AIR CONTROL LAYER(S)

- General Overview
  - The intent is to keep air from moving across the building enclosure carrying heat and moisture to locations that can create problems.
    - Primary driver is air pressures
    - You can (must) manage the pressure difference

- This is absolutely essential in modern construction.

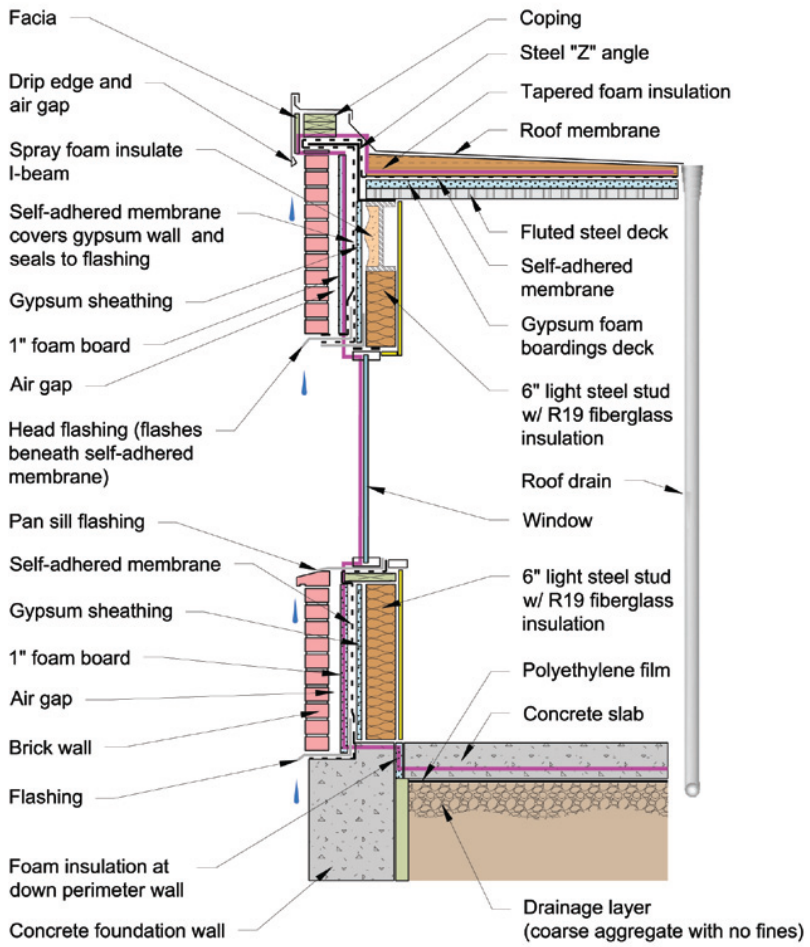
AIR CONTROL LAYER(S)

- Theoretical Framework
  - Material = 0.02 l/s-m^2 @75Pa
  - Assembly = 0.20 l/s-m^2 @75Pa
  - Building = 2.0 l/s-m^2 @75Pa
- Where does it belong?
  - Inside
  - Outside
  - In between
  - Both

AIR CONTROL LAYER(S)

	Code	ZERH	NZE
Airtightness			
– ACH @ 50PA	3 ACH	2 ACH	1 ACH

PEN TEST: PURPLE LINE FOR AIR



VAPOR CONTROL LAYER(S)

- General Overview
  - The intent is to control vapor diffusion across a vapor pressure or thermal gradient.
    - Primary driver is vapor pressure
    - That vapor pressure can (should) be managed
- While perhaps not as critical as the other layers, it can't be ignored in …
    - Very cold climates
    - Hot humid climates
    - High humidity environments

VAPOR CONTROL LAYER(S)

- General Overview (continued)
  - As the thermal insulation increases the vapor permeance must decrease.
  - Today (due to air-conditioning) you must manage vapor from both directions.
  - And if anything gets wet, generally the only drying potential is by vapor diffusion so there must be a clear drying direction.
  - So, this is more of a strategy rather than a specific layer.

VAPOR CONTROL LAYER(S)

- Theoretical Framework
  - Class 1 = < 0.1 perm impermeable
  - Class 2 = 0.1 to 1.0 perm semi-impermeable
  - Class 3 = 1.0 to 10 perm semi-permeable
  - Class 4 = > 10 perm permeable

VAPOR CONTROL LAYER(S)

- Current building code (since 1991) requires a Class 1 or 2 vapor retarder
  - 1 perm or less on the warm side in winter.
- Code doesn't address exterior vapor retarders for summer conditions.
  - but inward vapor pressure is real depending on cladding choices
  - and best practice would suggest you must design for inward protection

VAPOR CONTROL LAYER(S)

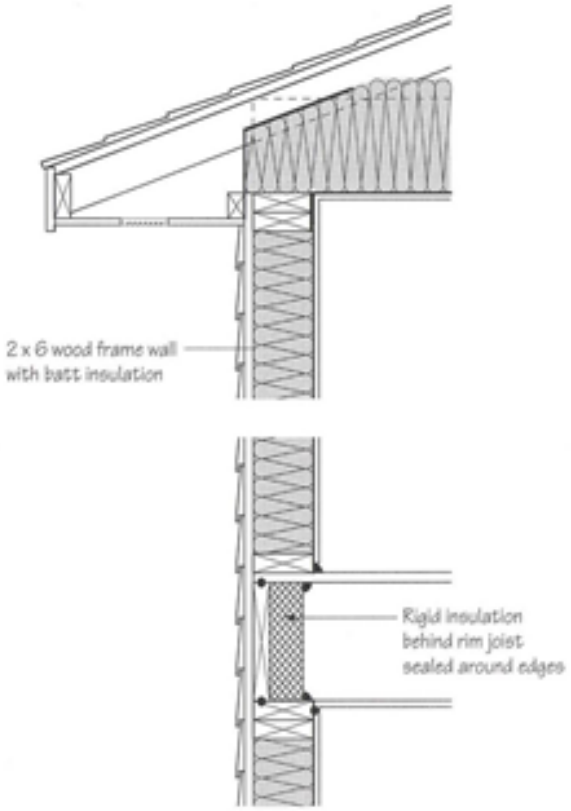
- 1 is an interesting (but not lonely) number!
  - ½” OSB (dry cup)
  - smart vapor retarder (dry cup)
  - 1” extruded polystyrene
  - Several coats of oil-based paint

