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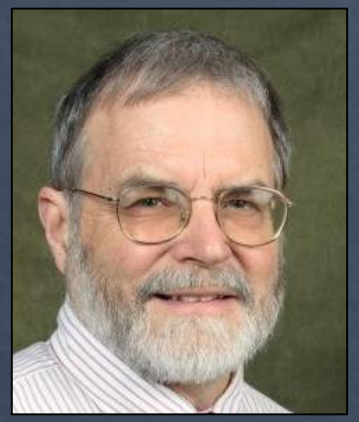
Excerpts: Thinking Through Water, Air, and Energy in Historic Structures



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Presentation Agenda

- Suggested Resources
- Basic Building Science
- Historic Systems and HVAC Management
- Adaptive Reuse Case Studies

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Suggested Reading

Resources to further explore managing water, air, and energy in historic buildings

Historic Preservation Building Science Suggested Reading:

1. Preservation Brief #24: Heating, Ventilating, and Cooling Historic Buildings – Problems and Recommended Approaches (National Park Service)
2. Preservation Brief #39: Controlling Unwanted Moisture in Historic Buildings (National Park Service)
3. Energy Advice for Owners: Historic and Older Homes (National Trust for Historic Preservation)

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Suggested Reading

Resources to further explore managing water, air, and energy in historic buildings

General Building Science Suggested Reading:

1. 40% Whole-House Energy Savings in the Cold and Very Cold Climates (US Dept of Energy)
2. Measure Guideline: Deep Energy Enclosure Retrofit for Interior Insulation of Masonry Walls (US Dept of Energy)
3. Building Sciences: Avoiding Mass Failures, ASHRAE Vol. 60, no. 5, May 2018

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Presentation Objective: Apply Four Building Science Basics to Historic Buildings

1. Bulk/Liquid Water Management
2. Heat Flow Management
3. Vapor Management
4. Air Flow Management

How does the historic House of the Seven Gables continue to balance water, air, and energy?

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Liquid Water, Energy (Heat), Vapor, and Air Rules

They’re all related.

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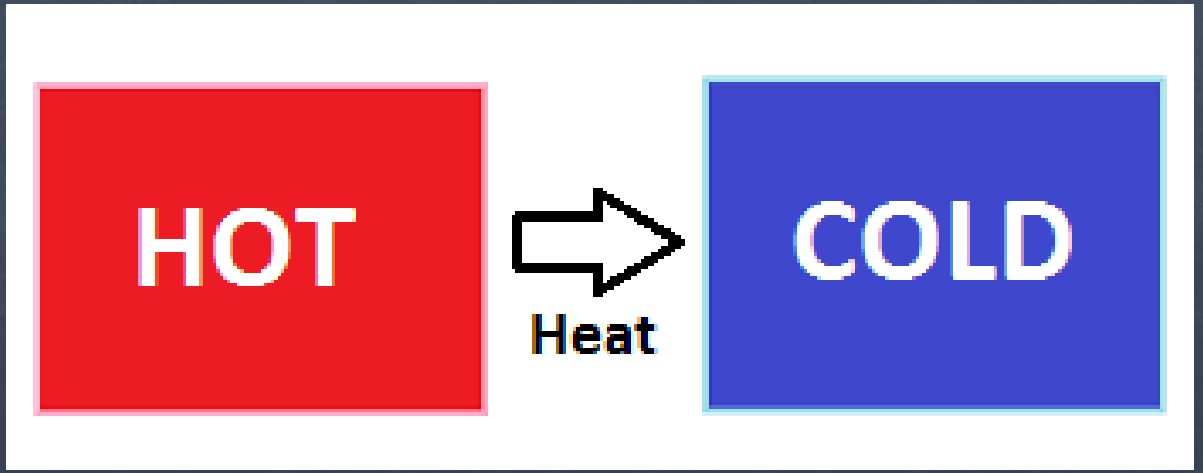
The Rules of Bulk/Liquid Water Movement

1. Gravity pulls water down

2. Capillary action wicks water up (Rising Damp)

The Rules of Heat Movement

1. Heat will always flow from **warmer** to **cooler**, or more to less
2. With no external energy, molecular vibrations slow down until equilibrium is reached



https://study.com/

The Rules of Water Vapor Movement

1. Water vapor moves from areas of **higher** concentration to areas of **lower** concentrations (more to less)

Drivers Include:

- Thermal differential (movement from warm to cool)
- Vapor pressure differential (movement from high to low)
- Permeability of substrate
- Air movement (movement from high air pressure to low pressure)

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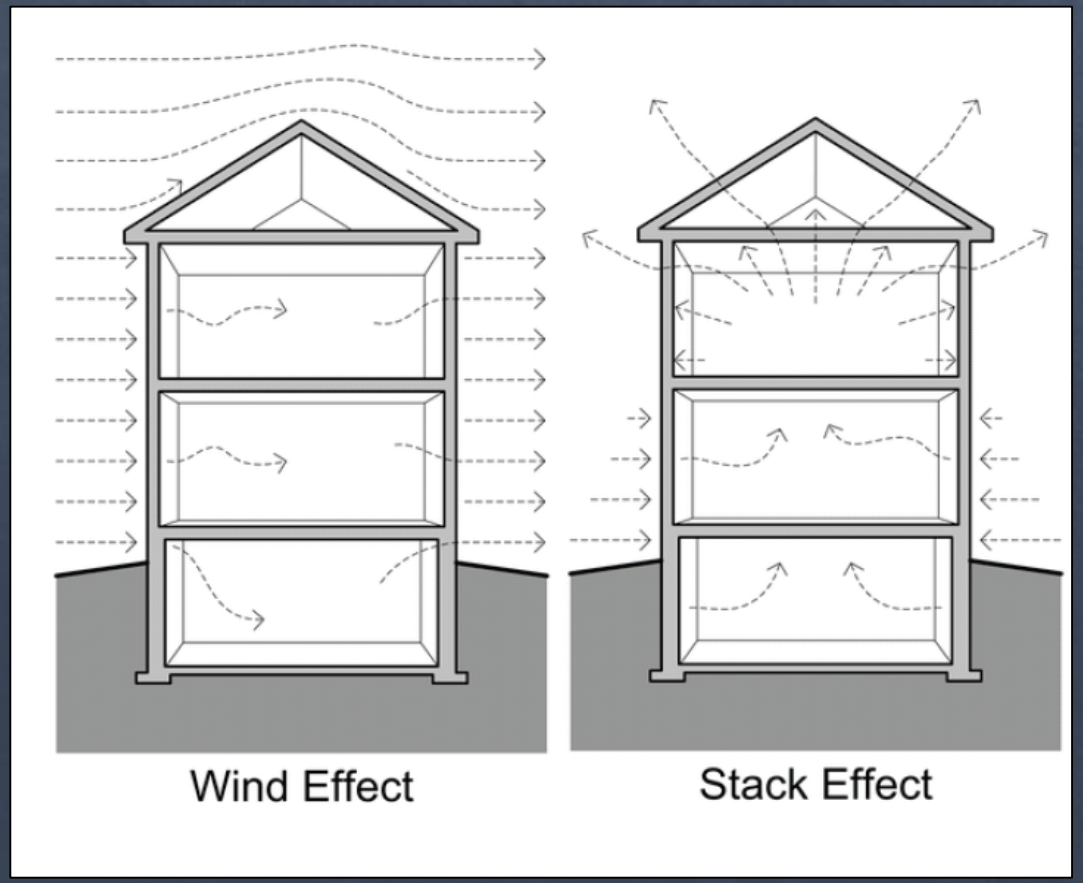
The Rules of Air Movement

1. Air always moves from **high** pressure to **low** pressure

Drivers Include:

- **Stack Effect** – buoyancy: hot air rises, cold air sinks
- **Fans** – create high and low pressures
- **Wind Effect** – can overpower both in the short term



www.buildingscience.com

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The Big Four

1. Bulk/Liquid Water
2. Heat
3. Vapor
4. Air

Managing these makes for healthy buildings, regardless of their age

Keep in Mind:

A building that has survived functionally for 50 years or more has likely somehow managed these four items reasonably.

Historic buildings have the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. They are RESILIENT.

Location, Location, Location

Where a building is will determine the outcomes of water, air, and energy interacting with one another.

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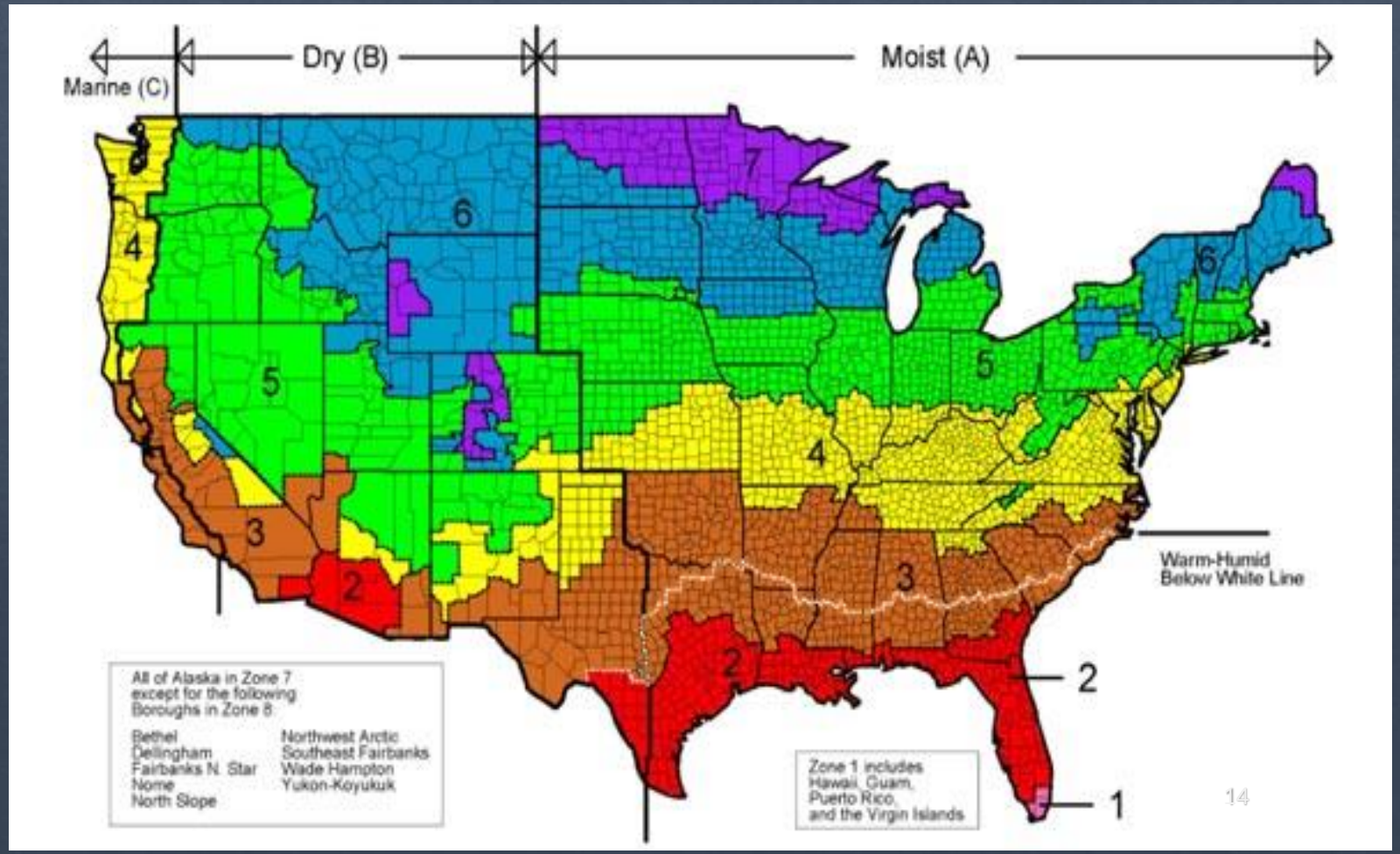
Think Through the Climate

Always Ask: What is the climate where the building is?

