2018 WESTFORD UPDATE ON BUILDING SCIENCE EDUCATION

Patrick Huelman, Georg Reichard, and Sam Taylor
Joint Committee on Building Science Education
http/www.BuildingScienceEducation.net

August 5, 2018

AGENDA

- Introduction & Brief Summary
- Past Year's Progress & Highlights
- Next Year's Priorities, Challenges, Opportunities
  - ✓ New Resources
  - ✓ Solar Decathlon Design Challenge (RTZ) – Sustaining Critical Building Science
  - ✓ Joint Task Group (JTG) for BSE
  - ✓ Other FY 19 Highlights
- Open Discussion

PERSPECTIVE

- The current "desired outcome" is to ensure all students in building design, engineering, construction, and operations will have:
  - ✓ a substantive "building science fundamentals" course early in their program,
  - ✓ solid "building science" concepts infused into their traditional courses, and
  - ✓ access to specialized, in-depth building science coursework and teaching resources

OUTREACH ON BUILDING SCIENCE RESOURCES

- **Westford 2017**
- EEBA – Atlanta, GA
- Joint WebEx Working Meetings – Hygrothermal Analysis Guide
- NIBS/NIBS BETEC & Credentialing Councils/Resilience
- ASHRAE, Chicago
- 4th Penn State Residential Conf. - BSE Sessions, March 2018
- 2018 DOE Peer Review, Arlington, VA
- 4th DOE RTZ Competition, Golden – Faculty Advisors Meeting
- AHSRAE, Houston, TX
- **Westford 2018**

HIGHLIGHTS SINCE WESTFORD ‘17 BSE

- **New Resources and Approaches Under Development**
- **2018 RTZ Faculty Advisors Meeting**
  - ✓ **need for faculty teaching resources & training**
- **Building Science Education Solution Center – FY17**
- **Successful BSE Sessions at Penn State Residentia**

UPDATE ON BUILDING SCIENCE RESOURCES

- **Update on new Moisture Control Handbook, 2nd Edition – Joe Lstiburek**
- **New Building Science Advisor – Eric Werling, Andre Desjarlais**
- **Other DOE Building Science Products, e.g., MOISTHERM, etc.**
- **Update: new textbooks, supplemental resources, curricula**
- **New/Expanded Website Resources**
  - ✓ **BSE Website** – expanded teaching resources – Huelman, Taylor
  - ✓ **U Toronto eLearning** Building Science Fundamentals - Pressnail
  - ✓ **Building America Solution Center**: Updates; Image Gallery, Fundamentals; ZERH Resources - Baechler
  - ✓ **SBSE Education Resources** – Reichard
  - ✓ **NIBS**: WBDG; Mitigation Saves; etc.

UPDATE ON BUILDING SCIENCE WEBSITES

- **New/Expanded Website Resources**
  - ✓ **Building America Solution Center**: Updates; Image Gallery, Fundamentals; ZERH Resources - Baechler
  - ✓ **BSE Website** – expanded teaching resources – including U MN Lecture Modules - Huelman, Taylor
  - ✓ **U Toronto eLearning Building Science Fundamentals** – Pressnail/Touchie
  - ✓ **SBSE Education Resources** – Reichard
  - ✓ **NIBS**: WBDG; Mitigation Saves; etc.

UPCOMING EVENTS RELEVANT TO BSE

- ***EEBA Summit***, San Diego, CA – October 16-18, 2018
- ***NIBS Conference***, Washington, DC, - Jan. 7-10, 2019
- NAHB-IBS, Las Vegas, NV – February 19-21, 2019
- ASHRAE, Atlanta, GA – January 12-16, 2019
- ***Design Challenge (RTZ)***, Golden, CO – April 2019

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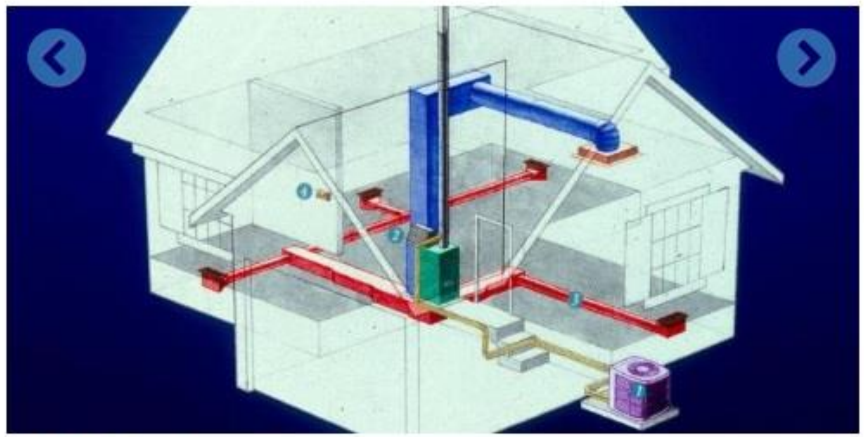
  - Provide Comments
  - Offer Content

Building science skills are the difference between buildings that will work or fail. Yet, there is no consistent platform for ensuring consistent building science skills across all workforce professions engaged in the buildings sector. The **Building Science Education (BSE) Solution Center** provides professors, trainers and students with accurate, easy-to-access training materials on the fundamentals of building science.



HVAC Systems

This module describes basic components, basic installation and ratings of HVAC systems.

READ MORE

Recently Updated

SEPTEMBER 28, 2017
Fenestration

SEPTEMBER 28, 2017
Codes and Standards

SEPTEMBER 28, 2017
Disaster Resistance and Resiliency

More Guides

Recently Added Content

SEPTEMBER 28, 2017
Plumbing (Domestic Hot Water) Systems

SEPTEMBER 28, 2017
Disaster Resistance and Resiliency

SEPTEMBER 28, 2017
Codes and Standards

BUILDING SCIENCE EDUCATION SOLUTION CENTER - 2017

- Major Effort to Create a Teaching Resource for Key Building Science Core Competencies
- Lessons Provided at Different Proficiency Levels (Blooms Taxonomy)
  - Some at Levels 1-5; all at least Levels 1-3
- No Funding Provided in FY 18 – Work stopped 9/30/17;
  - However, website remains valuable resource
- Future Development - TBD

2018 PENN STATE RESIDENTIAL D&C CONFERENCE

- Building Science Education Sessions – Emphasized
  - ✓ New Teaching Resources
  - ✓ Modifying Curricula to Enhance Pairing of Academic & RTZ Experiential Learning
  - ✓ New Verified BSE Infusion Approaches & Resources
- 3 Building Science Education (BSE) sessions on first day
  - ✓ 8 speakers plus wrap-up forum
- One session by Penn State on Day 2 on Design, Curricula & Tour of RTZ-Design GreenBuild Project (house under construction)
- Continue Enhancement of BSE Curricula; Participate in SD Design Challenge (RTZ) – Demonstrating Best BSE

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SOLAR DECATHLON

2018 DOE Race to Zero Student Design Competition Update

August 5, 2018

Stacey Rothgeb
National Renewable Energy Laboratory
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2018 DOE Race to Zero Student Competition

Unprecedented Participation

84 student teams

68 collegiate institutions

900 students & faculty

Fresh Faces

68% more teams

56% more institutions

87% more students

Diversity & Determination

73% teams return in 2018

28 US States & 8 countries

Residential & Commercial

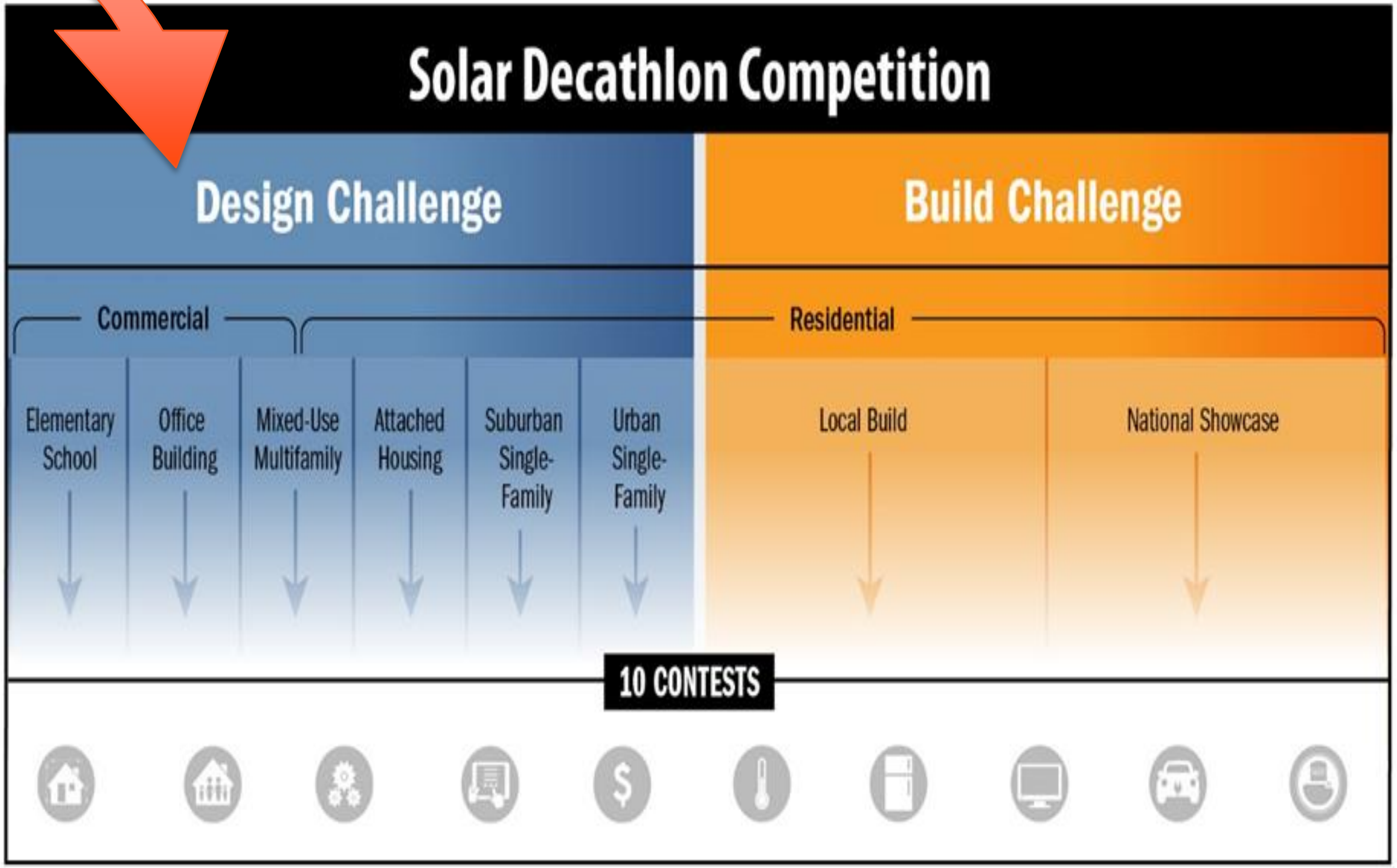
Faculty Meeting:

- 23 Faculty / 10 Staff
- All but 3 of universities have building science in curriculum

Competition is achieving goal of advancing and enhancing building science curriculum

U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON

New for 2019...



RACE TO ZERO
U.S. DEPARTMENT OF ENERGY
STUDENT DESIGN COMPETITION

U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON www.solardecathlon.gov

Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

Moisture Control Handbook

- **The “DOE Moisture Control Handbook – New, Low-rise, Residential Construction” was published in October 1991. It contained 6 chapters, a glossary and index:**

- Chapter 1. Mold, Mildew and Condensation
- Chapter 2. Moisture Movement
- Chapter 3. Wetting and Drying of Building Assemblies
- Chapter 4. Moisture Control Practices for Heating Climates
- Chapter 5. Moisture Control Practices for Mixed Climates
- Chapter 6. Moisture Control for Cooling Climates

- The original document did not have a specific chapter on Roof Assemblies. Rather, specific roofing details were scattered throughout the document. The new chapter outline organizes the document by assemblies (wall, roof and foundation) rather than climate.

- Additionally, notably missing was a discussion on properties of water and its interaction with materials. A basic discussion about the properties of water molecules, the four phases of water and sorption should be the first chapter of the new document.

- Also missing is a detailed discussion of air flow in assemblies and interaction of the air flow with mechanical systems. Significantly lacking is a discussion of ventilation systems and their climate challenges.

- The following organization is proposed. It is proposed that mold and mildew be discussed in Chapter 2 as part of the materials discussion. The air flow and interaction of air flow with mechanical systems be discussed in Chapter 3 as part of the air transported moisture section.