THE MODERN ENCLOSURE CONUNDRUM

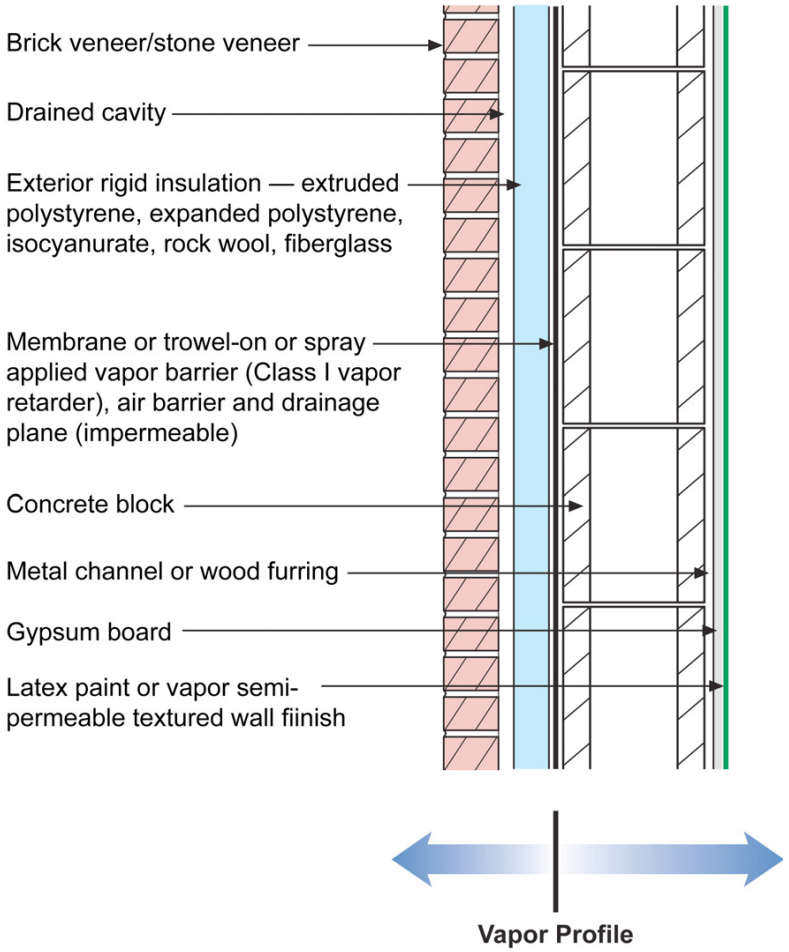
- It gets wet from inside out and outside in!
  - In general, it will wet outward in winter and inward in summer
- Things will get wet at some point due to imperfect design, execution, or operation.
- Therefore, all moisture susceptible materials must be able to dry out
  - In general, that can be outward in the winter or inward in the summer

THE MODERN ENCLOSURE CONUNDRUM

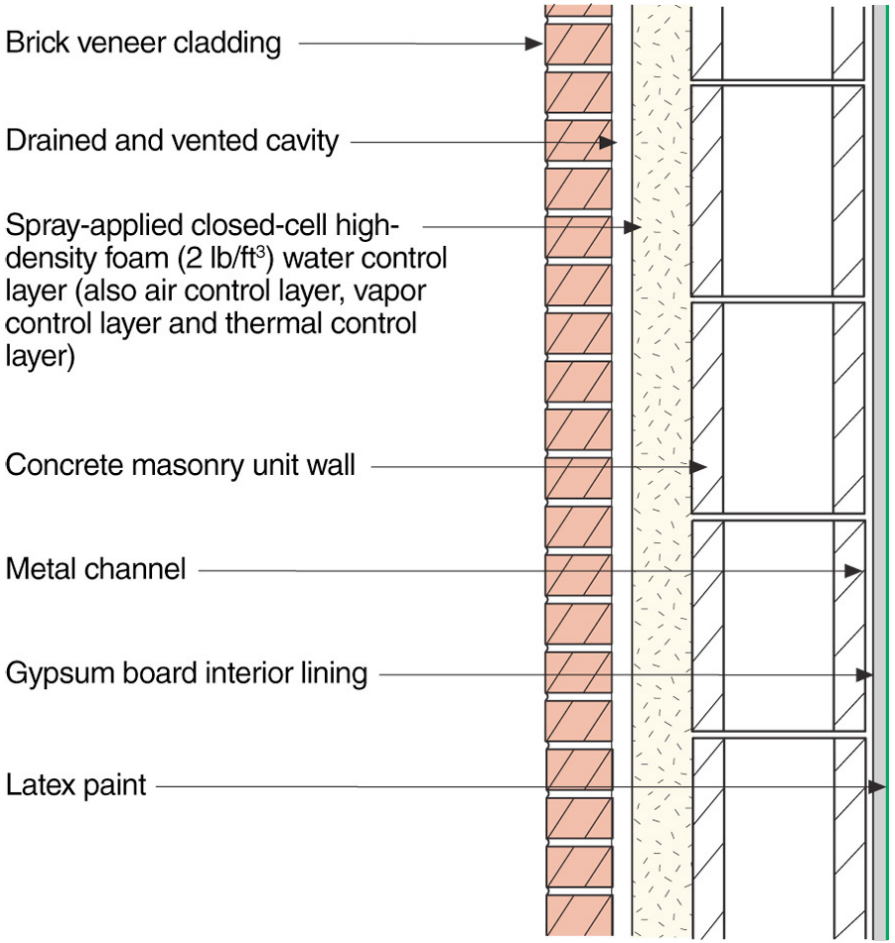
- Has the 2x6 cavity wall hit the end of the road?
  - Too little thermal control
  - Too risky / not robust
    - requires high end execution
  - Too little drying potential
- Biggest Risks
  - Cladding is not drained & vented
  - Poor water control
  - Significant air-conditioning



