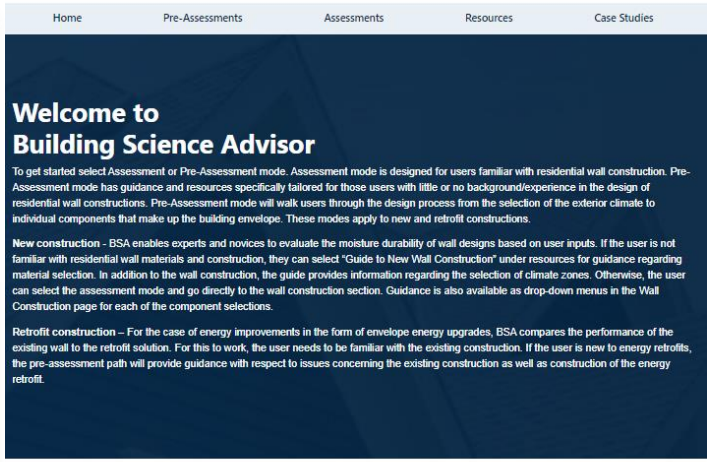
Hygrothermal Performance of New and Retrofit Residential Building Envelopes



Building Science Advisor (BSA) is a website that provides expert advice on building envelope system performance from industry's best researchers and building scientists. This knowledge tool promotes better-informed decisions regarding energy efficient and moisture durable building envelope solutions for new and retrofit constructions. BSA communicates uncertainty associated with moisture durability in a simplified manner. Please refer to the Security & Privacy Notice before using Building Science Advisor.

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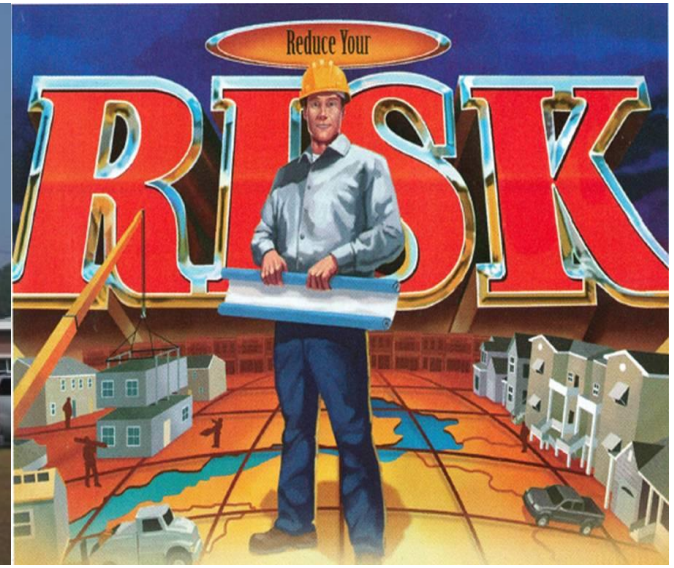
WBS # 01.01.01.02

Project Summary

Objective and outcome

Mitigate market uncertainty regarding the durability of high-performing building envelopes through the development and evaluation of building envelope materials, systems, and tools that are more robust and lead to a reduction in risk.



Team and Partners

Pacific Northwest National Laboratory

PHIUS

New Jersey Institute of Technology

Stats

Performance Period: 10/21 – 9/23

DOE budget: $1,800k, Cost Share: $100k

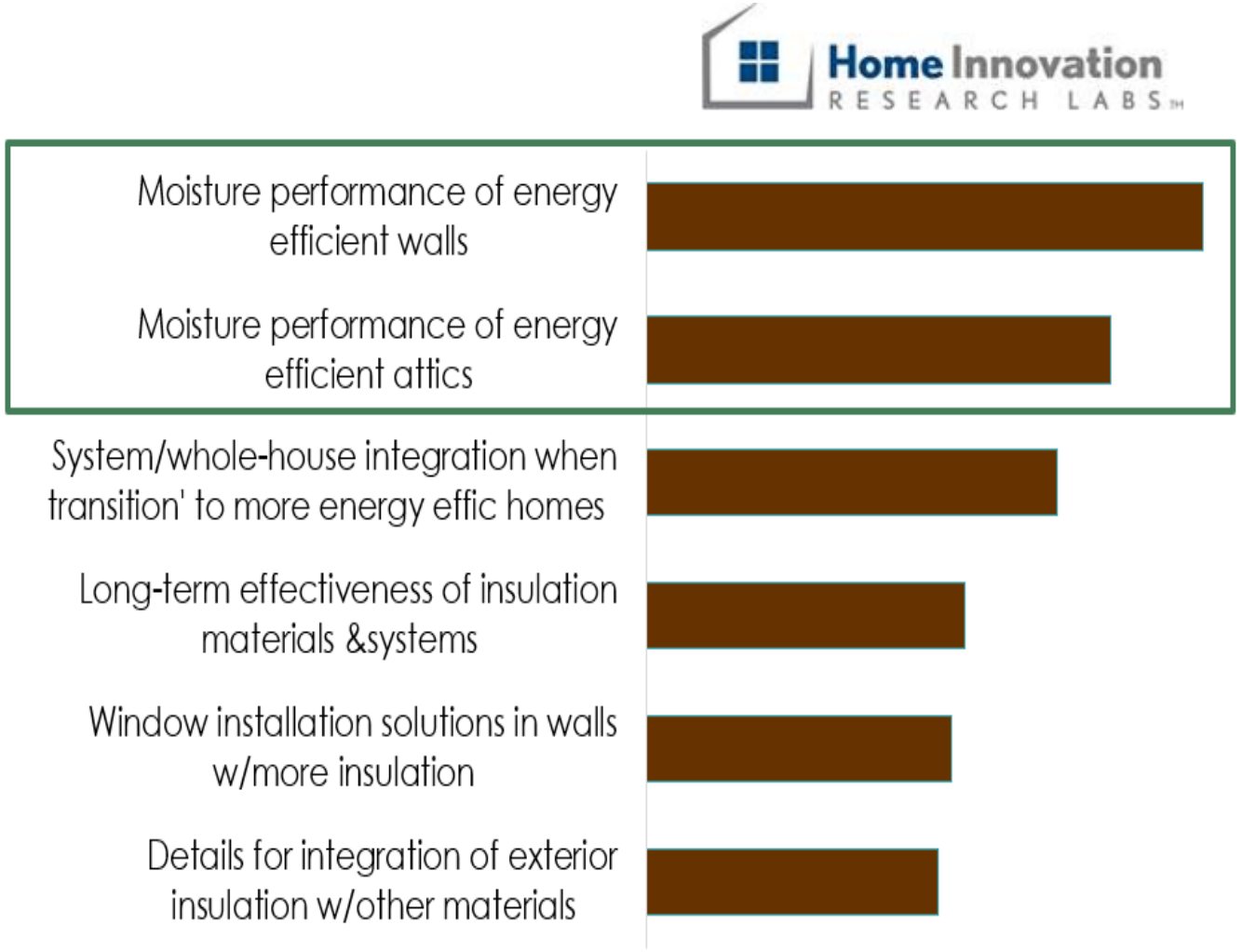
Milestone 1: Perform in-situ experiments to validate the durability of retrofit strategies.

