Of Building Science:

From Control Layers to High Performance Enclosures

Energy Design Conference

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OF BUILDING SCIENCE: CONTROL LAYERS FOR H-P ENCLOSURES

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OF BUILDING SCIENCE: CONTROL LAYERS FOR H-P ENCLOSURES

- Part 1: Making a Case for High Performance
- Part 2: It is All About the Control Layers
- Part 3: Building a Better Wall

=> Using building science to guide us towards more robust, high-performance enclosures!

OVERARCHING THEMES

- We can and must do better!
  - Challenge ourselves towards better performance
- Existing technology can get us there, but …
  - We need to reduce the focus on products.
  - We must embrace more robust systems.
  - We need improvement in design & execution.
- Together we must find more robust designs, technologies, and processes for the future.

Ultra-High Efficiency

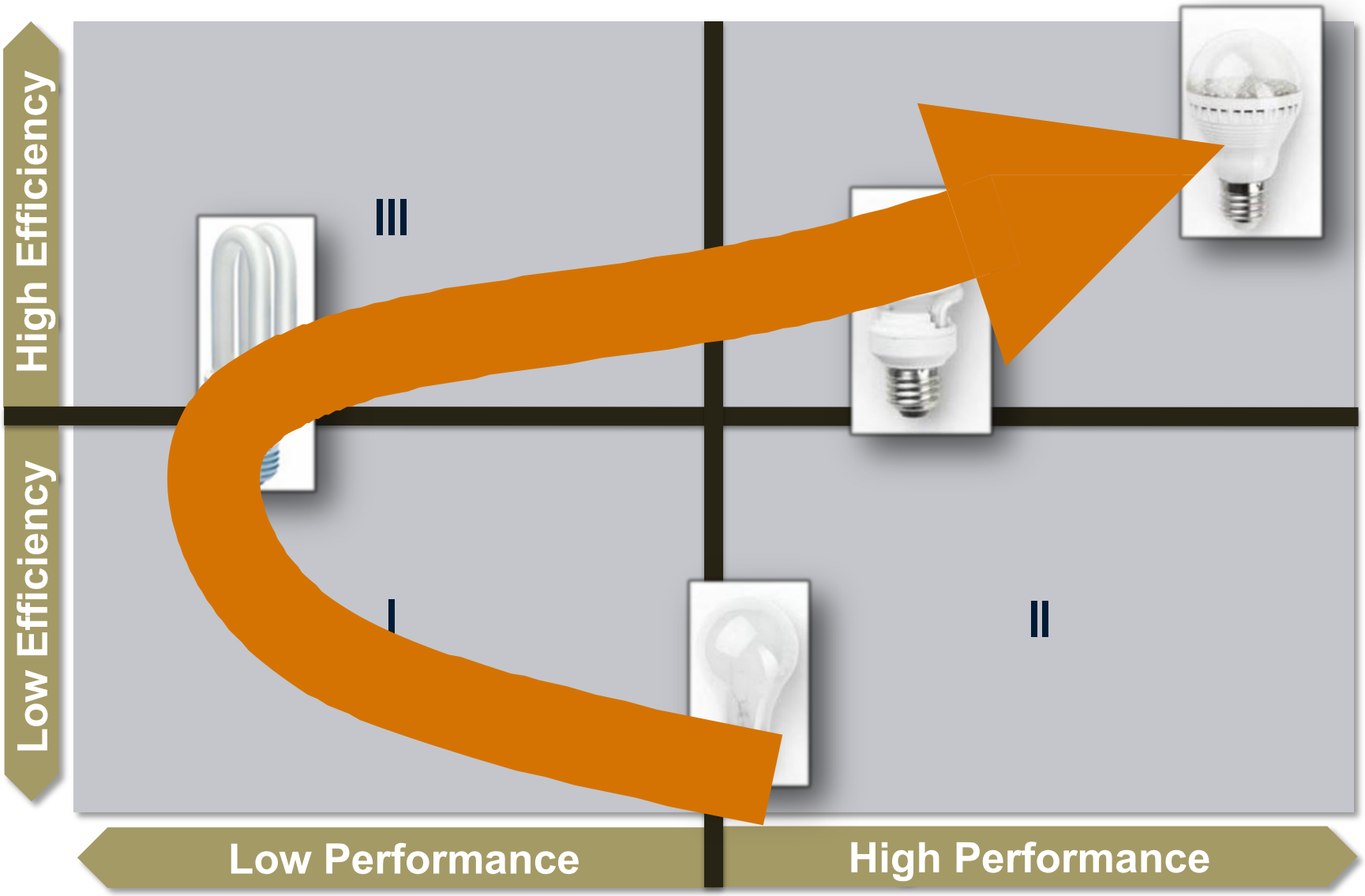
- Enclosure
- Low-Load HVAC
- Components

+

High-Performance

- Affordable
- Comfort
- Health
- Durability
- Renewable Readiness
- Water Conservation
- Disaster Resistance