Consider:

- Water – precipitation and humidity
- Heat
- Wind



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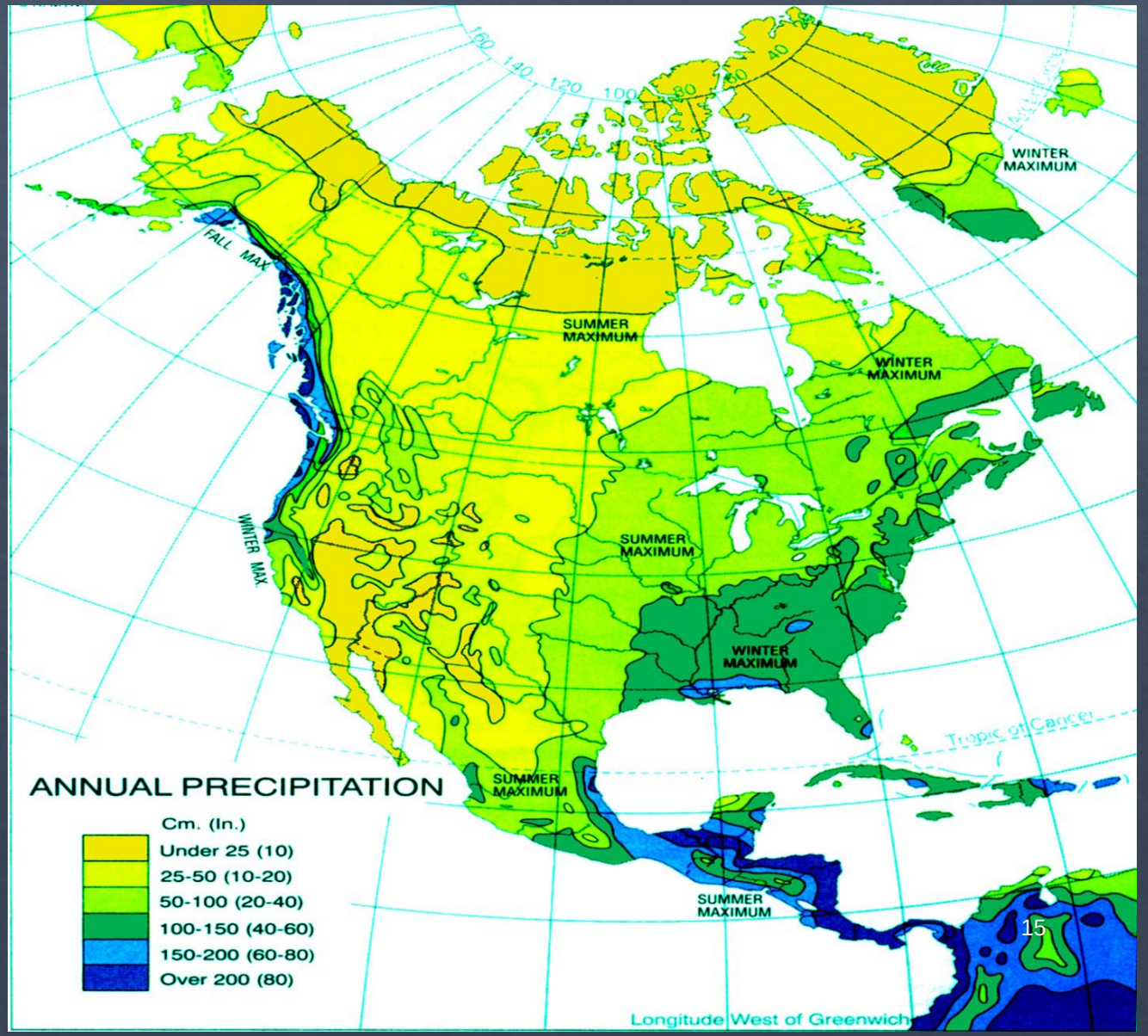
Think Through Precipitation

Always Ask:

Is the building in a climate with lots of precipitation?



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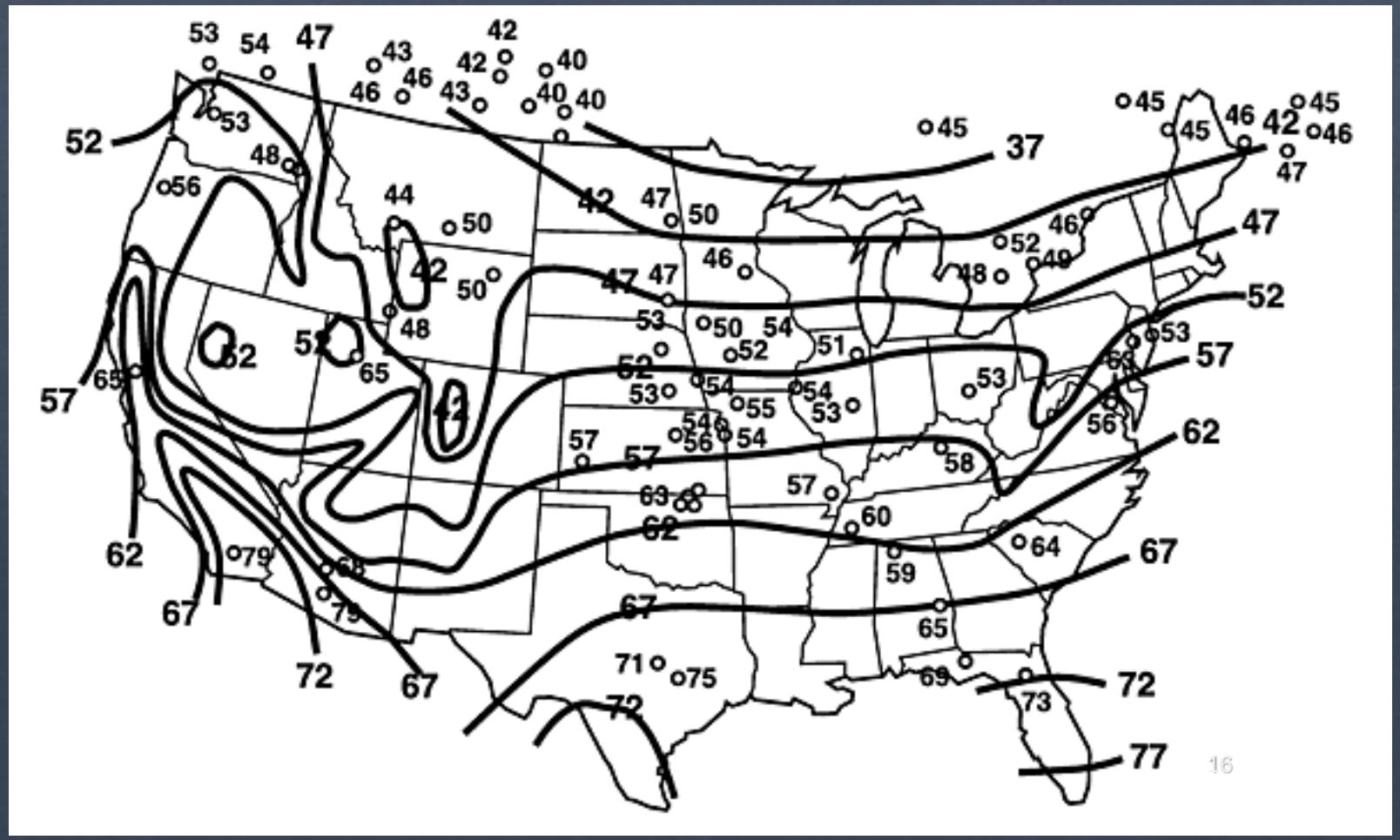
Think Through Earth Temperature

Always Ask: How does the building interact with the earth?

Understanding ground temperature will help determine if the source of moisture in a basement or crawlspace comes from liquid water or water vapor



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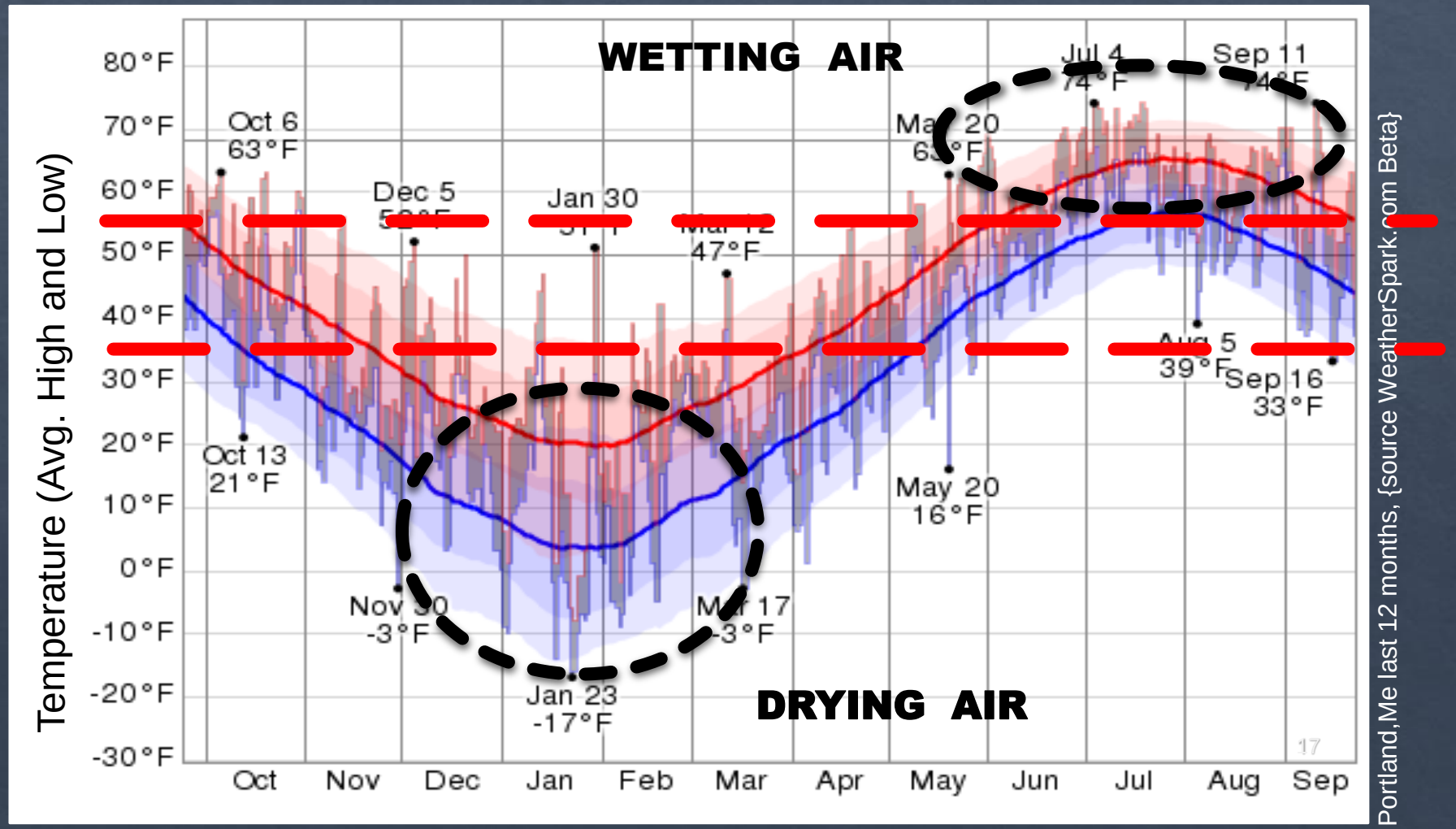
Example: Moisture in the Air: New England Dew Point Climate Graph

In Portland ME, the air is considered “dry” in November – March, but “wet” in May-August.



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Bulk Water Management

Make sure rain, snow, and ground water are directed away from your building.

