ICC INTERNATIONAL CODE COUNCIL®

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Task 3. International Energy Conservation Code Gaps and Issues Identification

Prepared for
FSEC Energy Research Center
In Support of Market-Driven Residential Energy Codes:
Comparing Performance in a Changing Technological Environment
DOE Funding DE-EE0008699

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TABLE OF CONTENTS

TABLES

FIGURES

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.

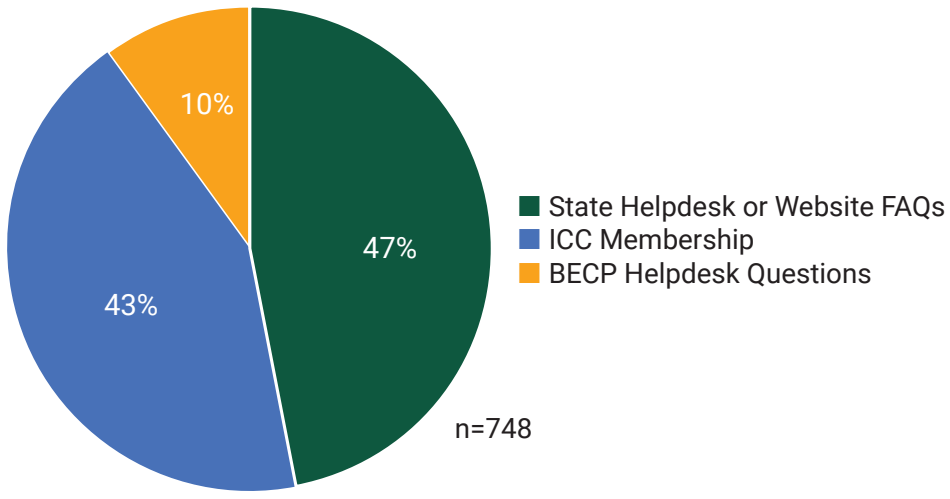
Duct sealing and air leakage testing are also mandatory requirements, although duct leakage levels can be "traded off" in the performance path. Likewise, duct insulation and leakage are prescriptive requirements that can also be traded against other efficiency measures. More information and training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

Envelope insulation is a prescriptive provision that can generally be traded using the performance path against other efficiency measures including (but not limited to) increased insulation in other assemblies, increased fenestration efficiencies, and lighting efficiencies, although certain "backstops" are included in the IECC. The impact of reduced insulation varies based on building geometry, orientation, climate zone, assembly type and other factors. Specific and comprehensive educational materials exist, although they may not be adequately reaching code users and installers.

Energy Code Inquiries

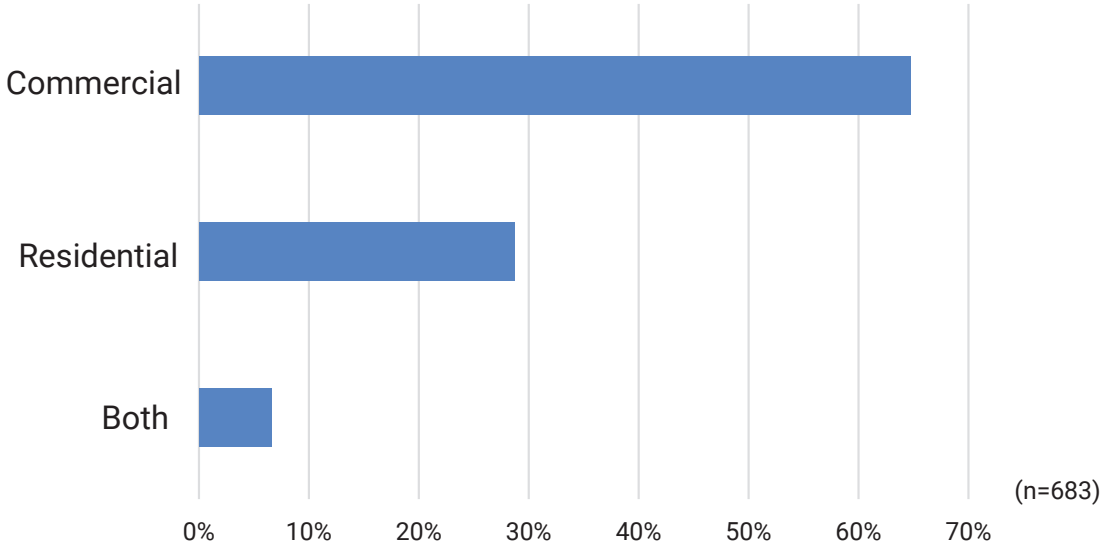
From the state helpdesks and FAQs, ICC's member requests for technical opinions, and BECP's helpdesk, the team categorized 748 questions by building type (residential or commercial), IECC chapter, and topic. Ninety percent of the inquiries came from individual state helpdesks or websites and ICC membership requests. Inquiries from state helpdesks or websites include data from 16 states; a complete list of states providing input and number of data points per state is included in Appendix A. Figure 1 shows the percentage of questions from each source.