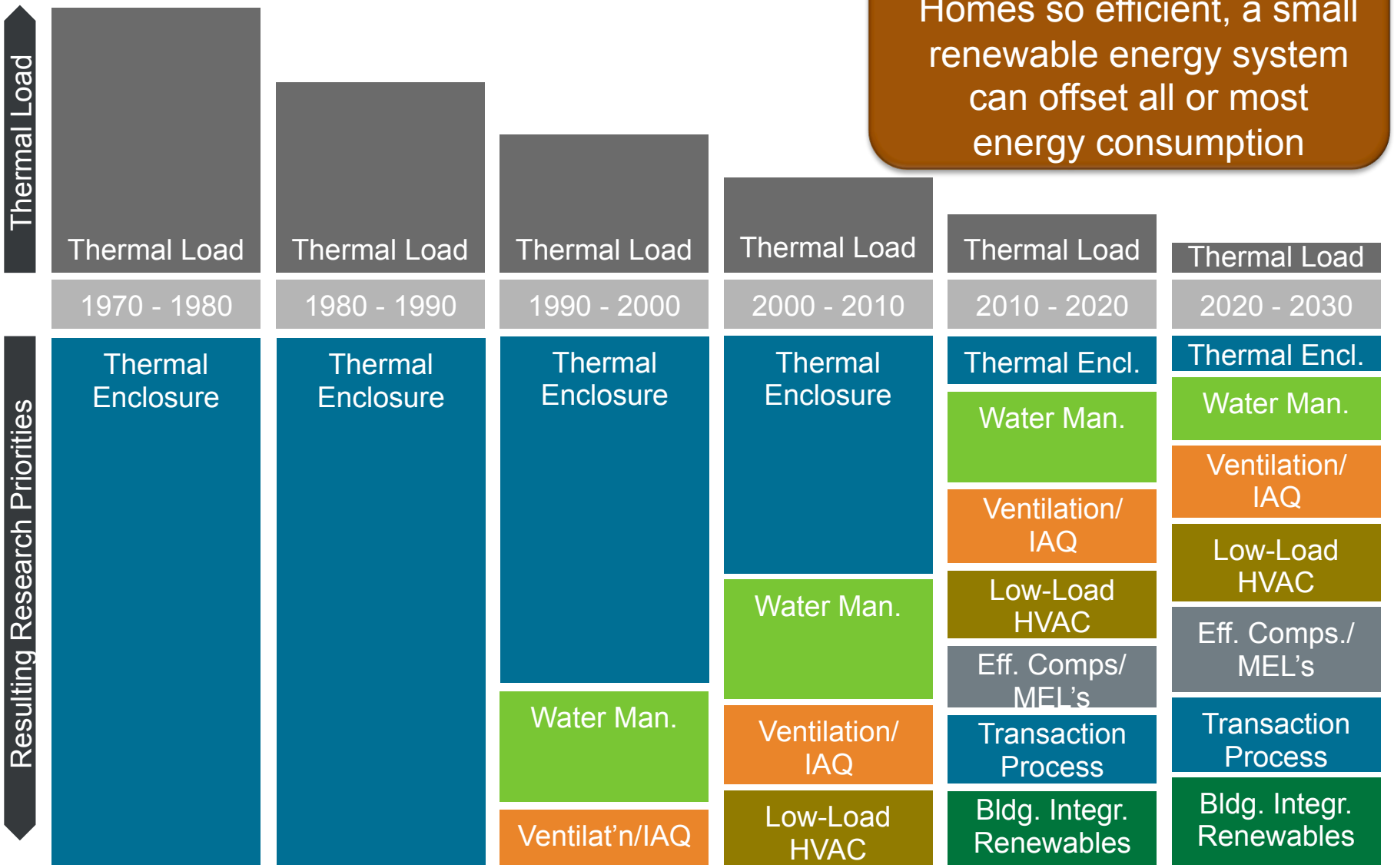
Efficiency + Performance Example



Building America Strategy

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Goal:
Homes so efficient, a small renewable energy system can offset all or most energy consumption



KEEPING OUR EYE ON THE BALL

- Is it possible that we are putting our “eggs into a pretty fragile basket”?
- Is it possible that our basket is getting increasingly fragile due to the nature of the industry, codes, materials, buyers, etc.?
- It appears that many designs, systems, materials, and operations are falling short of our performance expectations.

KEEPING OUR EYE ON THE BALL

- Is it possible that we have over-invested in things and under-invested in good design and proper execution?

- Are we not being realistic about the process?
  - Are we investing in risky designs, systems, and materials and hoping for perfect execution?
  - Are we counting on perfect homeowner operation and maintenance?

A GROWING EPIDEMIC: NOTMYJOBITIS

HIGH-PERFORMANCE HOUSING: MAKING THE CASE FOR ROBUST

- We must ensure our high-performance houses meet our expectations today and in the future?

- High-performance houses will push the envelope (mechanical systems, occupants, etc).
  - This will require more robust designs
  - It will demand systems with forgiveness/tolerance
  - We must have a more predictable delivery system
  - The owners/occupants will need to be in the loop

HIGH-PERFORMANCE HOUSING: MAKING THE CASE FOR ROBUST

- What must we do to move away from the fragile edge and move towards more robust
  - Designs,
  - Systems,
  - Materials,
  - Methods, and
  - Operation?

HIGH-PERFORMANCE HOUSING: MAKING THE CASE FOR ROBUST

- Robust: Don't think of it as a thing, but more of a conceptual way of evaluating new designs, systems, materials, execution, and operation.

- There are a number of ways to think of robust.
  - It is idiot proof, bullet proof, and unlikely to fail.
  - If it fails, it won't hurt anything else.
  - If it fails, there is a planned back-up or redundancy.
  - If it fails, it will be easy to repair or replace.

BUILDING SCIENCE REVIEW => HAM

- Heat Transfer
- Air Flows
- Moisture Transport

HEAT: FUNDAMENTALS

- Heat always goes from hot (more energy) to cold (less energy)

- Modes of Heat Transfer
  - Conduction
  - Convection
  - Radiation

BASICS OF HEAT LOSS/GAIN

- Heat moves through the building enclosure in two distinct ways:
  - Transmission losses/gains
    - through the opaque ceilings, walls, floors
    - through windows and doors
  - Air exchange losses/gains
    - infiltration & exfiltration
    - exhaust devices
    - combustion equipment
    - ventilation

