Evaluating the Moisture Durability of Energy-Efficient Walls

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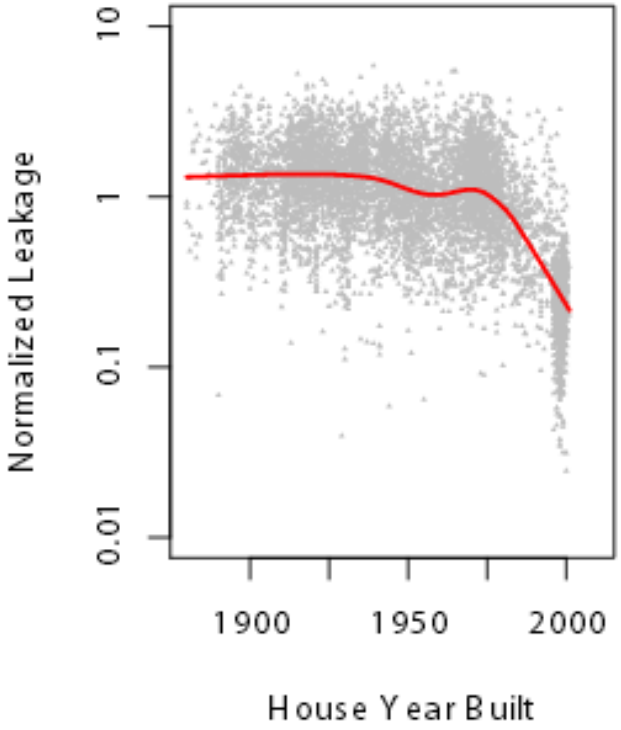
Why evaluate the moisture durability of walls?

- Energy loss through walls in homes:
  - 1.8 quads/yr.
- To decrease this energy loss we can:
  - Increase R-value of walls
  - Increase air-tightness of walls



- Both of these solutions require care so that the moisture durability of high performance walls is maintained.

*Chan W.R., et al. Analysis of U.S. Residential Air Leakage Database. LBNL Report

Why do we care about moisture and walls?

- Material degradation, structural stability
- Avoid cost associated with repairs, lawsuits, etc.
- Health/Comfort
- Air Quality (mold)
- Adoption rates:

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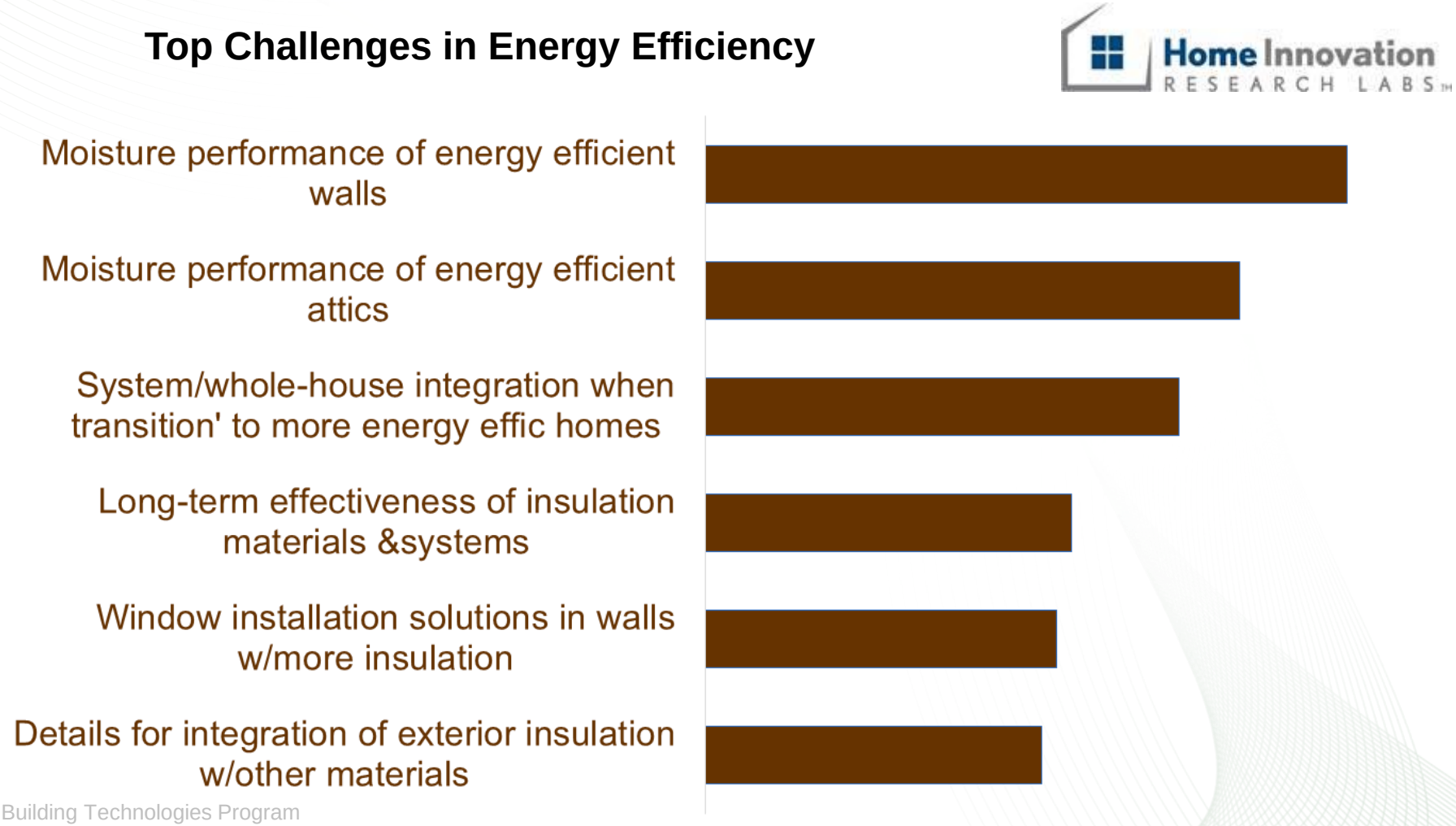
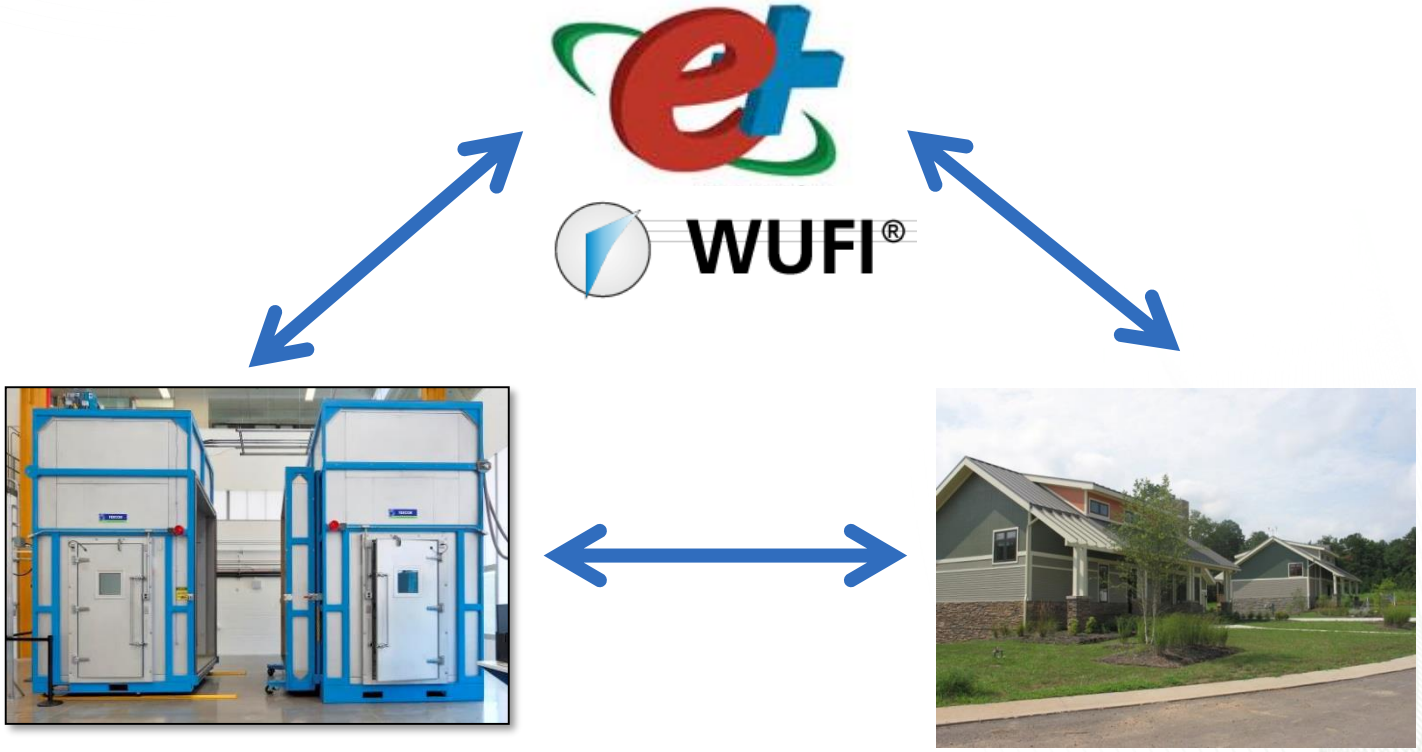
- Adoption rates:

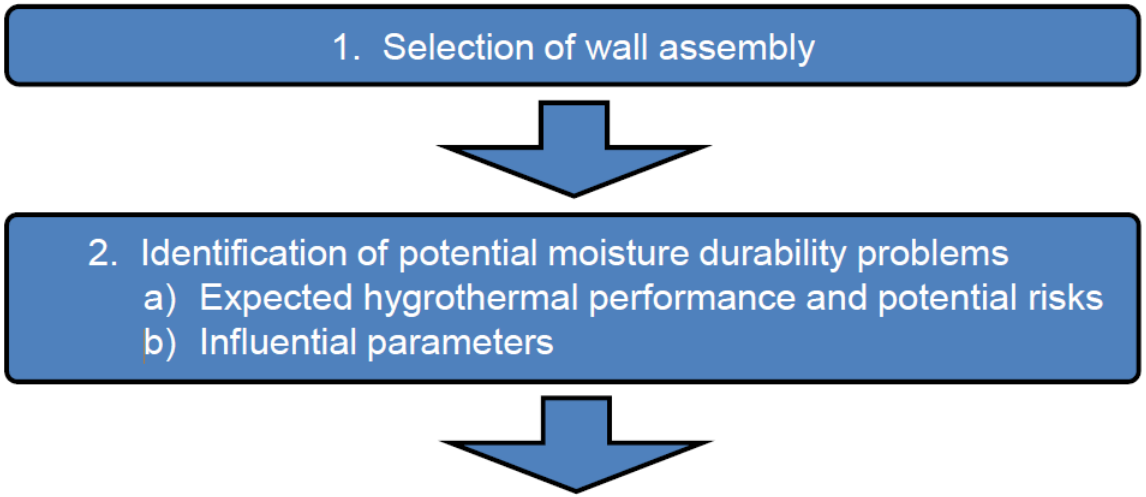


Evaluating walls for moisture durability

- We want to provide guidance so builders can easily construct energy efficient moisture durable walls.
- So we need a way to quickly and reliably determine the moisture performance (MC of wood, MGI) of wall designs across different climates, occupancy habits and building construction.



Protocol for evaluating walls for moisture durability



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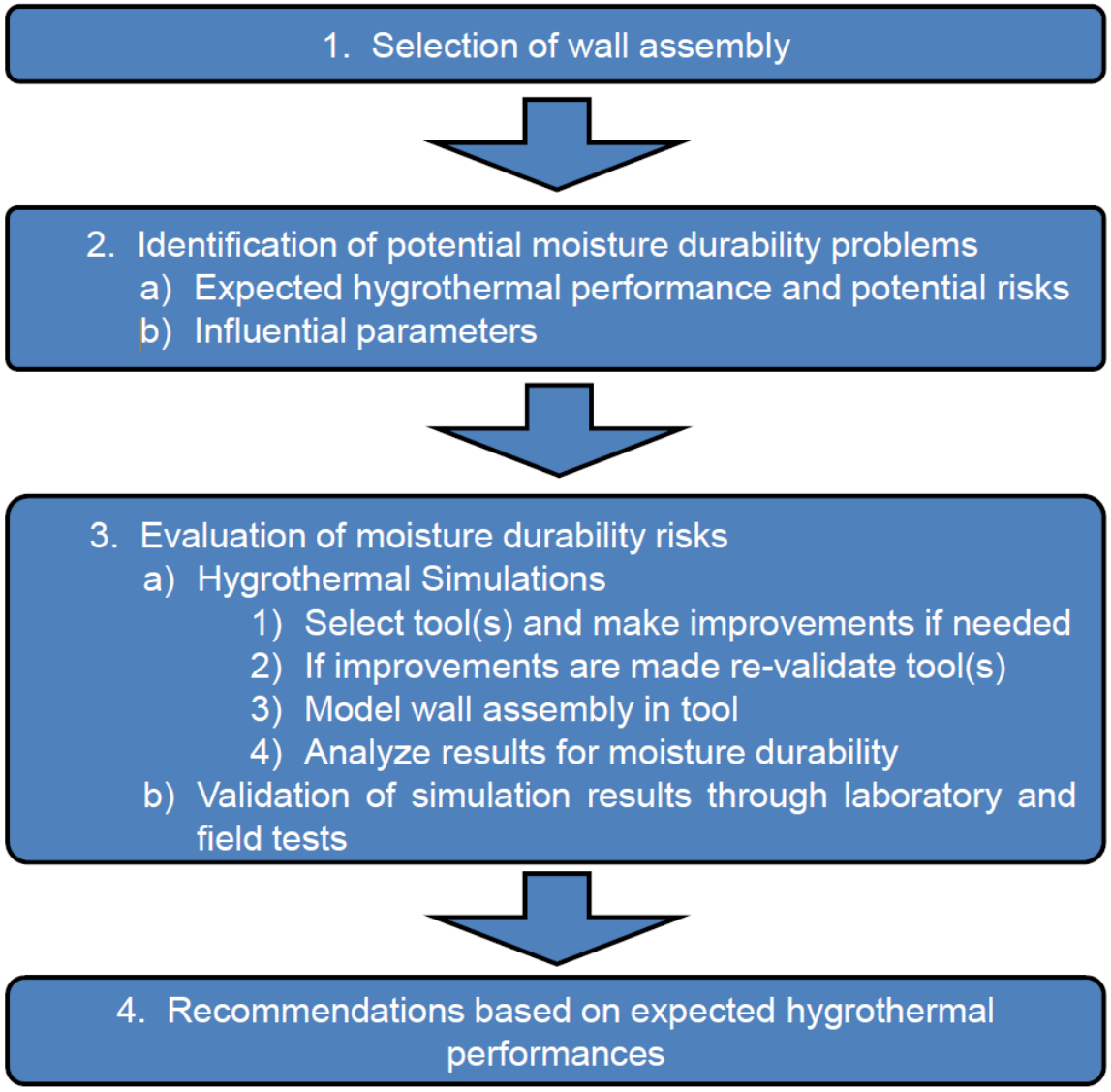
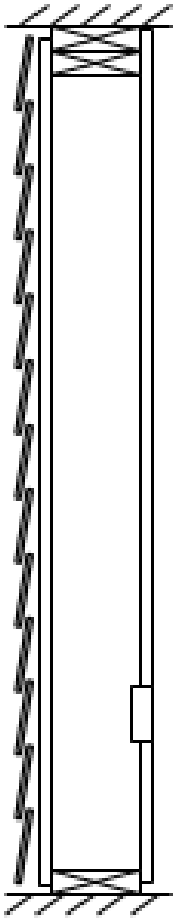