Figure 1. Sources of Energy Code Inquiries



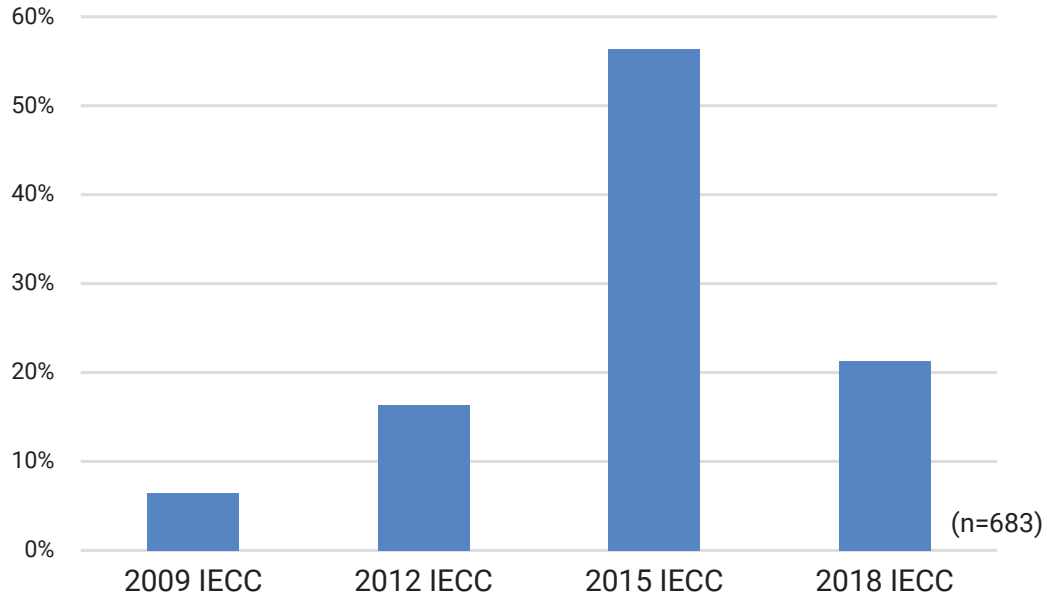
Most questions asked (65 percent) pertained to the IECC-Commercial provisions. This study was focused on identifying gaps in compliance with residential provisions of the IECC; as such, the team did not analyze commercial inquiries. Figure 2 shows the building type, as defined by the IECC, assigned to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

Figure 2. Percentage of Inquiries by Building Type



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).

Figure 3. Percentage of Inquiries by Code Year



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) that are applicable to both the residential and commercial sectors. ICC membership and BECP helpdesk questions also included inquiries applicable to both sectors. These included:

- Building-type clarification (residential, commercial, mixed-use)
- Permissible use of above code programs to demonstrate compliance with the energy code
- Use of third-party energy professionals and their relevant qualifications

State Example: Massachusetts' Technical Support Inquiries

The team also requested common energy code questions submitted to Massachusetts' Mass Save® technical support hotline. The implementer of the technical assistance records and tracks all energy code questions submitted to Mass Save and provided the percentages shown in Table 1 for residential sector inquiries. Although specific questions were not provided, information gleaned from the Mass Save program may offer unique insight, as Massachusetts has one of the most active technical assistance programs in the country and claims savings attributable to the program.

Table 1. Massachusetts Energy Code Inquiries

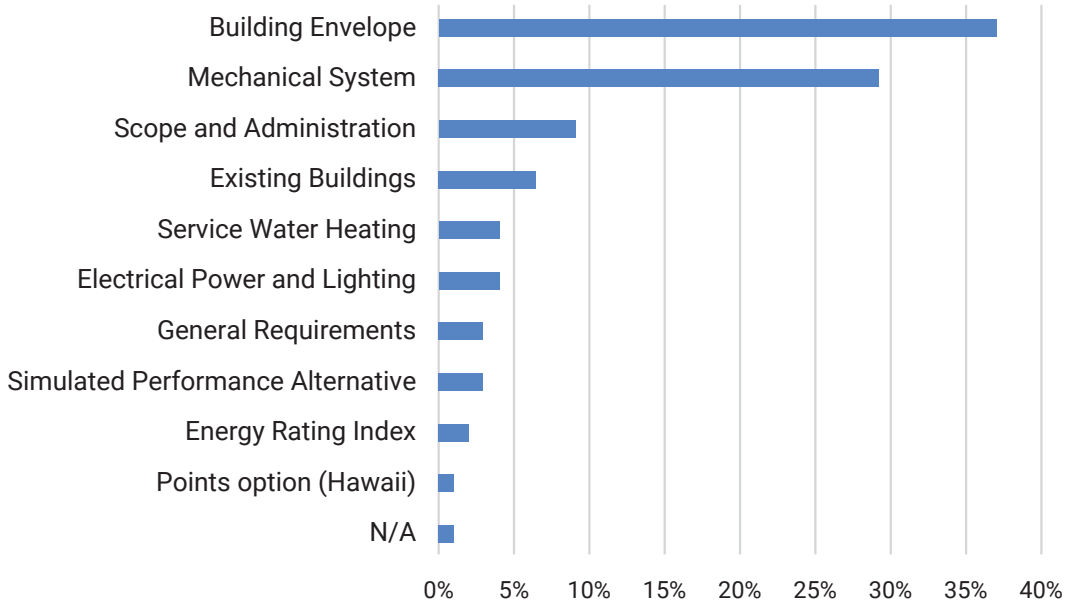
Residential Energy Code Inquiries (n=137)	
Topic	**Percentage**
Existing building requirements	25%
Building thermal envelope	23%
Stretch code/ERI requirements	18%
Mechanical systems	17%
Mass Save programs and incentives	6%
Misc./other	5%
2018 IECC adoption	4%
Solar ready	2%
REScheck	1%
Note: Total percentage may not sum due to rounding.	

Several anomalies were found that may be reflective of Massachusetts advanced energy initiatives and could be indicators of future national trends. While 65 percent of the inquiries reviewed as part of this study were commercial, Mass Save reported nearly three times as many residential inquiries as commercial. No in-depth research was conducted on this difference, but Mass Save inquiries may indicate energy code training or other code compliance enhancement efforts are addressing commercial questions; commercial code users may be utilizing other technical resources; state-specific residential requirements may be more difficult to meet; or residential energy code users may have a greater interest in "getting it right" in Massachusetts than observed nationally. Additionally, the percentage of residential questions related to a performance compliance path far exceeds what was observed in this study.

Common Residential Energy Code/IECC Inquiries

The complete list of residential energy code inquiries in this study is included in *Appendix A. List of Residential Energy Code Inquiries*. Most of the inquiries are related to the building envelope and mechanical systems (37 percent and 29 percent respectively). Figure 4 shows the percentage of residential inquiries by code chapter.

