SEDAC

SMART ENERGY DESIGN ASSISTANCE CENTER

Providing effective energy strategies for buildings and communities

Air Sealing, Infiltration & Ventilation

04.25.2018

12PM CDT

Who we are

Our goal: Reduce the energy footprint of Illinois.

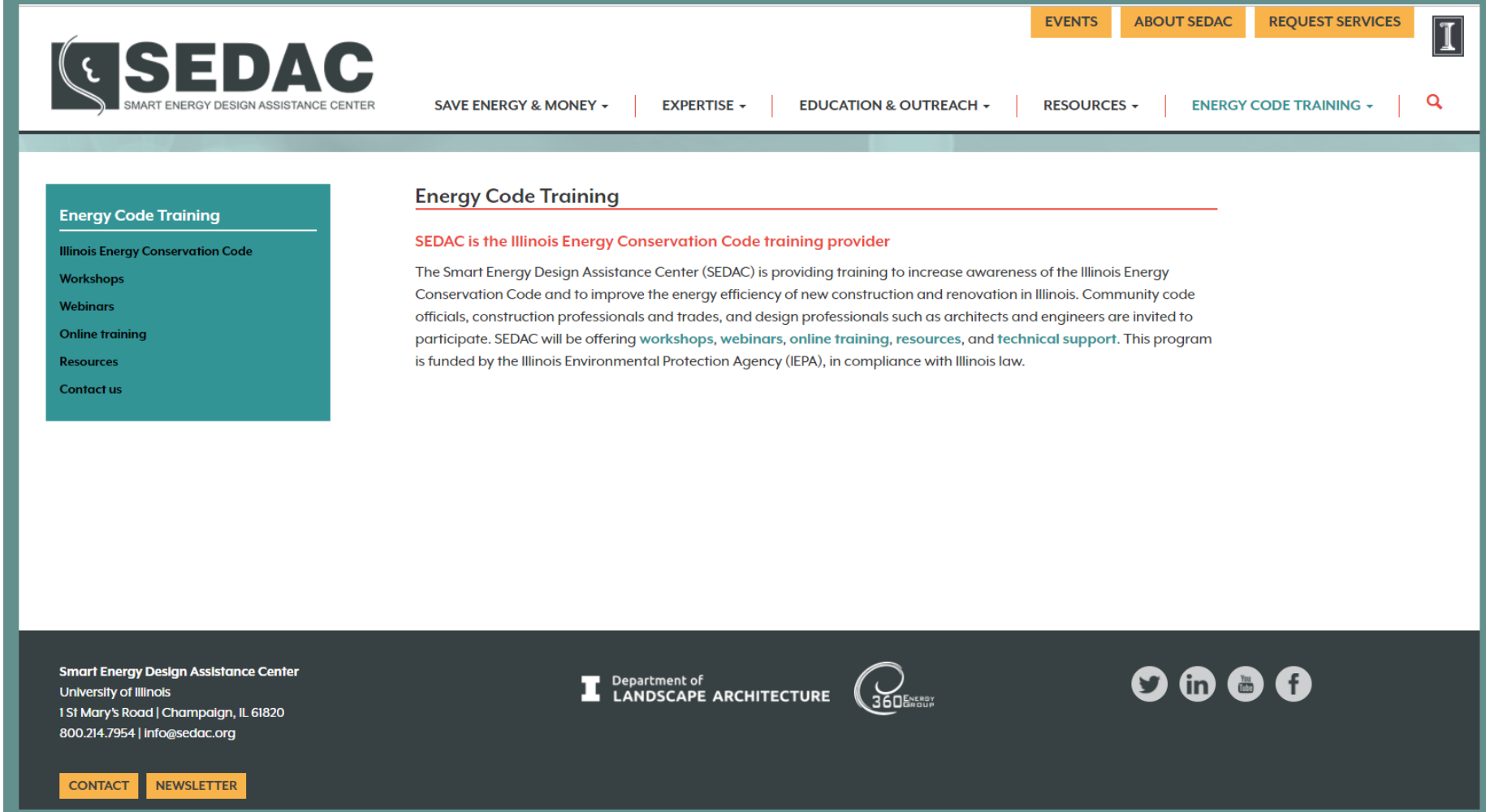
SEDAC is the Illinois Energy Conservation Code Training Provider

This training program is sponsored by Illinois EPA

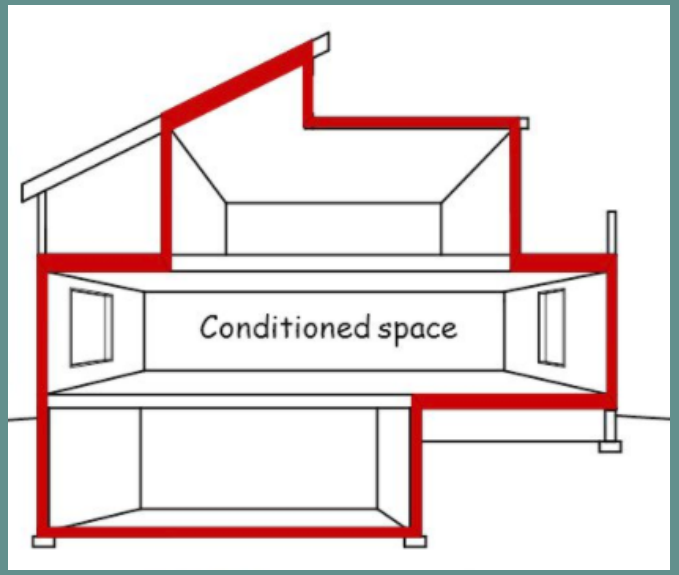
Energy Code Assistance

- Technical support
  - 800.214.7954
  - energycode@sedac.org
- Online resources at sedac.org/energy-code
- Workshops
- Webinars
- Online on-demand training modules

www.sedac.org/energy-code



Air Sealing & Infiltration: Building Science 101



Definitions

- **Air Sealing:** Restricting the passage of air through the building envelope by providing air barrier.

- **Air Barrier**: Materials assembled and joined together to provide a barrier to air leakage through the building envelope

- **Infiltration**: Uncontrolled inward air leakage into a building caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density or both

Why do we worry about air sealing?

- Energy conservation
- Temperature control
- Moisture control
- Air quality control
- Envelope durability
- Comfort
- Health

Photo Courtesy of National Grid

Is air sealing a big deal? …….. Yes!

Primary Energy Consumption attributed to building envelope components in 2010 (in quads)