Identifying walls, potential risks, and key influencing parameters

2. Identification of potential moisture durability problems
   a) Expected hygrothermal performance and potential risks
   b) Influential parameters

- Outdoor Climate
  - AMY (5 years) x 15 CZ



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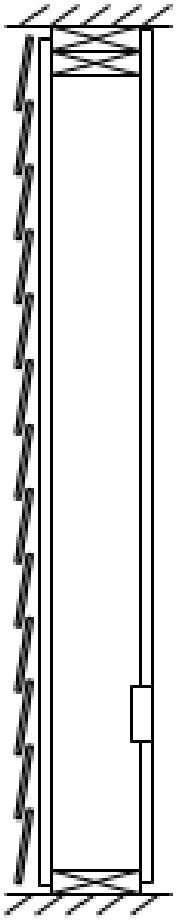

- Indoor Climate (T, RH)
  - Heat and Moisture Generation
  - Thermostat Set Point
  - Airtightness
  - Outdoor Climate
  - House Characteristics

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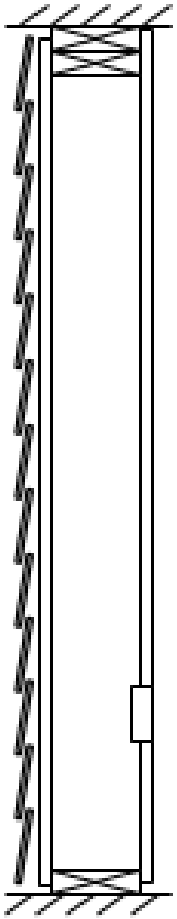

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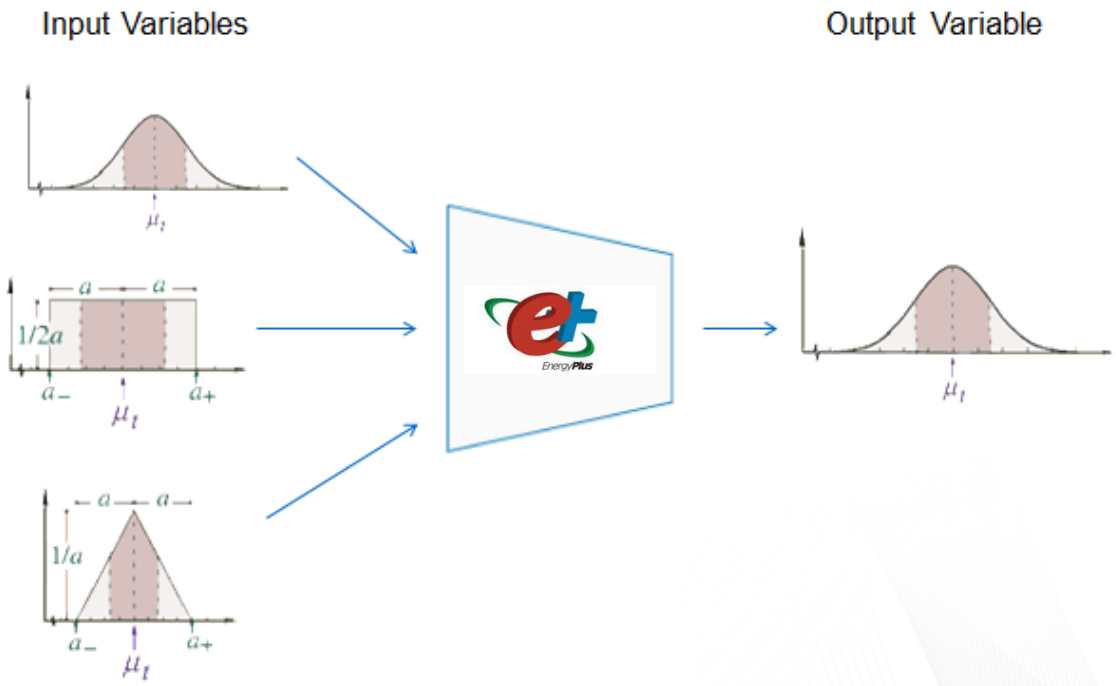
Evaluation of the wall assembly – Indoor Climate

3. Evaluation of moisture durability risks
   a) Hygrothermal Simulations
      1) Select tool(s) and make improvements if needed
      2) If improvements are made re-validate tool(s)
      3) Model wall assembly in tool
      4) Analyze results for moisture durability
   b) Validation of simulation results through laboratory and field tests



Evaluation of the wall assembly – Indoor Climate - Airtightness

- Used LBNL Envelope Leakage Calculator from Residential Diagnostics Database
  - Inputs:
    - Floor Area: 2376 ft^2
    - Ceiling Height: 16 ft
    - Year Built: After 2000
    - WAP? No
    - ENERGY STAR certified? Yes
    - Region: CZ specific
    - Foundation type: CZ specific
    - Duct System Location: inside the condition space

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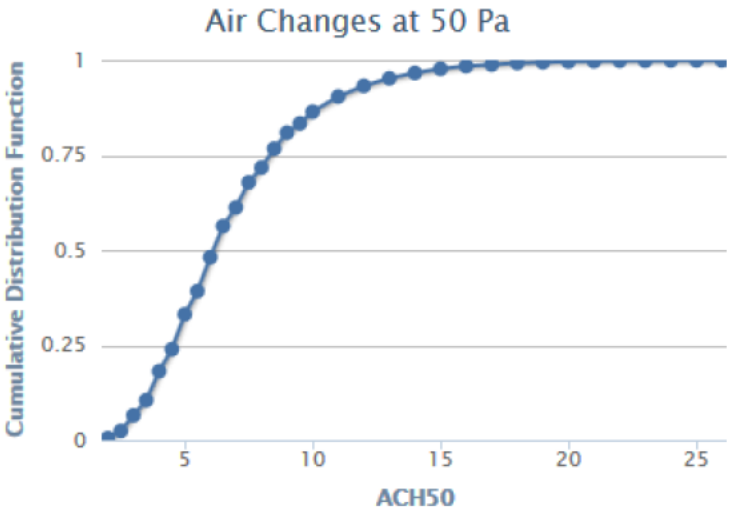