Figure 4. Percentage of Residential Inquiries by Code Chapter



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

Table 2. Common Residential Energy Code Inquiries

General Topic	Question Specifics
Air leakage and air barriers	• Testing requirements • Materials and installation • Maximum rate allowed • Calculations • Professional credentials for envelope testing • Multifamily testing requirements
Ducts	• Insulation requirements • Sealing requirements • Location, space type • Testing requirements • Professional credentials for duct testing • Requirements for duct insulation and testing in existing buildings
Insulation, all building envelope components	• Wall insulation • Ceiling and roof insulation • Attic insulation • Floor insulation • Foundation insulation • Insulated cavities • Insulation requirements for existing buildings
Mechanical ventilation	• Requirements • Equipment types • Controls

One of the research topics was to determine if the questions being asked indicated that problems associated with code compliance could be barriers to advanced technologies, however there was no clear correspondence found. Instead, the questions reflected general misunderstanding or additional information needed on essential code provisions associated with air leakage, ducts, insulation and mechanical ventilation. For each of the general topics identified in Table 2, the following information is provided:

- Specific questions asked on the topic
- A summary of energy impacts associated with the topic, and how the topic can impact building energy efficiency and the intent of the energy code provisions associated with the topic
- The relationship of the topic to the IECC compliance paths and whether the common questions are related to mandatory or prescriptive code requirements
  - » Mandatory provisions are required of every project irrespective of the path selected to demonstrate compliance including the performance and ERI path; no trade-offs are permitted for these requirements. Noncompliance with mandatory requirements impacts the energy use of all projects.
  - » Prescriptive requirements apply when a project demonstrates compliance using the prescriptive path; noncompliance of individual prescriptive components may have a large impact on the overall energy use of a building because the energy use is not offset by greater efficiencies elsewhere. However, some building thermal envelope prescriptive requirements may be traded-off if compliance is achieved using the Total UA Alternative compliance option. When using the Total UA Alternative, the total building thermal envelope UA (sum of U-factor multiplied by assembly area) must be less than or equal to the U-factors specified in the code multiplied by the same assembly area.
- An assessment of the technical resources available to address the topic

Air Leakage and Air Barrier Requirements

Table 3 presents the specific questions asked about air leakage. Questions broadly included the need to understand where the air barrier was to be located and acceptable materials, and when air leakage testing is required, and clarification on third-party requirements. Air leakage in the building envelope is called infiltration even though it is infiltration and exfiltration. Differentials in pressure and temperature cause air movement through the building thermal envelope if it is not properly sealed. This allows conditioned air to escape and can create particularly inefficient building energy use. Infiltration and exfiltration occur at the same time while the building works to balance itself, with air finding cracks and holes in the air barrier.

Table 3. Air Leakage Inquiries

Specific Air Leakage Questions
General Requirements
Is diagnostic testing required for assessing compliance with the energy code?
Are blower door tests required for R-2 buildings 3-stories or less in height?
Are all new homes required to pass an air tightness, or blower door, test?
Are apartments and multi-family buildings required to have a blower door test?
Am I required to test house leakage?

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?
Does Section R402.4.1.2 require each townhouse to be tested or can the entire "building" be tested?
When can the blower door test be performed?
What is a mid-point blower door test?
What is required to meet the new building air leakage testing requirements?
Is a blower door test required in conjunction with REScheck?
Is blower door testing required for all paths to compliance or just the prescriptive path?
When should I do the blower door test?
What is the difference between the commercial and residential building enclosure test criteria in the code?
Air Leakage Testing Details
For residential buildings, should vent openings to the outside such as fireplace, dryer, or bath exhaust vents, be covered prior to blower door testing?
What is the maximum air leakage rate allowed per code?
What areas of the home should be included in the volume calculation for the air leakage requirement?
Third-Party Testing
Regarding air leakage testing, section R402.4.1.2 reads, “Where required by the building code official, testing shall be required by an approved third party.” Shouldn’t testing be required, period?
Can you please clarify the professional credential requirements specified in the 2009 and 2012 Residential Codes for duct tightness and air leakage testing?
Who is approved to perform the blower door test for code compliance?
Do I need to hire a certified person or company to conduct the blower door test?
Where do I find someone to do a blower door test?
Who can do the blower door test in the residential energy code?
Air Barrier – General
The code requires an air barrier - what is that?
Air Barrier Material
Is polyethylene (poly) acceptable as an air barrier?
Can poly be sealed as an air barrier for a shower wall?
Can Kraft paper or cardboard be used as an air barrier?
Is Kraft facing allowed on fiberglass batts?
Air Barrier Location
What are the air sealing and air barrier requirements for rim joists?
Is an air barrier required behind shower units installed against an exterior wall?
Does the top side of attic insulation need an air barrier?
Does the text of the General Requirements row in Table R402.4.1.1 mean that even if the air barrier is created on the innermost side of the wall assembly (for example the drywall) that the exterior of the building thermal envelope of the wall should also contain an “air barrier”?
Is an air barrier required to be installed over un-faced fiberglass batt insulation installed in front of and in contact with a poured concrete basement foundation?
Is rim and band joist insulation required to have an air barrier material over fiberglass or cellulose insulation?
Air Barrier Sealing
Is the method of sealing described in the Energy Star checklist the equivalent to that described by the code?
Existing Building Air Leakage Requirements
Is a blower door test required for a residential gut rehab?
Is a blower door test required for an addition?

Specific Air Leakage Questions
envelope of which is not being altered? A blower door test would encompass the whole house, which isn't necessarily as airtight as the new addition.
When building an addition which must comply with the code, how do we comply with the blower door and duct leakage requirements of the addition and not the whole house?

Energy Impacts

Air leakage can account for 25 to 40 percent of energy used for heating and cooling in a typical residence. [ii]Findings from DOE Residential field studies across eight statesi 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

Limiting air leakage (2018 IECC Section R402.4) is a mandatory energy code requirement and applies to residential projects regardless of the compliance path selected by the builder. Air leakage requirements include air barrier criteria and testing. Noncompliance with these requirements impacts the energy use of all residential projects.

