

Humidity and Moisture Control Modeling for High Performance Building Enclosure Design

Presented to the Building Enclosures Council - Chicago

11.09.2023

Learning Objectives

- **Discover how modeling tools analyze moisture.**
- **Learn about commissioning procedures on enclosure systems to identify deficiencies in air, moisture and thermal performance.**
- **Understand air and vapor barrier placement.**
- **Discuss the value of high performance enclosure systems versus air and moisture risks.**



Approved Continuing Education

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The Presenters



Benjamin Skelton

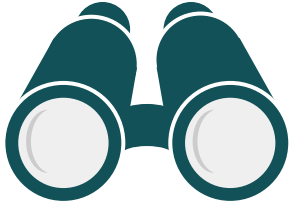
President



Charlie Saville

Principal + Director of Sustainability

Agenda



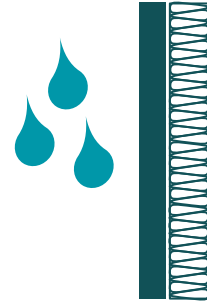
History of Code Updates



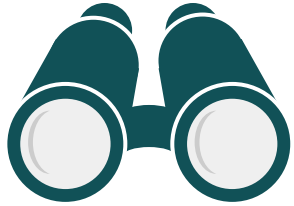
Enclosures and Codes



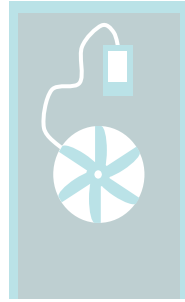
Energy Efficiency



Moisture Control in Enclosures



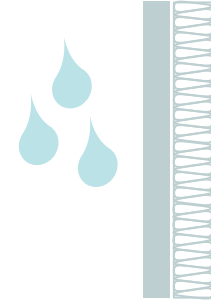
History of Code Updates



Enclosures and Codes



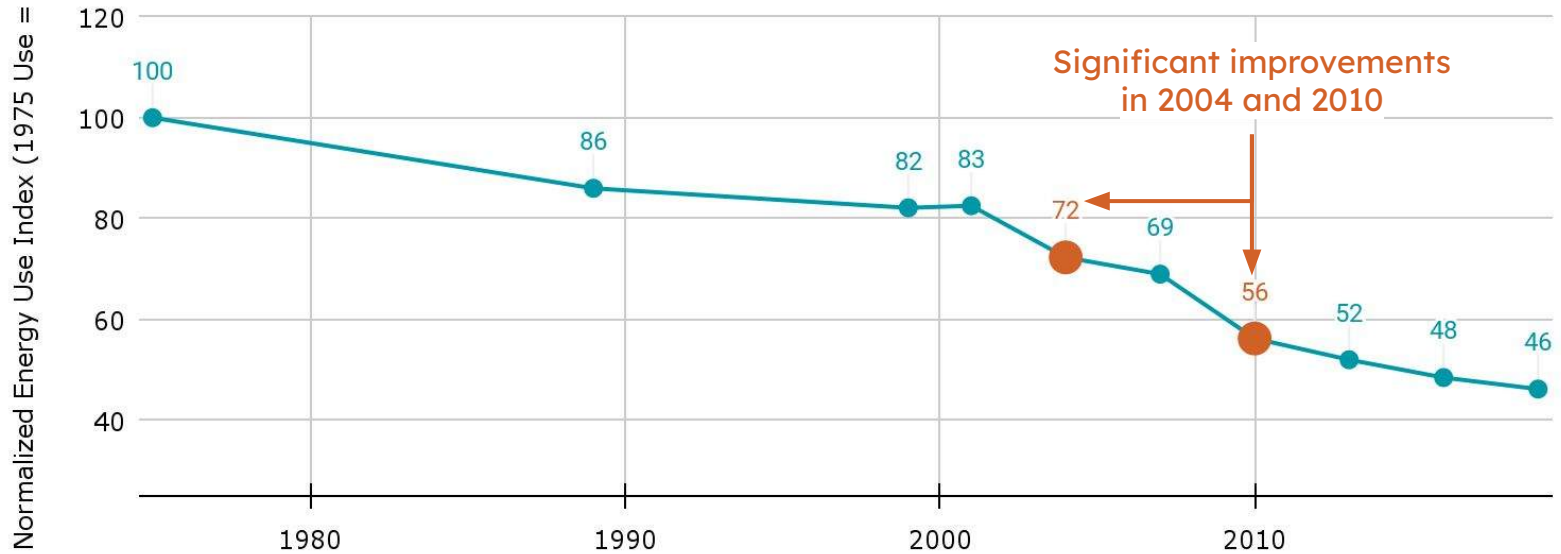
Energy Efficiency



Moisture Control in Enclosures

What progress we made in the last 50 years?

Estimated Improvement in Commercial Energy Standard



ASHRAE 90.1 Energy Code Improvement

[Historical Model Energy Code Improvement | Tableau Public](#)

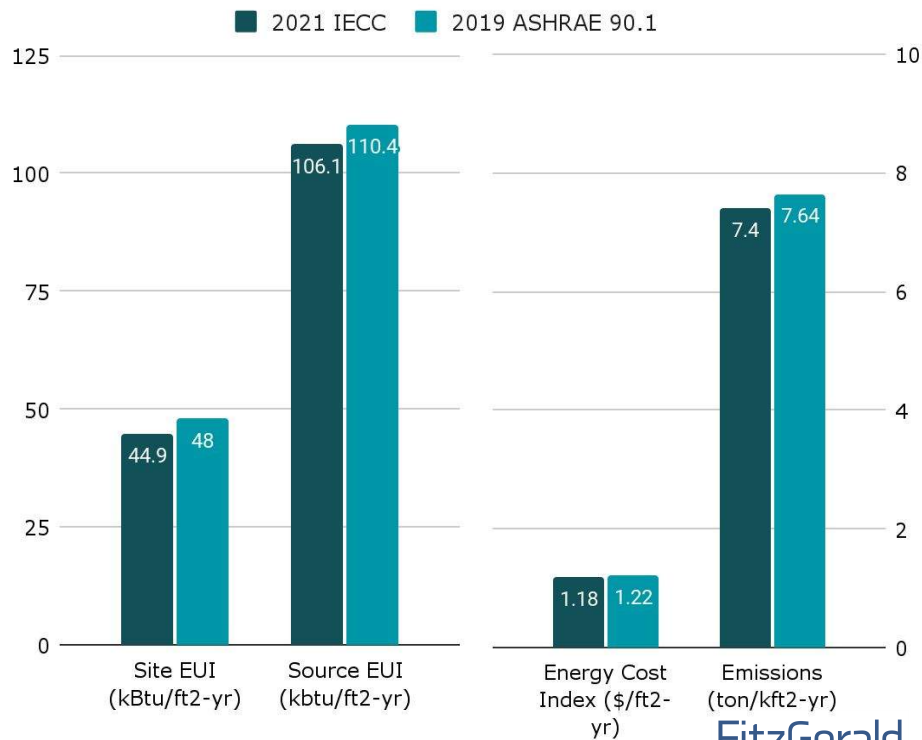
How do IECC 2021 and ASHRAE 90.1 2019 compare?

While **prescriptive performance** with IECC 2021 and ASHRAE 90.1 2019 is similar, requirements for IECC 2021 have tightened, making ASHRAE more appealing.

On a national weighted average basis, 2021 IECC is **7%** more efficient for site energy use and **3% more for energy costs than ASHRAE Standard 90.1-2019.**

	IECC 2018	IECC 2021	ASHRAE 90.1 2019
Window Wall Ratio	30%	30%	40%
Semi heated space	NA	NA	YES
Automatic Receptacle controls	NO	YES	YES
Energy Monitoring	NO	YES	YES

Prescriptive Performance for IECC 2021 vs. ASHRAE 90.1 2019

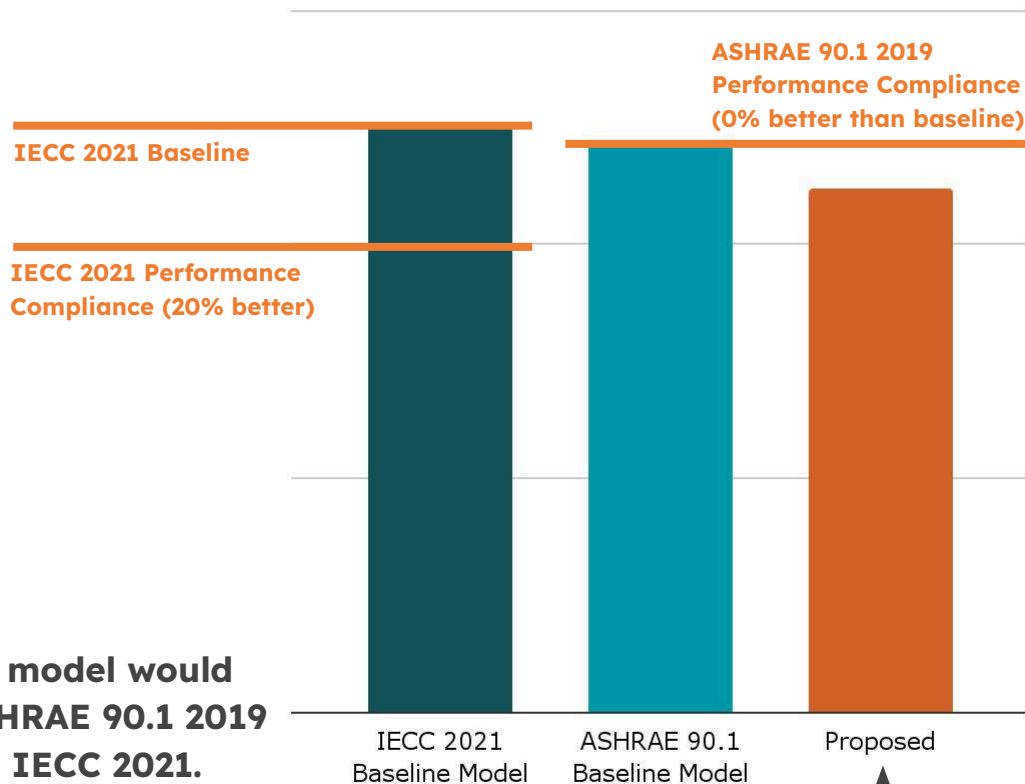


How do IECC 2021 and ASHRAE 90.1 2019 compare?

Performance compliance is significantly more challenging with IECC 2021 compared to ASHRAE 90.1 2019.

	IECC 2021	ASHRAE 90.1 2019
Window Wall Ratio	30%	40%
Semi heated space	NA	YES
Automatic Receptacle controls	YES	YES
Energy Monitoring	YES	YES
Performance Compliance	20%	0%

The proposed model would comply with ASHRAE 90.1 2019 but not with IECC 2021.