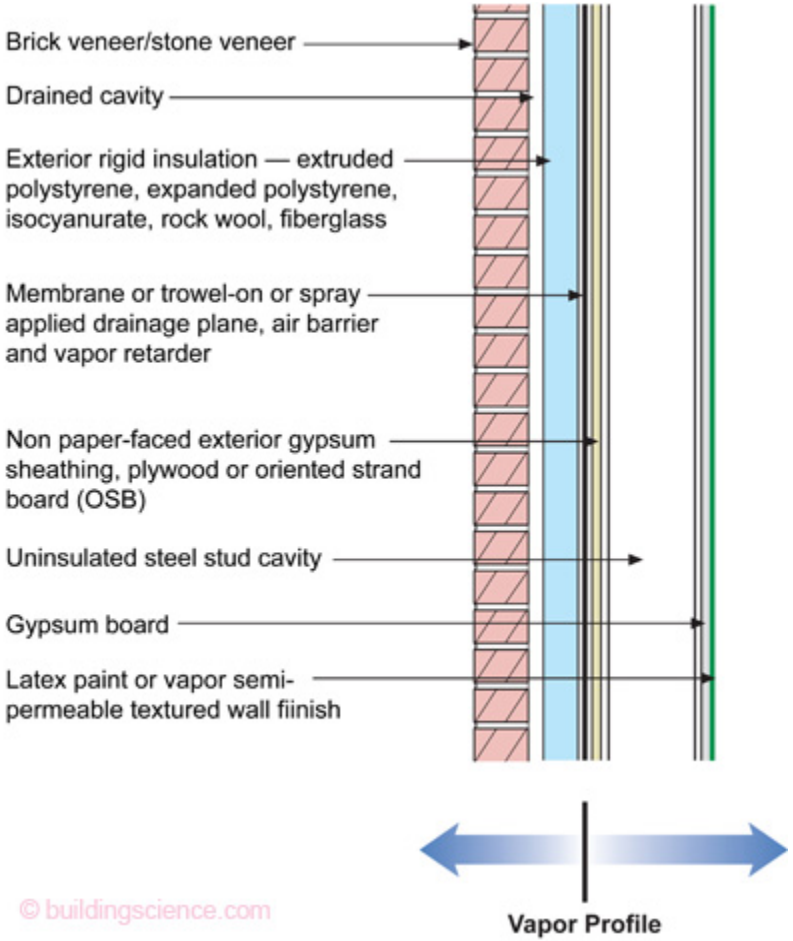
THE PERFECT INSTITUTIONAL WALL



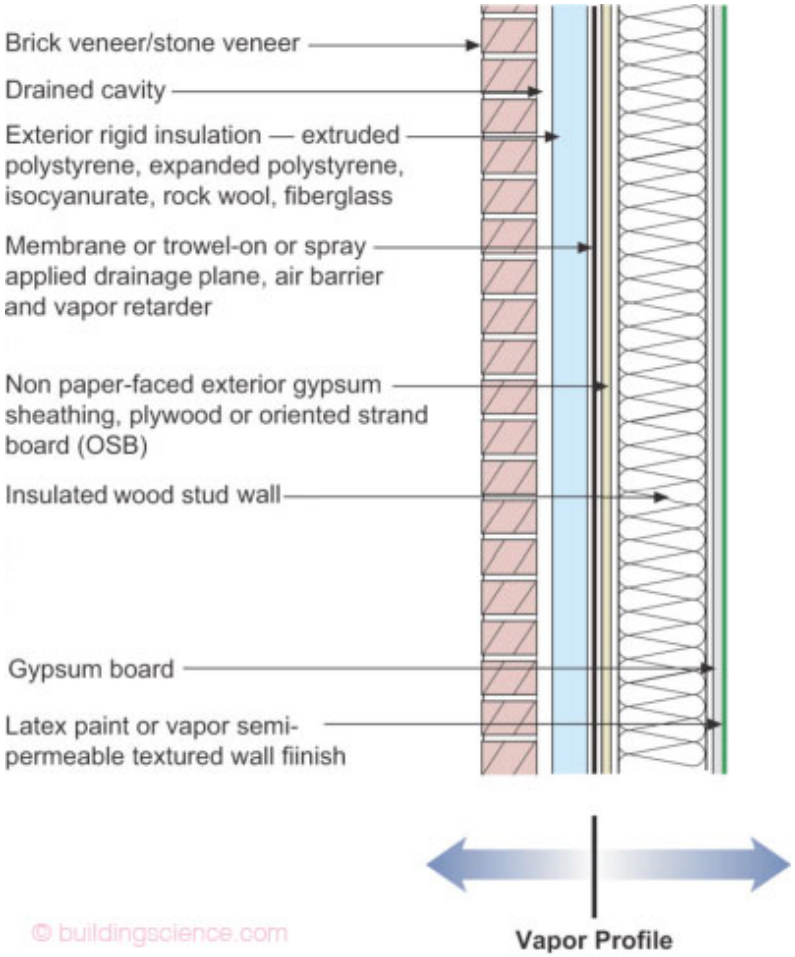
4 IN 1 CONTROL LAYER



THE PERFECT COMMERCIAL WALL

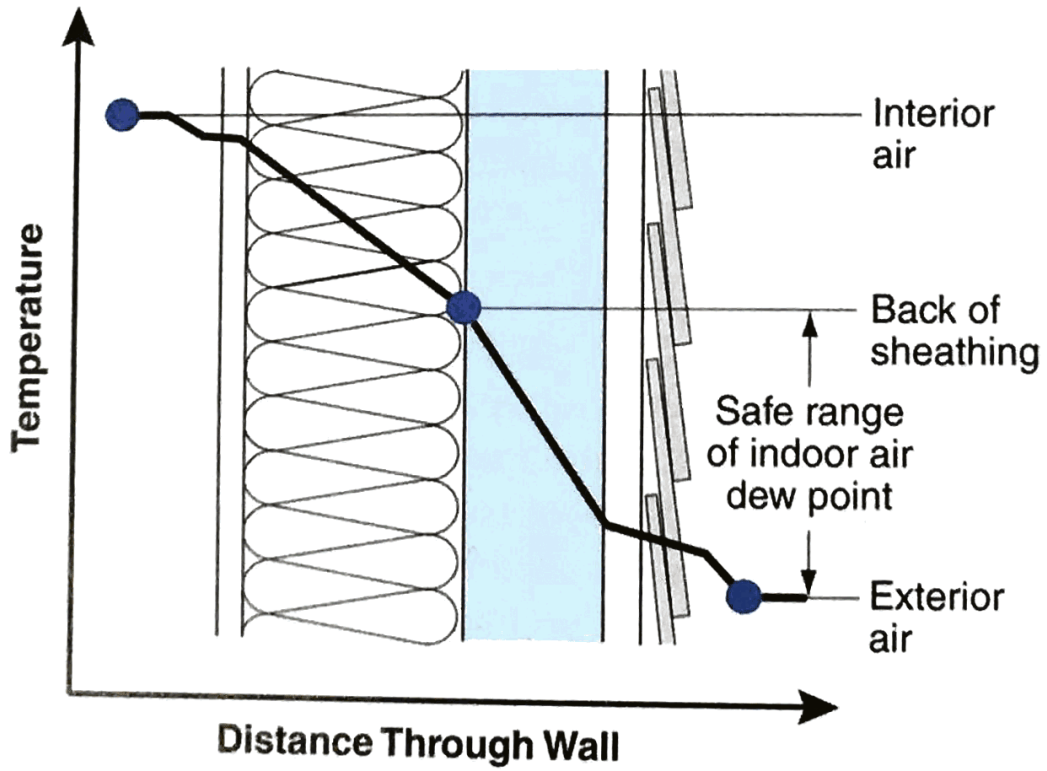


THE PERFECT RESIDENTIAL WALL