Chapters

- Chapter 1. Introduction
- Chapter 2. The Water Molecule and Materials
- Chapter 3. Moisture Movement
- Chapter 4. Wall Assemblies
- Chapter 5. Roof Assemblies
- Chapter 6. Foundation Assemblies
- Chapter 6. Ventilation Systems
- Chapter 7. Cold Climate Case Studies
- Chapter 8. Mixed Climate Case Studies
- Chapter 9. Hot Humid Climate Case Studies
- Chapter 10. Common Problems

Chapter 10. Common Problems

- Rain water entry at windows and doors
- Rain water entry at decks and balconies
- Ground water entry at basements
- Capillary rise at footings
- Wood flooring cupping
- Condensation in cold climate basements
- Stucco decay
- Cladding trim deterioration
- Mold at impermeable interior finishes
- Elevated interior humidity in hot humid and mixed humid climates
- Condensation on attic ductwork in vented attics
- Ice dams

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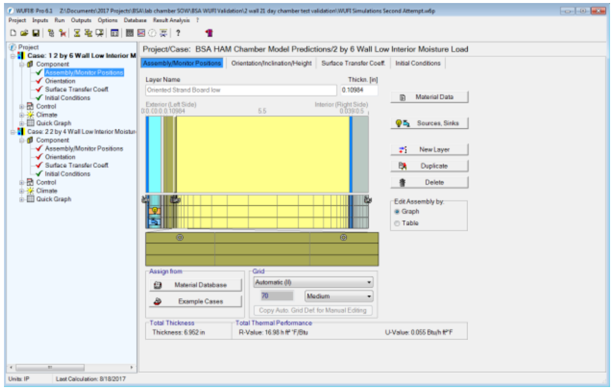
The Building Science Advisor



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Building AMERICA U.S. Department of Energy

Schedule

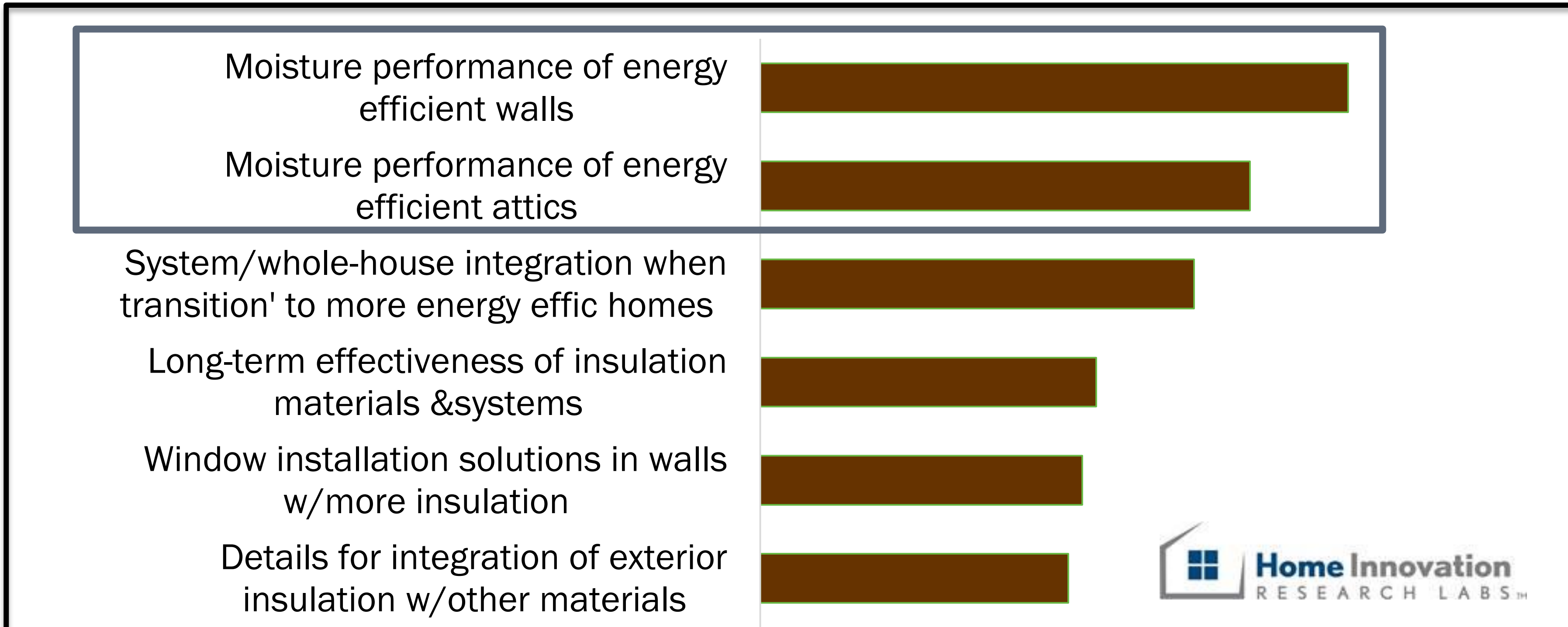
Release BSA V. 1.0 on 14 September 2018

What's next:

- Continue model validation exercises to include rainfall, air leakage, and solar effects;
- Continuously update moisture management guidance for new materials and envelope assemblies; and
- Initiate probabilistic modeling component to fill in blanks in expert advice.
- Expand to include roofing

Challenge

- As building envelope assemblies continue to evolve, they become less tolerant of design and installation flaws.
- There is market uncertainty regarding the moisture risk of high-performing envelope systems, which in turn hinders rapid adoption.
- Builders, architects, and other building professionals lack access to credible guidance on durable, energy-efficient wall assemblies to mitigate risks.
- Knowledge gap must be addressed to achieve residential energy reduction targets.

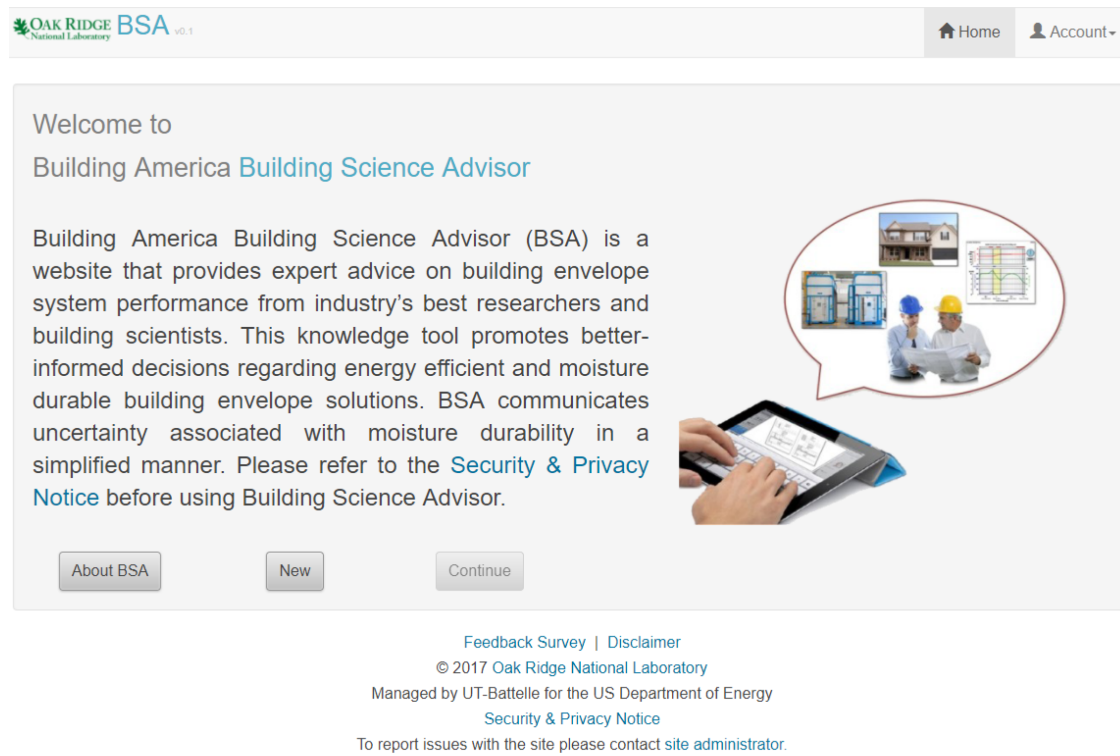


Approach

Give every building professional instant access to the knowledge of the industry's best researchers and building scientists.

Distinctive Characteristics:

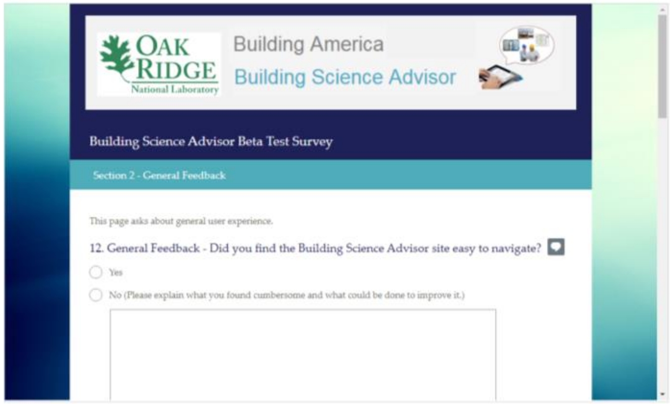
- First application of an expert system for moisture management in buildings.
- Articulates guidance for durable wall systems based on expert consensus, field data, and empirically validated hygrothermal modeling and simulation.
- Will employ probabilistic modeling analysis.
- Web-based; available as an App?

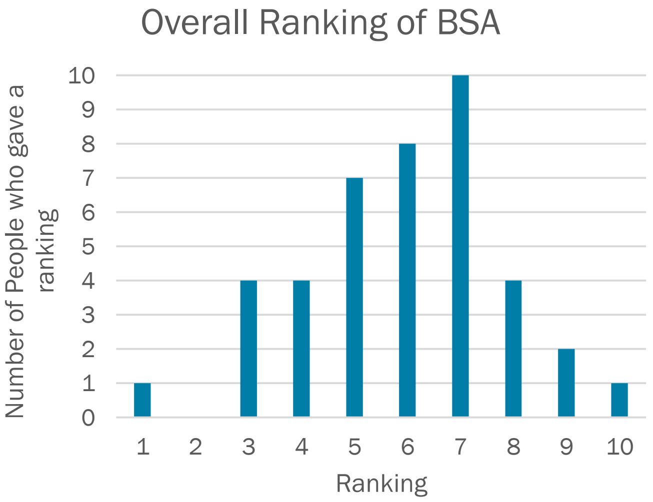


Survey summary

- In late summer 2017, a survey was circulated and 50 percent of the 170 experts, stakeholders, & practitioners surveyed supplied feedback

- **Respondents wanted more…**
  - Climate options
  - Other material options in the drop down menus
  - Additional performance indicators
    - Drying potential
    - Risk of decay
  - More guidance
  - Improved website graphics
  - Fewer input screens
  - Disliked "recommended walls" option



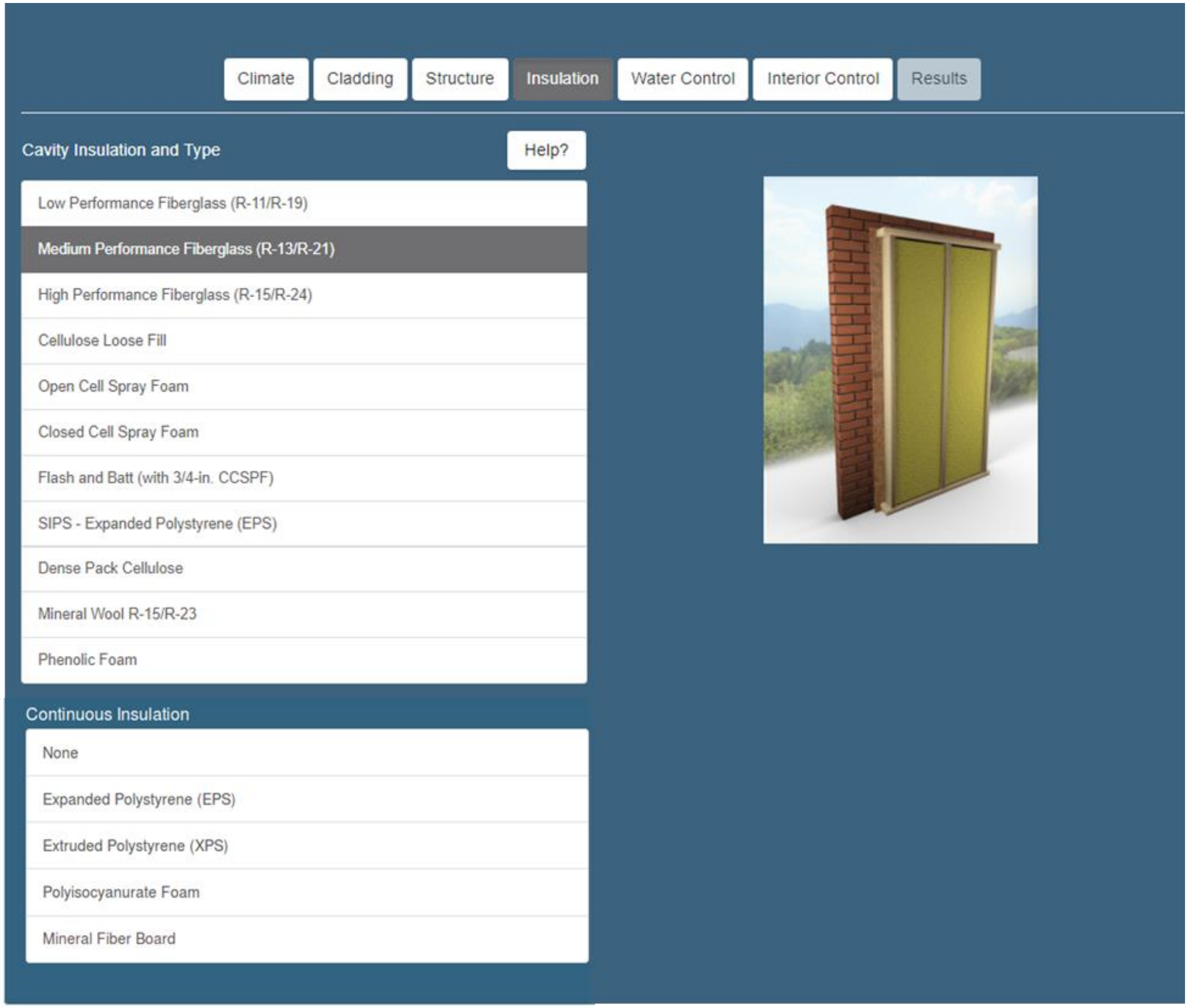


BSA after beta testing

What's new!