Milestone 2: Support hygrothermal standards.

Milestone 3: Improve educational content of the BSA; market to code bodies, institutions, and designers.

Problem

- In 2018, home repairs due to leaks and mold cost $32B and were more acute for low-income families (Federal Reserve Bank).
- New code and proposed retrofit requirements take builders out of their “tried and true” comfort range.
- Building science required to reduce risk associated with modern building envelope and retrofit strategies.



*Total of 14 issues and challenges presented to respondents

Alignment and Impact

This project utilizes ORNL's unique testing and simulation capabilities to assess the hygrothermal (heat and moisture) performance of building envelope systems, identify solutions, and places into the hands of builders data and industry knowledge helping them make better informed decisions.

- Accelerates adoption of energy efficiency solutions reducing building operational carbon contributions.
- Improves service life reducing building embodied carbon contributions.
- Reduces maintenance and repair costs for all homeowners by extending service life.

EERE/BTO goals

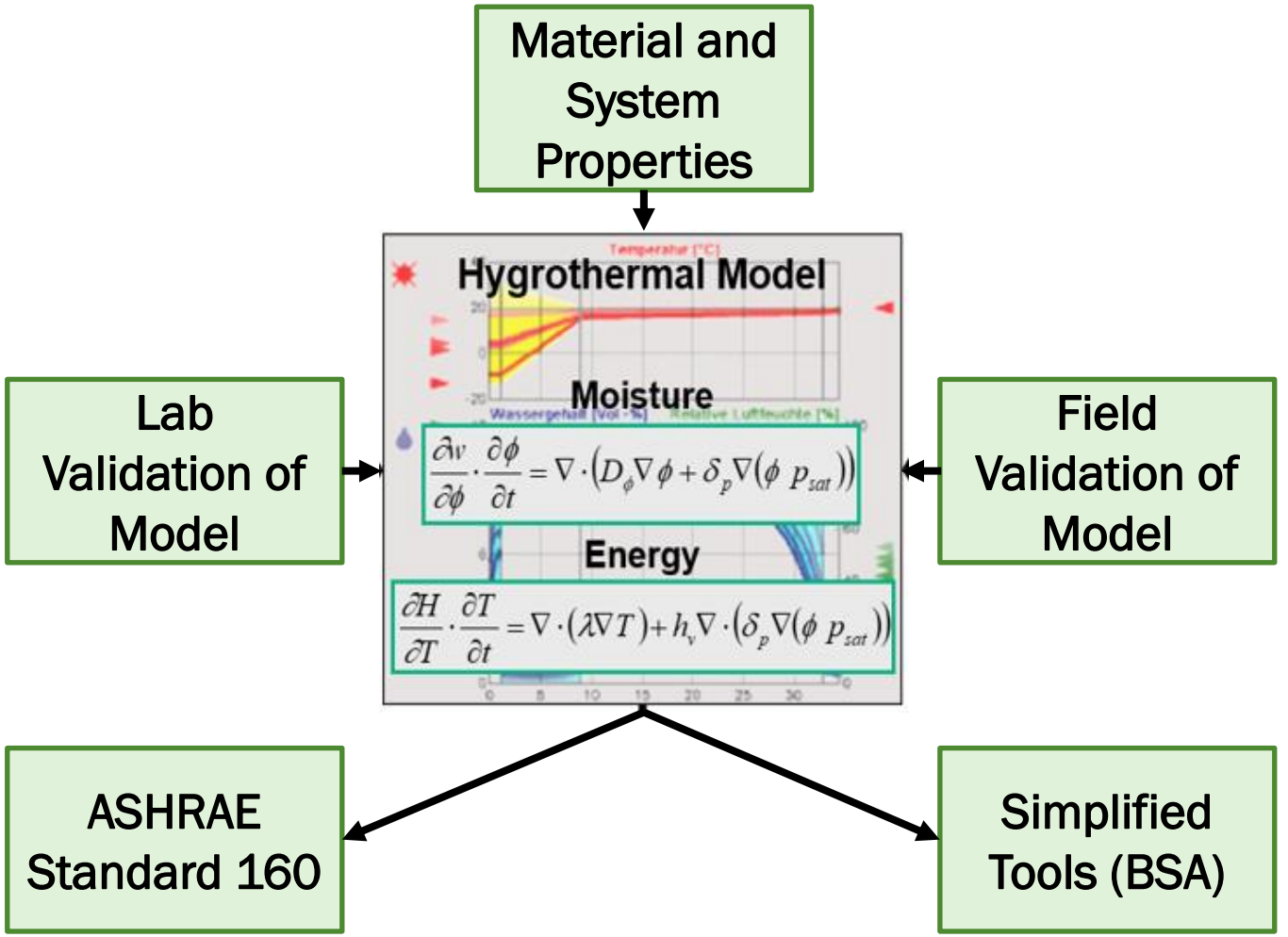
Greenhouse gas emissions reductions

50-52% reduction by 2030 vs. 2005 levels

Net-zero emissions economy by 2050

Approach (tasks)

- Hygrothermal material and system property characterization.
- Validating the accuracy of hygrothermal models.
- Field measurements show wall retrofits do not cause hygrothermal problems.
- Contribute to ASHRAE Standard 160.
- Simplified tools to assess hygrothermal performance (Building Science Advisor).