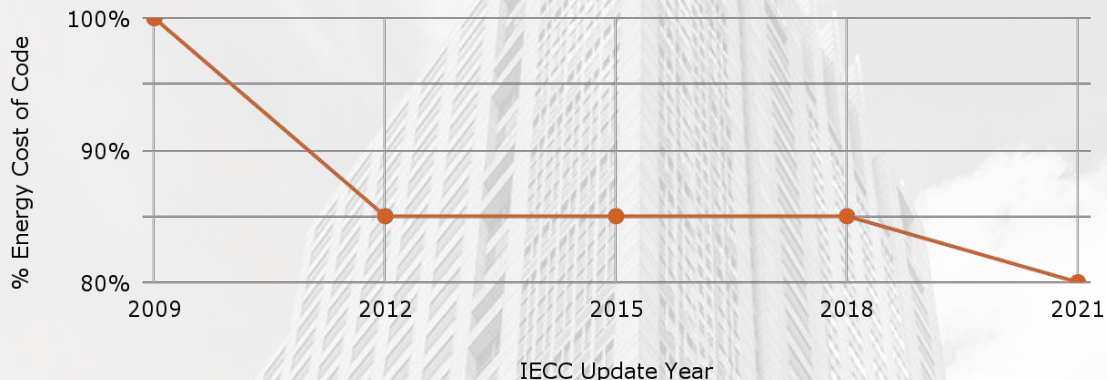


Total Building Performance

IECC 2021

Annual energy cost must be less than or equal to ~~85%~~ **80%** of the annual energy cost of a code baseline.

% of Annual Energy Cost vs. IECC Edition



ASHRAE 90.1 2019

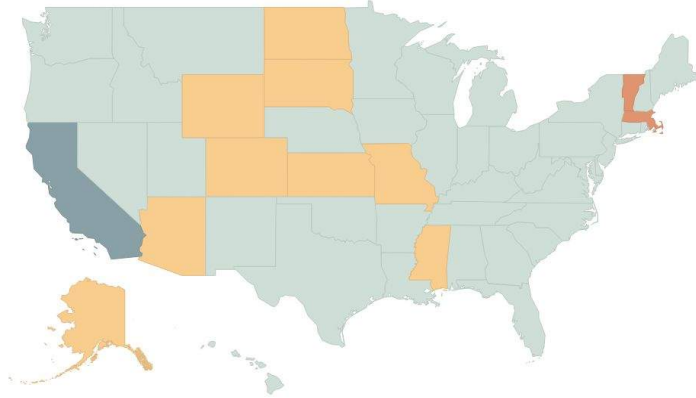
Annual energy cost must be 0% better than the annual energy cost of a code baseline.

USE ASHRAE



Introduction of Building Energy Conservation Codes

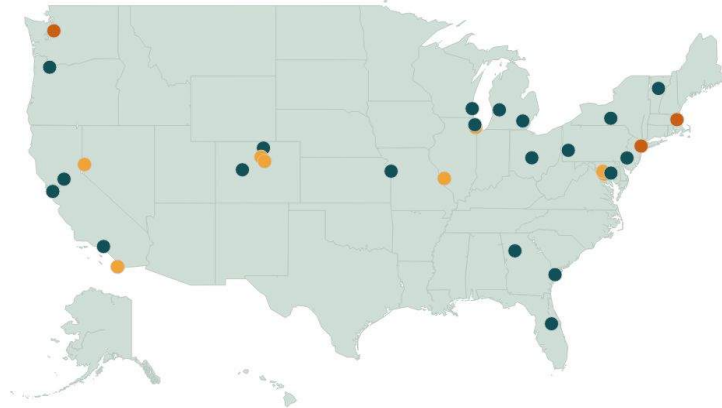
State Energy Code Adoption



- IECC
- Home Rule or No Energy Code
- Stretch Codes
- Title 24

Status of State Energy Code Adoption - Commercial, Energycodes.gov

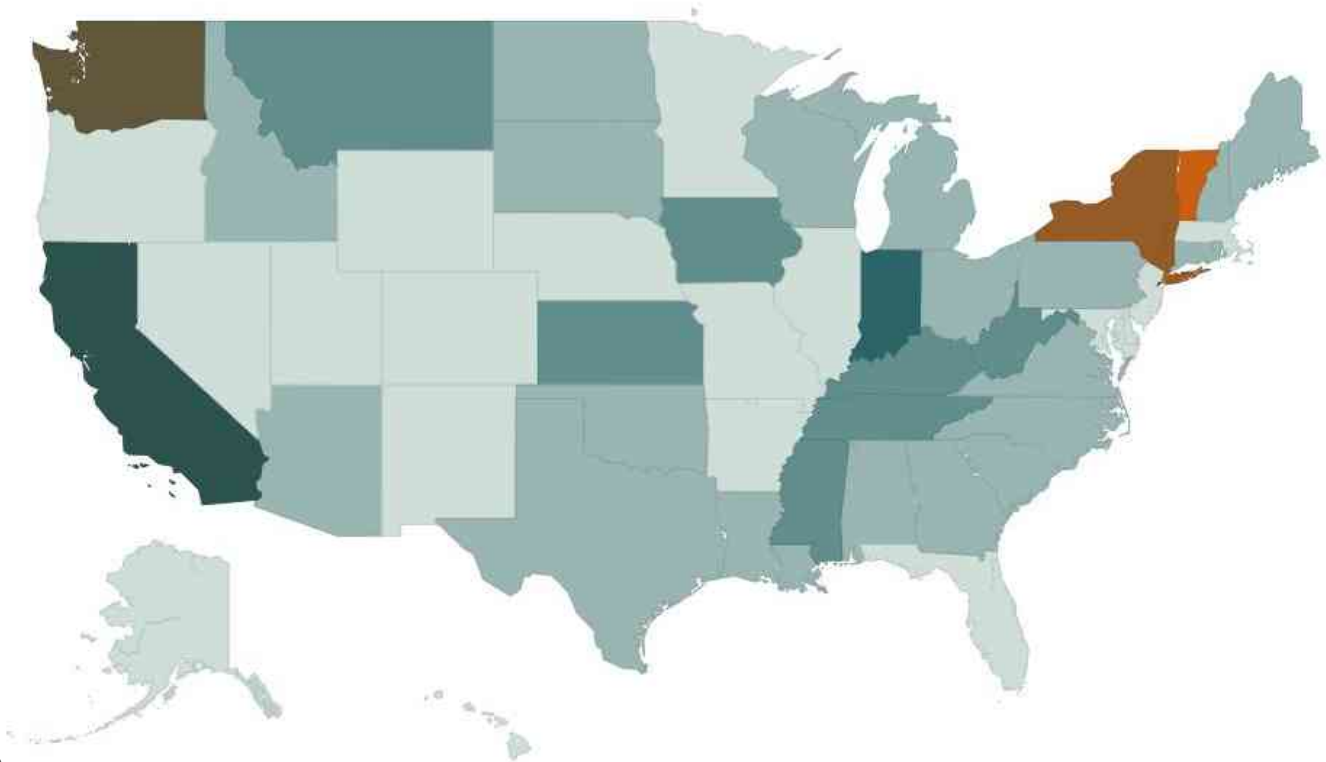
Progressive Building Performance Standards



- Energy or Emissions Reduction in Place (penalties incurred for noncompliance)
- Energy or Emissions Reduction in Place (penalties incurred for noncompliance)
- Reductions under consideration

State and Local Building Performance Standards, Tableau

State Energy Code Adoption



- IECC 2021/ASHRAE 90.1 2019
- IECC 2018/ASHRAE 90.1 2016
- IECC 2015/ASHRAE 90.1 2013
- IECC 2012/ASHRAE 90.1 2010
- IECC 2009/ASHRAE 90.1 2007
- Title 24
- 2018 Washington State Energy Code
- NYC Energy Conservation Code
- 2020 Vermont Commercial Building Energy Standards

[U.S. Energy Codes Adopted by States, Cove.Tool](#)

High Performance Codes in other Jurisdictions

1

California
Title 24 2022

2

Denver
Denver Energy Code 2022 + IECC 2021

3

Massachusetts
MA Stretch Code + Net Zero Code + IECC 2021 Base Code

4

Seattle
Seattle Energy Code

5

Washington
2018 Washington State Energy Code

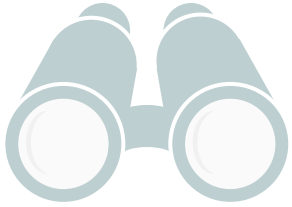
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Chicago
2022 Chicago Energy Transformation Code

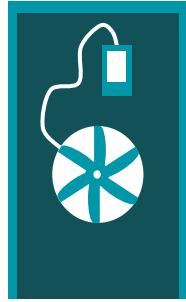
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New York City
2020 NYC Energy Conservation Code

← Ranking based on progressiveness



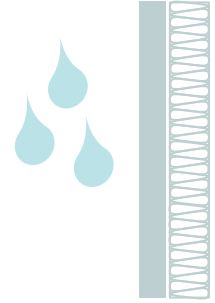
History of Code Updates



Enclosures and Codes



Energy Efficiency



Moisture Control in Enclosures

How do we assess the impact of IECC 2021?

Necessity

Necessity of the change is based on the ease or difficulty of substituting it.



Prescriptive - energy model trade-off is applicable.



Use ASHRAE. Mandatory for IECC.



Mandatory comparable requirements for both IECC and ASHRAE.

Performance and Cost Impacts

Performance and cost are evaluated on a low to high scale of impact.

Performance - Environmental Benefit, Maintenance, and Longevity

Cost - First Cost and Operational Cost



Low
There may be some change, but it will not be significant in the overall scope of the project.



Medium
Change will be noticeable.



High
There will be a significant change that will alter the project's parameters.

What are the most impactful changes to IECC 2021?

Here is a more in depth look at the most impactful changes in IECC 2021 in reference to the 2018 edition. We'll be going into more detail on the items emphasized in blue.

C402 Building Envelope

C401.3 Thermal Envelope Certificate

C402.1.4 Assembly U-Factor, C-Factor, or F-Factor

C402.5 Air Leakage

C402.5.11 Operable Openings Interlocking

C403 Mechanical Systems

C403.1.2 Data Centers

C403.2.3 Fault Detection and Diagnostics

C403.3.2 HVAC equipment performance requirements

C403.4.2.3 Automatic start and stop

C403.7.1 Demand control ventilation

C403.7.4 Energy recovery systems

C403.8.5 Low-capacity ventilation fans

C403.11 Refrigeration equipment performance

C404 Water Heating

C404.2.1 High Input Service Water Heating Systems

C405

Electrical Power and Lighting Systems

C405.2.1

Occupant sensor controls

C405.2.4.2

Sidelit daylight zone

C405.2.7.3

Exterior lighting setback

C405.2.8

Parking Garage Lighting Control

C405.3.2

Interior lighting power allowance

C405.11

Automatic receptacle control

C405.12

Energy Monitoring

C406

Additional Efficiency Requirements

C407

Total Building Performance

C6

Chicago Amendments

C603

Solar Ready Roofs

C604

Electrification Ready Residences

C605

Exterior Balconies and Parapet

C606

Gas Lighting Prohibited

C607

Roof Solar Reflectance

C608

Electric Vehicle Supply Equipment

C402.4.1.3 Fenestration Orientation

Thermal Envelope

USE ASHRAE



IECC 2021: A permanent thermal envelope certificate shall be completed by an approved party.

ASHRAE 90.1 2019: Building Envelope is part of the Verification, Testing, and Commissioning requirements (Mandatory). However, a thermal envelope certificate is not required.

Performance
Impact

Low

Cost
Impact

Low

Assembly Insulation

Commercial Requirements For Chicago (Climate Zone 5A)

IECC 2021:

Roof

Roof Deck

30ci.

30ci.

Metal

19 + 11 LS

19 + 11 LS

Attic + other

49

38

Wall

Mass

11.4ci.

11.4ci.

Metal

13 + 14ci.

13 + 13ci.

Metal Framed

13 + 10ci.

13 + 7.5ci

Wood framed

13 + 7.5ci OR 20 + 3.8ci.