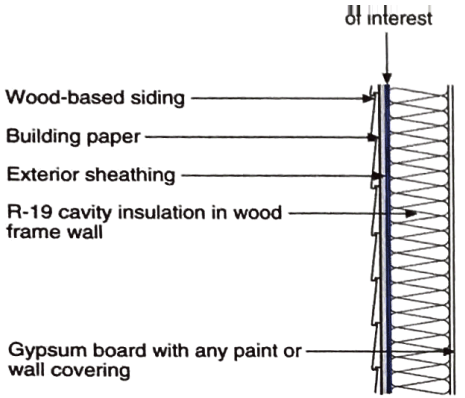


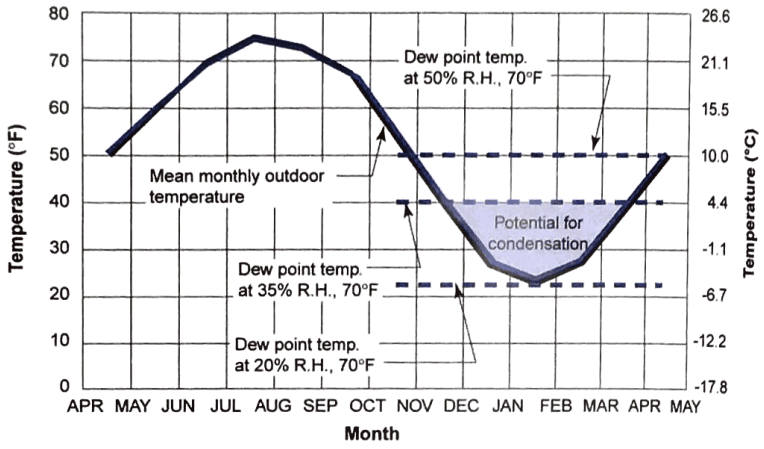
HOW MUCH EXTERIOR INSULATION?

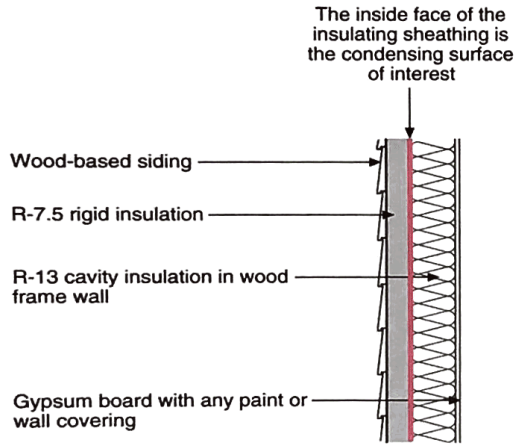
$$T_{back\ of\ sheathing} = T_{interior} - (T_{interior} - T_{exterior}) \frac{R_{batt}}{R_{total}}$$