MOISTURE: THE BASICS

- Moisture States

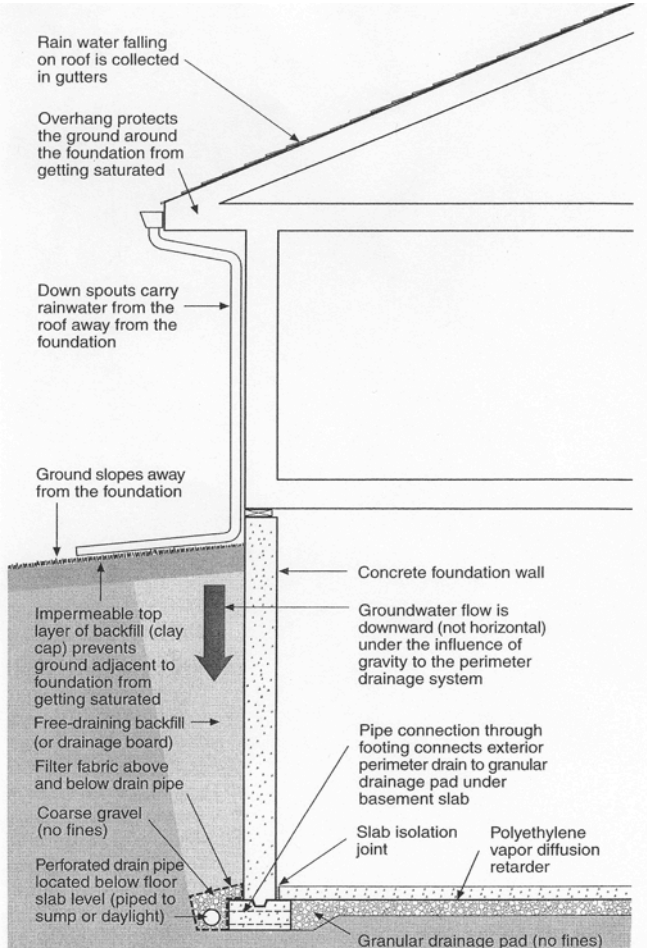
  Solid

  Liquid => Absorbed

  Vapor => Adsorbed

MOISTURE TRANSPORT: LIQUID

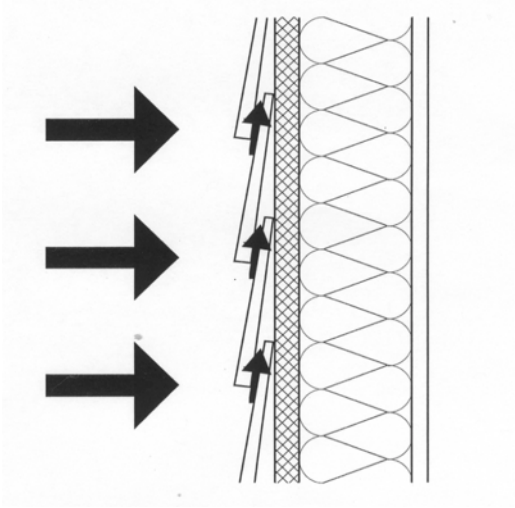
- Gravity (Bulk Water)
  - Above Grade
    - roof leaks
    - window/door leaks
    - wall penetrations
    - saturated materials
  - Below Grade
    - surface drainage
    - saturated soils

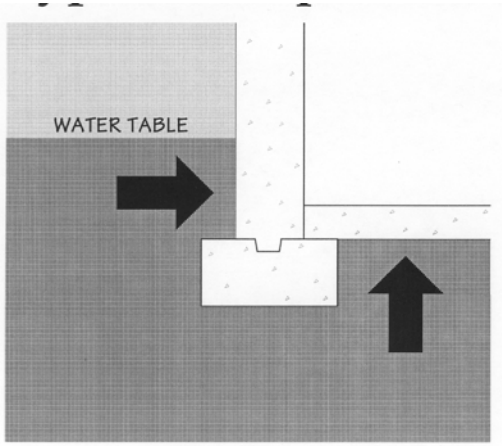


Courtesy of Building Science Corporation

MOISTURE TRANSPORT: LIQUID

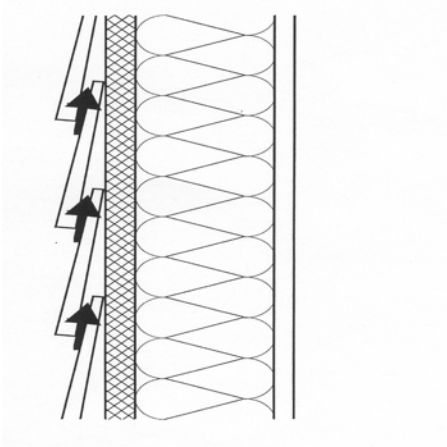
- Pressure Driven Flow
  - Above grade
    - wind-driven rain
  - Below grade
    - rising water table