13 + 3.8 ci OR 20

Below Grade

10ci.

7.5ci.

Slabs

Unheated

20 at perimeter

10 at perimeter

Vertical Fenestration

Fixed U-Factor

0.36

0.38

Operable U-Factor

0.45

0.45

SHGC (PF \leq 0.2)

0.38

SWE 0.38 N 0.51

Performance
Impact

Low

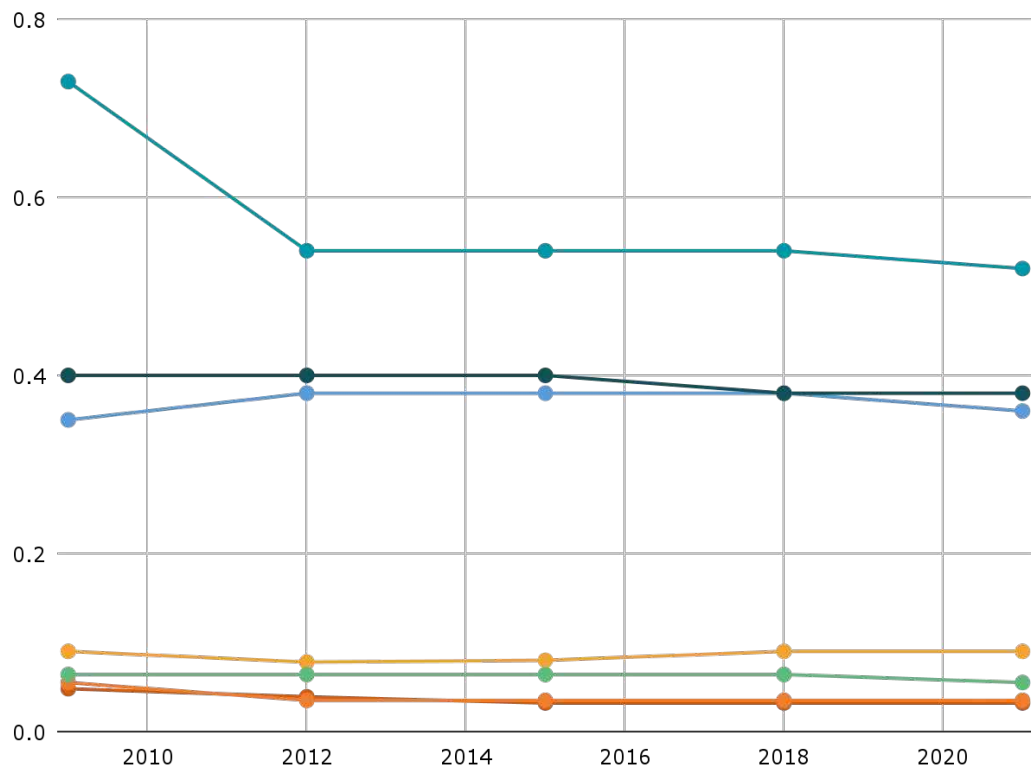
Cost
Impact

Low

PRESCRIPTIVE



How have insulation requirements changed in the last 50 years?



IECC 2012 brought significant insulation requirements changes. However, later code iterations haven't improved minimum insulation values significantly.

- Roof: Above Roof Deck (U-Value)
- Roof: Metal Building (U-Value)
- Wall: Mass (U-Value)
- Wall: Metal Framed (U-Value)
- Slab: Unheated (F-Factor)
- Window: Fixed (U-Value)
- Window: SHGC, PF<0.2

Operable Openings

IECC 2021 updates

USE ASHRAE



IECC 2021: Operable openings must be interlocked with HVAC setpoints if they are greater than 40 sf.

ASHRAE 90.1 2019: Similar requirements in 6.5.10 Door Switches, but it's prescriptive.

Performance
Impact

Medium

Cost
Impact

Medium

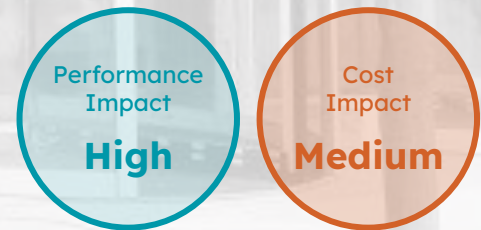
Air Leakage



IECC 2021: Air leakage testing is ~~optional~~ **required** for specified building types, building sizes, and climate zones; specific limits for different climate zones

For Chicago, almost all new commercial buildings require air leakage tests. Energy model trade off is not applicable.

ASHRAE 90.1 2019: Either whole building air leakage test (5.4.3.1.1), OR third party design review and field inspection during construction(5.9.1.2) is mandatory.



Air Leakage

MANDATORY



IECC 2021: Air leakage testing must be completed for applicable buildings. For multifamily residences, individual dwelling units and the whole building must be tested.

- **Group R and I:** 20% (or 8 units minimum) of residential units must achieve an air tightness of 0.30 cfm/sf @50pa.
- **Other than Group R and I:** Whole building must achieve an air tightness of 0.40 cfm/sf @50 pa.
 - Whole buildings that exceed 0.40 cfm/sf but don't exceed 0.60 cfm/sf may perform visual diagnostics and non-destructive resolutions with a code official.

Some exceptions apply

Performance
Impact

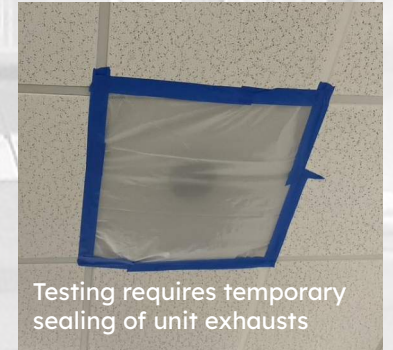
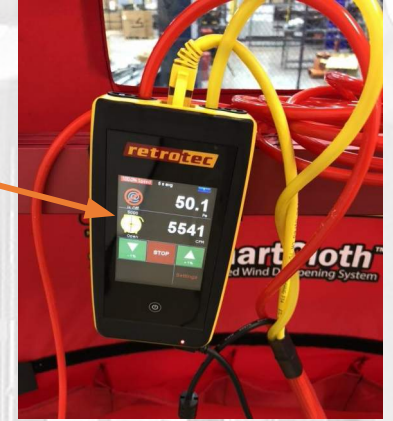
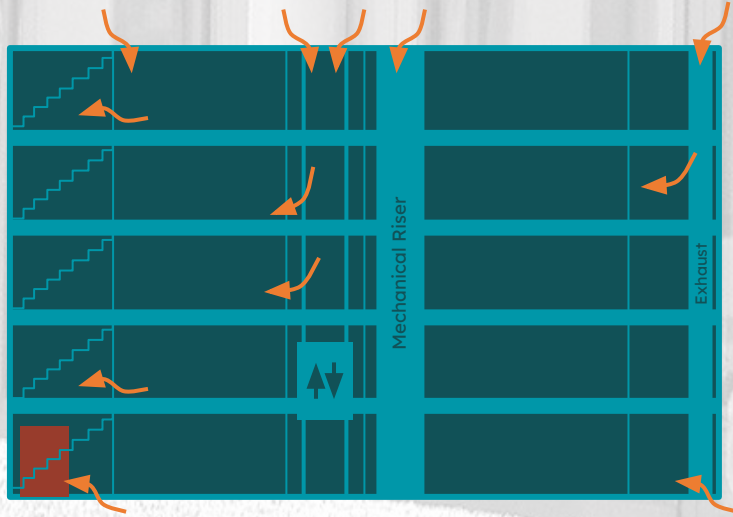
High

Cost
Impact

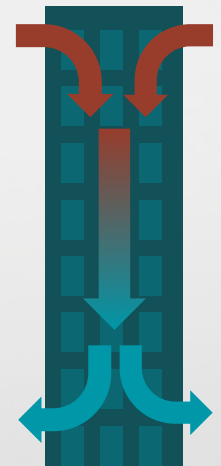
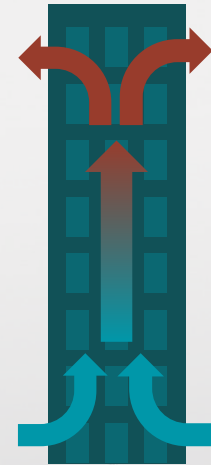
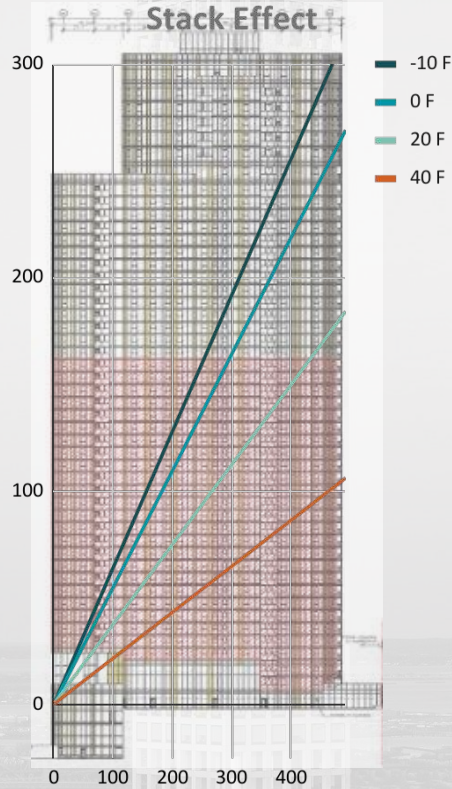
Medium

Air Leakage: Blower Door Test

A blower door test measures the air leakage of a building by pressurizing and depressurizing the space to better understand how the building performs.



Stack Effect Commissioning



Envelope Commissioning

Commercial drone pilots can quickly survey large buildings to identify performance issues

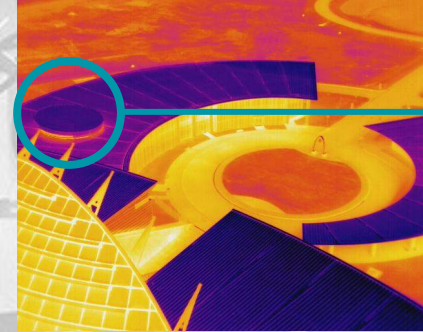
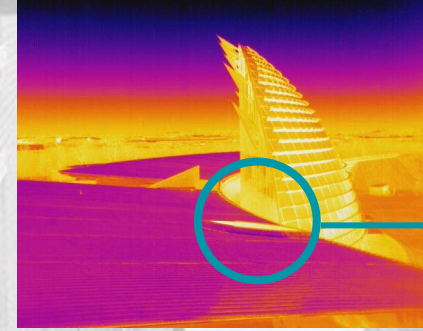


