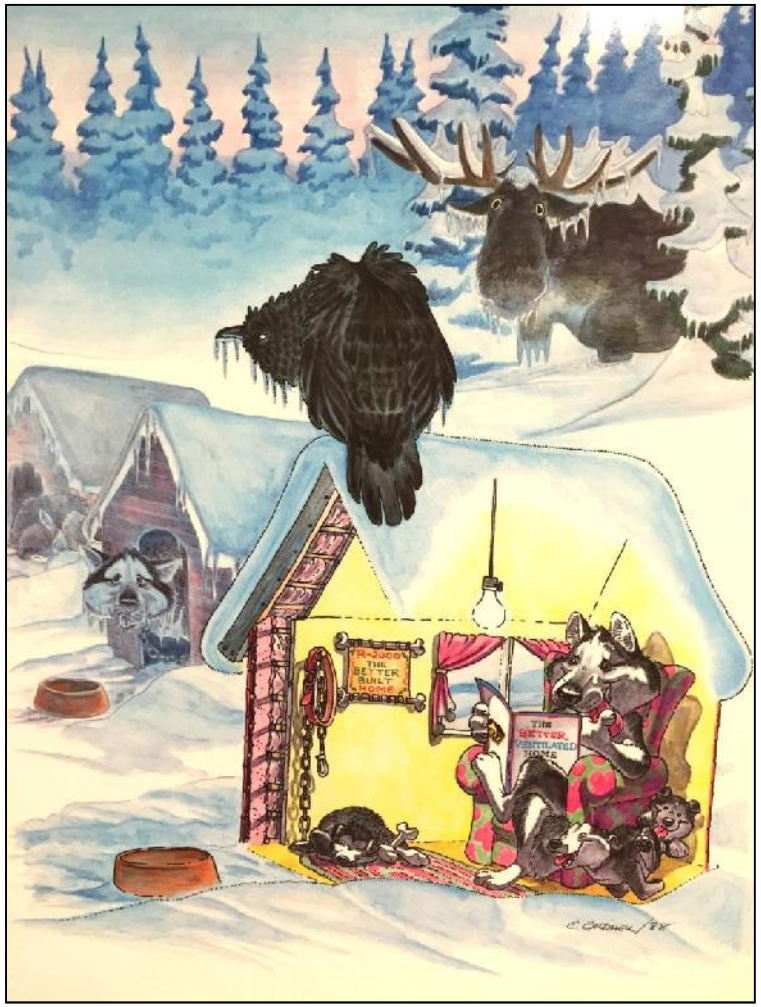
Essential Basics of Better Housing



Juergen Korn, P.Eng.
Yukon Housing Corporation
juergen.korn@gov.yk.ca

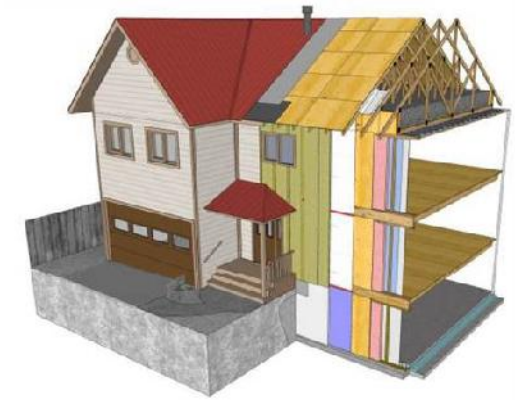
Feb 1, 2018

Principles of Better Housing:

- Background
- High performance
- Some basic science - that we never learned in school
  - Understanding air, moisture and mould
- Keeping it dry – build it for life times!
  - Control moisture, prevent mould, rot…
- Super Insulate
- Super air-tighten
- Ventilate – with an HRV
- Indoor Air Quality
- Keep it Simple
- Education
  - At all levels of society

Background:

- Major housing shortages across the north
- Over 3000 housing units in Yukon are in need of major repairs or replacement – worse across the north
- Most of our housing stock is over 30 years old; much of which is uncomfortable; uses too much energy; costly to maintain; often unhealthy to live in
- In 2030, 94% of the houses we have, have already been built – high demand for energy retrofits
- Moisture and mould is the biggest problem in housing
- We need to be innovative, adhere to the building codes – the lowest legal standard
- **The laws of physics will always rule**



Chris Caldwell - 1988

Harold Orr: Energy efficiency pioneer

Harold Walter Orr pioneered energy-efficient home-building in Canada. He is one of the original engineers of the Saskatchewan Conservation House built in Regina in 1977.

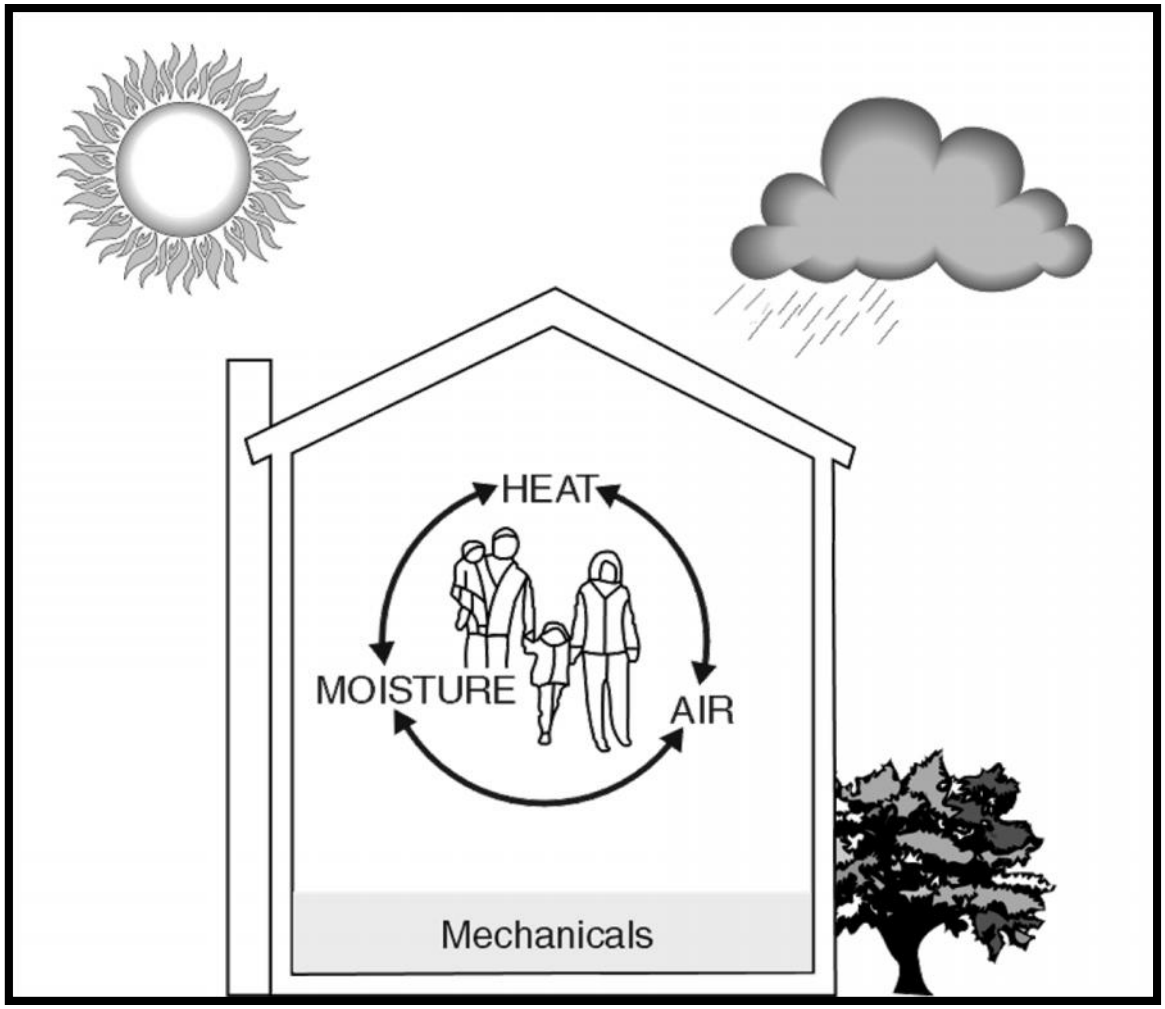
The Order of Canada is one of the country's highest civilian honours. (Governor General of Canada)

Harold Orr is one of the engineers who worked on the Saskatchewan Conservation House built in Regina in 1977. (CBC Saskatchewan)

2018

"Everybody should be building the equivalent to the passive house"

"House as a System" principles



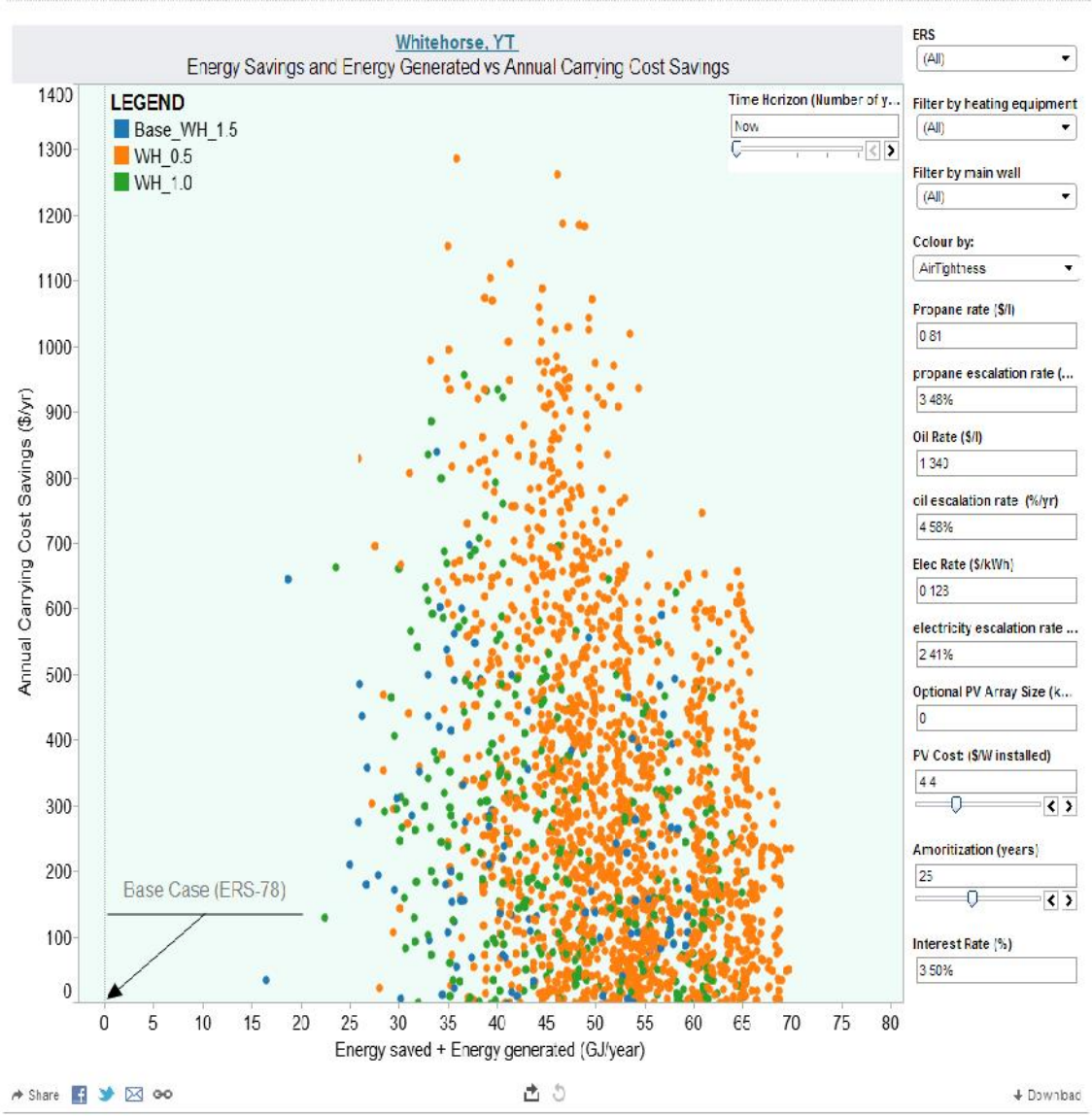
High Performance Houses:

- Use far less energy
- Are far more comfortable
- Are healthier to live in
- Are less prone to moisture problems
- Are simpler and easier to operate
- Need less maintenance
- Have a longer life
- Can cost less!
  - With good design and planning
- **We need to get the basics right!**

SuperGreenHome

Watson Lake, Yukon:

Are high performance walls and homes expensive?

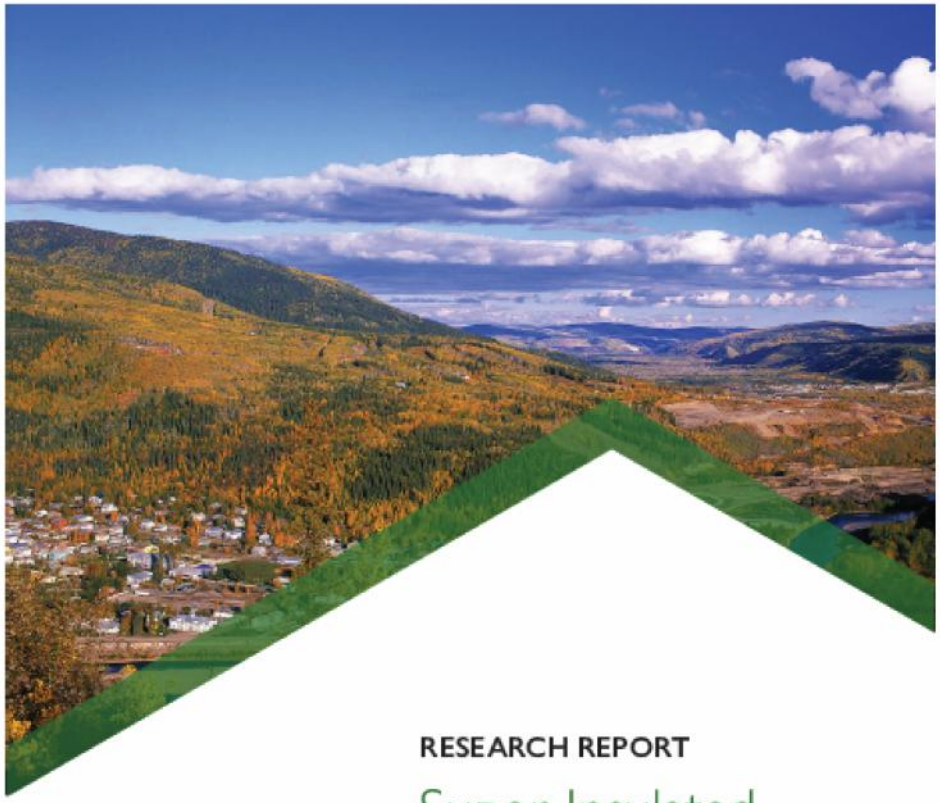


NRCan Whitehorse Residential Energy Optimization & Simulation

Whitehorse Affordable Family Housing 8-Plex:
~300 Super-Insulated units by YHC

Super insulated, HRVs in each unit, triple glazed 2 low-E windows, electric baseboard heating

Ground source heat pump not feasible – building needed too little heat



RESEARCH REPORT

Super-Insulated Housing in Yukon

Canada

CMHC SCHL

RESEARCH HIGHLIGHT

Documentation of Super-Insulated Housing in Yukon

March 2017 Technical Series

INTRODUCTION

Since 2007, Yukon Housing Corporation (YHC) has built 224 super-insulated public housing units, with approximately 300 market units built across the territory by the private sector. However, there has been little to no follow-up on the performance of these houses.

Anecdotal information suggested that these houses were neither difficult nor expensive to build but have far superior energy efficiency and comfort compared to standard construction. This study was undertaken to document the design and construction of super-insulated (SuperGreen™[1]) housing within Yukon and provide information on their performance, their return on investment (where possible) and the lessons learned by builder participants.

Figure 1 Structurally insulated panel SuperGreen™ home

METHODOLOGY

Builder and project identification

Canada Mortgage and Housing Corporation (CMHC) provided funding to the Yukon Government's Energy Solutions Centre (ESC) (YG's Energy Branch) to compile a list of homebuilders having constructed super-insulated houses that qualify as SuperGreen™ or meet a minimum EnerGuide™ rating of 85. Yukon Housing Corporation was consulted to help identify qualified homebuilders within the territory, while ESC consulted with territorial and regional homebuilder associations; water, fuel and electricity utilities; and local housing authorities to identify any other appropriate homebuilders.

Information gathering and phone survey

Based on the suggested list of builders and projects, ESC contacted the identified homebuilders to solicit participants for this project and schedule interviews. Participants also provided written permission for ESC to collect technical information on home construction, including data on energy performance, construction approaches, sustainable practices and technologies used, project size (number of storeys and heated floor area), tenure (ownership and rental), geographical location and likelihood of accessible information.

[1] SuperGreen™ represents a Yukon Housing Corporation standard for residential construction that requires buildings to meet an EnerGuide rating of 85 or better.

Canada

CMHC SCHL

- 2016 – Over 75% of new homes – EGH 85 or better
- 50% lower heat energy than new Code for Energy Efficiency

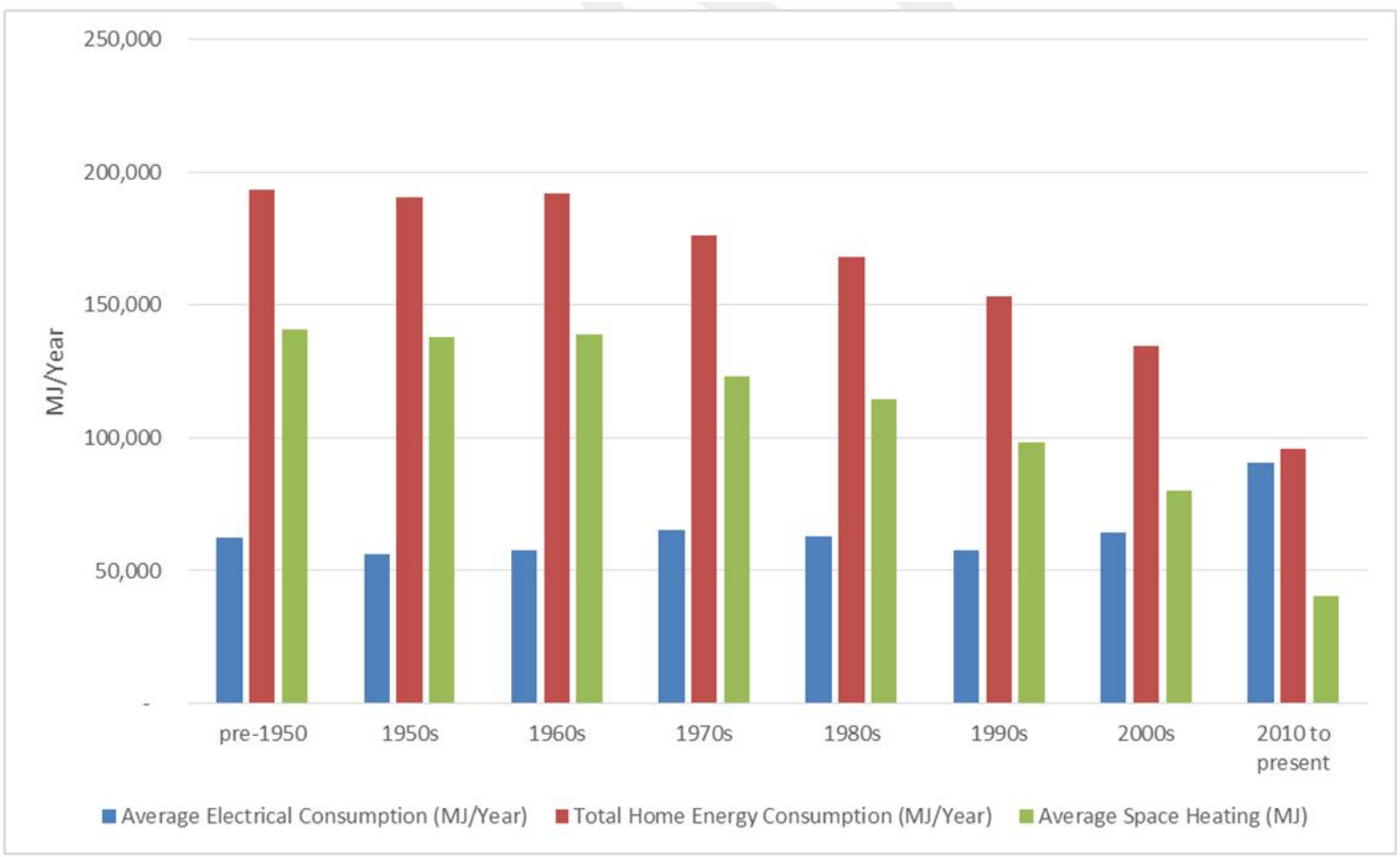


Figure 5: Average Annual Energy Use by Decade in which home was constructed (Source: Derived from Home Energy Assessment data collected over 2800 Home Energy Assessments by Certified Energy Assessors in Yukon)