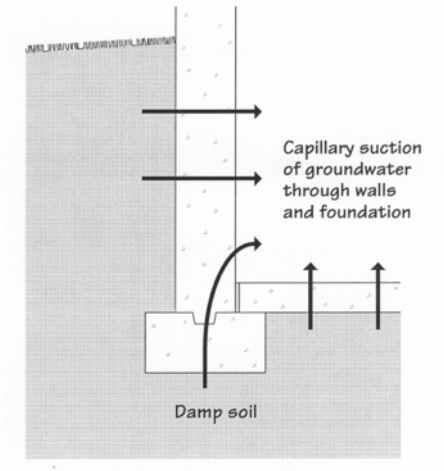




MOISTURE TRANSPORT: LIQUID

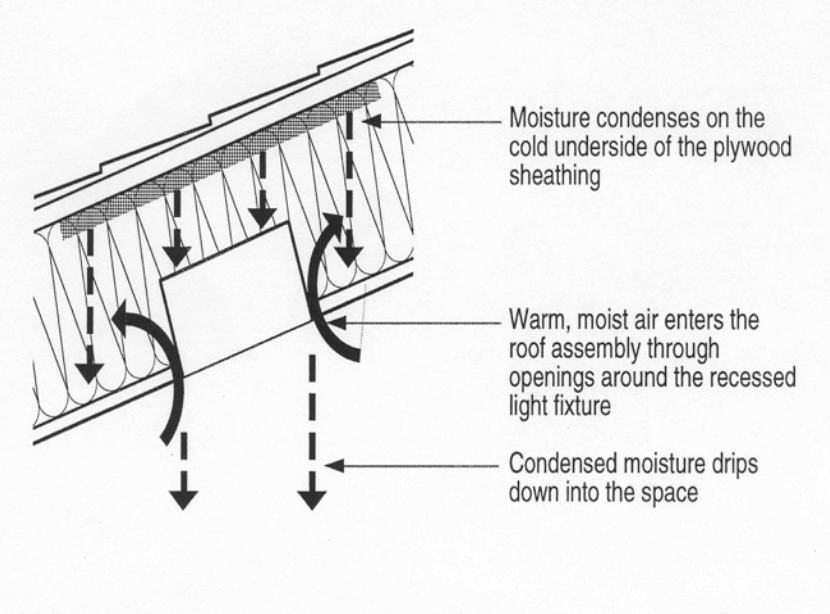
- Capillary Action
  - Above grade
    - seams/joints
    - flashing
  - Below grade
    - soils
    - footing/foundation
    - slab





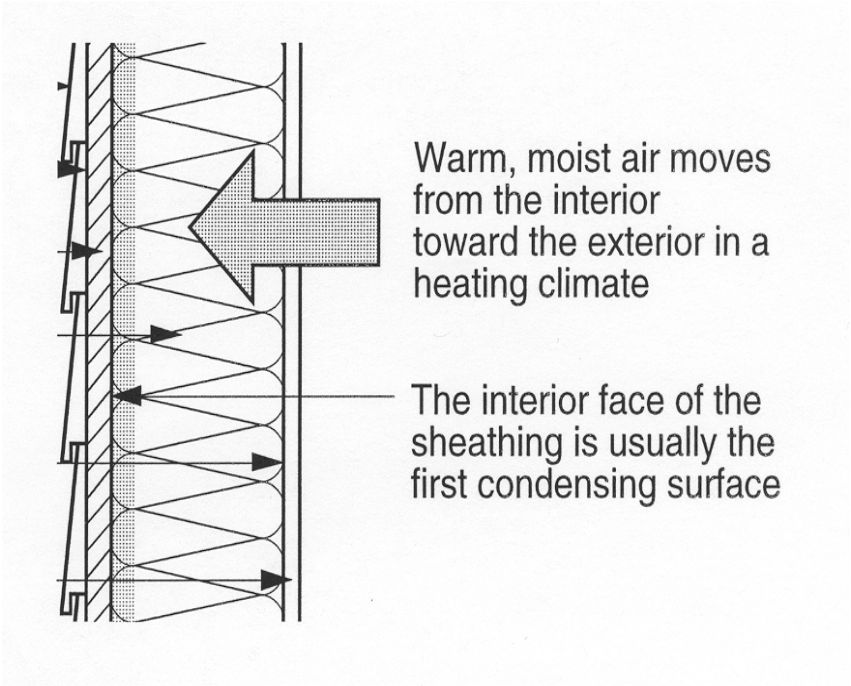
MOISTURE TRANSPORT: VAPOR

- Air Flow
  - Above grade
    - interior/exterior moisture
    - air barrier integrity
    - indoor-outdoor pressures
  - Below Grade
    - interior & soil moisture
    - air barrier integrity
    - basement-outdoor pressures

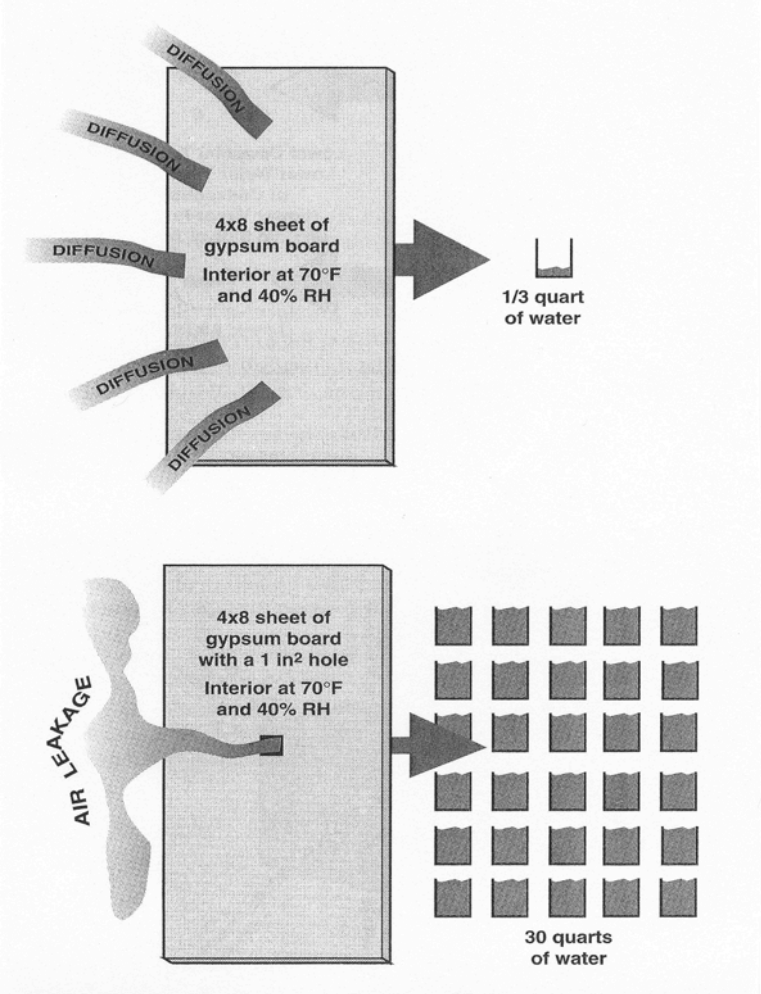


MOISTURE TRANSPORT: VAPOR

- Diffusion
  - Above grade
    - vapor pressure gradient
      - outward in heating
      - inward in cooling
    - permeability
  - Below grade
    - vapor pressure gradient
      - lower wall and slab is usually inward
      - upper wall is similar to above grade
    - permeability



