing new technologies. Instead, questions focused on topics that have generally long been associated with building energy efficiency. The queries included both mandatory (applicable to all compliance paths) and prescriptive items: air leakage and barriers, ducts, envelope insulation, and mechanical ventilation.

The first three items have been included in the DOE list of eight items key to energy savings and are included in the DOE residential field study data collection and analysis.ⁱ For consistency in analysis, this project should consider applying analysis methodology and assumptions from the field studies in relationship to these items. Mechanical ventilation is required by the International Mechanical Code (IMC®), not the IECC; however, the driver behind the IMC requirement is mandatory air leakage testing and air change rates in the IECC.

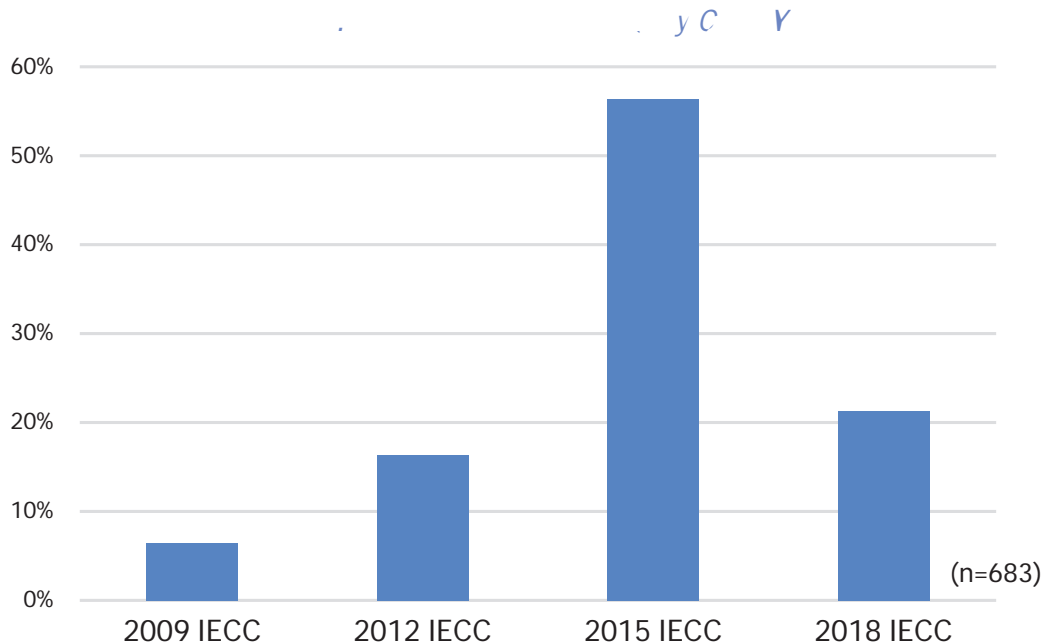
Limiting air leakage (2018 IECC Section R402.4) is a mandatory provision. Significant technical resources are available on the topic, but the training and education needs to be comprehensive from the sub-contractors to the specifiers.

Duct sealing and air leakage testing are also mandatory requirements, although duct leakage levels can be “traded off” in the performance path. Likewise, duct insulation and leakage are prescriptive requirements that can also be traded against other efficiency measures. More information and training are needed on effective