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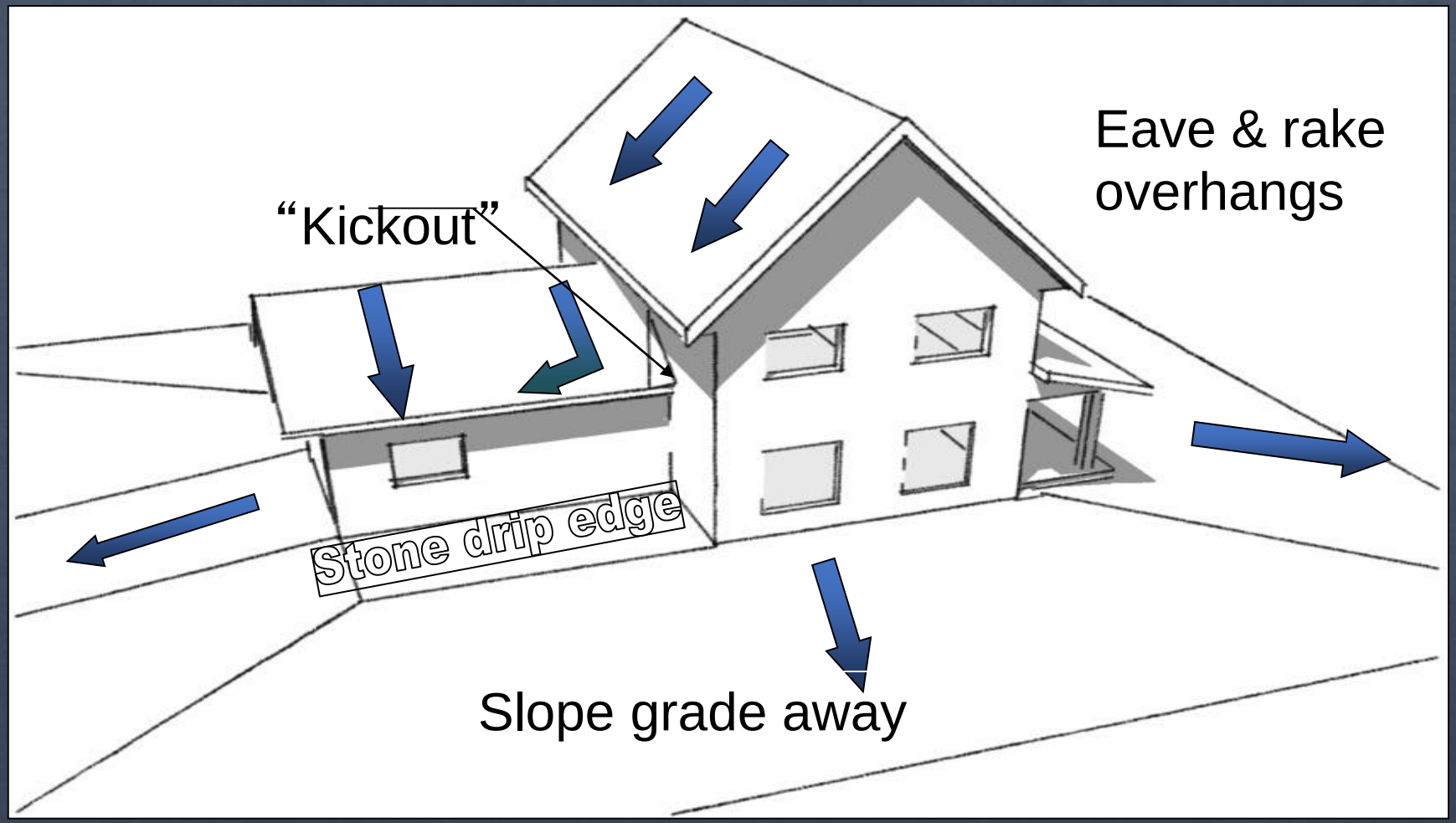
Bulk Water Management



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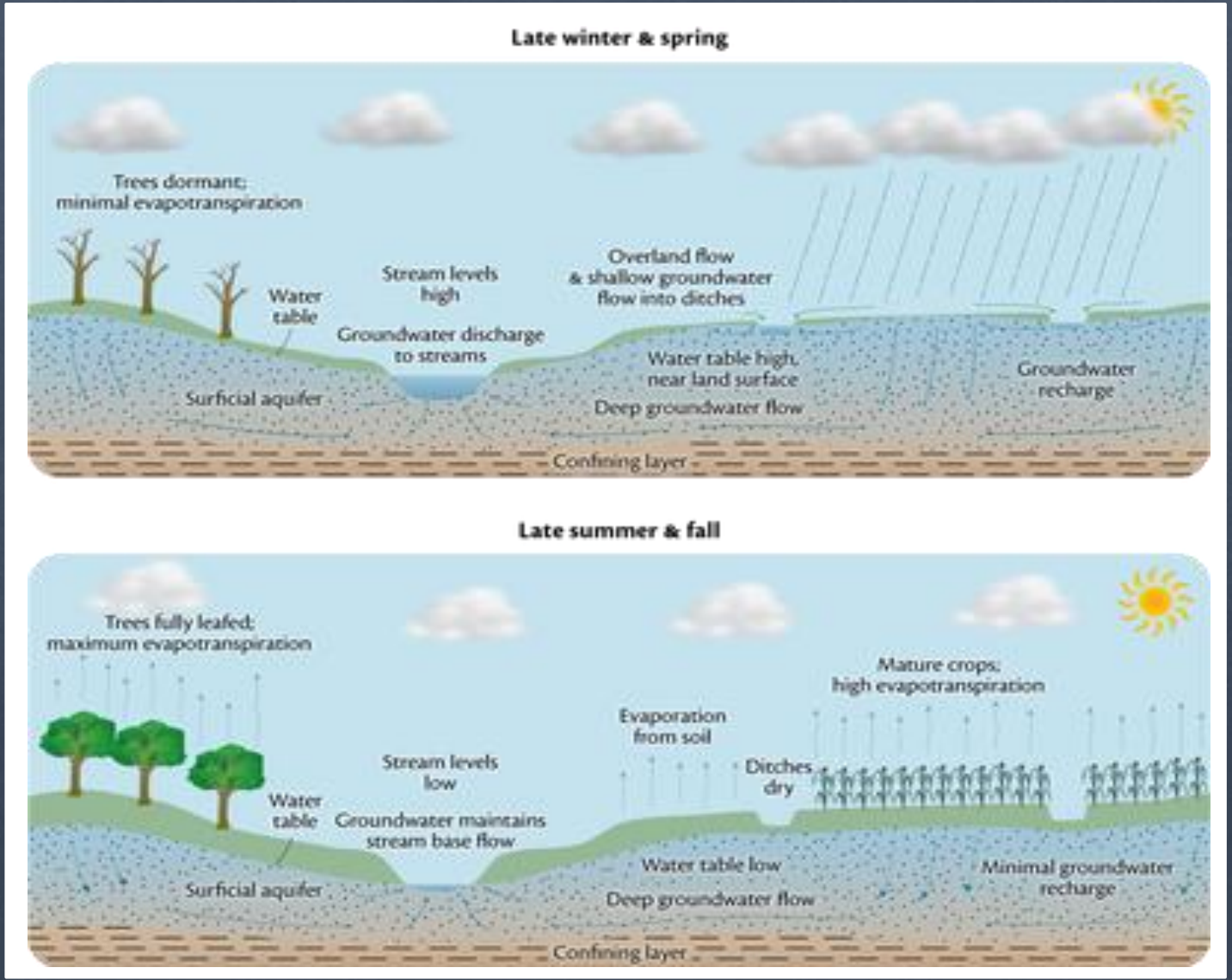
Bulk Water Management



http://ian.umces.edu/imagelibrary/displayimage-114-6965.html

Bulk Water Management

What adaptations may be necessary in areas prone to flooding?

“Guidelines on Flood Adaptation for Rehabilitating Historic Buildings” (NPS Resource)

Courtesy Camroden Associates

Heat Flow Management

Insulation changes everything – especially if it didn't have it originally

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Heat Flow Management

Insulation changes everything – especially if it didn't have it originally

https://www.greenbuildingadvisor.com/

This load bearing brick building had insulation added to its interior, which contributed to the bricks to failing.

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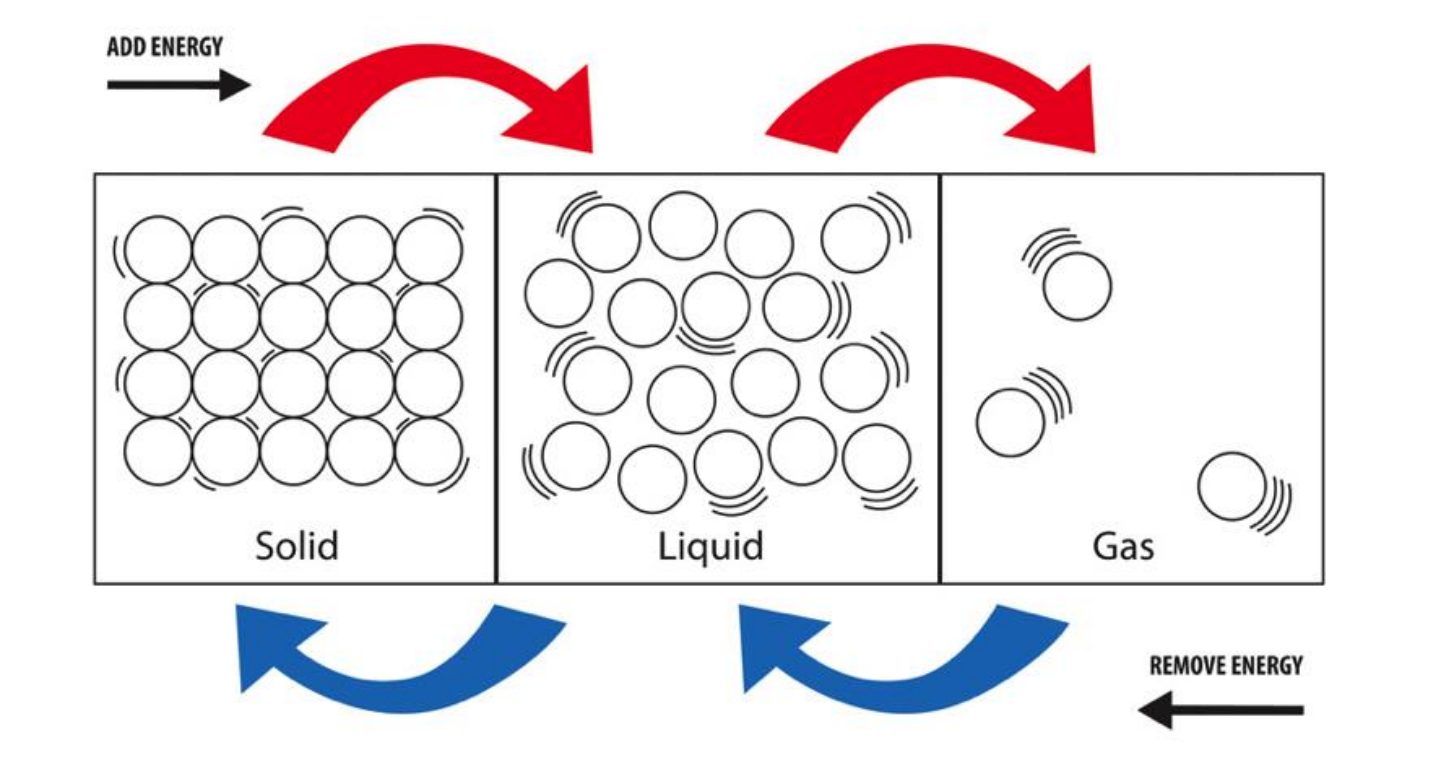
Heat Flow Management

Remember: The more insulation added to a building, the less ability it has to dry out if it gets wet.



