DuPont Safety & Construction

October 17, 2018

Durability, Resilience and Energy Efficiency: Working Together to Make Sustainable Buildings

HIGH PERFORMANCE HOME SUMMIT 2018
EEBA
OCTOBER 16-18 \ SAN DIEGO, CA

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Learning Objectives

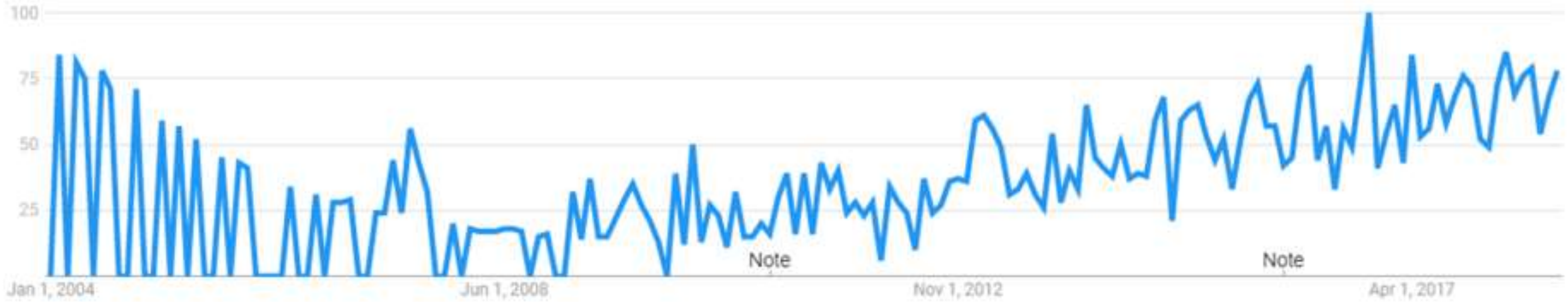
- Understand what Resilience is and how it relates to buildings
- Understand how to incorporate resilience into your buildings
- Understand basic building science principles of air, water and thermal management as they pertain to wall systems
- Understand the key material properties which must be assessed when designing wall systems with increased thermal and moisture performance

Resilience

Merriam-Webster definition:

2 : an ability to recover from or adjust easily to misfortune or change

Interest over Time (Google Trends)



Resilience –the new industry buzz word

Resilience is the New Sustainability

The US Resiliency Council is the nation's leading organization dedicated to helping achieve true community and corporate sustainability through the promotion of resilience based building design.

NIST's resilience research focuses on the impact of multiple hazards on buildings and communities and on post-disaster studies that can provide the technical basis for improved standards, codes and practices used in the design, construction, operation and maintenance of buildings and infrastructure systems.

The Uniqueness of ANCR's Community Resilience Benchmark

- Will provide a practical, easily understood benchmark for assessing cross-function resilience against which a community may measure itself and identify its strengths and weaknesses.
- Will provide a practical and easily understood pathway for action by identifying which standards, ratings, certifications and best practices a community should achieve or adopt to become more resilient.
- Will look at all aspects of the community's resilience – the built infrastructure, the economy and the social fabric – using a "whole community" approach.
- Will Consider the functions (rather than individual systems) that a community must perform to be resilient thereby inherently addressing the interdependency of critical systems.
- Will primarily uses existing standards, ratings, certifications and best practices to create the benchmark.

"The goal of the Community and Regional Resilience Institute (CARRI) is to strengthen any community or region's ability to prepare for, respond to, and rapidly recover from significant human caused or natural disaster with minimal downtime for the community."

Welcome to the RELi Resilience Action List + Credit Catalog. RELi <pronounced *rely*> combines a comprehensive list of resilient design criteria with the latest in proven integrative process for developing next generation communities, neighborhoods, buildings, homes and infrastructure. RELi is a project rating system similar to LEED®, but with added emphasis on resilience. The Credit Catalog includes *new* resilience-based actions (requisites + credits) pioneered for RELi in 2014. RELi also aggregates action items from other sustainable guidelines that support resiliency.

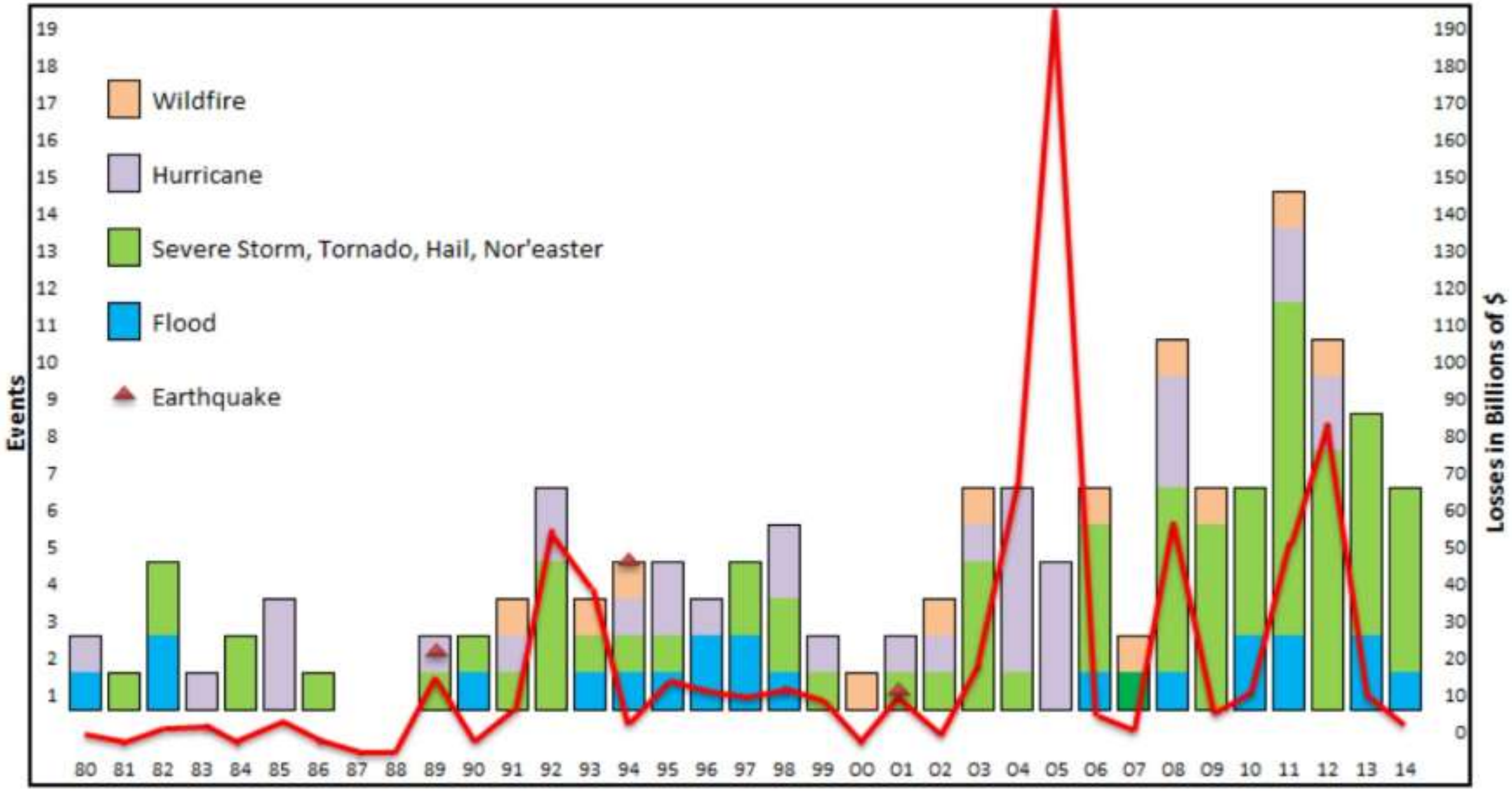
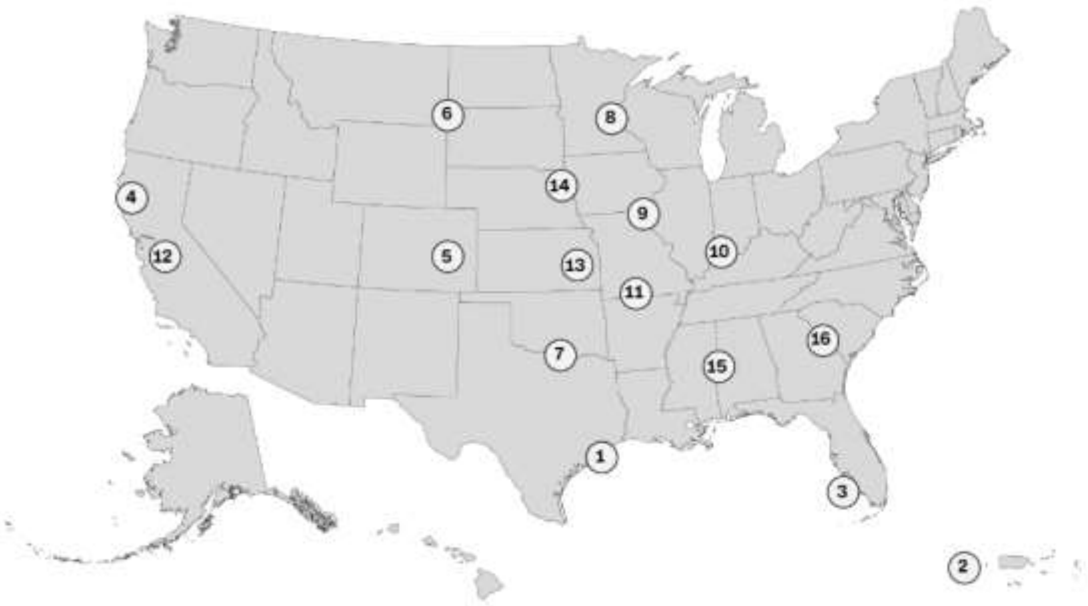


Figure 1: Billion Dollar+ Extreme Weather Events in Frequency and Losses from 1980-2014 (Earthquake Losses Included)[4]

From “Developing Pre-Disaster Resilience Based on Public and Private Incentivization,” National Institute of Building Sciences, October 29, 2015

2017 Disaster Costs



1. **$125B** Hurricane Harvey August 25-31
2. **$90B** Hurricane Maria September 19-21
3. **$50B** Hurricane Irma September 6-12
4. **$18B** Western wildfires, California firestorms Summer-Fall
5. **$3.4B** Colorado hail storm and Central severe weather May 8-11
6. **$2.5B** North Dakota, South Dakota and Montana drought Spring-Fall
7. **$2.6B** South/Southeast severe weather March 26-28
8. **$2.4B** Minnesota hail storm and Upper Midwest severe weather June 9-11
9. **$2.1B** Midwest tornado outbreak March 6-8
10. **$1.8B** Central/Southeast tornado outbreak February 28 - March 1
11. **$1.7B** Missouri and Arkansas flooding and Central severe weather April 25 - May 7
12. **$1.5B** California flooding February 8-22
13. **$1.5B** Midwest severe weather June 12-16
14. **$1.4B** Midwest severe weather June 27-29
15. **$1.1B** Southern tornado outbreak and Western storms January 20-22
16. **$1B** Southeast freeze March 14-16

Ref: *US shatters record for disaster costs in 2017* by Brandon Miller, CNN Meteorologist, Updated 12:06 PM ET, Mon January 8, 2018

Buildings are only one piece of resilience

Necessary Community Functions/Infrastructure:

- Buildings
- Business
- Communications
- Communication Infrastructure
- Culture & Recreation
- Education & Training
- Energy
- Finance
- Governance
- Local Government
- Natural Environment
- Neighborhoods
- Health Care
- Public Safety & Security
- Solid Waste
- Transportation
- Water

If one link is broken the community will not function properly.

An Ounce of Prevention is Worth a Pound of Cure.