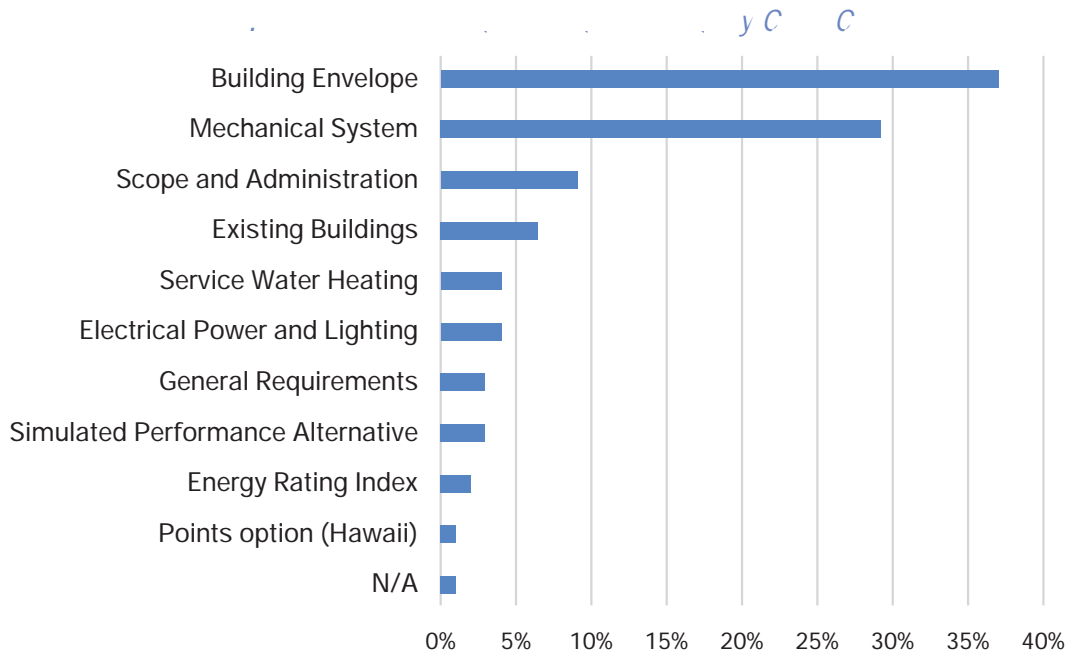
Most questions asked (65 percent) pertained to the IECC-Commercial provisions. This study was focused on identifying gaps in compliance with residential provisions of the IECC; as such, the team did not analyze commercial inquiries. Figure 2 shows the building type, as defined by the IECC, assigned to each question.



Finally, most questions were asked of the 2015 IECC; currently, 17 states have adopted the 2015 IECC residential provisions and the large number of 2015 ICC membership inquiries impacted the distribution. Figure 3 shows the percentage of commercial and residential questions by code year for those where a code year was provided or discernable (n=683).



In addition to technical questions, state-specific FAQs often addressed general topics such as the online location of the state adopted energy code, changes or updates to the energy code, adoption and effective dates, local permitting requirements, and documentation and compliance requirements (such as REScheck)



The most common residential questions are further sorted by general and specific topics in Table 2.

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Specific Air Leakage Questions

Does the entire building need to be tested in accordance with Section R402.4.1.2 (all dwelling units) or can a sample of several units be tested?

Energy Impacts

Air leakage can account for 25 to 40 percent of energy used for heating and cooling in a typical residence. Findings from DOE Residential Field Studies across eight states indicate the impact of non-compliance with air leakage requirements. Approximately one-third of the homes studied did not meet air leakage code requirements, representing an average statewide annual savings potential of 71,150 MMBtu (\$1,079,092). On heating days, infiltration of cold outside air lowers temperature within the space. Higher supply air temperature and greater volume of supply air is required to maintain space temperature. Likewise, exfiltration of conditioned indoor air (warm or cool) must be made up by the air handler beyond what would normally be needed for ventilation and building pressurization. A greater volume of outdoor air is required that then must be heated or cooled. Reducing infiltration can reduce the loads on the building, which in turn can reduce the required sizes of the heating and cooling equipment thereby providing secondary savings.