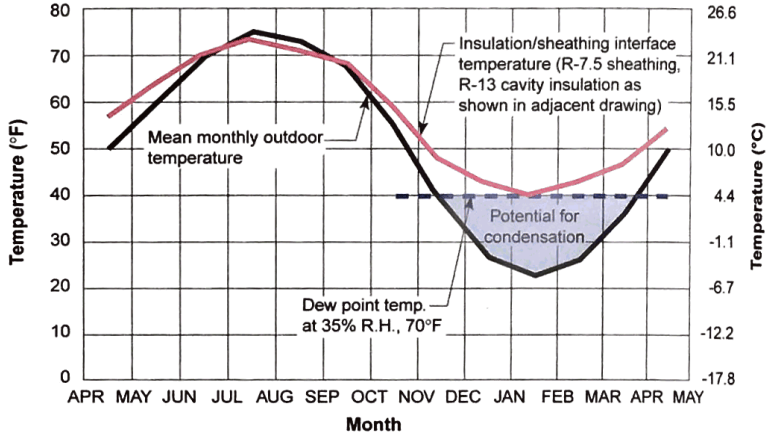


CONDENSATION POTENTIAL







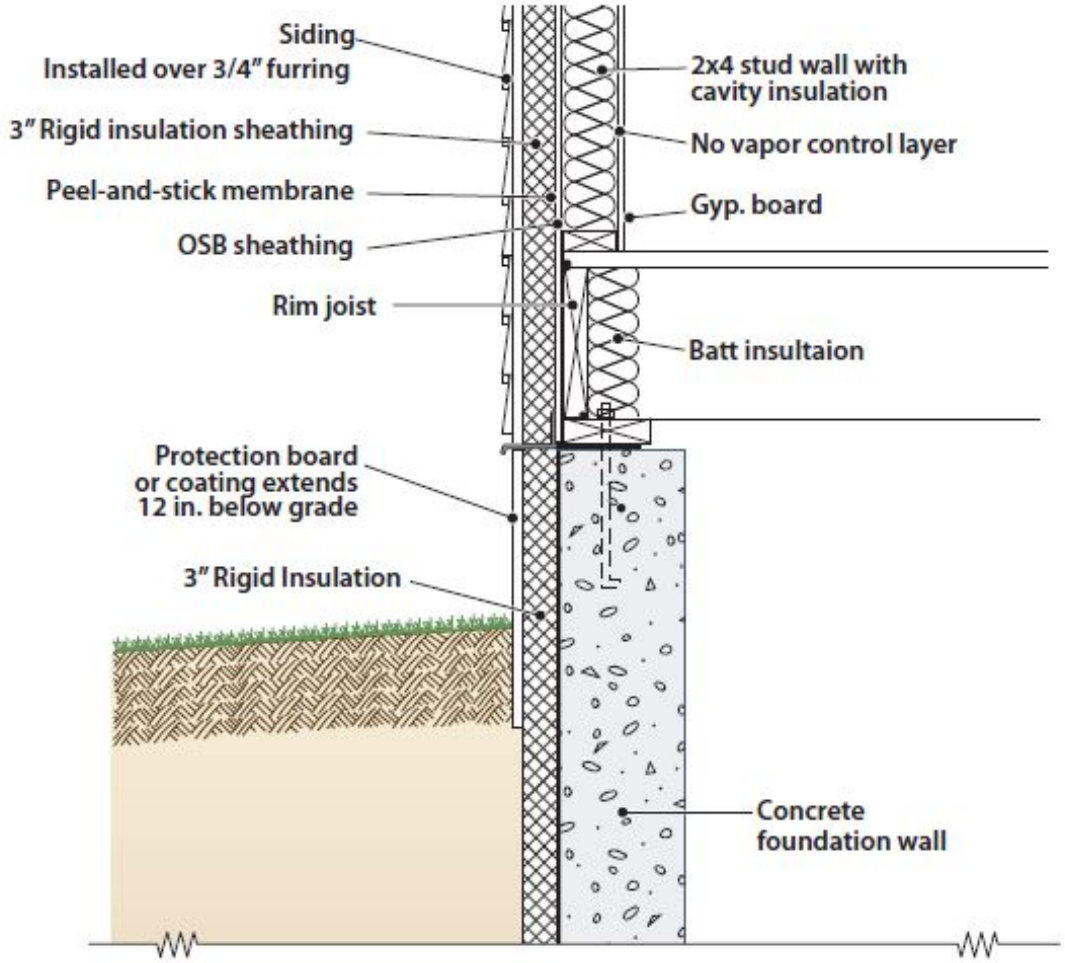


RATIO OF EXTERIOR TO INTERIOR

Indoor		RH	20	25	30	35	40	50	60
Dew point		°C	-3.0	0.0	2.5	4.7	6.6	9.9	12.7
		°F	26.6	32.0	36.6	40.5	44.0	49.9	54.8
$T_{outdoor}$	°C	°F							
	0	32	0.00	0.00	0.12	0.23	0.32	0.47	0.60
	-5	23	0.08	0.19	0.29	0.37	0.45	0.57	0.68
	-10	14	0.23	0.32	0.40	0.48	0.54	0.64	0.73
	-15	5	0.33	0.42	0.49	0.55	0.60	0.69	0.77
	-20	-4	0.41	0.49	0.55	0.60	0.65	0.73	0.80
	-25	-13	0.48	0.54	0.60	0.65	0.69	0.76	0.82
	-30	-22	0.53	0.59	0.64	0.68	0.72	0.78	0.84
	-35	-31	0.57	0.63	0.67	0.71	0.74	0.80	0.85
	-40	-40	0.61	0.66	0.70	0.73	0.76	0.82	0.86

- High Performance Enclosures: John Straube, 2012

CONTROL LAYERS – MN HYBRID



A BETTER WAY TO BUILD

- Step 1: Put the structure on the inside
  - Light-frame construction
  - Timber frame
  - Concrete masonry
  - SEP = Structural Engineered Panel (studless construction)

A BETTER WAY TO BUILD

- Step 2: Put the thermal and moisture control layers on the outside.
  - Perfect Wall
    - (Lstiburek, w/ credit to bright Canadians in CBDs)
  - PERSIST (Makepeace)
  - REMOTE (Alaskans)
  - PERFORM (Texans)
  - Out-sulation (???)
  - Exterior Thermal & Moisture Management System (ETMMS)