MOISTURE TRANSPORT: VAPOR



Courtesy of Building Science Corporation

MOISTURE CONTROL: GENERAL

- Over some critical period
  - drying must exceed wetting
  - material storage provides the buffer
- Moisture storage is critical
  - Because a perfect envelope is not realistic, wetting will occur. Ample storage must be provided until drying can be completed.
- But remember, water stored (adsorbed or absorbed) must leave as a vapor!

AIRFLOW: THE BASICS

- Pathways
  - Unintentional – leaks and holes
  - Intentional – windows, ports, & ducts
- Pressures
  - Natural
    - wind
    - stack
  - Mechanical
    - combustion venting
    - exhaust fans/devices
    - supply fans/devices
    - forced air systems

BUILDING SCIENCE REVIEW

- Heat Flows
  - Transmission losses/gains
  - Air exchange losses/gains
  - Solar gains
- Air Flows
  - Paths
  - Pressures
- Moisture Flows
  - Liquid
    - gravity
    - capillarity
  - Vapor
    - air transport
    - diffusion

BUILDING SCIENCE REVIEW

- **Key Building Science Principles**
  - Heat goes from _____ to _____ .
  - Water vapor goes from _____ to _____ .
  - Water vapor goes from _____ to _____ .
  - Air in _____ _____ air out (and vice versa).
  - Air must have a _____ and a _____ to flow.
  - ____ the rain (and the soil)
  - Most of the action is at _____ and _____ .
  - Gas concentration (pollutants, water vapor, etc.) is a function of _____ _____ and _____ _____ .

- **In the end -- _____ , _____ , and _____ flows will drive the performance of the system!**

HIGH-PERFORMANCE HOUSING: MAKING THE CASE FOR ROBUST

- A call for high-performance homes!

- But it will demand a new approach. We must …
  - design and engineer (not just build) our homes.
  - build forgiveness/tolerance into all systems.
  - build redundancy into critical materials.
    - or make it easy to repair and/or replace key components
  - develop a more predictable delivery system.
  - provide continuous feedback to the occupant.

FOCUS: HIGH PERFORMANCE ENCLOSURES

- Four Critical Control Layers
  - Water
  - Air
  - Thermal
  - Vapor

- Essential for all enclosure elements!

HIGH PERFORMANCE DEJA VU

- The “Ten Key Components for a Cold Climate House” (1988) that will ensure …
  - Energy efficiency
  - Moisture control & durability
  - Good indoor air quality

- A formula for …
  - How to have your cake and eat it too!!!

The Ten Key Components

Components	Energy	Moisture	IAQ
1. Full coverage optimal thermal insulation			
2. Continuous warm-side air barrier			
3. Full-coverage warm-side vapor retarder			
4. Continuous exterior-side weather barrier			
5. Energy efficient, condensation resistant windows			
6. Effective ground moisture / soil gas control			
7. Low toxicity materials, finishes, and furnishings			
8. Safe, efficient space heating and cooling			
9. Managed mechanical ventilation			
10. Efficient and safe appliances and lighting			

FOCUS: HIGH PERFORMANCE ENCLOSURES

- The “Perfect” Approach
  - Walls
  - Roof
  - Slab
  - Foundation

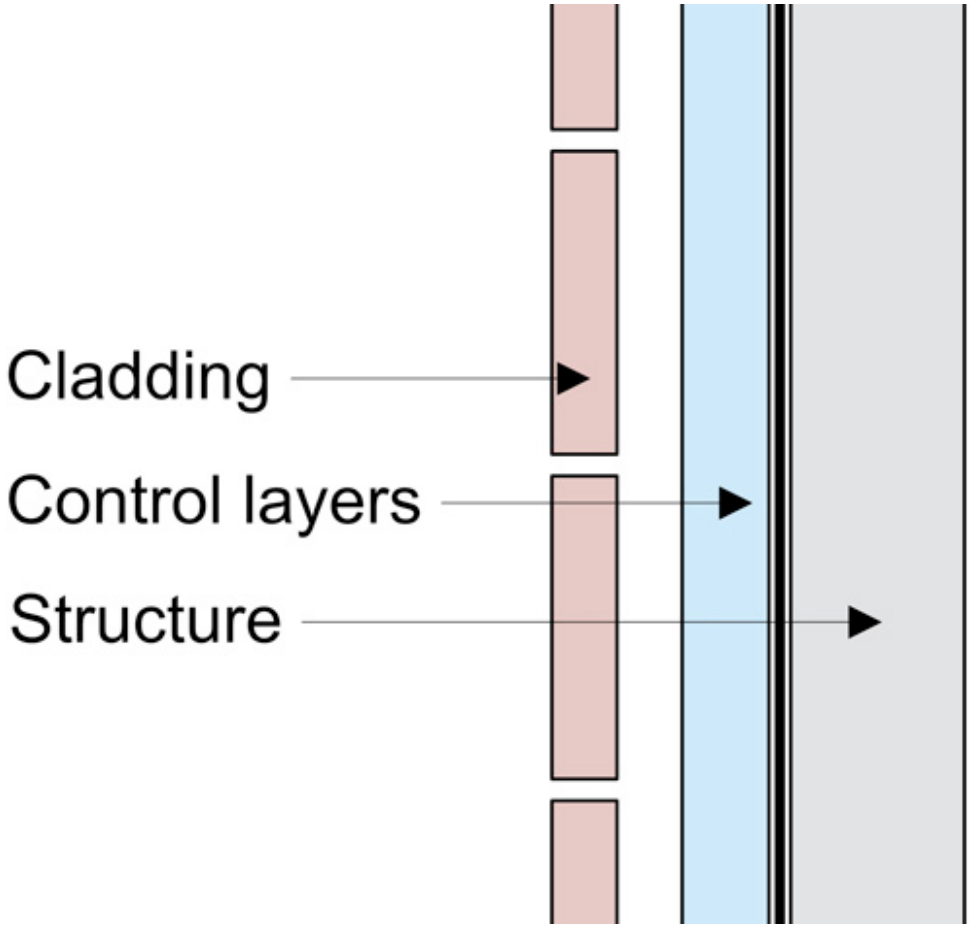
- Move the structure to the inside and the control layers to the outside …
  - It simply works and works everywhere!!!