Relationship to the IECC

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Title	Description	Author	Source Location
General Air Leakage Resources			
Air Leakage – Defined	Guide to air leakage that includes links to many other air leakage resources.	Home Energy Conservation, NC Cooperative Extension	_____ _____

Title	Description	Author	Source Location
Air Sealing For New Home Construction	Identifies techniques and materials identified as best practices for air barriers and air sealing.	Energy Saver, U.S. DOE's EERE	https://www.energy.gov/energysaver/air-sealing-your-home/air-sealing-new-home-construction
Caulking	In-depth look at caulking compounds.	Energy Saver, U.S. DOE's EERE	https://www.energy.gov/energysaver/weatherize/air-sealing-your-home/caulking
Weather-stripping	In-depth look at weather-stripping options.	Energy Saver, U.S. DOE's EERE	https://www.energy.gov/energysaver/weatherize/air-sealing-your-home/weatherstripping
What is an Air Barrier?	Identifies air barriers and techniques. (2013)	Ecohome	https://www.ecohome.net/guides/2298/what-is-an-air-barrier/
Air Leakage in Existing Buildings Resources			
Measure Guideline: Wall Air Sealing and Insulation Methods in Existing Homes	Overview of retrofit methods for existing homes. (2012)	U.S. DOE's EERE, Building Technologies Program	https://www.nrel.gov/docs/fy12osti/55480.pdf
Air Leakage Testing and Air Sealing in Existing Multifamily Units	Overview of techniques for measuring and sealing envelope air leakage in multifamily buildings. (2012)	U.S. DOE's EERE, Building Technologies Program	https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/air_sealing_multifamily.pdf

Duct and Duct Testing Requirements

The effectiveness of the ductwork is critical to efficient energy use in the building and providing comfort to occupants. The following table provides a summary of the requirements for duct testing and sealing.

Specific Duct Questions
General Requirements
If using a centrally located return register in a hallway and transom grills above bedroom doors, are those transom/transfer points required to be ducted?
Spray foamed attic no insulation to rooms below, is attic considered conditioned space or unconditioned so duct blower test will be required?
Are ducts in garage ceilings considered inside conditioned space?
I am a manufacturer of Insulated Duct and would like to obtain Code requirements (R value required) by Climate Zone for the use of Insulated Duct in both conditioned and unconditioned space in new construction residential
Can a duct be located in a stud space and interrupt the building thermal envelope at an exterior wall?

Energy Impacts

Many HVAC energy experts estimate that about 20 percent of conditioned air intended for distribution in the dwelling unit does not make it to the room or space due to leaks, holes, and poorly constructed ductwork systems. ⁱⁱⁱFindings from DOE Residential Field studies across eight statesⁱ indicate the impact of noncompliance with duct leakage requirements. Approximately 37 percent of the homes studied did not meet

Literature Review

RESUME AND COBID-2019-2020 ALSO IN THE (ANSWER) BUILDING ON TOP OF THE 30% OF COBID-2019-2020 (THE)

Title	Description	Author	Source Location
Is a Blower Door Test Required on a Renovation or Addition?	Provides guidance on duct testing for renovations and additions.	Andrew Lesperance, GreenEdge of Michigan	http://www.greenedgemichigan.com/is-a-blower-door-test-required-on-a-renovation-or-addition/
Duct Testing Standard For New and Existing Construction	Outlines exceptions for duct testing in existing homes. (2012)	Washington State University	http://www.energy.wsu.edu/Documents/Duct%20Testing%20Standards%20modified_new_rev_1_29_12.pdf

Building Envelope Insulation Requirements

The building thermal envelope separates the exterior from the interior conditioned space. Building elements of the thermal envelope include basement and exterior walls, roofs, windows, doors, skylights and floors. In some designs, garages, crawl spaces, attics, and areas behind knee walls are unconditioned and exposed directly to the outdoors, separated only by uninsulated exterior walls or roofs. In such cases, the building thermal envelope separates these unconditioned spaces from the interior of the building. Insulating the building envelope is fundamental to keeping a stable indoor temperature and reducing energy costs. Questions reflect a general need for understanding the level and location of required insulation. Table 7 presents the questions related to building envelope insulation found during the inquiry research.



Ecohome. Provides building component guides for new home construction and existing buildings. Each guide provides comprehensive resources; guides are located at www.ecohome.net/guides.

Manufacturer websites. Provide product specifications and installation best practices.