~ Benjamin Franklin

He was referring to the inadequacies of fire safety. This led to efforts to become more resilient. As a result the Philadelphia Union Fire Company was formed. The led efforts to educate the public about fire safety and improved fire fighting techniques.

https://www.ag.ndsu.edu/news/columns/beeftalk/beeftalk-an-ounce-of-prevention-is-worth-a-pound-of-cure/

Modern Building Code Adoption is recognized as an essential criteria for achieving Resilience.

FEMA analysis from 2014 estimated approximately $500 million in annualized loss avoided in eight southeastern states due to do the adoption of modern building codes.

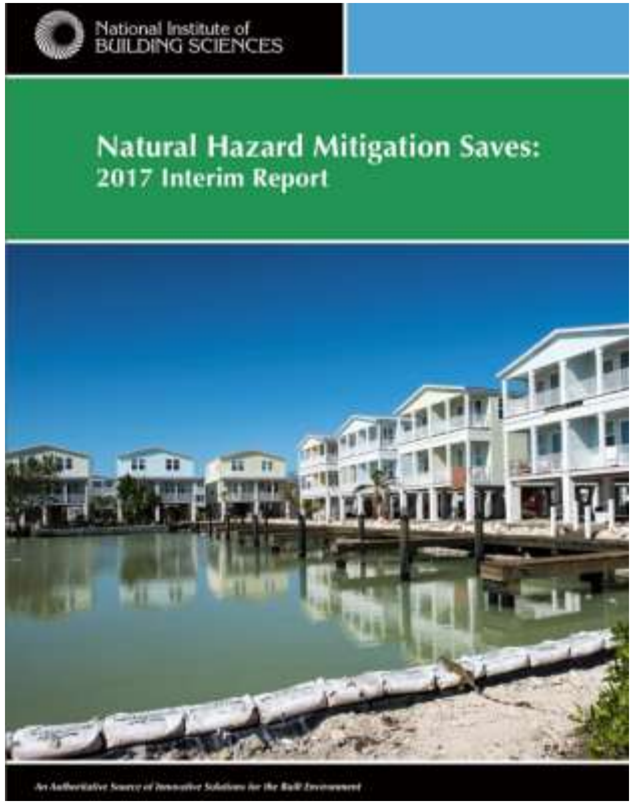
Disaster Recovery Reform Act of 2018 includes grants for updating codes.

Researchers at the Wharton School's Risk Management and Decision Processes Center found that modern and well-enforced building codes in Missouri have reduced hail damage to homes by 10 to 20 percent on average.

Alliance for National Community Resilience Buildings Benchmark Requirement (not yet published)

An Insurance Institute for Business & Home Safety study following Hurricane Charley found that post-Hurricane Andrew code improvements and code application in Florida reduced the frequency of property damage by 60 percent and the severity of damage by 42 percent for residences.

Benefit-to-Cost Ratio by Hazard and Mitigation Measure.



National Benefit-Cost Ratio Per Peril *BCR numbers in this study have been rounded	Federally Funded	Beyond Code Requirements
Overall Hazard Benefit-Cost Ratio	6:1	4:1
Riverine Flood	7:1	5:1
Hurricane Surge	Too few grants	7:1
Wind	5:1	5:1
Earthquake	3:1	4:1
Wildland-Urban Interface Fire	3:1	4:1

Resilient buildings are a critical component of resilient communities.

Building

Community

What makes a building resilient?

Buildings contribute to all phases of resilience.

Mitigation

- Moisture Management
  - Mold prevention
  - Condensation prevention
  - Decay prevention
  - Flood prevention
- Air Leakage Mitigation
  - Pollutant mitigation
  - Condensation prevention
  - Thermal performance
- Thermal Performance
  - Affordability
  - Comfort
- Structural Performance
  - Wind damage prevention

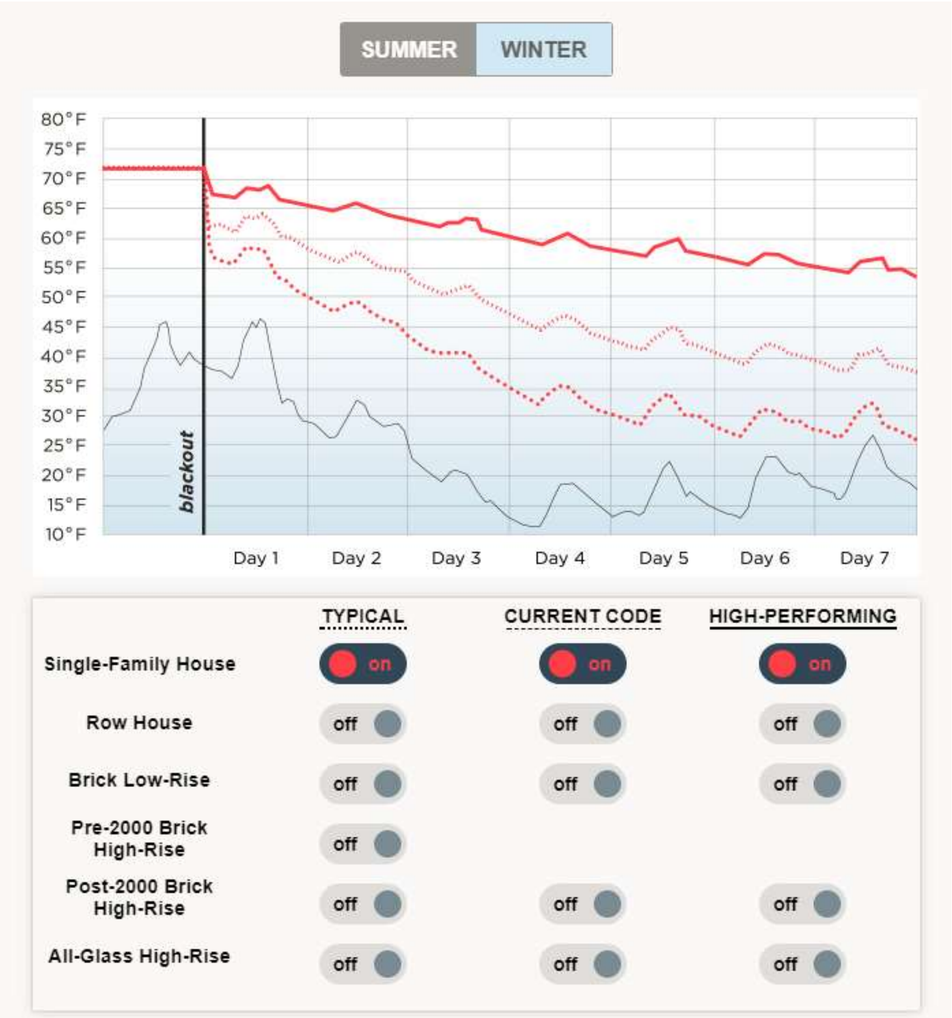
Response

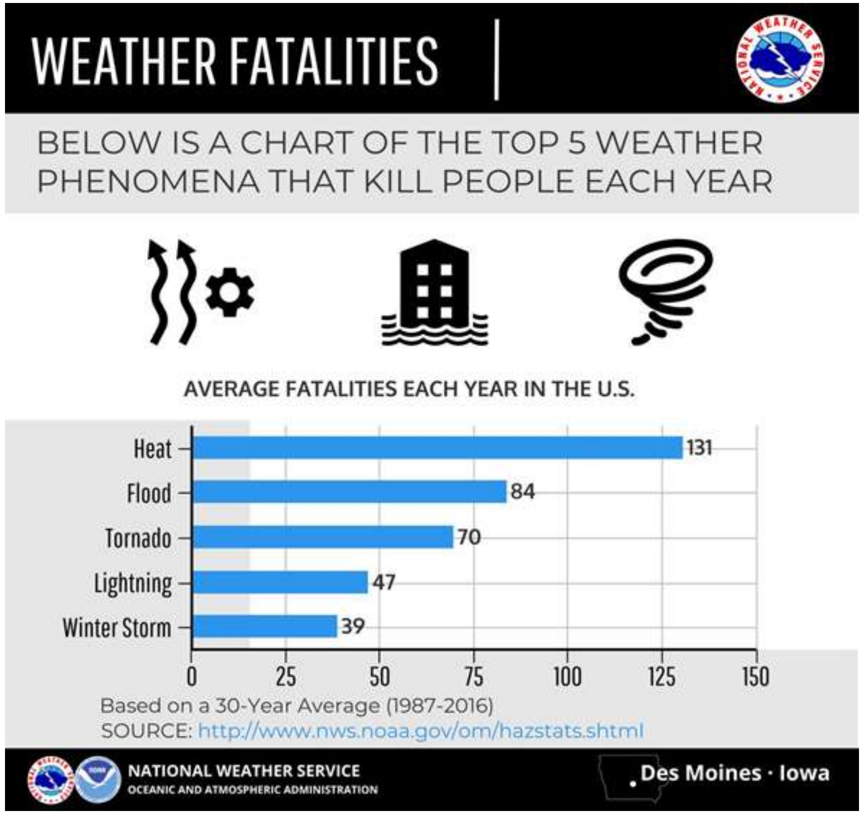
- Moisture Management
  - Manage bulk rain water
  - Condensation controlled
- Air Leakage
  - Smoke and other pollutants kept out
  - Condensation minimized
  - Thermal performance maximized
- Thermal Performance
  - Ability to shelter in place with power loss
- Structural Performance
  - Roof and exterior material stability under stress

Recovery

- Moisture Management
  - Materials and assemblies that stay dry or dry quickly
- Air Leakage
  - Condensation minimized
  - Thermal performance maximized
- Thermal Performance
  - Ability to shelter in place with power loss
- Structural Performance
  - Easy minor repairs

Energy Efficiency including thermal envelope efficiency is important aspects of Resilience.





Typical buildings would be between 32°F and 43°F indoors. New buildings are a little better, but still not resilient. A high-performing building that has better windows, fewer air leaks and more insulation would do much better. Without power, these buildings would stay at 54-66°F for a week or more.

Baby It's Cold Inside, 2014 report by Urban Green a Chapter of USGBC, modeling by Atelier Ten