Approach (communications and challenges)

Communications:

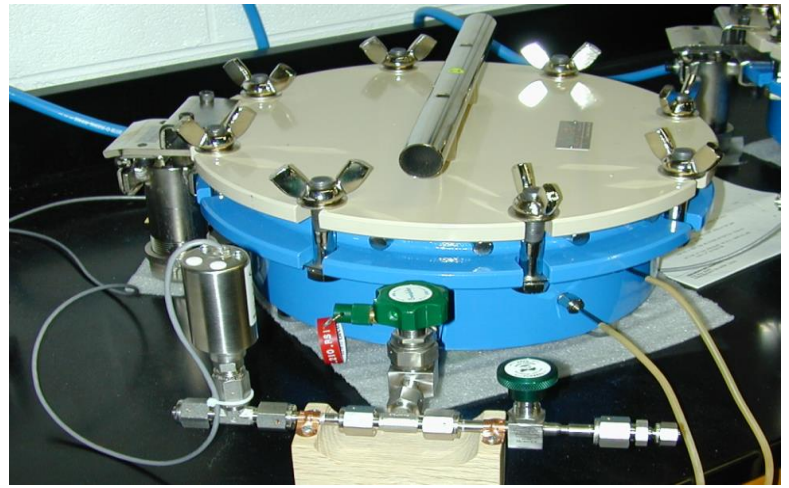
- Added architect via subcontract to communicate research. Presentations to code bodies, AIA, building associations, and enclosure specialists planned this fiscal year.
- Material property data included in hygrothermal model databases and ASHRAE Handbook of Fundamentals.
- Four research papers; most recent is Accawi, G., et. al., “User Friendly Web-Based Tool to Assess the Energy Efficiency and Durability of Residential Wall Retrofits”, ASHRAE Buildings XV Conference, December 2022.

Challenges:

- Identifying responsible organization for moisture control.

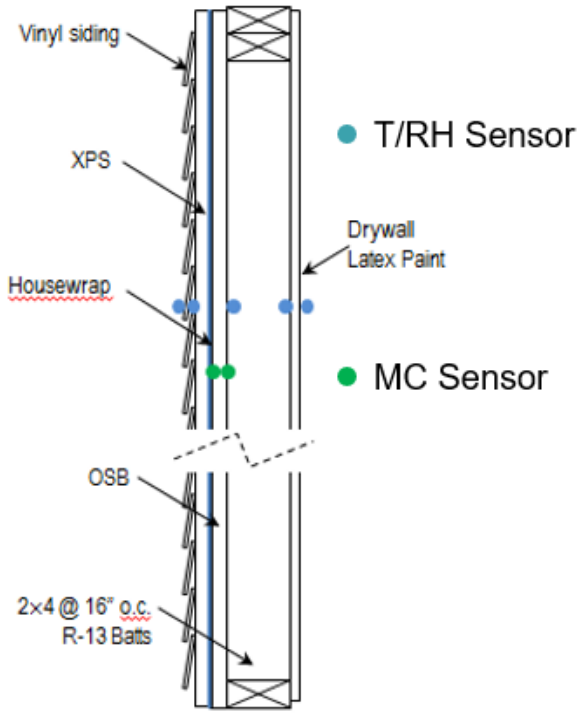
Progress (material properties)

- Develop ASTM test method standards for required properties.
- Develop or acquire instrumentation.
- Success: better material property databases available for hygrothermal modeling.



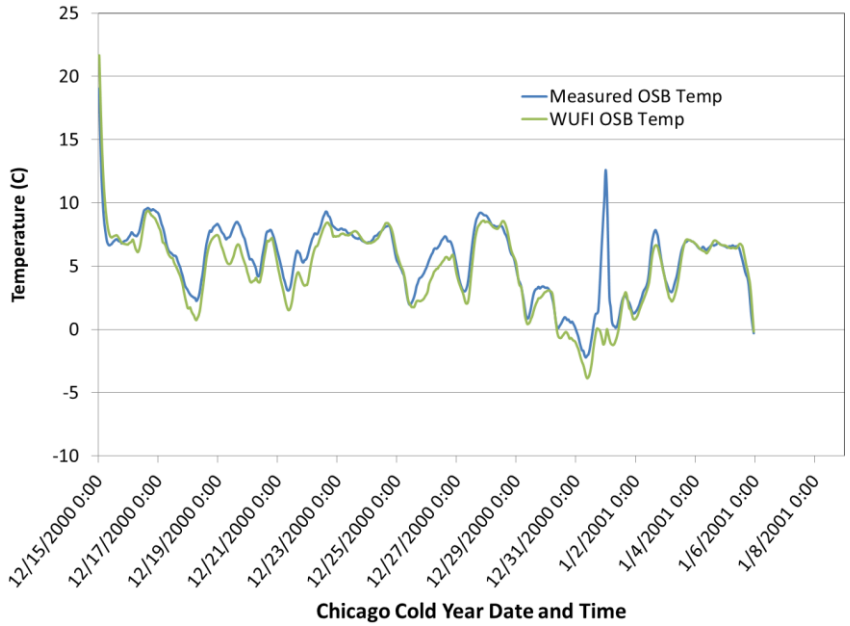
Progress (validating hygrothermal models)