There are several comprehensive resources available on insulating existing homes as well. These include:

Building America Solution Center. Offers a series of detailed code briefs (many included below) on how to insulate various building envelope components in existing homes.

Building America Solution Center. Provides an [Existing Homes Tool](#) that offers installation guidance designed around common home upgrades.

National Renewable Energy Laboratory. Presents [Standard Work Specifications](#) for building envelope components, including insulation.

While general information on insulating existing homes can be found, many of the existing building insulation questions included above in Table 7 are not easily answered with online resources. That is, current resources tell users to install insulation in existing buildings but do not always address when it is necessary to do so.

Resources listed in Table 8 for existing buildings are representative of those available on how to install insulation. Development of a guide on when it is necessary to insulate existing homes should be considered.

Title	Description	Author	Source Location
General Resources			
Insulation Materials	Guide to insulation materials.	Energy Saver, U.S. DOE's EERE	https://www.energy.gov/energysaver/weatherize/insulation/insulation-materials
Where to Insulate in a Home	Comprehensive look at where insulation is required in a home.	Energy Saver, U.S. DOE's EERE	https://www.energy.gov/energysaver/weatherize/insulation/where-insulate-home
Attic Insulation Resources			
How to Insulate and Air-Seal Pull-Down Attic Stairs	Insulating pull-down attic stairs to reduce heating and cooling loss. (2012)	Green Building Advisor	https://www.greenbuildingadvisor.com/article/air-seal-pull-down-attic-stairs

Title	Description	Author	Source Location
Air Sealing and Insulating Garage Walls - Code Compliance Brief	Provides code-specific information about air sealing and insulating garage walls	Building America Solution Center	https://basc.pnnl.gov/code-compliance/air-sealing-and-insulating-garage-walls-code-compliance-brief
Insulated Interior Exterior Wall Intersections – Code Compliance Brief	Provides code-related information about insulated interior/exterior wall intersections.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/insulated-interior-exterior-wall-intersections---code-compliance-brief
Floor Insulation Resources			
Floors: Above Unconditioned Basement, Vented Crawlspace, Cantilevered Floors, and Floors above Garage, Code Compliance Brief	Provides code-related information about the airspace between the floor sheathing and the top of the cavity insulation	Building America Solution Center	https://basc.pnnl.gov/code-compliance/floors-above-unconditioned-basement-vented-crawlspace-cantilevered-floors-and-floors
Crawlspace Insulation Resources			
Unvented, Insulated Crawlspaces	How to insulate closed crawlspaces with rigid foam board; how to insulate the band joist area with rigid foam board; how to install ducts in a sealed, insulated crawl space.	Building America Solution Center	https://basc.pnnl.gov/resource-guides/unvented-insulated-crawlspaces
Foundation Insulation Resources			
Slab-on-Grade Insulation – Code Compliance Brief	Provides code-specific information about slab-on-grade insulation	Building America Solution Center	https://basc.pnnl.gov/code-compliance/slab-grade-insulation-code-compliance-brief
Continuous Insulation Resources			
Continuous Insulation – Cladding/Furring Attachment - Code Compliance Brief	Provides code-related information about continuous insulation.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/continuous-insulation-%E2%80%93-claddingfurring-attachment-code-compliance-brief
Existing Building Insulation			
Sealing and Insulating Existing Exterior Walls – Code Compliance Brief	Provides code-related information on insulating and sealing existing walls in homes.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/sealing-and-insulating-existing-exterior-walls-code-compliance-brief
Sealing and Insulating Existing Vented Attics - Code Compliance Brief	Provides code-related information about sealing and insulating existing floors above unconditioned spaces in existing homes.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/sealing-and-insulating-existing-vented-attics-code-compliance-brief
Sealing and Insulating Existing Floors Above Unconditioned Spaces - Code Compliance Brief	Provides code-related information about sealing and insulating existing floors above unconditioned spaces in existing homes.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/sealing-and-insulating-existing-floors-above-unconditioned-spaces-code-compliance
Sealing and Insulating Existing Exterior Walls - Code Compliance Brief	Provides code-related information about sealing and insulating existing walls in existing homes.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/sealing-and-insulating-existing-exterior-walls-code-compliance-brief
Sealing and Insulating Existing Crawl Space Walls - Code Compliance Brief	Provides code-related information about sealing and insulating crawl space walls in existing residential	Building America Solution Center	https://basc.pnnl.gov/code-compliance/sealing-and-insulating-existing-crawl-space-walls-code-compliance-brief
Rigid Foam Board Interior Insulation for Existing Foundation Walls	Provides guidance for installing rigid foam board insulating in existing foundation walls.	Building America Solution Center	https://basc.pnnl.gov/resource-guides/rigid-foam-board-interior-insulation-existing-foundation-walls#quicktabs-guides=0
Spray Foam Insulation Applied to Existing Attic Floor	Provides guidance for insulating an attic in an existing home by installing spray foam on top of the ceiling plane (on the floor of the attic)	Building America Solution Center	https://basc.pnnl.gov/resource-guides/spray-foam-insulation-applied-existing-attic-floor
Above Deck Rigid Foam Insulation for Existing Roofs	Provides guidance for installing Insulating sheathing above the roof deck on existing homes.	Building America Solution Center	https://basc.pnnl.gov/resource-guides/above-deck-rigid-foam-insulation-existing-roofs