Building Resilience

Assembly Performance

Quality Installation

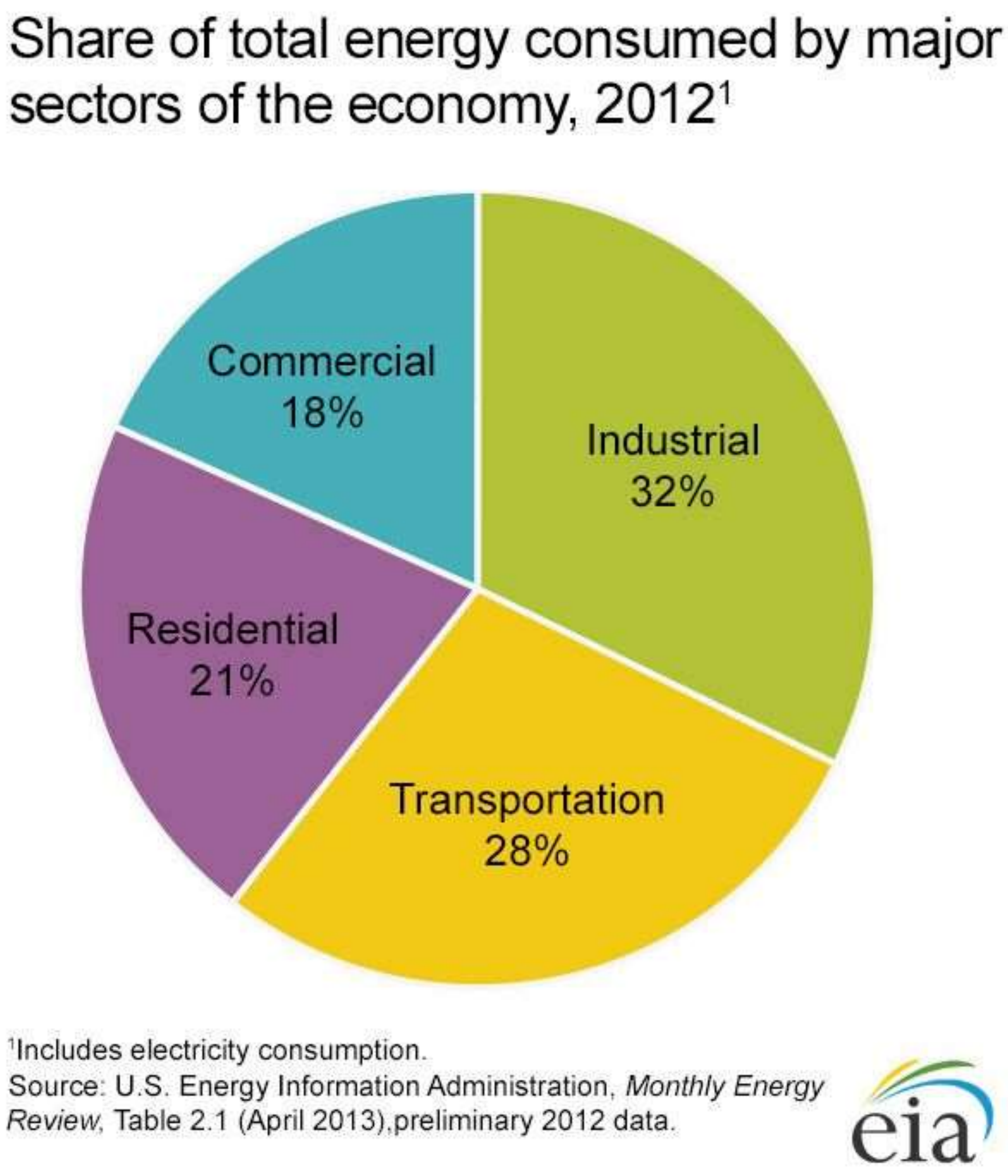
Quality Materials

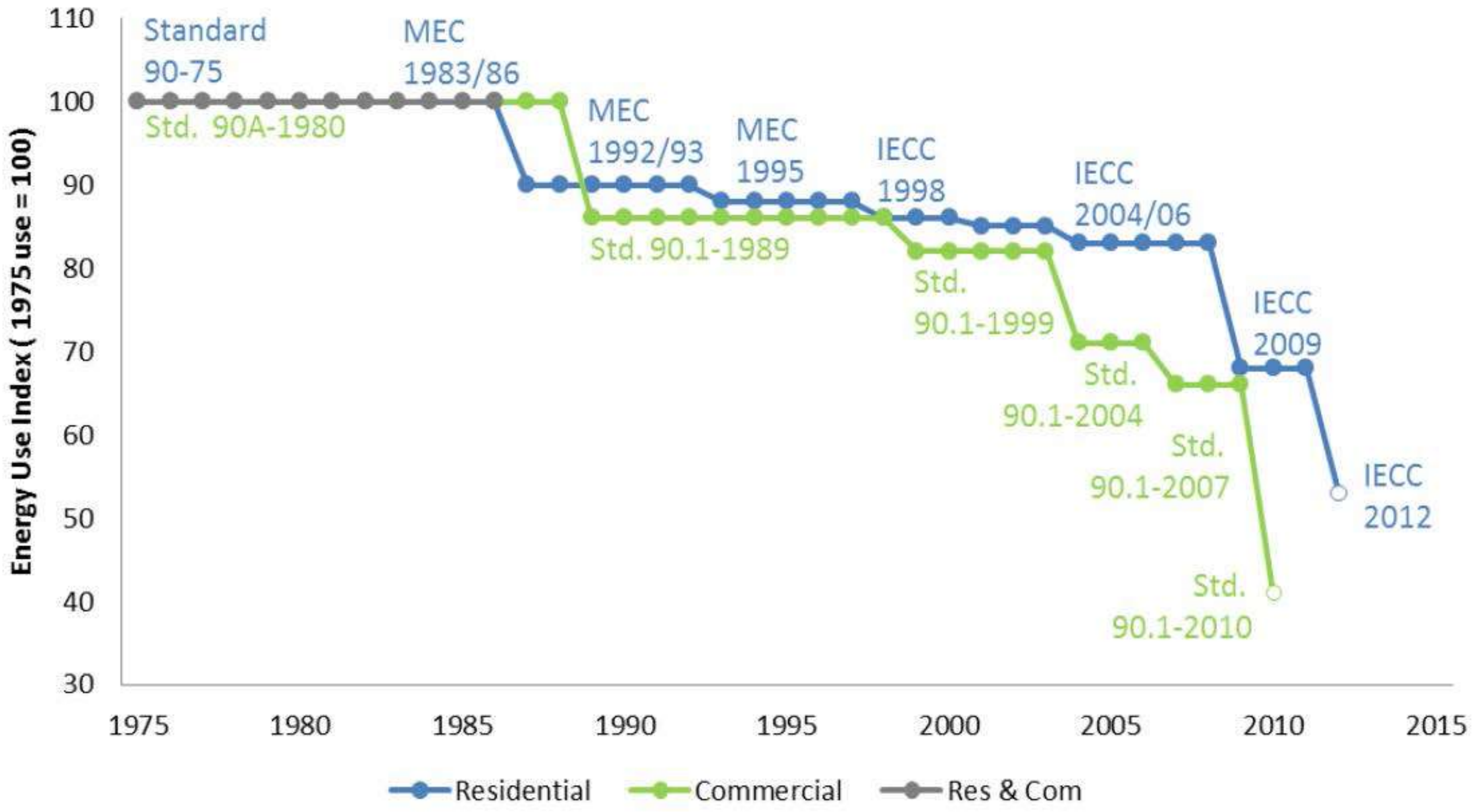
Durability

Energy Efficient

Air & Moisture Management

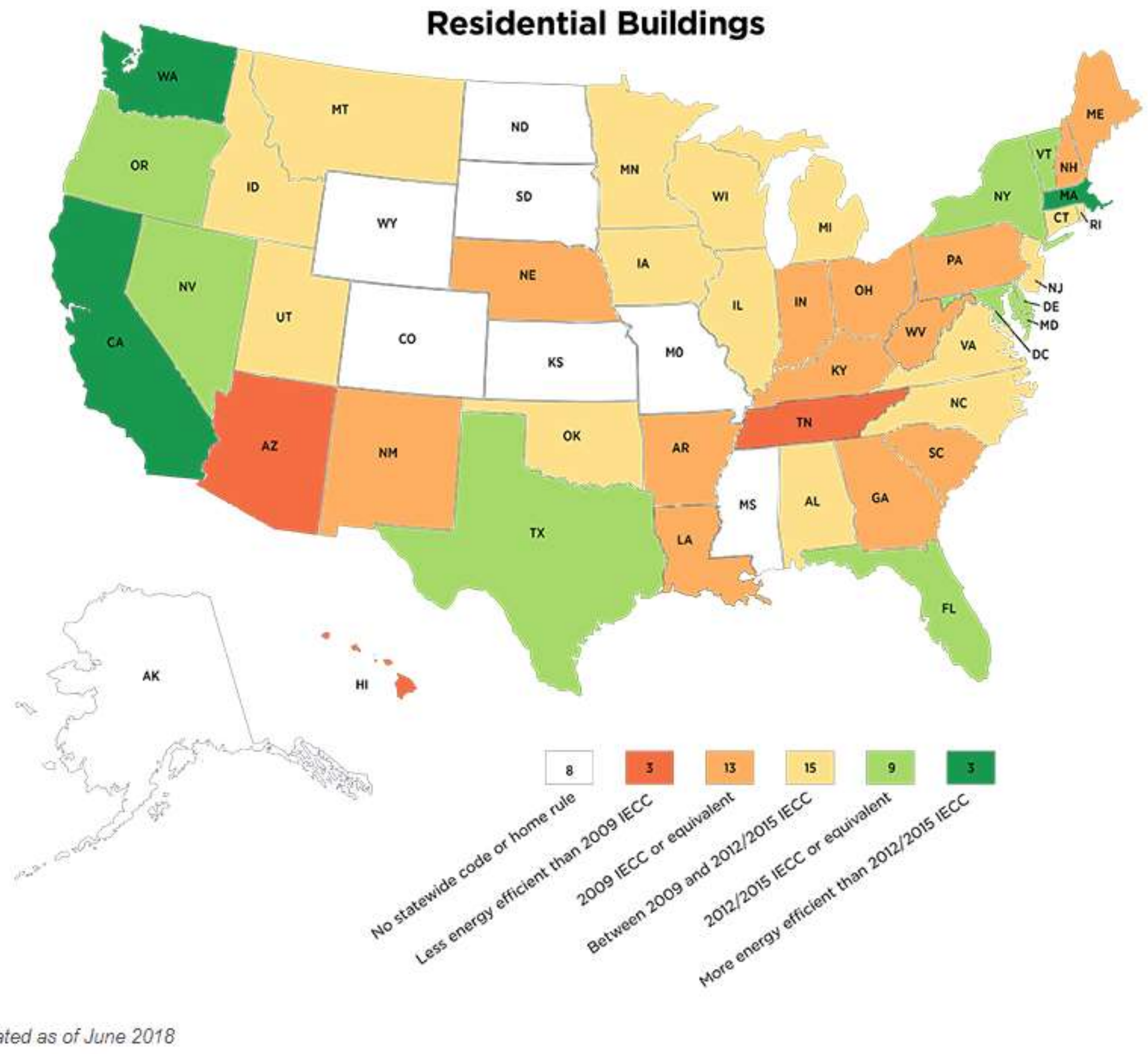
Energy Efficient





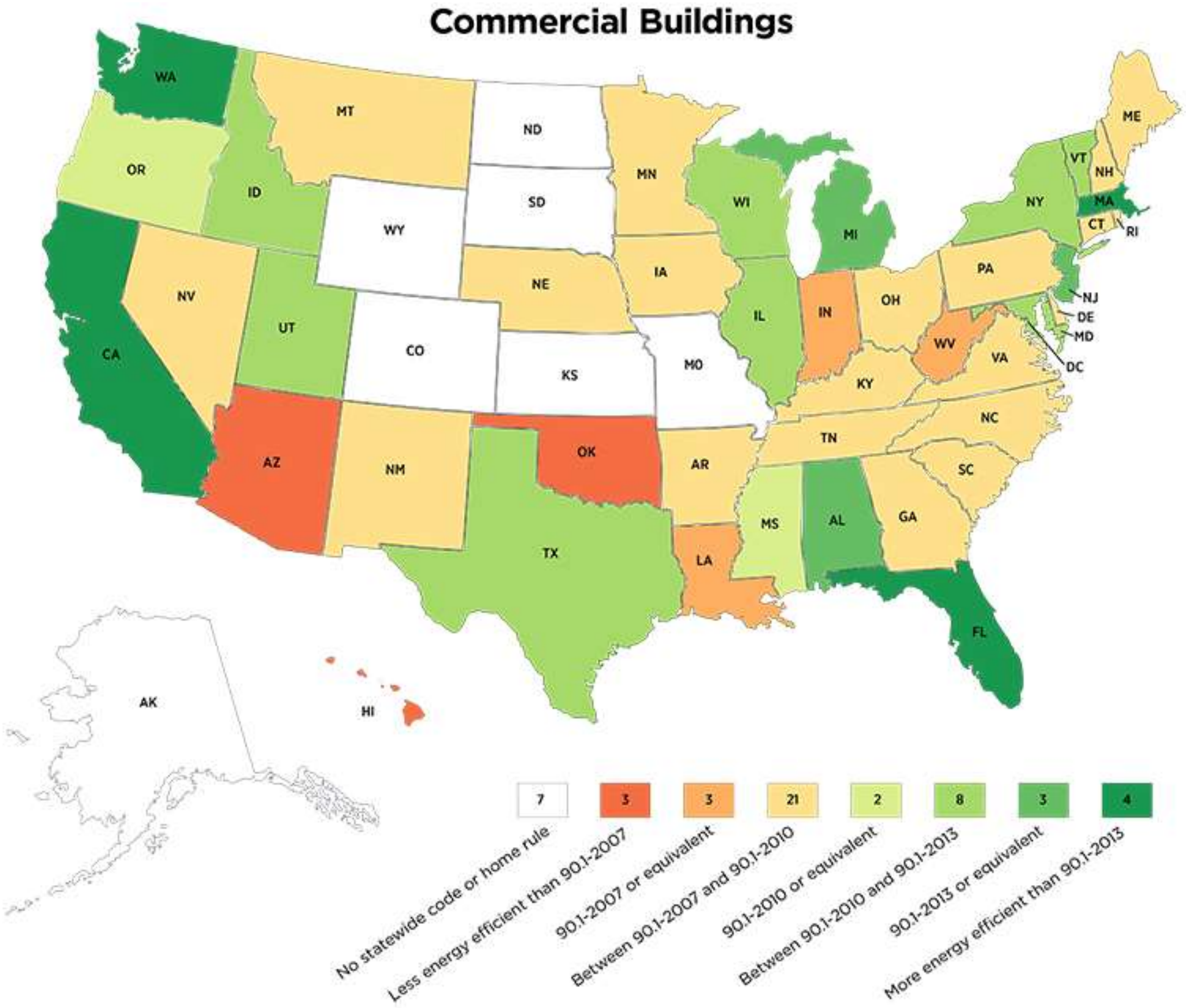
Dennis Hidalgo, LEED AP O+M, *The Importance of Building Energy Codes: How to Engage the Architectural Community,* prepared by the Building Codes Assistance Project at the Alliance to Save Energy for the Sea Change Foundation,