- Educational pathway replaces "recommended walls" option.
- Location selection now unlimited (analyses done at climate zone level).

Input selection screen



Improvements:

- Number of input screens reduced;
- More obvious "Help" menu;
- More "drop down" menu selections;
- "Results" button requires complete input selection;
- More thickness variations in the continuous insulation menu; and
- Better image graphics.

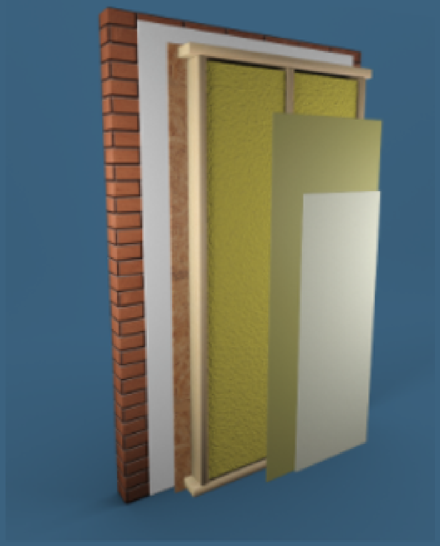
Results screen

Improvements:

- Durability indicator changed from traffic light to dial;
- Added code level R-value; and
- Added “drop down” menu capability (no need to return to input screens to modify wall).

Results screen

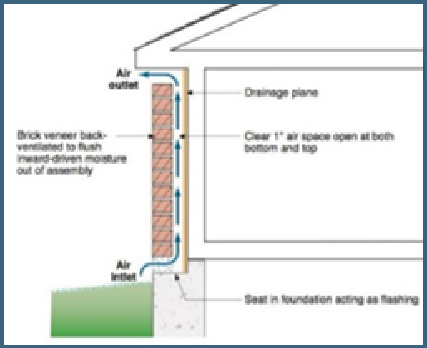
✉ Email a question about this wall.



Moisture Performance

The selected wall cladding can absorb water. If there is no ventilation behind the cladding water can potentially infiltrate the wall assembly. To ensure moisture durability, add at least a 1/4" (1" for brick or stone cladding to avoid mortar contacting sheathing) ventilation cavity behind cladding.

Read more…



General Guidance

The IECC 2015 *R*-value requirement is not met for the selected climate zone and wall assembly. This doesn't necessarily mean that your selection is in conflict with your state/county code. Please seek expert guidance to determine adopted code in your region.

Improvements:

- Significant improvements in guidance (more to come when new revision of the Moisture Control Handbook is added);
- Wall schematic added; and
- Option to display several wall systems simultaneously added.

Guidance/information sheet

Building America Building Science Advisor

DRAINAGE PLANE

Reservoir claddings in combination with rain and sun call for behind-cladding drainage and ventilation. A reservoir cladding is anything that absorbs and stores moisture; such as brick, stone, wood, stucco (non-synthetic), and fiber cement.

In addition, all exterior wall cladding systems leak to some extent. Some more than others…but all leak. Gravity, wind pressure and capillary action cause rainwater entry through the rainy cracks, joints and small gaps in a building's exterior. With typical residential cladding systems - and commercial wall systems - it is not possible to seal all those pathways.

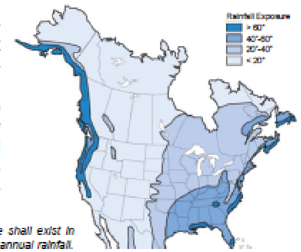


Figure 1: A drainage plane shall exist in areas with more than 20" of annual rainfall.

Cause and Effect

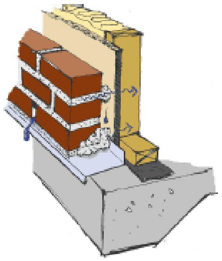


Figure 2: Excessive mortar in drainage plane allows for inward drive of moisture.

Wetting a reservoir cladding "charges" it. Think "moisture capacitor". Due to capillary forces of the absorptive cladding, a strong inward moisture transportation may occur. This transportation mechanism is even stronger when the sun hits the cladding and discharges the moisture. The heating of the stored water raises its vapor pressure and the warm water in the cladding drives both inward and outward. Outward is good… unless the paint coating has too low of a vapor permeance causing it to bubble and blister and peel and otherwise not behave nicely.

? *What is too low of a vapor permeance for a paint coating on the exterior of a reservoir cladding? - Less than 10 perms.*

Discharging the "moisture capacitor" inward can be a problem when moisture is absorbed by the sheathing, studs or insulation materials. Such unwanted supply of moisture may result in biological growth of mold and mildew, and ever worse, deterioration of the material structural strength due to wooden decay. Subsequently, the inwardly driven water needs to be handled.

Preventive Actions

There are a couple of ways to allow for drainage behind reservoir cladding. Back ventilation (Figure 3), requires a clear path behind the cladding, and openings at the bottom and top for air exchange. The width or the air gap will impact the drainage, but also the air exchange rate. The following minimum width applies:

- 1 inch - For vapor permeable sheathing (gypsum) + Brick/Stone
- ¼ inch – Wood/Stucco/Fiber Cement

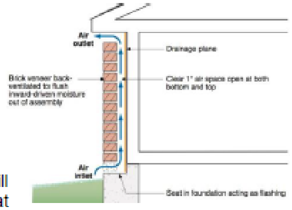


Figure 3: Back ventilation for brick veneer walls.

For non-brick/stone/stucco cladding, a width of 1/32 to 1/16 inch will suffice, but 1/4 inch is recommended. With this approach, any water that leaks through the cladding will hit a water-resistant surface, and safely drain down the wall. Remember to lap drainage plane materials over all exterior wall flashings so water flowing down the walls is directed away from the building. And, carefully seal around all penetrations through the wall.

References and Further Reading

Building Science Corporation

- BSI-061: Inward Drive - Outward Drying
- BSI-038: Mind the Gap, Eh!
- BSI-057: Hockey Pucks and Hydrostatic Pressure

BUILDING AMERICA SOLUTION CENTER BASC.ENERGY.GOV

- Drainage Plane Behind Exterior Wall Cladding
- Flashing at Bottom of Exterior Walls
- Taped Insulating Sheathing Drainage Planes

Thank You

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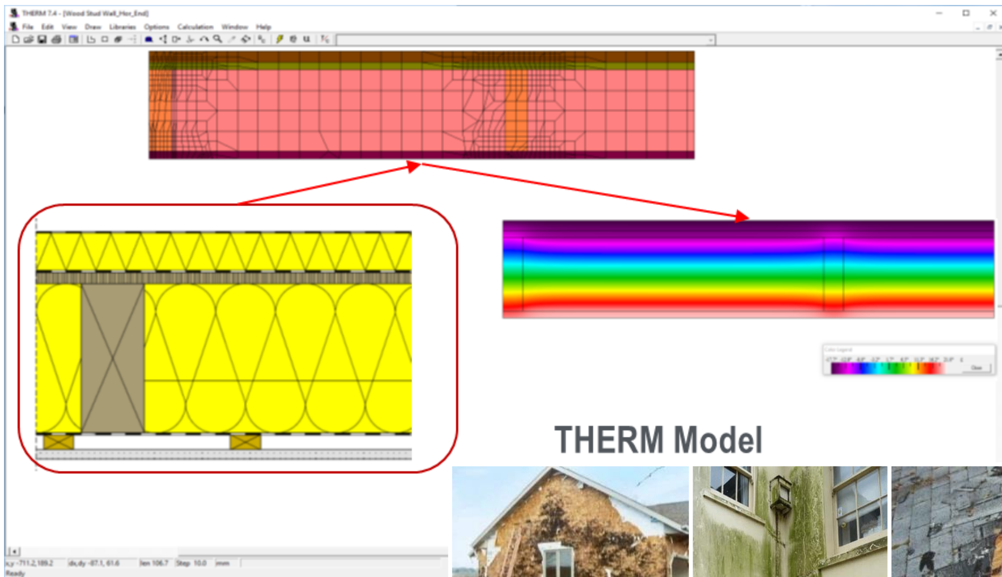
THERMM: Heat & Moisture Modeling Tool



THERM Model

Charlie Curcija, dccurcija@lbl.gov / LBNL

Simon Pallin, pallinsb@ornl.gov /ORNL

Project Summary

Timeline:

Start date: 10/1/2016 (actual start Jan, 2017)

Planned end date: 12/31/2019

Key Milestones:

1. Mathematical and numerical model – 3/31/2018
2. GUI design – 6/30/2018
3. Beta software tool release – 12/31/2018
4. Final software tool release and full technical documentation – 1/31/2020

Budget:

Total Project $ to Date:

- DOE: $718K (Last 12 months: $450K)
- Cost Share: $0K (Last 12 months: $0K)

Total Project $:

- DOE: $1,250K
- Cost Share: $250K

Key Partners:

NFRC	PassivHaus Institute US
AERC – Fenestration Attachment Rating	Forest Products Lab
ASHRAE	WESTLab
British Columbia Institute of Technology	Owens Corning

Project Outcome:

Software tool capable of modeling 2-D dynamic heat and moisture transfer in building envelopes, incorporating automated meshing and error estimation for rapid model development. Open source code base for third party contributions. API that can be utilized by other tools, such as E+, web-based custom tools.

Team


Charlie Curcija


Simon Vidanovic


Robert Hart


Howdy Goudey


Simon Pallin


Andre Desjarlais


Florian Antretter

LBNL Team

LBNL team is led by Dr. Charlie Curcija, co-leader of the LBNL's Windows group. Charlie is heat transfer expert, with extensive experience in windows and building envelop heat transfer and energy performance.

Simon Vidanovic is an engineer and programmer, with expertise in numerical methods. He is bringing the right balance to programming task.

Robert Hart is a scientist with the expertise in both modeling and measurements of heat transfer

Howdy Goudey is the manager of Windows group Thermal Lab, with extensive experience in the measurement of heat transfer

ORNL Team

ORNL team is led by Dr. Simon Pallin who brings extensive experience in modeling, measurements and analysis of moisture transport in building envelopes

Andre Desjarlais is Program Manager for the Building Envelope Systems Research Program at the Oak Ridge National Laboratory. He has been involved in building envelope and materials research for over 40 years, bringing unprecedented expertise in both heat and moisture transfer.

Florian Antretter brings his experience as a member of WUFI team at Fraunhofer institute for Building Physics in Germany.

Purpose and Objectives

Problem Statement: Moisture transfer and heat transfer are two critical and inter-related problems in building envelope characterization, design and optimization. The presence of moisture can degrade both the durability and thermal performance of the building envelope as well as introduce mold problems that endanger the health and safety of building occupants. Successful design of modern energy efficient envelopes is highly dependent on proper moisture management.

Target Market and Audience: Building envelope designers, manufacturers, rating organizations, certified simulators, other related professionals

Impact of Project: Technical potential for energy savings by 2030 from building envelopes (commercial and residential) is 7.1 quads/year, or over $70 Billions/year. Better moisture modeling capability would allow for better energy efficient design, helping save some of this energy.

World class modeling tools form the basis for good building design, as well as helping building envelope component manufacturers innovate and sell their products globally.

Approach

Approach: Enhance LBNL's state-of-the-art building envelope 2-D heat transfer modeling tool THERM with moisture transfer modeling capabilities. In the process, also bring dynamic modeling capabilities to THERM.