MUST HAVE RESOURCES FROM BSC

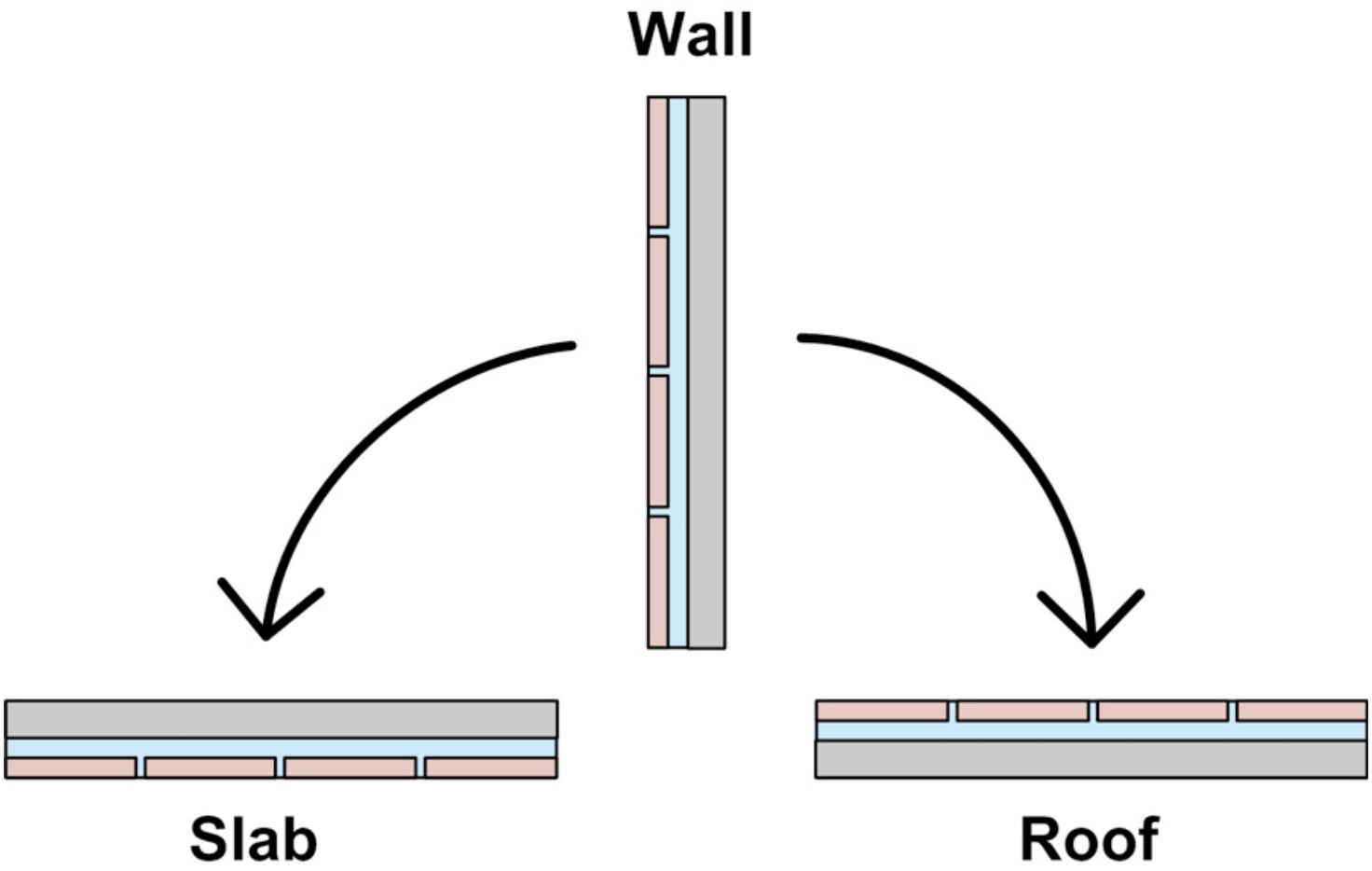
- BSI-001: The Perfect Wall
  - Joe Lstiburek, 2010
- BSI-090: Joseph Haydn Does the Perfect Wall
  - Joe Lstiburek, 2015

- Getting Enclosures Right in ZERH
  - Joe Lsitburek, 2016
  - http://energy.gov/eere/buildings/doe-zero-energy-ready-home-resources