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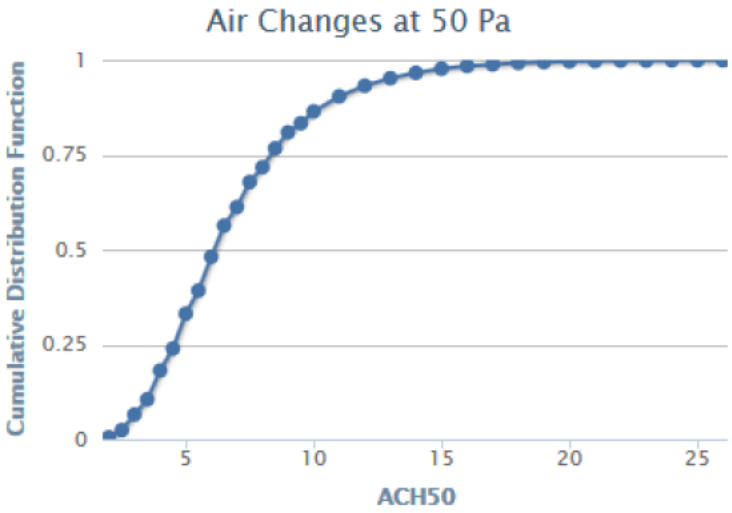
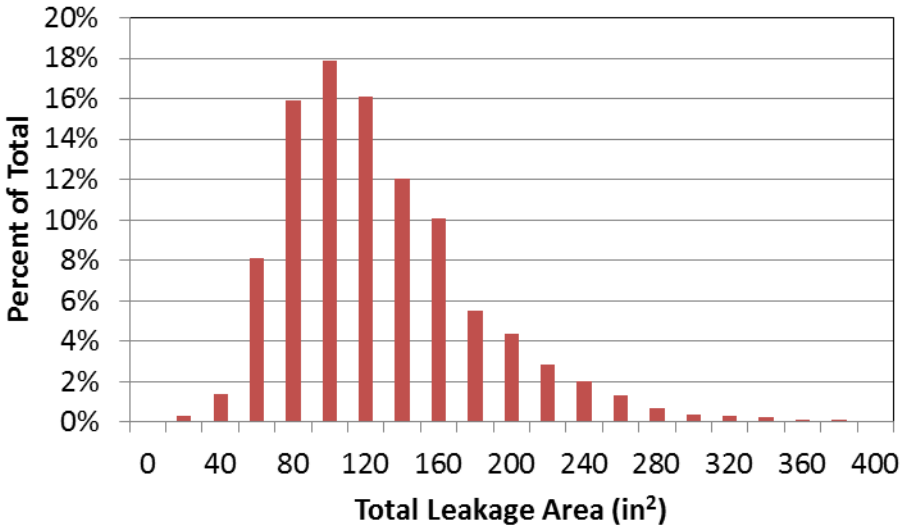
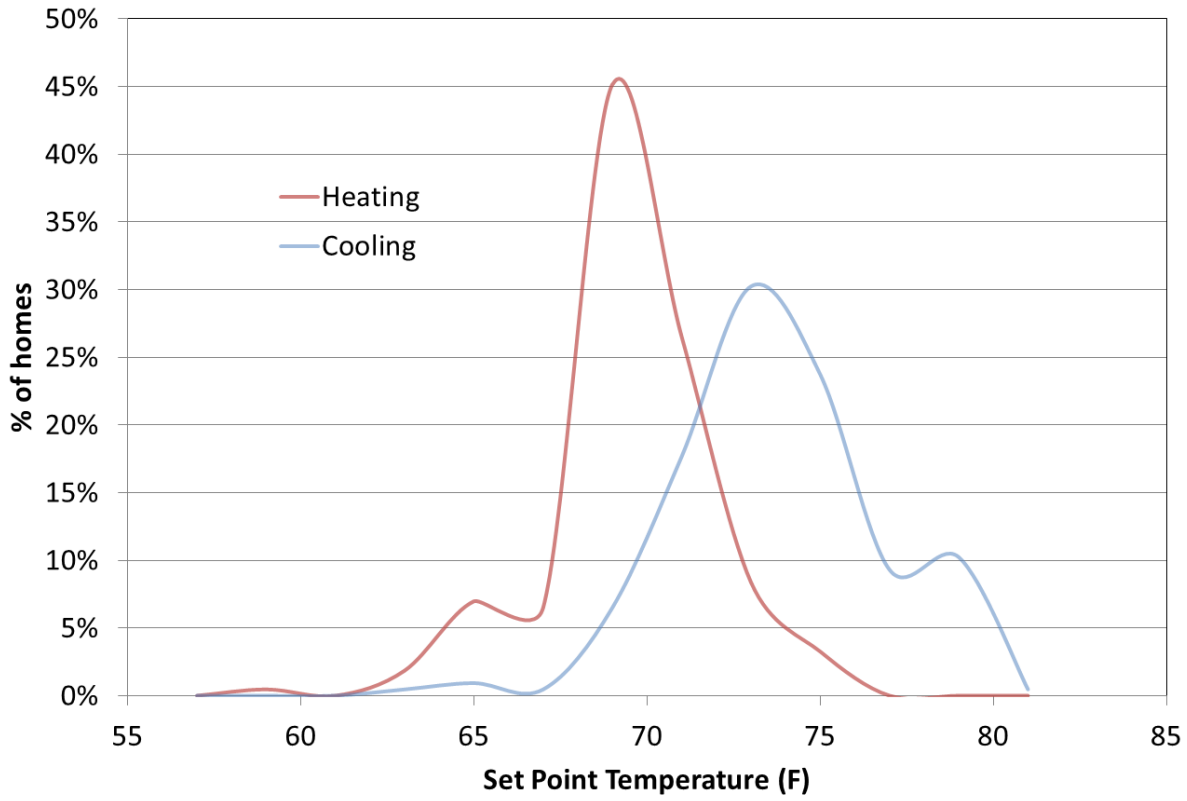




Evaluation of the wall assembly – Indoor Climate – Thermostat Setpoint

- Used RECS 2009 microdata
  - Created probability curves for each AIA CZ (250 – 1850 homes per CZ)

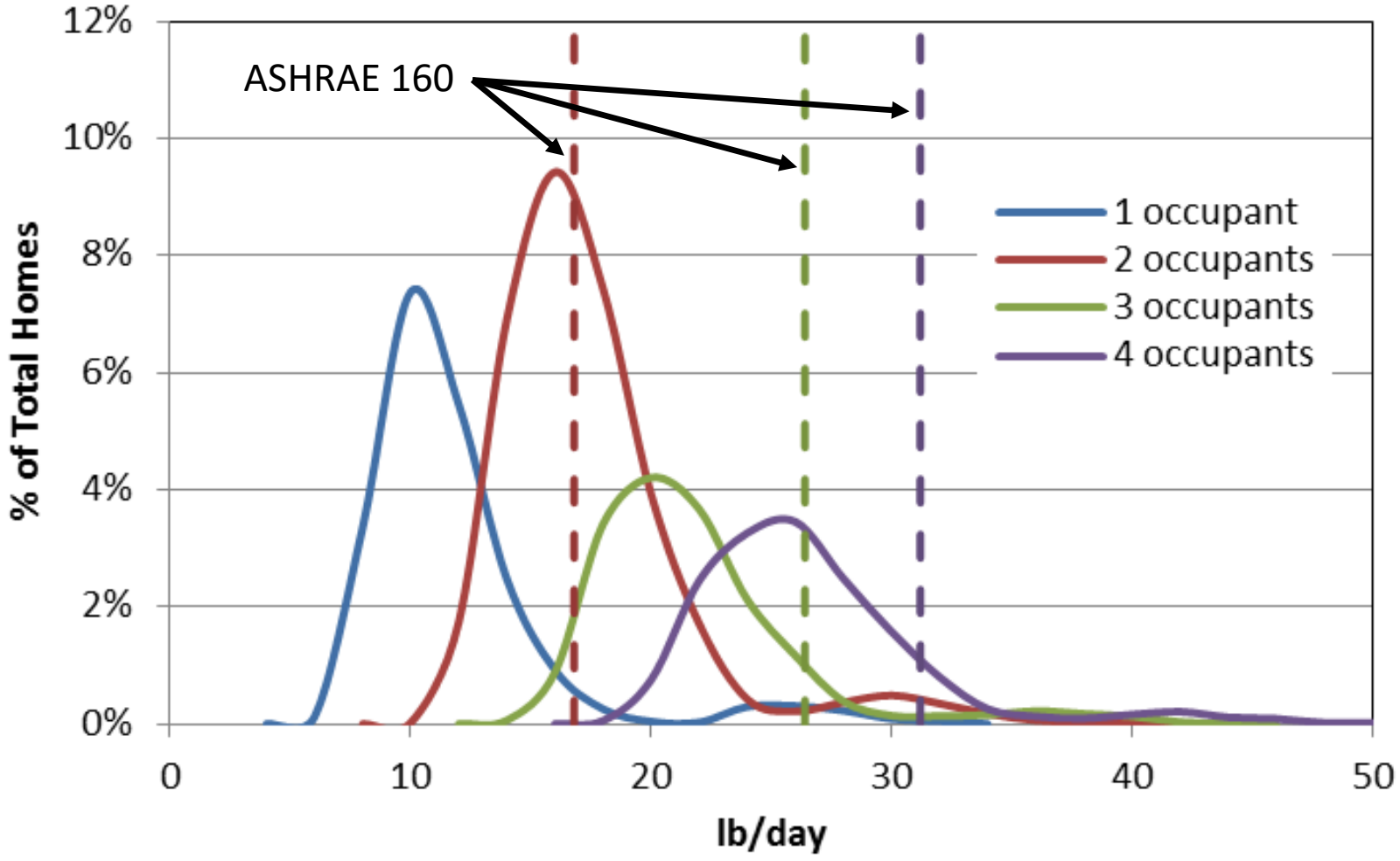


Evaluation of the wall assembly – Indoor Climate – Indoor Heat and Moisture Generation