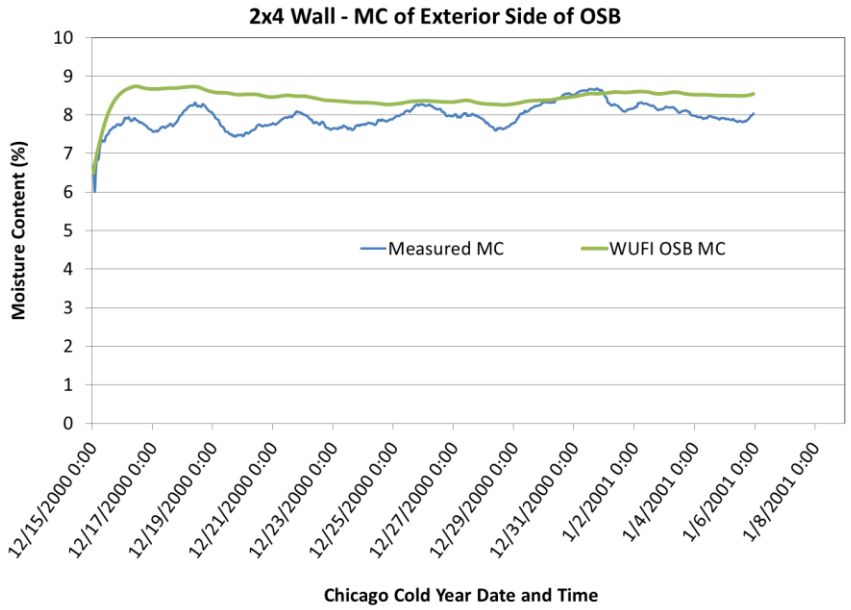
- Indoor Climate – constant 24°C at 50% RH.
- Outdoor Climate – cold year Chicago winter weather from hygrothermal model, began 12/15 and ran for 1 month.

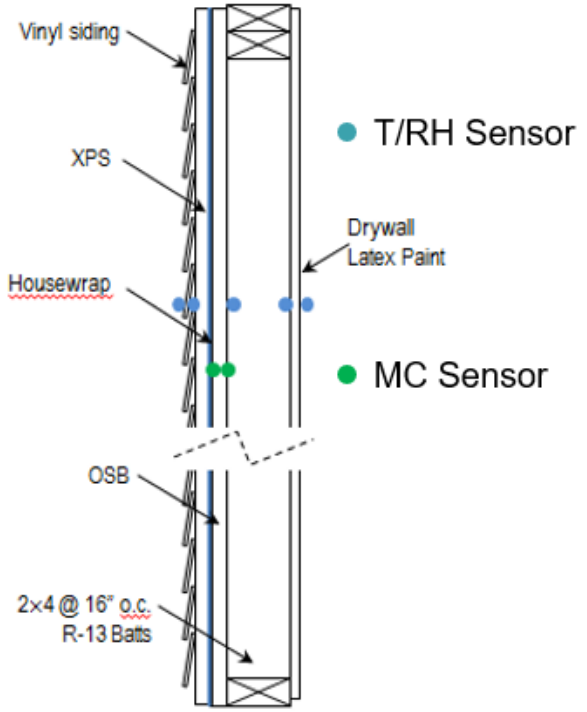


Progress (validating hygrothermal models)

- Chamber vs. modeling comparison







- Success: Greater confidence in the accuracy of hygrothermal models.

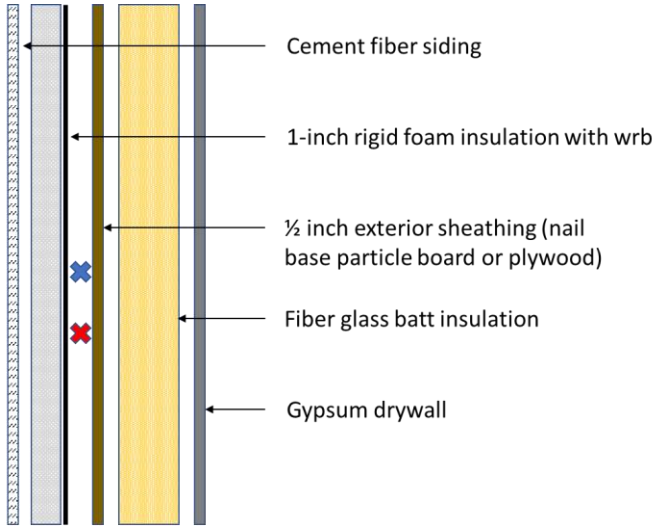
OSB	RMSE
Temp	1.3 °C
MC	0.6%

Progress (hygrothermal field performance)

Temperature and RH sensors were installed on all four sides to monitor conditions between the exterior insulation and sheathing

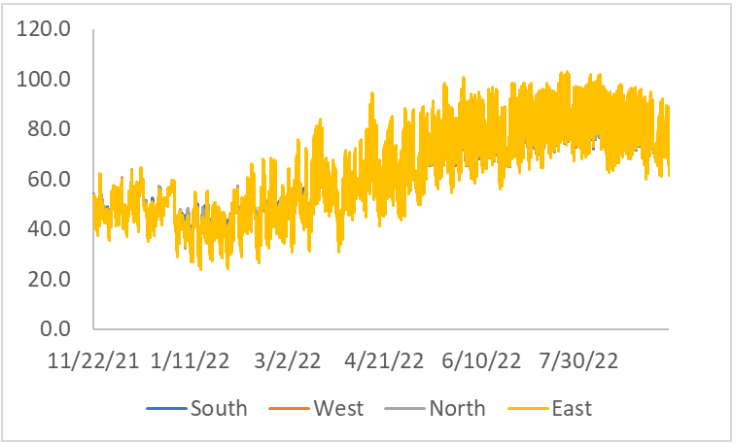
Temperature ✖

Relative humidity ✖

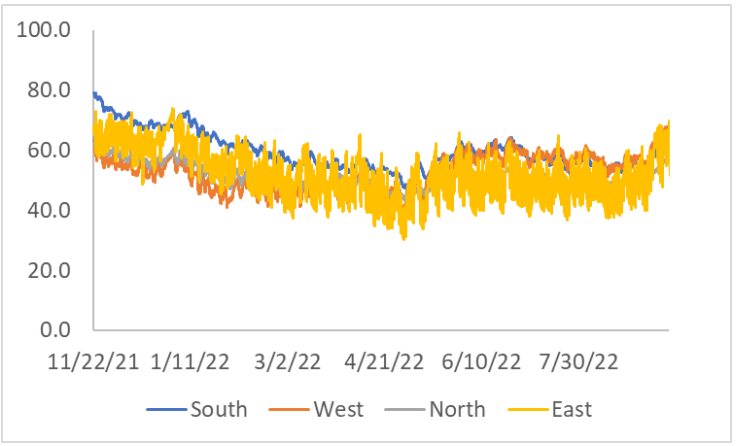


Post retrofit

Temperature (deg F)