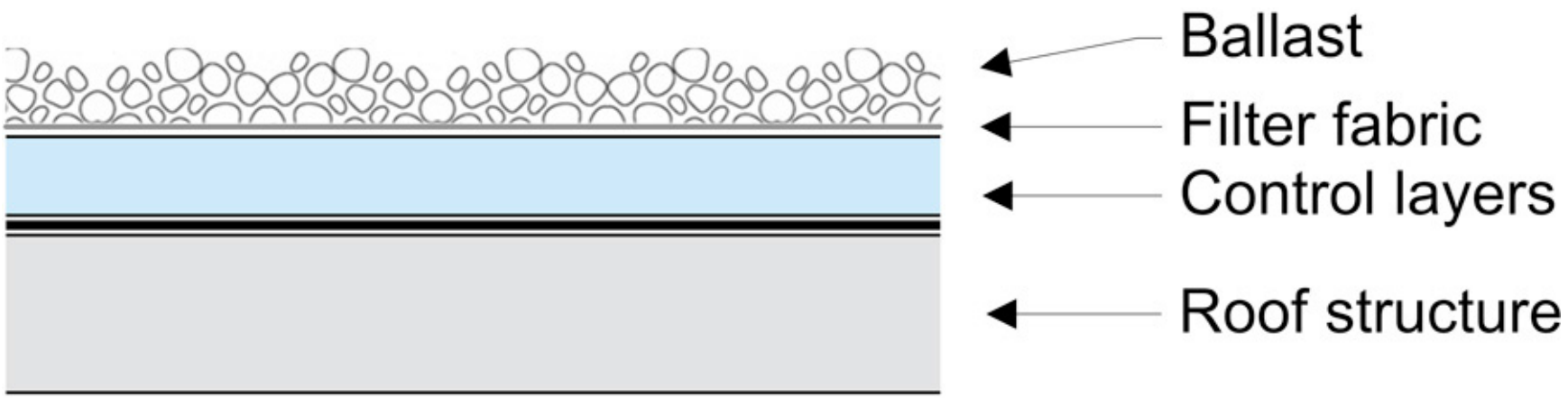
THE PERFECT WALL



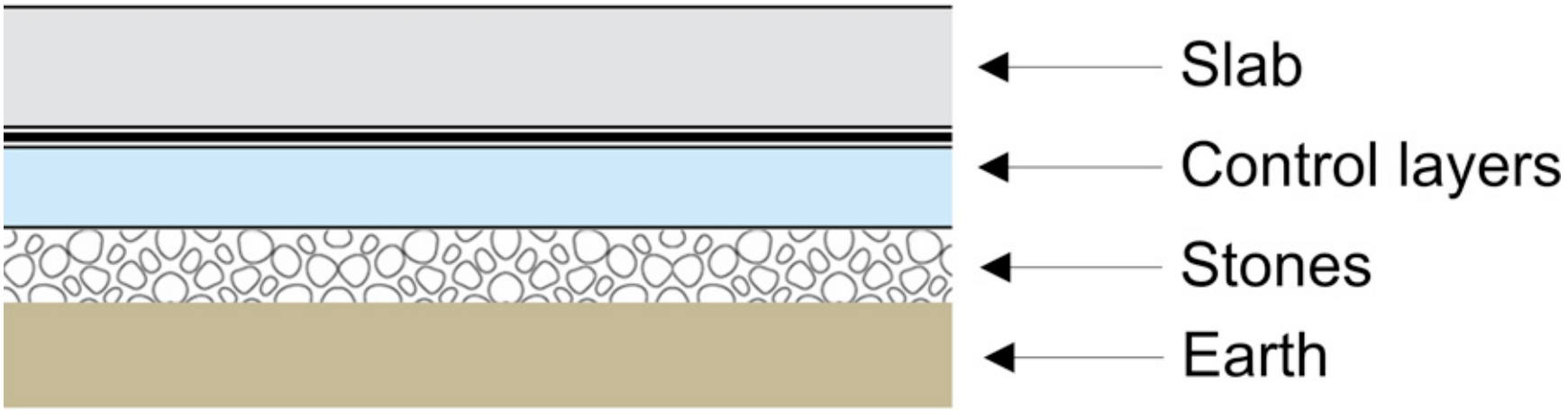
WORKS FOR ROOF & SLAB, TOO!