Literature Review

Air leakage and air barrier guidance proved to be well-researched and well-documented energy code provisions. Resources covering the energy and durability impact of air leakage, air testing procedures, air barrier materials, air sealing, and other air leakage topics are plentiful. Guidance on air leakage testing in existing buildings is also well documented. Trained and certified air barrier contractors can be found on the Building Performance Institute website (www.bpi.org) and Air Barrier Association of America website (www.airbarrier.org).

Table 4 presents a small portion of the available resources focused on air leakage; this list is not intended to be inclusive.

Table 4. Select Air Leakage Resources

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	https://energy.ces.ncsu.edu/air-leakage-defined/
Save Home Energy by Stopping Air Leaks	Resource for finding and managing air leakage in homes. (2011)	University of Nebraska Lincoln Extension	http://extensionpublications.unl.edu/assets/pdf/ec479.pdf
Keeping The Heat In - Chapter 4: Comprehensive air leakage control	Guide to finding air leakage areas and air sealing materials. (2016)	Natural Resources Canada	https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-homes/make-your-home-more-energy-efficient/keeping-heat/keeping-heat-chapter-4-comprehensive-air-leakage-control/15635
Air Sealing: Building Envelope Improvements	Factsheet developed by ENERGY STAR estimating energy use. (2005)	ENERGY STAR	https://www.energystar.gov/ia/home_improvement/home_sealing/AirSealingFS_2005.pdf
Methodology for Estimated Energy Savings from Cost-Effective Air Sealing and Insulating	Estimates of energy savings due to air sealing and insulating.	ENERGY STAR	https://www.energystar.gov/campaign/seal_insulate/methodology
Air Leakage Testing Resources			
Blower Door Tests	Describes blower door testing.	Energy Saver, U.S. DOE's EERE	https://www.energy.gov/energysaver/blower-door-tests
Diagnosing and Sealing Air Leakage	Comprehensive guide to conducting blower door tests. (2019)	Home Energy Plus	http://homeenergyplus.wi.gov/docview.asp?docid=27550&locid=25
All You Need to Know About Blower Door Test	Details testing procedures, meaning of results, and costs.	Bob Vila	https://www.bobvila.com/articles/blower-door-tests/
Air Leakage Testing Garage to House Air Barrier	Guidance for homes with an attached garage to test the air barrier between the house and the garage to verify its integrity.	Building America Solution Center	https://basc.pnnl.gov/resource-guides/air-leakage-testing-garage-house-air-barrier
Building Air Tightness: Code Compliance & Air Sealing Overview	Describes air tightness, testing, air sealing strategies, and air barriers. (2014)	ICC, National Association of Home Builders	https://cdn-web.iccsafe.org/wp-content/uploads/proclamations/TN02-Building-Tightness_pdf.pdf
Seven Tips for Multifamily Blower Door Testing	Provides insight into multifamily blower door tests. (2020)	Scott Home Inspection	https://scotthomeinspection.com/7-tips-for-multi-family-blower-door-testing/
Testing Air Leakage in Multifamily Buildings	Details different methods for blower door testing in multifamily buildings.	Green Building Advisor	https://www.greenbuildingadvisor.com/article/testing-air-leakage-in-multifamily-buildings
Air Barrier and Sealing Materials Resources			
Aerosol Sealing Building Enclosures, Single and Multifamily Dwellings - Code Compliance Brief	Provides code-related information for aerosol sealing building enclosures to achieve durable air tightness levels.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/aerosol-sealing-building-enclosures-single-and-multifamily-dwellings-code-compliance
How to Install an Air Barrier for Reduced Air Leakage	Video on air barrier installation. (2015)	Ecohome	https://www.ecohome.net/guides/2251/air-barriers-tips-for-building-airtight-homes/ https://youtu.be/BuG7orQni1o
Can Polyethylene Be Used as an Air Barrier?	Explores the ways polyethylene can be used as an air barrier. (2011)	Green Building Advisor	https://www.greenbuildingadvisor.com/article/can-polyethylene-be-used-as-an-air-barrier
Air Sealing Your Home	Presents air sealing tips.	Energy Saver, U.S. DOE's EERE	https://www.energy.gov/energysaver/weatherize/air-sealing-your-home
Air Sealing Techniques	Provides guidelines for proper air sealing.	Seal, Insulate, & Ventilate	https://www.sealinsulateandventilate.com/sealing/air-sealing-techniques/

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. Ducted systems must transfer fresh or conditioned air from the air-handling unit to rooms around the building. Provisions specific to ducts and air handlers improve energy efficiency in the design and installation of these systems. Questions generally addressed the relationship between duct location and requirements, and fundamental questions about sealing and testing requirements. Table 5 presents the specific questions gathered from states, ICC membership, and the BECP helpdesk related to ducts.

Table 5. Duct and Duct Testing Inquiries

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?
Can building cavities be used as return ducts?
If there is a duct in the framed floor over the garage (in the bonus room) does that duct still count as being inside the thermal envelope?
Is ductwork that is located above the air barrier and building insulation and below the subfloor within the building thermal envelope?
Do I have to duct my return ducts, or can they be panned?
What about ducts in insulated cavities? For example, is it okay to put a duct in a floor joist space and not achieve the mandatory floor's insulation requirements?
Duct Insulation
Does Section R403.3.6 require that the duct be completely surrounded or encased by R-19 (minimum) insulation or that the total R-value within the cavity be R-19 minimum, excluding the R-value of the duct insulation?
Duct Sealing Requirements
Do the gored elbow joints of metal transition ducts need to be sealed?
Why is duct sealing required within conditioned space?
What is the best product for sealing ductwork?
Should all the seams in heating system ductwork be sealed?
Duct Testing Requirements
Is duct testing required for every home in a development, or can only a sample be tested?
Is the duct testing required to be performed by a third party?
Is the ductwork required to be tested for air leakage?
A residence has an attic space outside of the thermal envelope that houses ductwork from a bath fan, dryer, or range exhaust, do the ducts need to be tested for air leakage?
The 2009, 2012, and 2015 editions of the IECC-Residential Provisions indicate that duct testing must be performed in either the rough-in stage or the post-construction stage in accordance with Section R403.3.3 (2015 IECC edition section reference). Where testing post-construction path is chosen, an exception allows for not performing the test where all of the ducts and air handlers are located entirely within the building thermal envelope. Does this exception (for not performing the test) mean that duct leakage to outside of the building thermal envelope can be assumed to be zero?
The exemption from duct testing in the 2012 and 2015 editions of the IECC-Residential Provisions is based on the ducts being within the building thermal envelope. The definition for building thermal envelope relies in part