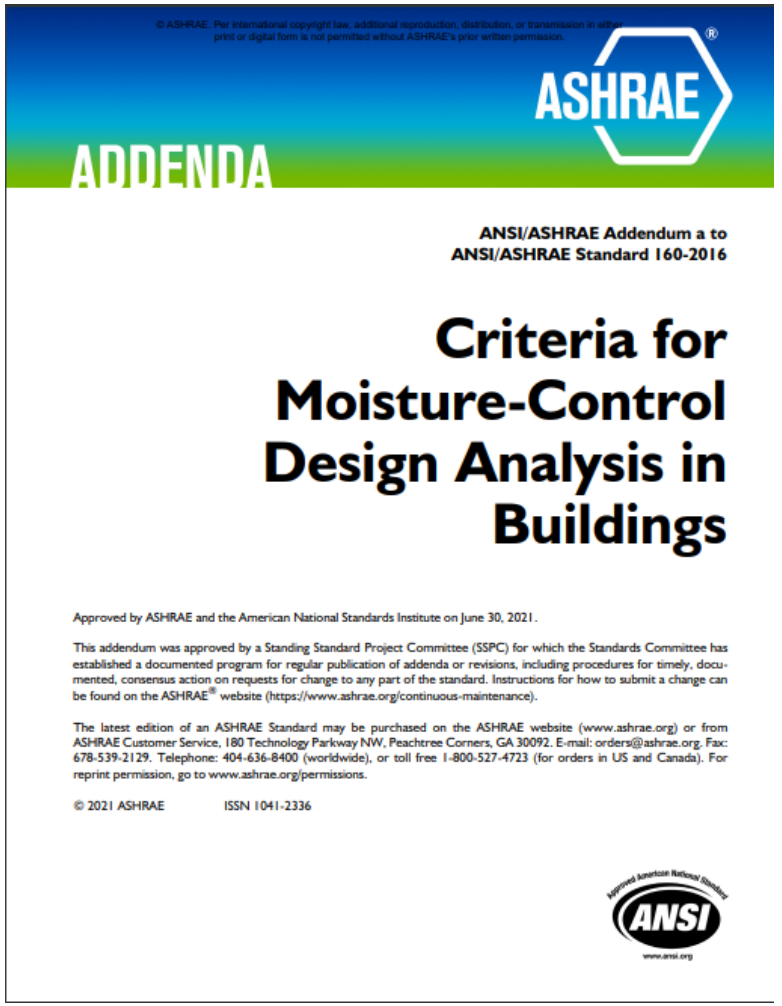


Relative humidity (%)



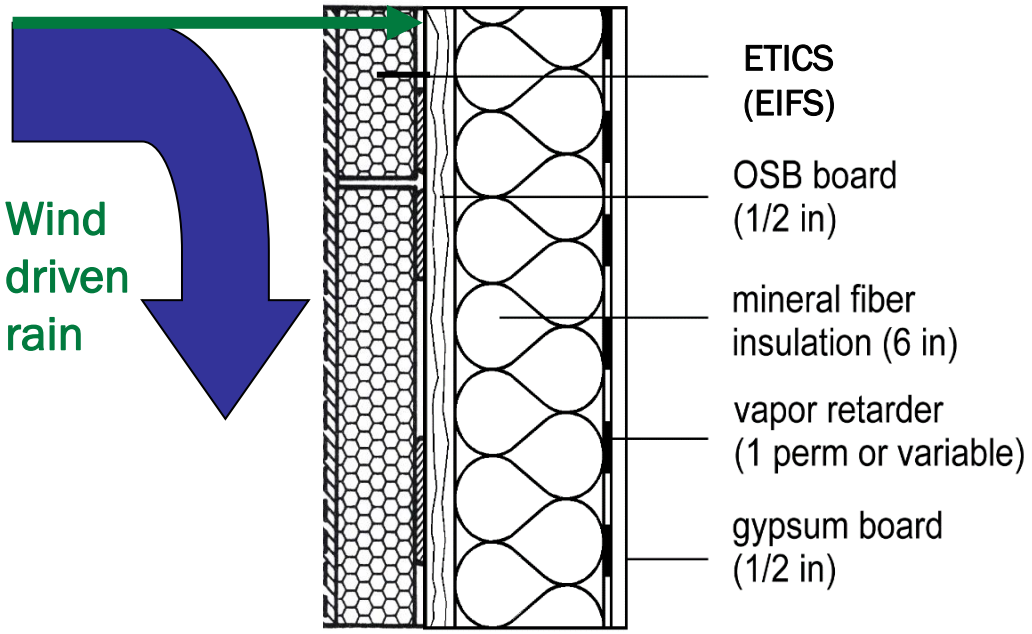
Progress (standards development)

- Better define the simulation of a "leak."
- Examine additional pass/fail criteria:
  - Maximum water content
  - Improved mold index calculation
  - Corrosion



Progress (standards development)

1% rainwater penetration



Rainwater penetration:

In the absence of specific full scale test methods and data for the considered exterior wall system,