State Adoption of IECC-R



From energycodes.gov

State Adoption of IECC-C



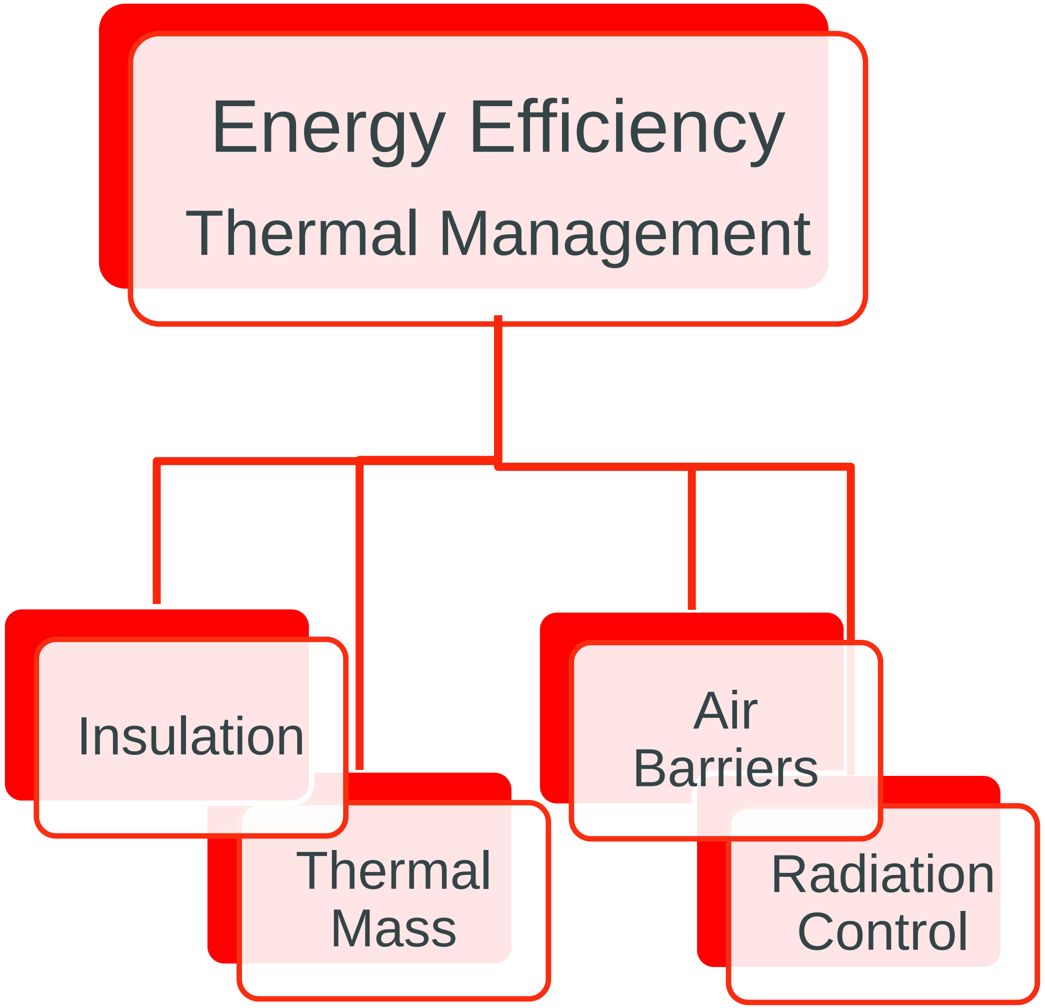
From energycodes.gov

Updated as of June 2018

Building Energy Efficiency

Building Envelope	• Insulation • Air Sealing • Fenestration
Mechanical Systems	• Heating & Cooling • Ventilation • Water Heating
Lighting	• Lighting • Controls

Building Envelope



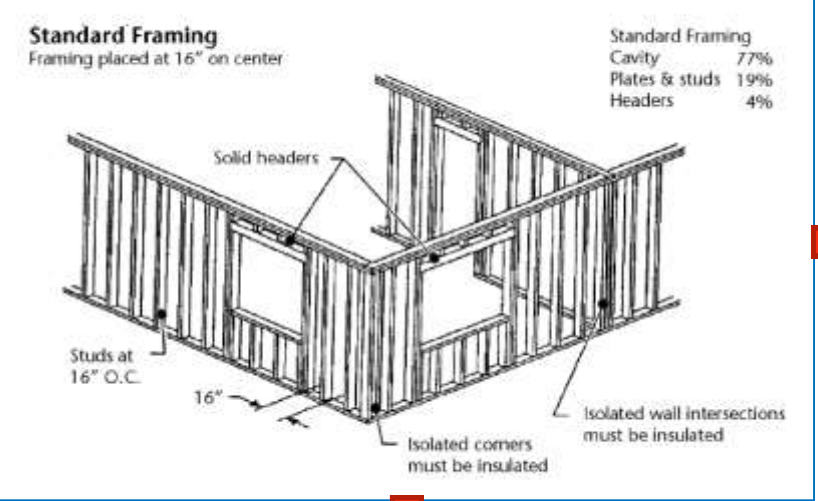
- Increase cavity insulation
- Increase continuous insulation (ci) Reduce thermal bridges
  - Advanced framing
  - Continuous insulation
- Reduce air leakage
  - Air barriers
  - Air impermeable insulation
  - Insulation installation

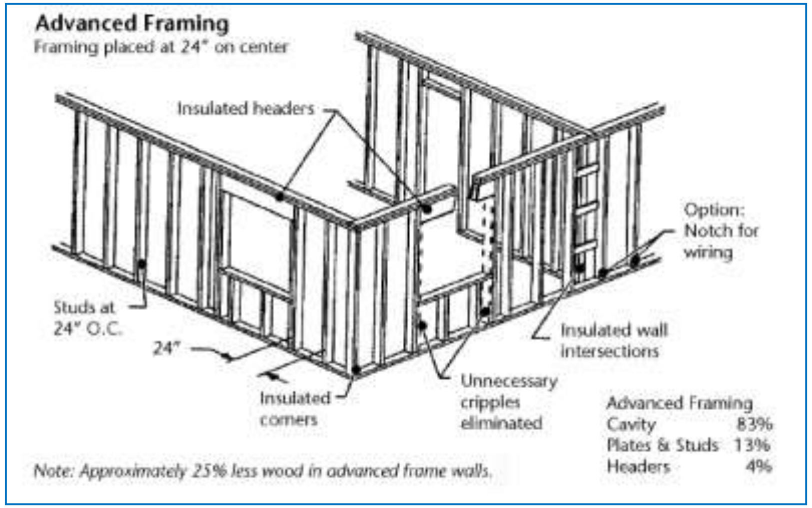
Thermal Bridges

No Exterior Continuous Insulation

With Exterior Continuous Insulation

Reducing Thermal Bridges





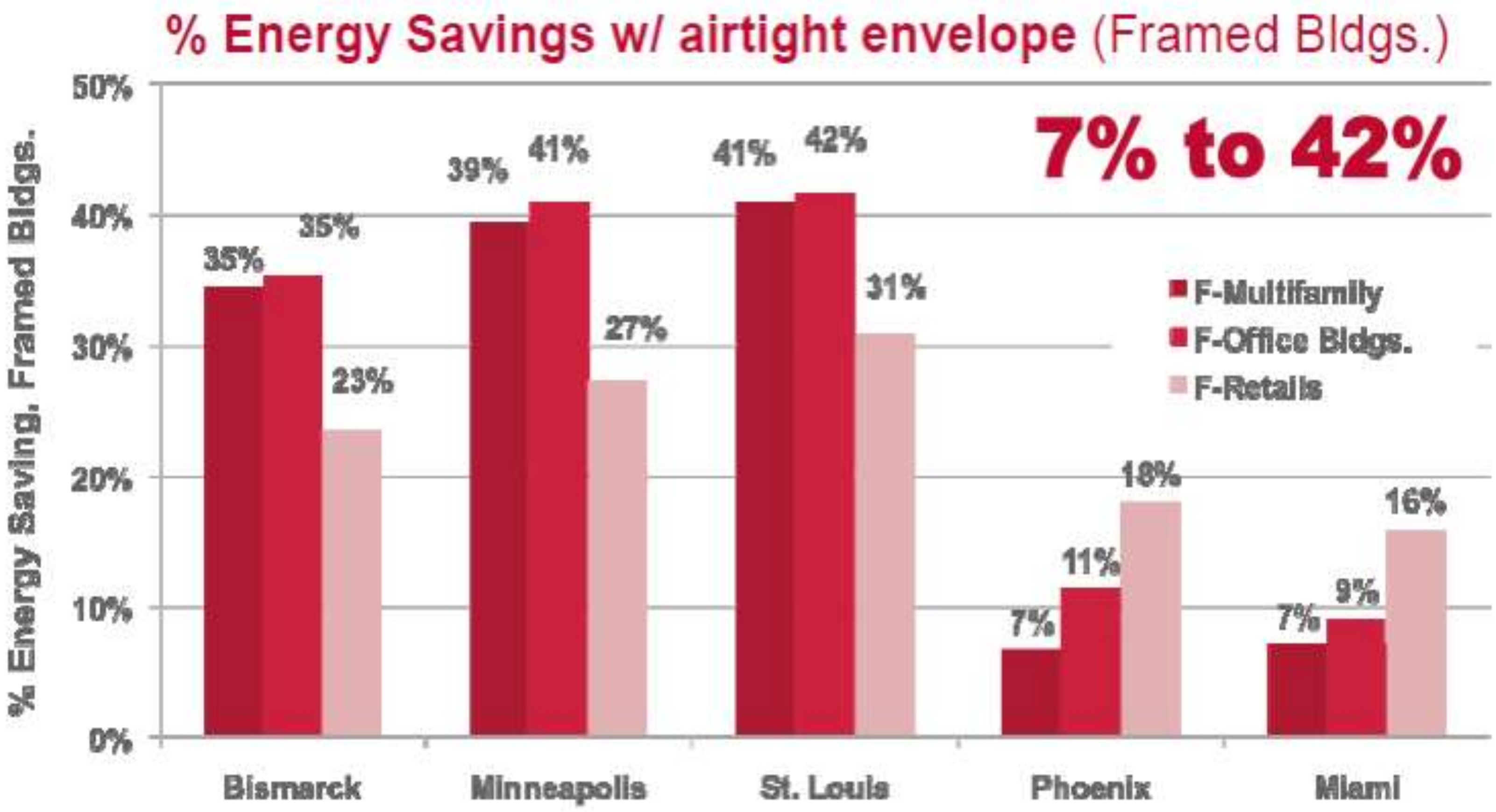
Exterior Continuous Insulation

Figures from *WSEC Builder's Field Guide, 8th Edition*, Washington State University Extension Energy Program. Photo courtesy of Construction Instruction.