Image Credit: YouTube



Sources of heat loss

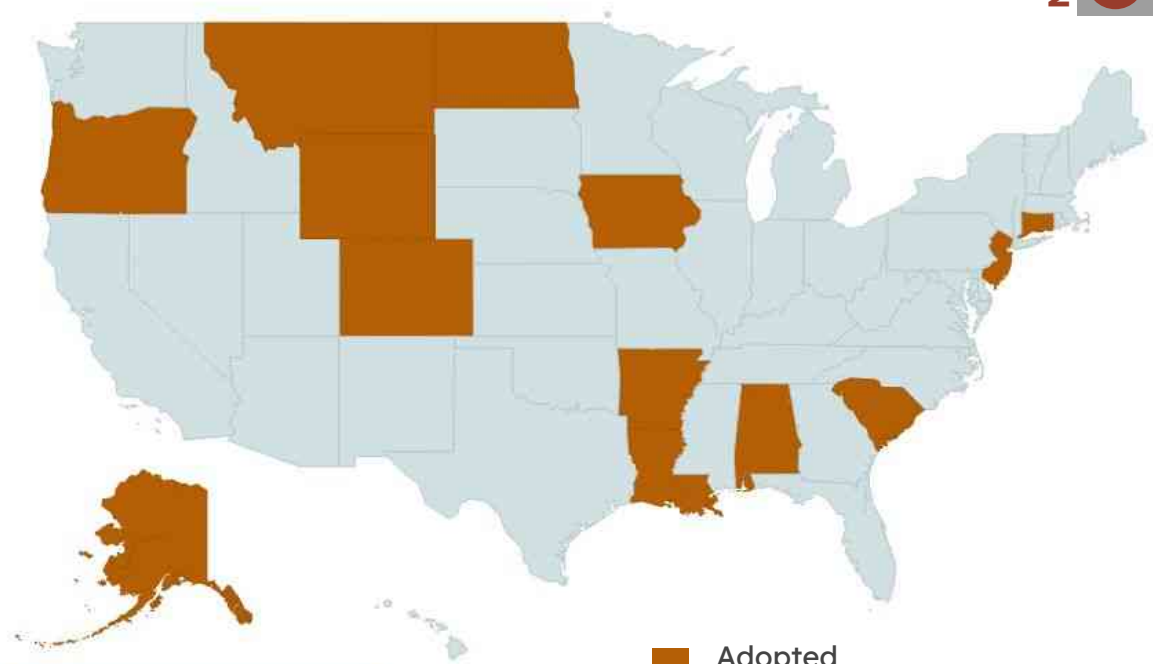
Ventilation

2021 International Mechanical Code

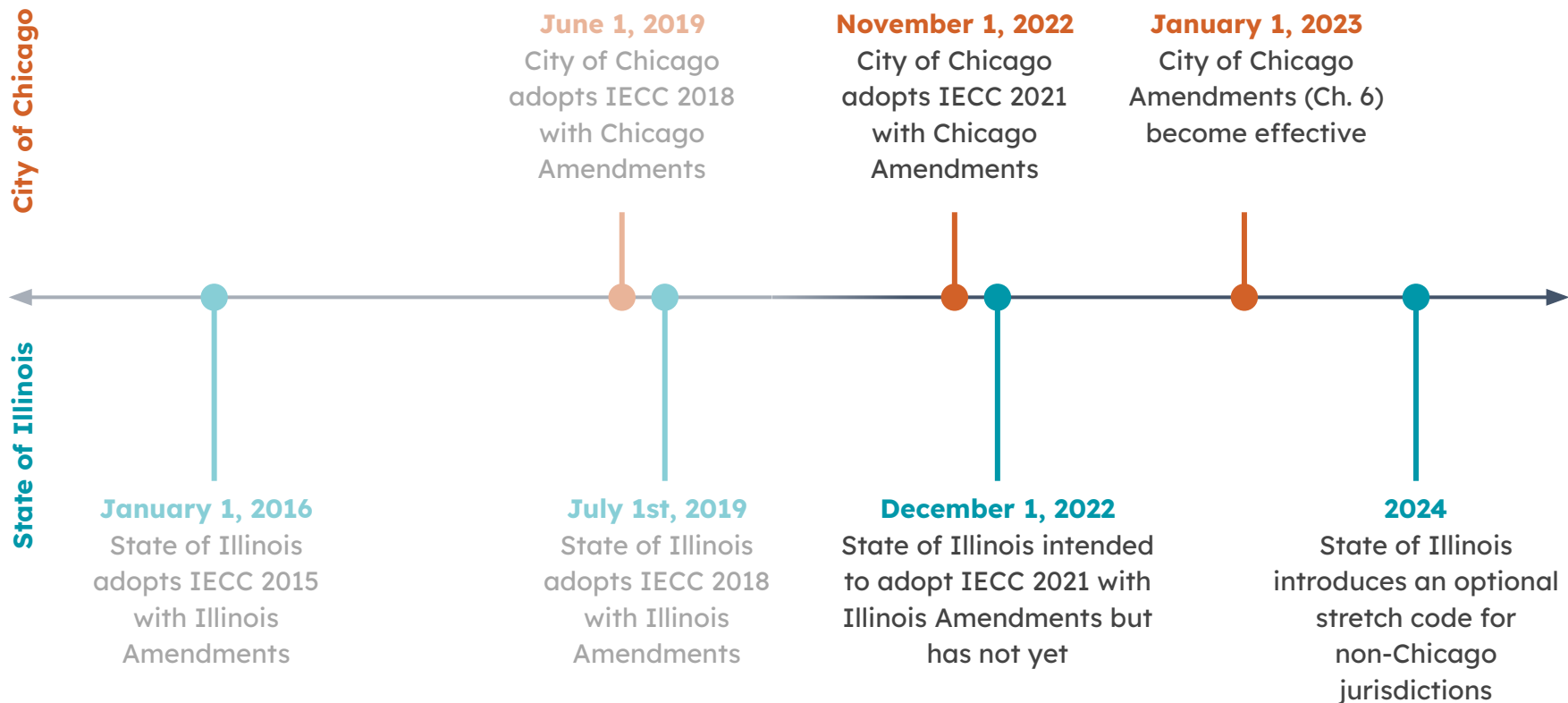
401.2 Ventilation Required

“Dwelling units complying with the air leakage requirements of the IECC or ASHRAE 90.1 **shall be ventilated by mechanical means.**”

*Applicable for jurisdictions that have adopted the 2021 ICC family of codes. This map does not include some major cities.



Code Adoption in Illinois & Chicago



Stretch Code

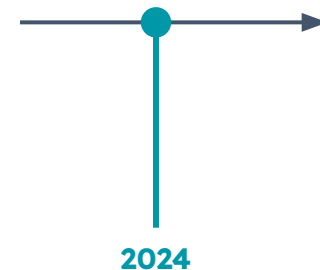
A stretch code defines a higher level of energy efficiency or sustainability for new construction than the applicable energy code.

Commercial Stretch Code Targets

Stretch Code Version	Implementation Date	Site Energy Index	Performance Targets (Over 2006 IECC)	Code Created By
2024	12/31/2023	0.60	≥40% better	Set by CDB by July 31, 2023
2026	12/31/2025	0.50	≥50% better	Set by CDB by July 31, 2025
2029	12/31/2028	0.44	≥56% better	Set by CDB by July 31, 2028
2032	12/31/2031	0.39	≥61% better	Set by CDB by July 31, 2031

Separate targets for residential stretch code.
Current commercial code in Illinois has a Site Energy Index of 0.66
Source: Illinois Climate and Equitable Jobs Act (CEJA) pages 237; 244-248; 630 - Stretch Code

Performance Targets reference
IECC 2006 baseline



2024
State of Illinois introduces an optional stretch code for non-Chicago jurisdictions

Compliance Paths for Chicago

START

Is your project in Chicago? →

Yes!

Does your project meet Chicago Amendments? →

Yes!

Which method would you like to seek compliance with?



Passive House or National Green Building Standard

Meet the required criteria.

↓
✓ **Compliance criteria is met.**

ASHRAE 90.1 or IECC 2021

Criteria for compliance is equivalent in most cases. Will the project be energy modeled? →

↓
No. Prescriptive pathway with limited/no trade-offs

Ensure to provide the COMcheck and/or local government required documents.

Yes! We love energy models.

Demonstrate that your project performs better than code baseline in energy/EUI or cost. ↓

→ ✓ **Compliance criteria is met.**

**PICK ONE PATH
DO NOT MIX
NO CHERRY PICKING ALLOWED**

Fenestration Orientation

USE ASHRAE



**Chicago
Amendment to
IECC 2021:**

**East and West facing glazing must comply with
% of Total Glazing Area**

West Glazing

25% maximum

East Glazing

25% maximum

**unless shaded at 9 a.m. and 3 p.m. on the summer solstice. With
IECC, energy modeling tradeoff is not applicable.**

$$A_{W/E} * SHGC_{W/E} \leq (A_T * SHGC_C) / 5$$

ASHRAE 90.1 2019:

Prescriptive. Modeling trade off applies.

ASHRAE 90.1 2022:

**Trade off goes away with
envelope backstop**

Performance
Impact

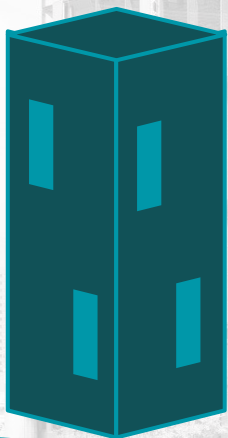
High

Cost
Impact

Medium

Fenestration Orientation

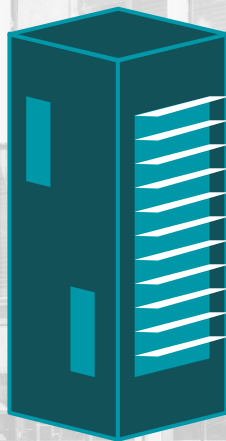
USE ASHRAE



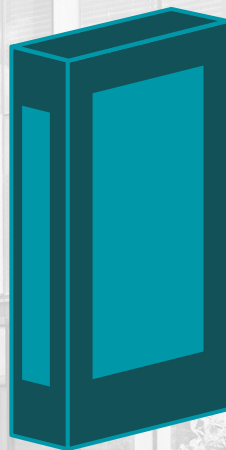
Equal glazing area on all sides of a square building



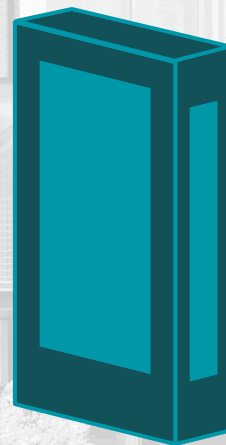
More glazing area on the East side than on the South



75% shading at 9 a.m. and 3 p.m. on the summer solstice (June 21)



More glazing area on the East side than on the South



More glazing area on the South side than on the East

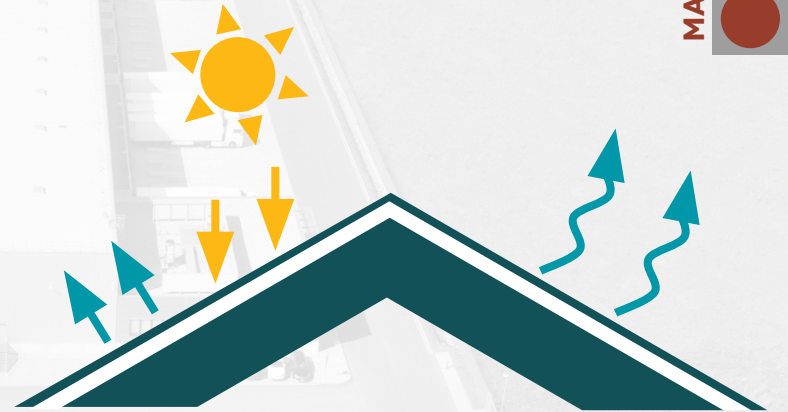
Roof Solar Reflectance

Chicago Amendments (Already Building Code)

C607 Roof Solar Reflectance

Roof coverings for low sloped roofs must have a reflectance value of 0.72 or greater when installed.