- Used ORNL developed GIHM tool
  - Yields hourly heat and moisture rates for an entire year
  - Probabilistic in nature

Moisture	Heat
--	Lighting
--	Refrigerator
Ironing, Aquarium, Humdifier, Dehumidifier	MELs
Humans	Humans
Pets	Pets
Bath	Bath
Shower	Shower
Jaccuzi Bath	Jaccuzi Bath
Breakfast	Oven, Stove
Lunch	Oven, Stove
Dinner	Oven, Stove
Hand Washing Dishes	--
Dishwasher	Dishwasher
Laundry	Clothes Washer, Clothes Dryer
Mopping	--
Plants	--
Toilets	--
Faucets	--

Evaluation of the wall assembly – Indoor Climate – Indoor Heat and Moisture Generation



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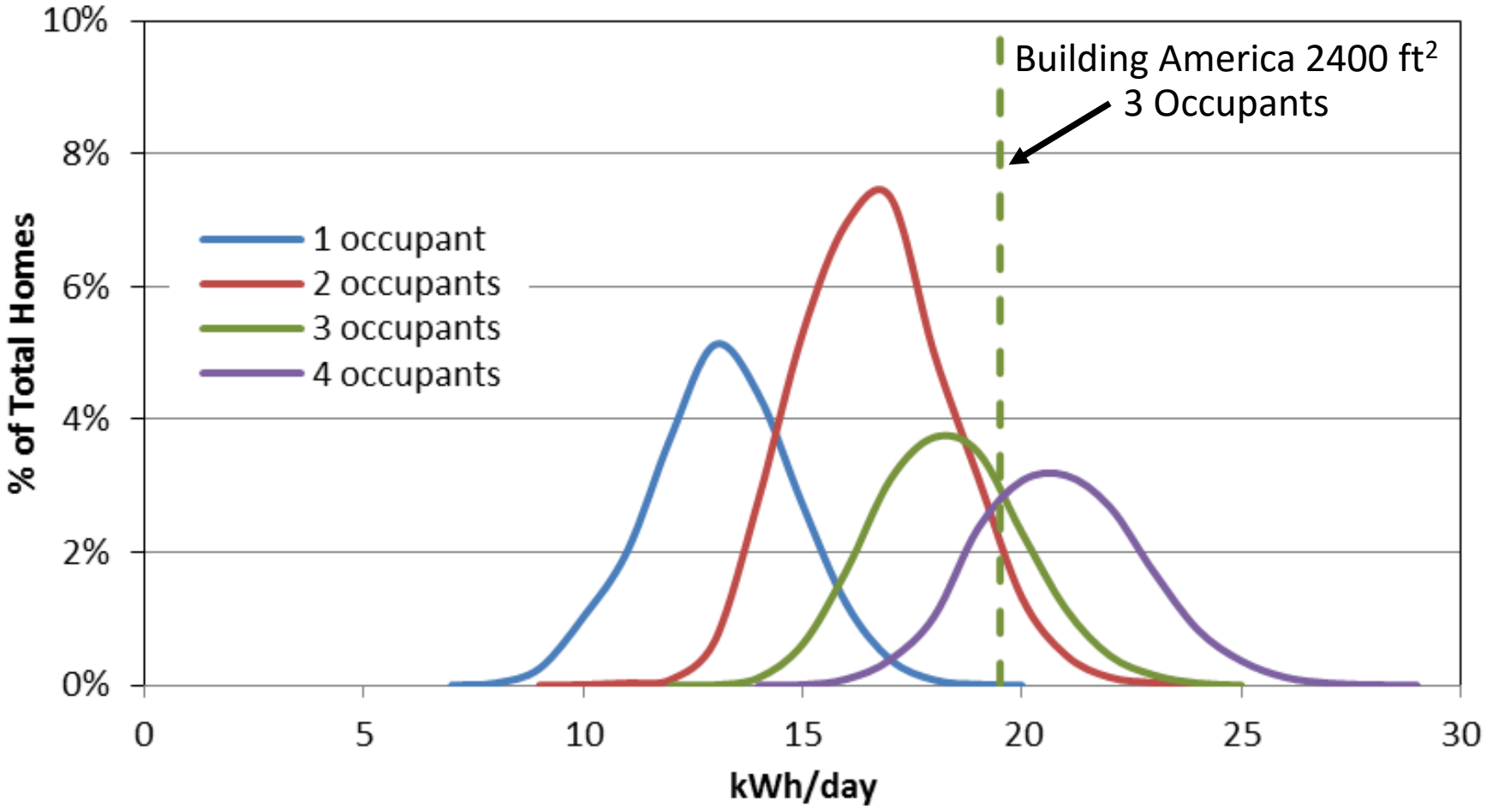

Evaluation of the wall assembly – Hygrothermal Analysis

- Outdoor Climate Boundary Condition from AMY file
- Indoor Climate (Energy Plus)
- WUFI® to evaluate moisture durability of wall
  - Eta method to help WUFI® handle air flow in 1-D
  - Used Mold Growth Index (MGI) as performance indicator

Mold Growth Index (Hukka and Viitanen 1999; Ojanen et al. 2011; Viitanen et al. 2015)

Index	Description of Growth Rate	Risk Level
0	No growth	Low
1	Small amounts of mold on surface (microscopic), initial stages of local growth	Low
2	Several local mold growth colonies on surface (microscopic)	Low
3	Visual findings of mold on surface, <10% coverage or <50% coverage of mold (microscopic)	Moderate
4	Visual findings of mold on surface, 10% to 50% coverage or >50% coverage of mold (microscopic)	High
5	Plenty of growth on surface, >50% coverage (visual)	High
6	Heavy and tight growth, coverage approximately 100%	High

Example wall evaluations

3. Evaluation of moisture durability risks
   a) Hygrothermal Simulations
      1) Select tool(s) and make improvements if needed
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Wall Assembly	**Houston, TX CZ2**	**New York, NY CZ4**	**Minneapolis, MN CZ6**
Siding	Vinyl		
WRB	Mechanically fastened membrane	R3.75 XPS	R11.25 XPS
Ext. continuous insulation	None	R3.75 XPS (same as air/water barrier)	R11.25 XPS (same as air/water barrier)
Ext. sheathing	7/16" OSB		
Framing	2×6 studs		
Cavity insulation	R20 fiberglass batts		
Int. sheathing	½" drywall		
Vapor retarder	Latex paint		

Example wall evaluations

- Indoor climate simulated using Energy Plus (x 1000/CZ)
- Output from Energy Plus (Indoor T/RH, air exchange rate), Outdoor Climate (AMY) and wall construction are input into WUFI® (x1000/CZ)
- The MGI is evaluated at one critical point along the airflow path in the wall.
- Each of the simulations was run for 5 consecutive years of actual weather.