Mechanical Ventilation Requirements
General Requirements
Is mechanical ventilation required for the dwelling units of R-2 buildings 3 stories or less in height?
In determining the amount of required mechanical ventilation, should we include the square footage of the basement to find the amount on table M1507.3.3(1)?
How can I meet the ventilation requirement?
Why am I required to ventilate my house after I just sealed it up?

Energy Impacts

While this is not included in DOE's eight key items impacting residential energy efficiency¹, energy is needed to drive mechanical ventilation systems so noncompliance with these requirements can impact the energy efficiency of projects. Additionally, there is a tension between health and safety ventilation requirements necessary for adequate indoor air quality, and over ventilating and decreasing efficiency of the dwelling.

Relationship to the IECC

Mechanical ventilation requirements are mandatory in the IECC (2018 IECC Section R403.6) and must be met regardless of the path selected for compliance – however note the IECC is triggering the requirements of the IMC through reduced air leakage and air infiltration testing requirements.

Literature Review

As with the previous topics, resources available on mechanical ventilation are plentiful. However, most resources are outdated, primarily covering requirements of the 2012 IECC. Resources that are not code specific – those that cover ventilation strategies and system options – are also many years old, though often thorough and relevant. Contractor and manufacturer websites frequently provide system descriptions and comparisons.

The Residential Building Systems group at Lawrence Berkley National Laboratory produced the _____

Conclusion

The survey and analysis illustrate how fundamental the code queries remain after 25 years of energy code implementation: air leakage and barriers, ducts, envelope insulation, and mechanical ventilation were the most common categories of residential code queries. It demonstrates that comprehensive technical support tools are available to address these compliance challenges. Follow-on work by ICC, the BECP and others would be useful to identify gaps in resources and address how communication, training and education can be used to build a broader understanding of how to apply the residential provisions of the IECC and overcome these gaps in knowledge.

Appendix A. List of Residential Energy Code Inquiries

This appendix presents the list of residential energy code inquiries from state energy code websites and FAQs, ICC's membership questions, and BECP's helpdesk.

- i. US Department of Energy Residential Field Studies <https://www.energycodes.gov/compliance/energy-code-eld-studies>
- ii. Air Sealing. Building Energy Improvements, https://www.energystar.gov/ia/home_improvement/home_sealing/AirSealingFS_2005.pdf accessed 5/10/2020
- iii. www.energystar.gov (see Home Improvement—Duct Sealing).
- iv. www.energystar.gov (see Home Improvement – Duct Insulation).