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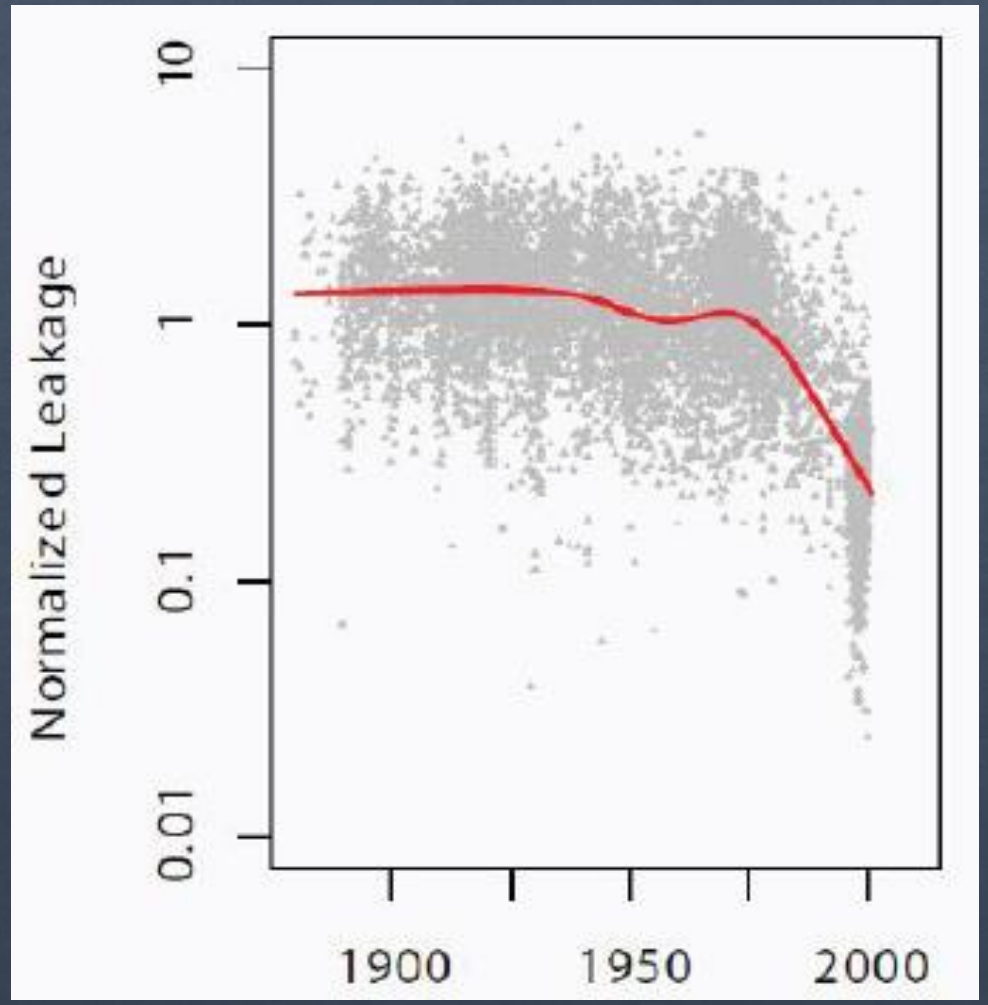
Heat Flow Management



New construction leaks significantly less air than old construction.

For historic construction, consider how this trait contributed to its *healthy functioning* and how it may have been a *deliberate* design choice.

What are potential problems when we make historic construction tight without considering this?

Vapor Management

Managing Condensation

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Vapor Management

Dew Point: What naturally happens outdoors can happen indoors

www.weather.gov/ilx/swop-springtopics3

Dew Point = the temperature at which water vapor condenses into liquid water

B

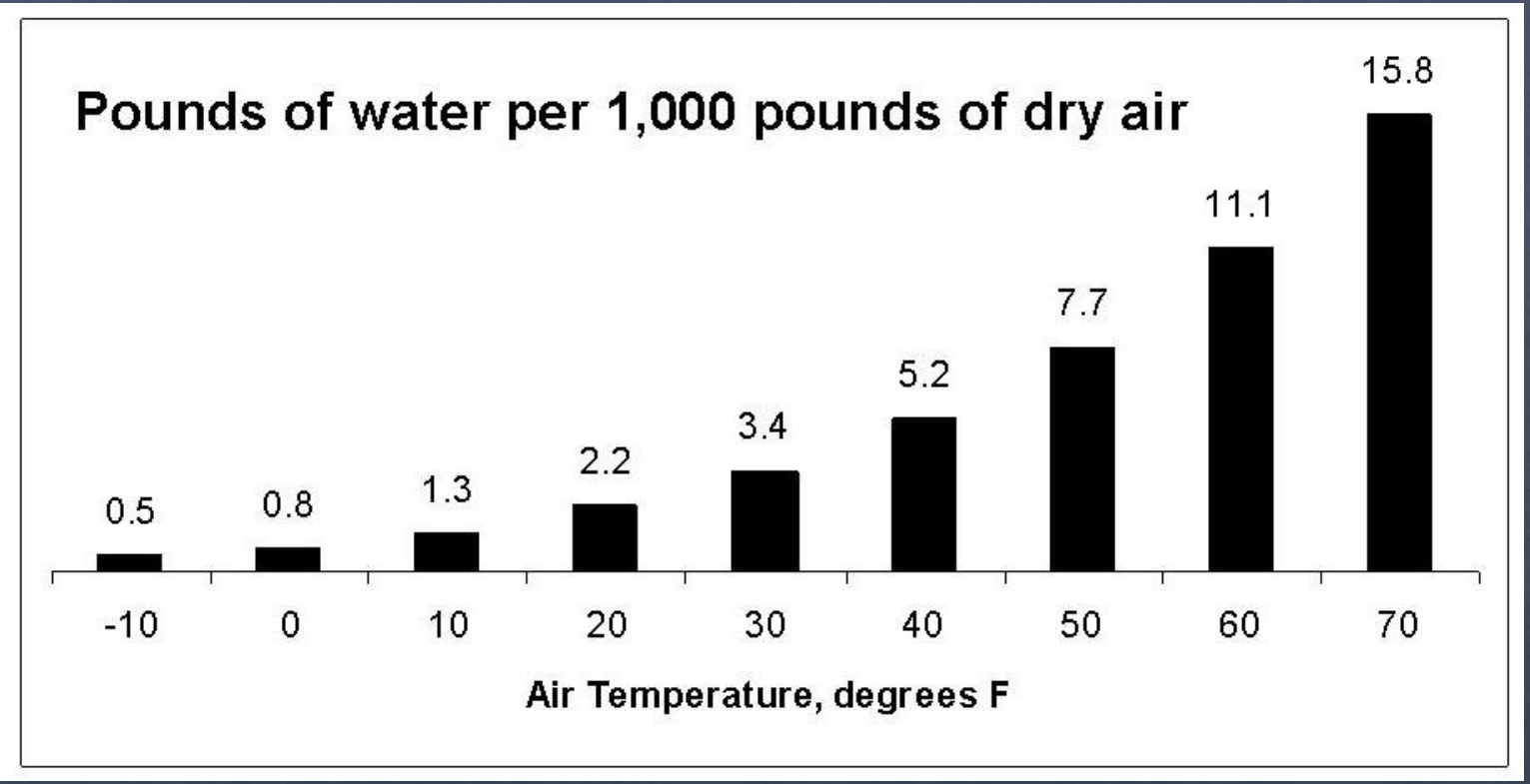
Vapor Management

Managing condensation

B

Vapor Management

The Moisture Holding Capacity of Air:



***the moisture holding capacity of saturated air doubles for every 20°F temperature rise.**

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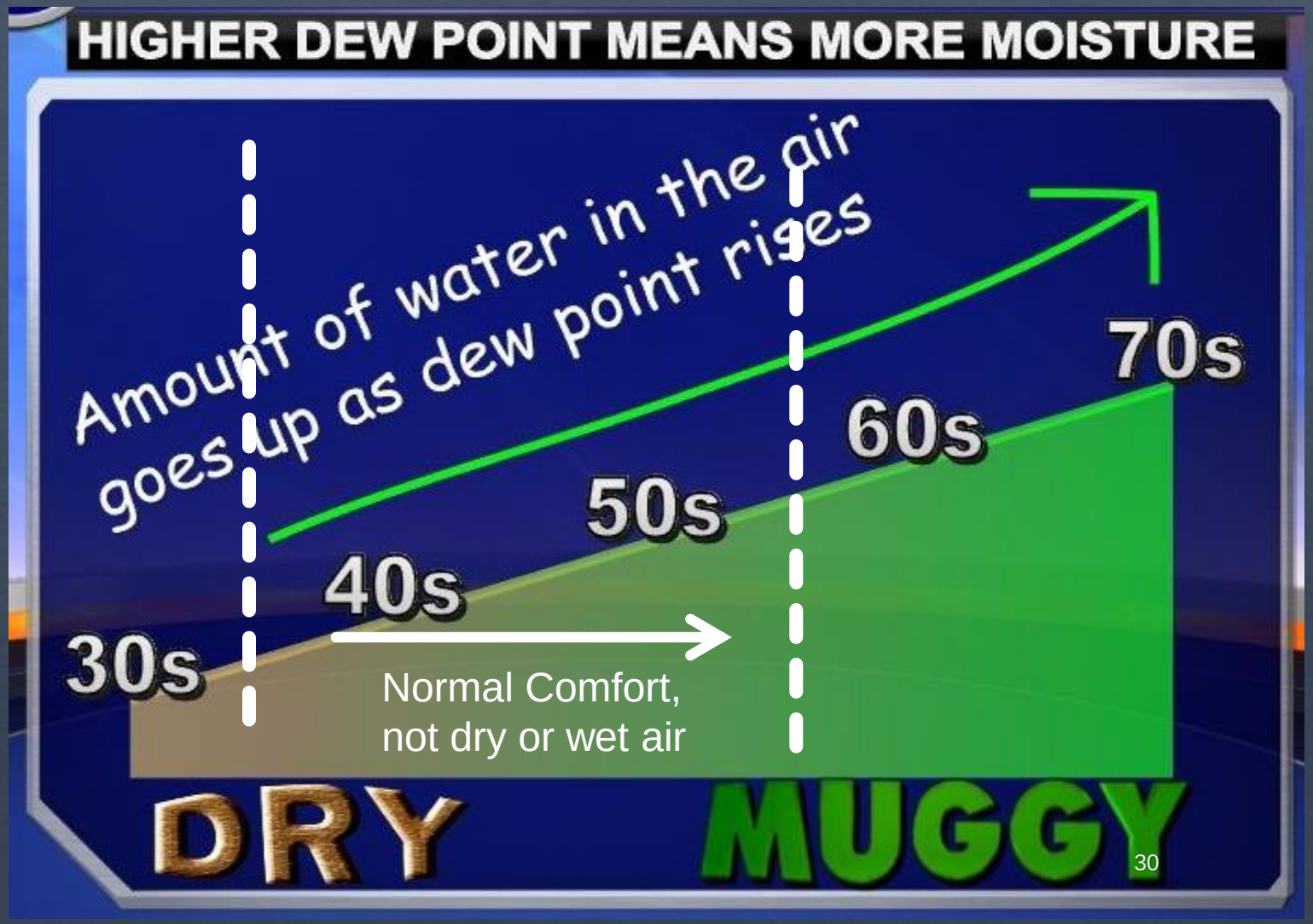
Vapor Management

The Drying and Wetting Potential of Air:

- Dew point above 55 degrees = wetting air
- Dew point below 35 degrees = drying air
- Dew point between 35-55 degrees is not dry or wet, but comfortable



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Vapor Management

Water vapor in a damp crawlspace or basement will migrate to the spaces above.