Example wall evaluations

- CZ2 – Wall orientation to maximize air infiltration
- CZ4 – Orientation to investigate infiltration and exfiltration
- CZ6 – Wall orientation to maximize air exfiltration

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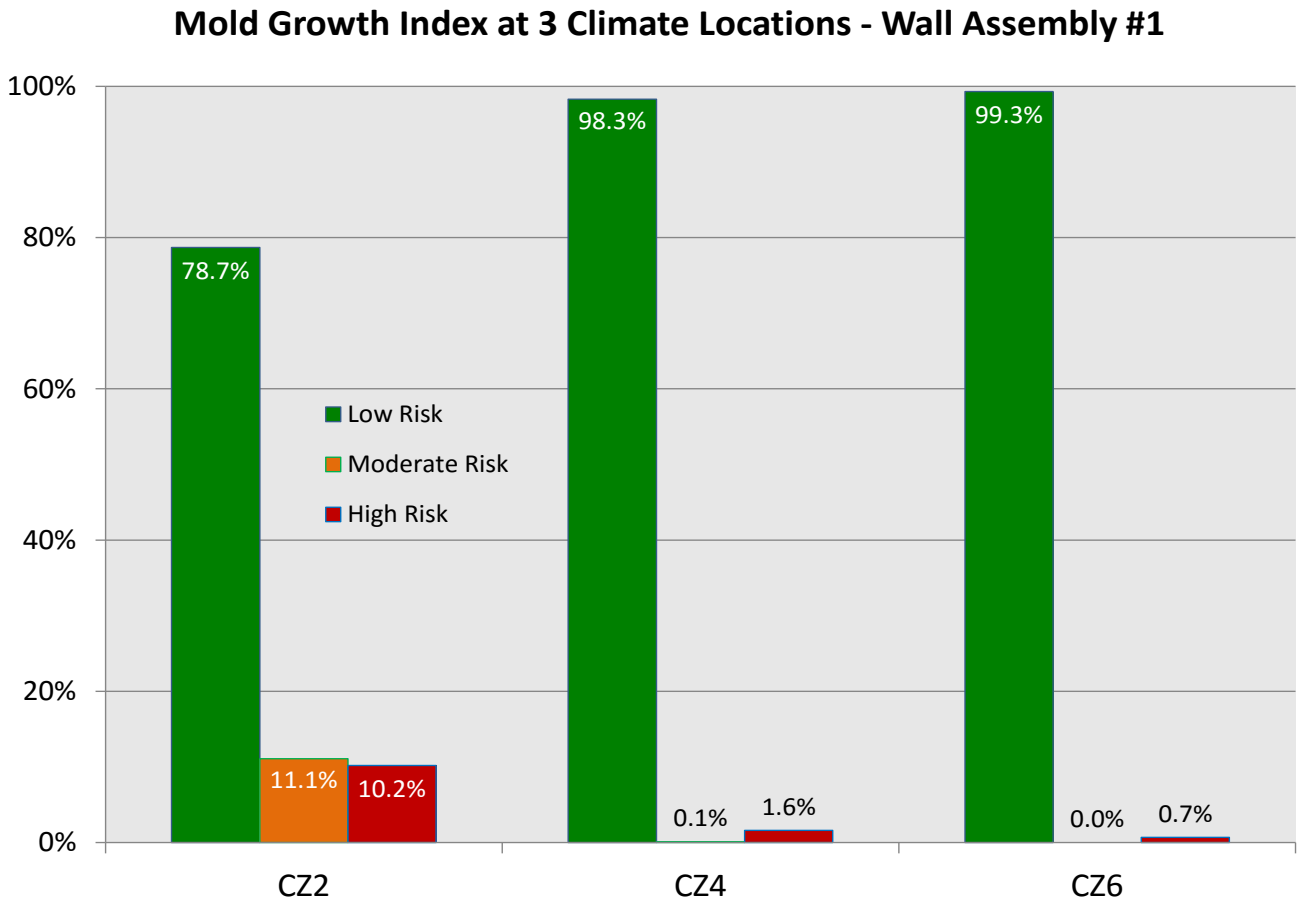
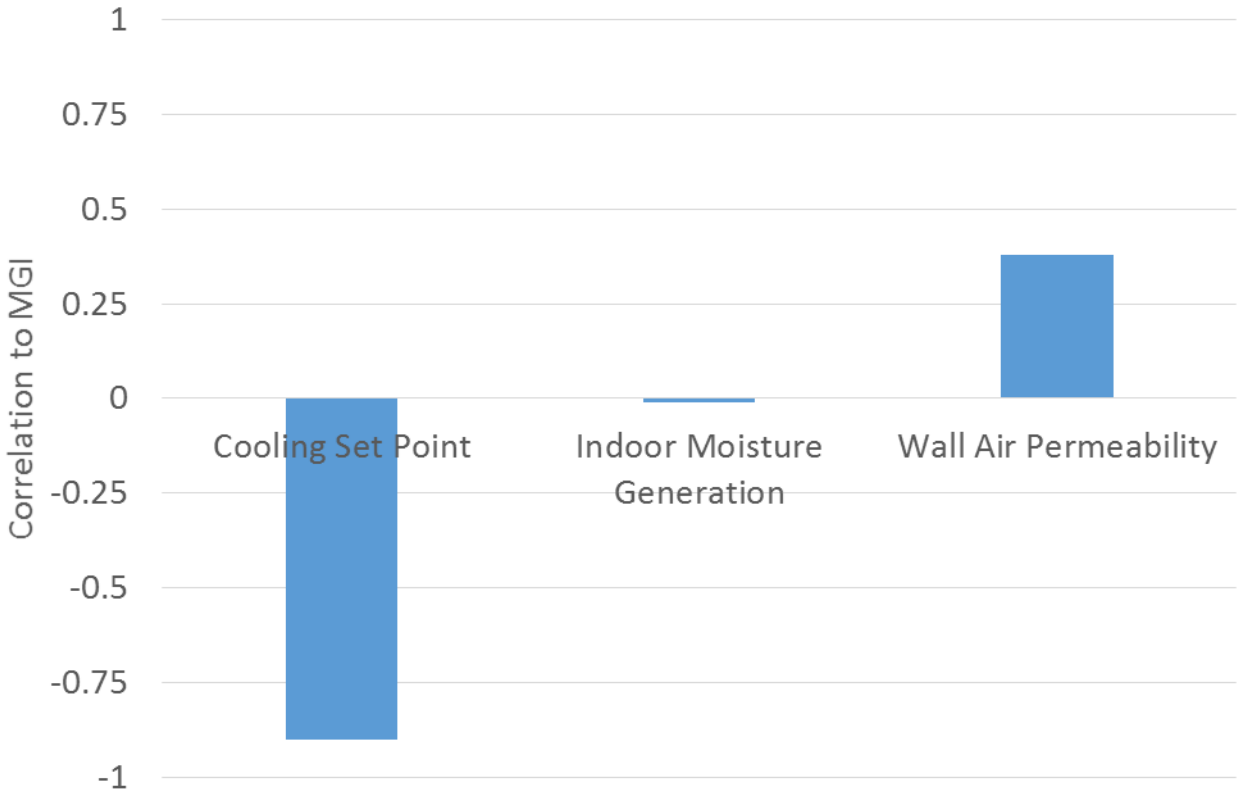


Example wall evaluations

- To understand why the wall in CZ2 has a potential for mold growth, a sensitivity analysis is helpful.