Roof coverings for roof other than low sloped roofs must have a reflectance value of 0.15 or greater when installed.



Solar Reflectance
ability to reflect solar energy back to the atmosphere

Emissivity
ability to dissipate absorbed heat

Two circular icons with a dark teal border and a light teal background. The left circle contains the text "Performance Impact" above the word "Low". The right circle contains the text "Cost Impact" above the word "Low".

Solar Ready Roofs

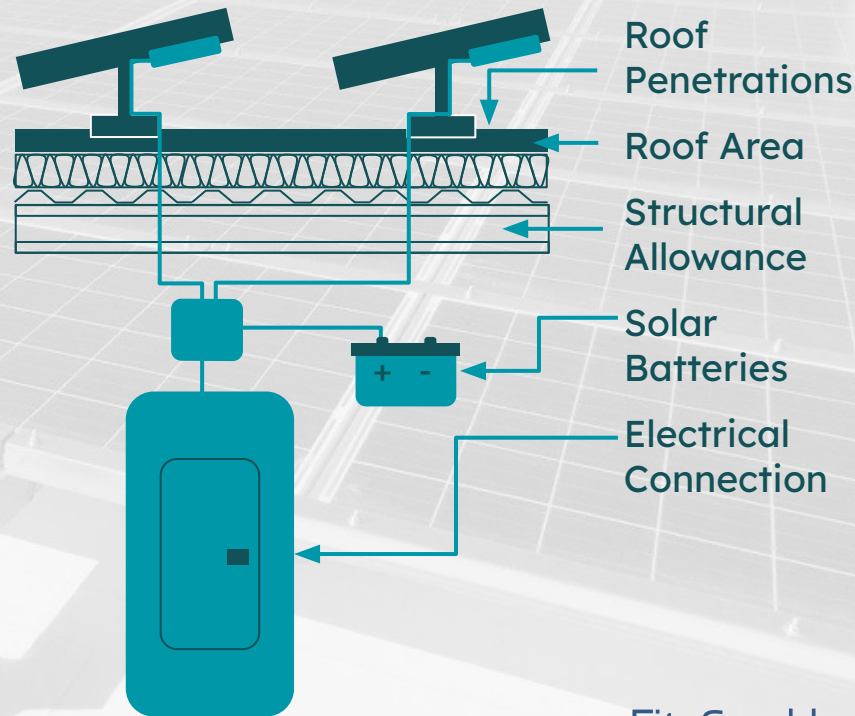
Chicago Amendments

C603 Solar Ready Roofs

'Solar Ready' requires that the building has roof area, structure allowance, electrical capacity and connection, and space reserved for future battery storage, etc. reserved for future PV.

New Construction or additions smaller than 7,500 sf or more than 60 ft tall are exempt.

A permanent Solar-ready certificate must be installed.



Exterior Balconies and Parapet

Chicago Amendments

C605.1 Continuous Insulation

Exterior balconies and parapets that interrupt the building thermal envelope must either

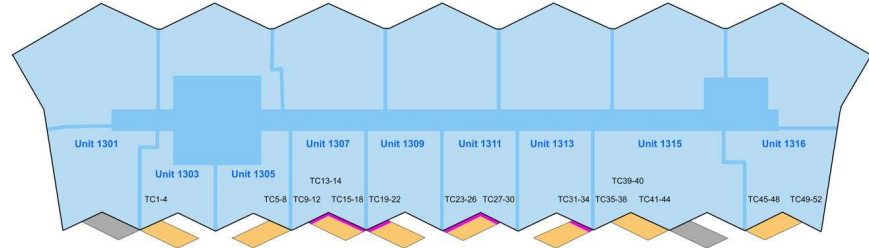
1. have continuous insulation equivalent to the R-Value of the adjacent wall assembly
1. OR incorporate an R-3 minimum thermal break



MANDATORY



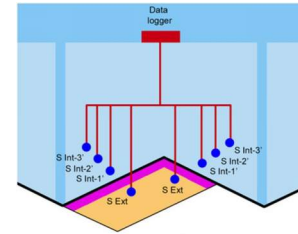
Exterior Balconies and Parapet



Control balconies

Balconies with thermal breaks

Control balconies



MANDATORY



Documentation Requirements

Chicago Amendments

[SO2022-2008.pdf \(chicago.gov\)](#)



Architectural

- Insulation materials and their R-values
- Fenestration U-factors and solar heat gain coefficients (SHGCs)
- Area-weighted U-factor and solar heat gain coefficient (SHGC) calculations
- Air barrier and air sealing details, including the location of the air barrier

Mechanical

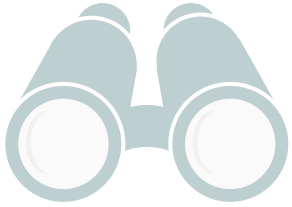
- Mechanical system design criteria. Mechanical and service water heating systems and equipment types, sizes, and efficiencies
- Economizer description
- Equipment and system controls
- Fan motor horsepower (hp) and controls
- Duct sealing and duct and pipe insulation locations

Lighting

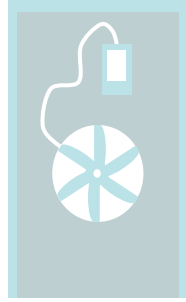
- Lighting fixture schedule with wattage and control narrative
- Location of required daylight zones on floor plans

Energy Modeler

- Energy compliance path



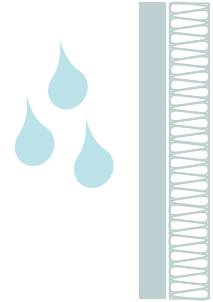
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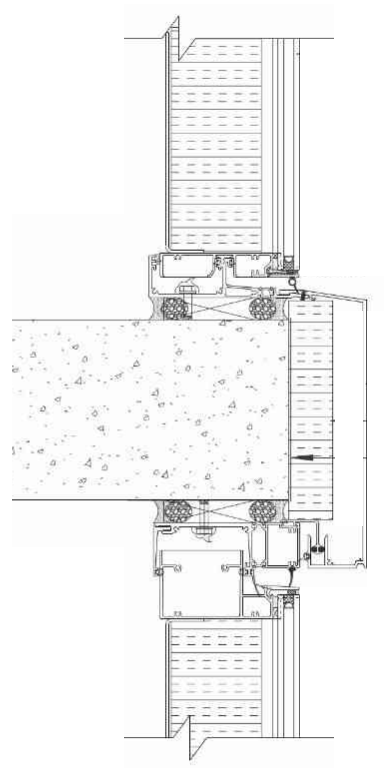
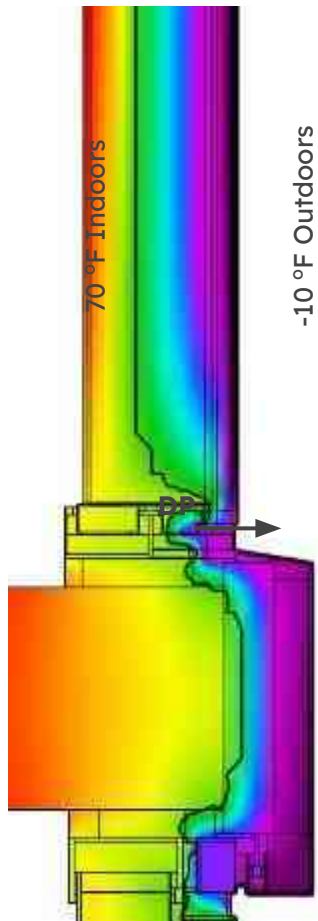
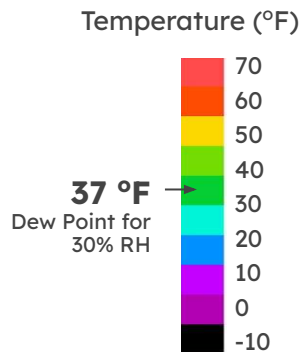
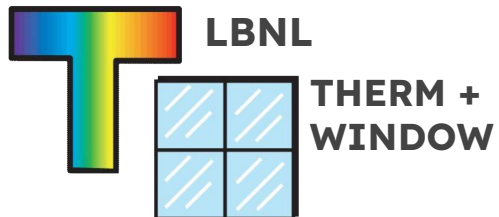
Energy Efficiency



Moisture Control in Enclosures

Heat Transfer

Two Dimensional Thermal Conductivity

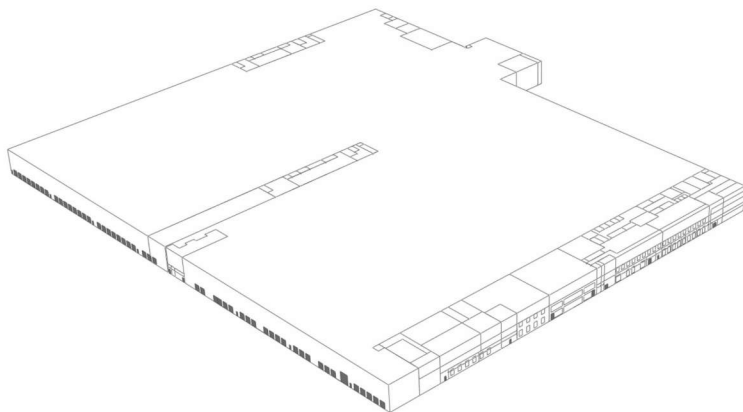


Condensate Resistance Factor

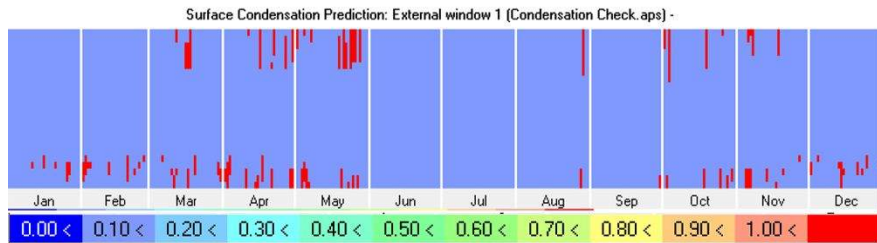
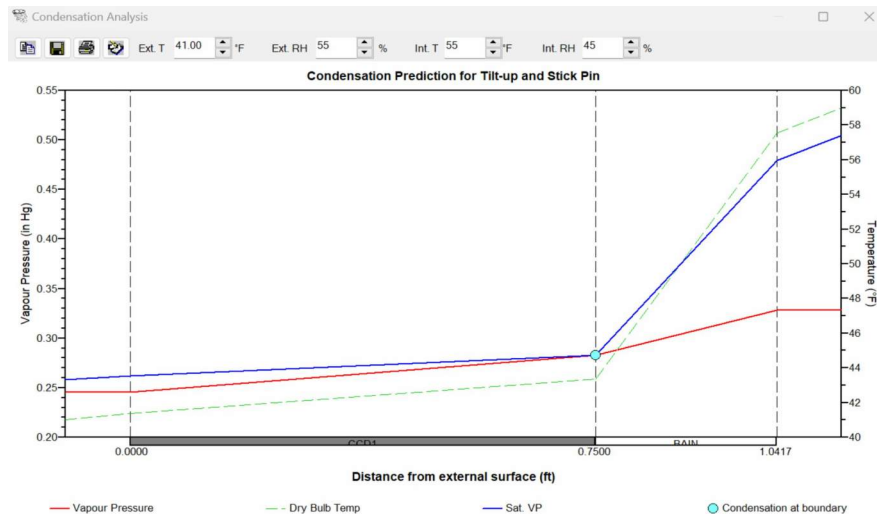
Surface Condensation + Interstitial Dewpoint