ETMMS: FOUNDATION, WALLS, & ROOF

- Build the entire structure;
  - foundation, floor systems, walls, and roof
- Wrap the entire envelope with a “peel & stick” membrane integrated with openings / penetrations
- Add rigid foam insulation
  - 2 to 3” on foundation
  - 3 to 4” on walls
  - 6 to 8” on the roof
- Add furring strips, overhangs, etc.
- Install trim; siding; roof sheathing and roofing


L S
722 2345


GRACE
Bituthene
Perm-A-Barrier
GRACE VYCOR PLUS
GRACE VYCOR


GRACE
Bituthene


METROPOLITAN

University of Minnesota's

Team OptiMN
WINS TOP AWARD

In DOE's "Race to Zero"

Student Design Competition

INTRODUCING | The Impact Home

INTRODUCING | Multi-Disciplinary Team

14 Students from Building Science, Construction Management, Business, Marketing, and Sustainable Design

Design, analyze, and present an affordable, resilient, high-performance "Zero Energy Ready Home" as infill new construction for a vacant lot in north Minneapolis

Residential Building Science

Collin Coltman
Matthew Dries
Maria Finsness
Tyler Kitzerow
Frank Peeters
Peter Schneider
Kristel Spiegelberg
Cavan Wagg

Construction Management

Collin Coltman
Jose Aaron Cruz-Salinas
Kyle Holmes
Jackie Larson
Peter Schneider

Business & Marketing Education

Aaron Hanson

Master of Science Sustainable Design & Masters in Architecture

Laurel Johnston

Bioproducts & Biosystems Science, Engineering, & Management

Maria Fernanda Laguarda Mallo (PhD candidate)

SPECIAL THANKS TO OUR PARTNERS

Urban Homeworks
Minneapolis, MN
Affordable Housing Developer

- Non-profit builder and developer
- Met with their project managers several times throughout the competition to receive feedback in the Impact Home's "market appropriateness"

URBAN HOMEWORKS

Residential Science Resources
Eagan, MN
Building Science Consultants

- Building science and energy rating consultants
- They provided resources, technical assistance, REMRate support, and financial support for the presentation team's travel to NREL

residential science resources

OVERALL DESIGN GOALS

Department of Energy's CHALLENGE
is to build a Zero Energy Ready Home

Urban Homeworks' MISSION
is to produce equitable, dignified, communities

Green Homes North INITIATIVE
is to revitalize North Minneapolis neighborhoods with affordable, sustainable, and quality homes

Team OptiMN's GOAL
is to design a home that makes an **IMPACT** on the community and environment by achieving all of the above