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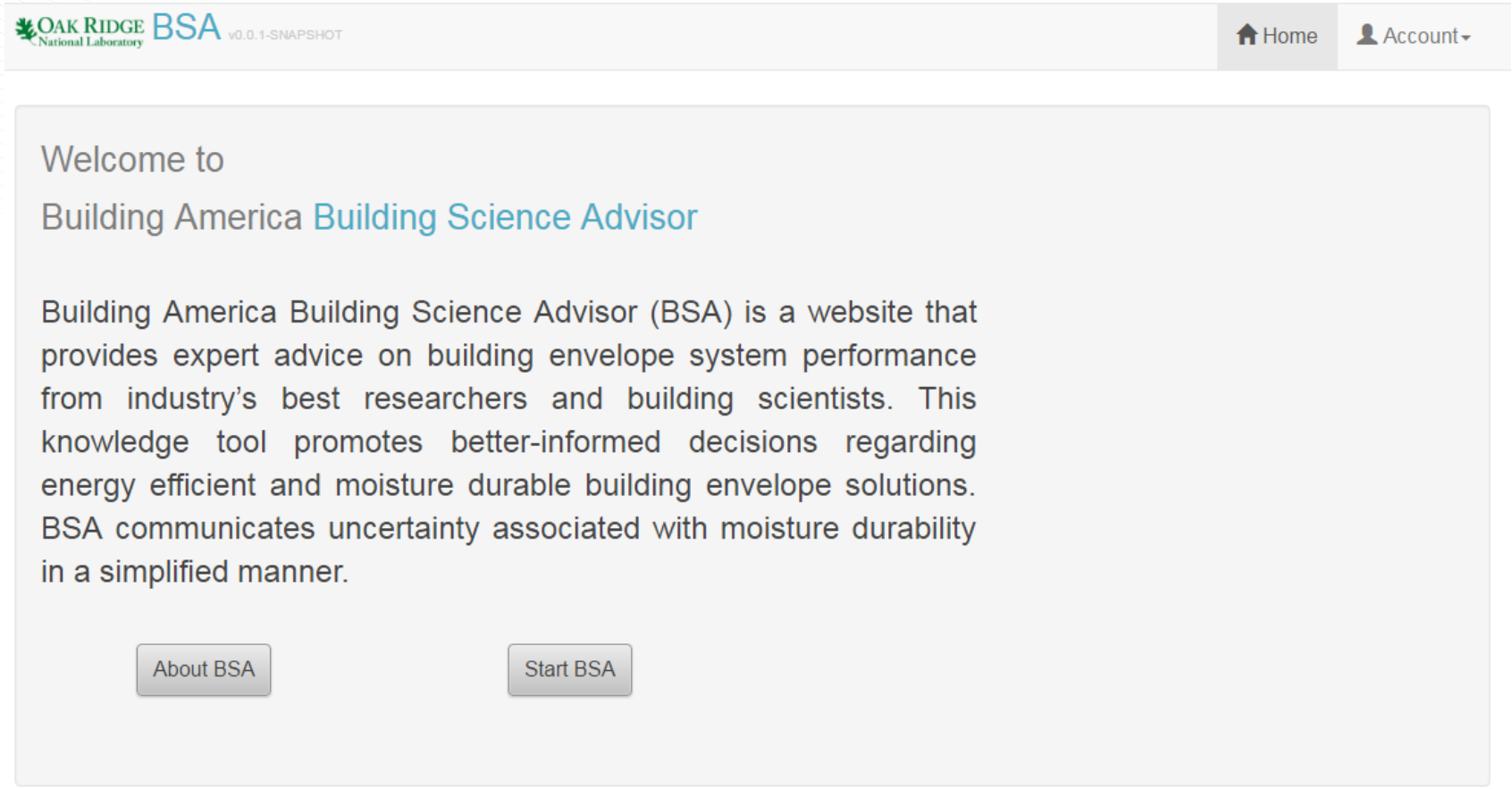
4. Recommendations based on expected hygrothermal performances



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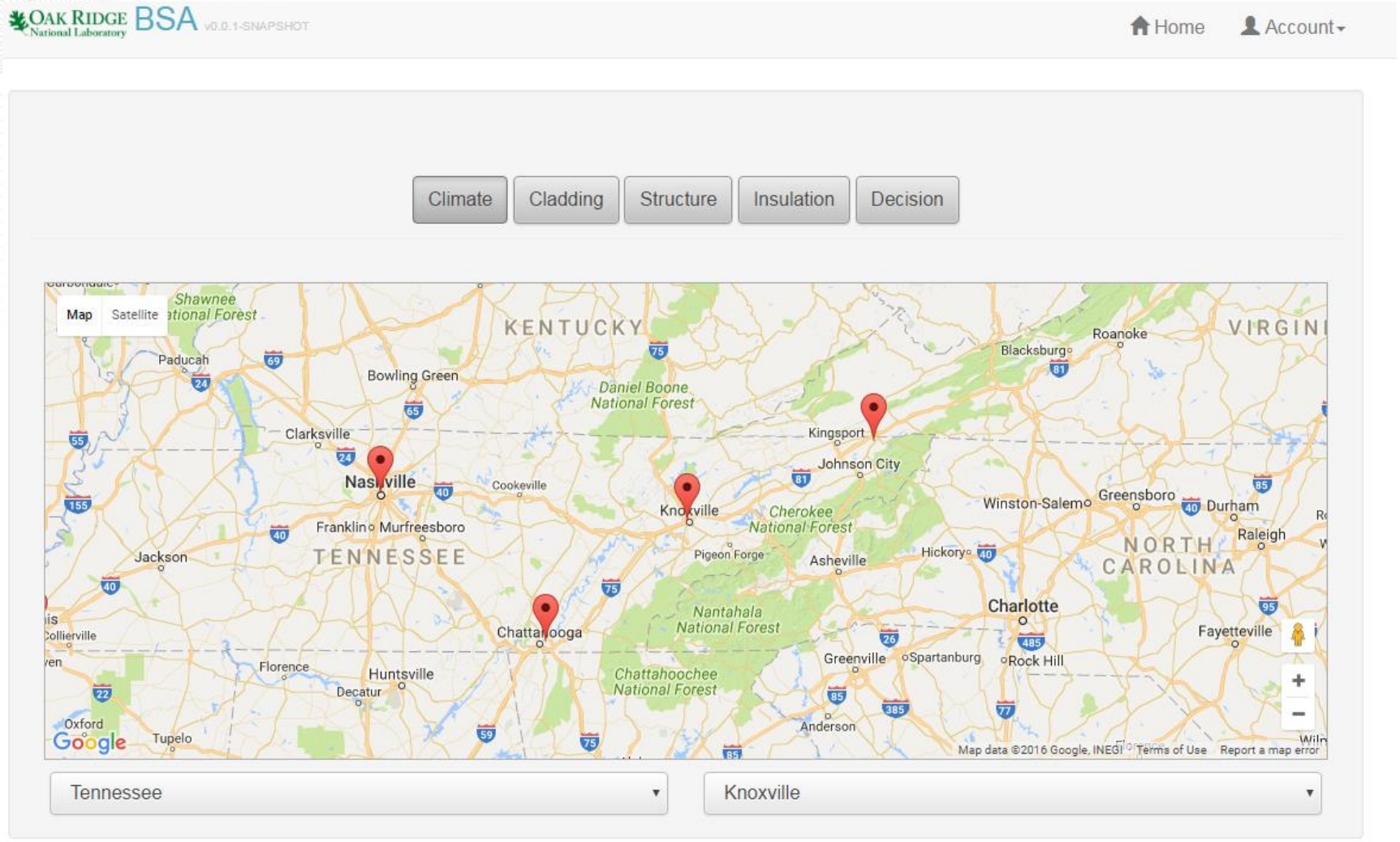

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Home Account

Climate | Cladding | Structure | Insulation | Decision

What is your cladding?

- Brick
- Stucco
- Fiber Cement Siding
- Vinyl Siding
- Stone
- Treated Wood Clapboard
- Treated Wood Shakes
- Untreated Wood Clapboard
- Untreated Wood Shakes
- Metal Siding

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What is your structure?