Sustainable Northern Communities

INNOVATIVE COLABORATIVE HOUSING DESIGN

Anaktuvuk Pass Prototype

Average house: 5,400 liters/yr
Prototype house: 500 liters/yr

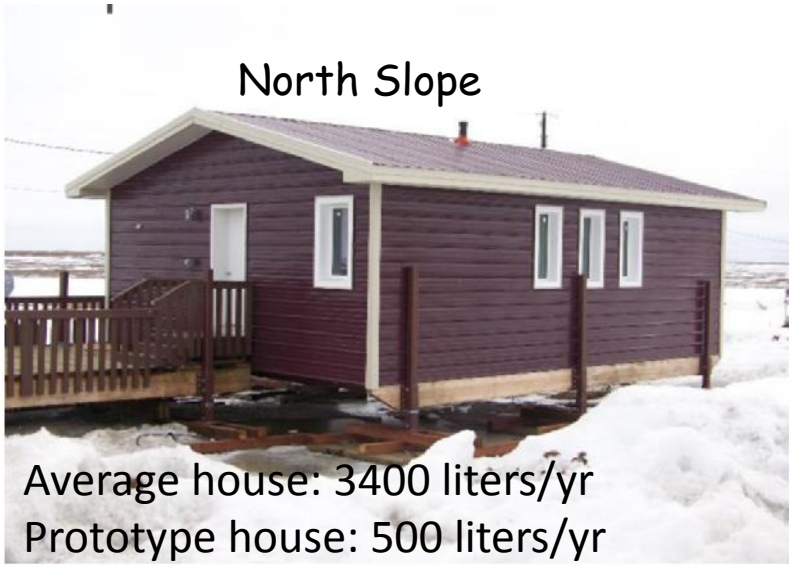
Atmautluak Prototype

Average house: 3600 liters/yr
Prototype house: 450 liters/yr

Quinhagak Prototype

Average house: 3800 liters/yr
Prototype house: 600 liters /yr

North Slope



Average house: 3400 liters/yr
Prototype house: 500 liters/yr

Moisture – number one problem:

- <u>Moisture can destroy homes and make people sick!</u>
- Moisture is involved in most building problems
- And is the number one problem in housing in Canada!
  - 50% of Canadian houses have moisture problems (CMHC study)
  - Moisture and mold problems are likely more widespread in the North
  - Most insurance claims and 70 % litigation in housing involve moisture problems and water damage.

Water-Stained Ceiling Tile

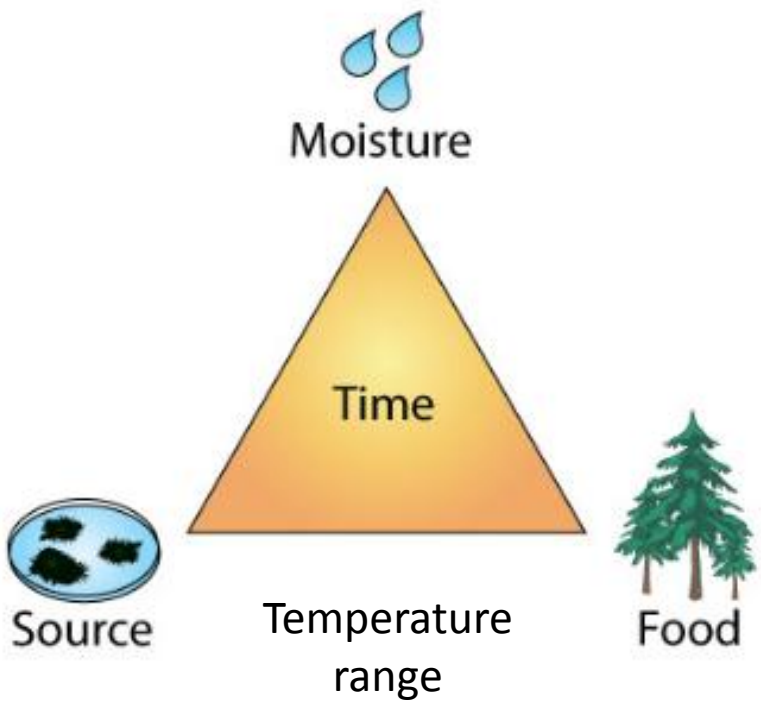
Mineral Deposits (Efflorescence) on Block

Water-Damaged Drywall

Water-Damaged (Rusted) Metal Bottom Plate

Control Moisture, Control Mold:

- Mold is everywhere
- Food is virtually everywhere in a house
- Moisture is needed
- Happens when wetting rates exceed drying rates
- Control the moisture, control the mold
- Mold can start in 24 hrs in the right conditions



Mold in housing is <u>completely</u> avoidable

Primary Causes of Moisture Problems:

- High humidity – Sources vs. Ventilation
- Condensation - cold surfaces – windows, thermal bridging, air leaks
- Air leaks in building enclosure
- Roof water, surface water, and site drainage
- Water leaks – plumbing, spills, overflows
- Lifestyle
- Lack of basic knowledge

All enclosures get wet:

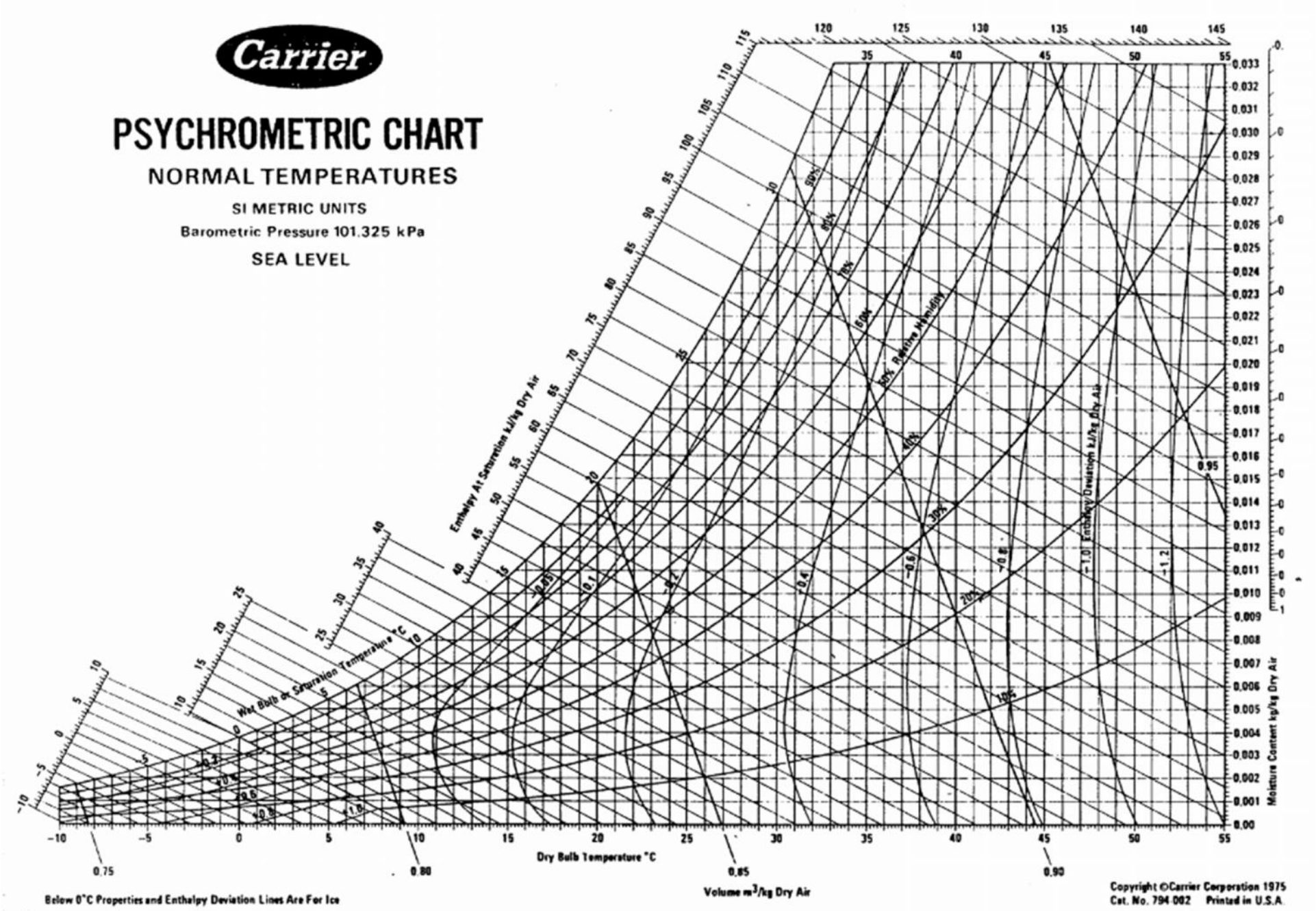
- Problems occur if
  they get **too** wet for **too** long
- Always need to:
  - limit wetting
  - encourage drying

First, some basic science:

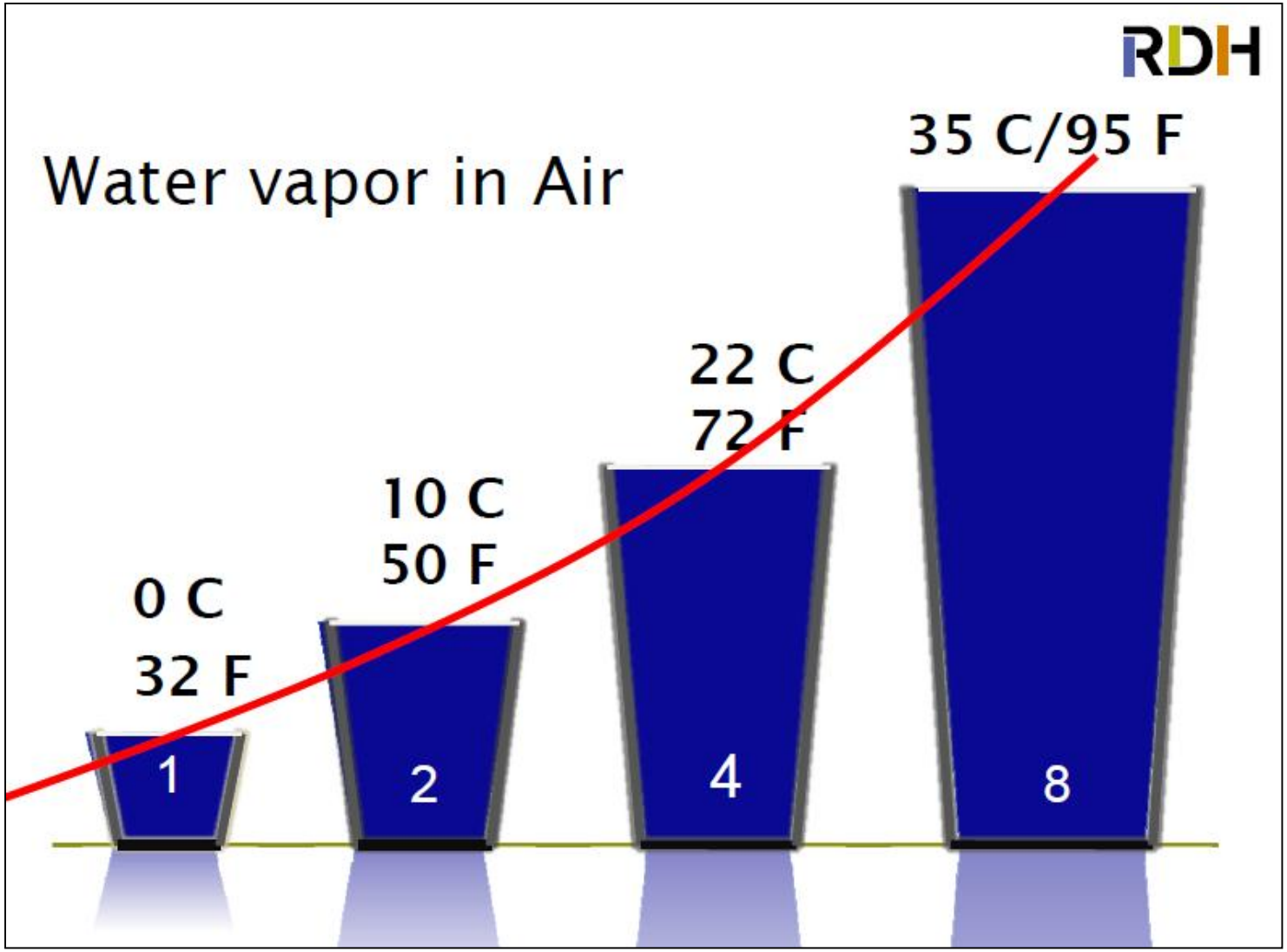
Building Science

Psychrometrics:

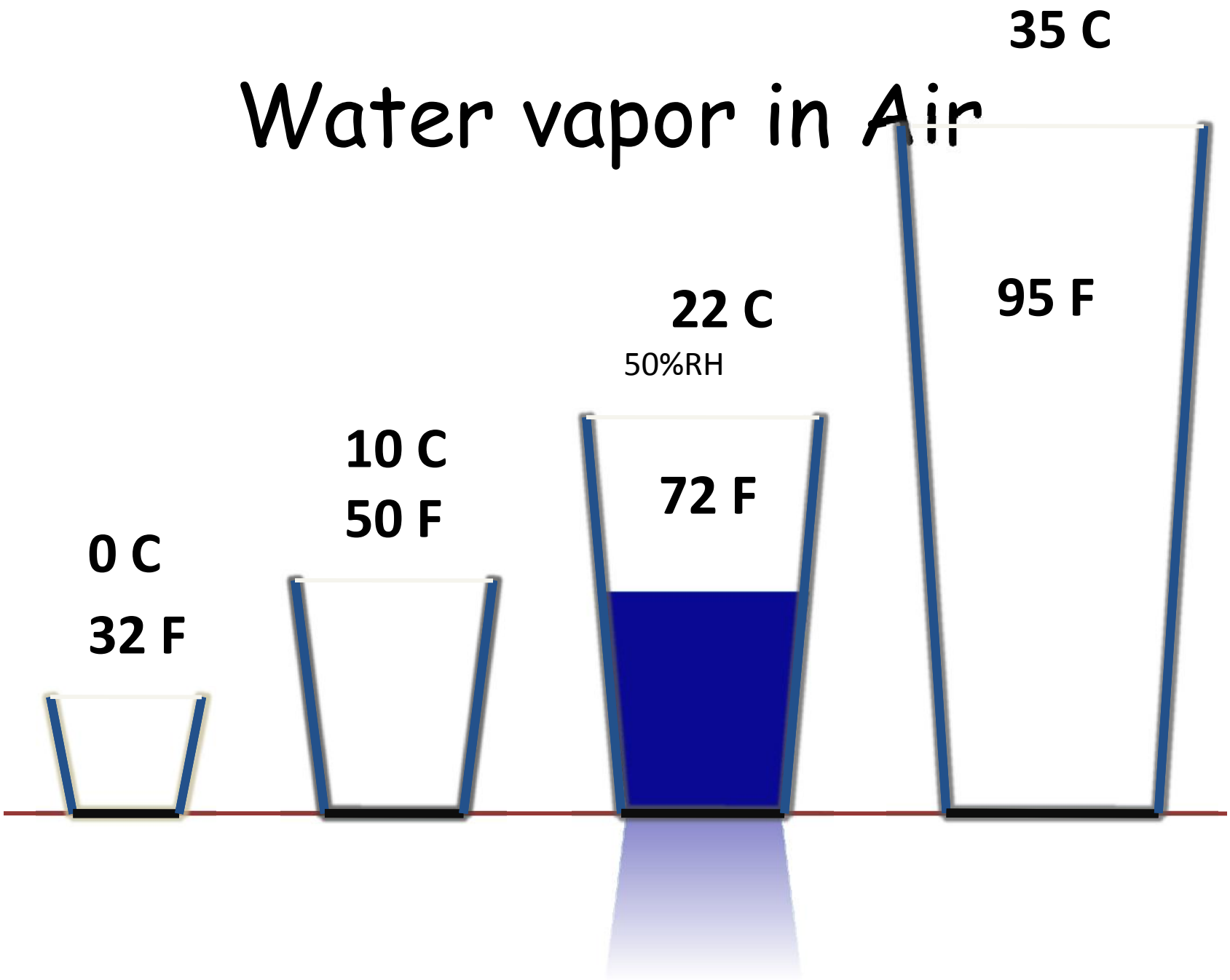
"the science of air and its moisture and energy content"


Carrier
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS
Barometric Pressure 101.325 kPa
SEA LEVEL
Enthalpy At Saturation kJ/kg Dry Air
Wet Bulb or Saturation Temperature °C
Dry Bulb Temperature °C
Volume m³/kg Dry Air
Moisture Content kg/kg Dry Air
50% Relative Humidity
Below 0°C Properties and Enthalpy Deviation Lines Are For Ice
Copyright ©Carrier Corporation 1975
Cat. No. 794 002 Printed in U.S.A.