PERFORMANCE GOALS | Site in DOE Climate Zone 6

Durable & Long-Lasting

ZERO ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

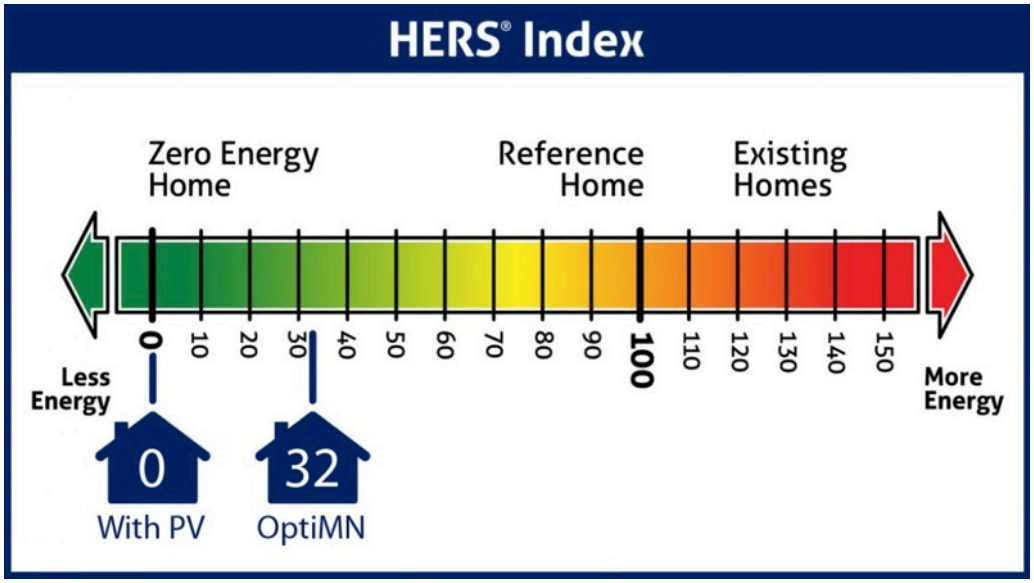
Fortified Home

FORTIFIED HOME

Indoor Air Quality

EPA Indoor airPLUS
QUALIFIED HOMES

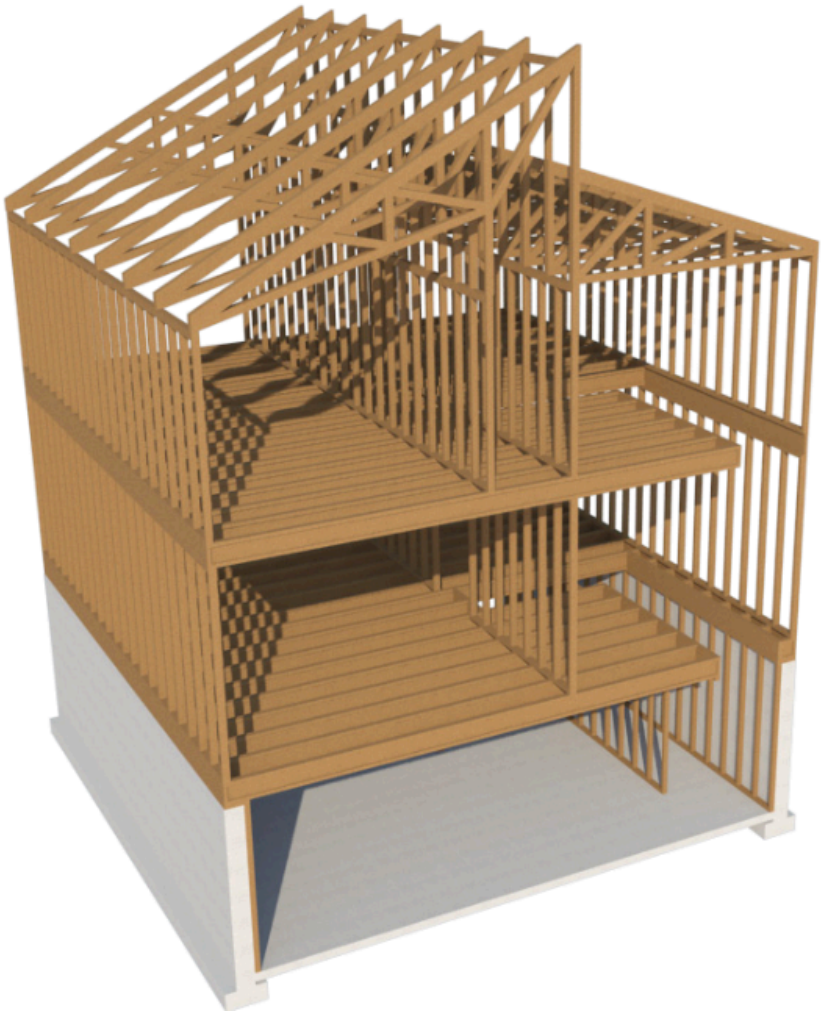
Energy Efficient | Zero Energy Ready

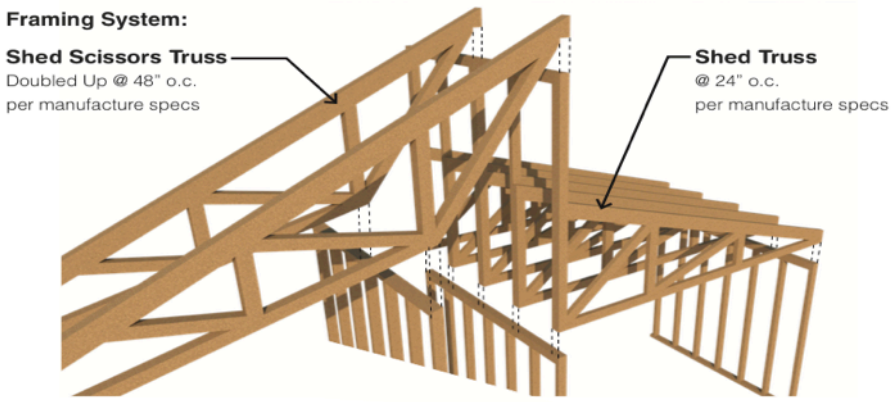


Water Stewardship

WaterSense
Meets EPA Criteria
SM

CONSTRUCTABILITY





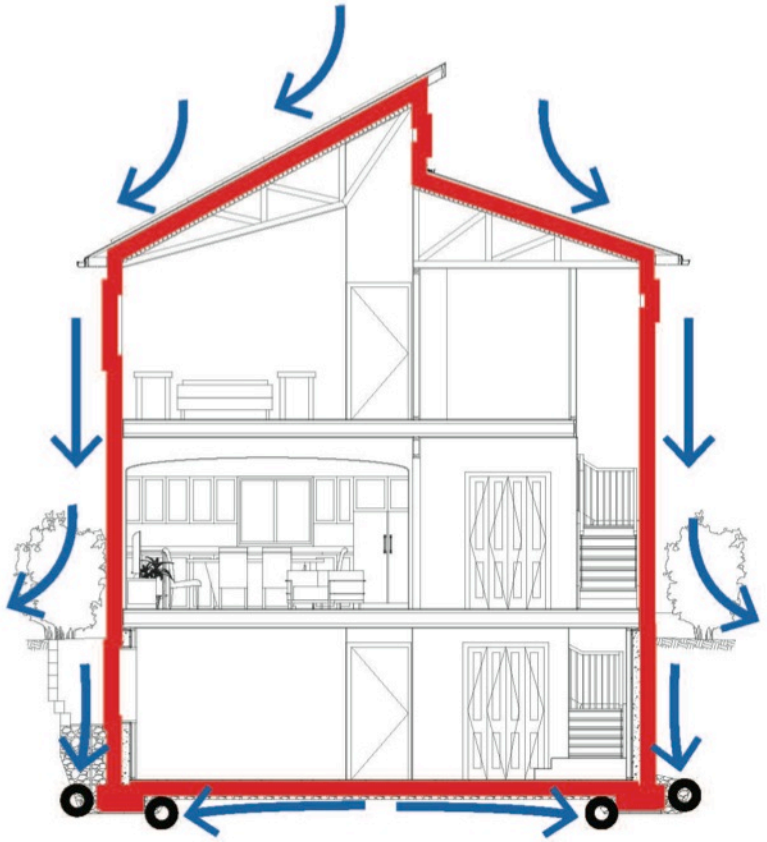
Approachable and Appropriate Construction Materials and Methods

- Simplified design and shape
- Based on traditional construction materials and techniques
- Simplified ducting and hot water systems