R-values of Components & Assemblies

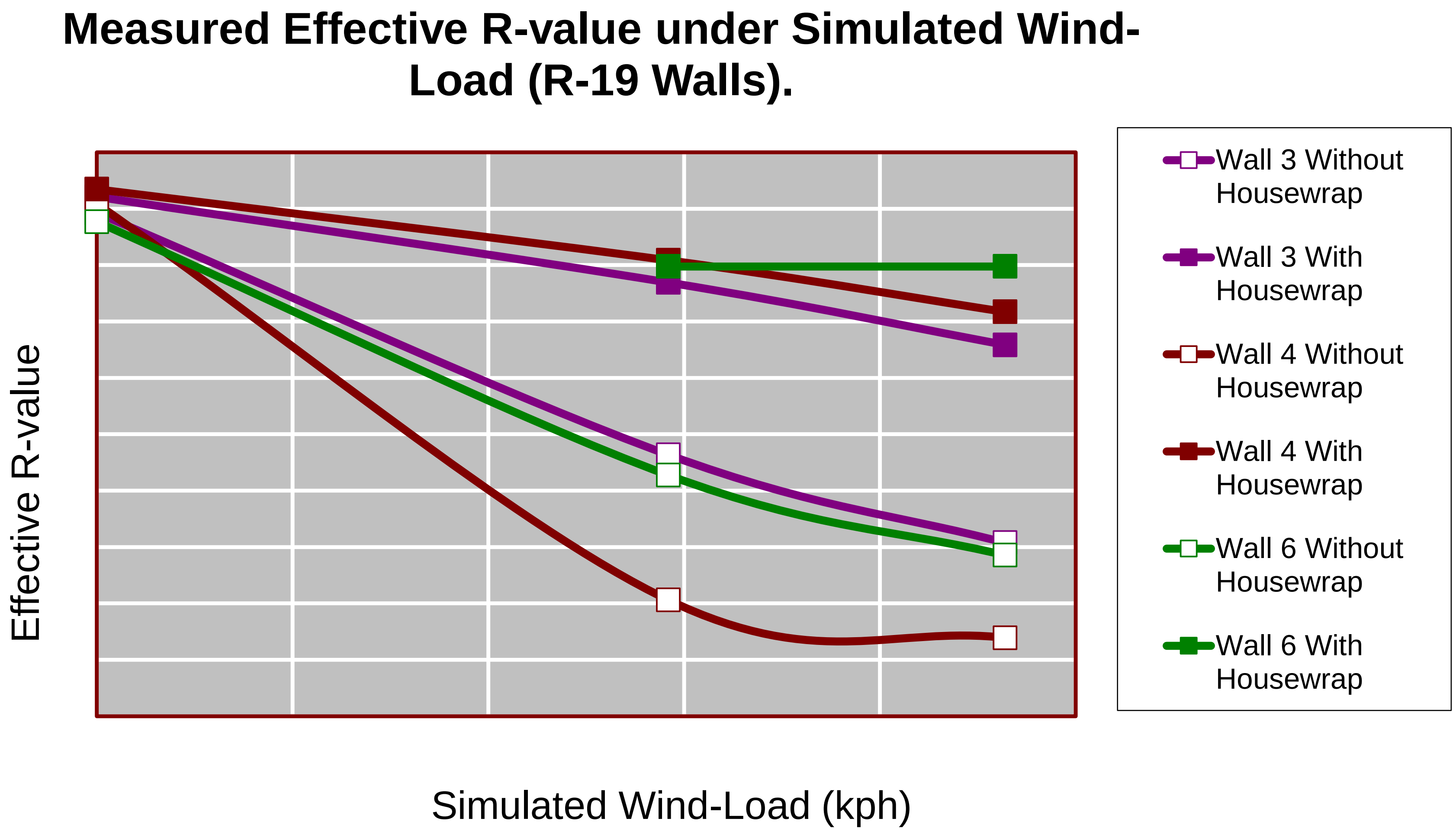
Wall Assembly Component	2x4		2x6		2x4 + c.i.	
	Studs	Cavity	Studs	Cavity	Studs	Cavity
Outside Air Film	.17	.17	.17	.17	.17	.17
Exterior Insulation	n/a	n/a	n/a	n/a	5	5
½” OSB	.62	.62	.62	.62	.62	.62
Stud Wood	3.71	n/a	5.83	n/a	3.71	n/a
Cavity Insulation	n/a	13	n/a	20	n/a	13
½” Gypsum Wallboard	.45	.45	.45	.45	.45	.45
Interior Air Film	.68	.68	.68	.68	.68	.68
Total	**5.6**	**14.9**	**7.75**	**21.9**	**10.6**	**19.9**
Total Wall (Standard Framing - 23%)	**11**		**15**		**17**	
Total Wall (Advanced Framing – 17%)			**17**			

Effect of Air Leakage on Heating and Cooling Energy



Source: "Investigation of the impact of Commercial Building Envelope Airtightness on HVAC Energy Use", *S. J. Emmerich, Tim McDowell, W. Anis*

Air Leakage Impact on Energy Use:
Degradation of Air Permeable Thermal Insulation Performance



Source: Impact of Airflow on the Thermal Performance of Various Residential Wall Systems utilizing a calibrated hot box, Thermal Envelopes VI/ Heat Transfer in Walls -- Principles

Sustainable

1. the ability to be sustained, supported, upheld, or confirmed.
2. Environmental Science. the quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance:

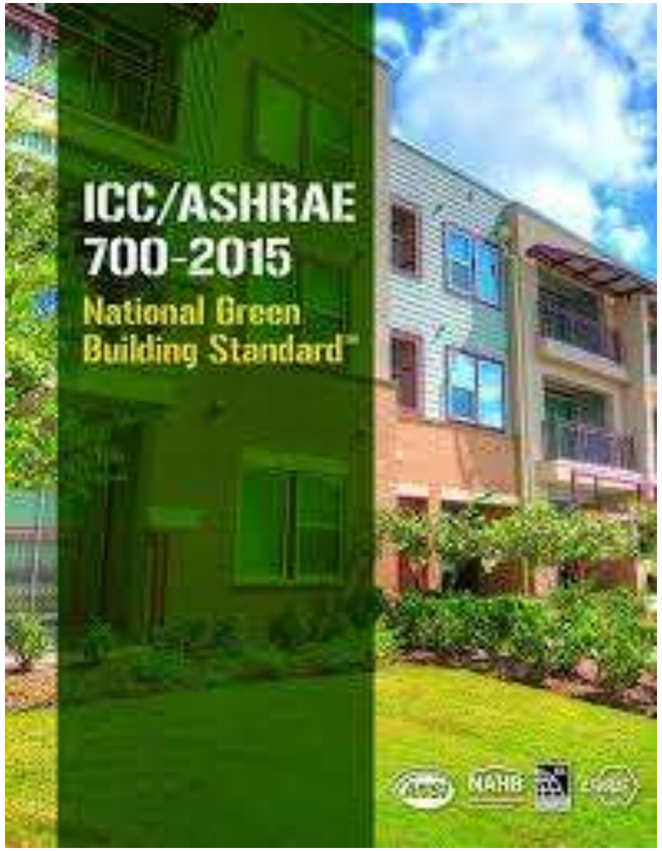
Interest over time: Google Trends


ENERGY
EFFICIENCY


LEED Credit Categories
Sustainable Sites
Water Efficiency
Innovation in Operations & Regional Priority
U.S. GREEN BUILDING COUNCIL
LEED
USGBC
Energy & Atmosphere
Indoor Environmental Quality
Materials & Resources

Building

Site



1) Scope and Administration
2) Definitions
3) Compliance Method
4) Site Design and Development
5) Lot Design, Preparation and Development
6) Resource Efficiency
7) Energy Efficiency
8) Water Efficiency
9) Indoor Environmental Quality
10) Operation, Maintenance and Building Owner Education
11) Remodeling
12) Remodeling of Functional Areas
13) Referenced Documents

Green-product attributes

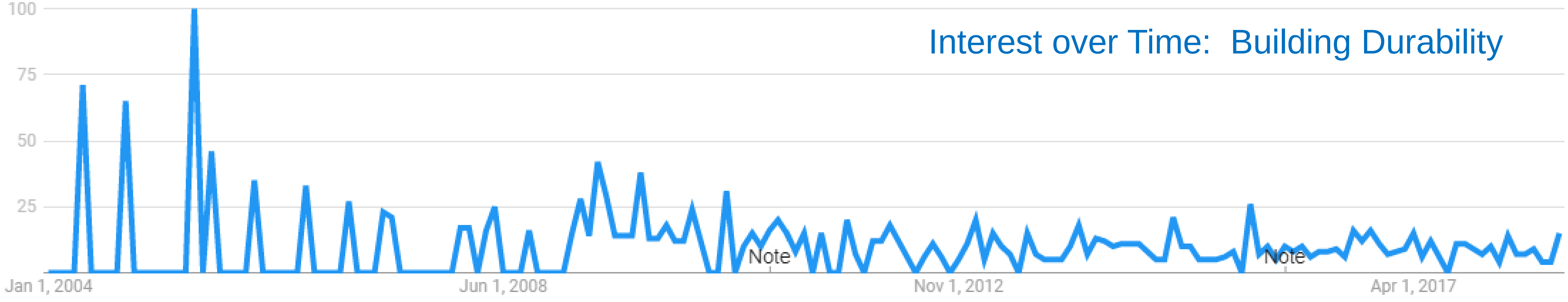
(rated by importance to user)

Ability to last the life of the building	4.38
Cost vs. equivalent conventional product	4.27
Availability of product to job site	4.16
Use of renewable resources	4.01

From Building Design & Construction White Paper on Sustainability, November 2003

Durability

1. the ability to withstand wear, pressure, or damage.



ASCE/SEI 7 Minimum Design Loads For Buildings and Other Structures

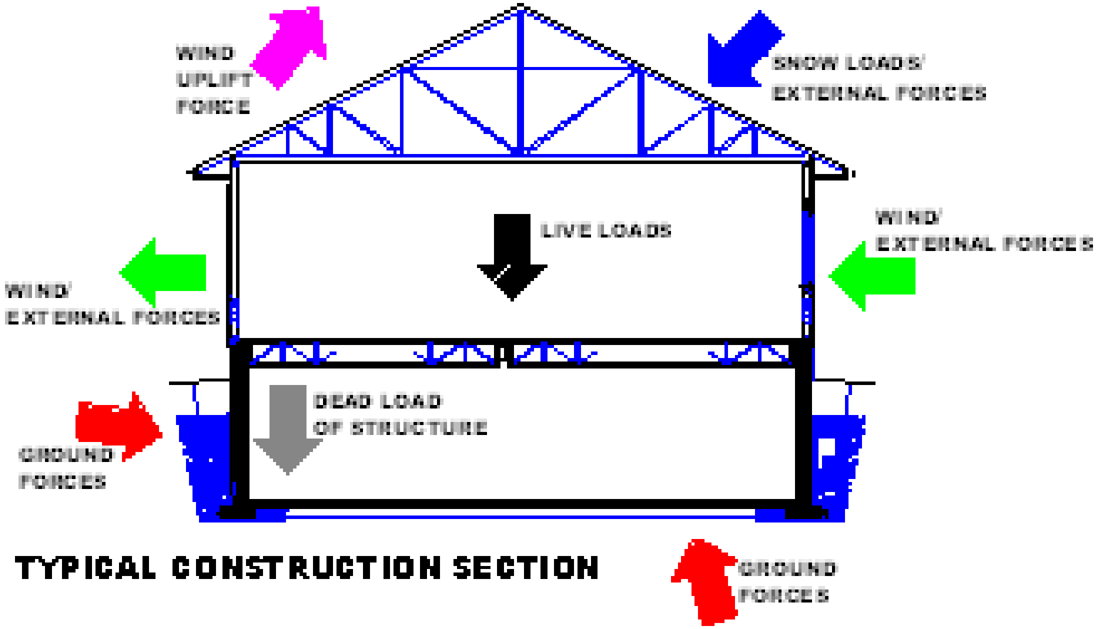


Figure from http://www.kdietrich.com/

S478-95

Guideline on Durability in Buildings

Structures (Design)

- Durability: *"the ability of a building or any of its components to perform its required functions in its service environment over a period of time without unforeseen cost for maintenance or repair."*

- *"Moisture, with or without contaminants, is the most important environmental agent causing premature deterioration. The application of principles of building science permits the generation of models for predicting the mechanisms, paths, volumes, and forms of moisture which building assemblies will need to accommodate and resist."*

Nationally, construction defect losses run into the billions.