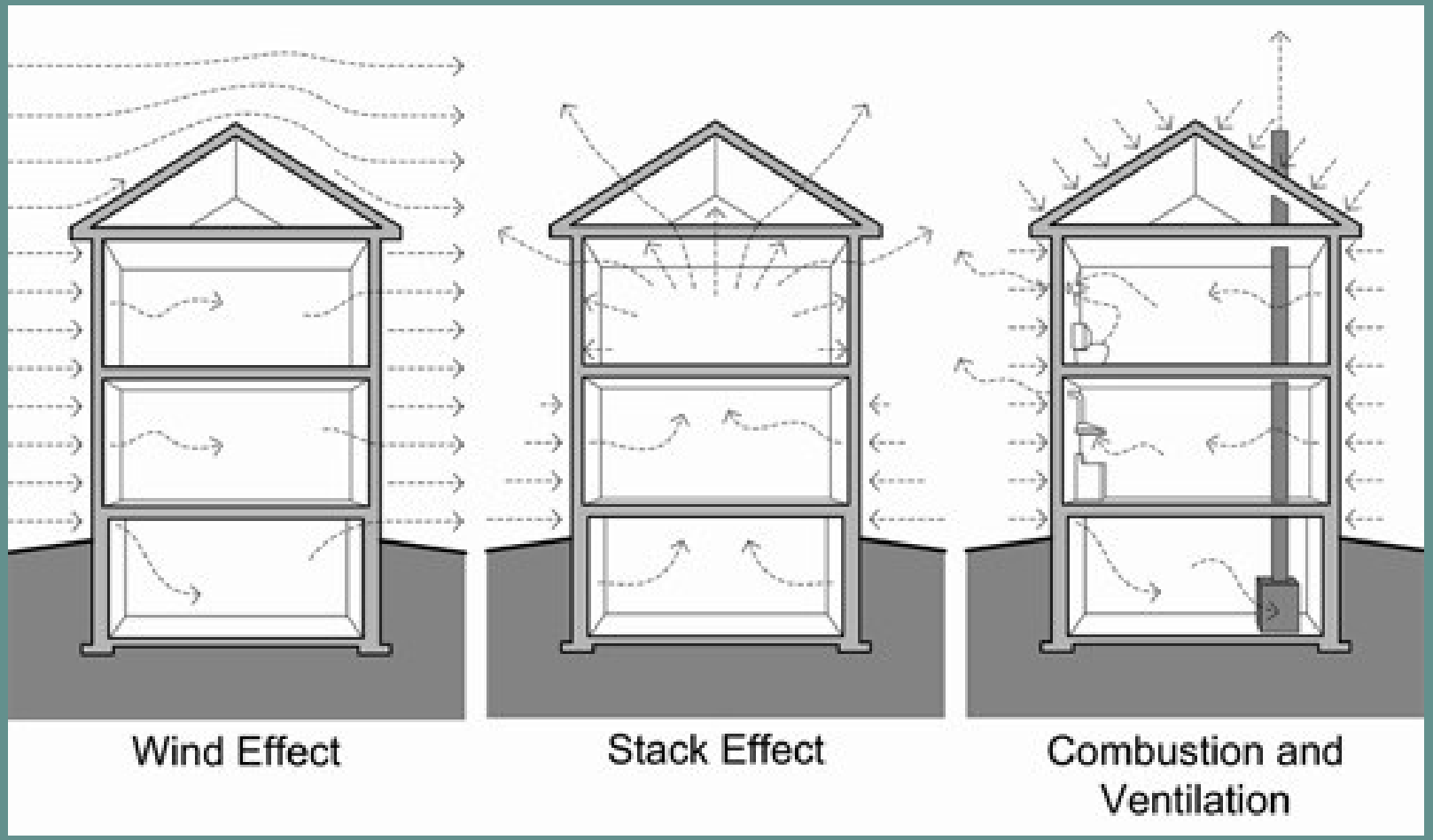
Building Component	Residential		Commercial	
	Heating	Cooling	Heating	Cooling
Roofs	1.00	0.49	0.88	0.05
Walls	1.54	0.34	1.48	-0.03
Foundation	1.17	-0.22	0.79	-0.21
Infiltration	2.26	0.59	1.29	-0.15
Windows (Conduction)	2.06	0.03	1.60	-0.30
Windows (Solar Heat Gain)	-0.66	1.14	-0.97	1.38

Source: Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies, DOE BTO, 2014
https://www.energy.gov/sites/prod/files/2014/02/f8/BTO_windows_and_envelope_report_3.pdf

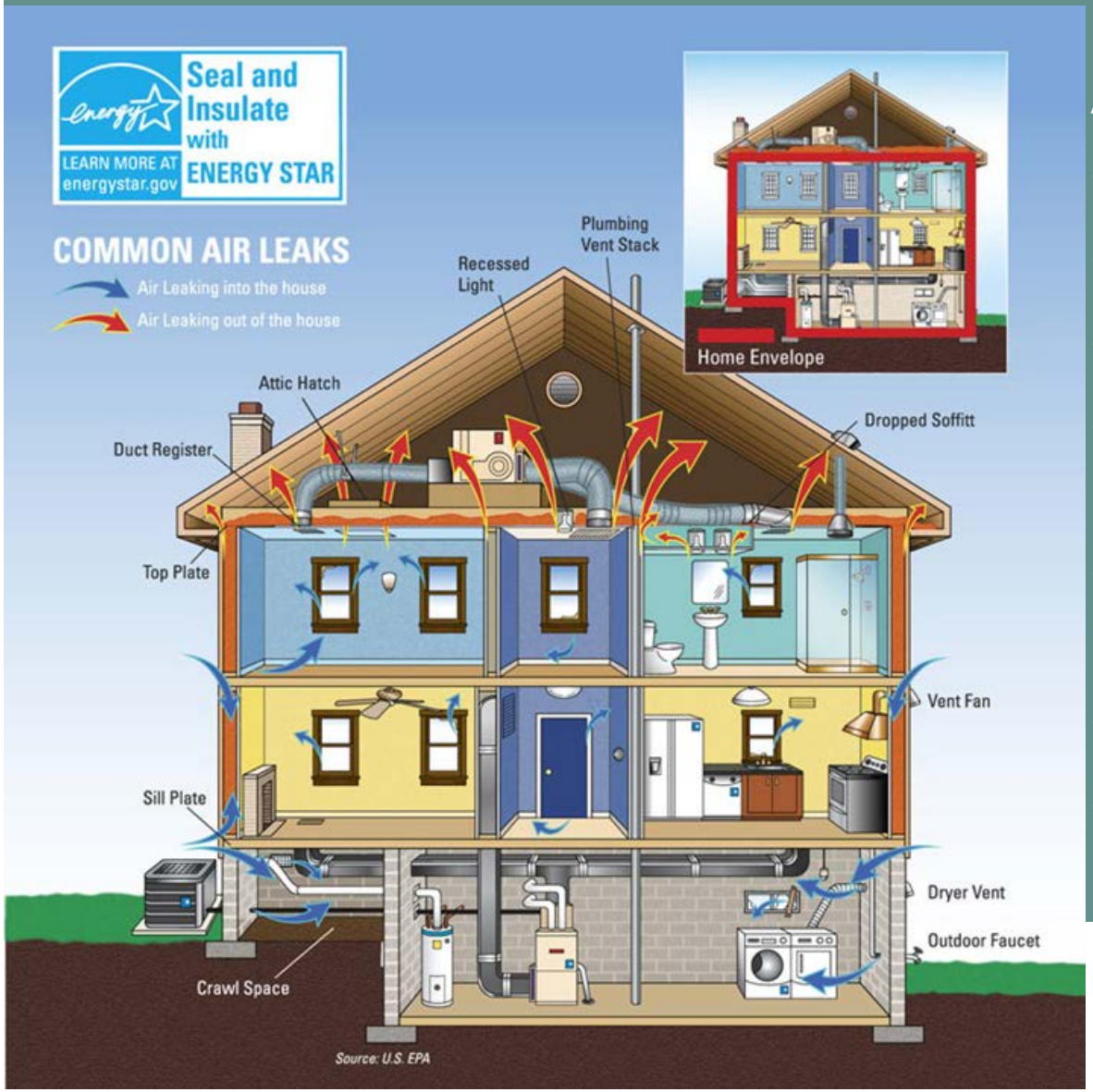
Adoption of Air Leakage Requirements

- Importance of an air barrier and its mandatory use was first included in ASHRAE 90.1 in 2010
- IECC first introduced concept of continuous air barrier in 2012
- Prior to 2012, IECC addressed sealing of building envelope, but did not specify a continuous air barrier

What causes air infiltration/exfiltration?