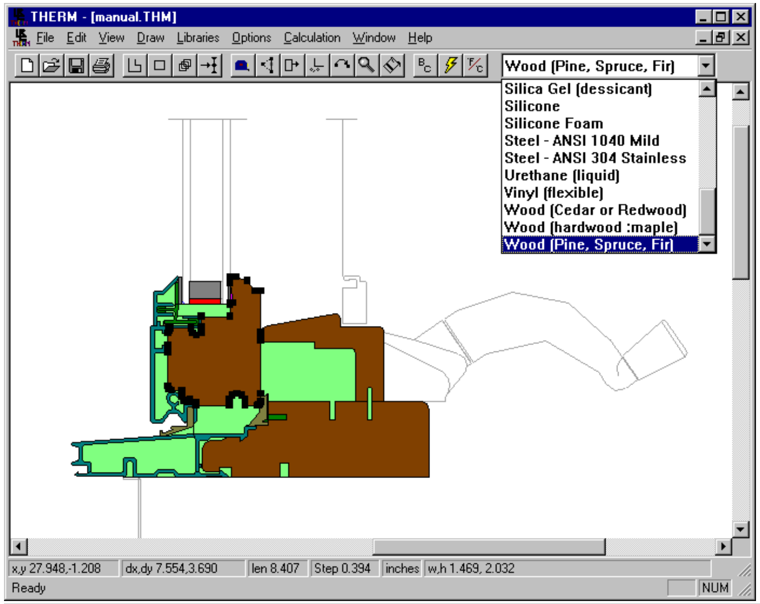
Key Issues:

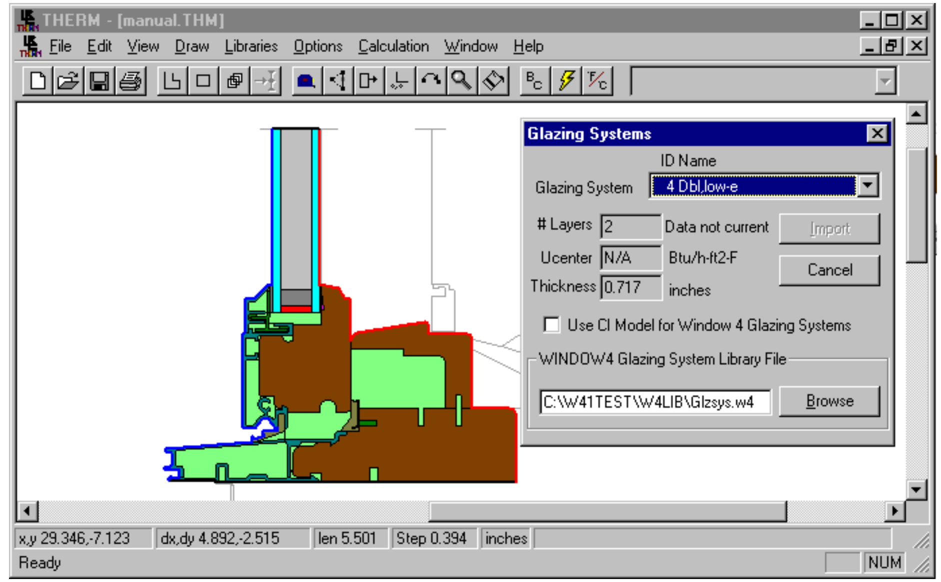
- Extend Finite Element Method (FEM) in THERM to time domain (currently steady-state)
- Add moisture modeling numerical model to THERM.
- Extend current GUI to enable additional data required to model dynamic performance and moisture transfer (e.g., add initial conditions and extend boundary conditions, add new outputs).
- Provide as much of the software tool as open source code, as feasible while complying with export restrictions and third party components.

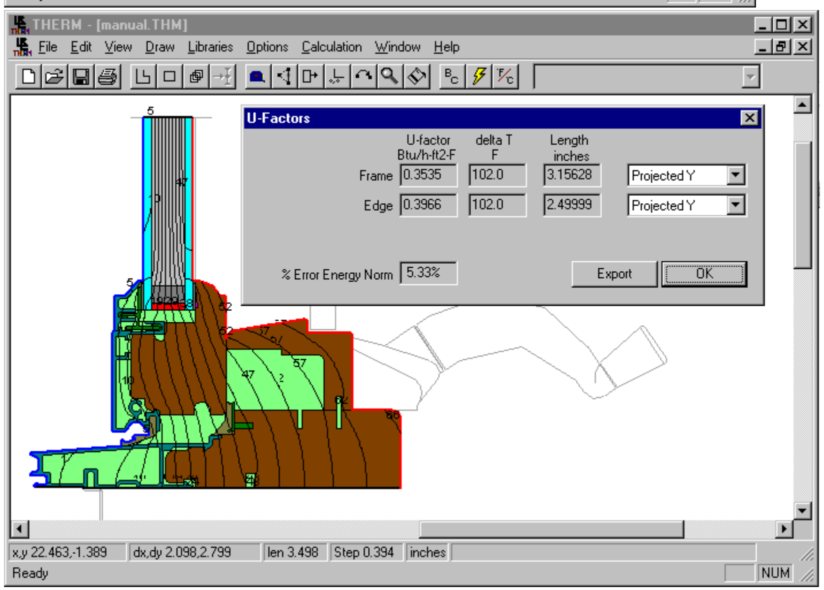
Distinctive Characteristics:

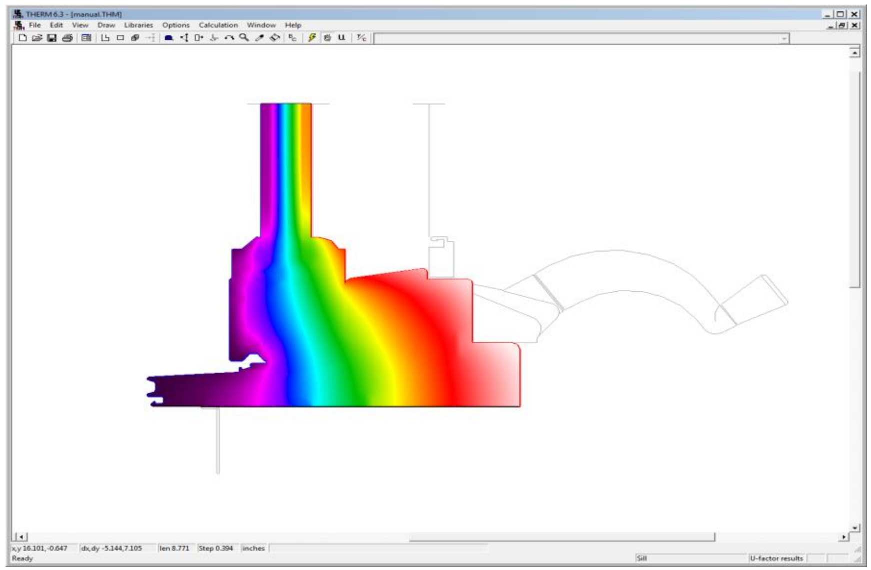
- THERM is used by approximately 25,000 users world-wide. Most widely used building envelope heat transfer modeling tool.
- Used currently primarily to model windows heat transfer and to lesser extent to model building envelopes. This new functionality will expand user base and application

Current THERM Capabilities – Fenestration

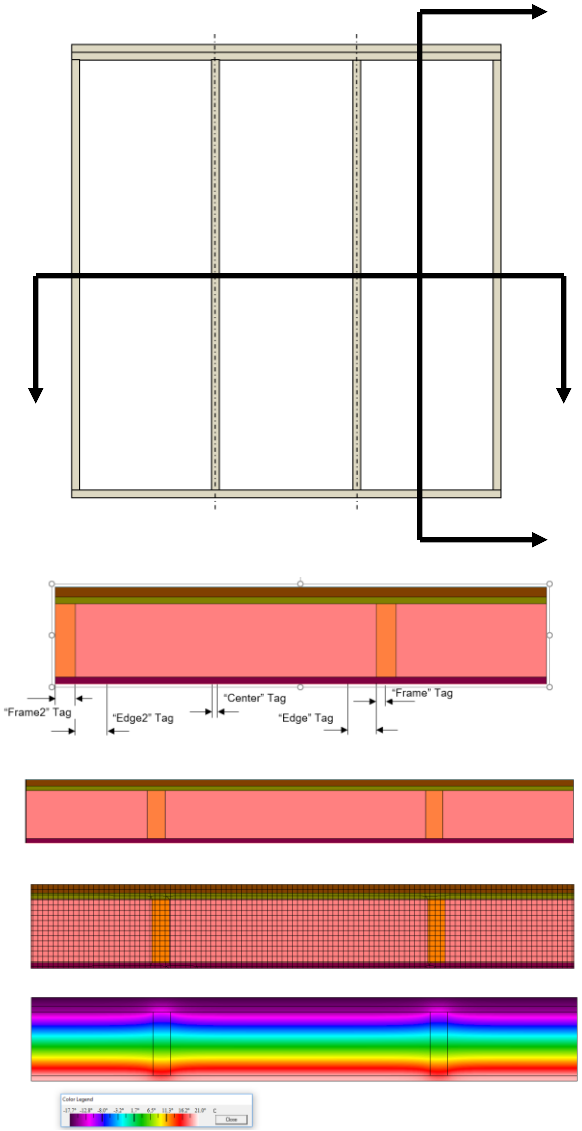


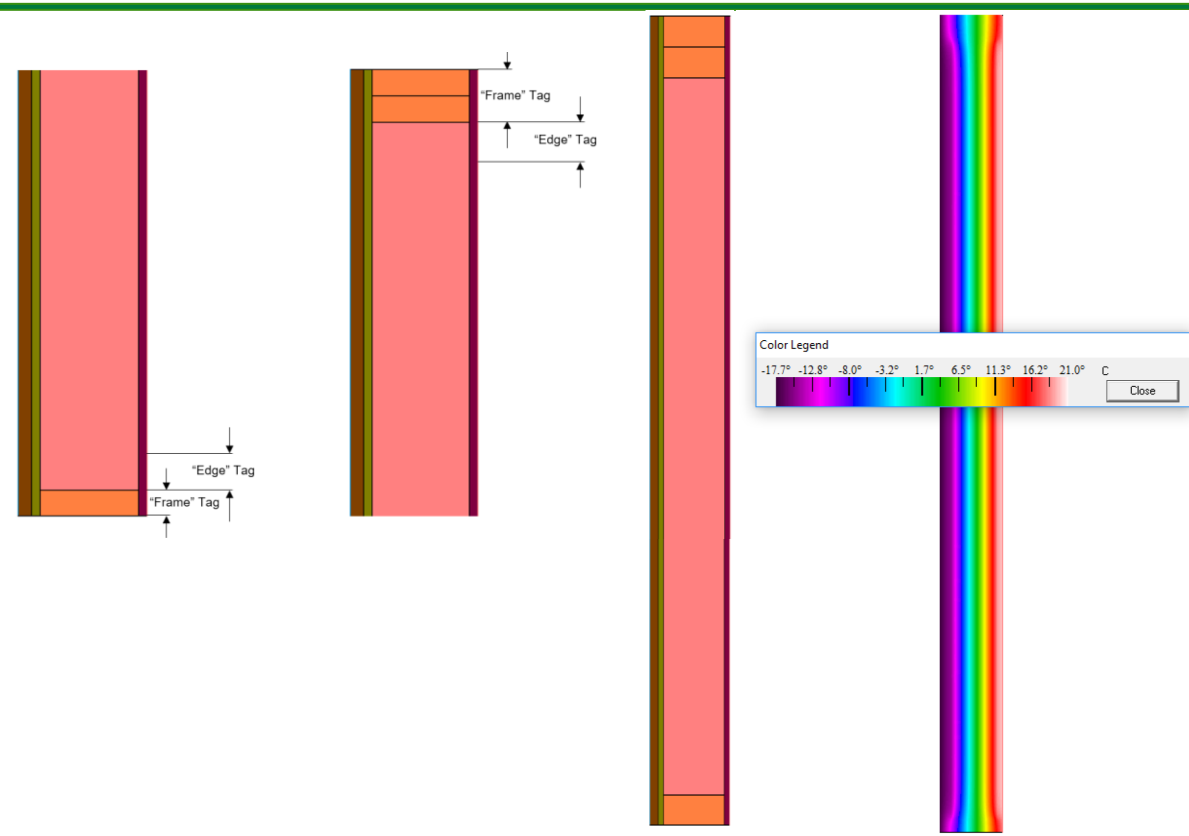






Opaque Envelope Assemblies Modeling in THERMM

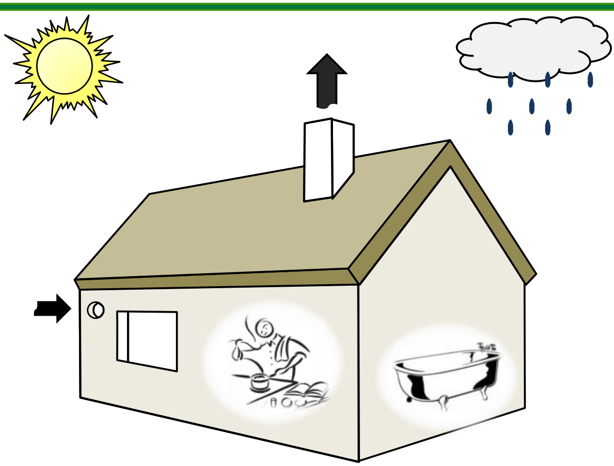


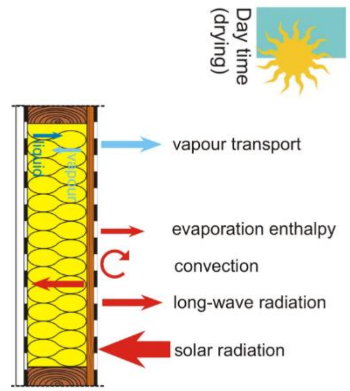


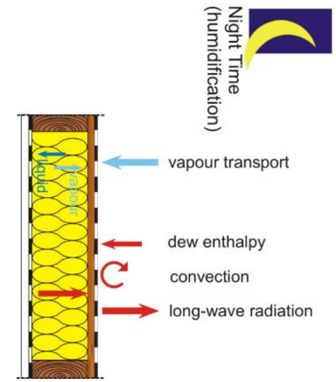
$$U = \frac{7 \cdot 1.5561 \cdot 0.282 + 1.702 \cdot 0.306 + 0.6322 \cdot 0.377}{7 \cdot 1.5561 + 1.702 + 0.6322} = 0.305 \frac{W}{m^2 \cdot K}$$