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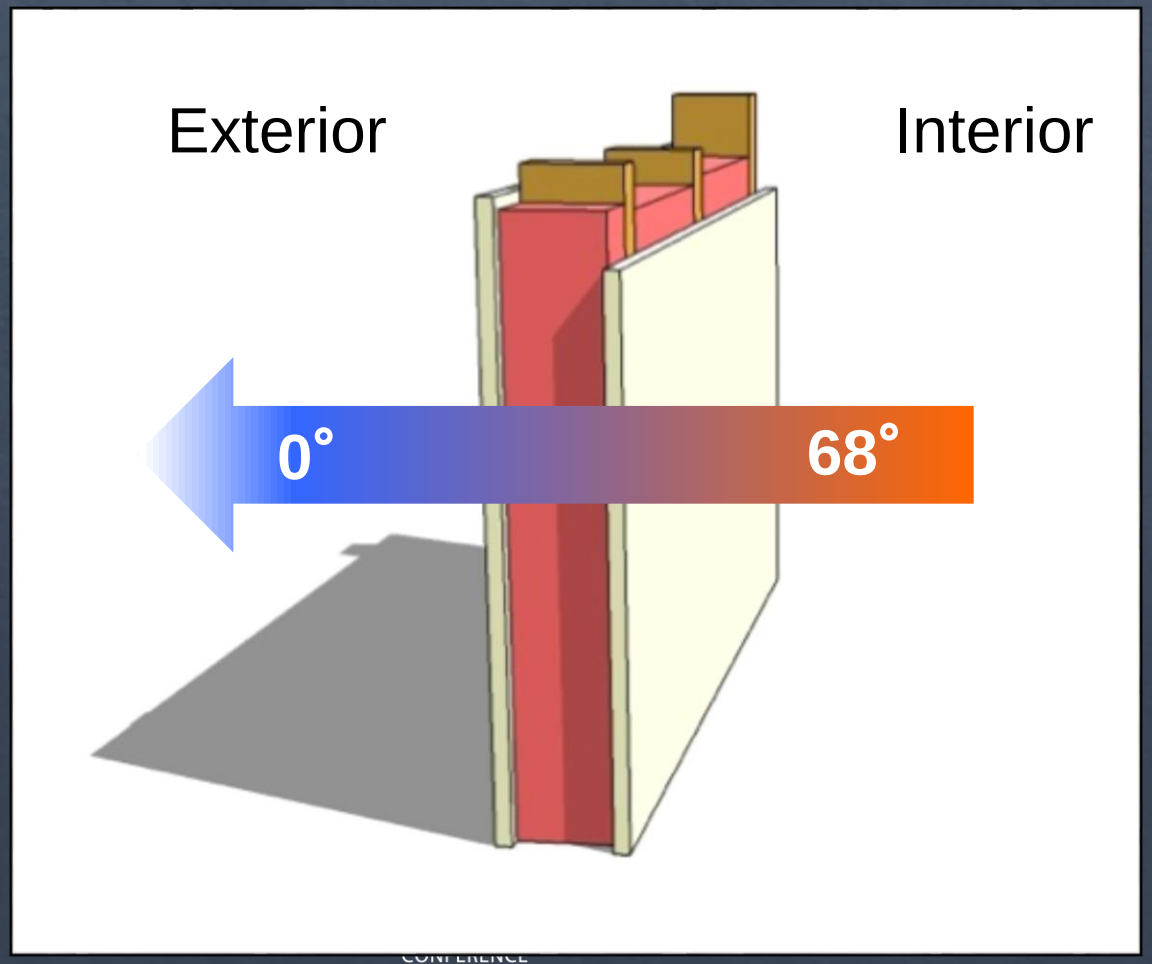
Vapor Management

Location of dew point in **heating** environment:



Temperature difference across a wall

Avoid water condensing inside of your wall

Air Flow Management

Air conditioning can change everything – especially in systems that never had it

B

Air Flow Management

Air condensing inside of a wall

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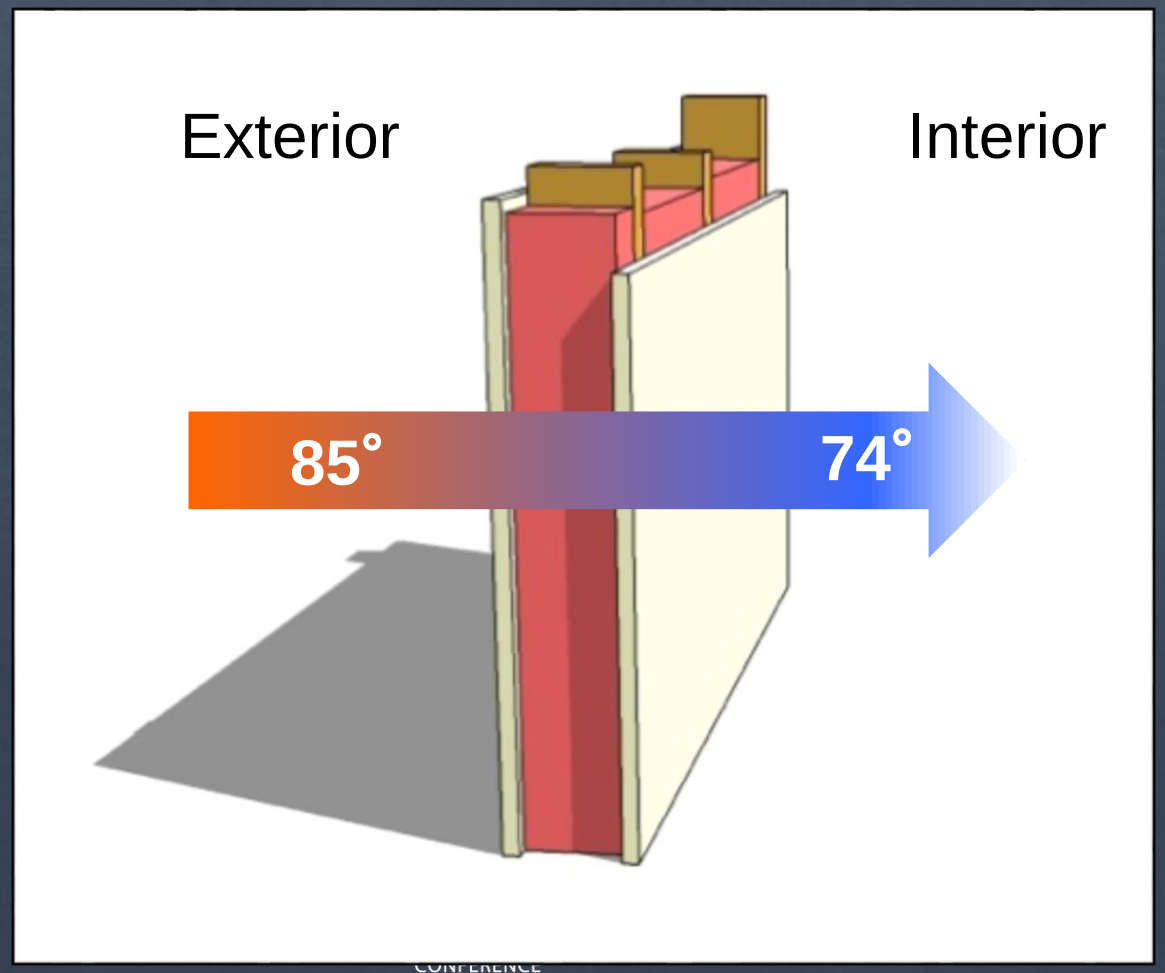
Air Flow Management

Location of dew point in **cooling** environment:



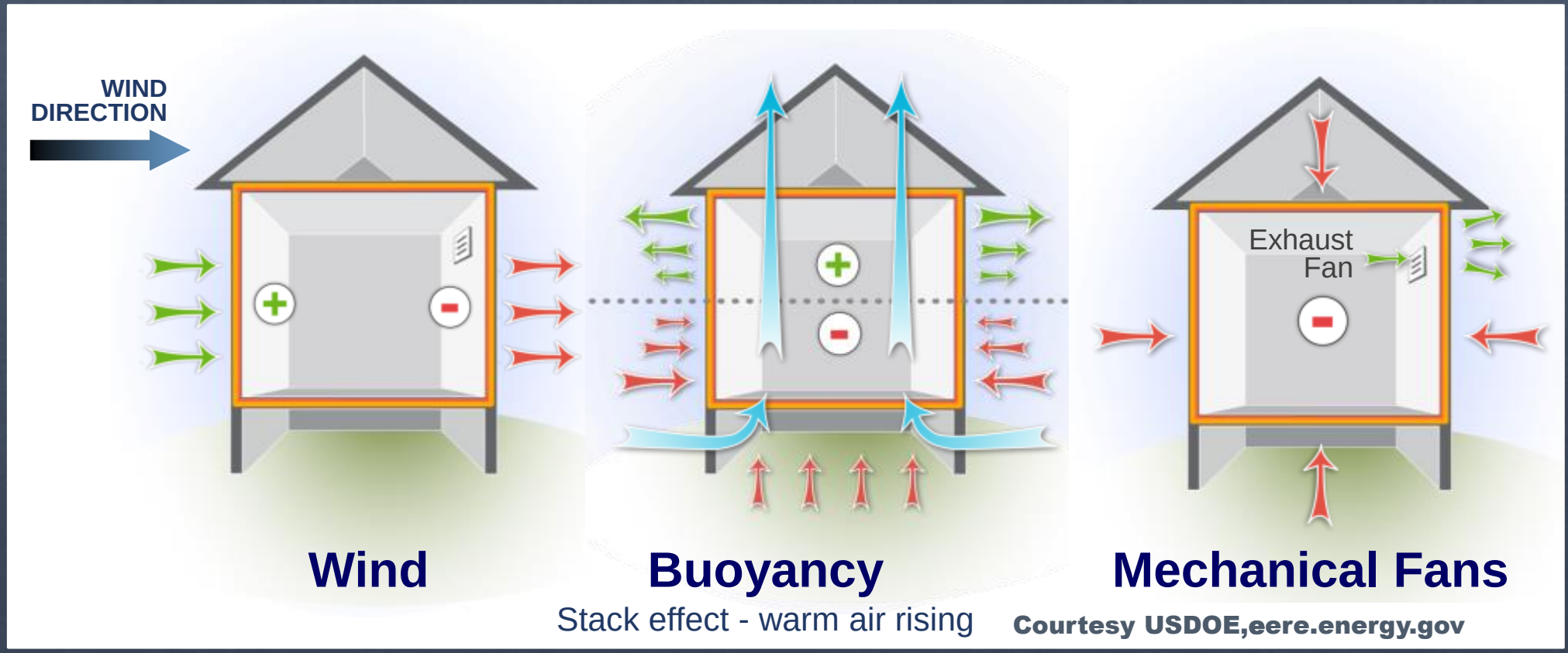
Temperature difference across a wall

Avoid water condensing inside of your wall

Air Flow Management

What moves air through buildings?

1. Wind
2. Buoyancy (stack effect)
3. Mechanical Fans

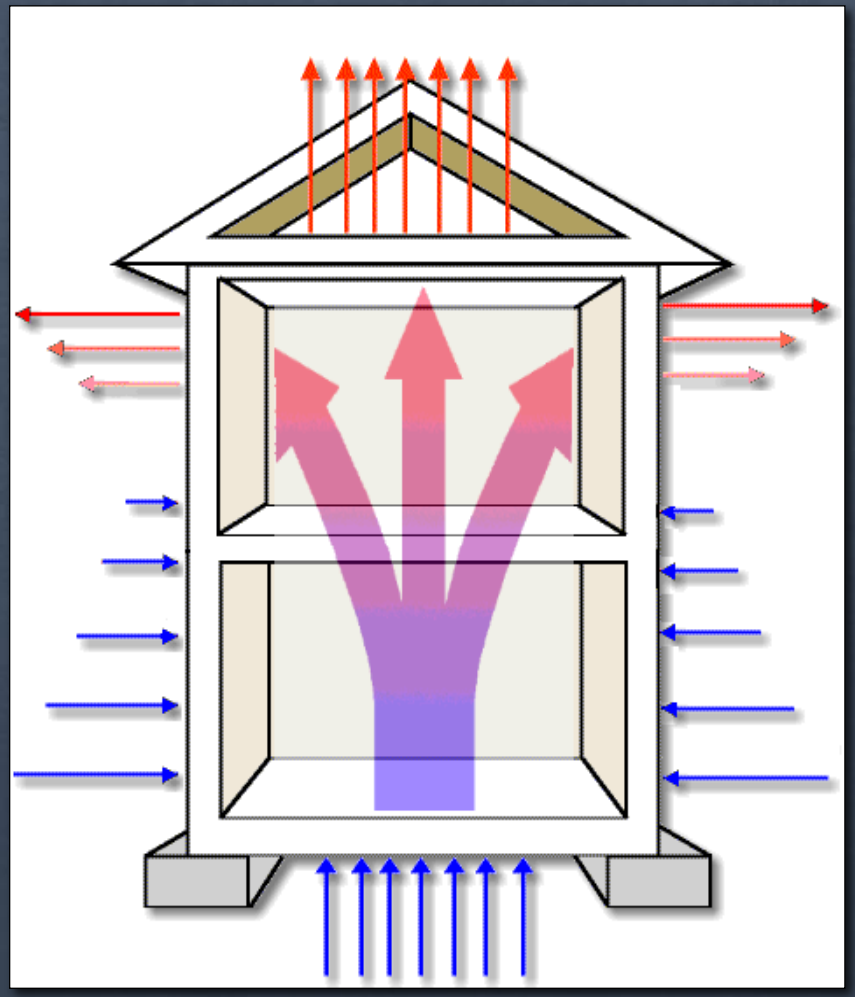


Air Flow Management

Air Leakage is NOT Constant

1. As the temperature difference between interior and exterior air increases, so does the rate of air leakage

2. As windspeed increases, so does air leakage



Courtesy Spruce Environmental Tech

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Air Flow Management

In cold climates, air leakage is responsible for Ice Dams:

Courtesy Blue Hills Roofing, Eau Claire, Wisconsin

With good air sealing comes the need for adequate snow load capacity and planned ventilation:

Historic Construction

Controlled liquid water, heat, vapor, and air in different ways

Historic Construction – Important Considerations

There are a few things that are helpful to remember:

- Designed to local environment, climate, site
- Heavy reliance on passive systems
- Different occupant comfort expectations
- Leveraged centuries of building craft and expertise

Historic Construction – Liquid Water Management

Like modern construction, included **overhanging eaves, gutters, downspouts etc**.