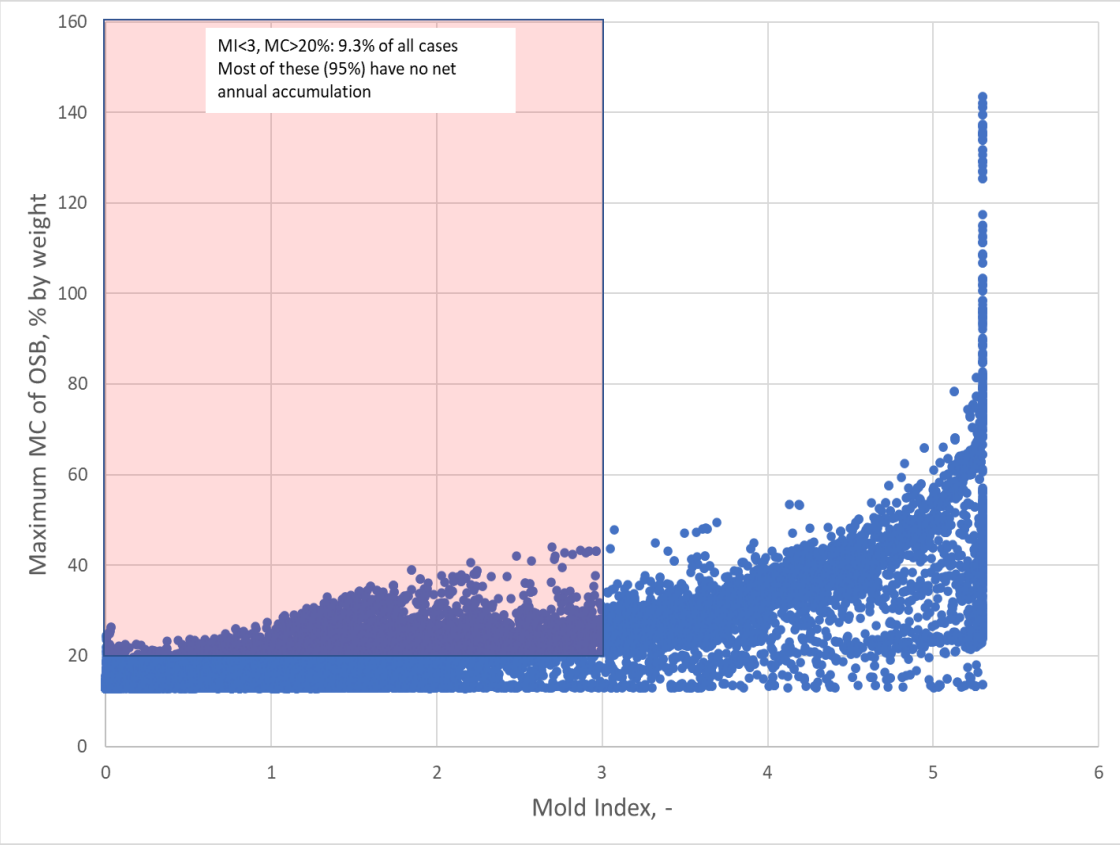
the default value for water penetration through the exterior surface is 1% of the water reaching that exterior surface.

The deposit site for the water shall be the exterior surface of the WRB. If a WRB is not provided then the deposit site shall be described, and a technical rationale shall be provided.

Leak Location	Total leak, lbs/ft^2	Unreleased MC, lbs/ft^2	OSB MC, lbs/ft^3
In WRB	3.43	2.98	3.2
In OSB	3.44	0.00	19.2
In Airspace	3.44	0.20	14.7
In XPS	3.44	0.68	16.4

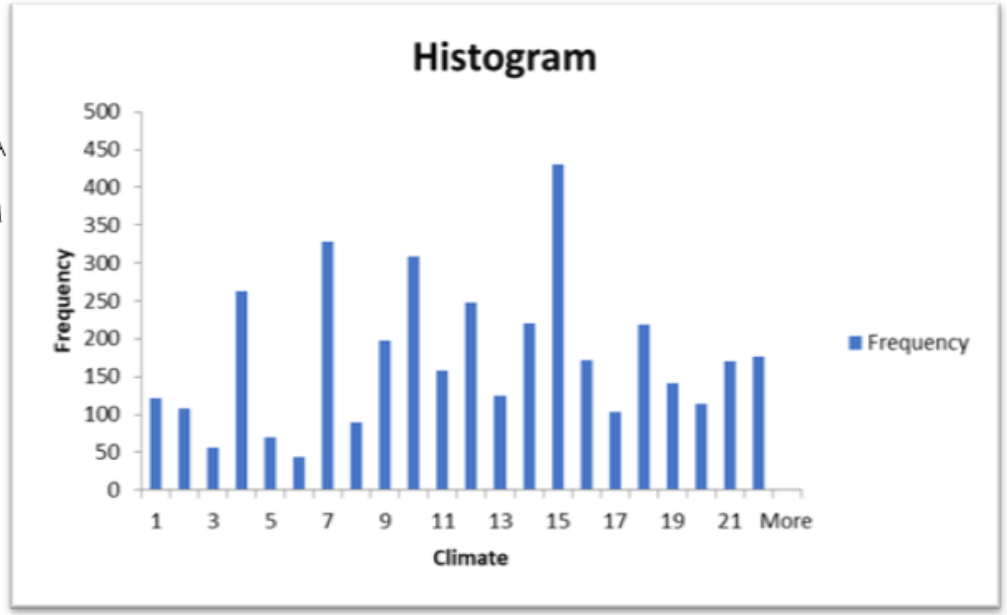
Progress (standards development)

- Adding a moisture content threshold.
- Success: the adoption of a durability requirement in the building codes.