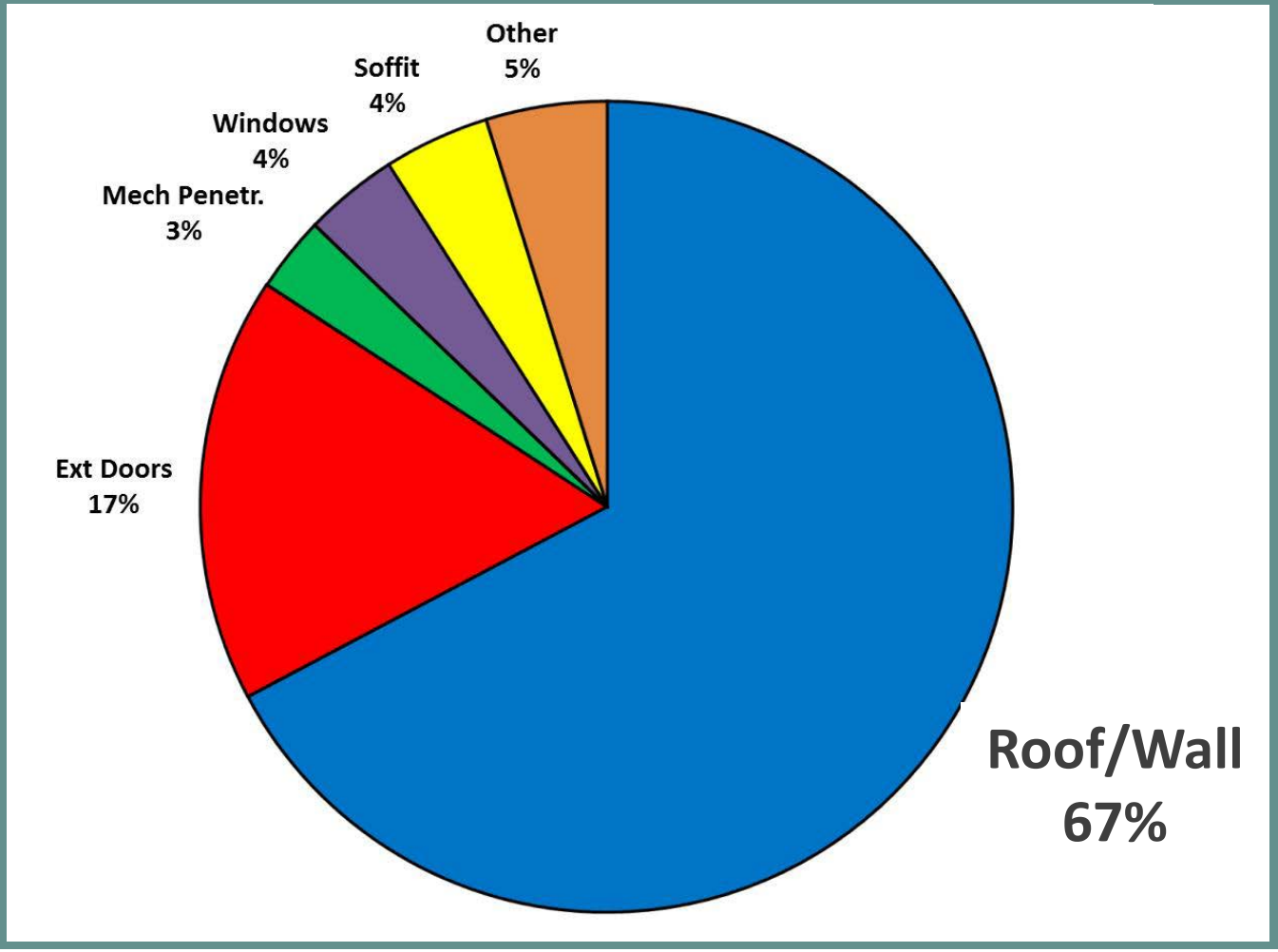
Typical air leakage locations



Additional leakage points:

- Around doors
- Bath fans
- Range hood exhaust
- Refrigerant line penetrations
- Combustion air intake & exhaust
- Water spigots
- Recessed lights

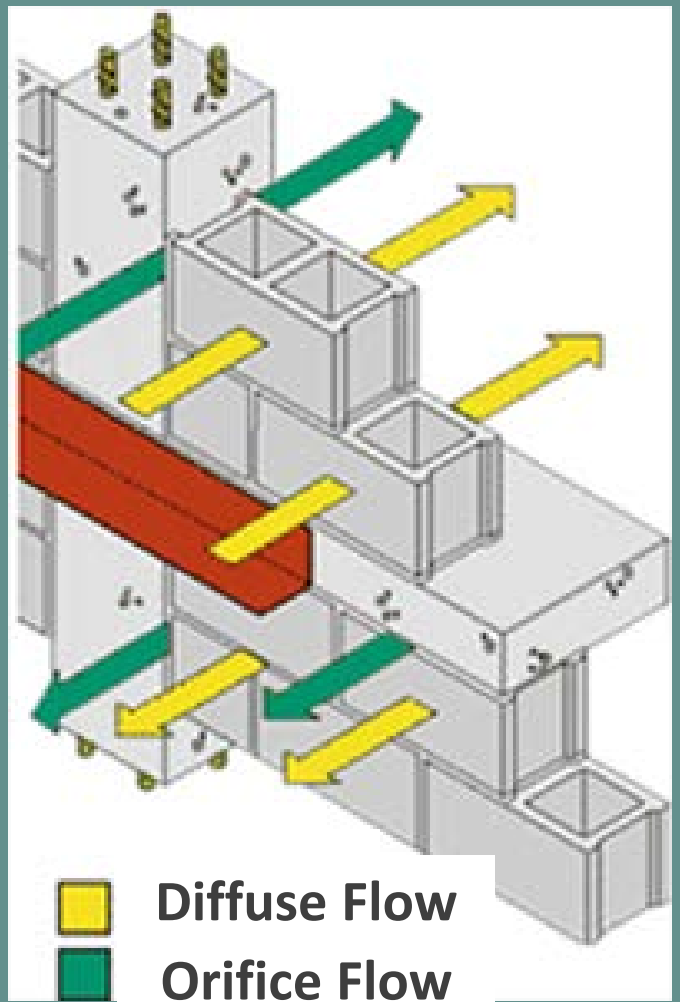
Where are the air leaks?

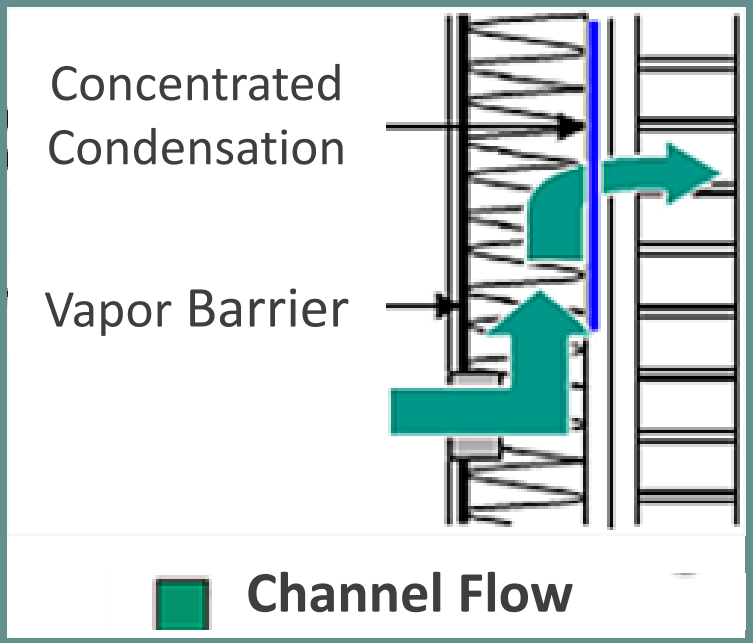


Based on average over 25 buildings in Minnesota

https://web.ornl.gov/sci/buildings/2016/docs/presentations/practices/practices-04/Practices04_Paper129_Bohac.pdf

Different types of air leakage pathways





Air Barrier System

Requirements:

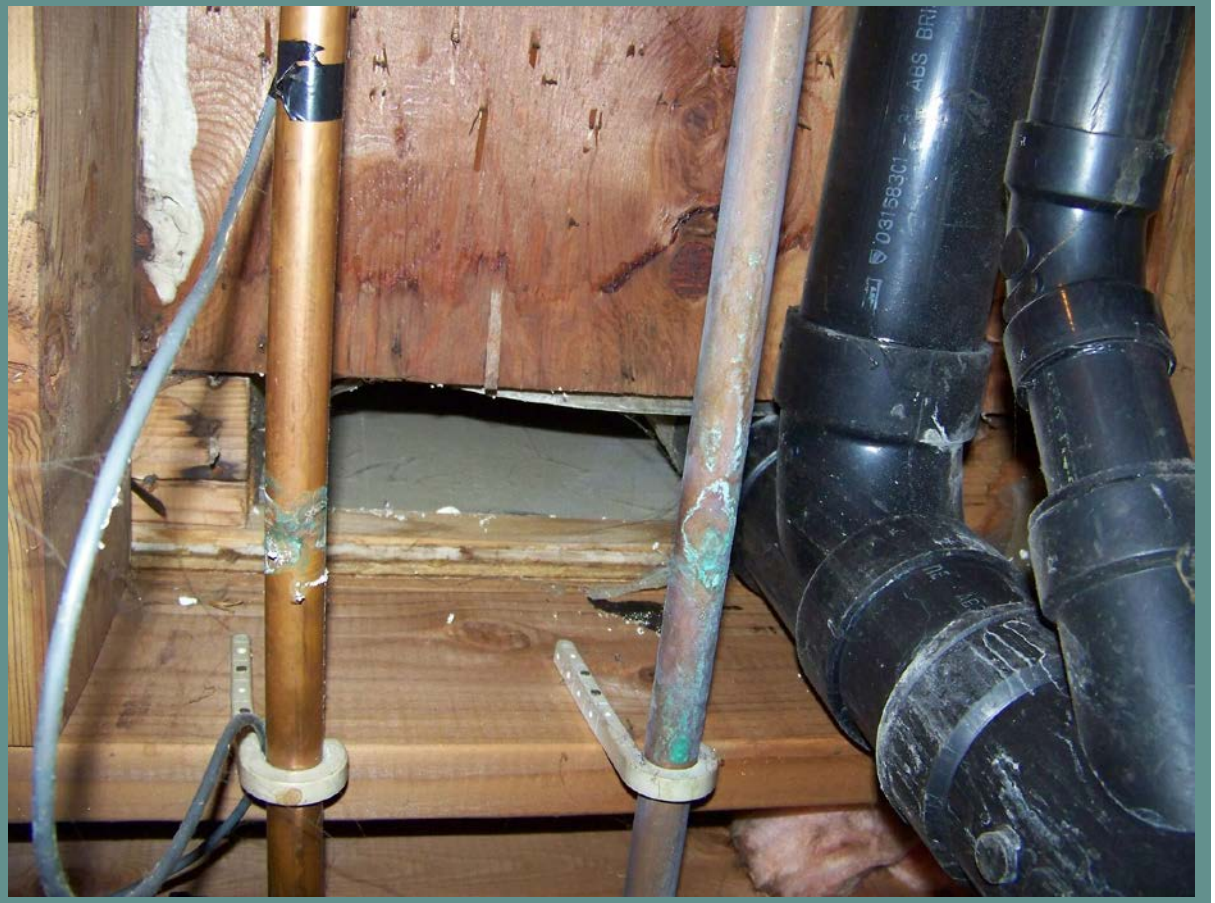
- Continuity
- Strength
- Durability
- Stiffness
- Impermeability

Multi-Function:

- Vapor barrier
- Water resistant barrier
- Improve insulation effectiveness

Major air pathways can cause problems

- Plumbing and electrical chases can provide paths for air to travel
- Air in this crawlspace is probably migrating into attic
- Moisture from crawlspace can end up causing mold problems in the attic
- Pipe penetration through top plates must be sealed



Consequence of air leaks through thermal envelope

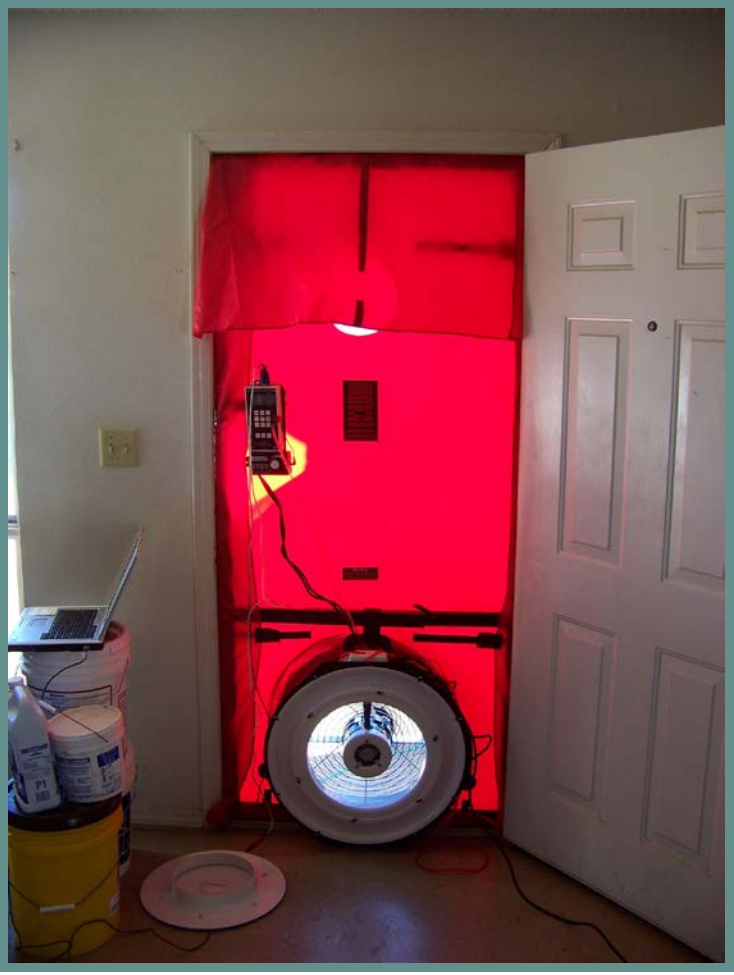
Note formation of mold where moist air leaked around the perimeter of the attic hatch and condensed on cold surfaces above

The same will happen inside wall and ceiling cavities where moisture laden air can condense

Existing construction

Blower door testing

- Not required for commercial construction
- Mandatory for residential construction
- Residential air leakage rate not to exceed 5 air changes per hour @ 50 pascals
- Testing performed after creation of all penetrations of the building thermal envelope



The power of blower door testing

Blower door testing can identify leakage points that you never would have imagined to be an air leakage point

This hole through the door jamb at the strike plate leaked air profusely

Air source was either the crawlspace or attic

Consequence of improperly used insulation

This rim joist was insulated with fiberglass insulation. Moisture migrated through the insulation and condensed on the rim joist

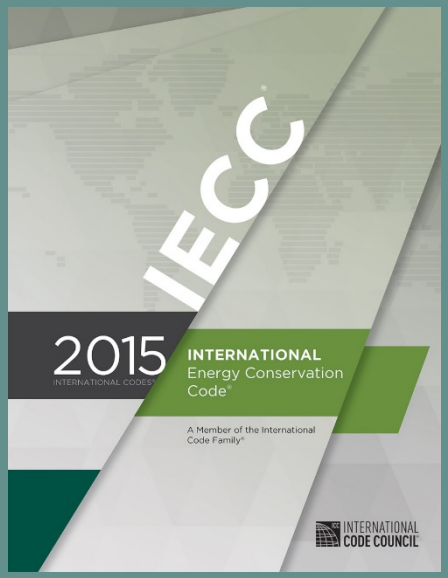
Mold was beginning to form on the rim joist