Massive wall construction acted as hygric buffers

Light construction included “drainage planes”

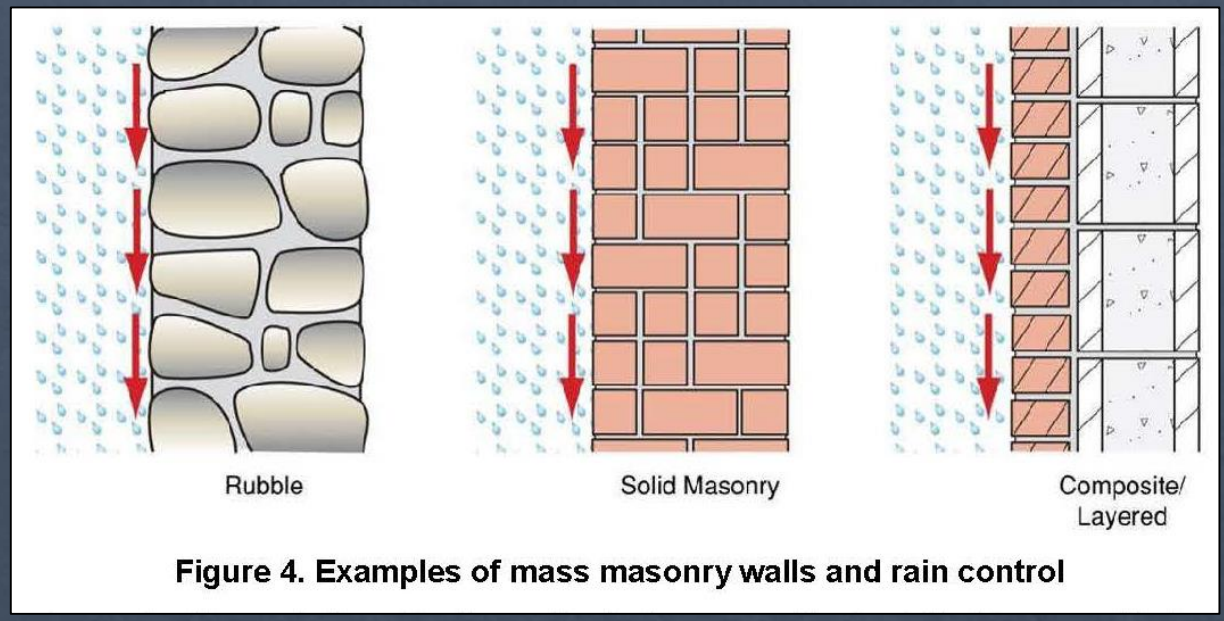

Figure 4. Examples of mass masonry walls and rain control

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Historic Construction – Heat Flow Management

Many historic buildings do not have what we now recognize as proper insulation.

- Rely on mass of walls – heating and cooling
- Stoves, boilers, fireplaces – location is deliberate
- Storm windows, shutters, curtains
- Building orientation
- Leverage heat + leakiness for drying

http://detroitarchitectjournal.blogspot.com/

https://www.oldhouseguy.com/

https://i.pinimg.com/

Historic Construction – Vapor Management

Most historic buildings do not have any vapor barriers, but *did* have good air barriers:

- Permeable materials - plasters and paints
- Vapor driven to exterior from natural ventilation and deliberate heat placement

http://historichousecolors.com/

https://www.brickunderground.com/

Historic Construction – Air Management

Most historic buildings are leaky and rely on passive ventilation

- Window placement
- Window design
- Porches

https://chambersarchitects.com/

https://designjournalmag.com/

https://www.window-guide.com/

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Historic Construction – Air Management

Ventilation and air flow is critical for the occupant

- Health
- Odor
- Comfort
- Cognitive Performance

Keep Carbon Dioxide below ~800 PPM

Walmart.com

CO2 Units can be purchased for $50

Case Studies

Any time you make changes to a historic building, ask the following:

1. What is the building's climate?
2. How does it interact with the ground?
3. What was its original use?
4. How is original use different than its proposed reuse?
5. Where could equilibrium be disrupted?

UNH T-Hall

Adapting horse stalls to offices

B

Adaptive Reuse: UNH T-Hall Basement

1. What is the building's climate?
   - Cold winters, hot summers, high RH
2. How does it interact with the ground?
   - Formerly open, now subgrade used space

B

Adaptive Reuse: UNH T-Hall Basement

1. What was its original use?
   - Horse Stalls, uninsulated, unconditioned
2. How is original use different than its reuse?
   - Horse stall vs. offices
3. Where could equilibrium be disrupted?
   - Conditioning a space that was never conditioned
   - Enclosing a space previously open

B

Adaptive Reuse: UNH T-Hall Basement

Unintended consequence:

- Fungus in the basement (formerly horse stalls), now offices

Steps taken to correct this:

- Interior floor insulation and drainage
- Application of rigid insulation and spray foam over protective and vapor retarder polyvinyl barrier for walls
- Planned ventilation

B

Adaptive Reuse: UNH T-Hall Basement

Unintended consequence:

- Fungus in the basement (formerly horse stalls), now offices

Steps taken to correct this:

- Exterior drainage

Maine 1920s Summer Home

Adapting a vacation home to a year-round residence

B

Adaptive Reuse: Maine Residence

1. What is the building's climate?
   - Cold winters, hot summers, high RH
2. How does it interact with the ground?
   - Small crawlspace, dirt floor

B

Adaptive Reuse: Maine Residence

1. What was its original use?
   - Summer home
2. How is original use different than its reuse?
   - Seasonal use vs. year-round occupation
3. Where could equilibrium be disrupted?
   - Heating and cooling something that never was heated or cooled

B

Adaptive Reuse: Maine Residence

Unintended consequence (one of them):

- Mold on insulation paper after insulating floor joists in the crawlspace

Steps taken to correct this:

- Isolate the crawlspace completely with materials moisture won't damage

- Allow it to be wet in summer and dry out in winter

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White Grass Main Cabin

Adapting a dude ranch's main cabin into a seasonal preservation training facility

Adaptive Reuse: White Grass

1. What is the building's climate?
   - Cold winters, hot summers, low RH, daily temperature swings, spring melt season

2. How does it interact with the ground?
   - Formerly thick slab foundation, now stem wall foundation, small crawlspace, dirt floor

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Adaptive Reuse: White Grass

1. What was its original use?
   - Summer day use
2. How is original use different than its reuse?
   - No measurable difference
3. Where could equilibrium be disrupted?
   - Creating an air space under the floor

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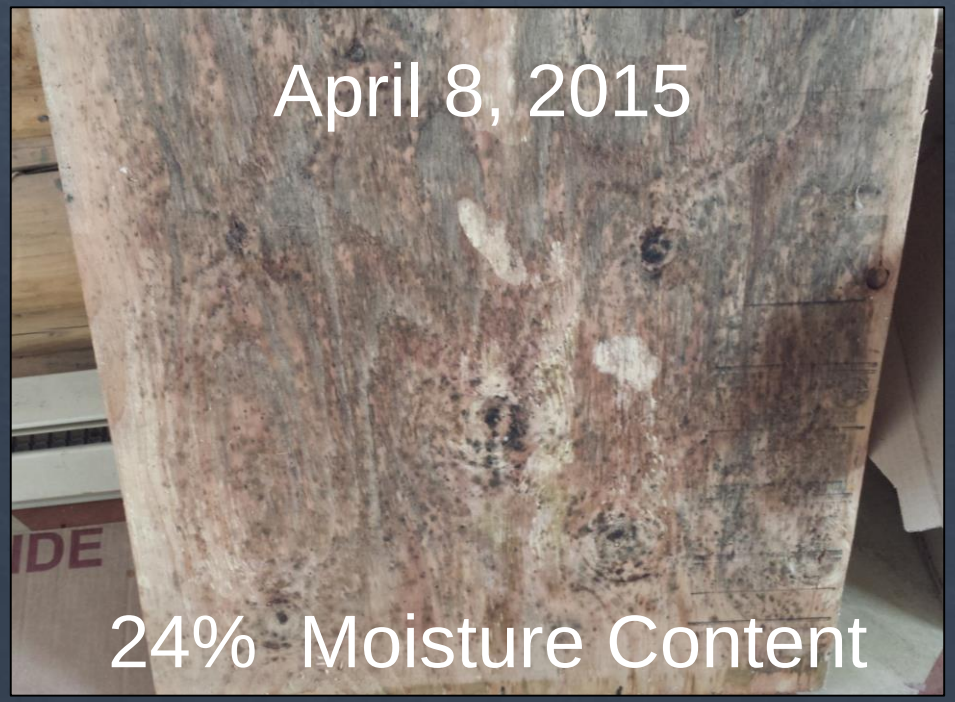
Adaptive Reuse: White Grass

Unintended consequence:

- Moisture in the crawlspace

Steps taken to correct this:

- Project planned for additional crawlspace ventilation

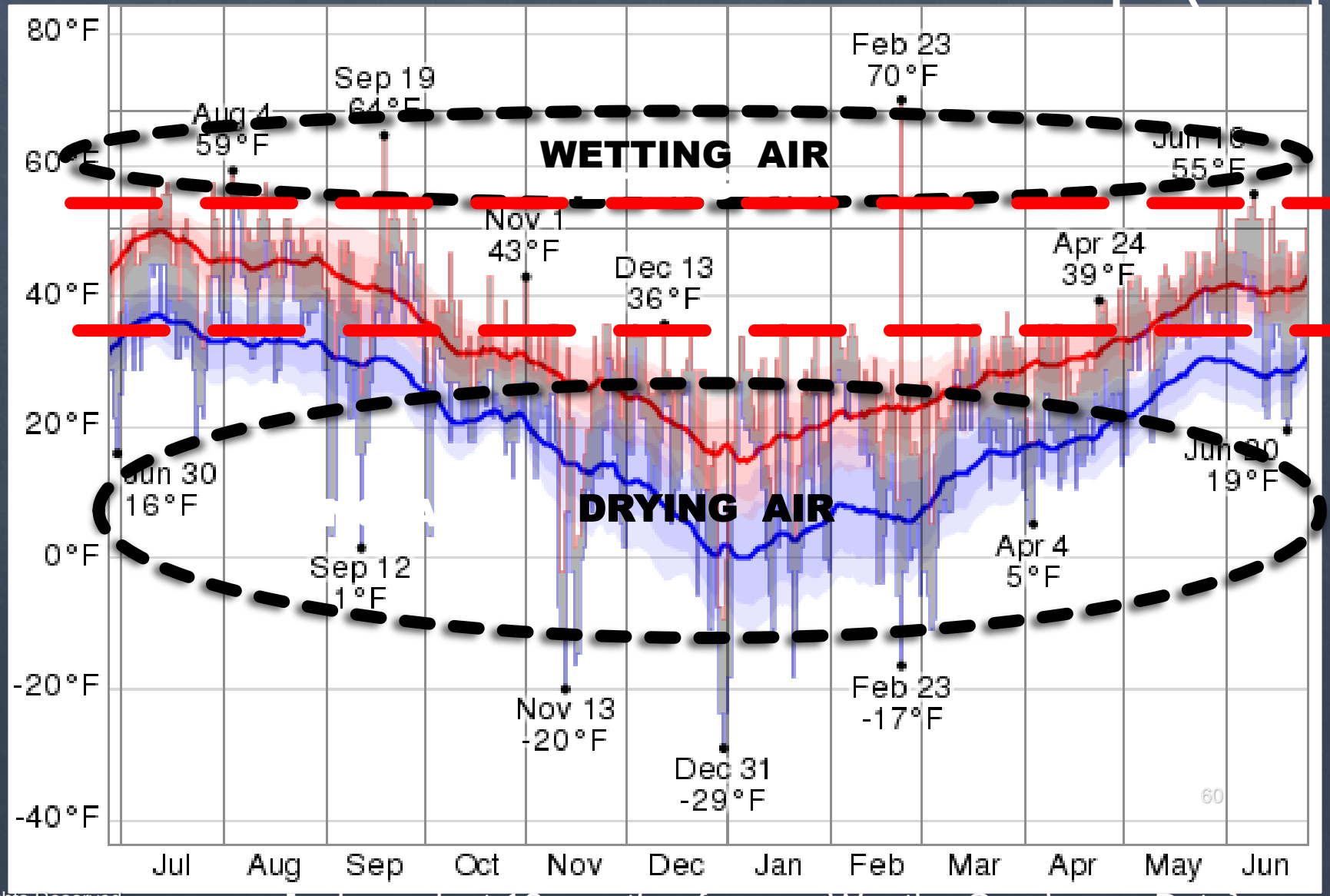


Adaptive Reuse: White Grass

Temperature and dew point show that the air is not the source of moisture

Moisture is introduced from a perched water table formed during the spring melt.