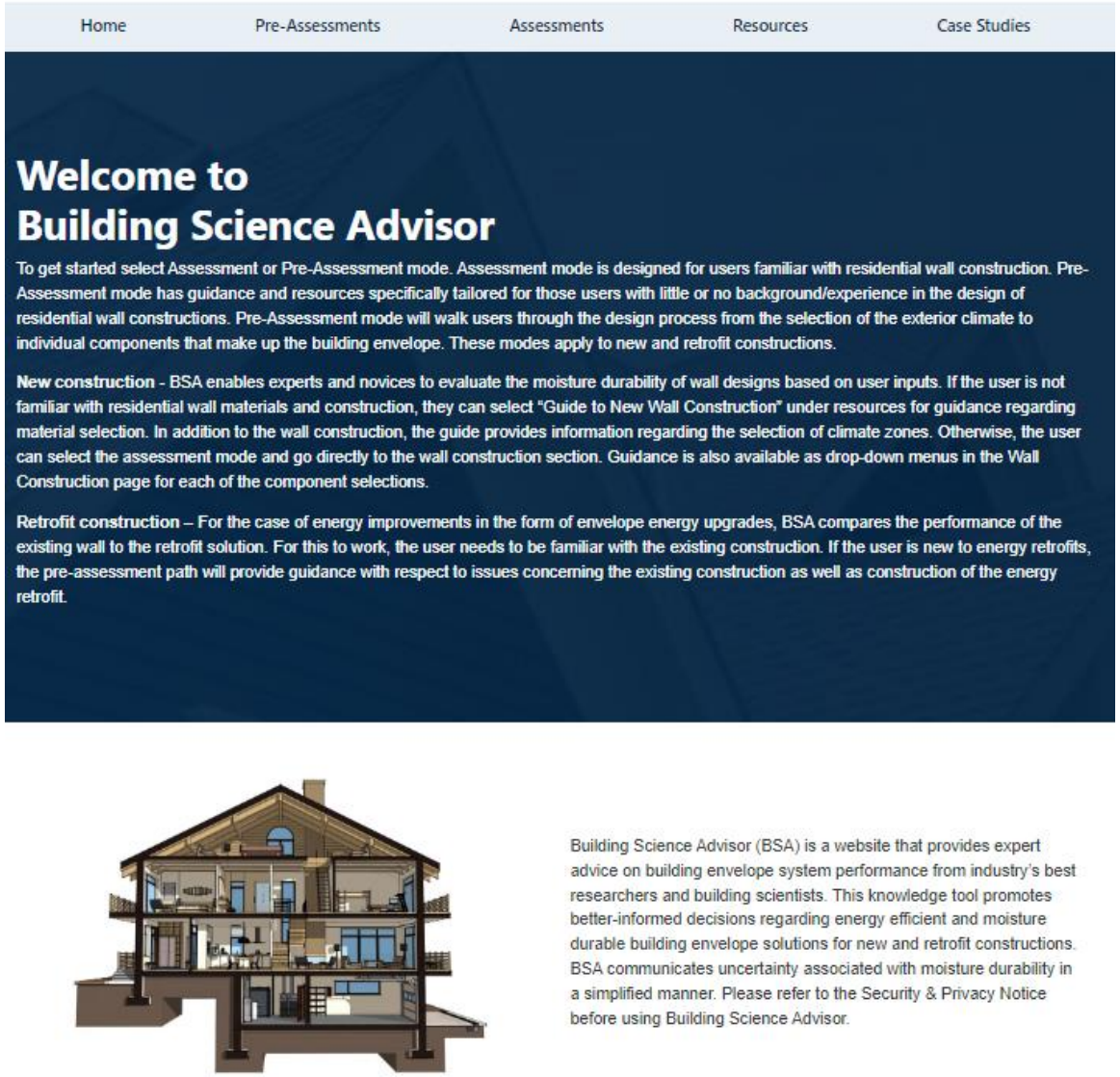
#	Location
1	Miami FL
2	Houston TX
3	Phoenix AZ
4	Atlanta GA
5	Los Angeles CA
6	San Francisco CA
7	Baltimore MD
8	Albuquerque NM
9	Seattle WA
10	Chicago IL
11	Flagstaff AZ
12	Minneapolis MN
13	Boise ID
14	Anchorage AK
15	Fairbanks AK
16	Knoxville TN
17	Tucson AZ
18	Madison WI
19	Syracuse NY
20	Mobile AL
21	Burlington VT
22	Grand Island NE

Number of cases with MI<3, MC>20% with no net yearly accumulation.



*Note: Climates have different total number of simulation cases.

Progress (tools)



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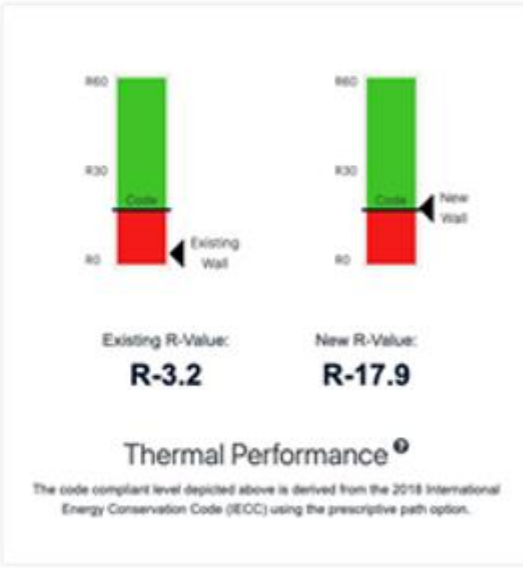
- Provides user with sources of information to consider prior to performing an energy retrofit.
- User defines wall he wants to construct or existing assembly.
- Tool rates its energy and moisture performance.
- Tool makes recommendations regarding improvements.
- bsa-new.ornl.gov

Progress (tools)

- Information on moisture durability and energy efficiency summarized along with recommendations to improve performance.
- Success: Builder confidence in new energy efficient designs.