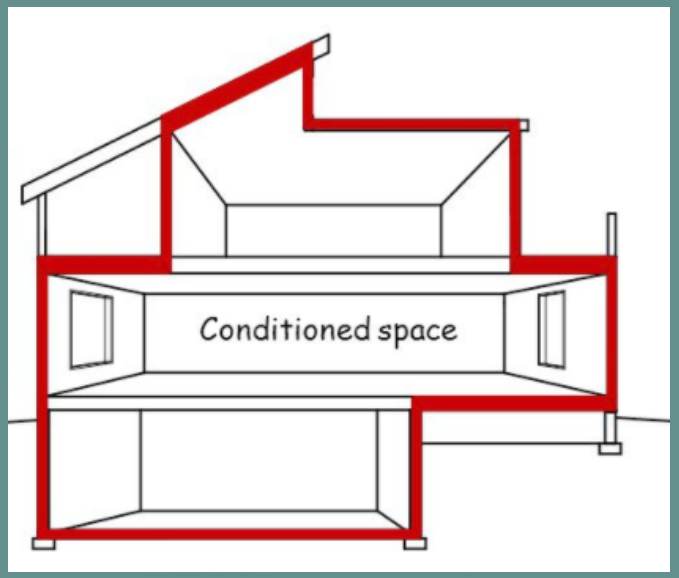
This was in a brand new house that hadn’t even been occupied yet

Better rim joist insulation

Insulated with vapor resistive insulation to keep moisture away from cold rim joist

Air Sealing & Infiltration: Illinois Energy Conservation Code





Air Leakage Requirements (Mandatory)

Commercial (C402.5):

The thermal envelope of buildings shall comply with Sections C402.5.1 through C402.5.8 or the building thermal envelope shall be tested in accordance with ASTM E 779 at a pressure of 0.3 inch water gauge (75pa) … Air leakage rate of the building thermal envelope is not greater than 0.40 cfm/ft^2

Residential (R402.4.1.2)

The building shall be tested and verified as having an air leakage rate of not exceeding **5 ACH**. The building shall be provided with a whole-house mechanical ventilation system as designed in accordance with Section R403.6. Testing shall be conducted in accordance with ASTM E 779 or ASTM R 1827 and reported at a pressure of 0.2 inches w.g. (50pa)

(text as found in Illinois Amendments)

Air Barrier Materials (C402.5.1.2.1)

1. Plywood not less than 3/8”
2. OSB not less than 3/8”
3. Extruded polystyrene insulation board not less than ½”
4. Foil-backed polyiso insulation board not less than ½”
5. Closed-cell spray foam with a minimum density of 1.5 pcf not less than 1.5” thickness
6. Open-cell spray foam with a density of between 0.4 and 1.5 pcf not less than 4.5” thickness
7. Gypsum board not less than ½”
8. Cement board not less than ½”
9. Built-up roofing membrane
10. Modified bituminous membrane
11. Fully adhered single-ply membrane
12. A cement/sand parge or gypsum plaster not less than 5/8”
13. Cast-in-place and precast concrete
14. Fully grouted concrete block masonry
15. Sheet steel or aluminum
16. Solid or hollow masonry constructed of clay or shale masonry units

Air Barrier Materials (Other Types)

- Fluid applied
- Membranes
- Tapes

Photo Courtesy of Matt Risinger

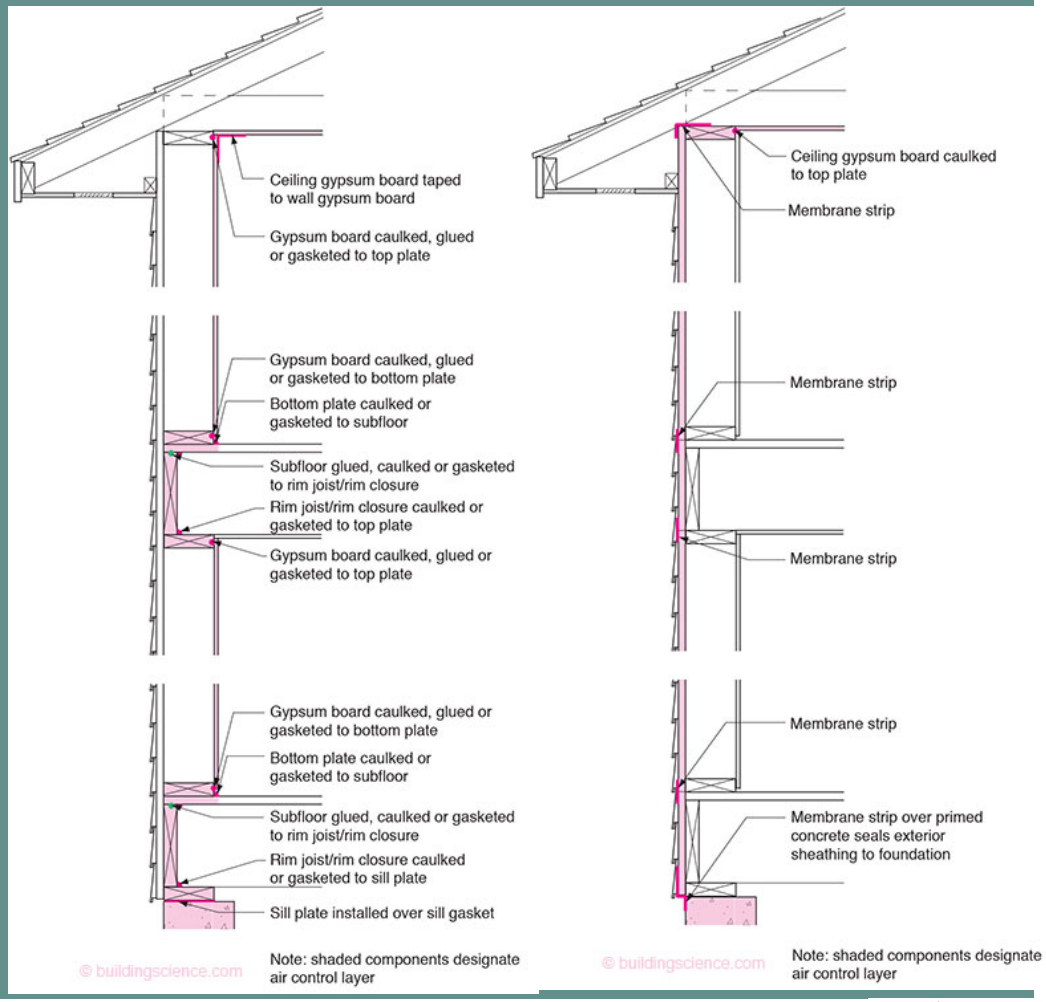
Air Barrier Materials (Other Types)

Photo Courtesy of Polyguard Architecutal

Photo Courtesy of Green Building Advisor

Continuous Air Barriers (C402.5.1)

- A continuous air barrier shall be provided throughout the building thermal envelope.
- The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof



Air Barrier Construction (C402.5.1.1)

- Must be continuous
- Joints and seams must be sealed including across changes in materials
- Must be able to withstand positive and negative pressure
- Integrity of air barrier must be restored at penetrations

Table R402.4.1.1 AIR BARRIER AND INSULATION INSTALLATION

COMPONENT	AIR BARRIER CRITERIA	INSULATION INSTALLATION CRITERIA
A. General requirements	A continuous air barrier shall be installed in the building envelope. The exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed.	Air-permeable insulation shall not be used as a sealing material.
B. Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier shall be sealed. Access openings, drop down stairs, or knee wall doors to unconditioned attic spaces shall be sealed.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.
C. Walls	The junction of the foundation and sill plate shall be sealed. The junction of the top plate and the top of exterior walls shall be sealed. Knee walls shall be sealed.	Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with a material having a thermal resistance of R-3 per inch minimum. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.
D. Windows, skylights, and doors	The space between window/door jambs and framing, and skylights and framing shall be sealed.	
E. Rim Joists	Rim joists shall include the air barrier.	Rim joists shall be insulated.
F. Floors	The air barrier shall be installed at any exposed edge of insulation.	Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking, or floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing, or continuous insulation installed on the underside of floor framing and extends from the bottom to the top of all perimeter floor framing members.
G. Crawl space walls	Exposed earth in unvented crawlspaces shall be covered with a Class I vapor retarder with overlapping joints taped.	Where provided instead of floor insulation, insulation shall be permanently attached to the crawlspace walls.
H. Shafts, penetration	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.	
I. Narrow Cavities		Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
J. Garage Separation	Air sealing shall be provided between the garage and conditioned spaces	
K. Recessed Lighting	Recessed light fixtures installed in the building envelope shall be sealed to the drywall.	Recessed light fixtures installed in the building thermal envelope shall be air tight and IC rated.
L. Plumbing and wiring		Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
M. Shower/tub on exterior wall	The air barrier installed at exterior walls adjacent to showers and tubs shall separate them from the showers and tubs.	Exterior walls adjacent to showers and tubs shall be insulated.
N. Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air-sealed boxes shall be installed.	
O. HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the subfloor or drywall.	
P. Concealed sprinklers	When required to be sealed, concealed fire sprinklers shall only be sealed in a manner that is recommended by the manufacturer. Calking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.	