Specific Duct Questions
on conditioned space. The conditioned space definition in turn indicates that any space with an uninsulated duct fits the criteria. Given this, it appears that all ductwork qualifies for the exemption unless it is located outside the skin of the building. Is this correct?
Can you please tell what can be done to test for duct leakage in an apartment?
Who is approved to perform the duct leakage test?
Who is certified to complete house and duct testing?
What happens if the ductwork goes outside the envelope and when the house is done, I don't pass the duct leakage test?
I am a mechanical contractor and have had inconsistent results with the duct testing. What causes these fairly significant differences?
For duct leakage testing, the code allows a leakage to the outside test or a total duct leakage test. What is the difference?
Which is better: a leakage to the outside test or a total duct leakage test?
What are the advantages/disadvantages of each test (leakage to the outside test or total duct leakage)?
If duct elbows are not sealed with mastic can a system still pass the duct leakage test?
What is the worst-case duct leakage input that is required for Section R405.4.2 (Simulated Performance Alternative)?
Existing Building Duct Requirements
Is the ductwork required to be insulated when a new HVAC system (air conditioning unit and ductwork) is installed within the basement of a single-family dwelling when there is no insulation between the basement and the story directly above and the story above was previously heated only?
Is a duct blaster test required if I am adding a minimal amount of duct work?
When building an addition which must comply with the code, how do we comply with the blower door and duct leakage requirements of the addition and not the whole house?

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. [iii]Findings 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 duct leakage requirements, representing an average statewide annual savings potential of 44,524 MMBtu ($832,368). These losses result in higher energy bills and a lower level of occupant comfort. Duct sealing is critical regardless of duct location. However, the value of duct insulation is more dependent on duct location. Ducts traditionally have been in unconditioned spaces such as attics, crawl spaces, garages, or unfinished basements and are made of thin materials (like sheet metal) that conduct heat easily. Due to extreme winter and summer temperatures in these spaces, 10 to 30 percent of the energy used to heat and cool the air is lost through the duct surfaces.[iv]

Relationship to the IECC

Duct sealing and testing are mandatory requirements and the minimum provisions must be met regardless of the path selected for compliance. (2018 IECC Section R403.3) Noncompliance with these requirements impacts the energy use of all residential projects.

Duct insulation and leakage are prescriptive requirements. Noncompliance with prescriptive provisions impacts the energy use of prescriptive projects (including those demonstrating compliance with the Total UA Alternative) but does not impact projects using the Performance path or ERI Compliance Alternative.

Literature Review

ANSI/RESNET/ICC 380-2016: Standard for Testing Airtightness of Building Enclosures, Airtightness of Heating and Cooling Air Distribution Systems, and Airflow of Mechanical Ventilation Systems provides a standard for testing the integrity of duct systems and air distribution systems. Other resources for duct provisions are largely outdated, most dating back to the late 2000s and early 2010s following the push for bringing ducts inside the building thermal envelope. Resources such as those describing the importance of duct work in conditioned space, are plentiful. Resources defining the thermal building envelope are also plentiful; however, it is evident there is confusion by code users on ducts and conditioned spaces. For example, *"Are ducts in garage ceilings considered inside conditioned space?"* and *"Is ductwork that is located above the air barrier and building insulation and below the subfloor within the building thermal envelope?"*

Updated resources, complementary to the Standard, and guidance on ducts in conditioned spaces with clear, illustrated examples should be considered.

Table 6. Select Duct and Duct Testing Resources

Title	Description	Author	Source Location
Duct Sealing and Insulation Resources			
ANSI/RESNET/ICC 380-2016. Standard for Testing Airtightness of Building Enclosures, Airtightness of Heating and Cooling Air Distribution Systems, and Airflow of Mechanical Ventilation Systems	Provides a methodology for evaluating the airtightness of building envelopes and heating and cooling air ducts and the airflows of mechanical ventilation systems.	RESNET	https://shop.iccsafe.org/ansi-resnet-icc-380-2016-standard-for-testing-airtightness-of-building-enclosures-airtightness-of-heating-and-cooling-air-distribution-systems-and-air-flow-of-mechanical-ventilation-systems-1.html
Sealing Heating, Ventilating, and Air-Conditioning Supply and Return Register Boots - Code Compliance Brief	Provides code-related information about properly sealing heating, ventilating, and air conditioning register boots.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/sealing-heating-ventilating-and-air-conditioning-supply-and-return-register-boots
Place Ducts Inside the Building Envelope	Describes how to bring ducts into conditioned space. (2016)	Zero Energy Project	https://zeroenergyproject.org/2016/12/16/place-ducts-inside-building-envelope/
Measure Guideline: Buried and/or Encapsulated Ducts	Outlines methods of reducing thermal losses associated with ductwork in unconditioned spaces with a focus on burying ductwork.	U.S. DOE's EERE, Building Technologies Office	https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_buried_encap_ducts.pdf
Duct Testing Resources			
Testing Duct Leakage	Provides guidance on finding duct leakage; includes links to Total Duct Leakage Test and Outside Duct Leakage Test.	Energy Vanguard	https://www.energyvanguard.com/diagnostic-performance-testing/duct-leakage https://www.energyvanguard.com/diagnostic-performance-testing/duct-leakage/total-duct-leakage-test https://www.energyvanguard.com/diagnostic-performance-testing/duct-leakage/outside-duct-leakage-test
Duct Testing Best Practices	Presents best practices for duct testing. (2018)	Sam Meyers	https://retrotec.com/blog/post/duct-testing-best-practices/
Testing and Sealing Ductwork	Describes methods for tracking leaks.	A. Tamasin Sterner and Larry Armanda	https://energy.ces.ncsu.edu/wp-content/uploads/2013/10/V-training-testing_and_sealing_ductwork_from_fine_homebuilding.pdf?fwd=no
RESNET Guidelines for Multifamily Energy Ratings	Describes procedures for multifamily dwelling unit and duct testing. (2014)	RESNET	https://www.resnet.us/wp-content/uploads/Adopted_RESNET_Guidlines_for_Multifamily_Ratings_8-29-14.pdf

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.