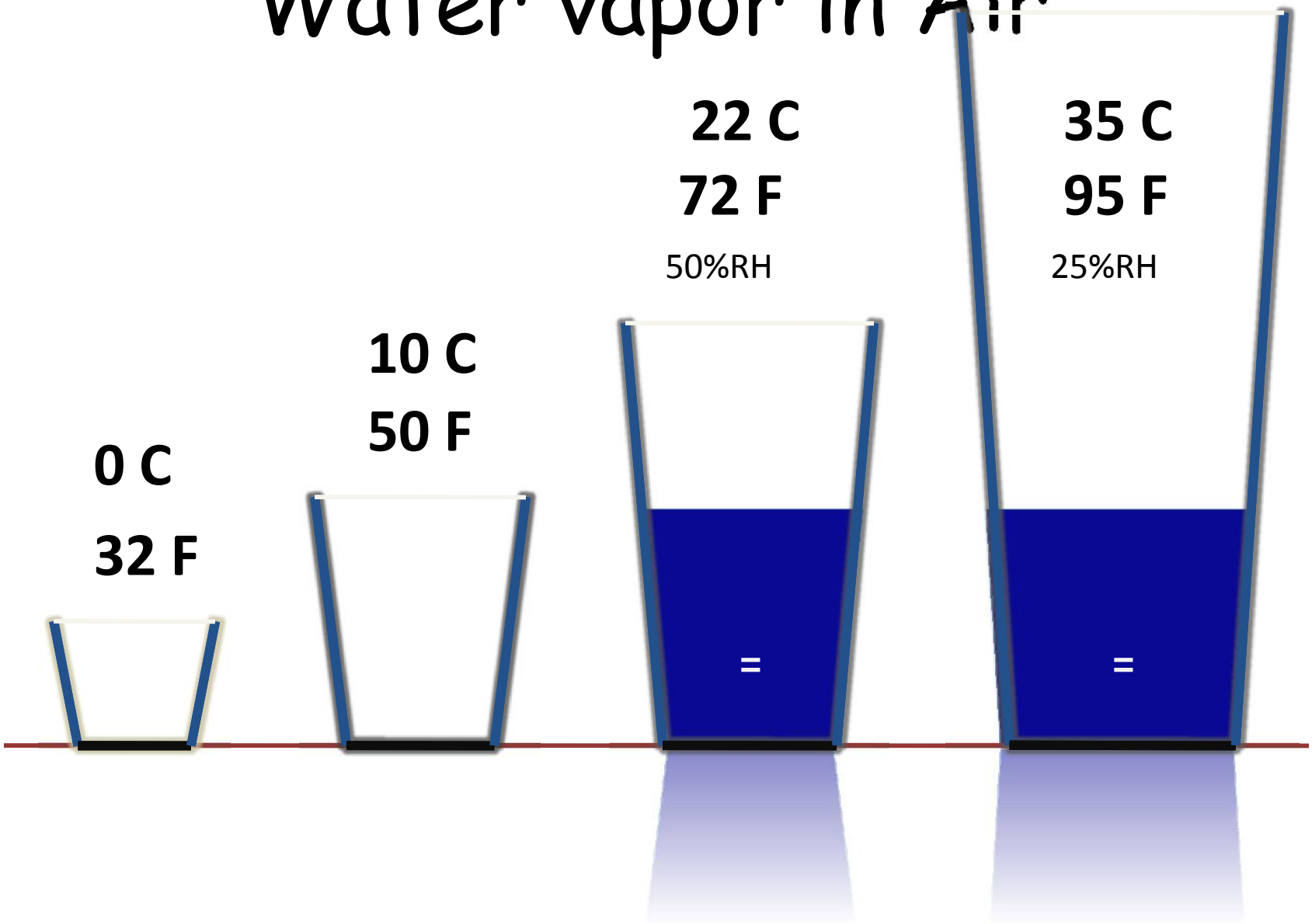
Water Vapour and Air



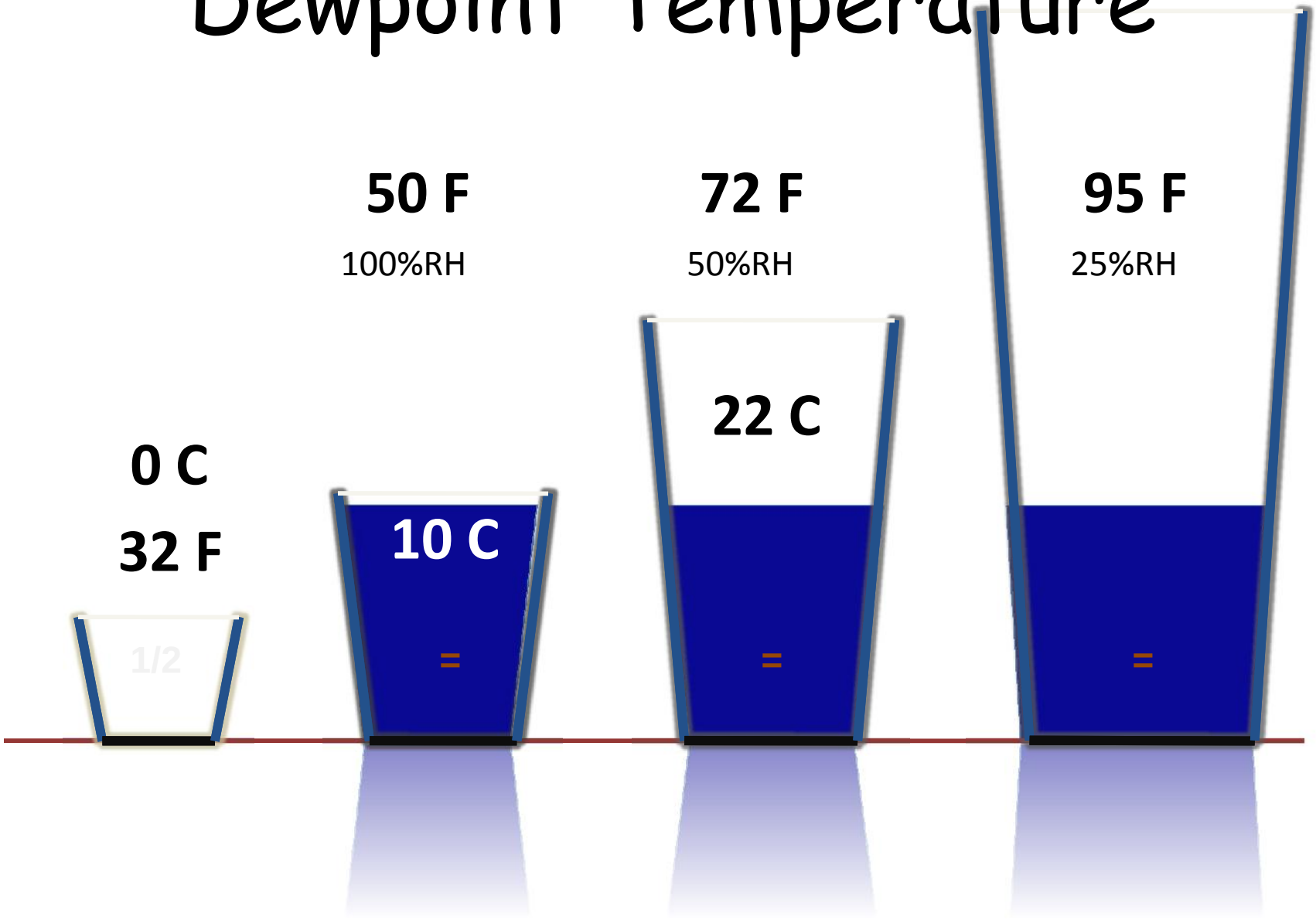
Water vapor in Air



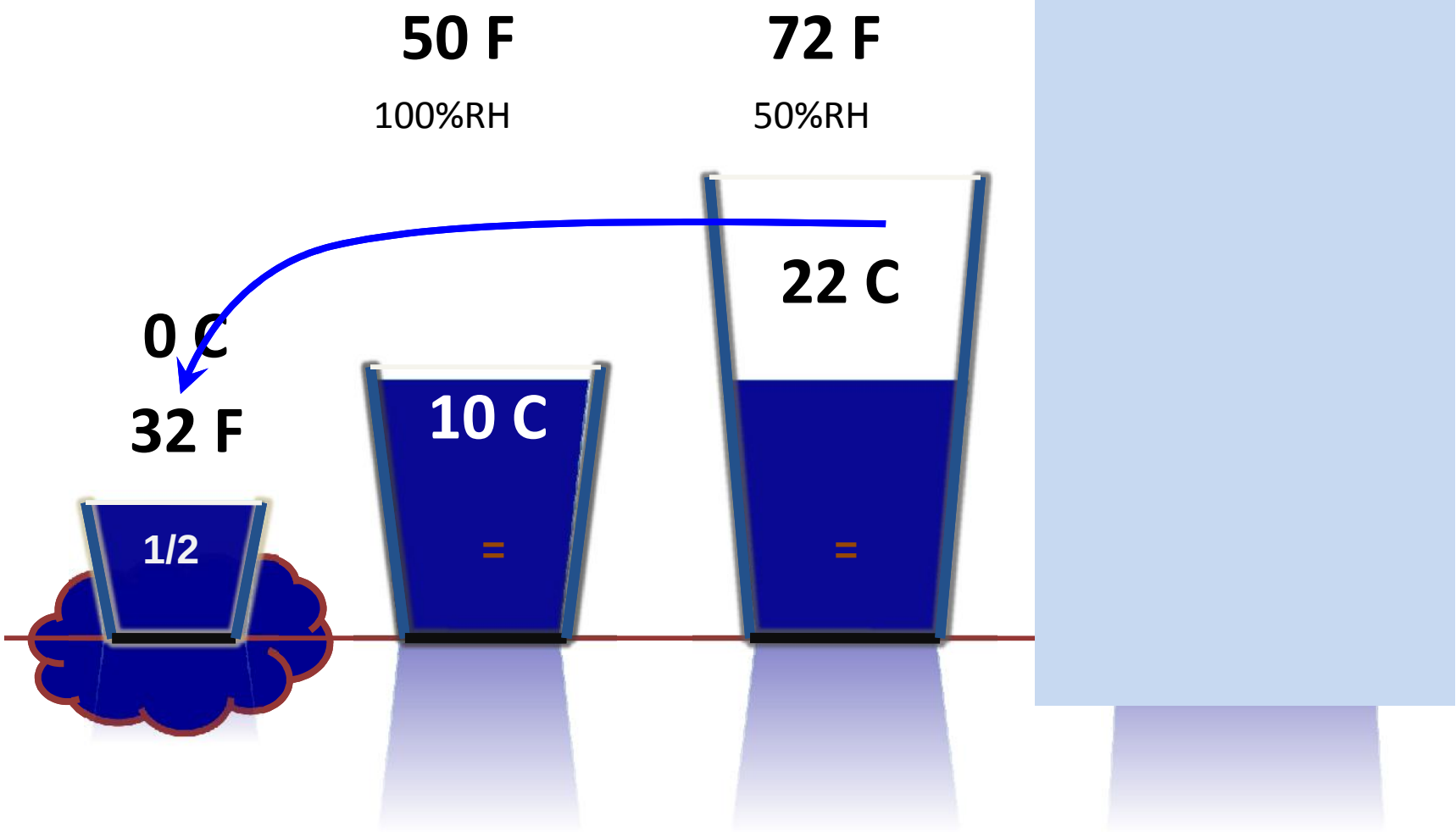
Water vapor in Air



Dewpoint Temperature



Cold weather condensation



Condensation:

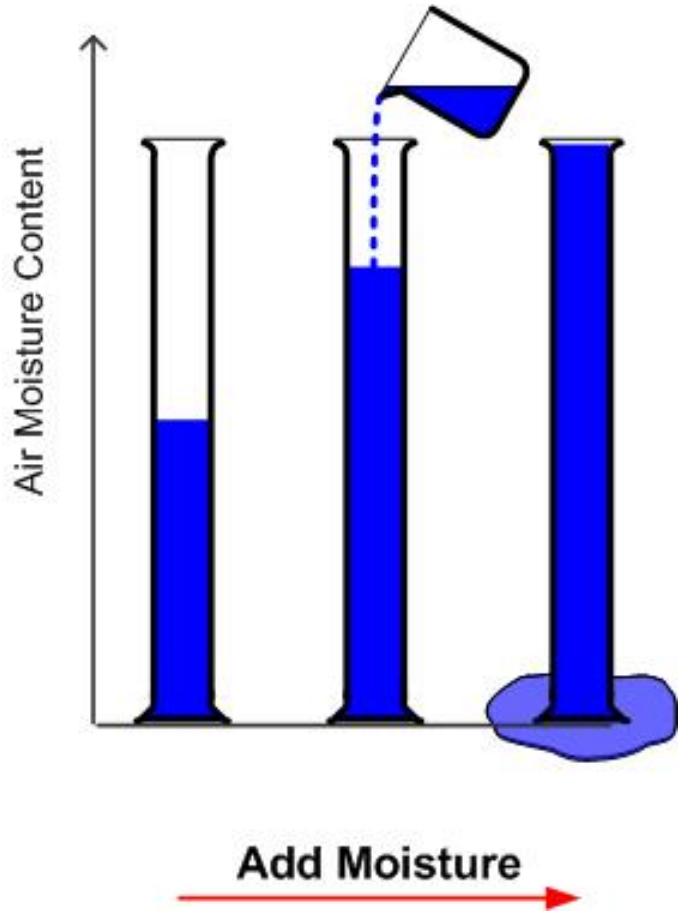
Water vapor converting to liquid

Not… materials “sweating”

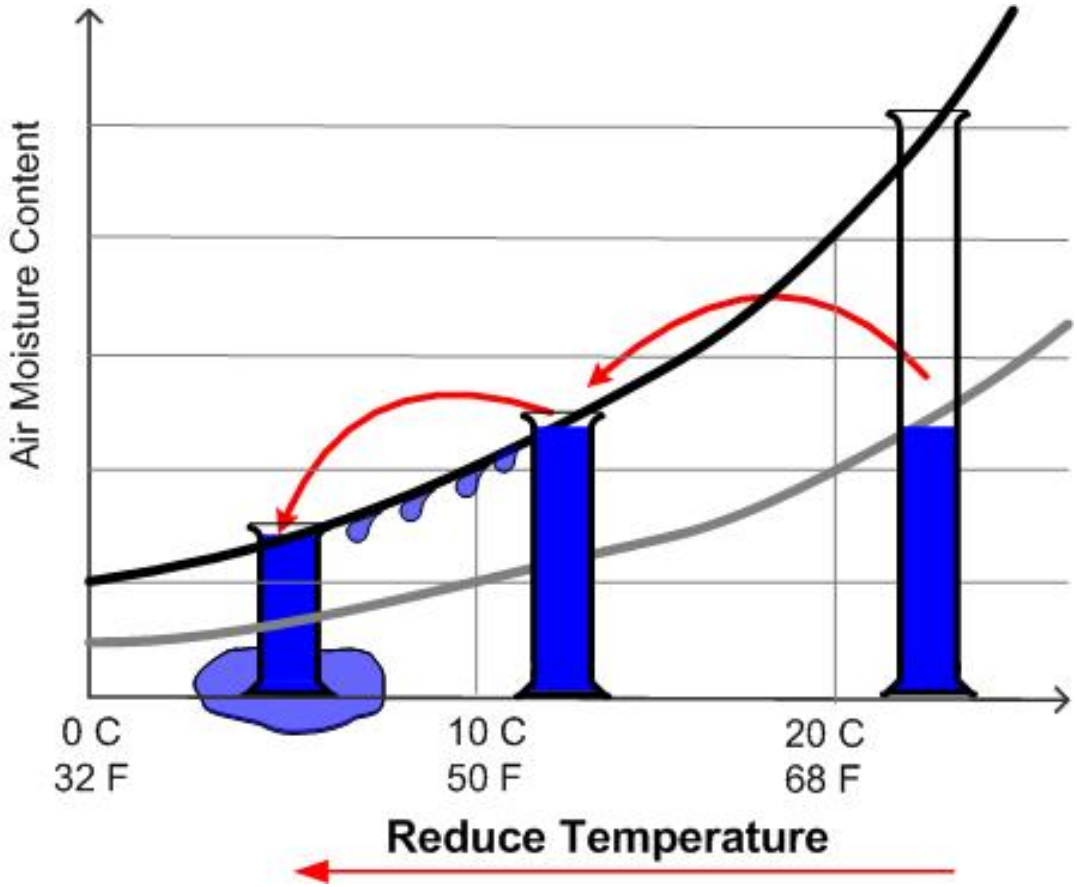
Window moisture:

Methods to get Condensation:

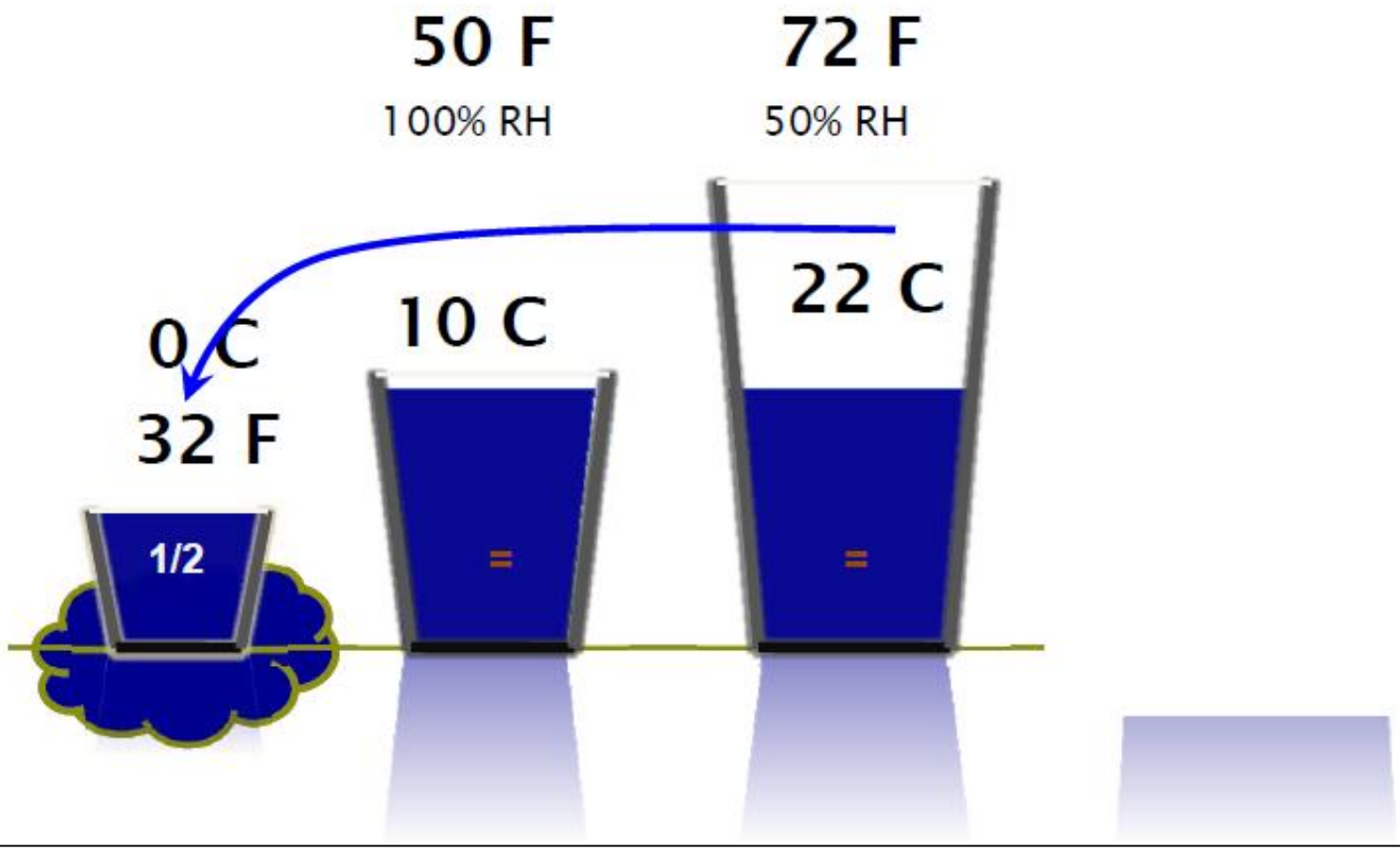
- Add vapor



Cool Air

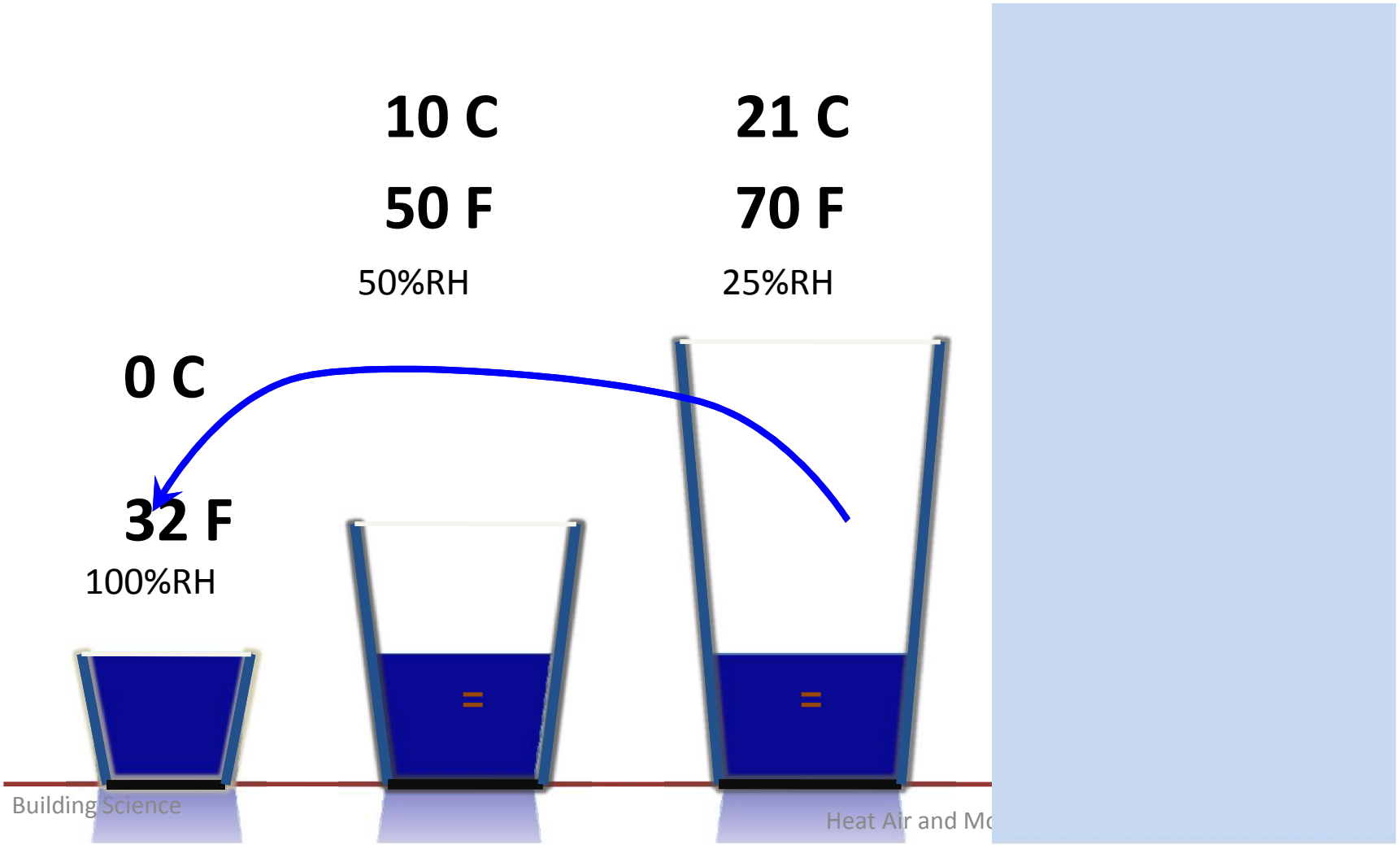


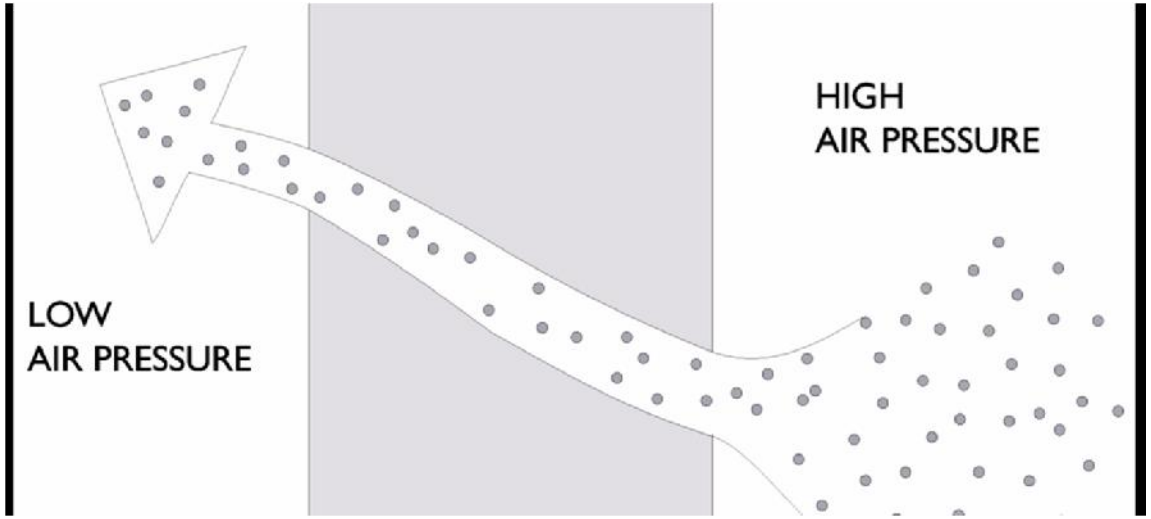
Cold weather condensation



Control Interior RH

Powerful means of controlling condensation in cold climate buildings





Air needs 2 conditions to flow:

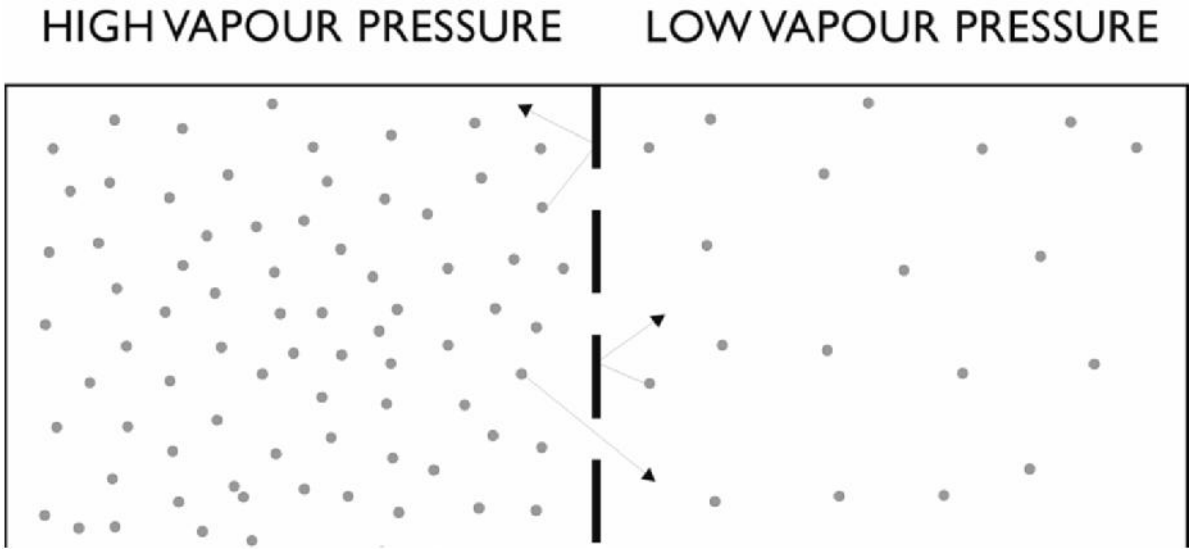
- A pressure difference
- A pathway

Air transport

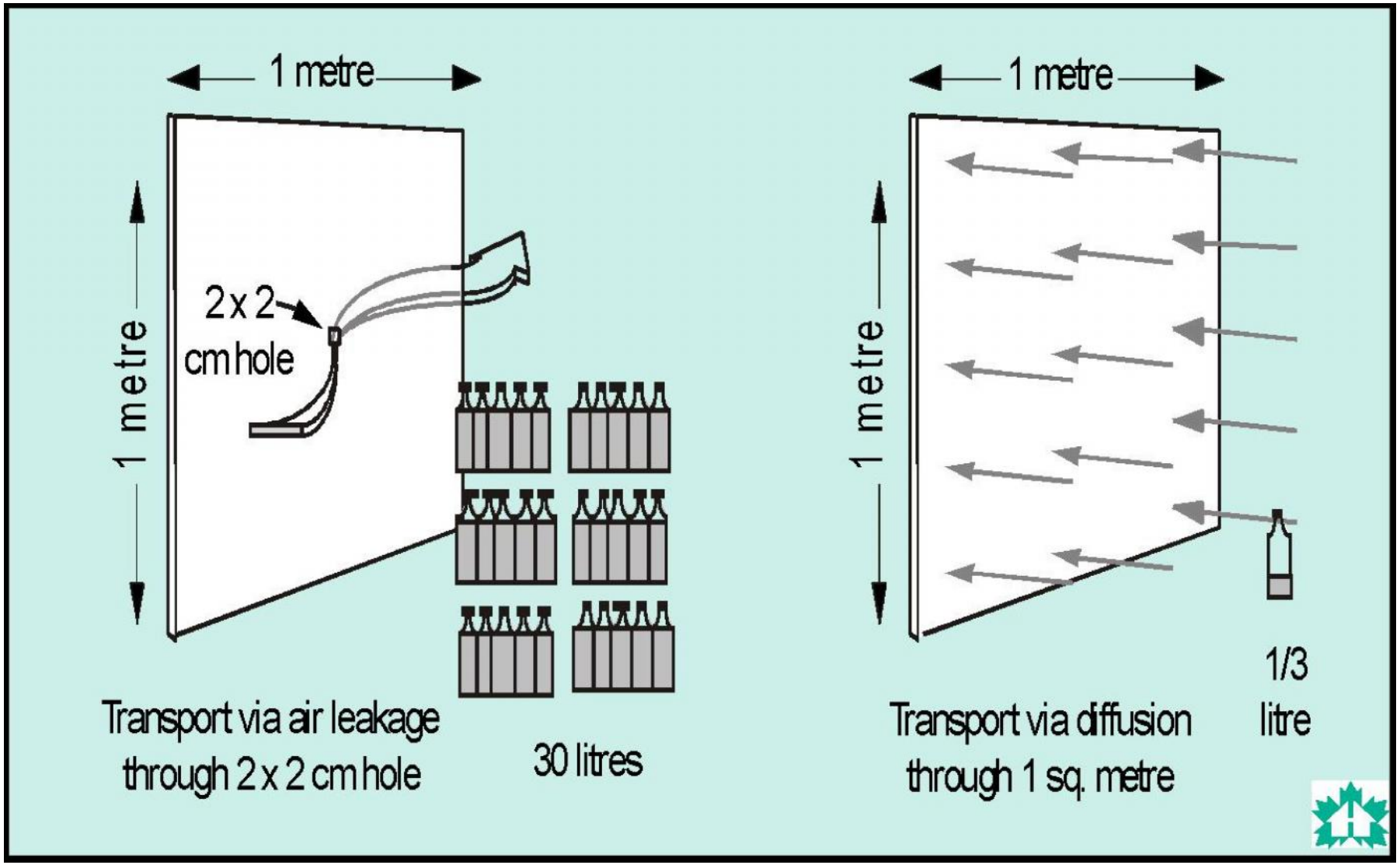
(air barrier)

Diffusion

(vapour barrier –
or vapour retarder)



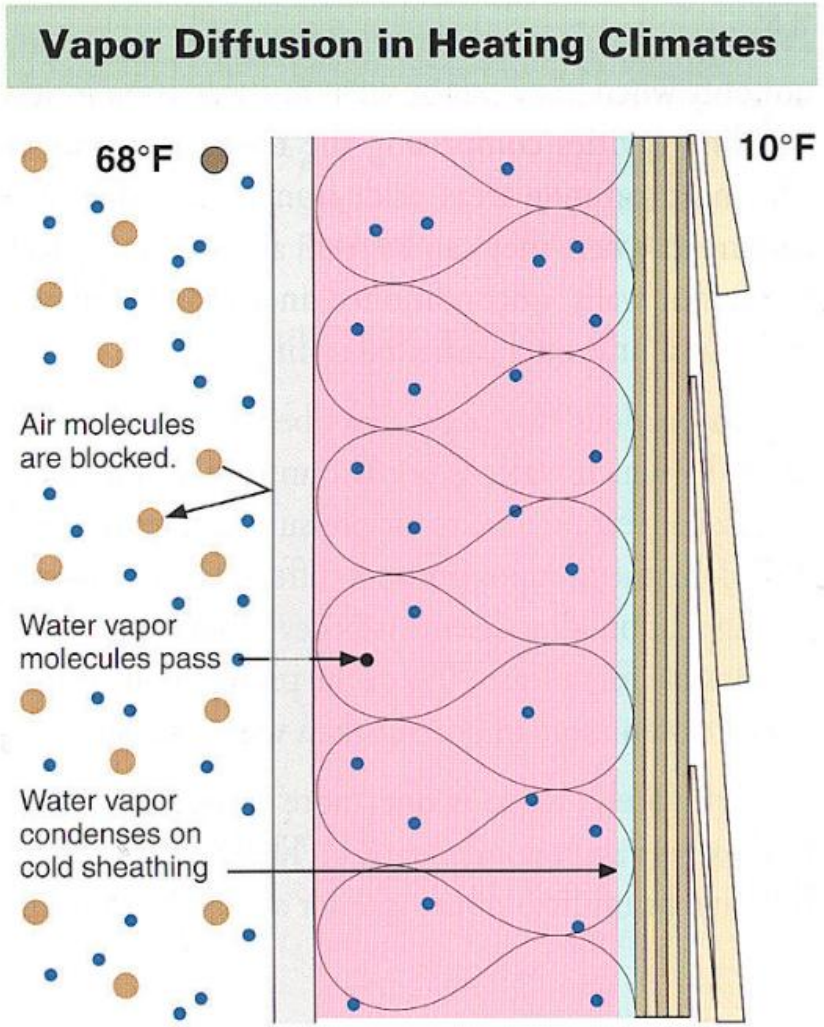
Vapour Transport vs Vapour Diffusion

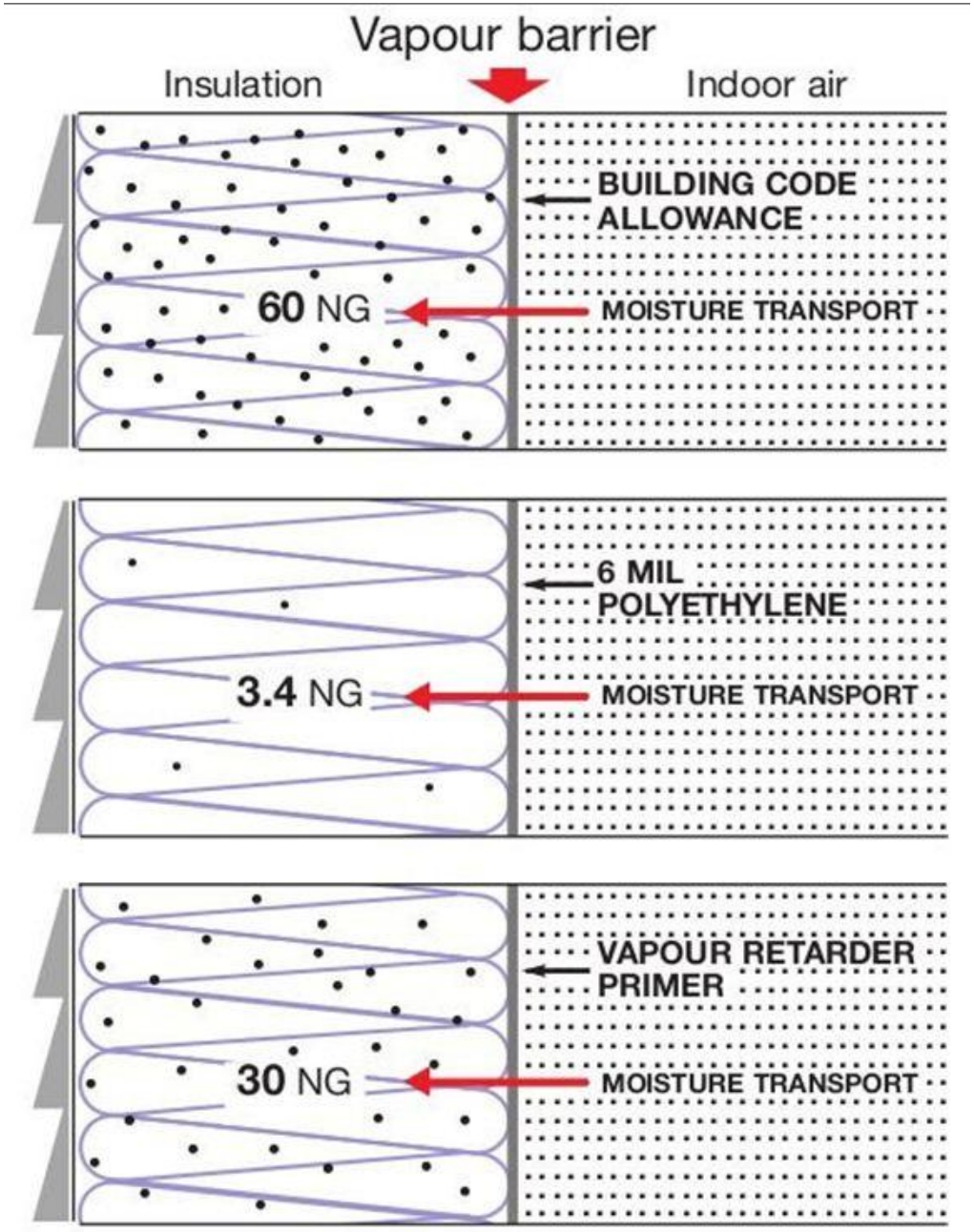


Basic Principles:

Vapour diffusion:

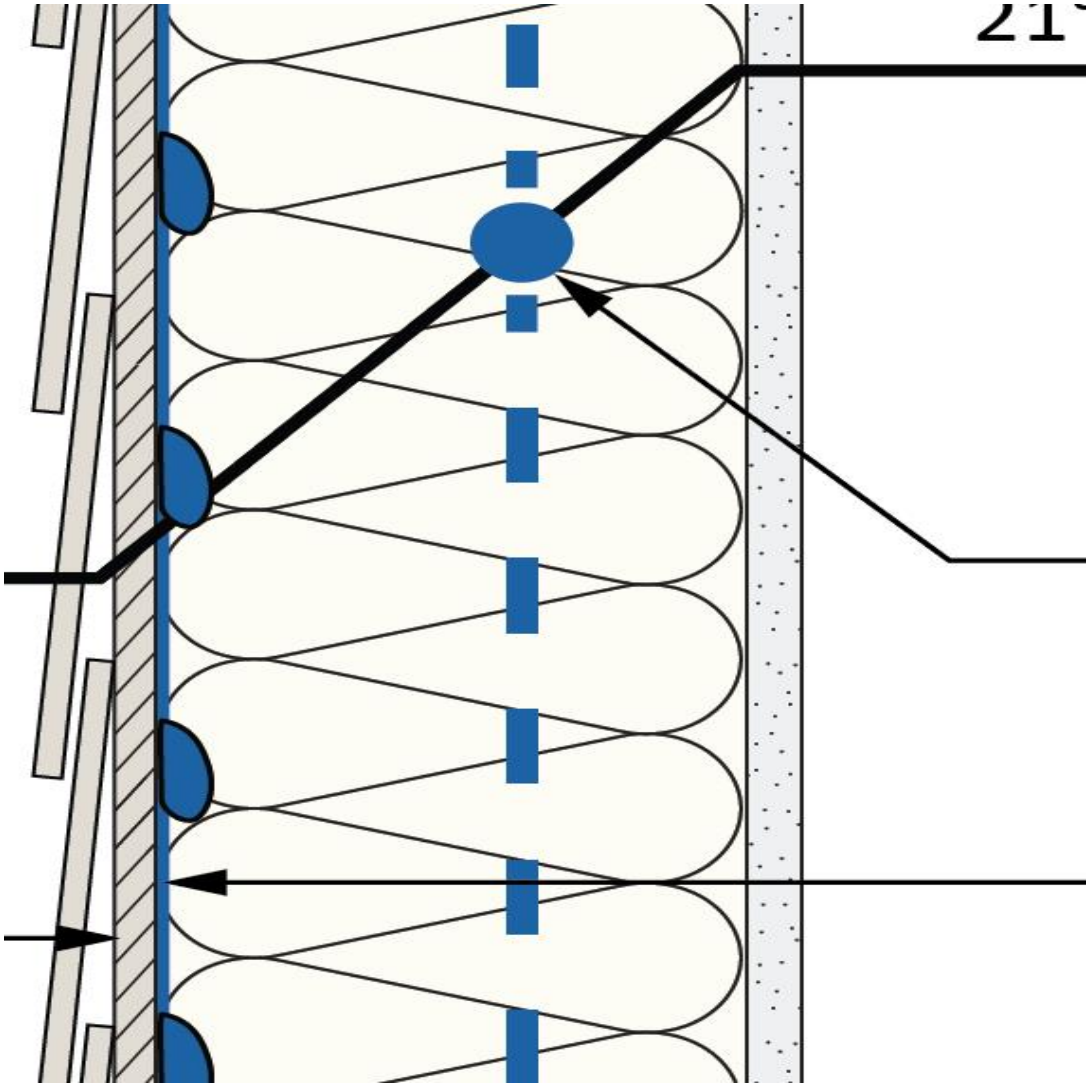
- Water molecules in air want to come to equal concentration everywhere
- regardless of Relative Humidity (RH)