A. General Requirements (R402.4.1.1)

Air Barrier

- A continuous air barrier shall be installed in the building envelope. The exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed.

Insulation

- Air-permeable insulation shall not be used as a sealing material

B. Ceiling/attic (R402.4.1.1)

Air Barrier

- The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier shall be sealed. Access openings, drop down stairs, or knee wall doors to unconditioned attic spaces shall be sealed.

Insulation

- The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.

Insulation installed to correct depth and aligned with air barrier

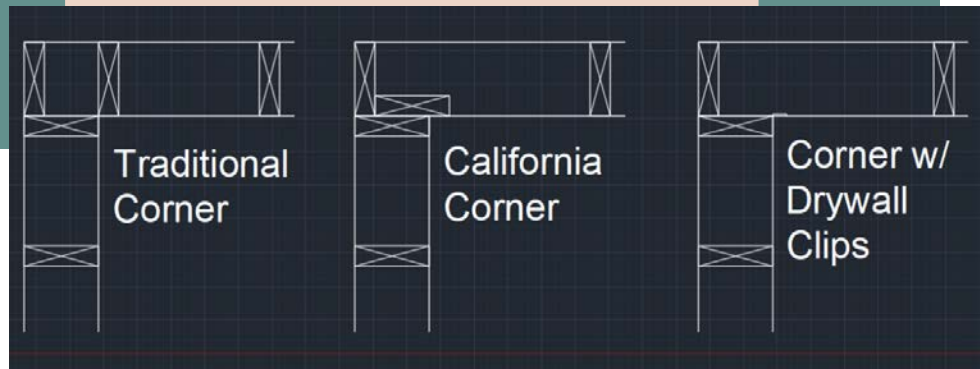
C. Walls (R402.4.1.1)

Air Barrier

- The junction of the foundation and sill plate shall be sealed. The junction of the top plate and the top of exterior walls shall be sealed. Knee walls shall be sealed.

Insulation

- Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with a material having a thermal resistance of R-3 per inch minimum. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.



D. Windows, Skylights & Doors (R402.4.1.1)

Air Barrier

- The space between window/door jambs and framing, and skylights and framing shall be sealed.

Appropriate door framing

E. Rim Joists (R402.4.1.1)

Air Barrier

- Rim joists shall include the air barrier.

Insulation

- Rim joists shall be insulated

F. Floors (R402.4.1.1)

Air Barrier

- The air barrier shall be installed at any exposed edge of insulation

Insulation

- Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking, or floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing, or continuous insulation installed on the underside of floor framing and extends from the bottom to the top of all perimeter floor framing members.

G. Crawl Space Walls (R402.4.1.1)

Air Barrier

- Exposed earth in unvented crawlspaces shall be covered with a Class I vapor retarder with overlapping joints taped.

Insulation

- Where provided instead of floor insulation, insulation shall be permanently attached to the crawl space walls.

There is 6 mil. Polyethylene sheeting installed and sealed in the crawlspace

H. Shafts, Penetration (R402.4.1.1)

Air Barrier

- Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.

Sealed Duct Shaft

I. Narrow Cavities (R402.4.1.1)

Bad Batt insulation

Insulation

- Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation, readily conforms to the available cavity space.

J. Garage Separation (R402.4.1.1)

Air Barrier

- Air sealing shall be provided between the garage and conditioned spaces.

Closed-cell foam insulation in the shared wall to air seal the wall and protect occupants from garage pollutants

K. Recessed Lighting (R402.4.1.1)

Air Barrier

- Recessed light fixtures installed in the building envelope shall be sealed to the drywall.

Recessed light caulked and sealed

Insulation

- Recessed light fixtures installed in the building thermal envelope shall be air tight and IC rated.

Recessed light not caulked and sealed

L. Plumbing & Wiring (R402.4.1.1)

Insulation

- Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.

M. Shower/tub on Exterior Wall (R402.4.1.1)

Air Barrier

- The air barrier installed at exterior walls adjacent to showers and tubs shall separate them from the showers and tubs.

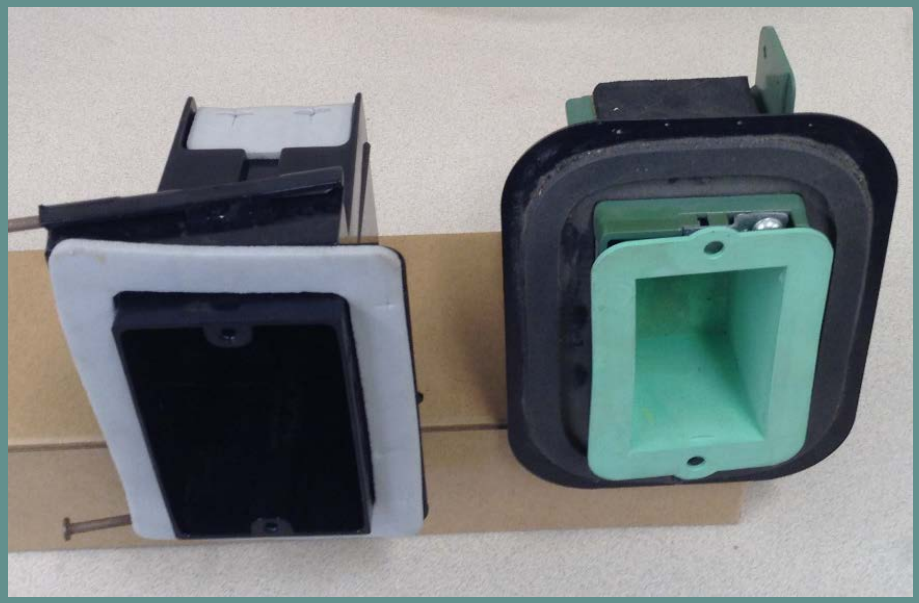
Insulation

- Exterior walls adjacent to showers and tubs shall be insulated.

N. Electrical/Phone Box on Exterior Walls (R402.4.1.1)

Air Barrier

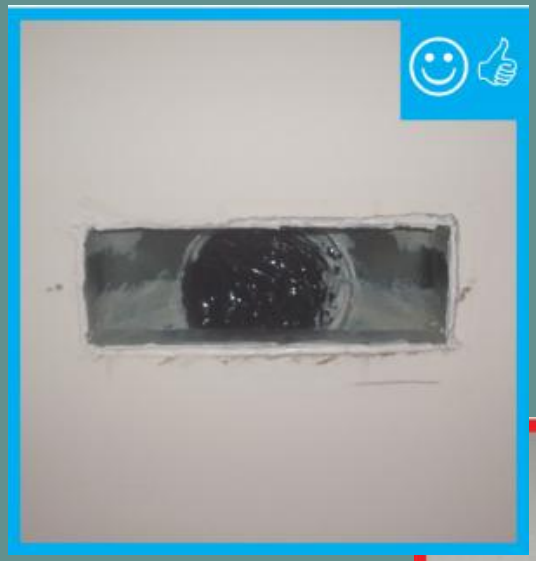
- The air barrier shall be installed behind electrical of communication boxes or air sealed boxes shall be installed.



O. HVAC Register Boots (R402.4.1.1)

Air Barrier

- HVAC register boots that penetrate the building thermal envelope shall be sealed to the subfloor or drywall.