Table 7. Building Envelope Insulation Inquiries

Building Envelope Insulation Requirements
Attic Insulation
Am I required to install R-49 in my attic?
How does one insulate an attic access panel?
An exception states that R-38 attic insulation is acceptable if uncompressed over the top plate at the eaves at the exterior walls. Is R-38 acceptable just at the perimeter where R-49 will not fit, or can you use R-38 over the entire ceiling?
Ceiling Insulation
Is batt insulation allowed to be used in ceiling assemblies that are strapped with furring strips?
I have architects specifying R-38 to be fit in ceiling joist bays of 2x8 and 2x6. These are usually open to the attic (uncompressed). My question is: what is the actual R-value when thickness of insulation exceeds joist depth? Should I require the particular insulation that can fit in bay uncompressed and then have additional perpendicular unfaced layer over that to achieve R-38 min?
Is it mandatory for walls to have R-15 insulation and roof R-38? Can I use the performance approach for energy calculations to use R-13 for walls and R-30 for roof?
To use the R-38 insulation instead of R-49 at the ceiling does the truss heel height have to allow for unrestricted insulation plus 1-inch air gap space or full height with a baffle?
What is the current R-Value for insulation in ceilings, walls, floors?
Roof Insulation
Is the entire roof allowed to use the lower R value of Section R402.2.1?
Where is the R-value requirement for insulation above deck in a residential home provided in the IECC?
Wall Insulation
What are the compliance options for walls made of concrete masonry units or poured-in-place concrete?
How do I deliver an R-20 wall?
Is there a requirement to insulate the common wall between townhouses?
How do you properly frame a knee wall when roof trusses are being used?
What is the R-Value requirement for a knee wall in Climate Zone 2?
Can the back of knee wall insulation be covered with poly?
What is the current R-Value for insulation in ceilings, walls, floors?
Floor Insulation
Does the exception of Section R402.2.8 permit the insulation of a floor above an unconditioned space to be installed at the ceiling membrane below and at the rim around the framed floor space without any insulation contacting the subfloor decking?
I'm having difficulty understanding the exception provided in this code section. More specifically, how would the installation of insulation in contact with the topside of sheathing be achieved?

Building Envelope Insulation Requirements
I have an interpretation question about 2018 IECC Table R402.1.2. For the Floor R-value in Climate Zone 5, R-30 is required, but then there's a footnote g that says "alternatively, insulation sufficient to fill the framing cavity and providing not less than R-19". Is this exception only for renovations? Trying to understand why this exception exits. I'm in Climate zone 5 and EVERYONE tries to use this footnote to get out of the R-30 requirement. Can you shed light on when this is applicable and when it's not?
What is the current R-Value for insulation in ceilings, walls, floors?
Foundation / Slab-on-Grade Insulation
For slabs less than 12” below grade, If I meet the insulation requirements, do I need anything else to protect the foundation?
Since insulation is required on the full height of the foundation wall, can I insulate the exterior below grade section of the wall then insulate the interior side for the above grade portion, so I don’t have to protect the above grade insulation on the exterior?
Do the requirements under heading "Slab, R Value and Depth" apply to garage floors, attached to a home, that are being heated with in floor radiant tubing?
What strategies can be used to trade off slab insulation in Zone 4 for other energy efficiency measures?
Is there a way to install slab insulation that will protect it from being damaged during construction and/or by homeowners using weed eaters, etc.?
If heat rises, then how can slab insulation be effective in eliminating heat loss?
How do I insulate the edges of my slab-on-grade?
For slab-on-grade construction, what are the insulation requirements?
What is the proper technique to provide vertical insulation to the inside face of a foundation wall when the wall is 4ft out of the ground, and 4ft in the ground – total height 8ft.
Crawl Space Insulation
Does making a crawlspace a conditioned space remove the 24 vertical and/or horizontal inch insulation length requirement of Section R402.2.11?
Are the walls of an unconditioned crawl space that is naturally ventilated required to have insulation when the floor above is insulated as required by the IECC?
Am I allowed to seal up my crawlspace?
When installing ductwork in an insulated enclosed crawlspace (with no vents to the outdoors), do the ducts need to be insulated or does there need to be a register supplying heat to the crawlspace in order to call it “conditioned space”?
Why does the code require basement and crawlspace walls to be insulated?
Continuous Insulation
How is "continuous insulation" defined, as referenced in Table R402.1.2 for Basement Wall R-value.
Would mineral fiber blanket insulation draped over the interior surface of a basement wall, secured at the top and bottom but using no framing members, be considered "continuous insulation"?
Existing Building Envelope Requirements
If I open a wall, do I need to add the required amount of insulation if there isn't enough space?
If the roof sheathing or above-deck insulation is exposed during a roof replacement and the cavity is not exposed, but there is some insulation in the existing ceiling cavity, is additional insulation required above and/or below deck if the cavity is not completely filled or does not meet the current requirements of the IECC or both?
If the interior finish is removed from an exterior wall and the cavity is exposed, does the code require the wall to be insulated as required for new construction?
If the studs are removed and rebuilt for an exterior wall, does the code require the wall to be insulated as required for new construction or can the stud spaces be filled with insulation and be deemed to comply per Exception 2 of Section R503.1.1?
When Exception 5 of R503.1.1 of the 2018 IECC states “Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing shall be insulated either above or below the sheathing”, does the word ‘and’ mean that if there is any insulation in the cavity, the rest of the requirements do not apply?