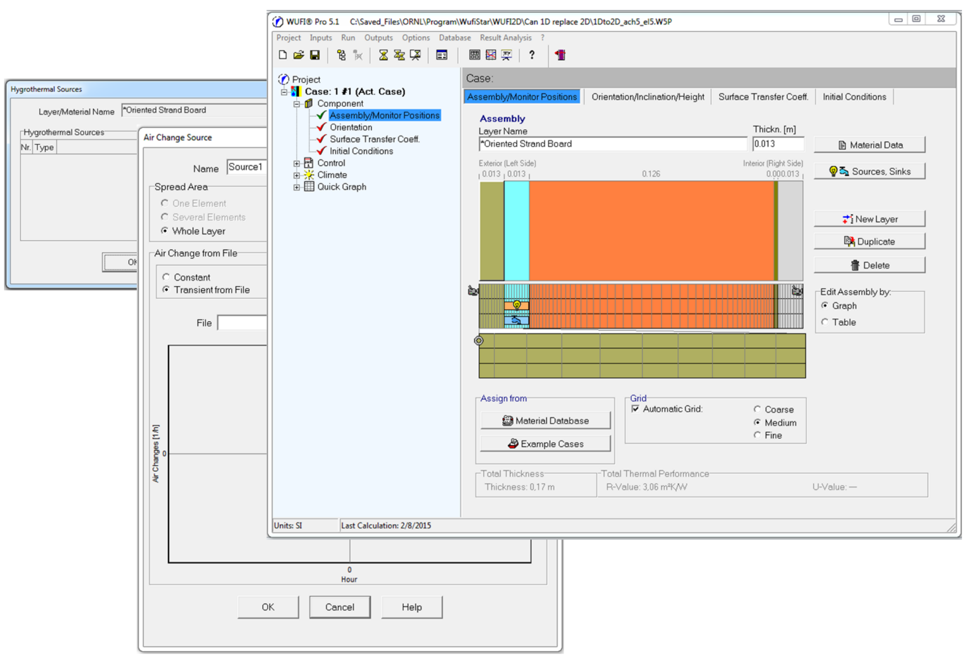
$$U\text{clear wall} = 0.250 \frac{W}{m^2 \cdot K}$$

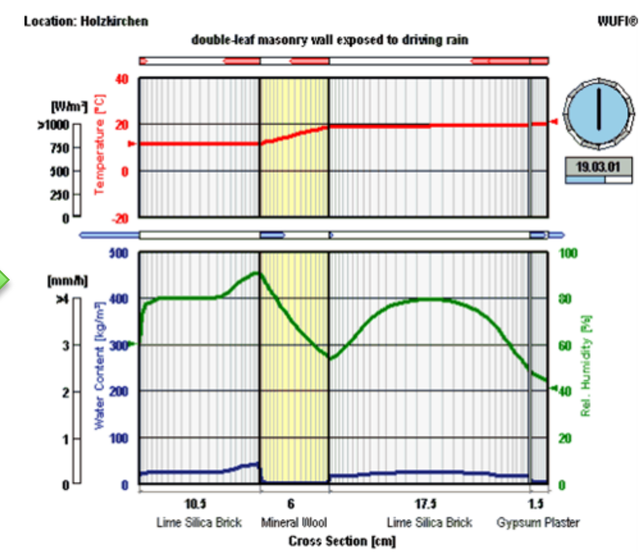
Current Modeling of Moisture Transfer - WUFI



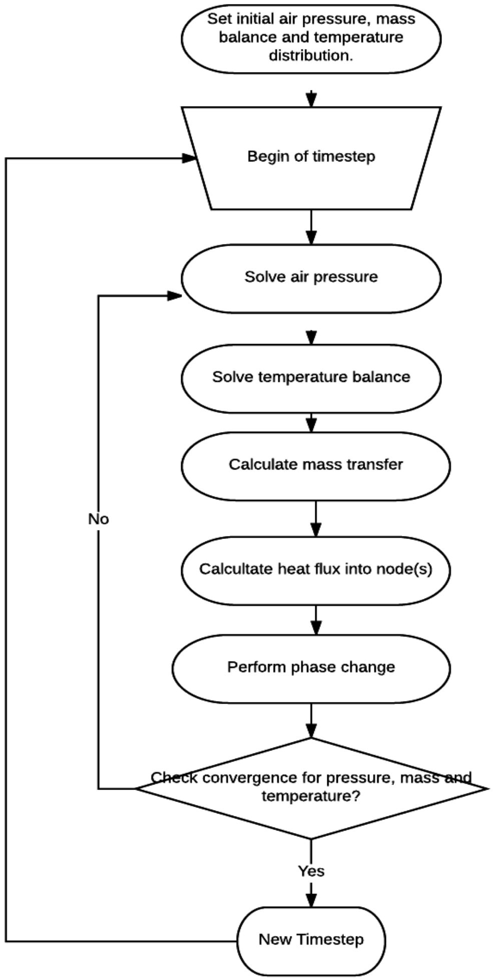








Coupled Heat, Air & Moisture (HAM) Transport Model



Steps in Solving HAM problem

Heat Transfer Model:

$$\rho_{eq}\cdot C_{eq}\frac{\partial T}{\partial t}+S\cdot H_{il}=$$

$$=\frac{\partial \bar{q}_{c,x}}{\partial x}+\frac{\partial \bar{q}_{c,y}}{\partial y}+h_{lg}\left(\frac{\partial \bar{g}_{v,diff,x}}{\partial x}+\frac{\partial \bar{g}_{v,diff,y}}{\partial y}+\frac{\partial \bar{g}_{v,adv,x}}{\partial x}+\frac{\partial \bar{g}_{v,adv,y}}{\partial y}\right)+$$

$$C_l\left(\bar{g}_{l,x}\cdot\frac{\partial T}{\partial x}+\bar{g}_{l,y}\cdot\frac{\partial T}{\partial y}\right)+C_v\left(\bar{g}_{v,x}\cdot\frac{\partial T}{\partial x}+\bar{g}_{v,y}\cdot\frac{\partial T}{\partial y}\right)+C_{air,d}\left(\bar{g}_{air,x}\cdot\frac{\partial T}{\partial x}+\bar{g}_{air,y}\cdot\frac{\partial T}{\partial y}\right)+Q$$

Moisture Transfer Model:

$$\frac{\partial \gamma_w}{\partial \varphi}\frac{\partial \varphi}{\partial t}=\frac{\partial}{\partial x}\left(\frac{E}{\mu_x}\frac{\partial \varphi\gamma_{v_{sat}}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{E}{\mu_y}\frac{\partial \varphi\gamma_{v_{sat}}}{\partial y}\right)+$$

$$\frac{\partial}{\partial x}\left(\frac{k_{air,x}\cdot\varphi\gamma_{v_{sat}}}{\eta_{air}}\cdot\frac{\partial P_{air}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{k_{air,y}\cdot\varphi\gamma_{v_{sat}}}{\eta_{air}}\cdot\frac{\partial P_{air}}{\partial y}\right)+$$

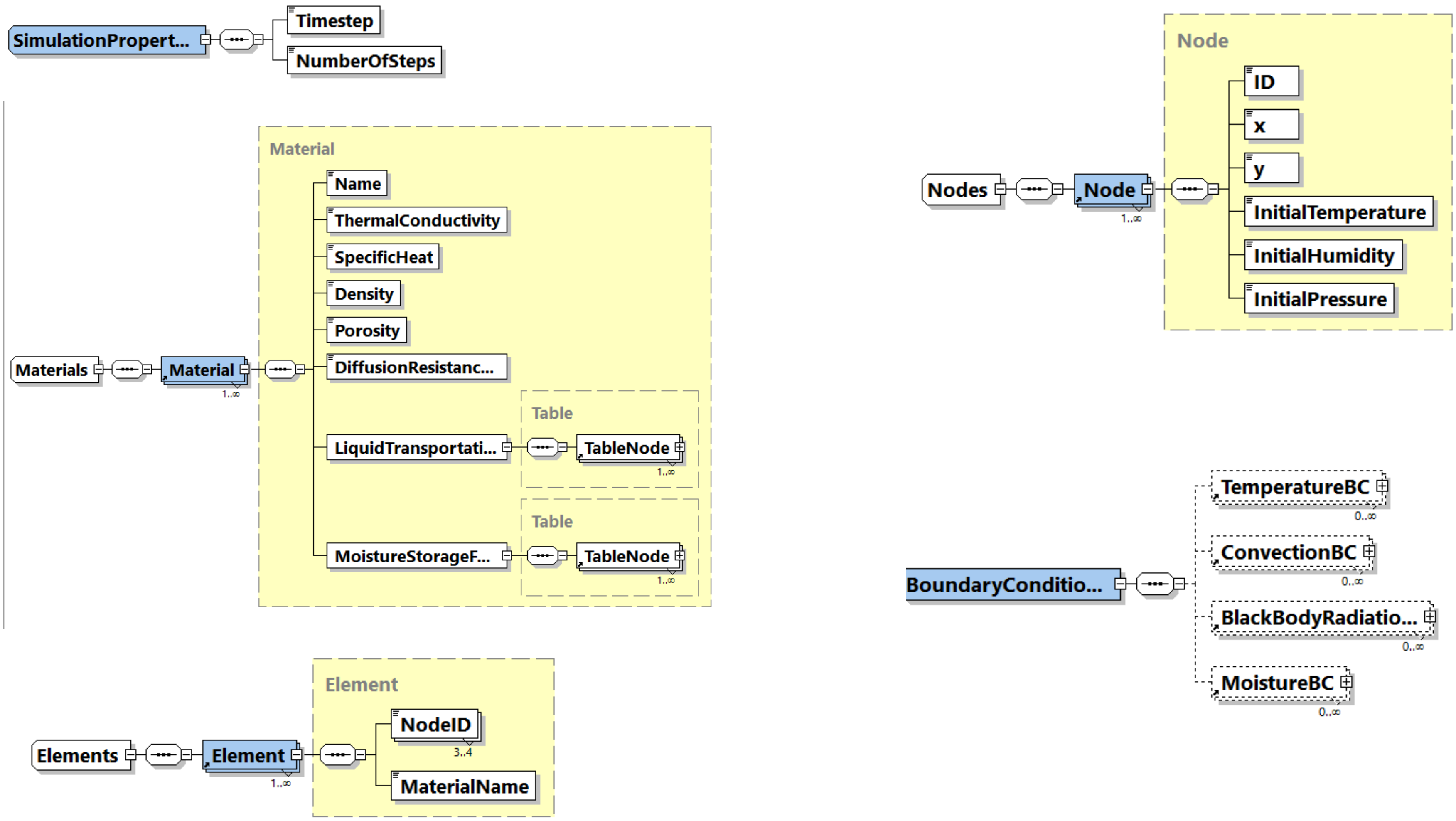
$$\frac{\partial}{\partial x}\left(D_{\varphi,x}\left(\frac{\partial \varphi}{\partial x}\right)\right)+\frac{\partial}{\partial y}\left(D_{\varphi,y}\left(\frac{\partial \varphi}{\partial y}\right)\right)+S_l+S_v$$

Air flow model:

$$\frac{\partial \gamma_{air}}{\partial t}=\frac{\partial}{\partial x}\left(\frac{k_{air}\cdot\rho_{air}}{\eta_{air}}\cdot\frac{\partial P_{air}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{k_{air}\cdot\rho_{air}}{\eta_{air}}\cdot\frac{\partial P_{air}}{\partial y}\right)$$

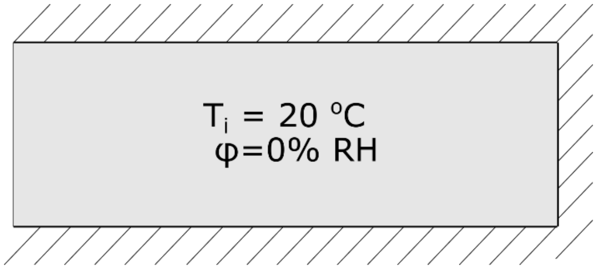
API Development

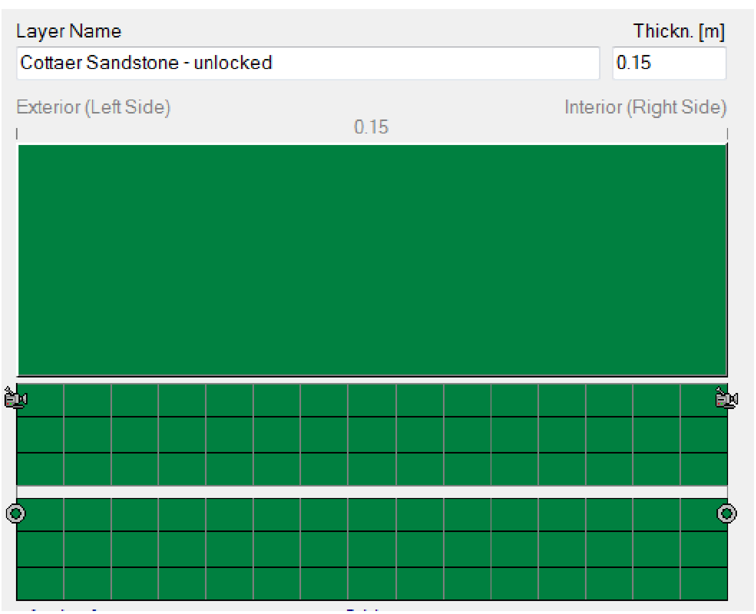
- XML file format to communicate with THERMM engine