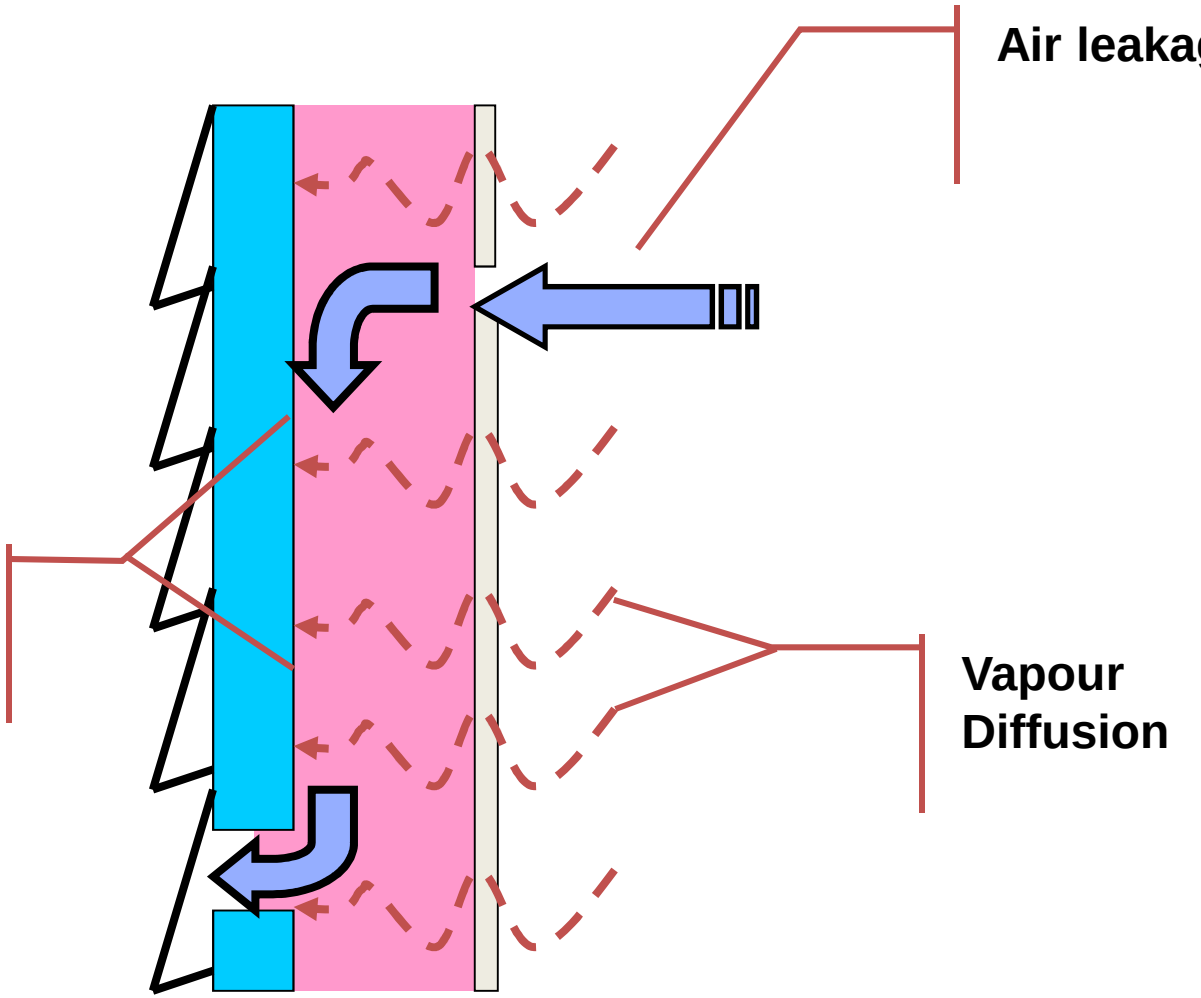


Vapor barrier primer meets building code © Ecohome

Where does condensation occur?
Diffusion or Air Leakage (Convection)



Wall with Insulated Sheathing



How Much Water in a Cubic Meter of Air?

- **One cubic meter** of indoor air at **room temperature** and **30% RH** contains about **one teaspoon** of water (5 ml)
- The **maximum** that cubic meter of air can contain at **room temperature** is about **one tablespoon** of water (15 ml)
- All the air in the house contains between **1.5 and 3 litres** of water at normal winter humidity

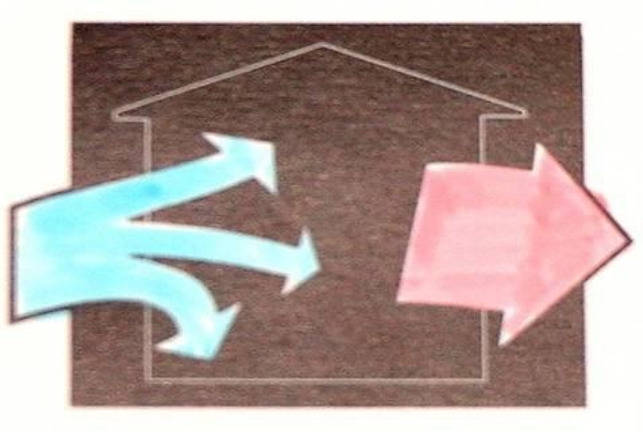
Moisture Sources

Our houses can "generate" as much as 30 litres of water per day.

For example:	Litres per day
4 people	5
Damp basement / crawlspace	3 - 8
Bathing / showers	2 - 10
Firewood, per cord	1 - 3
Washing floors, laundry etc	2 - 5
Cooking	1 - 5
Plants (each)	0.2
TOTAL	15-30

Where does the moisture go?

Ventilation is ...



- A “dilution” strategy
- A “mopping up” strategy
- Fresh, dry air in - stale, contaminated, wet air out
- Runs continuously
- Stale air exhausted from the kitchen and bath
- Fresh air delivered to bedrooms and other main living areas
- It must be quiet, comfortable and affordable, otherwise it will be turned off
- **Target ~ 0.3 ACH or ~ 8 air changes per day**
- **We have always had it, we have always needed it**

Ventilation:

Is this a ventilation system?

HRV – Heat Recovery Ventilator

The most sensible way to ventilate

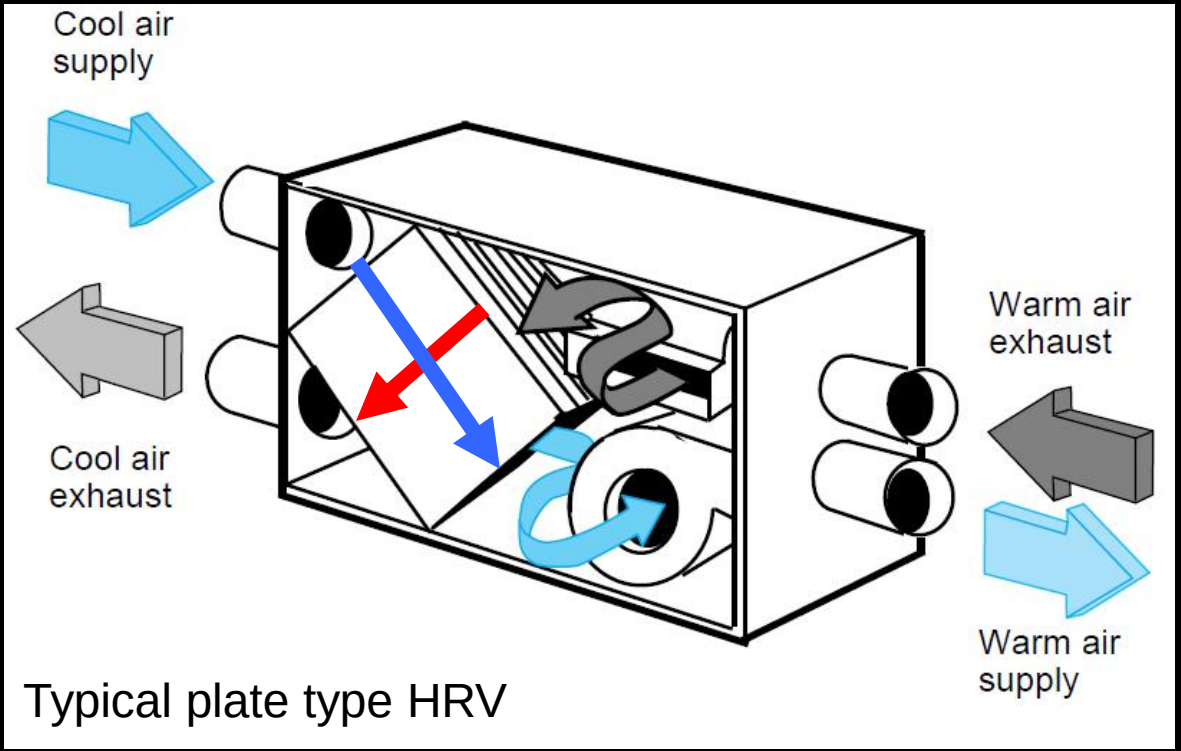
Heat Recovery Ventilators:

Temp = -20 C

RH = 80 %

Temp = -8 C

RH = 100 %



Typical plate type HRV

Temp = 20 C

RH = 30 %

Temp = 8 C

RH = 5%

Efficiency = 70 % Temp Rise = 28 C Final RH = <3 %

(Minimum Efficiency in the City of Whitehorse = 64% @ -25C)

Residential w/ Balanced Ventilation (and Heat Recovery)

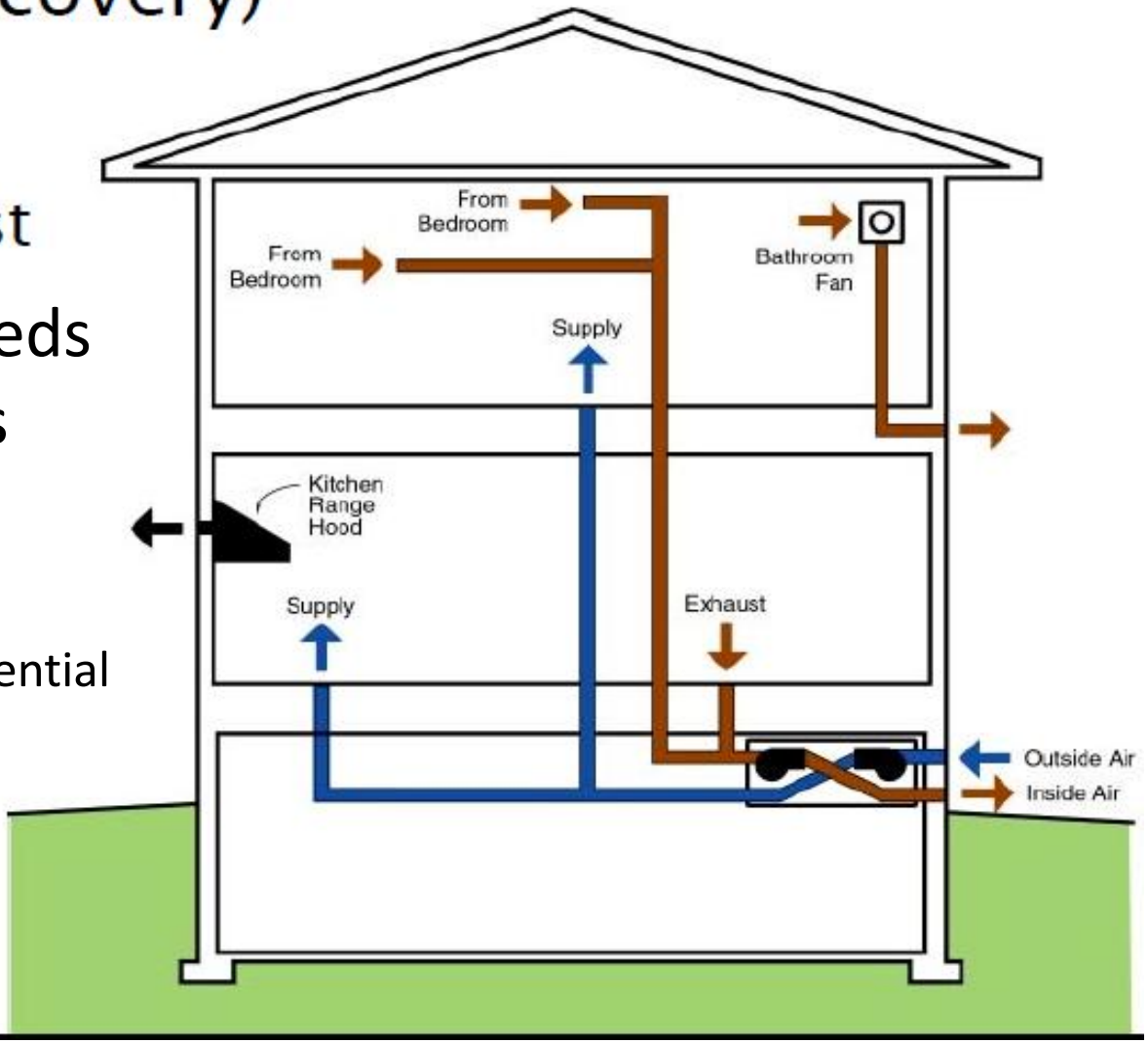
- HRV/ERV
- Point exhaust

•Low and high speeds

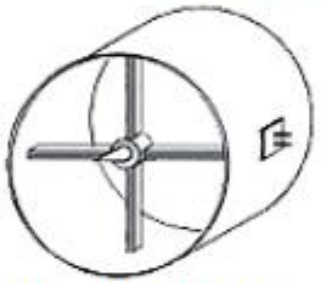
•Down to 20 Watts operating power

HRVs

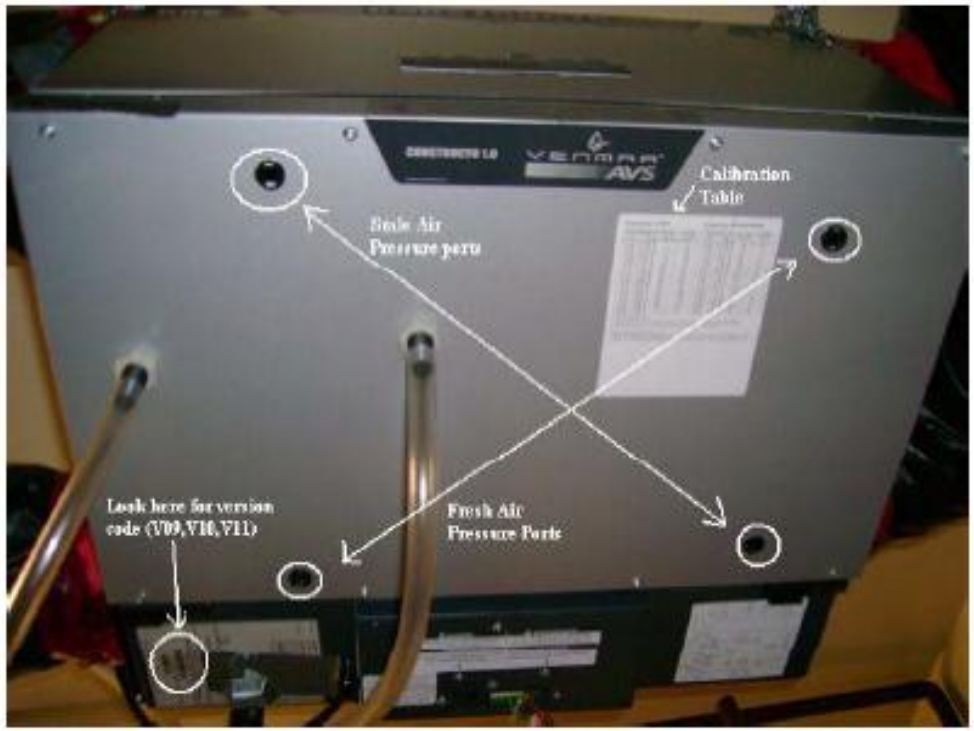
– Individual in Multi-residential



Balancing



- Either built-in or using flow-collars
- Flow collars require smooth straight length of duct



Window moisture:

Outside - handling bulk water:

- Direct water
  - off of,
  - out of,
  - and away from

- Keep the soil dry
- Keep the structure dry

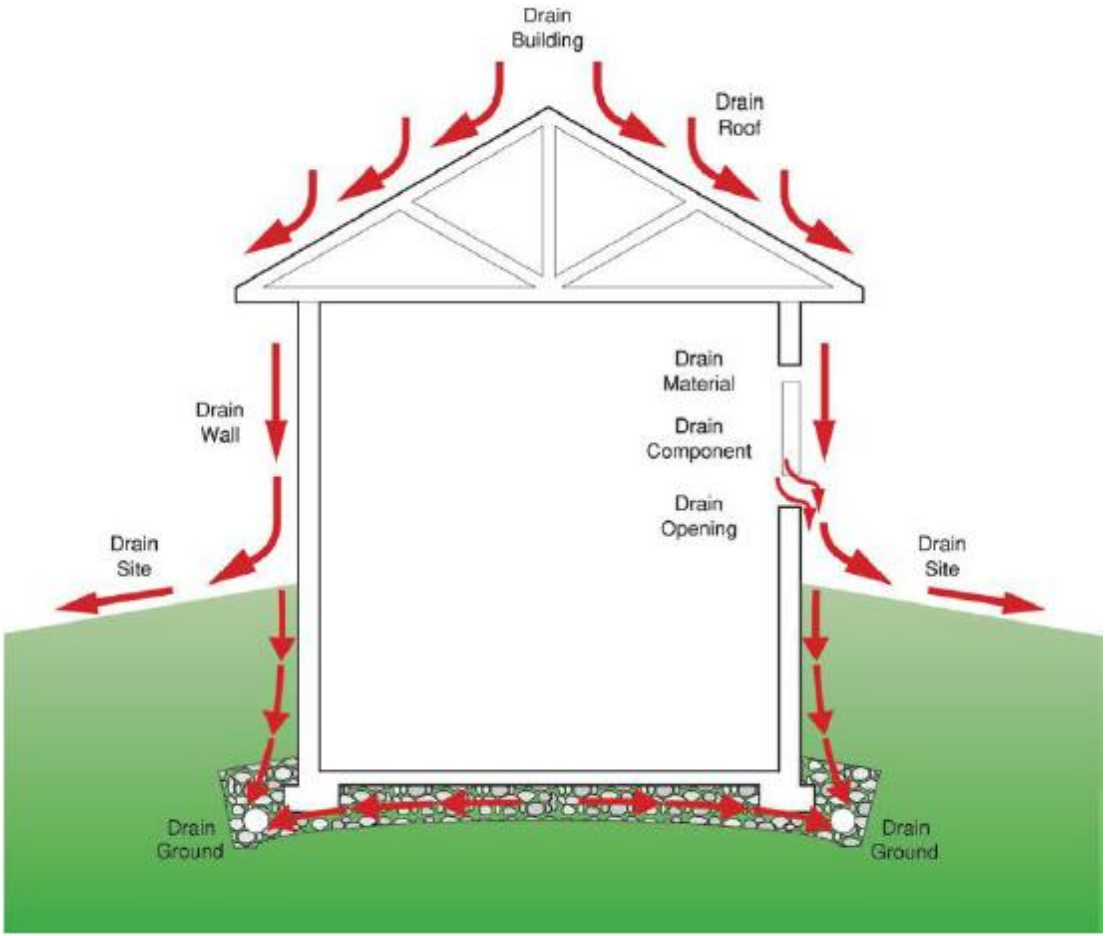


Figure 1. Foundation Bulk Water Control Overall Concepts

http://www.buildingscience.com/documents/bareports/ba-1015-bulk-water-control-methods-for-foundations

Snow and Rain Water:

- From the roof
- Eaves trough
- Down spouts
- Ground sloped away from house

Rain Volume:

- **1 mm of rain on 1 square meter = 1 litre of water**
- **Assume:** 1000 sqft home has a roof = 120 sqm
- **25 mm of rain = 3000 litres of water = 120 5 gal jerry cans or 15 x 45 gallon drums**
- This will result in nearly 10 times more saturated soil – unless site and foundation drainage is provided

Moisture in basements and crawlspaces:

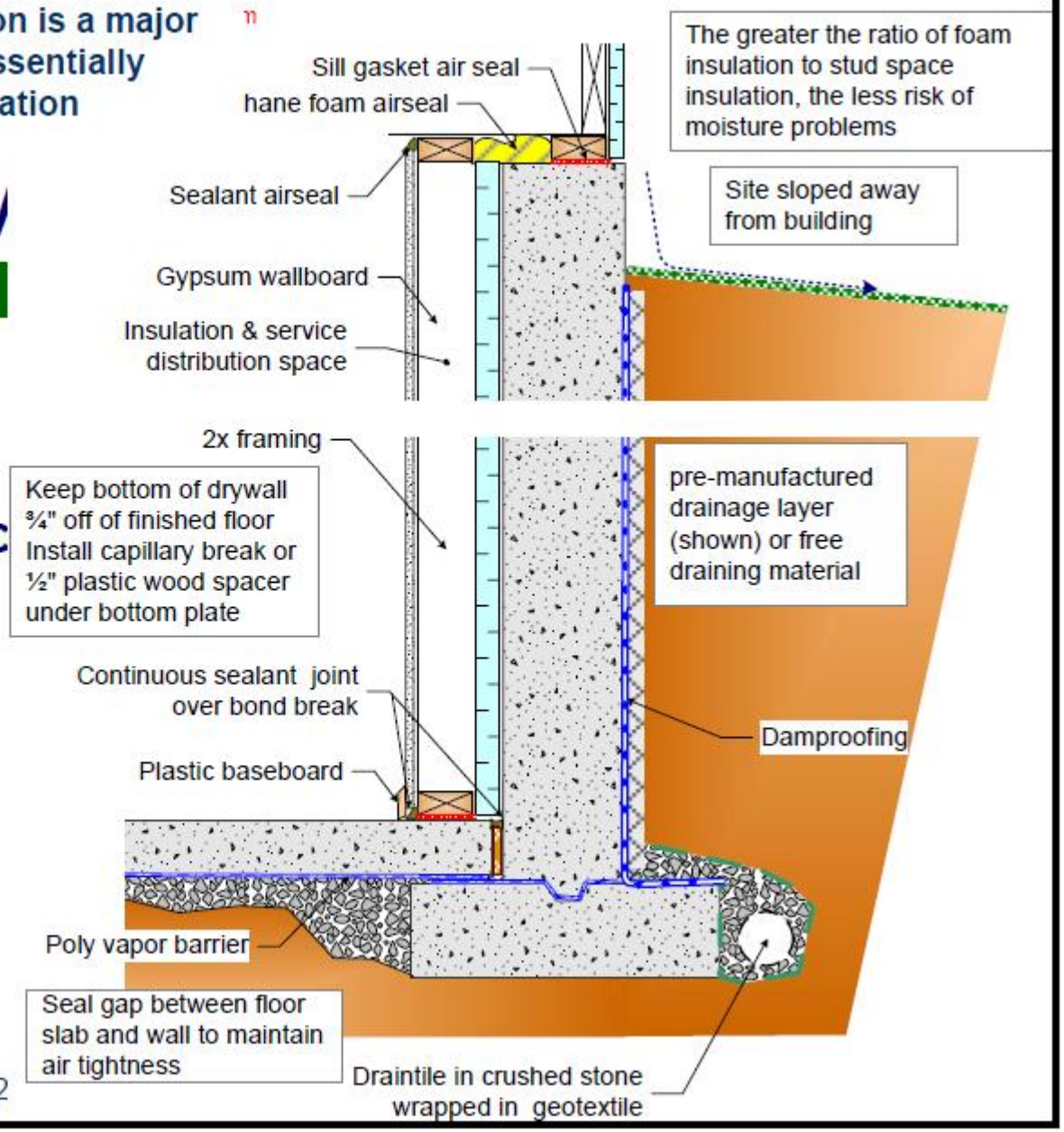
Built to stay Dry
Build to Last - Durability:

Swiss home and barn built in 1700's

Even 1" of sub-slab insulation is a major comfort improvement and essentially eliminates summer condensation

Summary

- Hybrid
- Very good performanc

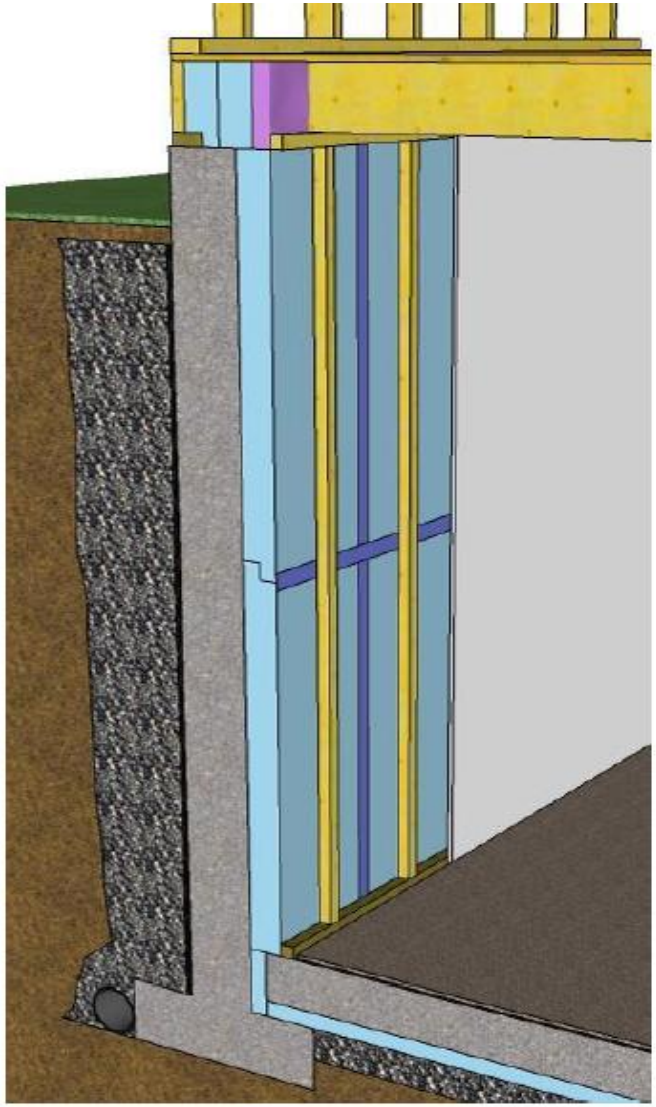


University of Waterloo

2006-08-02

Basement Insulation Problems:

Insulating a basement wall:



Foundation wall damp proofing:

Figure 14. Air gap membrane applied over dampproofing on cast concrete wall

Figure 15. Air gap membrane applied over waterproofing membrane and insulation

Capillary rise through footing:

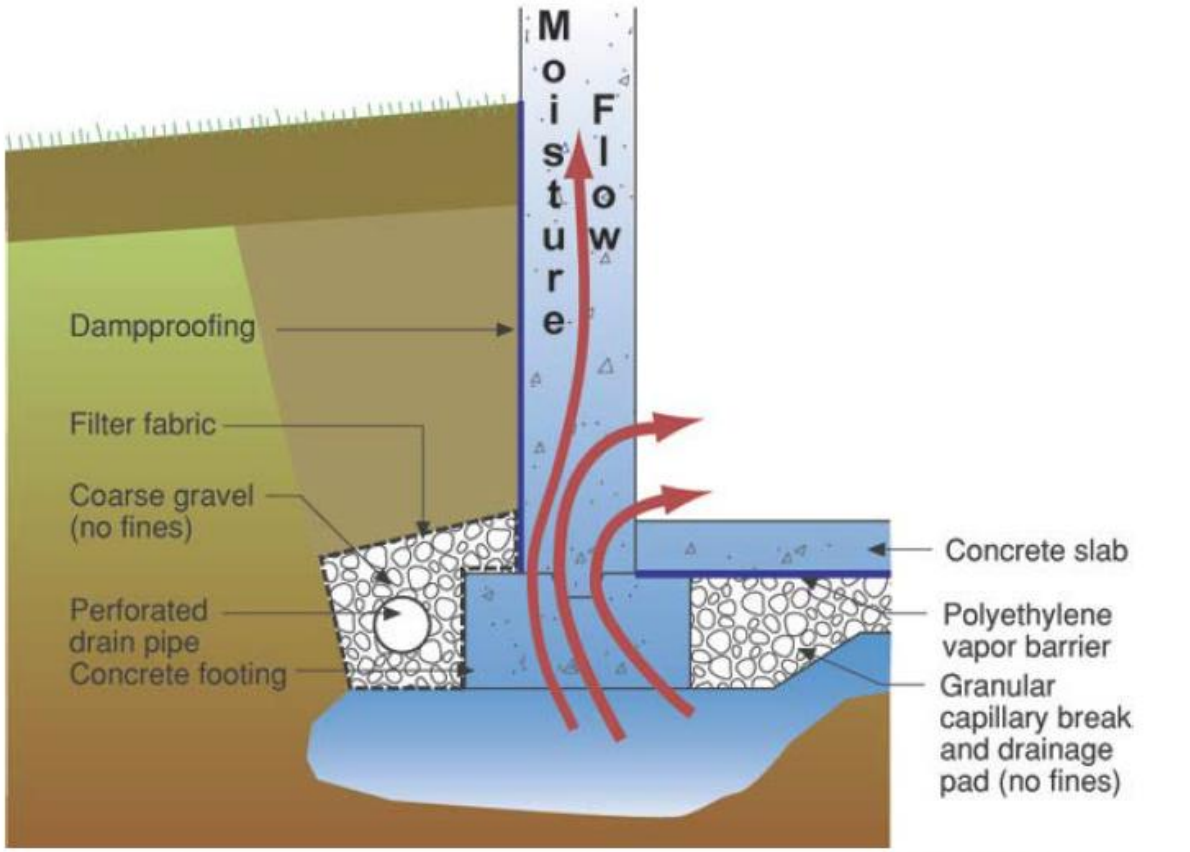


Figure 21. Capillary uptake of water through footing-to-foundation-wall connection

Concrete can wick moisture up several stories sealed in – ICF foundations

http://www.buildingscience.com/documents/bareports/ba-1015-bulk-water-control-methods-for-foundations

Capillary Breaks:

Figure 22. Capillary break using liquid-applied dampproofing on top of footing

Figure 23. Capillary break using proprietary roll-applied material during casting of footing

http://www.buildingscience.com/documents/bareports/ba-1015-bulk-water-control-methods-for-foundations

Water Leaks:

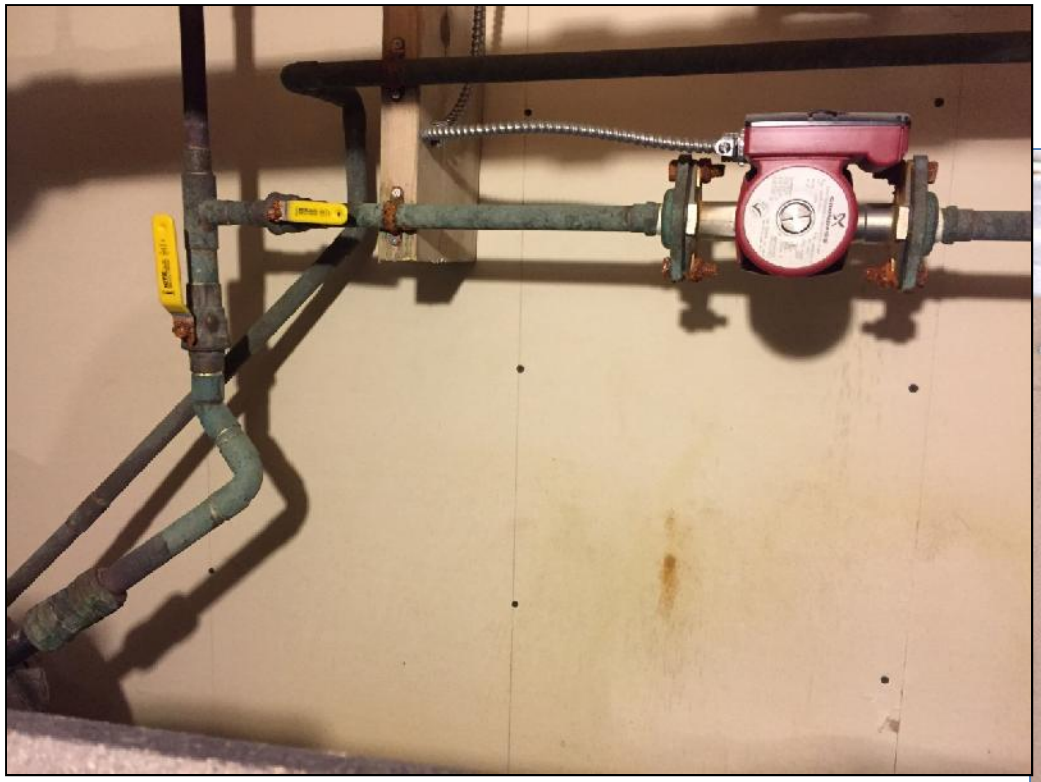
- Can be extremely expensive
- If not fixed will cause mould, and eventually rot

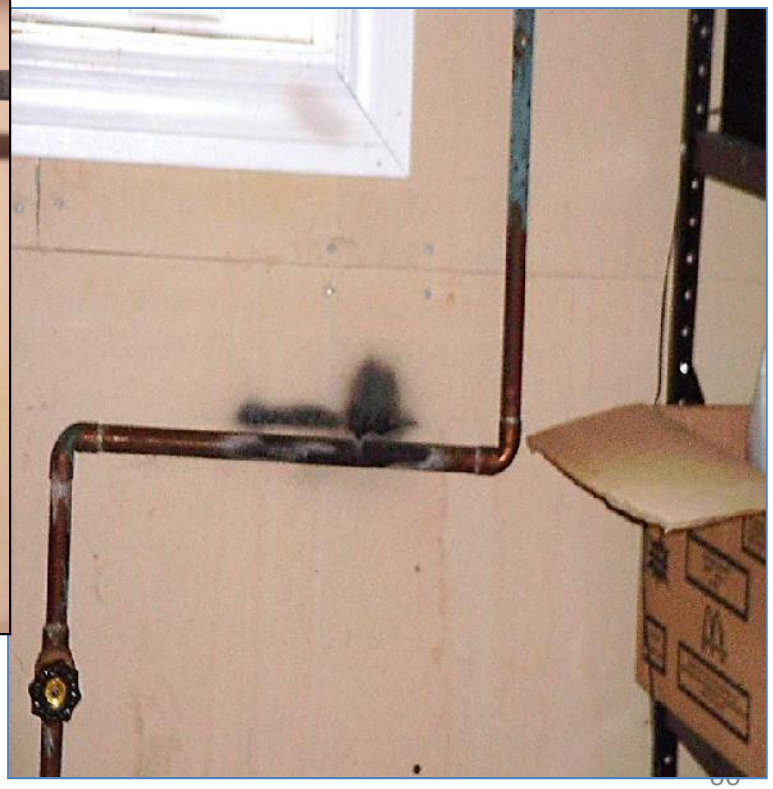
Water Leaks:

- Fix plumbing right away
- Caulk the inside bottom of cabinets

Condensation on a cold water line:

Cold water plumbing and water tanks should be insulated

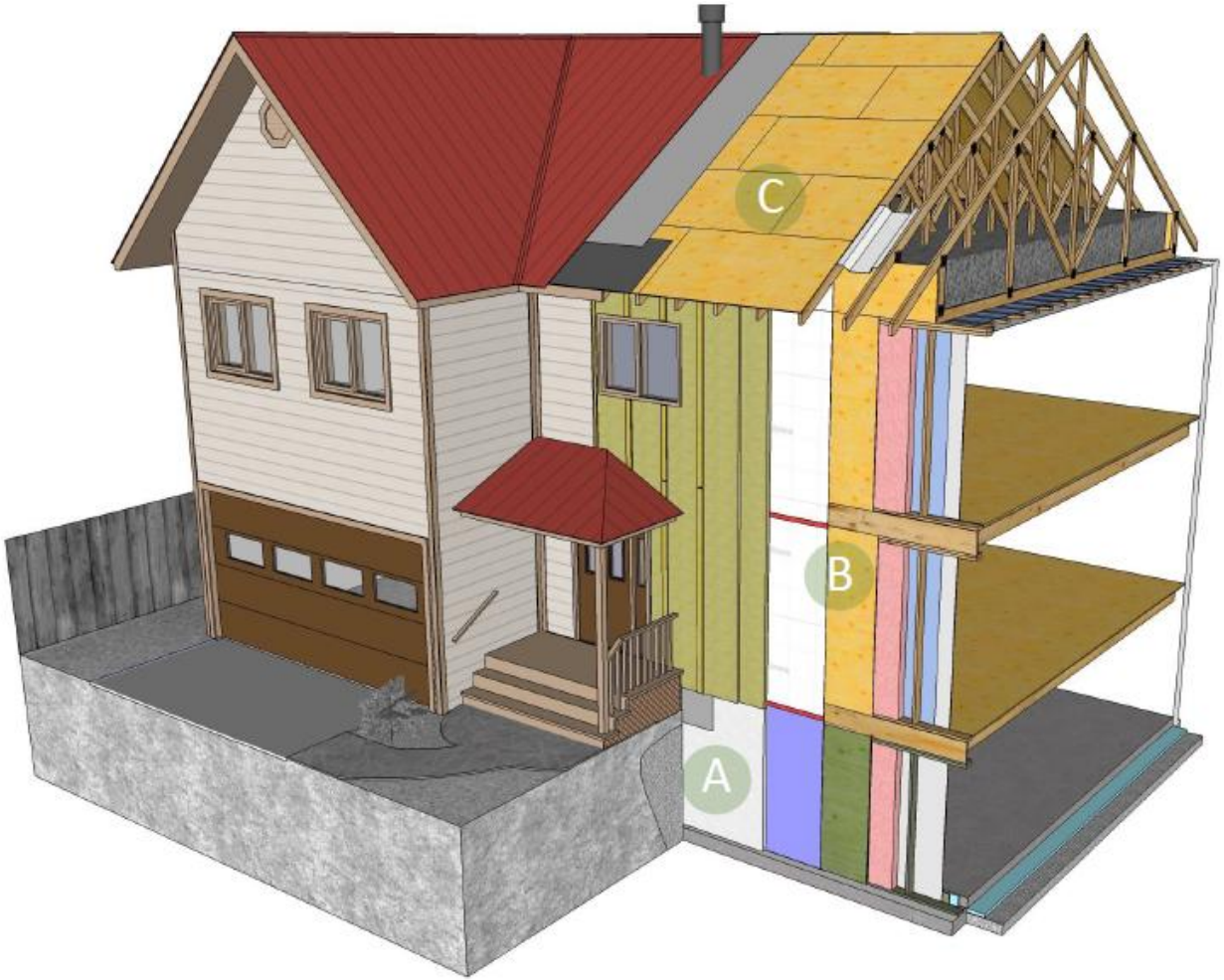




Drain pans to contain leaks:

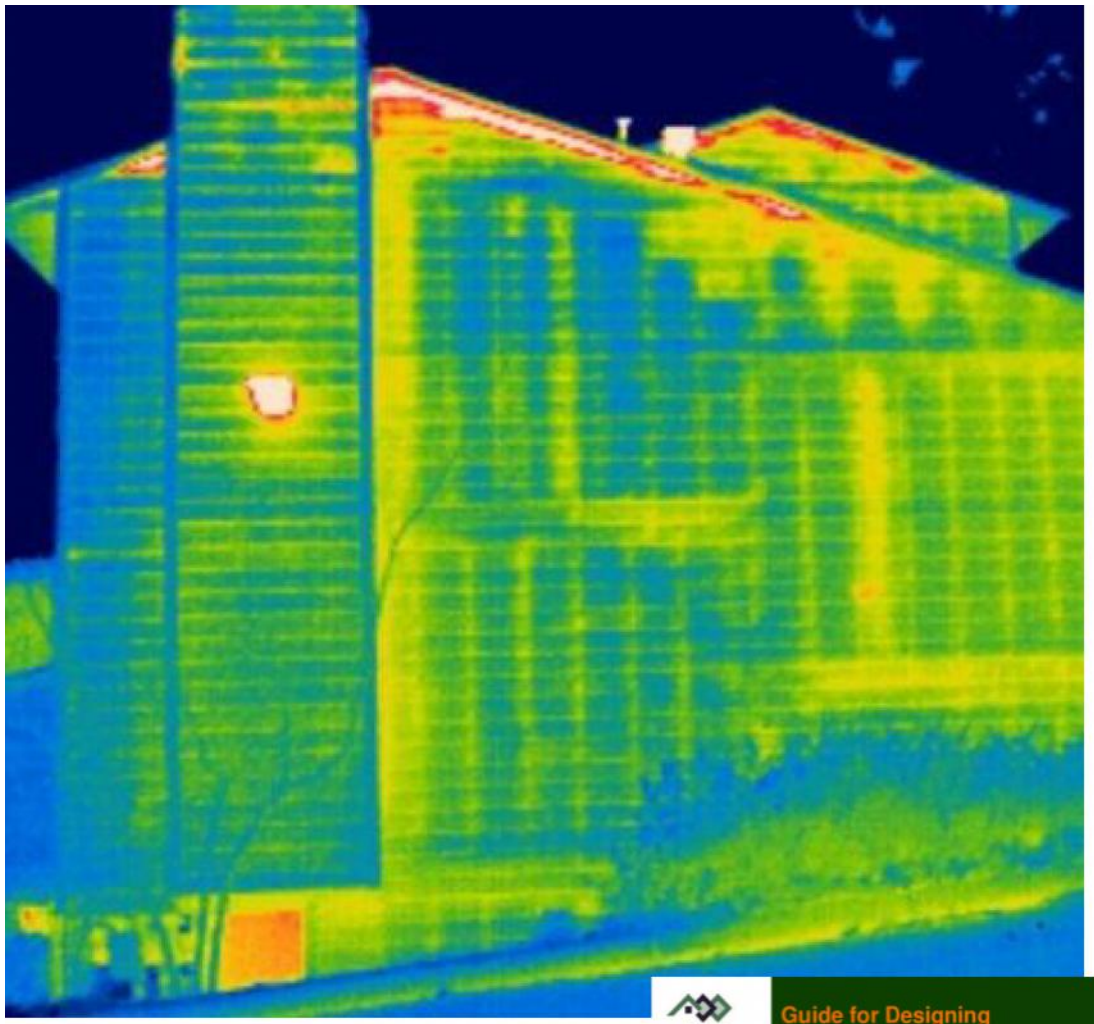
Water detection systems:

Building Enclosure Assemblies:



Construction of the Past:

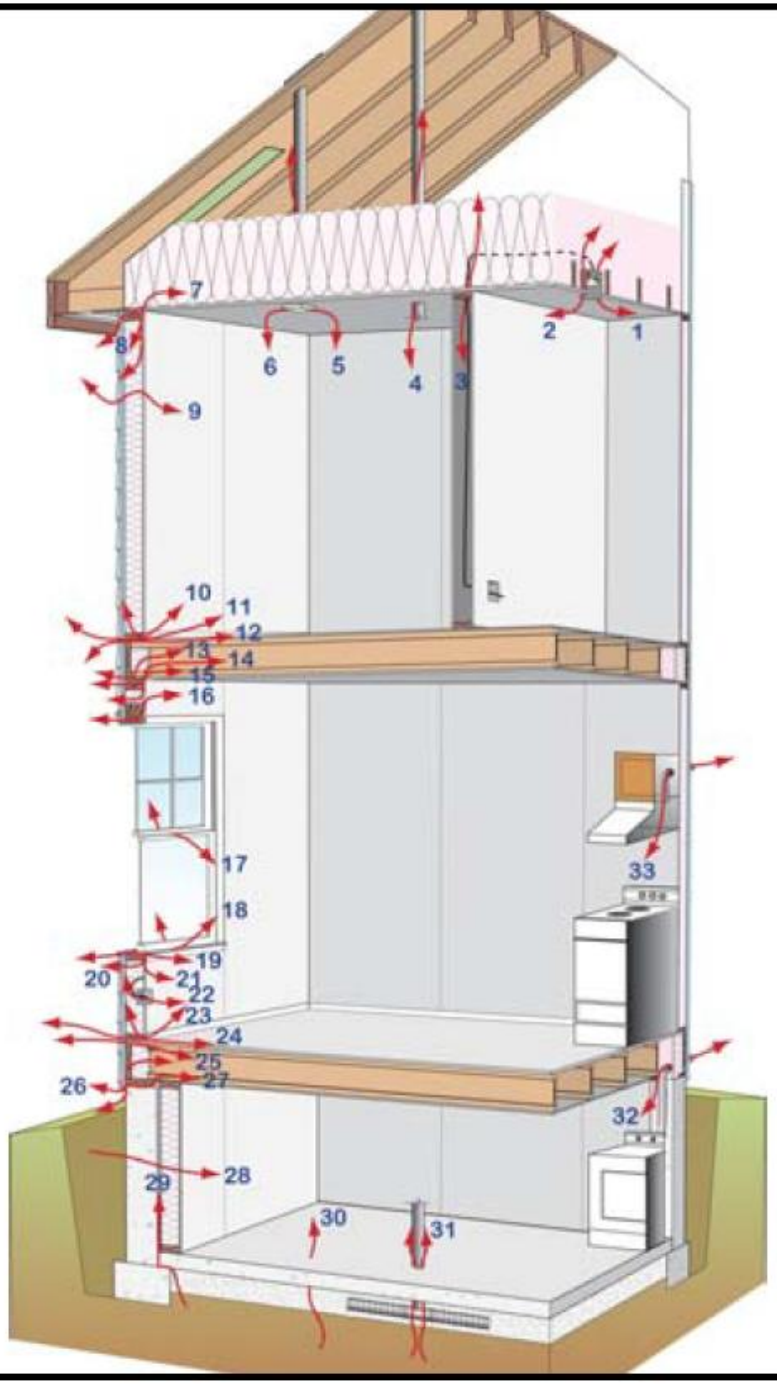
- Thermal bridging
- Air leakage



Guide for Designing
Energy-Efficient Building Enclosures
for Wood-Frame Multi-Unit Residential Buildings
in Marine to Cold Climate Zones in North America

Air Barrier Challenges

- Most air leakage paths are not in the middle of the wall, but at penetrations, details and intersections



Moisture due to air leakage; poor siding drainage / ventilation

Frost in attics:

Not because of a leaking roof!
Or inadequate attic ventilation

A leaking roof?

Air leaks at floor / wall junctions:

Moisture in rim joist area:

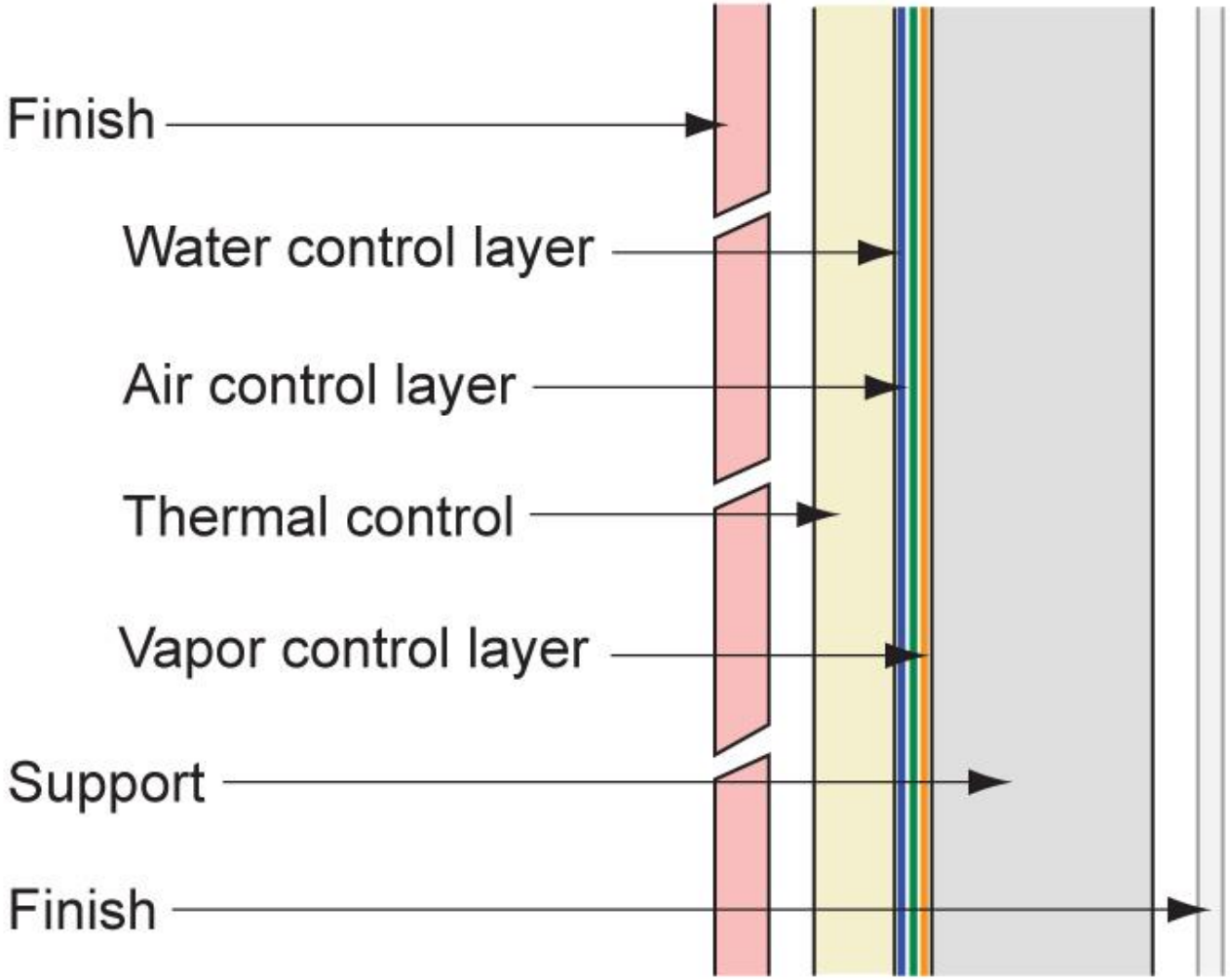
Vapour barrier and/or air barrier detail

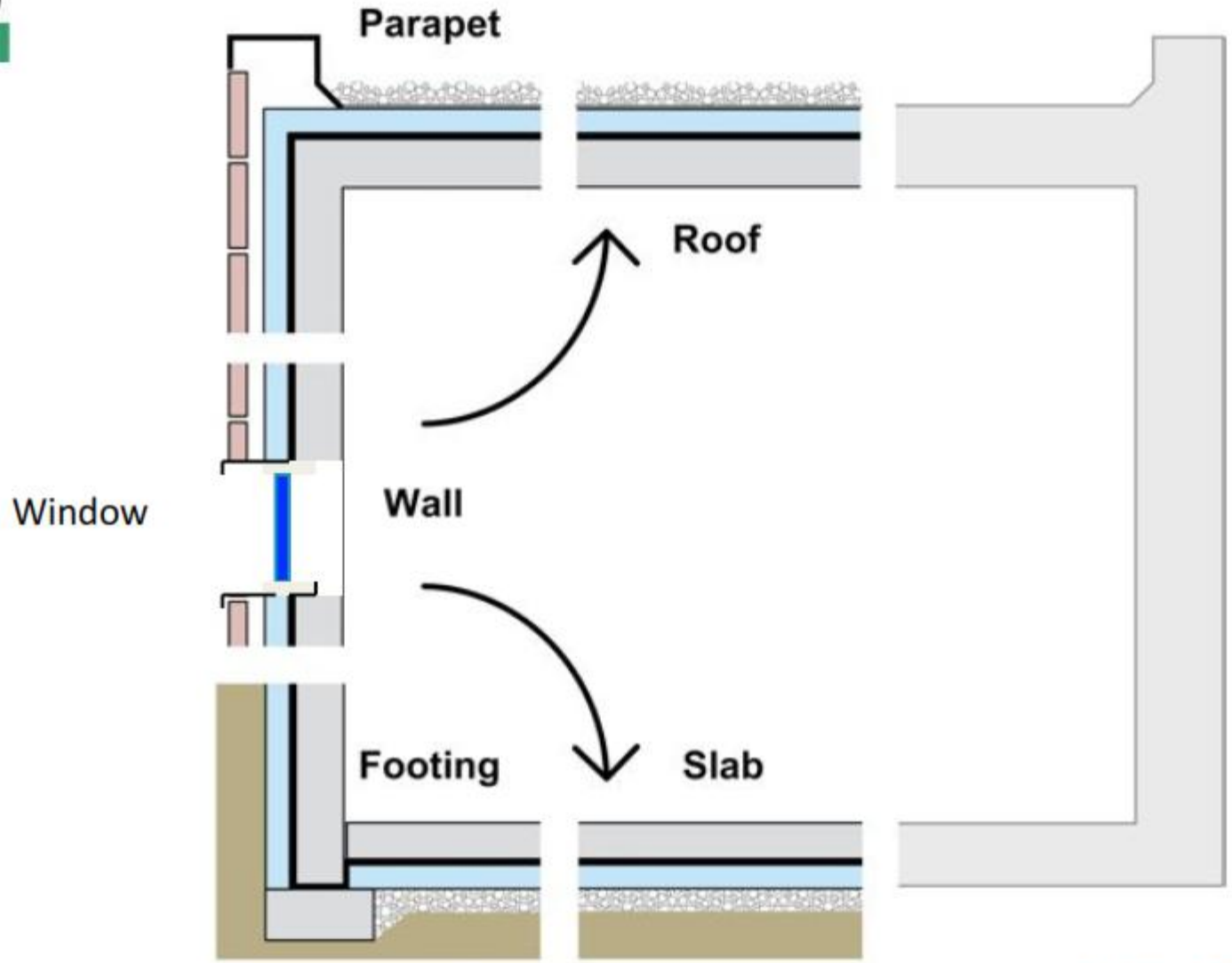
Air Leakage:

- Critical issue for durability and energy efficiency
- Need to define and build an air barrier
- Need to test
  - ACH@50 < 1.5
  - ACH@50 < 0.5 possible
  - 0.07 ACH@50 achieved in P.G.

Wood Innovation Research Lab

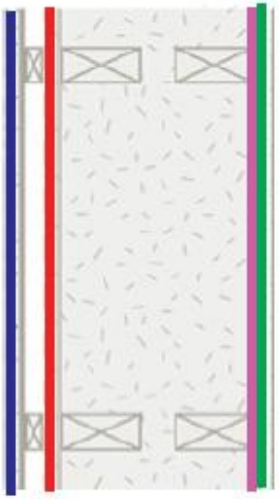
The Perfect Wall Concept




Parapet
Roof
Window
Wall
Footing
Slab

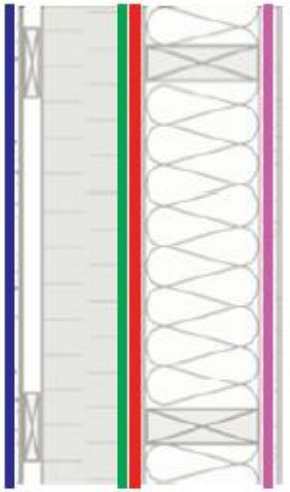
Building Enclosure Assembly Critical Barriers

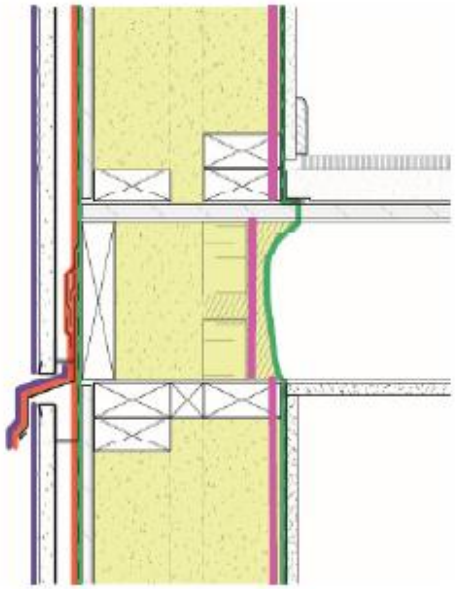
RDH

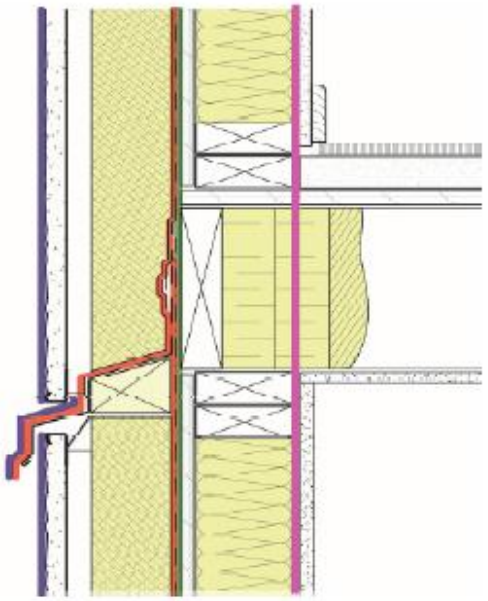


Water Shedding Surface **(WSS)**
Water Resistive Barrier **(WRB)**
Air Barrier **(AB)**
Vapour Retarder **(VR/VB)**

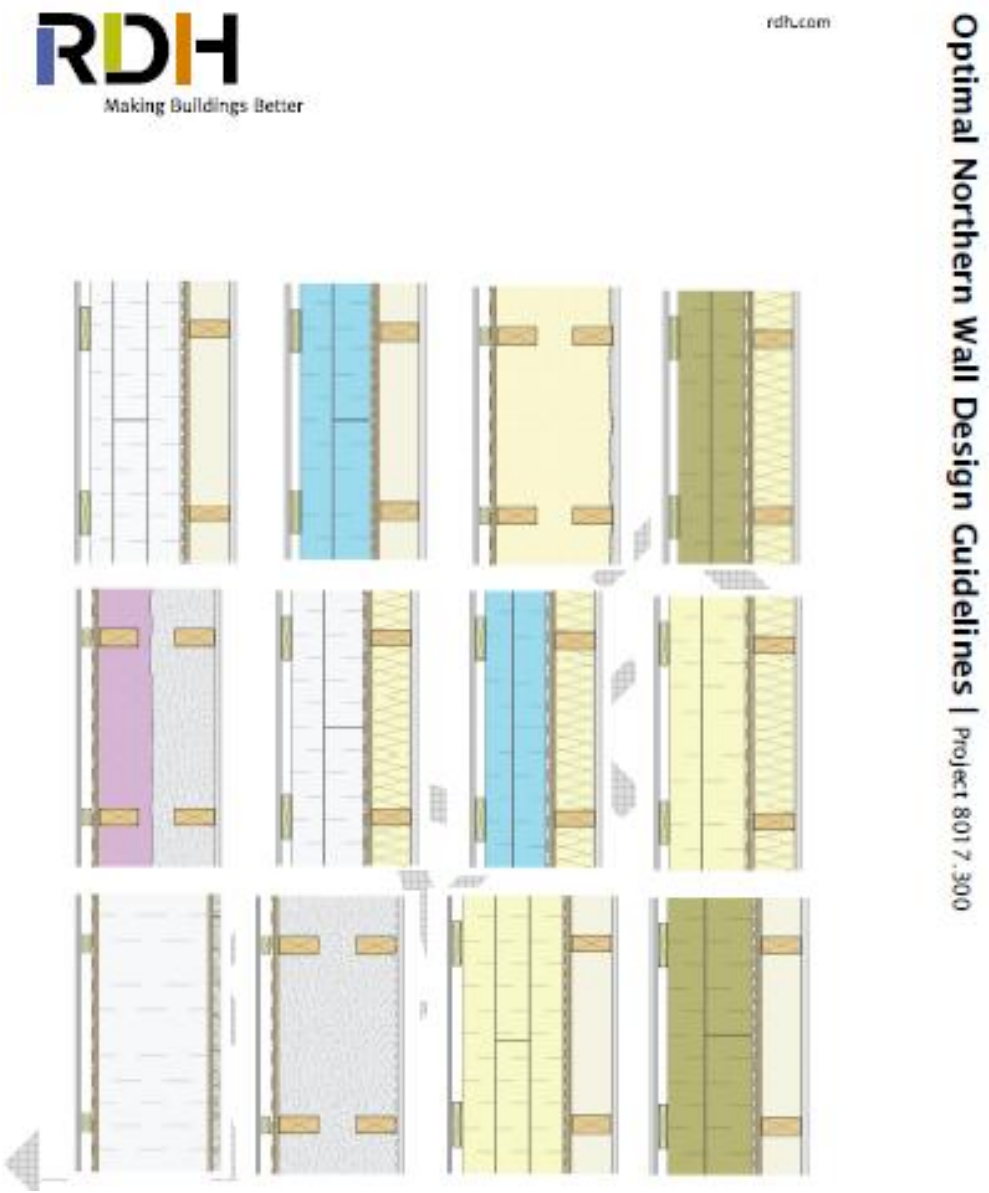
Thermal Barrier **(Insulating Materials)**