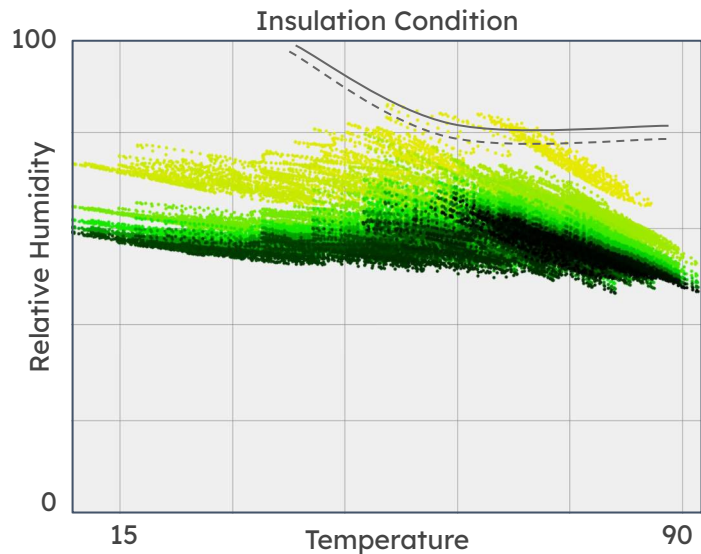
INTEGRATED ENVIRONMENTAL SOLUTIONS
Authorized Training Center



Whole Building Energy Simulation



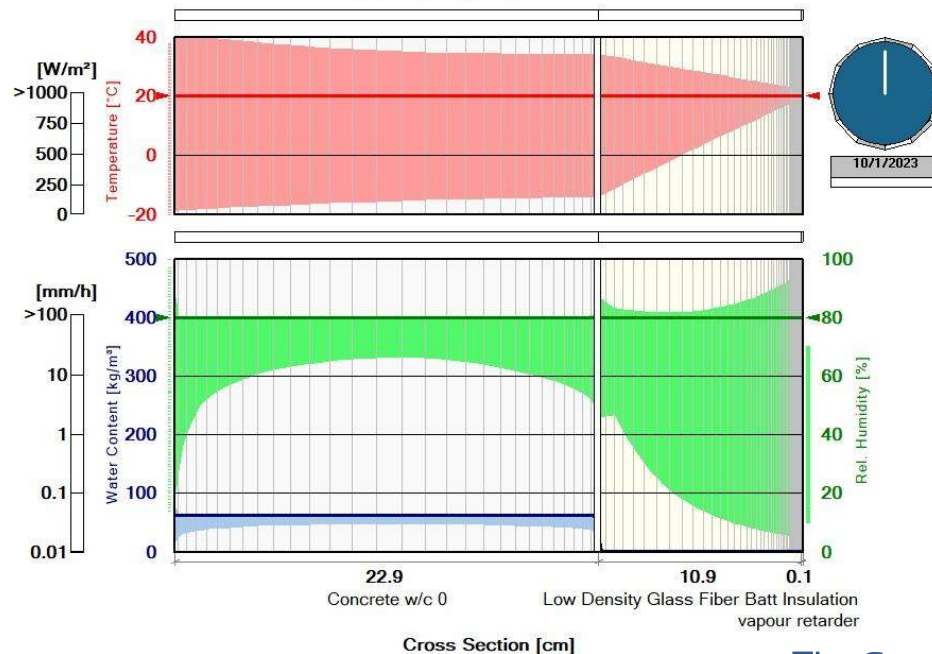
Annual One-Dimensional Heat + Moisture Transport

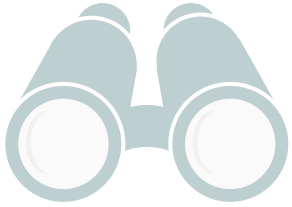


Location: St. Louis, MO; cold year; 0.0 °F;

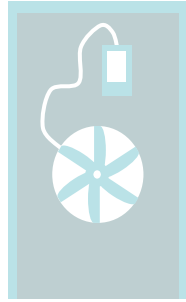
South Coating + 0.4 + None

WUFI®





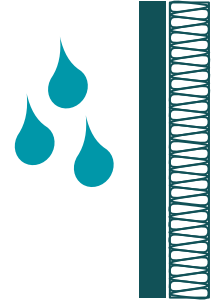
History of Code Updates



Enclosures and Codes



Energy Efficiency

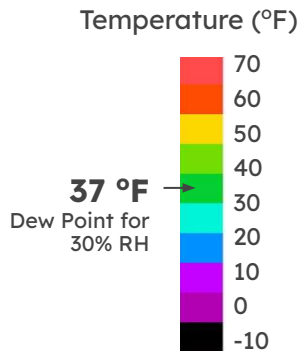


Moisture Control in Enclosures

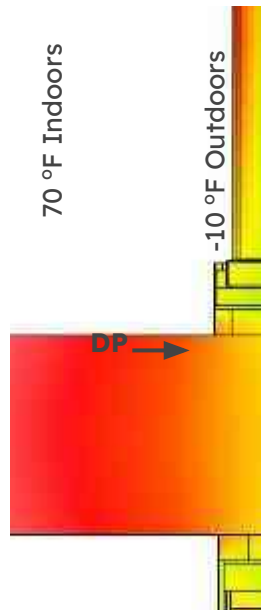
Case Study: Multifamily High Rise

Balancing performance goals

Inboard insulation moves the dew point toward the interior

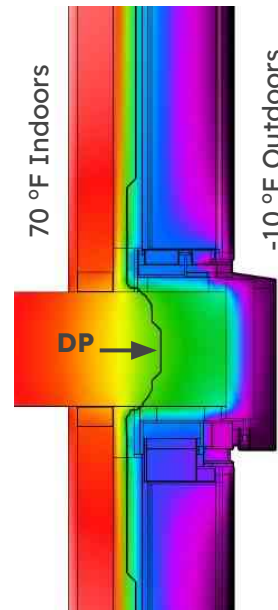


Baseline
R-8.5 Wall

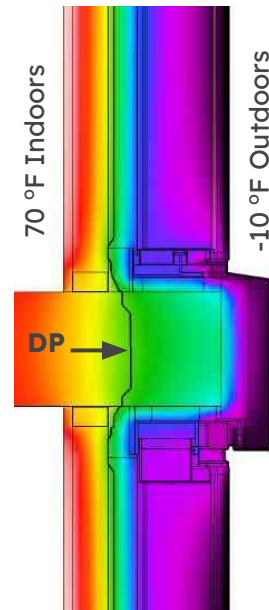


Insulated furring wall details

R-21.5 Wall



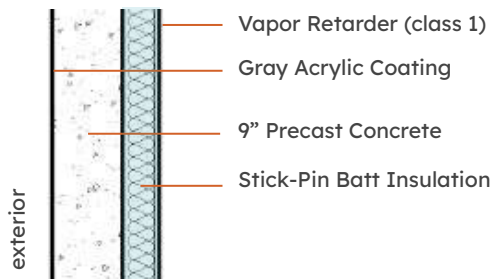
R-26 Wall



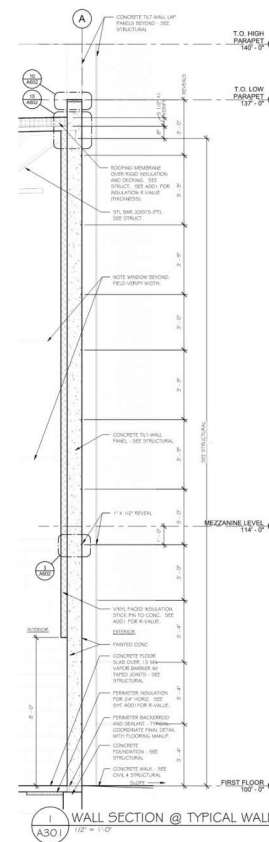
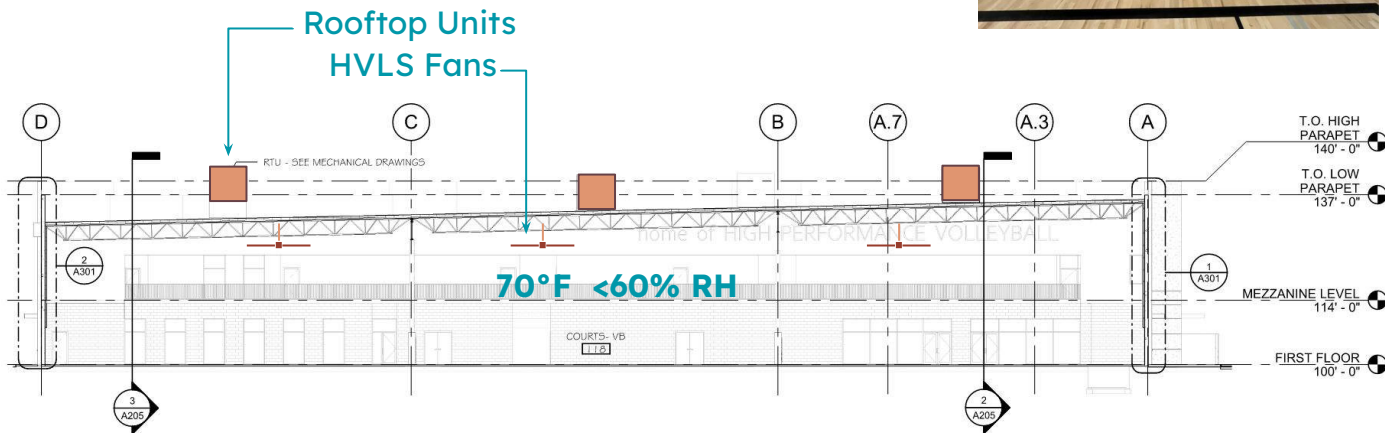
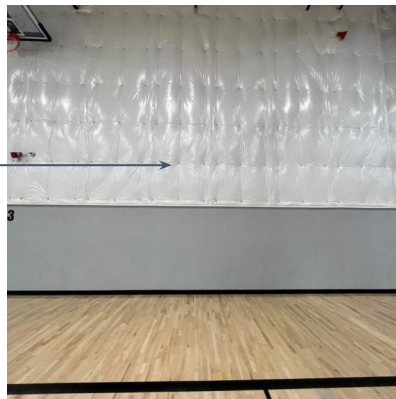
FitzGerald