Jackson Hole Dew Point Climate Graph (dew pt.)



Jackson, last 12 months, {source WeatherSpark.com Beta}

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Lake Yellowstone Hotel

Adapting a hotel to modern HVAC standards

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Adaptive Reuse: Lake Yellowstone Hotel

1. What is the building's climate?
   - Cold winters, hot summers, low RH, daily temperature swings, spring melt season

2. How does it interact with the ground?
   - Crawlspace (variable height), dirt floor

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Adaptive Reuse: Lake Yellowstone Hotel

1. What was its original use?
   - Summer lodging only
2. How is original use different than its reuse?
   - Historic HVAC scheme vs. modern HVAC scheme
3. Where could equilibrium be disrupted?
   - New HVAC infrastructure disrupting water, air, and heat flow patterns
   - Duct and chases creating new wall intrusions

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Adaptive Reuse: Lake Yellowstone Hotel

Unintended consequence:

- Peeling paint (applied previous year)

Steps taken to correct this:

- Extensive testing to determine the cause of peeling paint.

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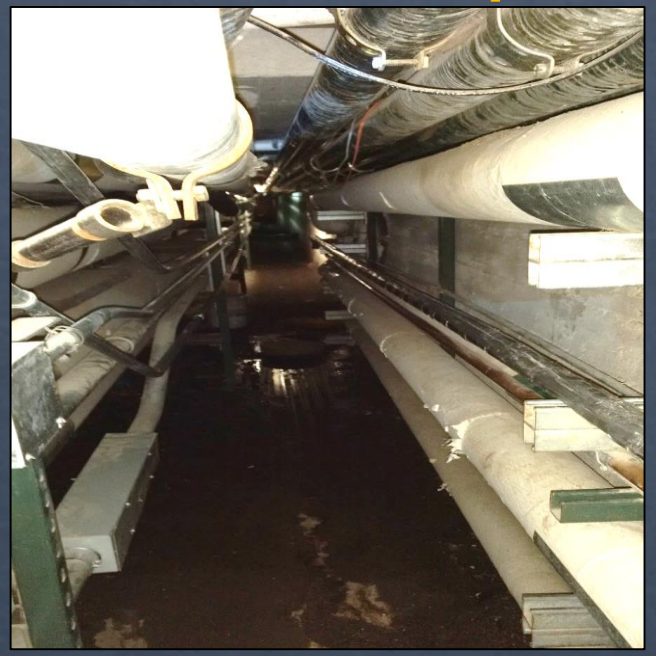
Adaptive Reuse: Lake Yellowstone Hotel

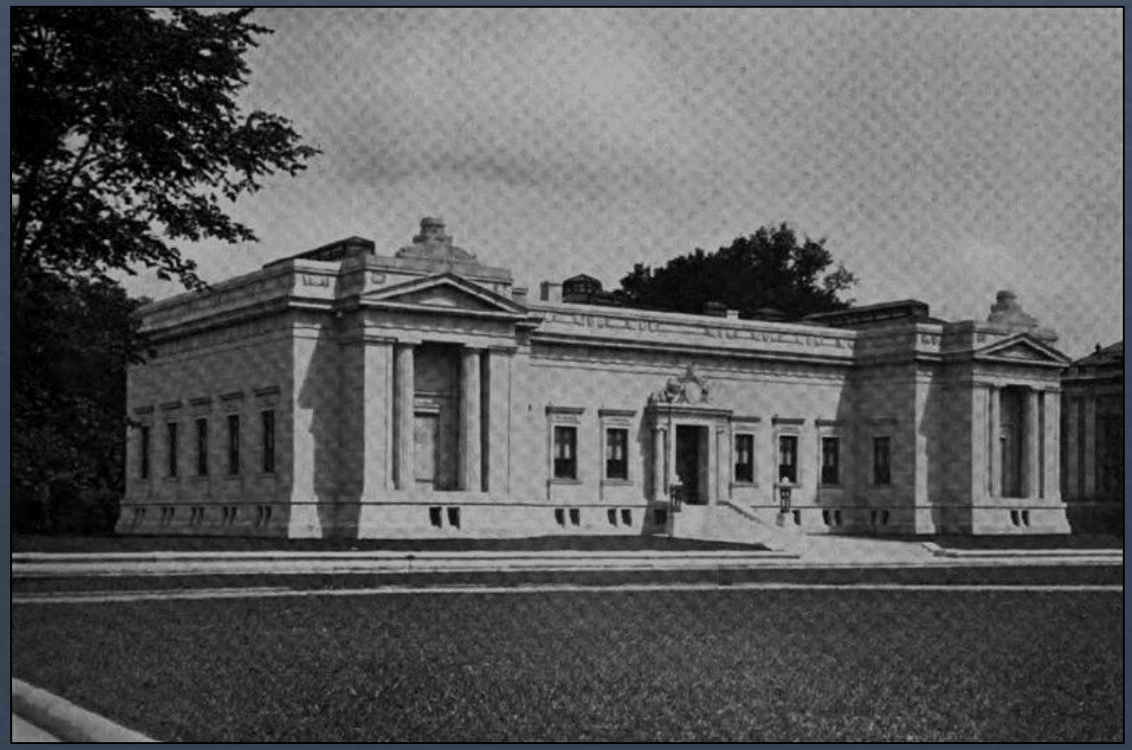


Conclusion:

- Moisture in the crawlspace = 70% RH
- Vapor drive pushed this moisture up into the building
- Prevailing winds pushed vapor to the north side's 3rd and 4th floors
- No continuous air or vapor barrier added to new ductwork chases allowed moisture to push to outside
- Impermeable finish failed with resulting pressure from moisture escaping

Tuck Library NH Historical Society and Museum

Adapting a historic library to collections' needs



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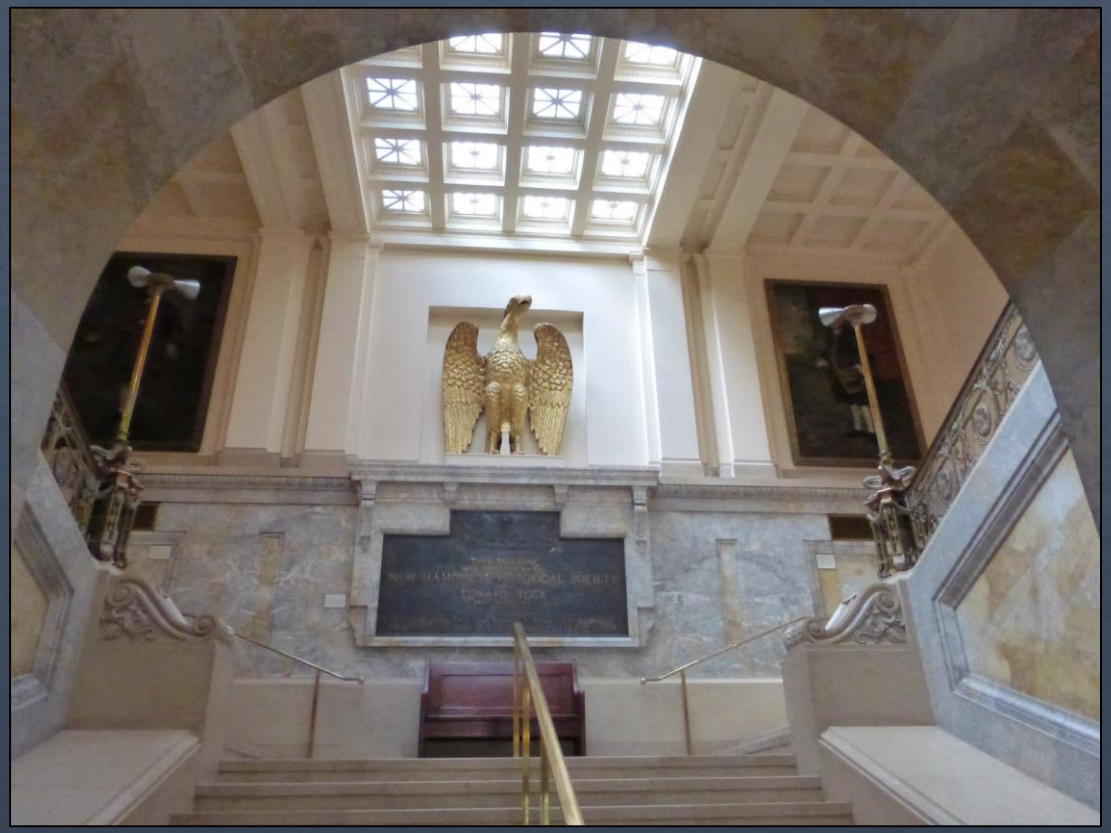
Adaptive Reuse: Tuck Library

1. What is the building's climate?
   - Cold winters, hot summers, high RH,
2. How does it interact with the ground?
   - Finished basement



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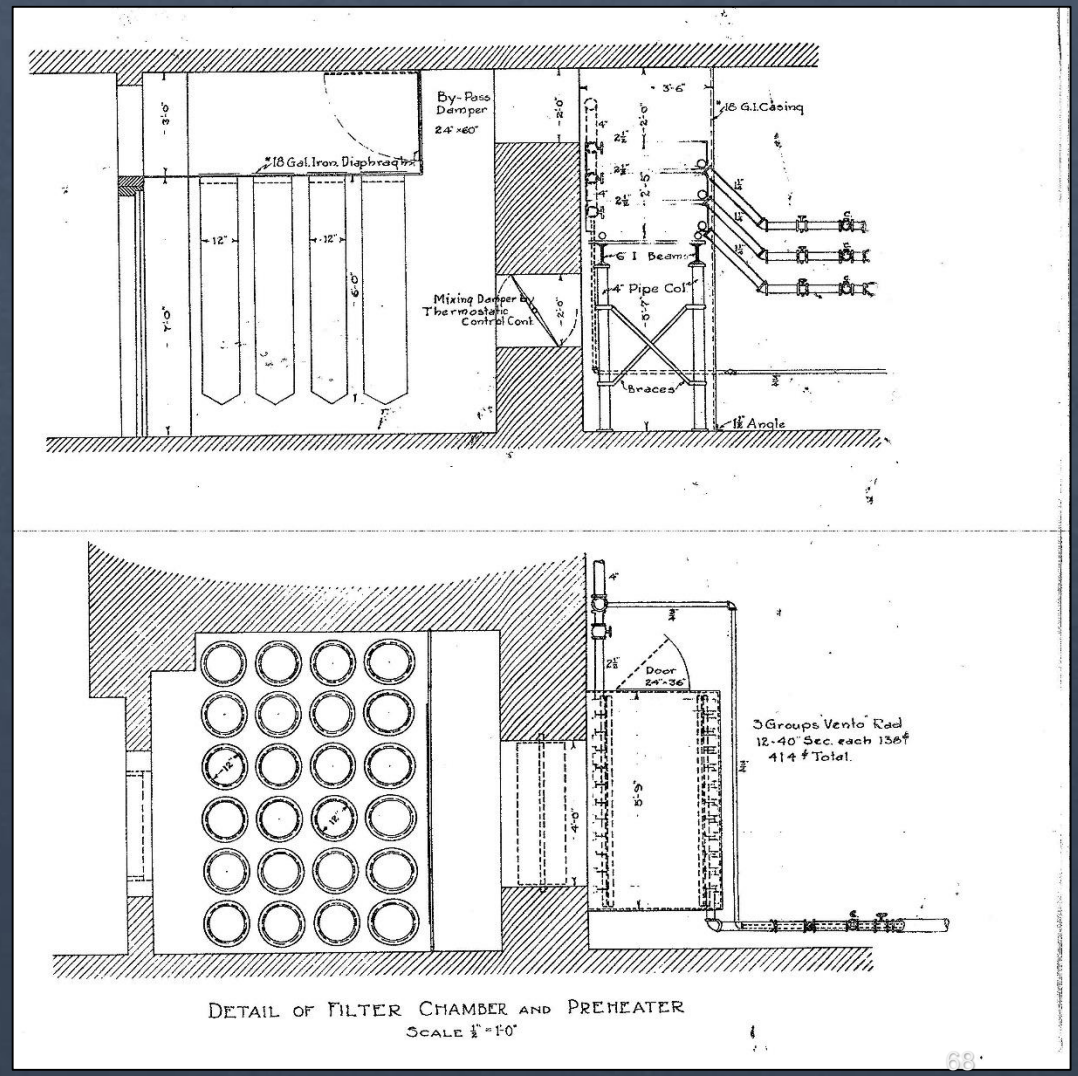
Adaptive Reuse: Tuck Library