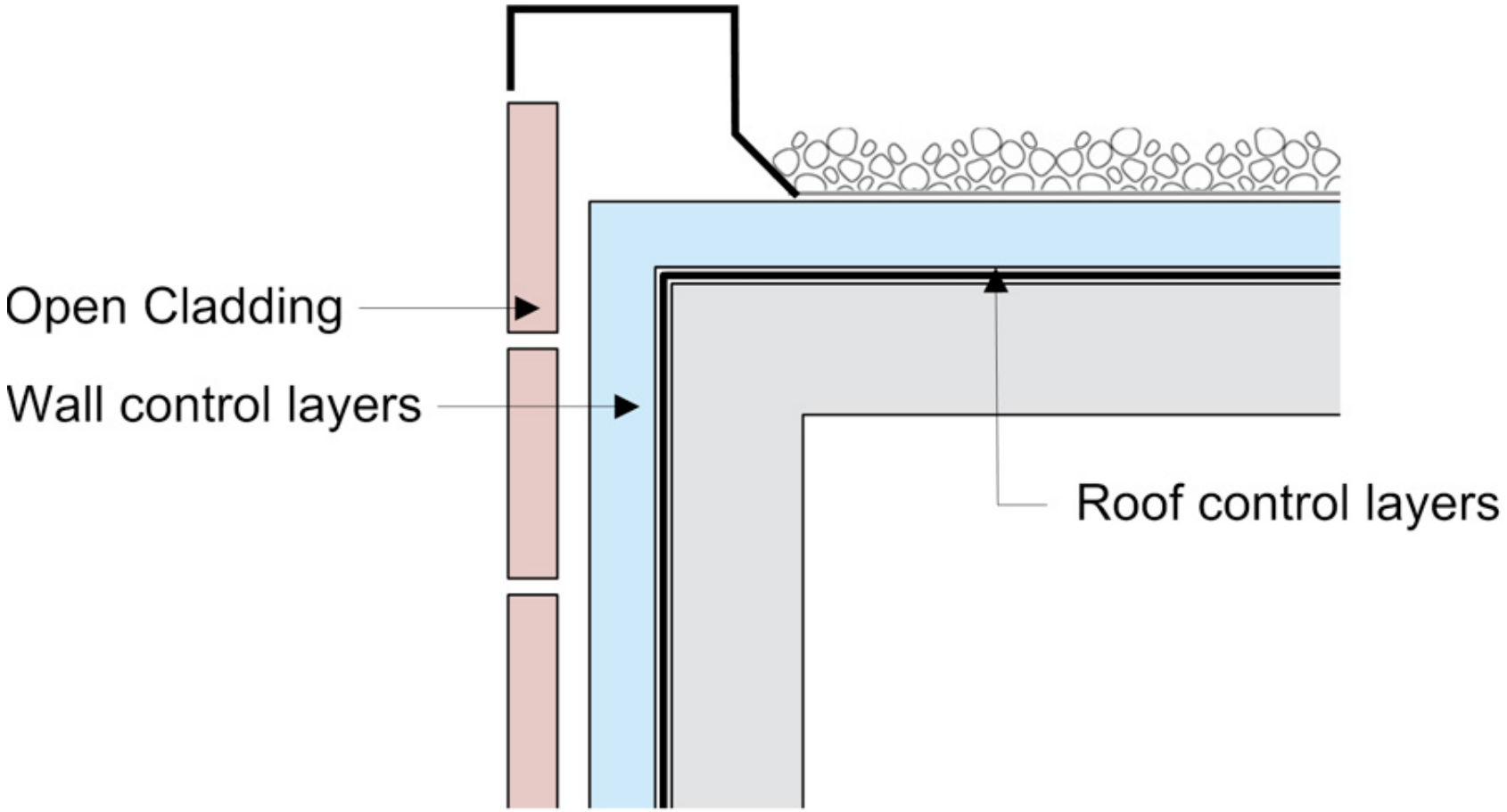
THE PERFECT ROOF



THE PERFECT SLAB



PERFECT CONNECTIONS



THE 4 CONTROL LAYERS

- Every enclosure element must have four control layers!

- In rank order, they are:
  - Thermal control (???)
  - Water control
  - Air control
  - Vapor control

THERMAL CONTROL LAYER(S)

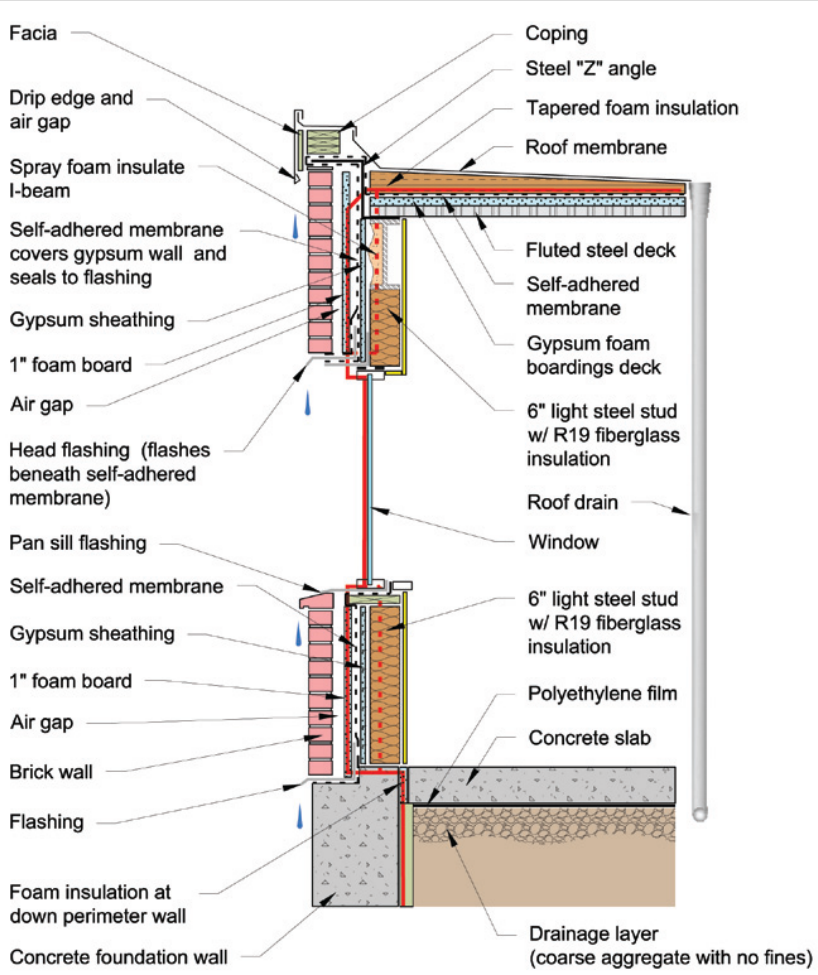
- General Overview
  - The intent is to slow the transmission of heat energy going from warm to cold.
    - Driver is the temperature difference
    - Primarily set by indoor and outdoor conditions
- This is the easy one!
    - How much?
    - Where?
    - What type?

THERMAL CONTROL LAYER(S)

Insulation	Code	ZERH	NZE*
– Ceiling (flat)	50	50	60
– Walls	20	25	40
– Fenestration	3	4	5
– Floor (frame)	30	40	50
– Foundation	15(10+)	15	20
– Slab	0	0	10

* From “Zeroing In” by Joseph Lstiburek

PEN TEST: RED LINE FOR INSULATION



WATER CONTROL LAYER(S)

- General Overview
  - The intent is to keep water from reaching any moisture susceptible layers.
    - Primary drivers are gravity, wind, capillarity
    - You can (should) take steps to reduce the drivers

- This is absolutely critical,
  - especially as we remove drying potential with increased insulation, reduced air flow, and multiple vapor retarders!

WATER CONTROL LAYER(S)

- Theoretical Framework: 3 D's
  - Deflect
  - Drain
  - Dry

PEN TEST: BLUE LINE FOR WATER