- 2 x 4 16" o.c.
- 2 x 4 24" o.c.
- 2 x 6 16" o.c.
- 2 x 6 24" o.c.
- Structural Insulated Panels
- Insulated Concrete Form System
- Masonry Block (Interior Insulated)
- Masonry Block (Exterior Insulated)

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Cavity Insulation and Type

- **Fiberglass Batt**
- Fiberglass Loose Fill
- Cellulose Loose Fill
- Open Cell Spray Foam
- Closed Cell Spray Foam
- Flash and Batt (with 3/4-in. CCSPF)
- SIPS - Expanded Polystyrene (EPS)

Continuous Insulation and Thickness

- **None**
- Expanded Polystyrene (EPS)
- Extruded Polystyrene (XPS)
- Polyisocyanurate Foam
- Mineral Fiber Board

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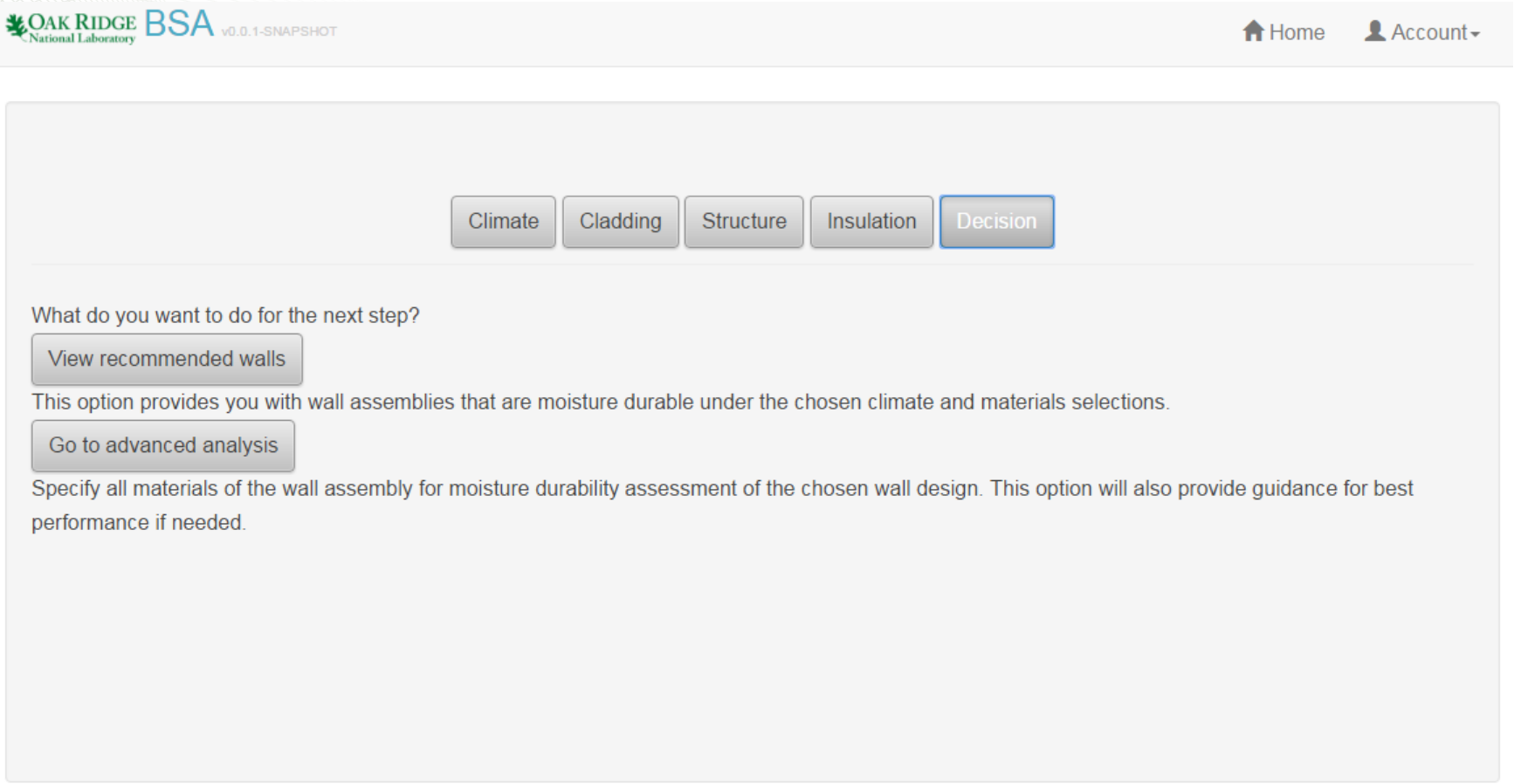

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Home Account

Back/Decision | Air Gap | Water/Air Barrier | Sheathing | Vapor Retarder | Interior Finish | Air Tightness | Results

Air gap between sheathing & cladding?

- None
- Vented Air Space
- Ventilated Air Space

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Type of resistive & air barrier?

- **Housewrap**
- Building Paper
- Liquid-Applied Coating
- Permeable Fully-Adhered Membrane
- Impermeable Fully-Adhered Membrane
- Insulated Sheathing
- Uninsulated Sheathing
- Spray Foam

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Exterior sheathing?

- Plywood
- **Oriented Strand Board**
- Fiberboard
- Expanded Polystyrene (EPS)
- Extruded Polystyrene (XPS)
- Polyisocyanurate Foam
- Mineral Fiber Board

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Type of vapor retarder?

- None
- Polyethylene Sheet
- **Kraft Paper**
- Aluminum Foil
- Smart Vapor Retarder

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Interior finish on drywall?

- Vapor Barrier Paint
- **Latex Paint**

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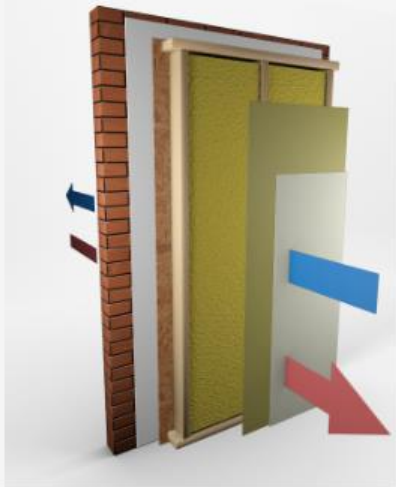
Expected air tightness of your building?

- 1 ACH50
- **3 ACH50**
- 5 ACH50
- 7 ACH50



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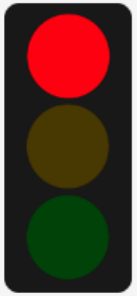
Home Account

Back/Decision | Air Gap | Water/Air Barrier | Sheathing | Vapor Retarder | Interior Finish | Air Tightness | Results

Summary of your wall

Map Location	Knoxville, TN
Exterior Cladding	Brick
Continuous Insulation	None
Structure	2 x 4 16" o.c.
Cavity Insulation	Fiberglass Batt
Air Space	None
Water/Air Barrier	Housewrap
Exterior Sheathing	Oriented Strand Board
Vapor Retarder	Kraft Paper
Interior Finish	Latex Paint
Air Tightness	3 ACH50

Predicted moisture durability performance



For "yellow" and "green" please use guidance table for optimized performance.

Guidance

- The selected wall cladding can absorb water. If there is no ventilation behind the cladding water could infiltrate the wall assembly. To ensure moisture durability add at least a 1/4" (2" for brick or stone cladding to avoid mortar contacting sheething) ventilation cavity behind cladding.

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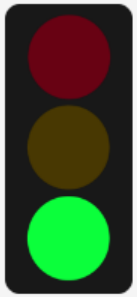

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Guidance

Summary

- Methodology for evaluation of moisture durability of walls
  - Use simulations, validate with selected field studies and chamber tests
  - Use probabilistic modeling to capture range of environments the wall will “see” in the field.
  - Use MGI as performance indicator (red, yellow, green)
  - Use BSA to communicate evaluation results and offer guidance to builders and other stakeholders

Discussion

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