Boot to drywall connection sealed

Boot to drywall connection not sealed

P. Concealed Sprinklers (R402.4.1.1)

Air Barrier

- When required to be sealed, concealed fire sprinklers shall only be sealed in a manner that is recommended by the manufacturer. Calking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.

Ventilation:
Building Science 101

Why Ventilate?

- Provide oxygen to occupants
- Pollutant dilution & removal
  - CO_2
  - Moisture
  - VOCs
  - Odors
  - Other pollutants such as in industrial or agricultural buildings

Adult man has frequency of breathing typically 16 times per minute – 8 l/min.

Oxygen consumption varies between 250 – 350 ml/min

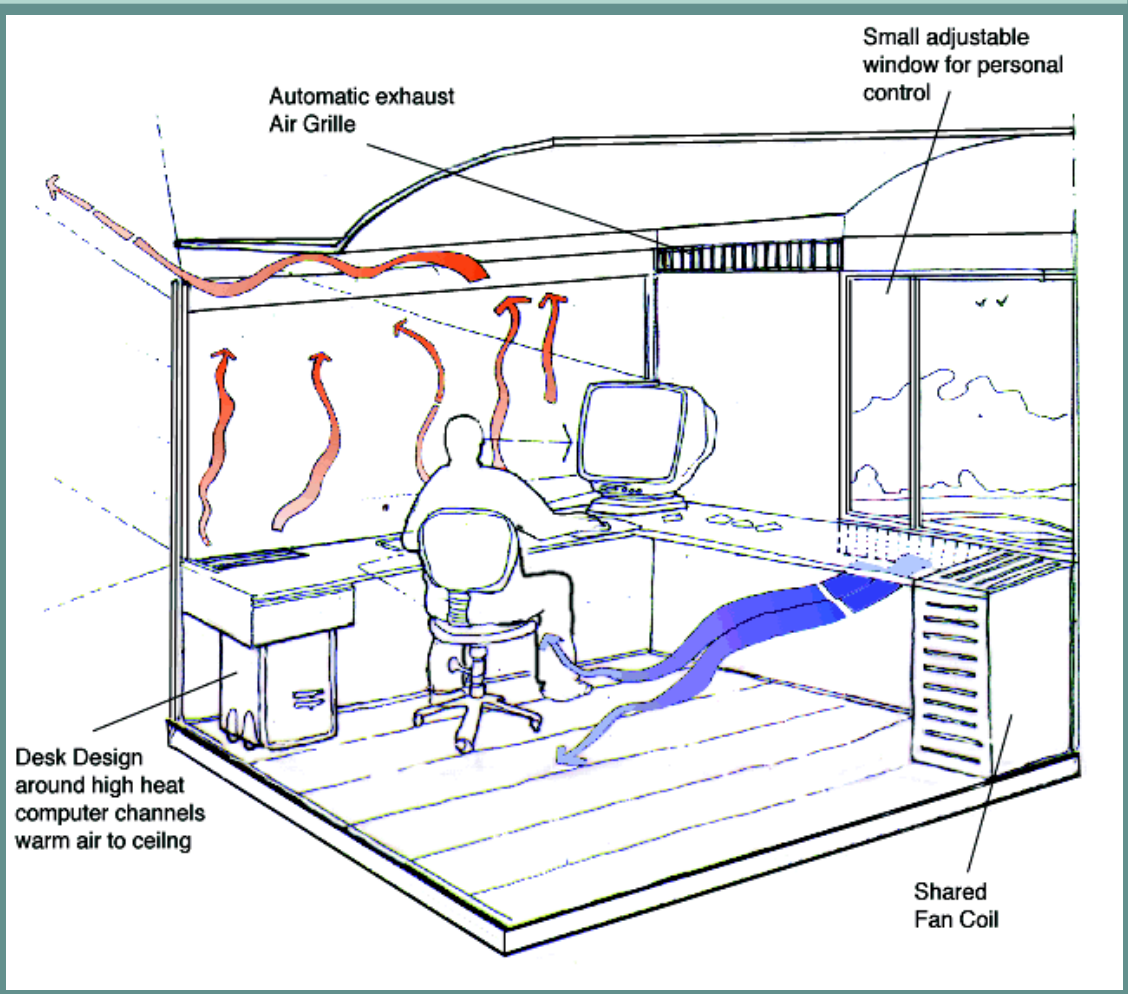
Respiration:

Into lungs (atmospheric air) - 21 % O_2, 78 % N_2, 0.03 % CO_2

Out from lungs - 16 % O_2, 79 % N_2, 4 % CO_2 (plus water vapor)

Types of Ventilation

- Natural
- Mechanical
- Hybrid



Natural Ventilation

Differences in air pressure between the inside of a building relative to the outside Air pressure differences are created by natural forces such as wind and temperature.

Air moves into and out of naturally ventilated buildings through windows, doors, vents and other openings incorporated into the building design and via infiltration/exfiltration.

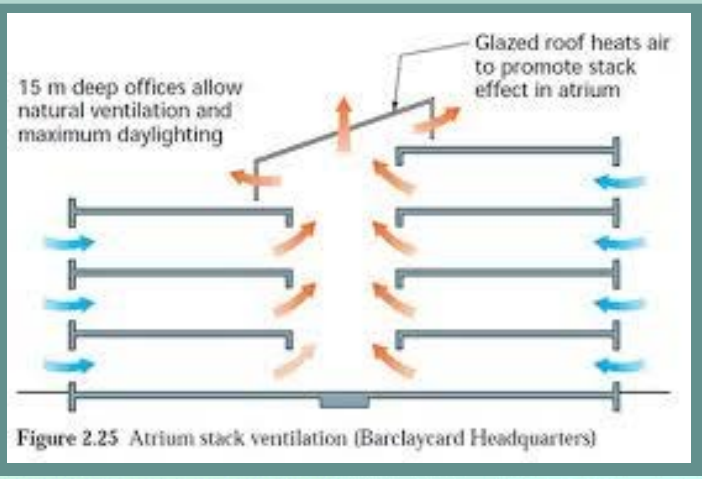
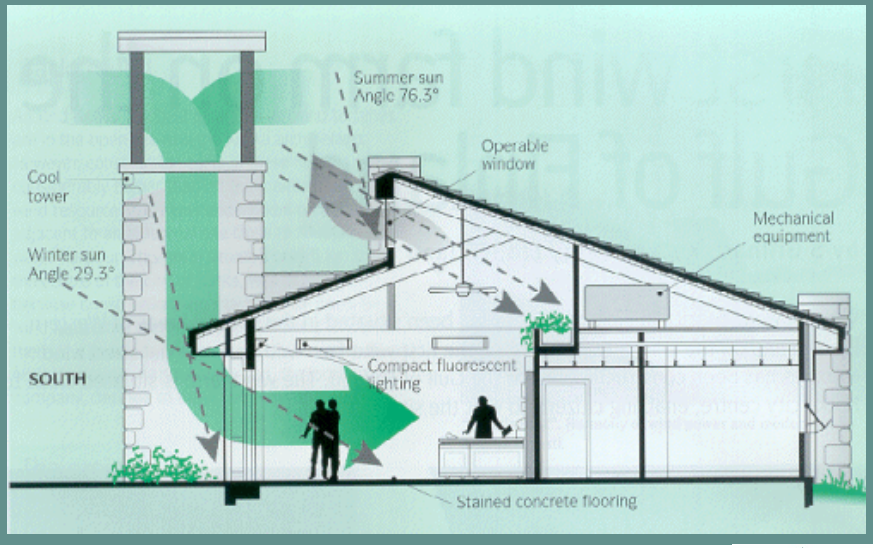
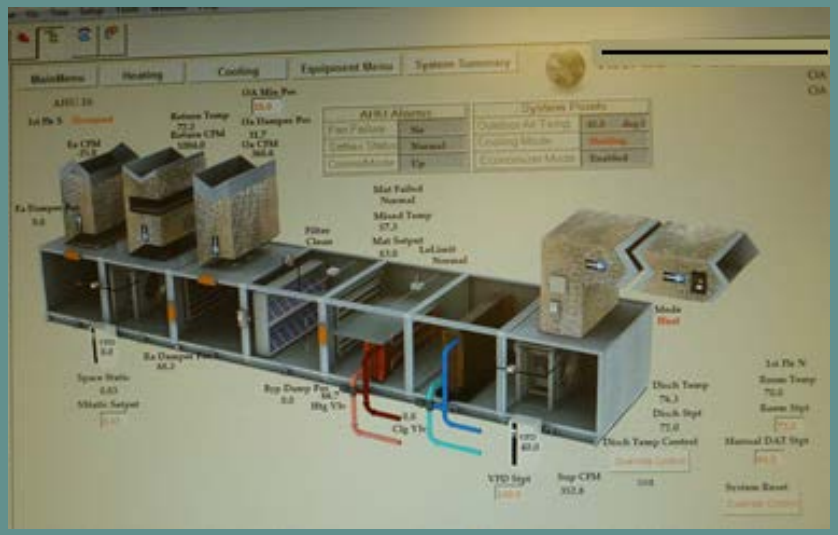