Building Envelope Insulation Requirements
For a low slope roof replacement, what should be done if there is not enough room to provide the full R-30 insulation and install flashings properly?
AN AOAO is reroofing a concrete roof. Do they need to insulate?

Energy Impacts

Building envelope insulation directly impacts building energy use by reducing the heating and cooling loads of the building. The DOE Residential field studies across eight states.[I] Found nearly 60 percent of the homes studied did not meet insulation prescriptive requirements, representing an average statewide annual savings potential of 67,869 MMBtu ($1,205,180). Data is not available to determine what percentage of the units may have used the performance or ERI compliance path and traded the insulation levels against other efficiencies. Additionally, the reduction in loads can reduce the required sizes of the heating and cooling equipment, thereby providing secondary cost savings.

Relationship to the IECC

Insulation requirements for the building thermal envelope, including ceilings, roofs, walls, floors, and foundations, are prescriptive. Such requirements may be traded off depending on the compliance path selected for the project (2018 IECC Sections R402.1; R402.2). Noncompliance with building envelope insulation requirements has a significant impact on the energy use of prescriptive projects when allowed trade-offs (e.g., Total UA Alternative) are not used. The energy impact of reduced insulation is mitigated in projects complying with either the Performance or ERI paths by increasing the efficiency of other building components.

Literature Review

Many resources dedicated to insulation in general are available, and information related to most of the inquiries into new construction insulation can be found online from a reliable source. Table 8 includes a subset of the available resources. Additional information is available through the following resources, all of which offer comprehensive guidance on insulating the building envelope:

- International Code Council. Offers a wide-ranging TechNotes Series that provides builders with the latest code requirements and best practices.
- Energy Saver. Provides thorough and helpful resources for consumers, including insulation information. Energy Saver is managed by the U.S. DOE's Office of Energy Efficiency and Renewable Energy (EERE).
- Building America Solution Center. Offers over 250 resource guides on a variety of building components. Insulation of the building thermal envelope is extensively covered in these guides. The guides are available at https://basc.pnnl.gov/resource-guides and are not individually referenced below in Table 8. Code compliance briefs on relevant topics are included.
- Building Energy Codes Program (BECP). Provides resources and information on energy code related topics through its Resource Center.
- Building Science Corporation. Offers extensive research and resources on building science topics. The library of resources, including guides and manuals, can be sorted by topic. All resources are available at www.buildingscience.com.
- Green Building Advisor. Offers informative blog posts, videos, and drawing details for many insulation inquiries and other building thermal envelope concepts. (Note: While some resources on Green Building Advisor are free, others require users to sign up for an account. A 10-day free trial is available after which the cost is approximately $150 per year. Resources that require payment were not included in this literature review as they otherwise are not available to the general public.)

- 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 *how* to install insulation in existing buildings but do not always address when it is necessary to do to.

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.

Table 8. Select Building Envelope Insulation Resources

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/how-to-insulate-and-air-seal-pull-down-attic-stairs
How to Insulate and Air Seal an Attic Hatch	Guide to using multiple layers of rigid foam insulation, high quality weather-stripping, and several secure latches for attic hatches. (2012)	Green Building Advisor	https://www.greenbuildingadvisor.com/article/how-to-insulate-and-air-seal-an-attic-hatch
Installation of Common Insulation Types: Wood-Frame Walls and Attics	Addresses insulation types and installation. (2017)	National Association of Home Builders	https://www.iccsafe.org/wp-content/uploads/TN08-installation-of-common-insulation-types-20170607.pdf
Wall Insulation Resources			
Air Sealing and Insulating Common Walls (Party Walls) in Multi-Family Buildings - Code Compliance Brief	Provides code-specific information about air sealing and insulating common walls in multi-family buildings.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/air-sealing-and-insulating-common-walls-party-walls-multi-family-buildings-code
Air Sealing and Insulating Attic Knee Walls - Code Compliance Brief	Provides code-related information about attic knee walls.	Building America Solution Center	https://basc.pnnl.gov/code-compliance/air-sealing-and-insulating-attic-knee-walls-code-compliance-brief

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

Title	Description	Author	Source Location
Below Deck Spray Foam Insulation for Existing Roofs	Provides guidance for insulating an attic in an existing home by installing spray foam (open cell or closed cell) on the underside of the roof deck.	Building America Solution Center	https://basc.pnnl.gov/resource-guides/below-deck-spray-foam-insulation-existing-roofs
Blown Insulation for Existing Vented Attic	Provides guidance for insulating a vented attic in an existing home by installing blown insulation on the ceiling deck of the attic.	Building America Solution Center	https://basc.pnnl.gov/resource-guides/blown-insulation-existing-vented-attic
Batt Insulation for Existing Vented Attics	Provides guidance for insulating a vented attic in an existing home by installing batt insulation on the ceiling plane of the attic.	Building America Solution Center	https://basc.pnnl.gov/resource-guides/batt-insulation-existing-vented-attics
Batt Insulation for Existing Exterior Walls	Provides guidance for installing batts in the walls of an existing home.	Building America Solution Center	https://basc.pnnl.gov/resource-guides/batt-insulation-existing-exterior-walls
Blown Insulation for Cavities of Existing Exterior Walls	Provides guidance for upgrading existing exterior walls that are uninsulated or poorly insulated by adding blown-in insulation in the wall cavities.	Building America Solution Center	https://basc.pnnl.gov/resource-guides/blown-insulation-cavities-existing-exterior-walls

Mechanical Ventilation Requirements

Many building designs rely on natural ventilation, meaning an opening and closing windows, to provide interior temperature control. Mechanical ventilation systems are covered by requirements in the 2018 IECC. The designs are either exhaust-only, supply-only or balanced air-exchange systems. System details regarding sources of supply air, locations of exhaust air and ventilation rates are provided in *International Residential Code*® Section M1505.4 and IMC Section 403. The IMC states, “the amount of supply air shall be approximately equal to the amount of return and exhaust air,” and that “the system shall not be prohibited from producing negative or positive pressure.” The IECC does not include requirements for system design, although it does include provisions for whole house mechanical system fan efficacy and overall equipment sizing and efficiency rating. As buildings have become tighter, mechanical ventilation has become more critical in ensuring healthy indoor air quality. Table 9 lists the questions related to mechanical ventilation and the equipment available to meet ventilation provisions.