Case Study: Athletic Center

St. Louis, Missouri

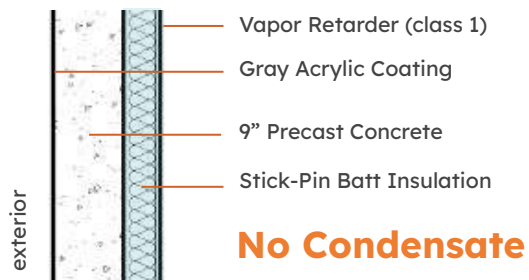


Summer condensation after construction



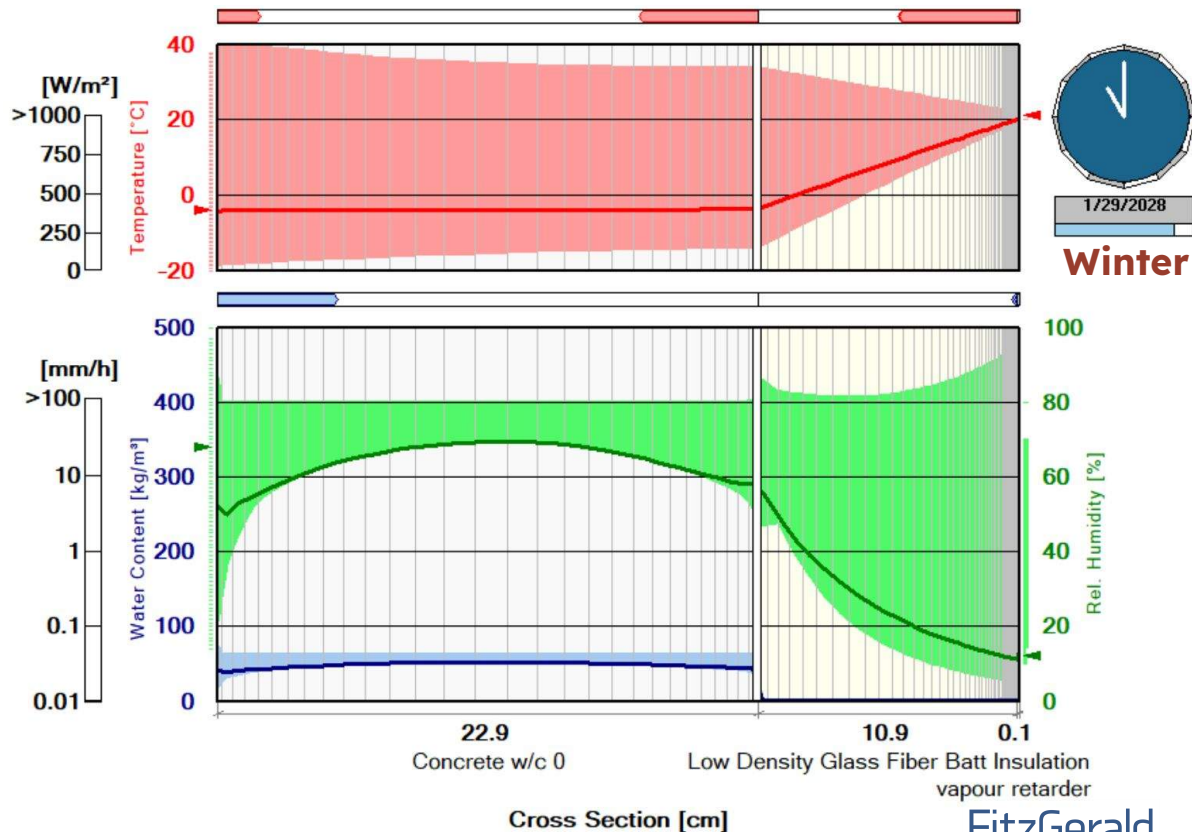
Case Study: Athletic Center

How it should work



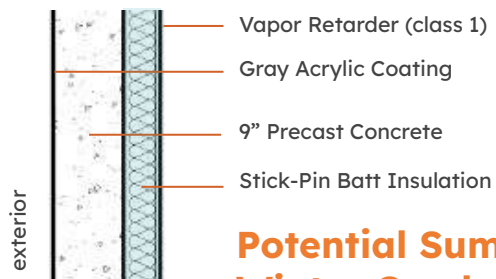
- Exterior coating prevents driving rain absorption
- Vapor barrier prevents indoor moisture transmission

South Oriented Assembly



Case Study: Athletic Center

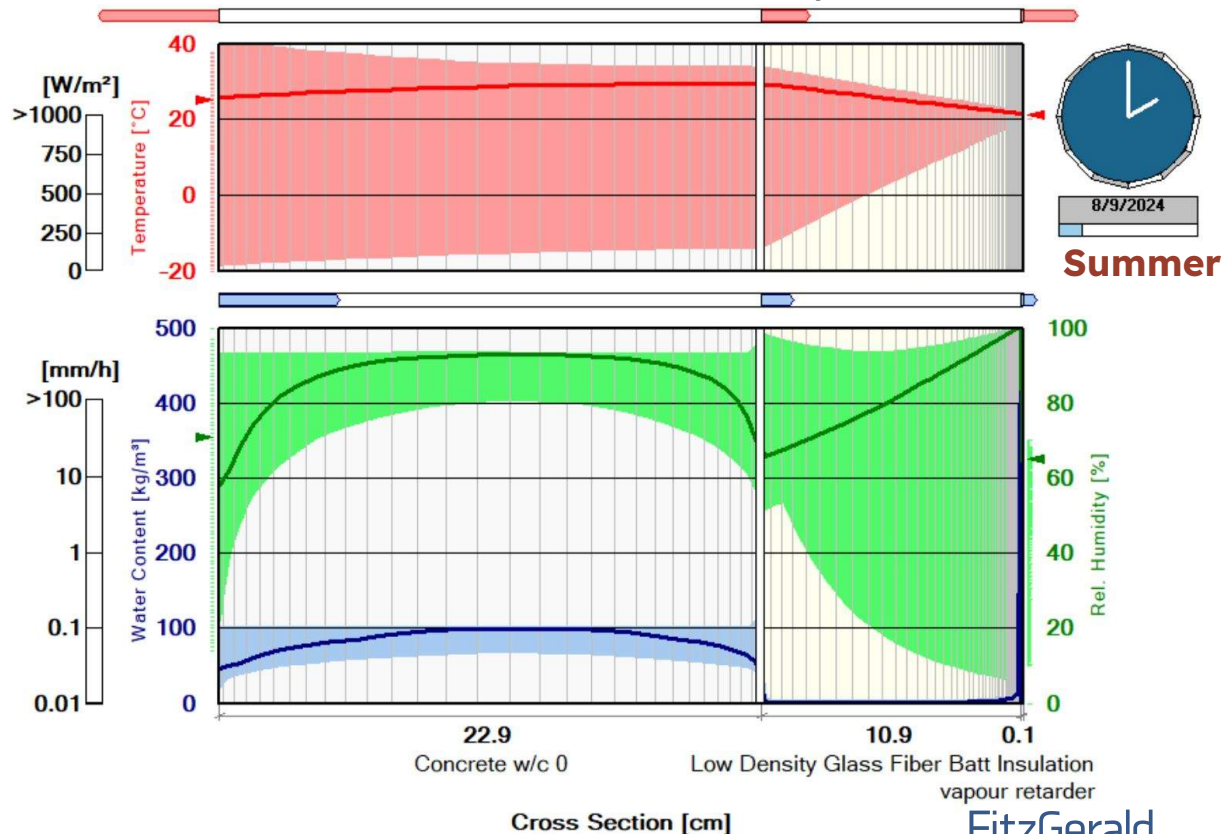
How it does work



Potential Summer + Winter Condensate

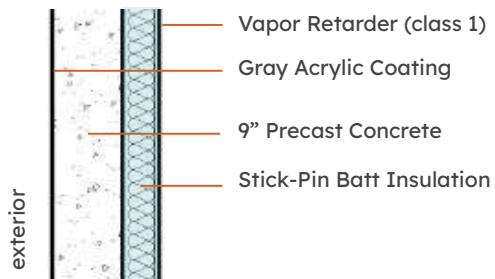
- Concrete holds higher moisture levels while curing
- Moisture stabilization may take several seasons

South Oriented Assembly

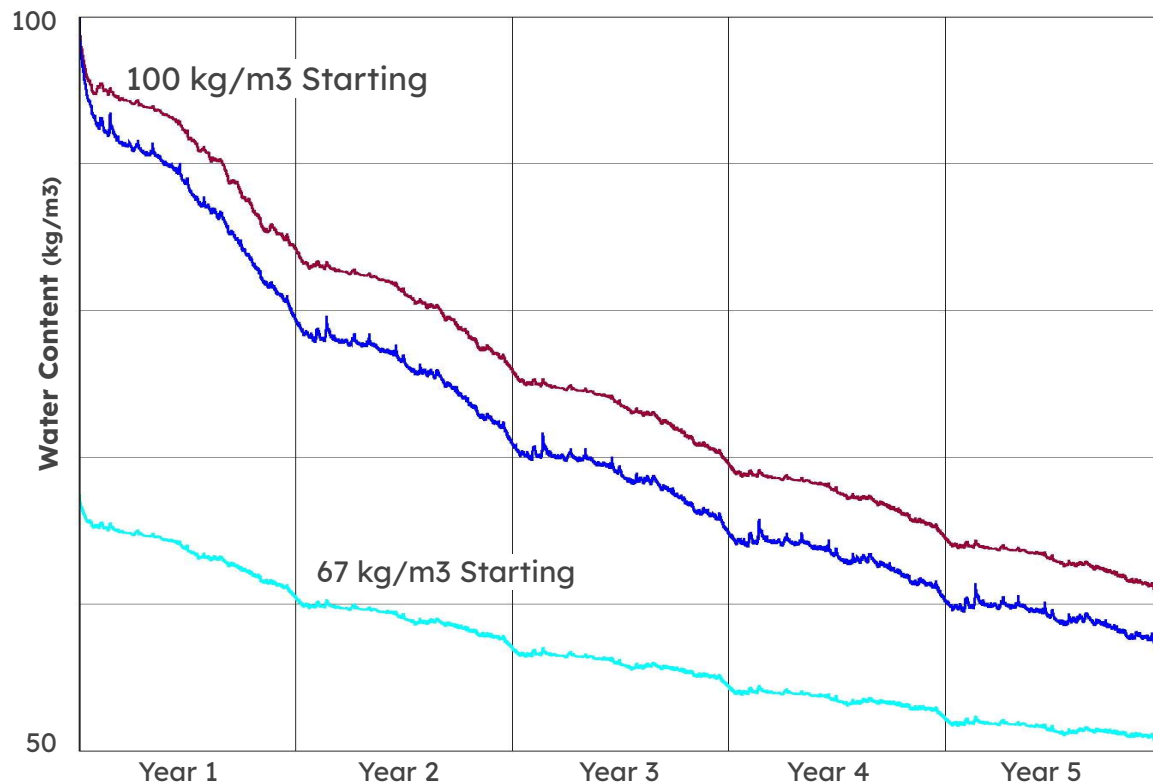


Case Study: Athletic Center

Concrete needs to dry!