Figure 2.25 Atrium stack ventilation (Barclaycard Headquarters)



Mechanical Ventilating

- Mechanical
  - Rather than relying on natural ventilation, mechanical ventilation systems circulate fresh air using ducts and fans
- Supply ventilation
- Exhaust ventilation
- Balanced ventilation

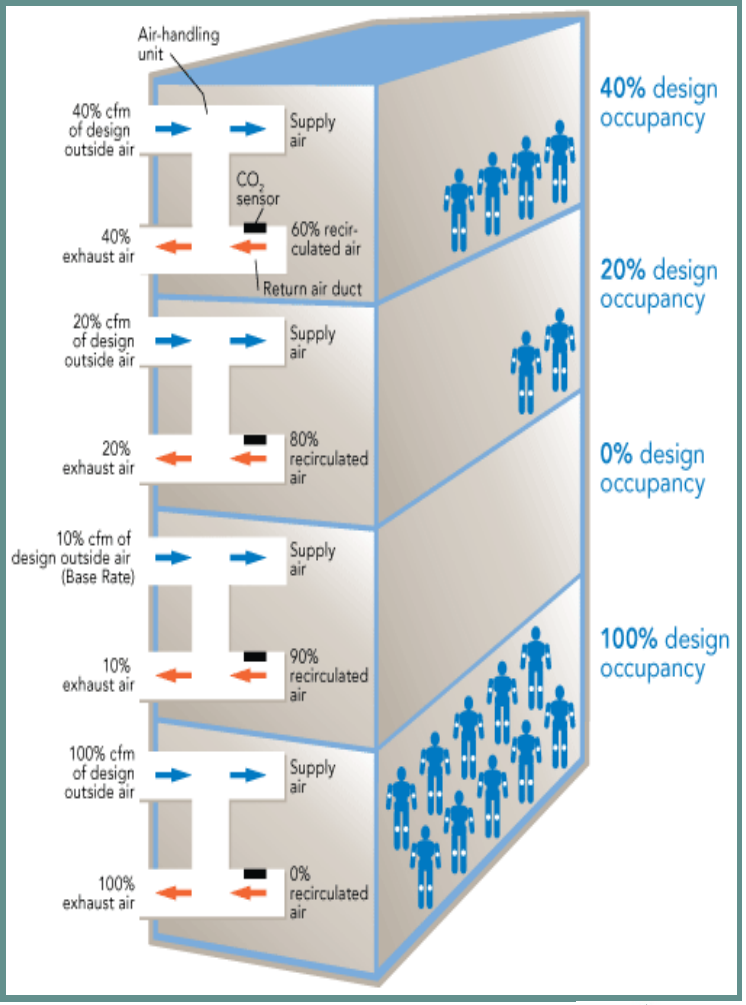


Mechanical ventilation rates

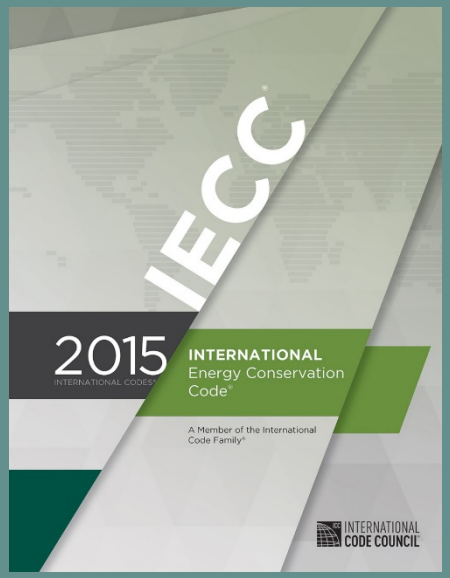
The maximum amount of outside air (OA) that needs to be provided to a space is based on the number of occupants and the square footage of the space.

Ventilation rates vary by building type

Most buildings are not at maximum occupancy much of the time. This means that if we are ventilating at a fixed rate based on maximum occupancy, we may be over-ventilating



Ventilation: Illinois Energy Conservation Code



Commercial Ventilation (C403.2.6)

Ventilation, either natural or mechanical shall be provided in accordance with Chapter 4 of the International Mechanical Code.

- Where mechanical ventilation is provided, the system shall provide the capability to reduce the outdoor air supply to the minimum required by Chapter 4 of the International Mechanical Code.

Demand Controlled Ventilation (C403.2.6.1)

Required for spaces larger than 500 square feet with occupant load of 25 persons per 1,000 square feet or more

- Air-side economizer
- Automatic modulating control of the outdoor air damper
- Design outdoor airflow greater than 3,000
- Exceptions:
  - Systems with energy recovery complying with Section C403.2.7
  - Multi-zone systems without zone DDC communicating to a central control panel
  - Systems with a design outdoor airflow of less than 1,200 cfm
  - Spaces with supply airflow minus any makeup or outgoing transfer air is less than 1,200 cfm
  - Ventilation provided for process loads only

Enclosed Parking Garage Ventilation (C403.2.6.2)

Requires contamination sensing devises to modulate airflow rates to 50% or less of design capacity or intermittently operate fans less than 20% or as required to maintain acceptable contaminant levels in accordance with International Mechanical Code provisions. Systems shall fail to full design.

Exceptions

- Garages with total exhaust capacity of less than 22,500 cfm with ventilation systems that do not utilize heating or mechanical cooling
- Garages with a ventilation system motor nameplate power ratio that exceeds 1125 cfm/hp and do not utilize heating or mechanical cooling

Energy Recovery Ventilation Systems (C403.2.7)

Where the supply rate of a fan system exceeds the values specified in Tables C403.2.7(1) and C403.2.7(2), the system shall include an energy recovery system.

Table C403.2.7(1) Excerpt [Systems operating less than 8,000 hrs/yr]							
% Outdoor air at full Design Flow							
10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80%+
Design supply fan airflow rate (cfm)							
26,000+	16,000+	5,500+	4,500+	3,500+	2,000+	1,000+	>0

Residential Ventilation (R403.6)

… the building or dwelling unit shall be provided with ventilation that meets the requirements of this section or the International Mechanical Code, as applicable, or with other approved means of ventilation.

- Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating.

Additional Illinois Amendments

- R403.6.2 Recirculation of air (M1507.2, 2015 IRC)
- R403.6.3 Whole-house mechanical ventilation system (M1507.3, 2015 IRC)
- R403.6.4 System design (M1507.3.1, 2015 IRC)
- R403.6.5 System controls (M1507.2, 2015 IRC)
- R403.6.6 Mechanical ventilation rate (M1507.3.3, 2015 IRC)
- R403.6.6.1 Different Occupant Density
- R403.6.6.2 Airflow measurement
- R403.6.7 Local exhaust rates (M1507.4, 2015 IRC)

Questions?

energycode@sedac.org
800-214-7954