Table 9. Mechanical Ventilation Inquiries

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?
Does compliance with ASHRAE 62.2 meet the requirement for whole house ventilation?
Where insulation is required between rafters, is the ventilation still required if that space is completely filled with insulation? For example, where the ceiling is attached directly to the bottom chord of I-Joists with roof sheathing attached to the top chord. It a 1" space for ventilation necessary in that space, or can I fill it with insulation and have no ventilation?
System / Equipment
Is a balanced system like an HRV (heat recovery ventilator) or ERV (energy recovery ventilator) required to meet the mechanical ventilation requirement?
Do I need to install an ERV/HRV for mechanical ventilation?
Does the makeup air intake with a counter-weighted “skuttle” damper count as mechanical ventilation?
Is the whole house ventilation requirement satisfied when an outside air damper is interlocked with an air handler by a controller which opens the damper when the thermostat calls for heating or cooling?
Do the residential provisions of the IECC require energy recovery or heat recovery for the outdoor air for a 2 story R-2 building when it is ducted to a return plenum at the dwelling unit’s air handling units and it is used in conjunction with a continuous exhaust fan in a bathrooms to meet the ventilation requirements for the dwelling units?
Where does make-up air come from when a home uses an exhaust-only ventilation strategy?
Do ventilating dehumidifiers have to meet any of the set requirements in R403.6.1?
Is a ventilation fan that is not part of a whole house ventilation system required to meet the efficiency requirements of Table R403.6.1?
Natural Ventilation
Does having an operable window in the kitchen allow me an exemption from venting the range hood to the outdoors?
Does having an operable window in the bathroom allow me an exemption from venting the bathroom?

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 *Ventilate Right: Ventilation Guide for New and Existing California Homes*. This comprehensive guide presents ventilation essentials beyond those required in California. It provides a thorough look at the health benefits of mechanical ventilation, options for ventilation systems and control strategies, and pros and cons of ventilation systems, among other topics. While most of the guide is up to date, references to ASHRAE 62.2 are outdated. Table 10 includes the Ventilate Right guide and other resources available on mechanical ventilation, prioritized by relevancy and published date.

Table 10. Select Mechanical Ventilation Resources

Title	Description	Author	Source Location
Ventilation and Health	Provides sources for indoor pollutants and associated health problems.	U.S. DOE's Residential Building Systems group, LBNL	https://homes.lbl.gov/ventilate-right/ventilation-and-health
Whole-Building Ventilation Examples	Illustrated examples of different whole-building ventilation strategies.	U.S. DOE's Residential Building Systems group, LBNL	https://homes.lbl.gov/ventilate-right/whole-building-ventilation-examples
Occupant Education	Brochures and labels for homeowners.	U.S. DOE's Residential Building Systems group, LBNL	https://homes.lbl.gov/ventilate-right/occupant-education
Whole-Building Ventilation Rate	Calculations and resources for determining the appropriate ventilation rate for a home.	U.S. DOE's Residential Building Systems group, LBNL	https://homes.lbl.gov/ventilate-right/step-3-whole-building-ventilation-rate
Whole-Building Ventilation Type	Inclusive look at ventilation system types.	U.S. DOE's Residential Building Systems group, LBNL	https://homes.lbl.gov/ventilate-right/step-4-whole-building-ventilation-type
System Pros and Cons	Thorough list of pros and cons for each ventilation system type.	U.S. DOE's Residential Building Systems group, LBNL	https://homes.lbl.gov/ventilate-right/system-pros-and-cons
Control Strategies	Describes ventilation control strategies with best practice recommendations.	U.S. DOE's Residential Building Systems group, LBNL	https://homes.lbl.gov/ventilate-right/step-5-control-strategies
Commissioning Ventilation Systems	Best practices and step by step guide to commissioning, including links to resources for combustion testing.	U.S. DOE's Residential Building Systems group, LBNL	https://homes.lbl.gov/ventilate-right/step-8-commissioning
Indoor Air Quality	Comprehensive resource for IAQ in homes and buildings. Provides resources, FAQs, education on IAQ.	EPA	https://www.epa.gov/indoor-air-quality-iaq
Whole-House Ventilation	Compares whole-house ventilation systems.	Energy Saver, U.S. DOE's EERE	https://www.energy.gov/energysaver/weatherize/ventilation/whole-house-ventilation
Ventilation	Describes ventilation strategies.	Energy Saver, U.S. DOE's EERE	https://www.energy.gov/energysaver/weatherize/ventilation
Whole-House Mechanical Ventilation Code: Safety and Performance Considerations	Describes whole-house mechanical ventilation, benefits of ventilation, and performance and cost considerations. (2013)	ICC, National Association of Home Builders	https://cdn-web.iccsafe.org/wp-content/uploads/proclamations/TN01-Whole-House-Ventilation_pdf.pdf
Top 10 Issues in Residential Ventilation Design	Explores issues with ventilation design. (2013)	Building Science Corporation	https://www.buildingscience.com/documents/insights/bsi-016-ventilation-top-ten-list?searchterm=Ventilation
Homeowner's Guide to Ventilation	Illustrated guide for homeowners. (2015)	NYSERDA	http://bcapcodes.org/wp-content/uploads/2015/12/homeowners-vent-guide.pdf

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-field-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).