	Existing Wall	New Wall
Exterior Cladding	Acrylic Stucco/Treated Brick	Brick/Stone
Air Space	None	Drained/Ventilated
Continuous Insulation	None	Foil Faced Polyiso
Insulation Thickness	None	1 in.
WRB Air Barrier	Housewrap/Building Paper (>= 10 perm)	Housewrap/Building Paper (>= 10 perm)
Exterior Sheathing	Plywood/OSB /Fiberboard/Wood Plank	Plywood/OSB/Fiberboard/Wood Plank
Wall Structure	2 x 4 16 inch o.c. Wood Frame	
Cavity Insulation	None	Fiberglass/Cellulose/Open Cell Foam (R-13/R-21)
Interior Continuous Insulation	None	
Interior Continuous Insulation Thickness	None	
Interior Vapor Retarder	None	
Interior Finish	Drywall/Latex Paint	



Future Work

- Continue expansion of material property database to include newer lower embodied carbon materials.
- Complete the inclusion of additional performance criteria in ASHRAE Standard 160.
- Use unique laboratory and “in-situ” experimental facilities and protocols to address concerns regarding hygrothermal durability of well insulated building envelopes.
- Expand capabilities of the BSA:
  - Add new systems and expanded boundary conditions.
  - Expand educational content.
  - “Advertise” availability and capabilities to increase use.

Thank you

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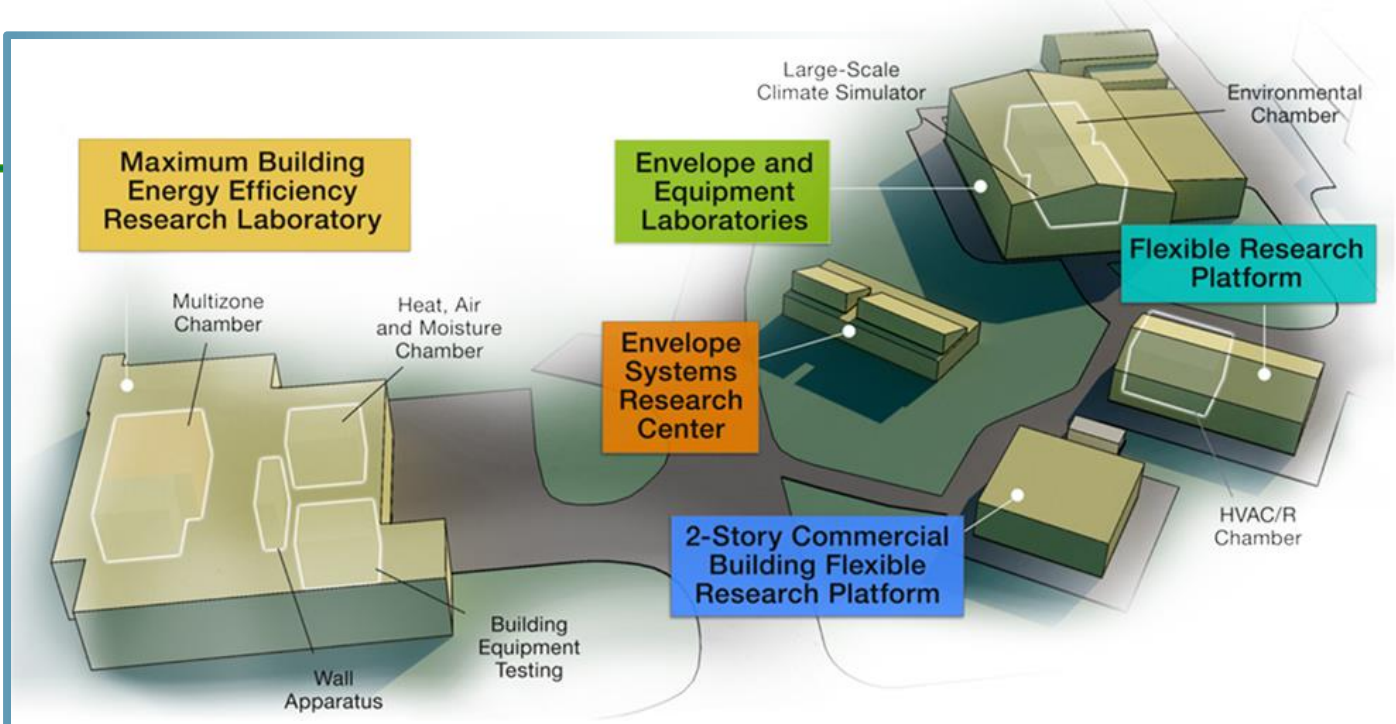

ORNL's Building Technologies Research and Integration Center (BTRIC) has supported DOE BTO since 1993. BTRIC is comprised of 60,000+ ft^2 of lab facilities conducting RD&D to support the DOE mission to equitably transition America to a carbon pollution-free electricity sector by 2035 and carbon free economy by 2050.

Scientific and Economic Results

236 publications in FY22
125 industry partners
54 university partners
13 R&D 100 awards
52 active CRADAs

BTRIC is a DOE-Designated National User Facility

REFERENCE SLIDES

Project Execution

	FY2022				FY2023				FY2024			
Planned budget	$1,300K				$1,200K				$1,200K			
Spent budget	$1,100K				$1,100K (planned)				$1,200K (planned)			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Support PNNL Façade Upgrade project												
Support NJIT Reside Right project												
Support hygrothermal standards (define leakage)												
Complete retrofit version of BSA												
Support PNNL "Adding Insulation when Re-Siding" project												
Current/Future Work												
In-situ experiments to validate durability of retrofit strategies.												
Improve educational content and market the BSA												
Support hygrothermal standards (add moiture levels)												

Team

Antonio Aldykiewicz, PhD
Fire resilience
Sustainability

Philip Boudreaux
Optics
Non-destructive diagnostic tools

Andre Desjarlais
Advanced insulation materials
Hygrothermal simulations

Gunnar Johnson
Lab and field evaluations
Advanced surveying

Emishaw Iffa, PhD
Sustainability
Hygrothermal simulations

Mikael Salonvaara
Envelope retrofits
Machine learning

Mengjia Tang
Indoor air quality
Material characterization

Rui Zhang, PhD
Retrofits
Corrosion