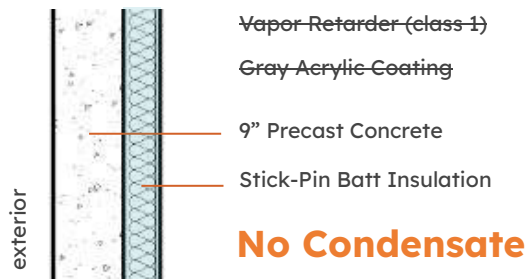


- Concrete holds higher moisture levels while curing
- Moisture stabilization may take several seasons



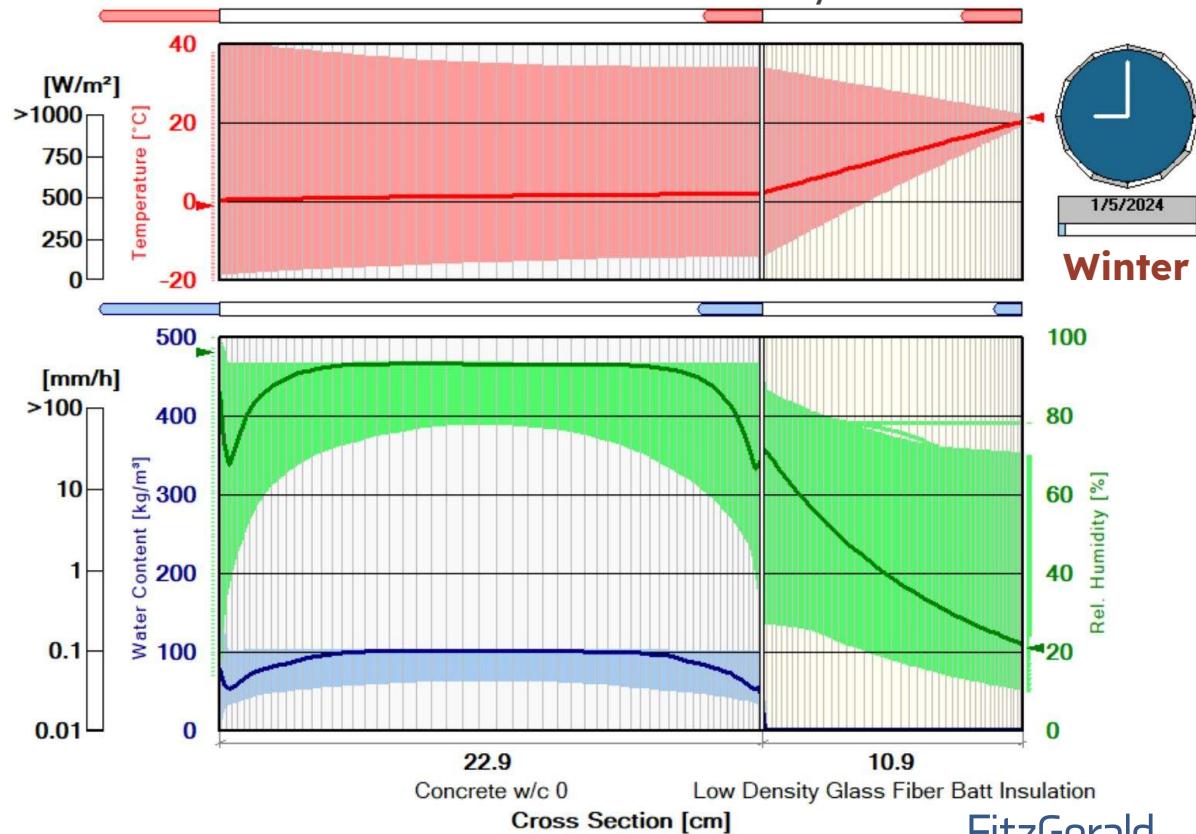
Case Study: Athletic Center

How it could work!



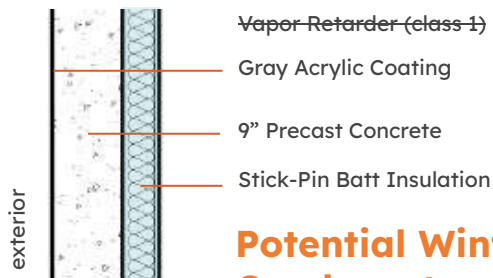
- Vapor diffusion is permitted to the interior/exterior
- Insulation stabilizes at a lower relative humidity

South Oriented Assembly



Case Study: Athletic Center

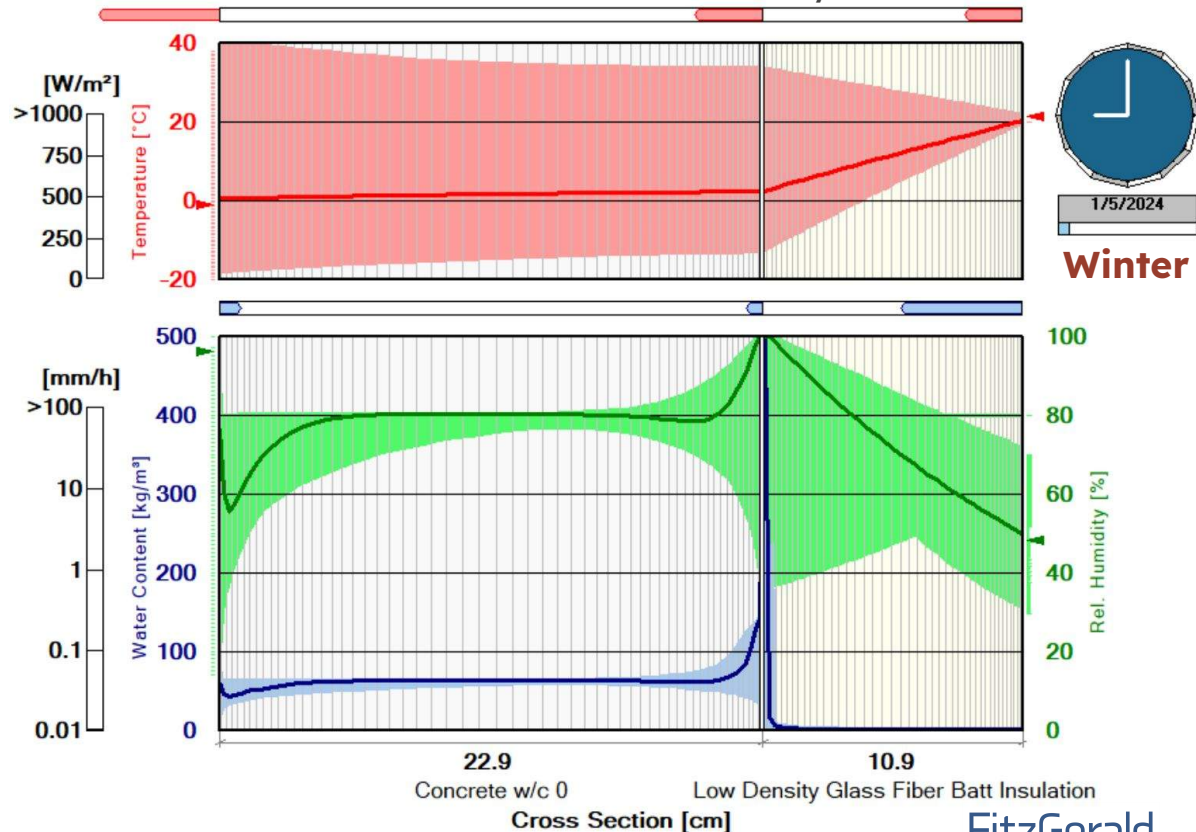
Air tightness matters



Potential Winter Condensate

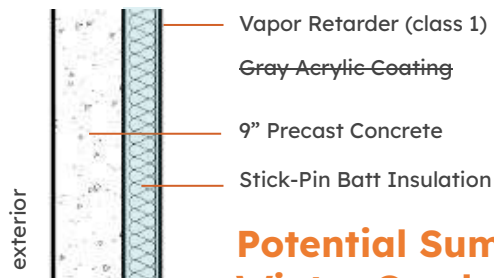
- Lower moisture content concrete gets much colder
- Unrestrained interior moisture will condense

South Oriented Assembly



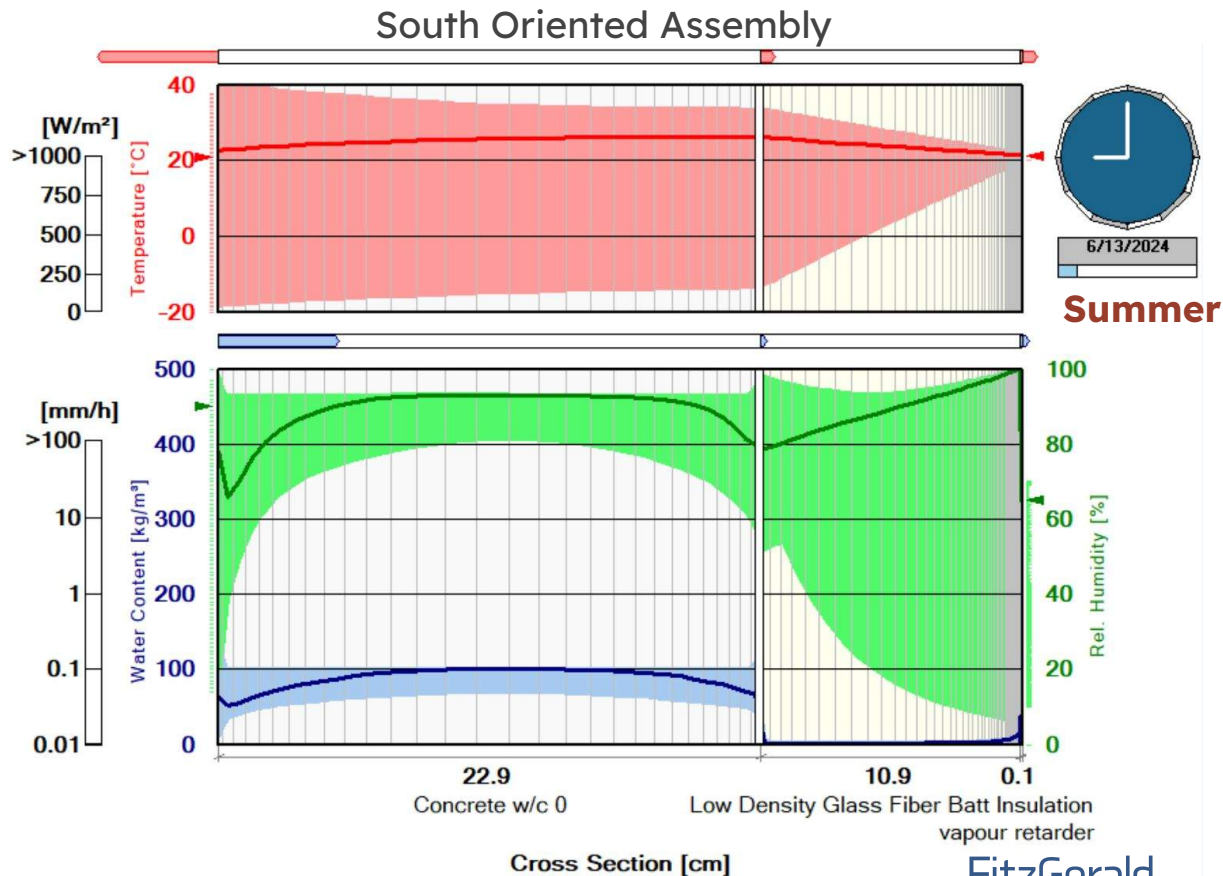
Case Study: Athletic Center

Careful with Vapor Barriers

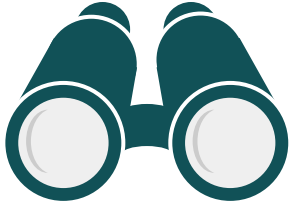


Potential Summer + Winter Condensate

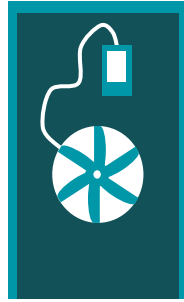
- Concrete naturally absorbs + diffuses moisture
- Vapor barrier will trap diffusion and condensate



In conclusion...



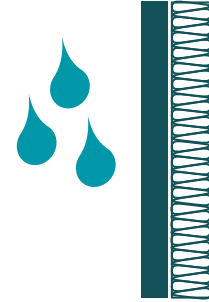
History of Code Updates



Enclosures and Codes



Energy Efficiency



Moisture Control in Enclosures

Thank You!
Questions?

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Charlie Saville

bskelton@cyclone.energy
csaville@fitzgeraldassociates.net