1. What was its original use?
   - Year-round library
2. How is original use different than its reuse?
   - Regular collections vs. historic resources collections
3. Where could equilibrium be disrupted?
   - HVAC changes disrupting water, air, and heat flow patterns



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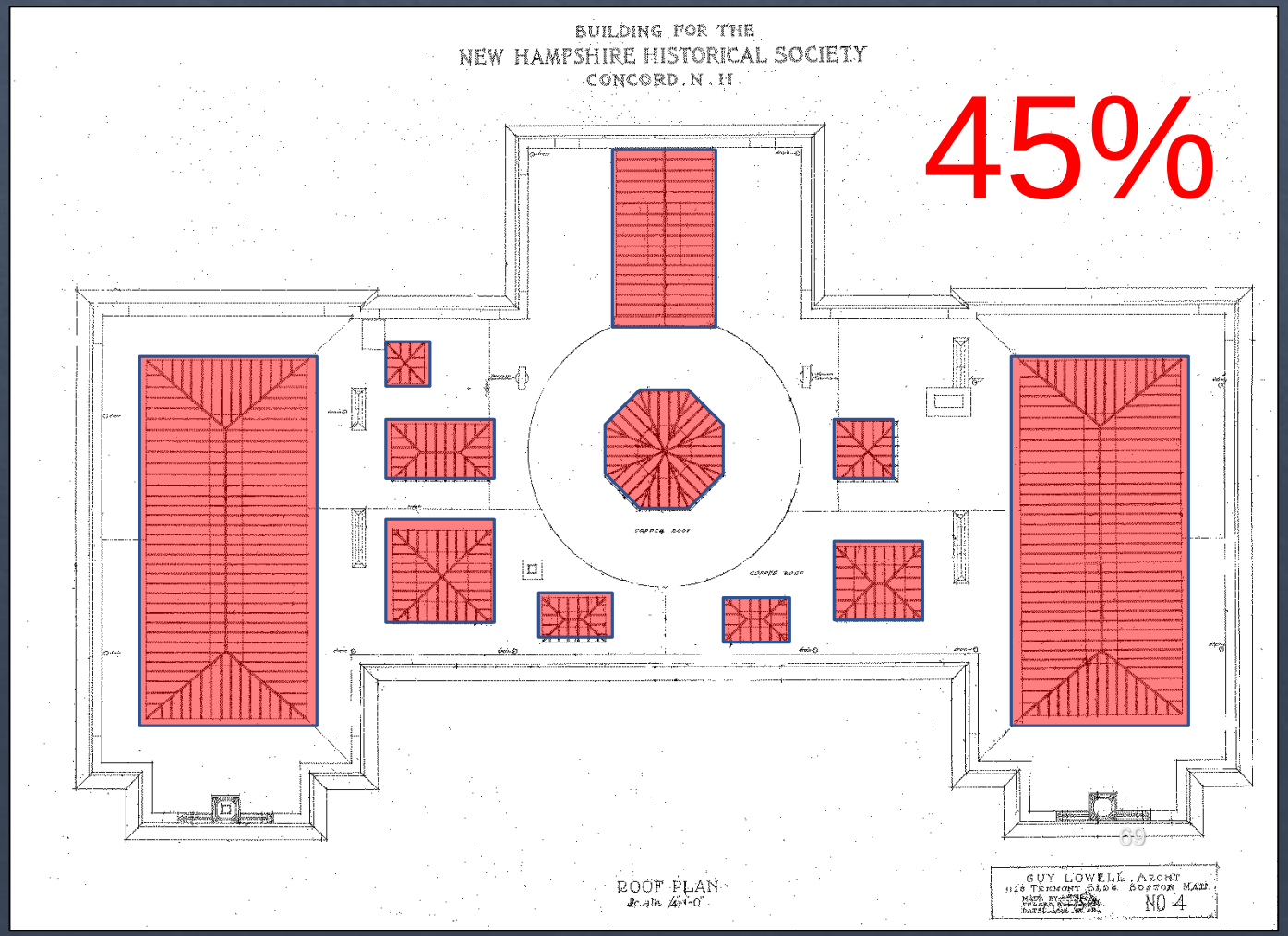
Adaptive Reuse: Tuck Library

Unintended consequence:

- Before project, huge fluctuations in acceptable temperatures, humidity, and UV radiation for collections



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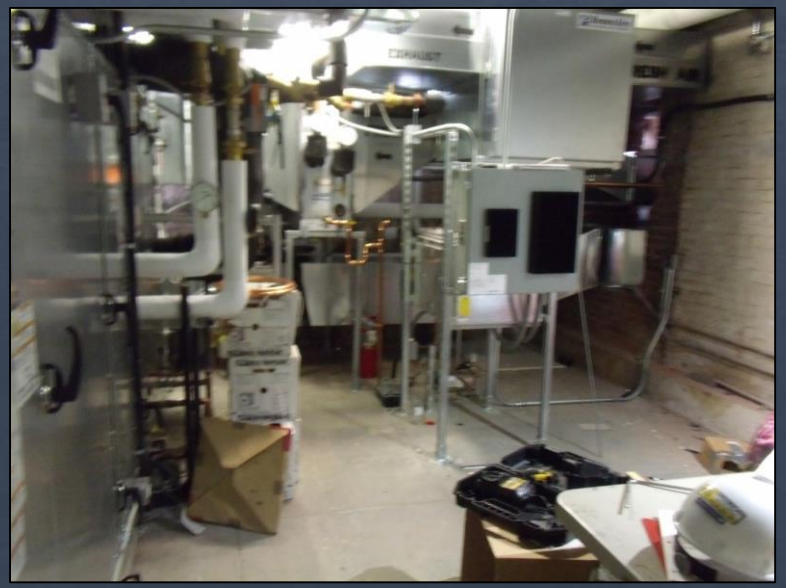
Adaptive Reuse: Tuck Library

Steps taken to correct this:

- Air barrier between collections space and roof (LED lighting to simulate daylight)
- New mechanical systems (including air drying) that used existing ductwork



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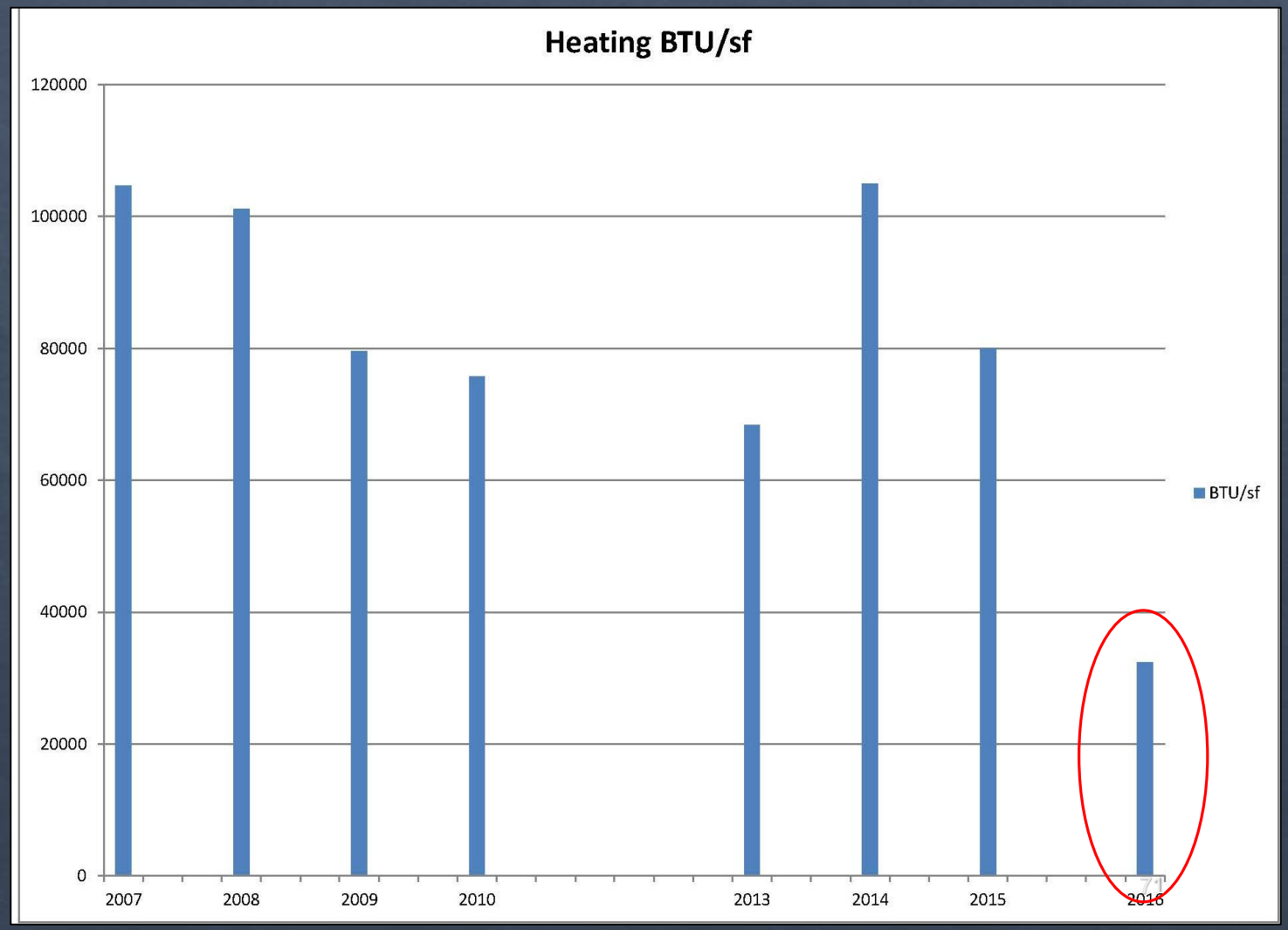
Adaptive Reuse: Tuck Library

Bonus:

- Heating load reduced dramatically



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Summary

1. Enclosure upgrades should target surfaces with the lowest insulation value or highest air leakage (rarely windows).

2. Humidity control in most buildings starts with controlling dew point of ventilation air.

3. Historic buildings successfully managed water, heat, air, and vapor, but in a different way than modern systems and for different uses. This must be understood and respected before making changes to the system.

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https://www.nps.gov/orgs/1098/western-center-for-historic-preservation.htm

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If this interested you

3 Day Workshop – Thinking Through Water, Air, and Energy in Historic Buildings

White Grass Dude Ranch, Grand Teton National Park

4th week in August.

Disclaimer

- This presentation is not intended to be a comprehensive program covering all aspects of this topic.
- All are participants are encouraged to read and follow applicable standards, codes and regulations related to this topic.
- The views and opinions following are the presenter's opinions and not necessarily the official position of the Maine IAQ Council, IAQnet LLC, or Healthy Indoors.