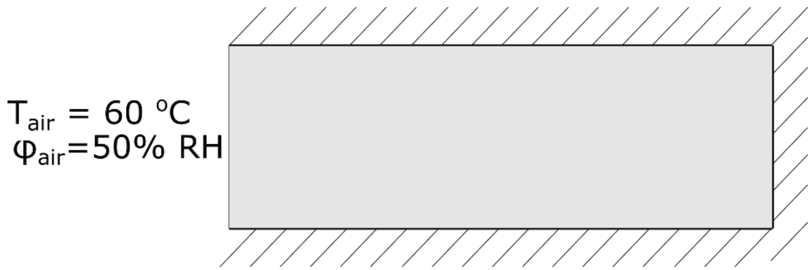


Simple WUFI Comparison Example

- 15 cm Cottaer Sandstone
- Initial conditions: 20 °C and 0 % RH
- Boundary conditions: 20 °C and 50 % RH applied on left side
- Modified material properties
- Liquid and heat transfer disabled

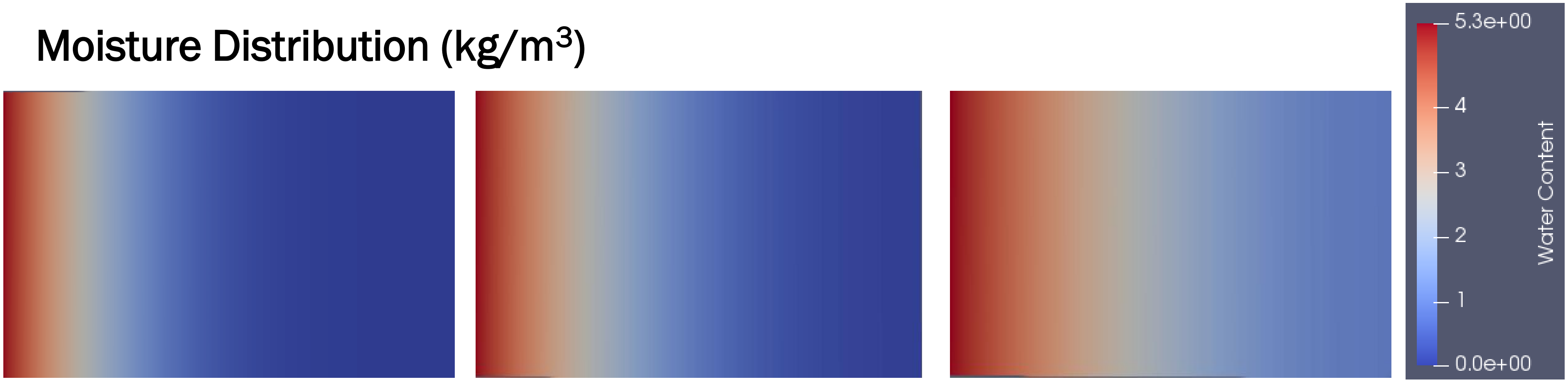






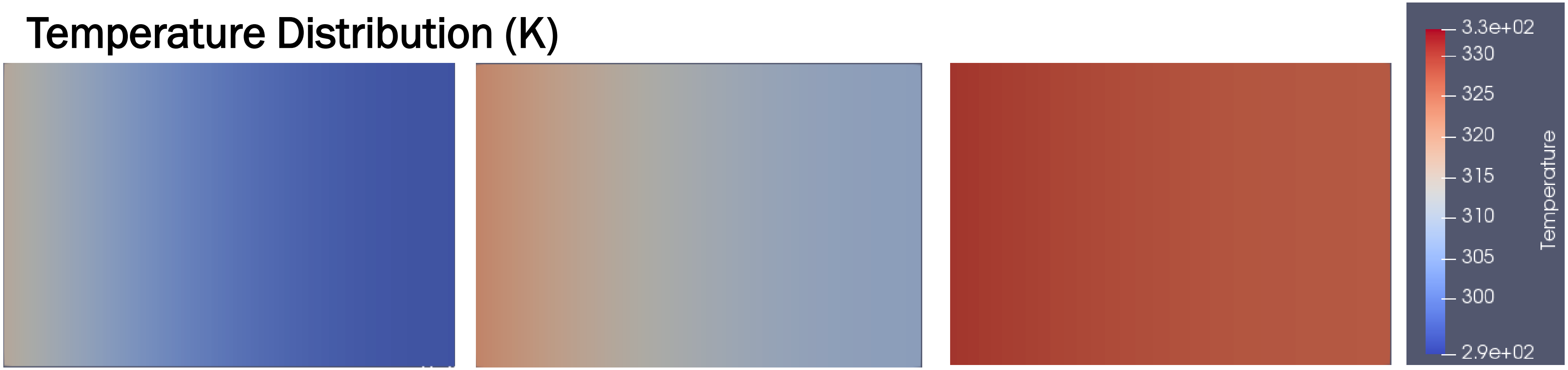
Modeling results from THERMM

Moisture Distribution (kg/m^3)



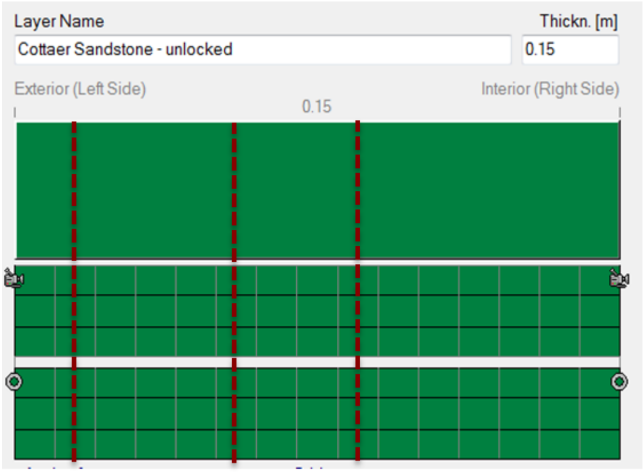
Time at 10 hours | Time at 20 hours | Time at 50 hours

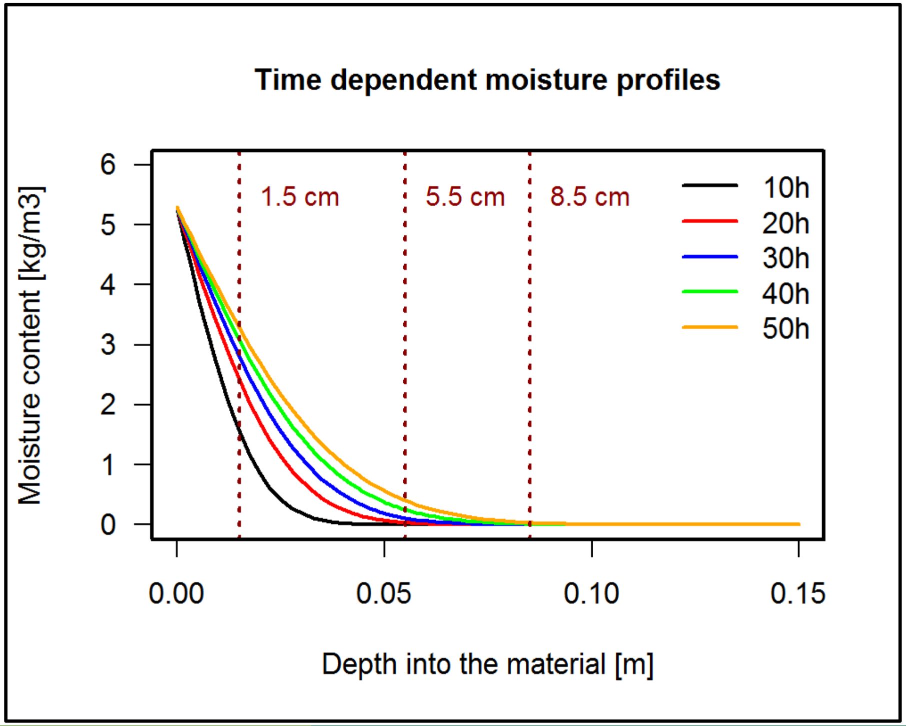
Temperature Distribution (K)

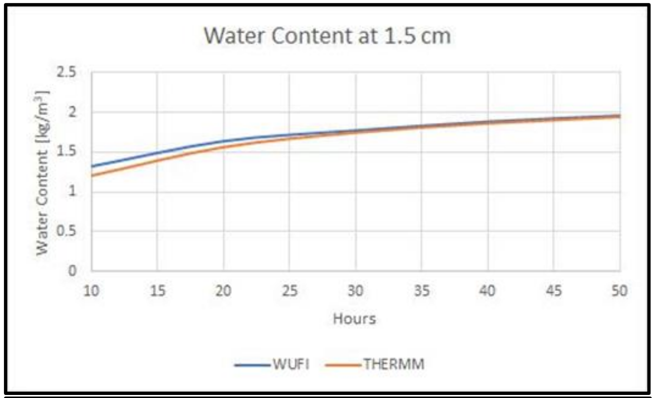


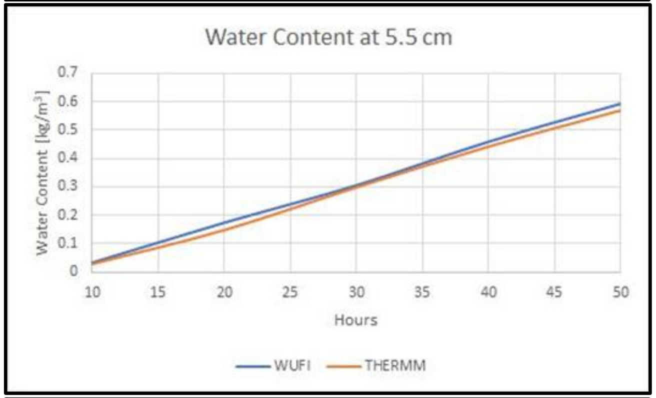
Time at 1 hour | Time at 3 hours | Time at 10 hours

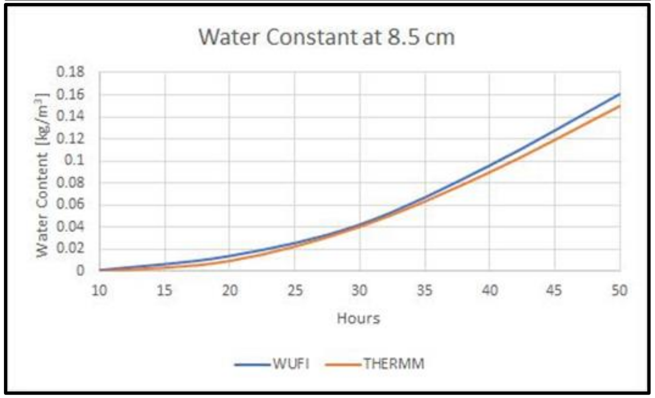
THERMM Results vs. WUFI











Identified validation cases

- Hygric model with EN 15026 with analytical limit value table and graphic

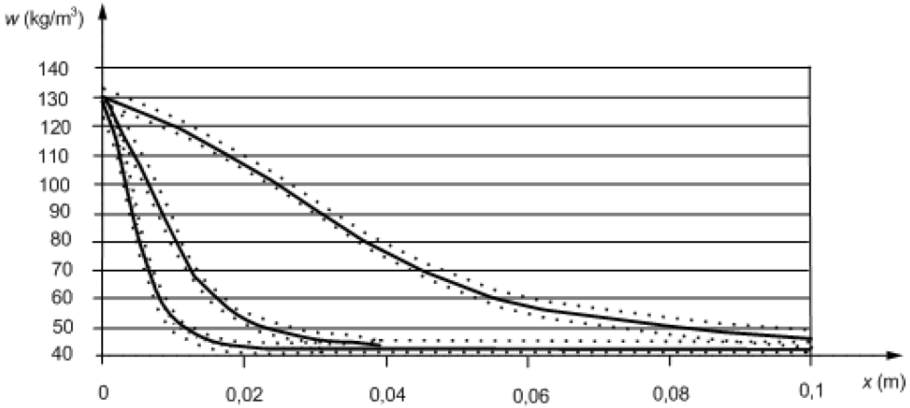
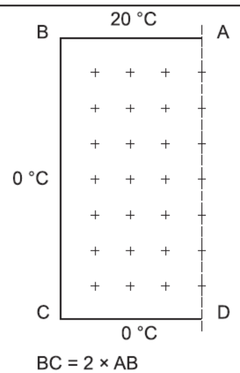


Table A.1 — The limits of validity for results from the humidity calculations

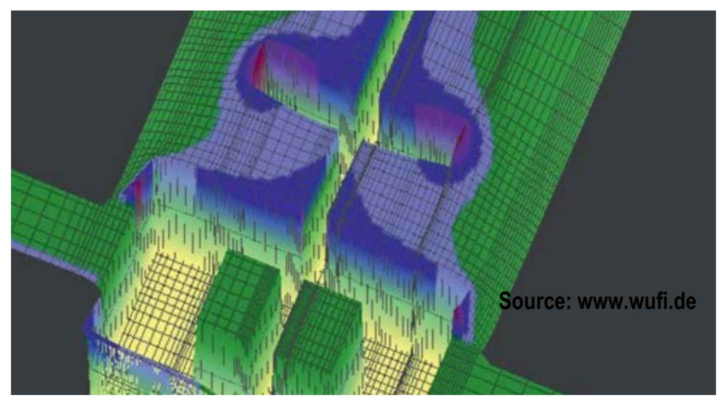
Days	x = 0,01		x = 0,02		x = 0,03		x = 0,04		x = 0,05		x = 0,06		x = 0,08		x = 0,10	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
7	50,2	54,5	41,3	45,6	40,8	45,1	40,8	45,1								
30	81,0	85,3	51,1	55,3	43,6	47,9	41,5	45,7	40,9	45,2	40,8	45,1	40,8	45,1		
365	117,5	121,8	104,4	108,7	88,7	93,0	75,6	77,9	62,8	67,1	55,7	60,0	47,9	52,2	44,1	48,4