- 69% of all construction defect claims are related to moisture penetration through the building envelope (2007 Study by University of Florida)
- The availability of general liability insurance for homebuilders and subcontractors has become increasingly limited and more expensive
  - *“The companies are finding it more difficult than five years ago to tap insurance to cover payments to homeowners because insurers have added so many exceptions, said Dave Stern, vice president at West Coast Casualty Service Inc., an insurance adjuster in Westlake Village, California. In California, “basically, the thing leaks, it’s the builder that’s liable,” Stern said.“*
- Some moisture problems are blamed on increasing energy efficiency
  - *"Building codes adopted in the 1970s and strengthened through the '80s and early '90s, required greater energy efficiency. Paradoxically, the demise of the drafty house had an unintended consequence: When moisture penetrates today's walls, they tend to stay wet."*

Sources: “Building Defects Spoil Homeowners’ Dreams, The Oregonian, June 19, 2005; “Homebuilder Shares Undermined by Creeping Costs of Construction Boom Flaws”, Bloomberg, February 10, 2011; Grosskopf and Lucas, “Identifying the Causes of Moisture-Related Defect Litigation in U.S.Building Construction”, COBRA 2008 The construction and building research conference of the Royal Institution of Chartered Surveyors, Dublin Institute of Technology, 4-5 September 2008.

Structural performance can be affected by moisture durability

"*EMERALD ISLE, N.C. – Nails deteriorated by years of exposure to the sand, salt and moisture from the ocean gave way, causing a deck collapse that hurt 24 people as they posed for a picture at a North Carolina beachfront home, authorities said.*" (Foxnews, July 6, 2015)

"*A memorandum from inspectors at the Berkeley Building and Safety Division says that the deck's severed joist ends -- horizontal, parallel beams that support a ceiling or floor -- looked "extensively rotted" where the structure had ripped from the wall.* " (CNN, June 23, 2015)

Photo from L A Times

Building Durability

↑

Assembly Durability

↑

Material Durability

Durability Defined Design Service Life of the Building

Table 2
Categories of Design Service Life for Buildings
(See Clauses 5.2.3 and 6.2.)

Category	Design service life for building	Examples
Temporary	Up to ten years	• non-permanent construction buildings, sales offices, bunkhouses • temporary exhibition buildings
Medium life	25 to 49 years	• most industrial buildings • most parking structures*
Long life	50 to 99 years	• most residential, commercial, and office buildings • health and educational buildings • parking structures below buildings designed for long life category*
Permanent	Minimum period, 100 years	• monumental buildings (eg, national museums, art galleries, archives) • heritage† buildings

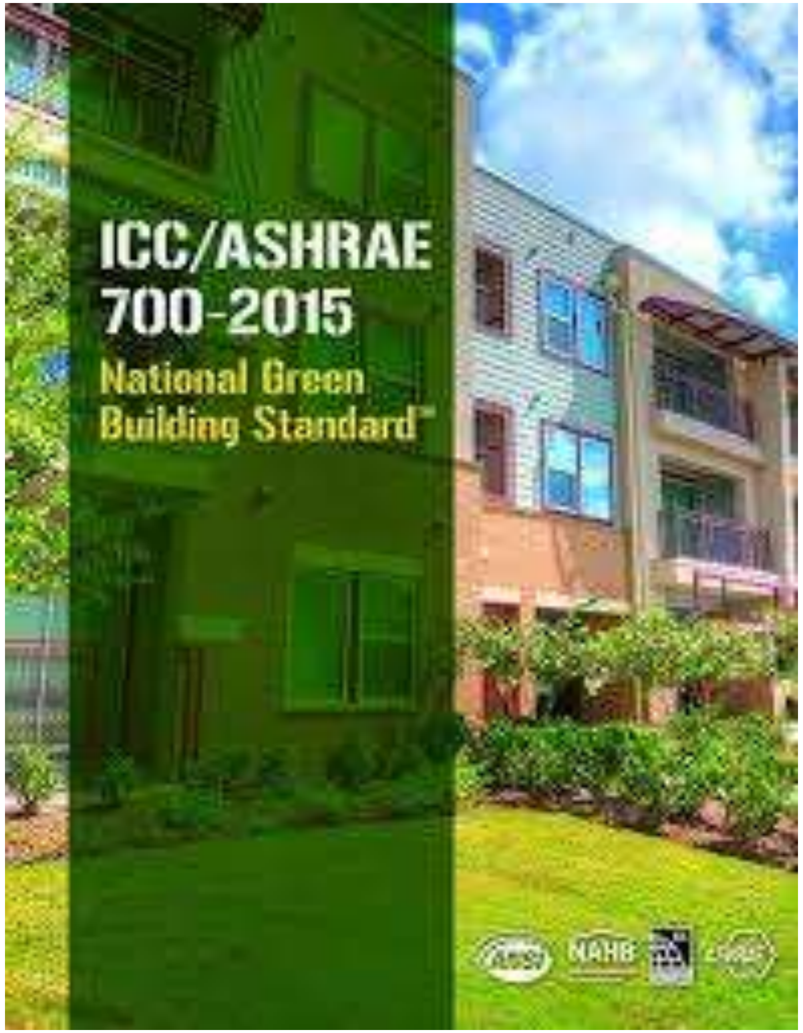
Reference: CSA S478-95 Guideline on Durability in Buildings

Building Durability

Assembly Durability

Material Durability

ICC/ASHRAE 700-2015 Chapter 6: Resource Efficiency



1. Quality of Construction Materials and Waste
2. **Enhanced Durability and Reduced Maintenance**
    1. **Intent**
    2. **Moisture management – building envelope**
    3. **Roof surfaces**
    4. **Roof water discharge**
    5. **Finished Grade**
3. Reused or Salvaged Materials
4. Recycled-Content Building Materials
5. Recycled Construction Waste
6. Renewable Materials
7. Recycling and Waste Reduction
8. Resource-Efficient Materials
9. Regional Materials
10. Life Cycle Assessment
11. Innovative Practices

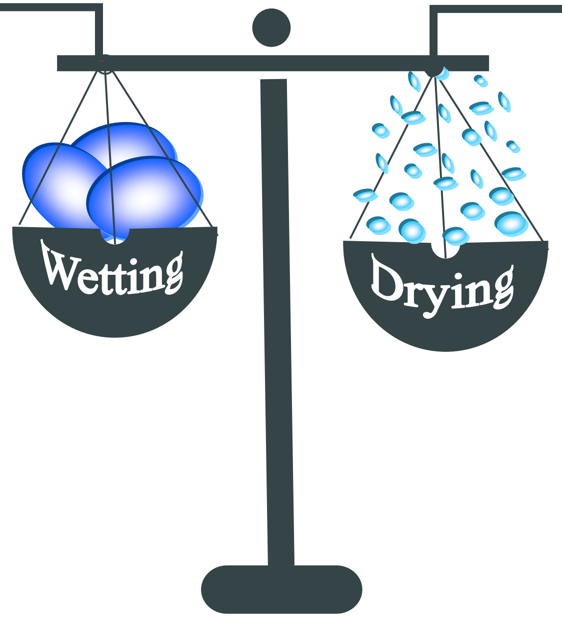
Manage the Moisture Balance to Avoid Potential Long Term Durability Risks

Minimize

Maximize

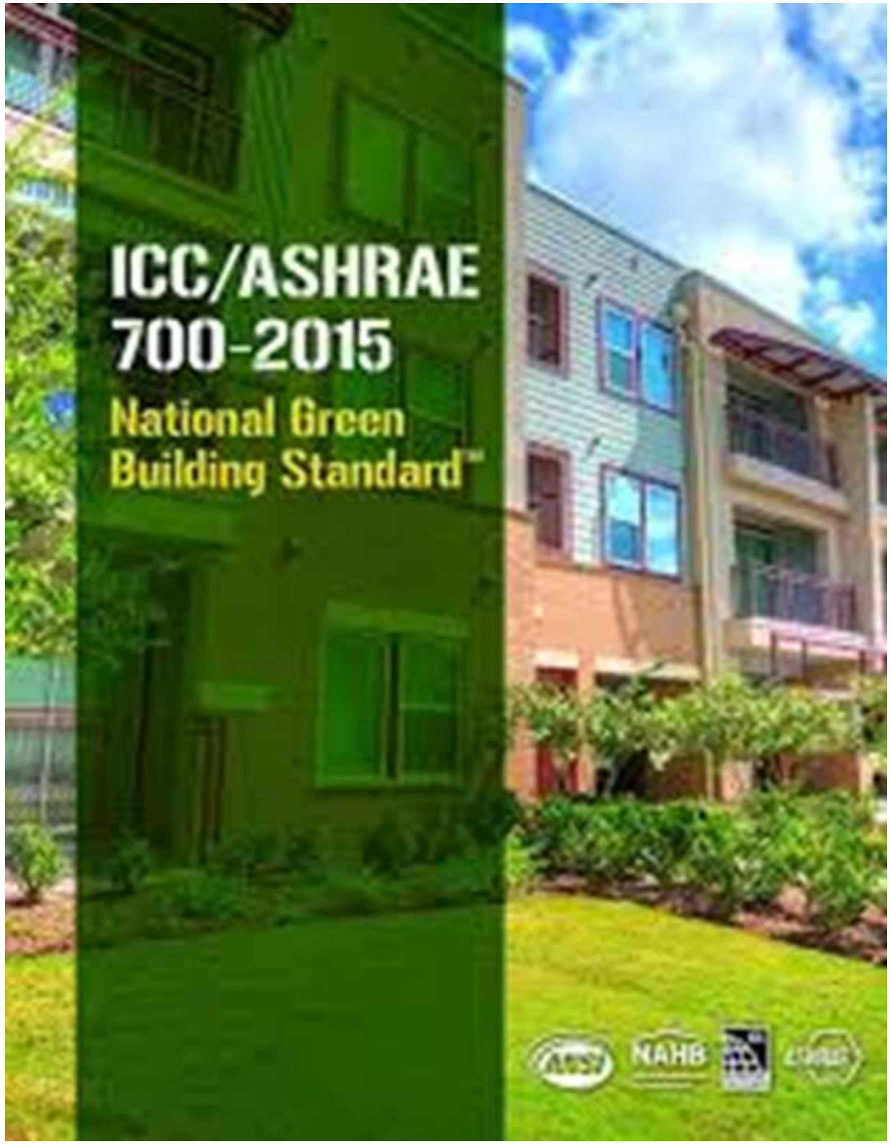
Wetting

1. Bulk Water
2. Air Flow transport
3. *Molecular Diffusion*



Drying

1. Drainage
2. Venting
3. Molecular Diffusion



- **602.1.8 Water-resistive barrier**. Where required by the ICC, IRC, or IBC, a water-resistive barrier and/or drainage plane system is installed behind exterior veneer and/or siding
- **602.1.9 Flashing.** Flashing is provided as follows to minimize water entry into wall and roof assemblies and to direct water to exterior surfaces or exterior water-resistive barriers for drainage. Flashing details are provided in the construction documents and are in accordance with the fenestration manufacturer's instructions, the flashing manufacturer's instructions, or as detailed by a registered design professional.