Many ways to build high performance walls



Energy Efficient Housing Guidelines for
Whitehorse, YT:

Cost Optimized House

Construction Detail Sequencing

RDH

Detail 1 Foundation Wall at Footing

Detail 2 Foundation Wall to Above Grade Wall

Detail 3 Rim Joist

Detail 4 Above Grade Wall to Sloped Roof

Detail 5 Exposed Floor

Detail 6 Window (Jamb, Head, Sill)

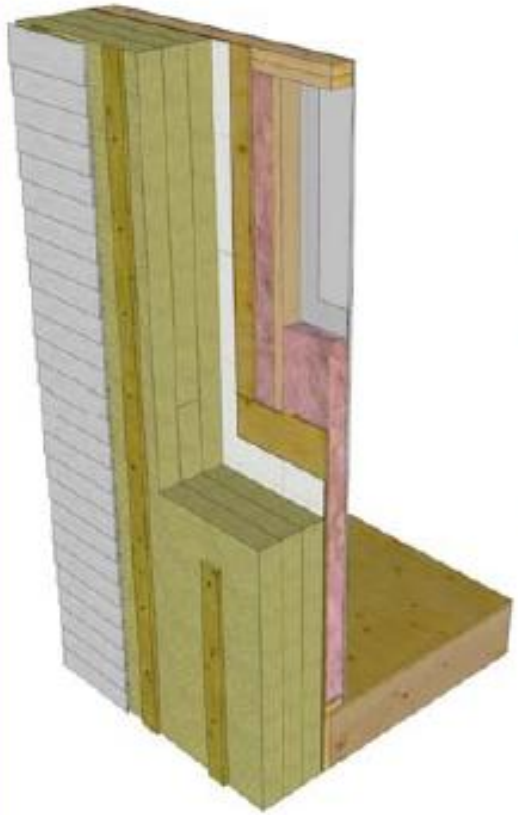
Detail 7 Chimney Flue

RDH

Cost Optimization Winner:

Split Insulated

RDH



- Water Control:
  - Drained/ventilated rainscreen cladding with synthetic housewrap WRB & surface of exterior insulation
- Vapour Diffusion Control:
  - Poly/VB paint or plywood sheathing
- Air Control:
  - Taped & sealed plywood or sealed sheathing membrane
- Cost/Constructability*:
  - Rigid insulation is expensive (high shipping and labour handling costs), though less than all exterior insulated
  - Thicker insulation results in unique wall penetration details & cladding attachments

(Some builders prefer others)

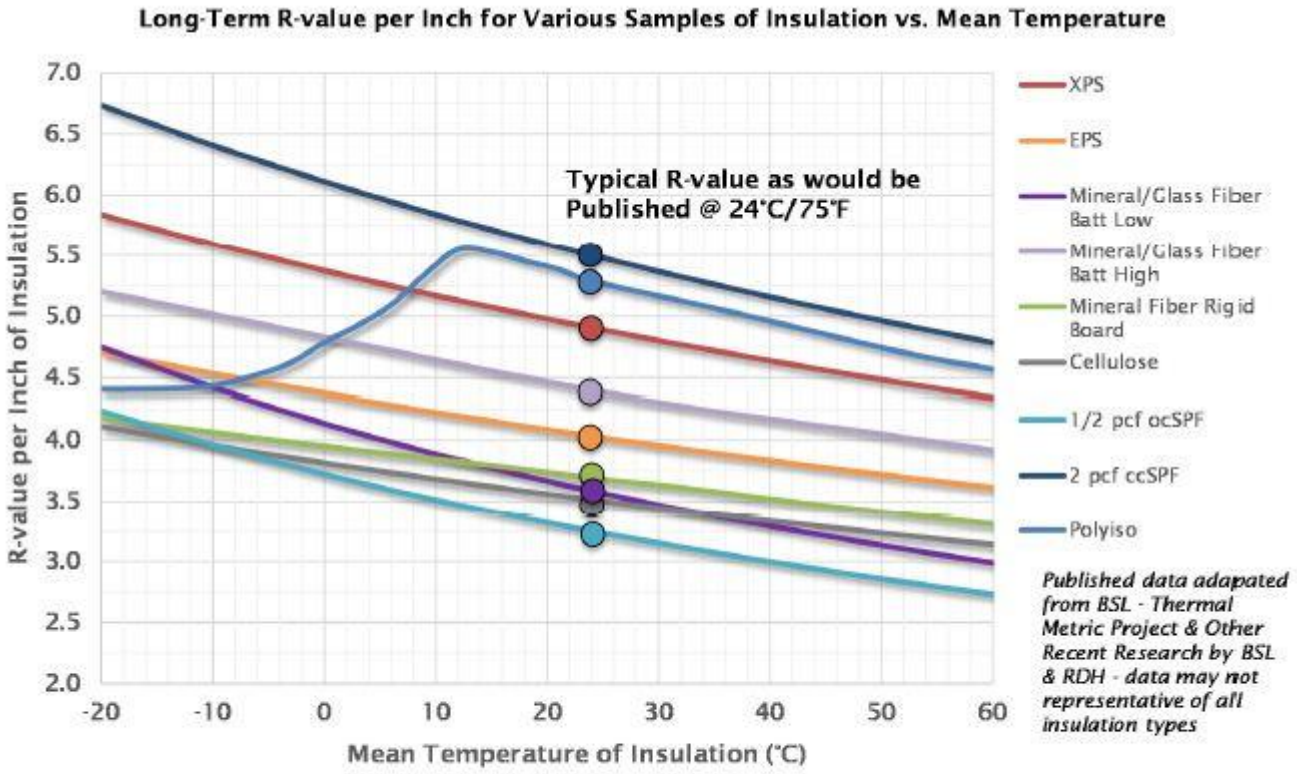


Figure B-1 – Temperature Dependant R-values for Common Insulation Materials

Split Insulated Wall:

- Riverdale Affordable Housing 8 Plex and Watson Lake 12 Plex
- 2x6 batt insulated
- 6” EPS foam
- Nominal R50 wall

Exterior Retrofit of Log Home:

Photo: Bill Greer

Exterior Retrofit of Log Home:

Photo: Bill Greer

One Exterior Retrofit Solution:

Details are Important!

- Provide clear drawings and detailed specifications
- Builders and installers are not designers

DRAWING 2 - LEGEND

A - 3/4" Cellular PVC trim board

B - 3/4" X 3 " plywood nailer

C - 1-1/2" X depth to suit H

D - Horizontal fiber cement siding

E - 5/8" X 3-1/2" fiber cement trim plank

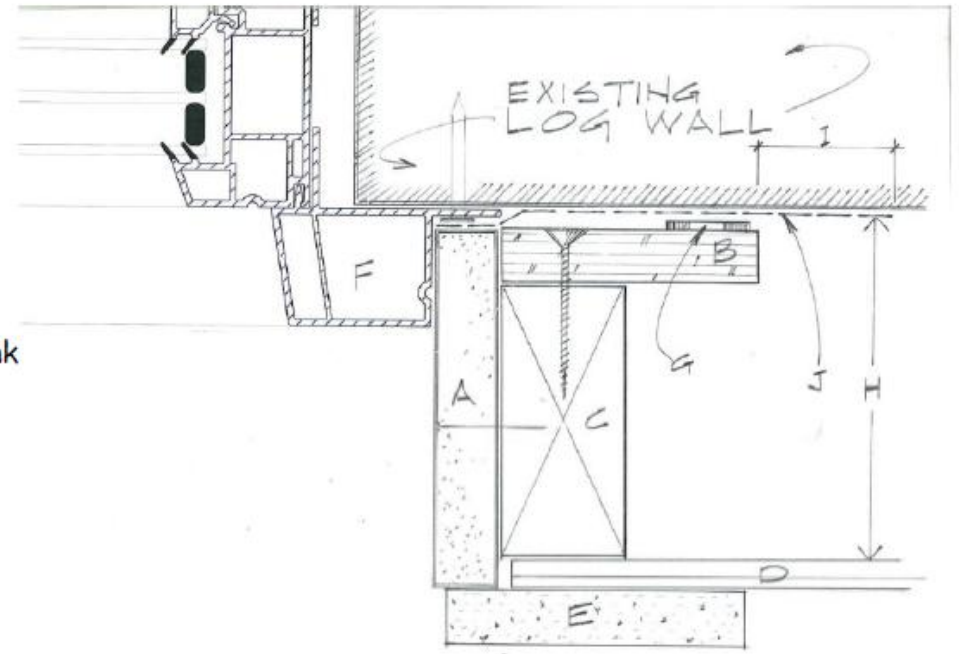
F - Existing PVC window brick mould

G - 1/8" Vinyl spacer stapled to B

H - Depth to match adjacent vertical insulation furring members

I - Minimum 3" SAM Exposure to spray foam

J - Self Adhered Membrane (SAM)



SECTION THROUGH VERTICAL WINDOW OPENING

DRAWING 2

Exterior Retrofit Optimization and Construction Guide is coming

Windows

Weakest part of the building enclosure


WARNING

Basic Strategies for Windows:

- Reduce household humidity
  - Reduce moisture sources
  - Increase ventilation
- Warm the window surface
  - Better glazing – triple, low-E argon or better
  - Insulated spacers
  - Better frames
  - Improve air flow across window – window coverings?
- Complete air and water sealing around window – great attention to details
- High performance windows may not indicate high RH – hence other IAQ issues

Window Temperatures:

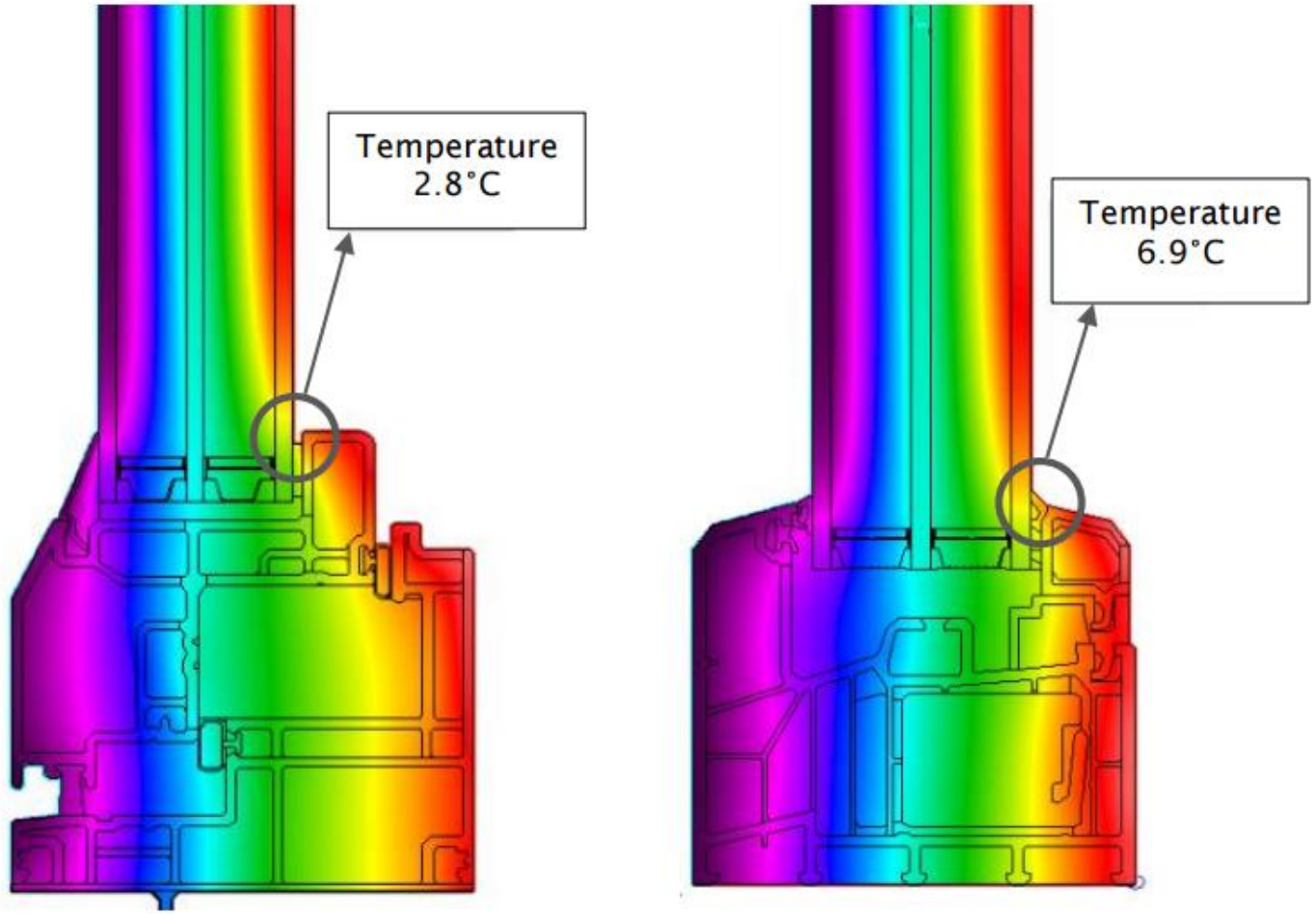


Figure 5.1 Interior window surface temperatures during -34 °C exterior conditions for a triple glazed finyl frame window (left) and a triple glazed vinyl Passive House frame window (right).

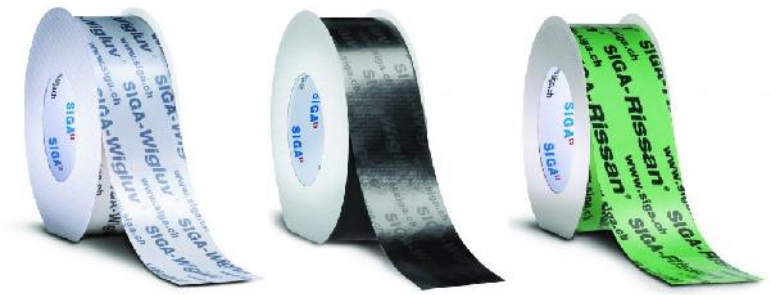
Backdams / Slopes are Important

Sill flashing

- Pre-formed
- Flexible tapes (Siga, Pro clima…)
- Liquid applied membranes
- Drain to exterior

Advanced tapes and membranes

Make air sealing easier and more durable



Keep it Simple!!

Super insulation can reduce this:

Keep it simple!

Because moving parts fail
and plumbing will leak

Electric Heat:

Perhaps even in diesel communities

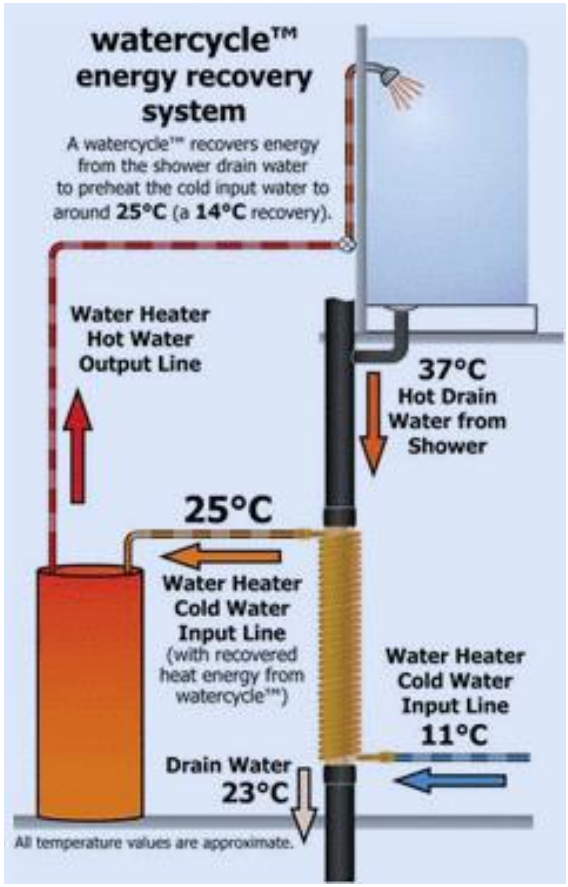
Air Source Heat Pumps:
Mini-split or ducted

- Heating and cooling
- Electric ~ 200% efficient
- No combustion risk
- Reliable but need cleaning

Cold Climate Air Source Heat Pumps:

- Produce heat in Whitehorse with 50% less energy than electric baseboards
- Operate to -30 C

Drain Water Heat Recovery:



Improving Indoor Air Quality:

IAQ can have serious health implications

- **WHO report: 7.7% of global mortality in 2012 – 4.3 million deaths**
  - Chemical – CO, CO_2, VOCs – smoking, cleaners, building materials, fuels
  - Biological – Molds, dust mites, pets, plants
  - Particulate – Smoke, dust, ultra-fine particulates

Improving Indoor Air Quality:

If you had a skunk in the house:

- Would you spray air freshener?
- Open a window?
- Or get rid of the skunk?

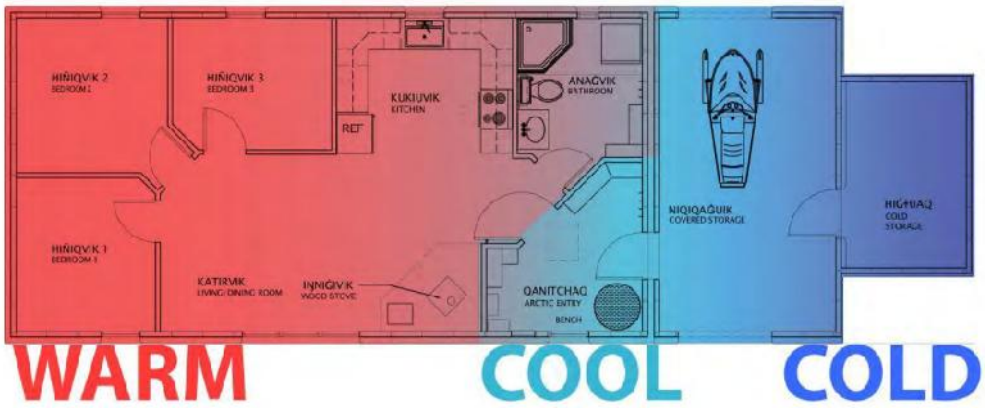
Main Strategies to improve IAQ:

- Eliminate sources - keep the skunks out!
- Seal / Separate – attached garages
- Ventilate / Filter

Beyond the Technical Issues:
Houses are for people!

- Integrated design including all stakeholders
- Consider owners / occupants needs / disabilities
- Cultural / social / lifestyle
- Community engagement and buy-in needed

- Builds a sense of pride, ownership, and responsibility



Community engagement in design and construction using Integrated Design approach

- Culturally appropriate housing forms
  - CMHC examples

Changing Building Codes and Housing Technology:

Government of Canada Invests in Healthier, Energy-efficient Homes and Buildings for Canadians

Energy Efficient Buildings Research, Development and Demonstration

A **call for Expressions of Interest (EOI)** under the Energy-Efficient Buildings RD&D Program is **now open for** Canadian industry, Indigenous groups, utilities and academia.

Our government is investing $182 million to increase energy efficiency and address climate change by improving how our homes and buildings are designed, renovated, and constructed. **$48.4 million** is going to support the development and implementation of building codes for existing buildings and new net-zero energy-ready buildings through RD&D initiatives that:

- **Accelerate development and adoption** of technologies, design and construction
- **Provide** more cost-effective solutions
- **Validate locally** with real-world demonstrations
- **Build confidence** for adoption of updated codes

Other resources:

- www.buildingsciencelabs.com
- www.RDH.com
- www.buildingscience.com
- www.greenbuildingadvisor.com
- CMHC, NRCan websites
- BC Housing
- Many other very great sources of info.

RDH BUILDING SCIENCE LABORATORIES

Learning about Building Science

Online Courses:

What we didn't talk about

- Maintenance
- Energy Efficiency
- Energy costs
- Indoor Air Quality (IAQ)
- Real R values – Nominal vs Actual
- Heating system options
- Ventilation systems
- Wall retrofit and energy upgrade options
- Pressure balance in homes
- Heat transfer and heat loss principles
- Glazing performance
- Comfort
- Insulation and building materials
- Energy modeling and cost optimization
- Renewable energy for homes
- Lighting, Appliances, Mechanical
- Innovation - further research needs
- Product development needs

Questions?