- Thermal model with ISO 10211 (static 1D and 2D analytical reference case)



Analytical solution at grid nodes (°C)

9,7	13,4	14,7	15,1
5,3	8,6	10,3	10,8
3,2	5,6	7,0	7,5
2,0	3,6	4,7	5,0
1,3	2,3	3,0	3,2
0,7	1,4	1,8	1,9
0,3	0,6	0,8	0,9



- Cross-validation with WUFI 1D and 2D

Project Integration and Collaboration

Project Integration:

- Involving NFRC, AERC and PHIUS
- Diverse technical advisory group - TAG
- Reporting at ASHRAE
- Planning to fead future standard implementation

Partners, Subcontractors, and Collaborators:

- Rating organizations
- Government – Forest Products Lab
- Building envelope manufacturers: Owens Corning, window manufacturers
- Associations - ASHRAE
- Universities: University of Waterloo, British Columbia Institute of Technology
- Certified simulators – WESTlab
- Software Companies – Bigg Ladder Software

Communications:

- e-mail/phone user support
- web-based software support forum
- Conferences, Webinars
- TAG meetings

Progress and Accomplishments

Accomplishments

- IP management and data plan completed
- Mathematical model completed
  - Combined heat and moisture model – HAM
  - Identified areas of future development
- Numerical model being finalized
- Early results show good agreement
- Open source plan

Market Impact

- THERM is used by all major fenestration manufacturers, including globally
- Increasing number of users use it for opaque parts of building envelope
- When HAM functionality is completed, we expect further explosion of user base

Recognition

- THERM is most widely used software tool for modeling building envelopes in the world

Lessons Learned

- Decision what to include in software tool vs. what to leave out is very difficult

Next Steps and Future Plans

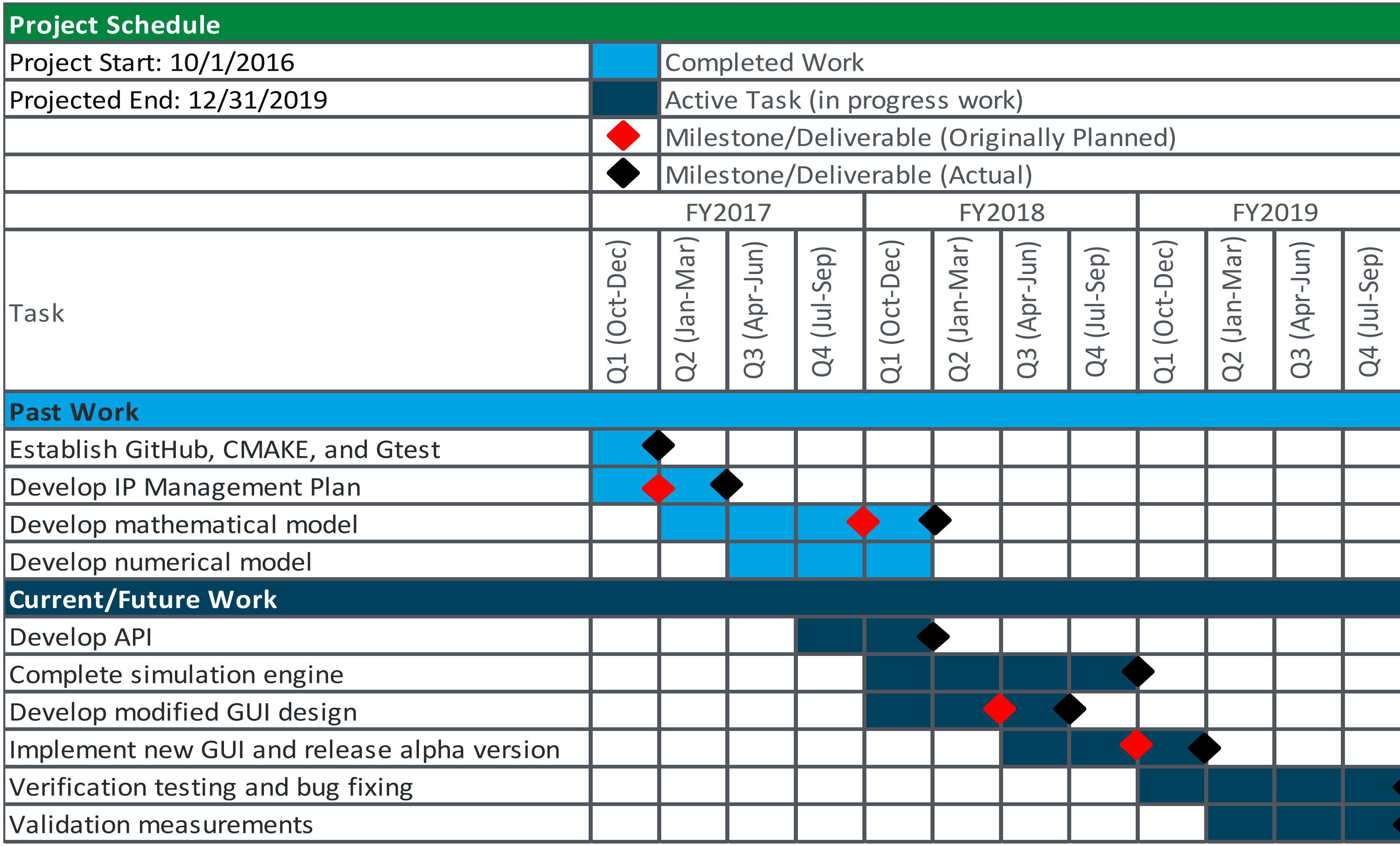
FY18

- Finalize API
- Complete development of numerical model
- Implement numerical model in FEM engine (current FEM engine name is CONRAD)
- Release Alpha version of software tool to selected group of reviewers (TAG and some selected others)
- Begin verification and validation

Out Years

- Release Beta version to wide public
- Complete verification and validation of THERMM modeling results
- Collect feedback and implement in full release version
- Write final verification and validation reports
- Write user's manual, and technical documentation
- Release final software tool version

Project Plan and Schedule



NEW TEXTBOOKS UNDER DEVELOPMENT & SUPPLEMENTAL RESOURCES

- Building Science for Building Enclosures, 2nd Edition
  - ✓ New Draft Tested in Waterloo 2018 Spring Semester
  - ✓ Revised Draft for New Architectural Engineering School
  - ✓ Current Status
- MEEB, 13th Edition
  - ✓ Updates Hygrothermal Performance
- Moisture Control Handbook, 2nd Edition
  - ✓ "Textbook" companion to Building Science Advisor
- Other Textbooks Under Development
- Supplemental Resources for Existing Textbooks
  - ✓ "High Performance Enclosures" augmented differently by different Professors – topic for discussion
  - ✓ Standard Textbook Supplements – See Website Resources

UPDATE ON BUILDING SCIENCE WEBSITES

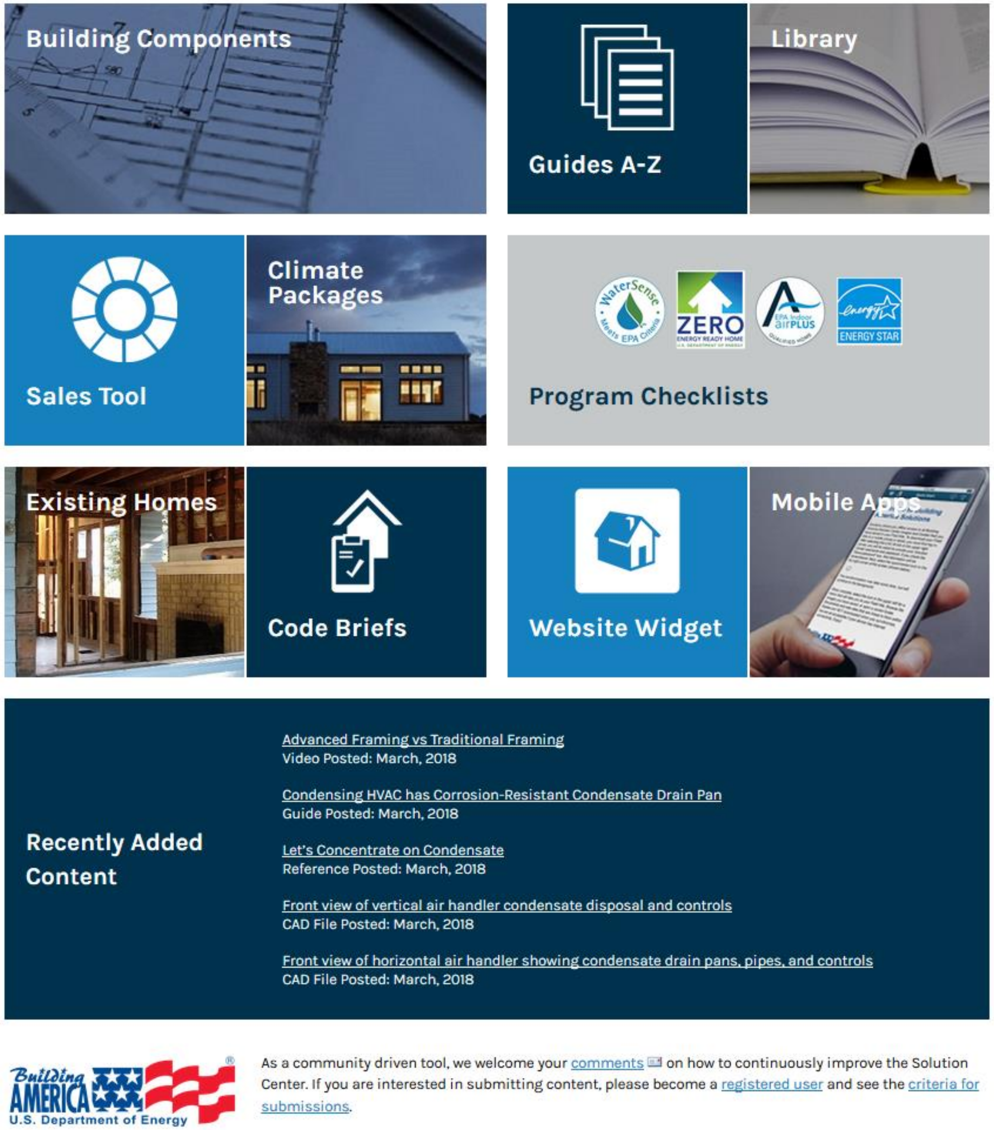
- **New/Expanded Website Resources**
  - ✓ **Building America Solution Center**: Updates; Image Gallery, Fundamentals; ZERH Resources - Baechler
  - ✓ **U Toronto eLearning Building Science Fundamentals** – Pressnail/Touchie
  - ✓ **BSE Website** – expanded teaching resources – including U-MN lecture modules – Huelman/Taylor
  - ✓ **SBSE Education Resources** – Reichard
  - ✓ **NIBS**: WBDG; Mitigation Saves; etc.

BASC.energy.gov
Easy Access to Expert Guidance

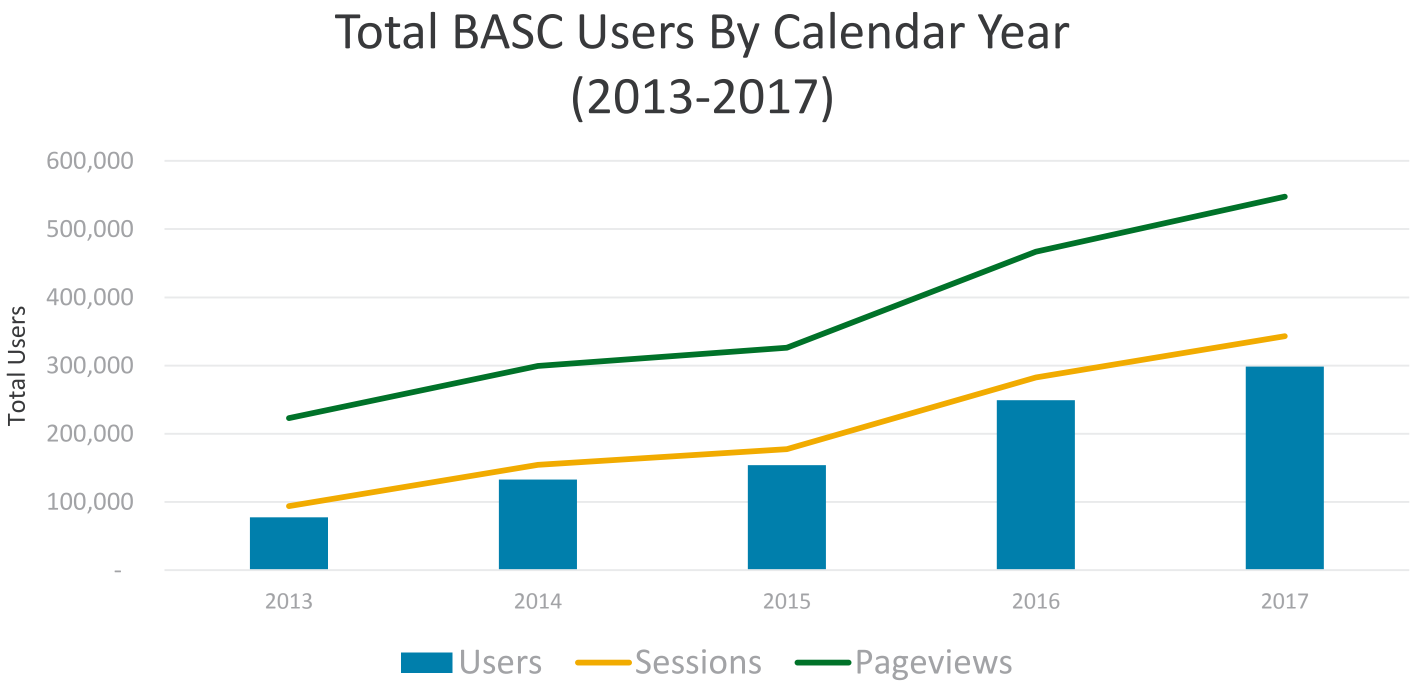
Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by **Battelle** *Since 1965*

Access to:

- 252 Guides
- 1,700+ Images
- 330+ Proven Performance Case Studies
- 130+ CAD Drawings
- 980+ Building Science References & Resources
- 30+ Code Compliance Briefs
- 110+ Videos
- 40+ Sales Briefs



Impact



"The Building America Solution Center is full of best practices. Every guide in there is based on the right way to do things."