International Residential Code (2018): Wall Weather Resistance Requirements

R703.1 General. Exterior walls shall provide the building with a weather-resistant exterior wall envelope. The exterior wall envelope shall include flashing as described in Section R703.4.

R703.1.1 Water resistance. The exterior wall envelope shall be designed and constructed in a manner that prevents the accumulation of water within the wall assembly by providing a water-resistant barrier behind the exterior veneer as required by Section R703.2 and a means of draining to the exterior water that penetrates the exterior cladding.

- **Flashing**
- **Water-resistive barrier**
- **Means of draining water**

Vapor Retarder Requirements – Interior side of frame walls

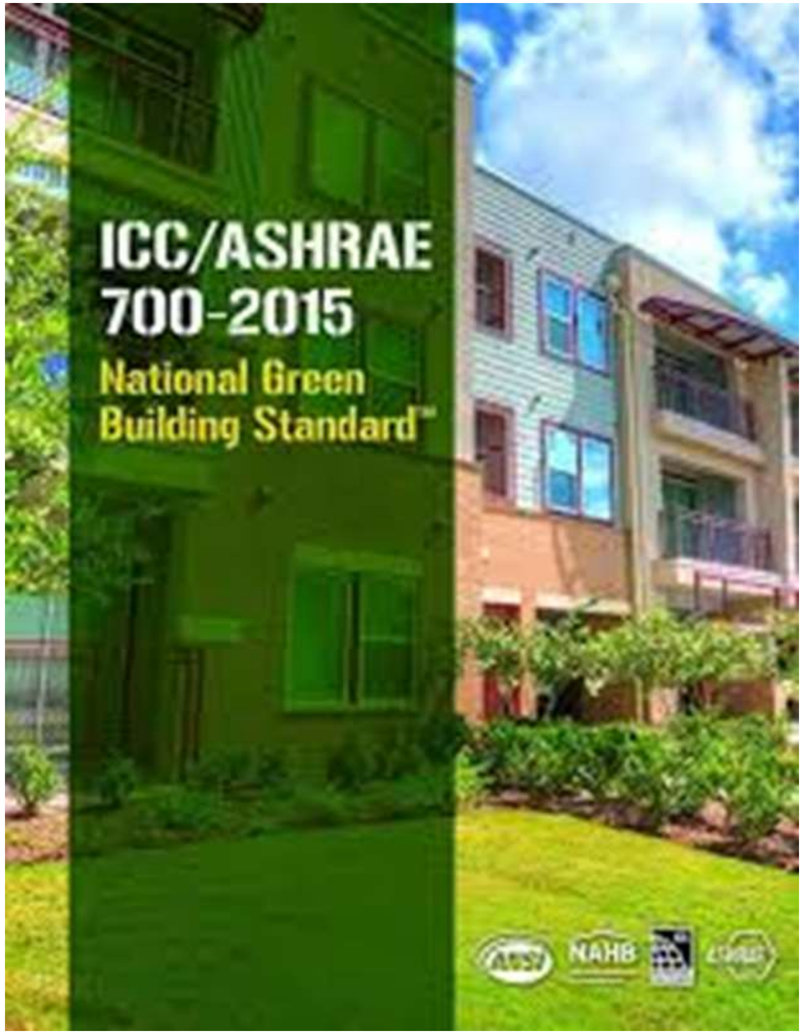
Climate Zone	IRC Requirement	IRC Exceptions	IBC - Requirement	IBC Exceptions
1 & 2	No required vapor retarders		Class I or II vapor retarders shall not be provided	
3	No required vapor retarders		Class I vapor retarders shall not be provided	
4 x-marine	No required vapor retarders		Class I vapor retarders shall not be provided	
4 marine	Class I or II vapor retarders shall be provided	Class III vapor retarders can be used with vented cladding or specific R-values of exterior insulation.	Class II vapor retarders shall be provided	Class III vapor retarders can be used with vented cladding or specific R-values of exterior insulation. Only Class III vapor retarders shall be used with exterior foam plastic insulating sheathing with perm rating of less than 1 perm
5 to 8	Class I or II vapor retarders shall be provided	Class III vapor retarders can be used with vented cladding or specific R-values of exterior insulation.	Class I or II vapor retarders shall be provided	Class III vapor retarders can be used with vented cladding or specific R-values of exterior insulation Only Class III vapor retarders shall be used with exterior foam plastic insulating sheathing with perm rating of less than 1 perm

Assembly Durable Design Demonstration

Demonstrated Effectiveness

Modelling

Testing



602.1.7.3 Building envelope assemblies are designed for moisture control based on documented hygrothermal simulation or field study analysis. Hygrothermal analysis is required to incorporate representative climatic conditions, interior conditions and include heating and cooling seasonal variation.

(4 points)

Modelling

- Simulation and Analysis
- Moisture Performance Evaluation Criteria
  - Mold
  - Corrosion

STANDARD

ASHRAE

ANSI/ASHRAE Standard 160-2016
(Supersedes ANSI/ASHRAE Standard 160-2009)
Includes ANSI/ASHRAE addenda listed in Annex D

Criteria for Moisture-Control Design Analysis in Buildings

See Annex D for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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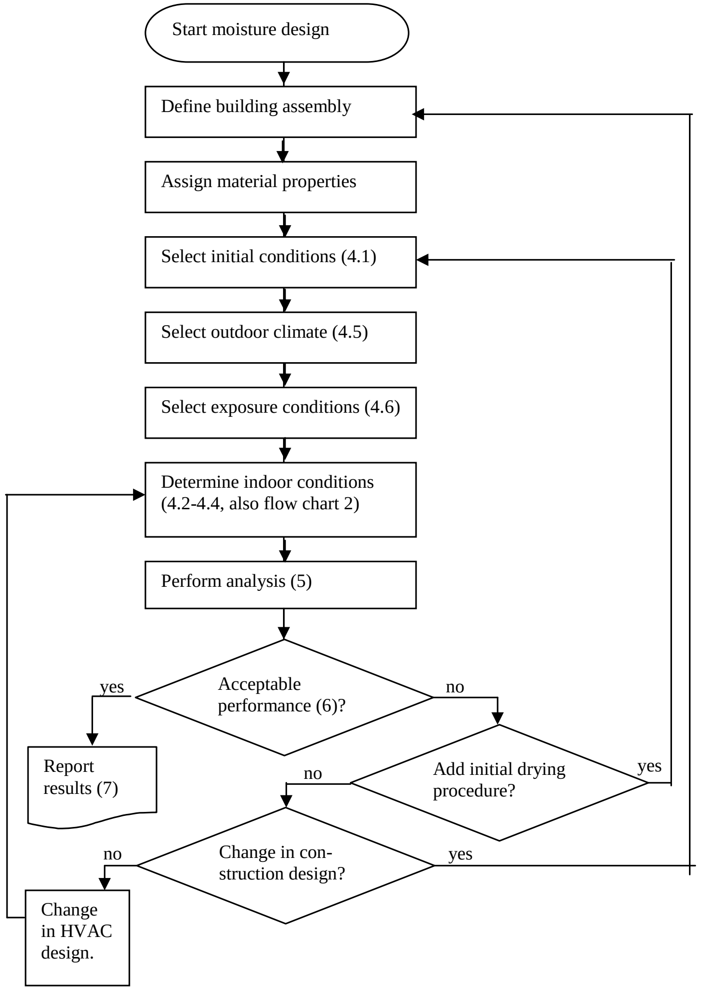
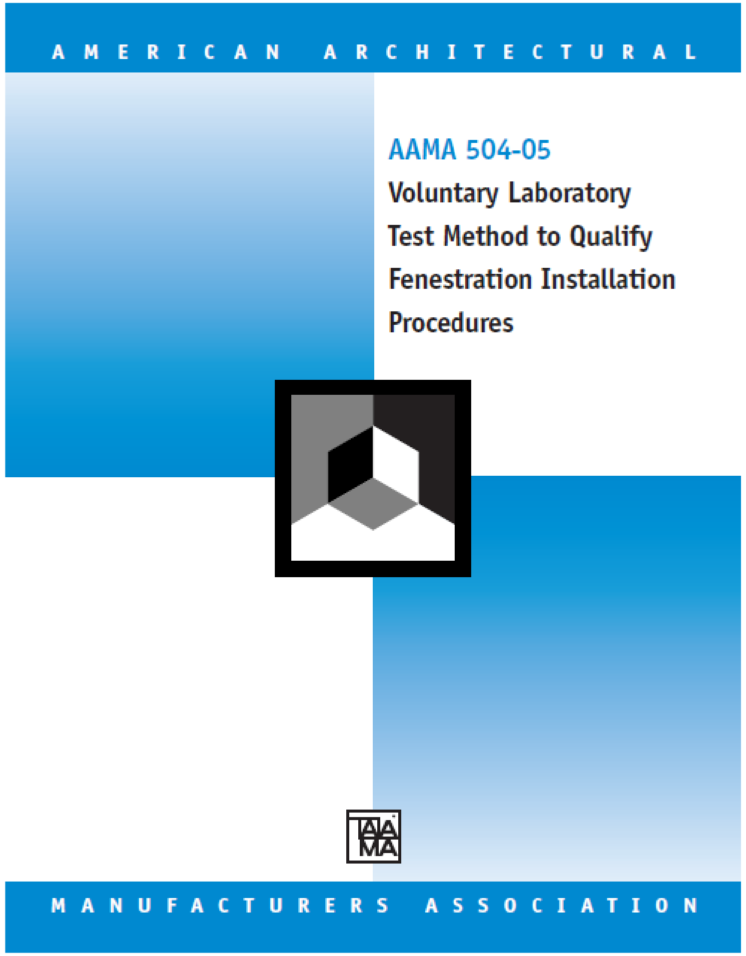
ANSI



Testing



Test Assembly: fenestration product, fasteners, sealant, flashing components and weather resistant barrier shall be included. Exterior cladding, interior perimeter cavity insulation and expanding foam shall not be applied to the test mockup for this evaluation.

The completed mockup shall be preloaded prior to testing using 10 positive cycles of 480 Pa (10 psf) followed by 10 negative cycles of 480 Pa (10 psf).

Test for air leakage in accordance with ASTM E 283 at a pressure differential of 75 Pa (1.57 psf).

Test for water penetration resistance in accordance with ASTM E 331 at a minimum test pressure of 150 Pa (3.0 psf) for 60 minutes.

The entire mockup shall be subjected to 14 twelve hour durability cycles in accordance with ASTM E 2264 Method A, Level 1:

- *Exterior Temperature Exposure*
  - **Level 1 49°C (120 °F)**
  - Level 2 3°C (150 °F)
  - Level 3 82°C (180 6°F)

Exterior Low Ambient Air Temperature: –30°C (–22°F)

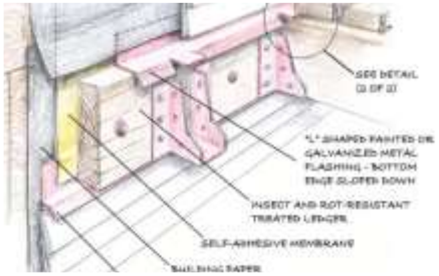
Following cycling, the mockup shall again be tested for air leakage and water penetration resistance

The entire mockup shall be tested for structural loads in accordance with ASTM E 330 at a minimum test pressure of 1440 Pa (30 psf) positive and negative.