C.R. Herro
V-P of Environmental Affairs, Meritage Homes

"We built our business on the shoulders of giants, including the Building America Solution Center."

Gene Myers
CEO, Thrive Home Builders
(Professional Builder Magazine Builder of the Year)

Thank You

BASC.energy.gov

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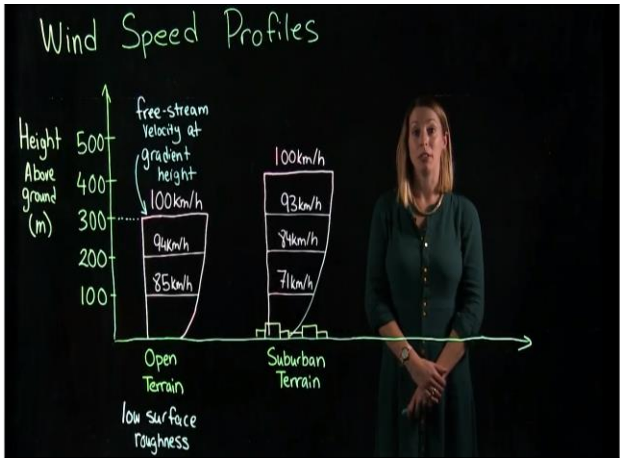
The Fundamentals of Building Science:

Free, online learning modules

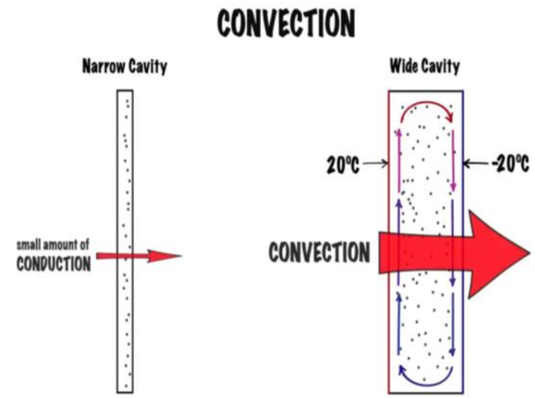
UNIVERSITY OF TORONTO

Over 100 videos available for reuse and download to various Learning Management Systems or direct online access

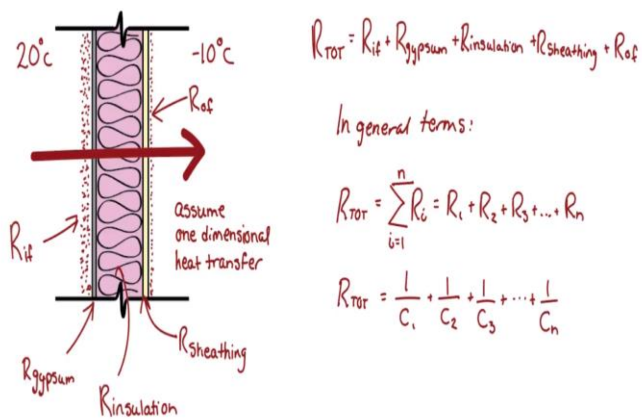
A variety of presentation formats with embedded interactive knowledge checks



Light Board



Motion Graphics



Tablet Capture

Live Demonstrations

How to access these modules

Official release: August 21, 2018

Sneak Peek?

Visit: http://edtech.engineering.utoronto.ca/project/building-science-fundamentals

1. Scroll down to Project Components
2. Click on one of the components (e.g. "Heat Transfer") and then "Read More"
3. Once on the module page, click "View this Module"

Enjoy and please let us know what you think!

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Kim Pressnail pressna@ecf.utoronto.ca

UNIVERSITY OF TORONTO

JOINT COMMITTEE WEBSITE

- www.BuildingScienceEducation.net/Resources
  - ✓ Online Resources
  - ✓ DOE Resources – DOE/PNNL Solution Centers
  - ✓ Other
- www.BuildingScienceEducation.net/Resources/Teaching-Resources ---"Supplemental Teaching Resources"
  - ✓ Prof. John Straube – Waterloo Resources
  - ✓ Dr. Joe Lstiburek - BSC Resources
  - ✓ Prof. Carl-Eric Hagentoft 14 YouTube Videos
  - ✓ Prof. Patrick Huelman – **UMN Resources/Lecture Modules**
  - ✓ U of Toronto **Building Science Fundamentals eLearning**

EXCELLENCE IN BUILDING SCIENCE EDUCATION
Transforming the Design/Construction Profession

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Home › Resources

Resources

As a first small step toward achieving excellence in building science education, select curricula, key courses, teaching methodologies, and content are ***shared*** to aid in the development and improvement of university building science programs. Initially, the focus of the shared curricula would include schools of: engineering (e.g., civil, mechanical, architectural), architecture (skilled in building performance), construction management, and others (e.g., material science, EU building physics). Key courses would, for example, address high performance enclosures, including hygrothermal analysis, systems engineering, quality management, indoor air quality, advanced detailing, and other subjects.

Resources provided to support the development and enhancement of building science curricula include:

- Shared University Curricula
- Supplemental Teaching Resources
- Building Energy Software Tools
- Bibliography of Building Science Education Publications
- Online Resources for Building Science
- US Government and other Resources Useful for Building Science Education.

Resources

- Resources
  - Additional University Resources
  - Additional US Government Resources
  - Select Links
  - Publications
    - Housing and Residential Building Construction

RESOURCE Webpage

NOTE Links to Supplemental Teaching Resources & Online Resources

EXCELLENCE IN BUILDING SCIENCE EDUCATION
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Home | About | Programs/Task Groups | Resources | Events/News

Home › Resources › Teaching Resources — Preliminary Listing

Teaching Resources — Preliminary Listing

Task Group Working File – Review of Suggested Resources

Supplemental Teaching Resources

Supplemental Teaching Resources – Professor John Straube, University of Waterloo (*Updated June 22, 2017*)

1. Building Enclosure Fundamentals
2. Building Science Control Layers Definitions
3. Material Selection for Building Enclosure Design
4. Arch Heat Flow Basics
5. Enclosure Options
6. Insulation Thermal Control Layers
7. Air and Vapor Barriers
8. heat flow eg 1
9. building science bibliography (rough draft)
10. RDH/Building Science Laboratories ***Net Zero Housing Reading List***

Supplemental Teaching Resources – Dr. Joseph Lstiburek, Building Science Corporation (Adj. Prof., U of Toronto)

1. Building Science Fundamentals – see "Reading Material"
2. Building Science Fundamentals – Slides – Past Events
3. Building Science Fundamentals – Moisture Transport
4. Building Science Insights
5. ZERH High Performance Enclosures Webinar
6. Lstiburek, J., K. Ueno, and S. Musunuru. *Strategy Guideline: Modeling Enclosure Design in Above-Grade Walls*. United States: N. p., 2016. Web. doi:10.2172/1239889. ***See Moisture Physics Background, pg. 5***

Building Physics Introduction lectures – 14 YouTube videos – Professor Carl-Eric Hagentoft, Chalmers University of Technology, Sweden

University of Minnesota Building Science Teaching Resources

University of Toronto – eLearning Building Science Fundamentals – Official Launch Scheduled for August 21, 2018 – Preview Slides

Online Resources

- Building America Publications Library features a database of Building America publications from 1995 to present.
- Building America Meetings and Webinars
- Building Science Publications – search tool under the Building America Solution Center.
- DOE Zero Energy Ready Home (ZERH) Resources
- Home Innovation Research Labs Reports – provides information on design/construction documentation and related work on quality management. See "Quality Resources" and "Scopes of Work" [Includes resources from former NAHB-RC ToolBase].
- Building Science Information: Building Science Corporation, on their Information site, provides extensive online resources for educators and building professionals about building physics, system design concepts, and sustainability for design and construction of energy efficient, healthy, durable buildings.
- Building Science Reading Lists and Presentations — RDH-Building Science Consulting, Inc. and their Building Science Labs research division, provide resources for students, educators and building professionals. See their "Library", including the "Net-Zero Housing Reading List" and their "Presentations". Also, RDH has a listing of guideline documents.
- DOE Building Energy Codes Resource Center: provides tools and training resources to facilitate energy code compliance, development, adoption, implementation, and enforcement.
- Whole Building Design Guide issues building-related guidance, criteria and technology from a whole buildings perspective from the National Institute of Building Sciences. (For example, see design recommendations within the WBDG Building Envelope Design Guide, including Wall Systems guidance)
- BRIK Enclosures Research – The NIBS/AIA Building Research Information Knowledgebase (BRIK) offers online access to peer-reviewed research projects and case studies in all facets of building, from predesign, design, and construction through occupancy and reuse.
- Efficient Windows Collaborative gives information on the benefits of energy-efficient residential windows, descriptions of how they work, and recommendations for their selection and use.
- Windows for High Performance Commercial Buildings – Tools & Resources
- Tips for Daylighting, Jennifer O'Connor, Eleanor Lee, Francis Rubinstein, and Stephen Selkowitz. These guidelines provide an integrated approach to the cost-effective design of perimeter zones in new commercial buildings. They function as a quick reference for designers through a set of easy steps and rules-of-thumb, emphasizing "how-to" practical details.
- Foundation Design Handbook – Final Draft
- "Best of Building Science Online Training" – Developed by the Oklahoma State Energy Office
- Center for Green Schools – Resources (USGBS Partner)
- EEBA, the Energy & Environmental Building Alliance, delivers unique and relevant, multi-platform educational resources in the design, marketing and execution of the building process.
- IIBHS FORTIFIED Performance Requirements
- FEMA Building Science Resources
- NRC Canada Publications – Includes NRC Publications Archive, construction innovation and technology, and some access to IRC reports.
- BChydro Resources – including "Building Envelope Thermal Bridging Guide"
- NIST Net-Zero Energy Residential Test Facility – see Project Details
- ACCA has a number of free online and discounted Resources for Educators and schools. Also, see: Quality Standards; Speed Sheets; and Q-Tech.

Partial Listing – Online Resources

- DOE Building America Solution Centers, *plus*
  - https://basc.pnnl.gov/; https://bsesc.pnnl.gov/ ; https://www.osti.gov/
- Building Science Corporation
  - www.BuildingScience.com/Information
- RDH Building Science Labs
  - www.buildingsciencelabs.com/the-library/
- Joint Committee Website
  - www.BuildingScienceEducation.net/Resources
- U Toronto eLearning Building Science Fundamentals
  - http://edtech.engineering.utoronto.ca/project/building-science-fundamentals
- SBSE Website
  - www.sbse.org/resources/
- NIBS Whole Building Design Guide (*Updated*)
  - http://www.wbdg.org/

CHALLENGES & OPPORTUNITIES: FY2019

- DOE FY18 funding is comparable to FY17, though slow in getting to certain field programs
- FY19 RTZ becomes SolarDecathlon "Design Challenge"
  - ✓ TBD - Competition criteria emphasis on critical building science
- Success will depend on pulling together with focus
  - ✓ SD Design Challenge (RTZ) impact can be enhanced with resources & support for paired academic learning
  - ✓ ZERH – proven BSE resources & industry partners for RTZ
  - ✓ BA Research can provide critical "building science content, but must be formatted for both educators and industry
  - ✓ JTG – include FOCUS on near term resources for RTZ

JOINT TASK GROUP – PRIORITY THRUSTS

- Hygrothermal Performance & Analysis Guide
  - ✓ Near-term focus on Interim Measures for 2019 SD-DC (RTZ) to enhance pairing of academic and experiential learning
  - ✓ classroom companion resource to webinars
- Filling Resource Gaps –
  - ✓ open source lecture modules
  - ✓ open source / easily citable images for modules
- Peer Review of New & Recommended Existing Resources
  - focus on "Infusion Modules"
- Annotated Bibliography of Good Resources
- Other: Input to new textbooks

OPEN DISCUSSION; NEXT STEPS

Thank you for participating today!

Let's keep the discussion and work going here at Westford and beyond

THANKS FOR PARTICIPATING IN THE 2018 ANNUAL WESTFORD BUILDING SCIENCE EDUCATION UPDATE