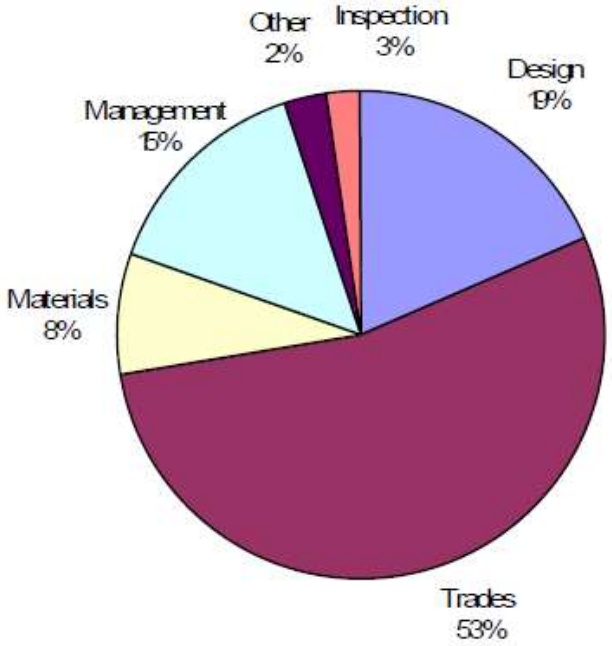
Durability of Assemblies

Design

Construction



Compatibility at Interfaces



Percentage of construction defect claims by cause

Reference: Grosskopf, K. R. and D. E. Lucas, "Identifying the Causes of Moisture-Related Defect Litigation in U. S. Building Construction", COBRA 2008 – The Construction and Building Research Conference of the Royal Institution of Chartered Surveyors, Dublin, Sept 4-5, 2008

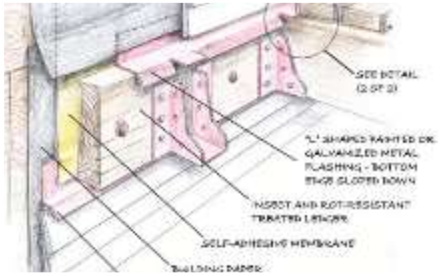
Construction

- Safety & ergonomics during the construction process
- Job-site storage requirements
- Installation dependence on environmental conditions
- Ease of installation
  - installed in a similar way to existing products?
  - can be installed by existing trades?
  - does it require a high level of specialization to install ?
- Reliability & repeatability of the installation.
- Integration with other products
  - can the next group of laborers work easily on top of it?

Durability of Assemblies

Design

Construction



Material Interfaces

Designing Details

Window and Wall Assemblies should be considered as a system, not individually.

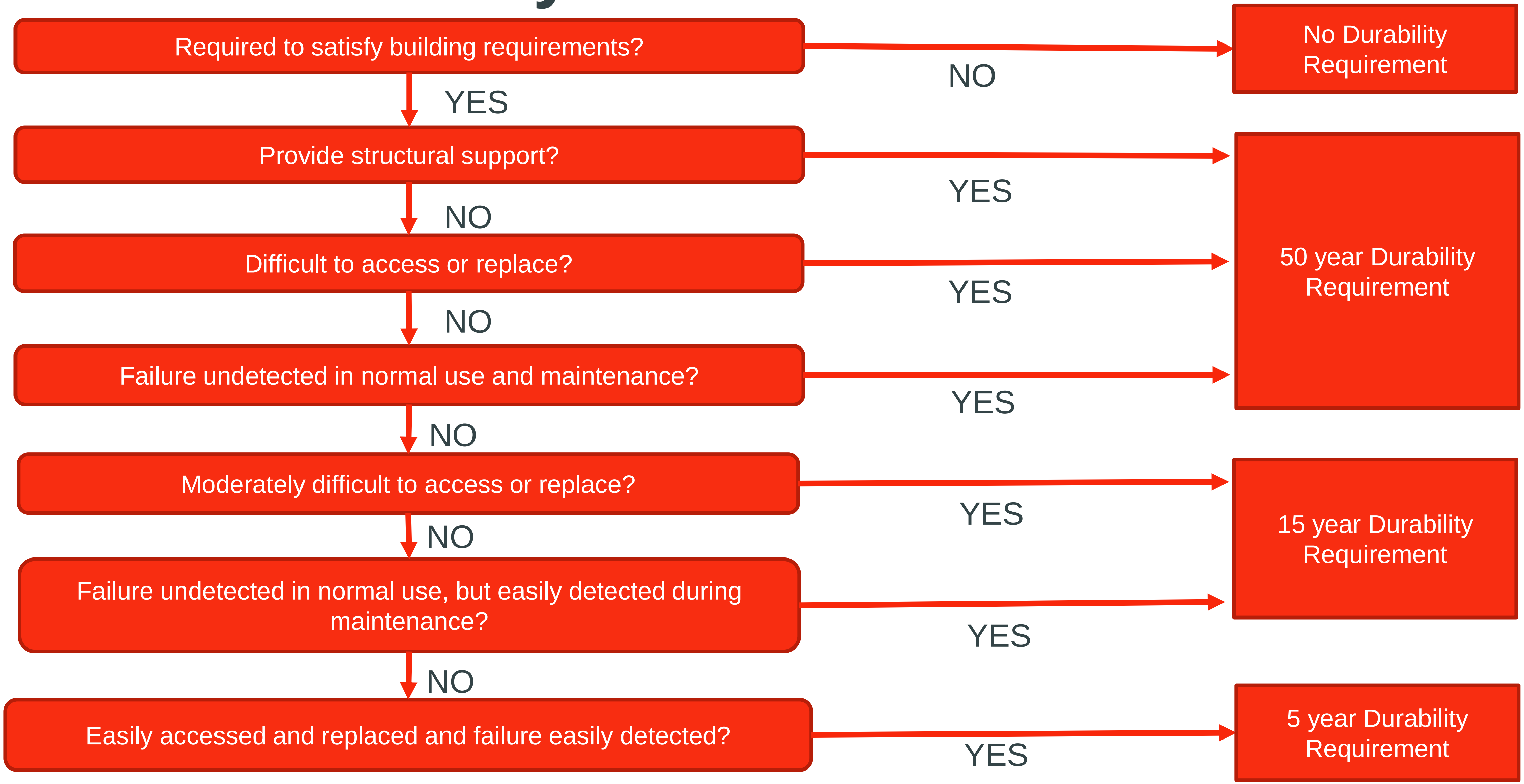
Building Durability

Assembly Durability

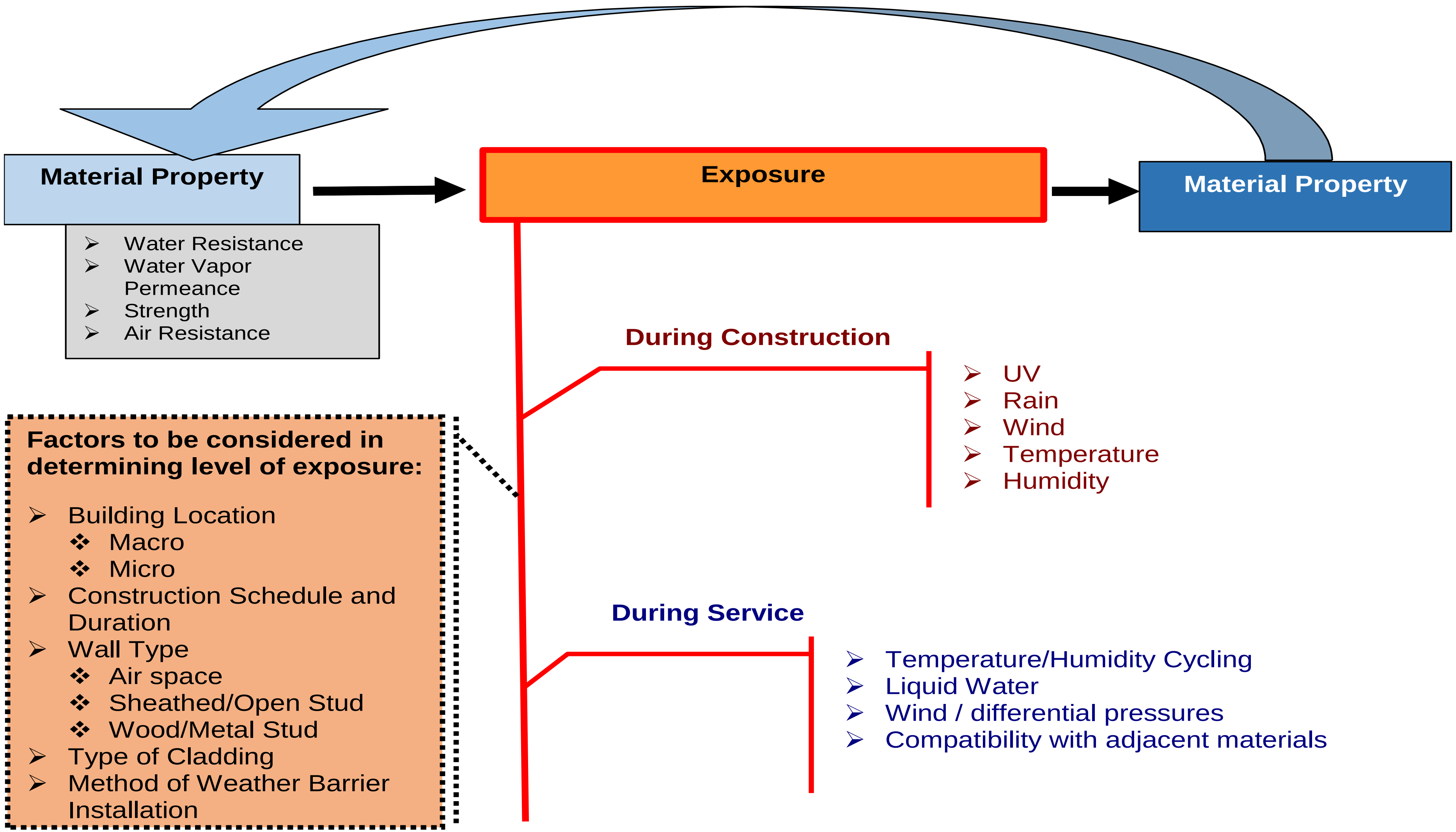
Material Durability


Exposure Intensity
During Construction
During Service
Time

Material Durability Assessment



Criteria from NZ Building Code



Material Property
Water Resistance
Water Vapor Permeance
Strength
Air Resistance
Exposure
Material Property
During Construction
UV
Rain
Wind
Temperature
Humidity
During Service
Temperature/Humidity Cycling
Liquid Water
Wind / differential pressures
Compatibility with adjacent materials
Factors to be considered in determining level of exposure:
Building Location
Macro
Micro
Construction Schedule and Duration
Wall Type
Air space
Sheathed/Open Stud
Wood/Metal Stud
Type of Cladding
Method of Weather Barrier Installation

Field Durability Concern	Exposure	Construction Period	In Service
Asphalt leaching causing embrittlement and water saturation / leakage	cyclic moisture loading (wet/dry cycle)	X	X
Embrittlement	UV	X	
Cracking at corner bends (inside and outside)	Cyclic bending with or without accelerated aging	X	X
Leakage / lack of sealing at fasteners; elongation of fastener holes	Accelerated aging; thermal/moisture expansion, contraction or wrinkling; wind forces	X	X
Seepage of water (absorption vs. drainage capability)	Water on both sides; with or without accelerated aging	X	X
Decrease in water resistance or degradation due to chemical imcompatibility	Exposure to: wood chemicals, paints, sealants / primers, etc.	X	X
Uneven surface (wrinkling) causing variation in stucco depth	UV; wet/dry cylcles; thermal and humidity cycles	X	

Example durability issues identified in ASTM task-group

If you want to be on the cutting edge of defining Resilience check out the following:

Alliance for National Community Resilience
National Institute for Standards and Technology
National Institute for Building Sciences
U.S. Resiliency Council
RELi
ISO 55000
Smart Cities Council
Institute for Building and Home Safety – Fortified Home
ASTM

- E53.07 Sustainable Property Management
- E06 Committee on Performance of Buildings

“Resilience: Know you can bounce back from anything. Think of criticism as faith in your potential. Rent room for improvement. Remember jet lag is just a temporary thing.”

Thank you for your attention. Please ask any questions.

Empowering the world with essential innovations to thrive.