Heat Management

Air Management

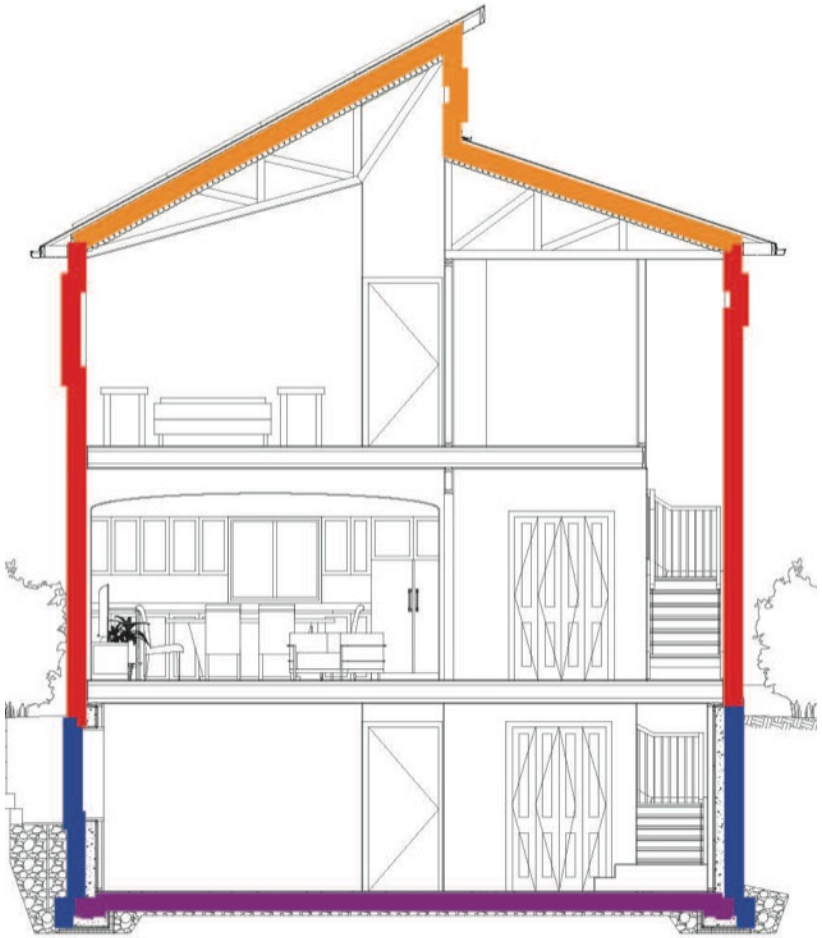
Moisture Management



ENCLOSURE DESIGN | 4 Control Layers

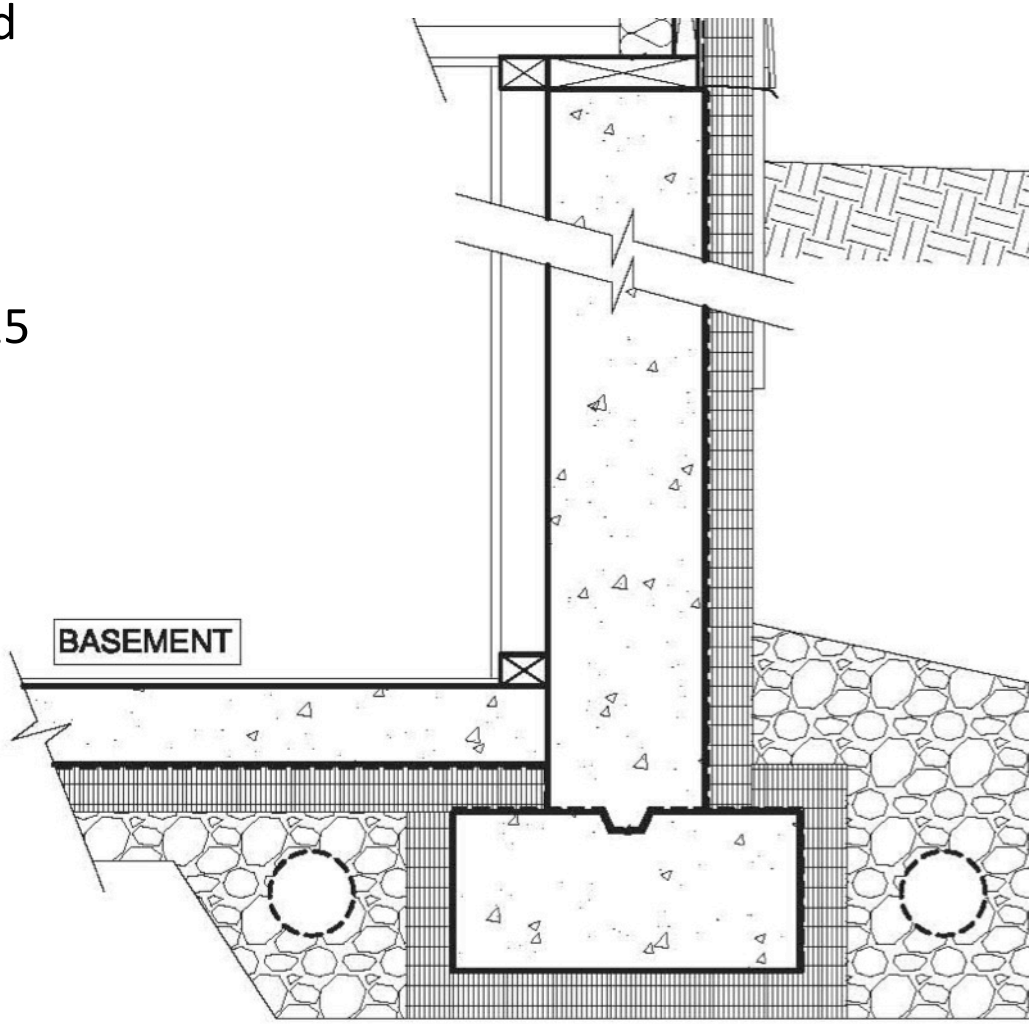
- **Thermal** insulation to retard heat flow
- **Water** control membrane to prevent wetting of moisture sensitive materials
- **Air** barrier to stop unwanted heat and moisture flow
- **Vapor** retarder strategy to prevent wetting, yet allow drying

  - **Orange**: W.R. Grace Perm-a-Barrier
  - **Red**: Huber ZIP sheathing system
  - **Blue**: Foundation waterproofing
  - **Purple**: Cross-laminated polyethylene membrane



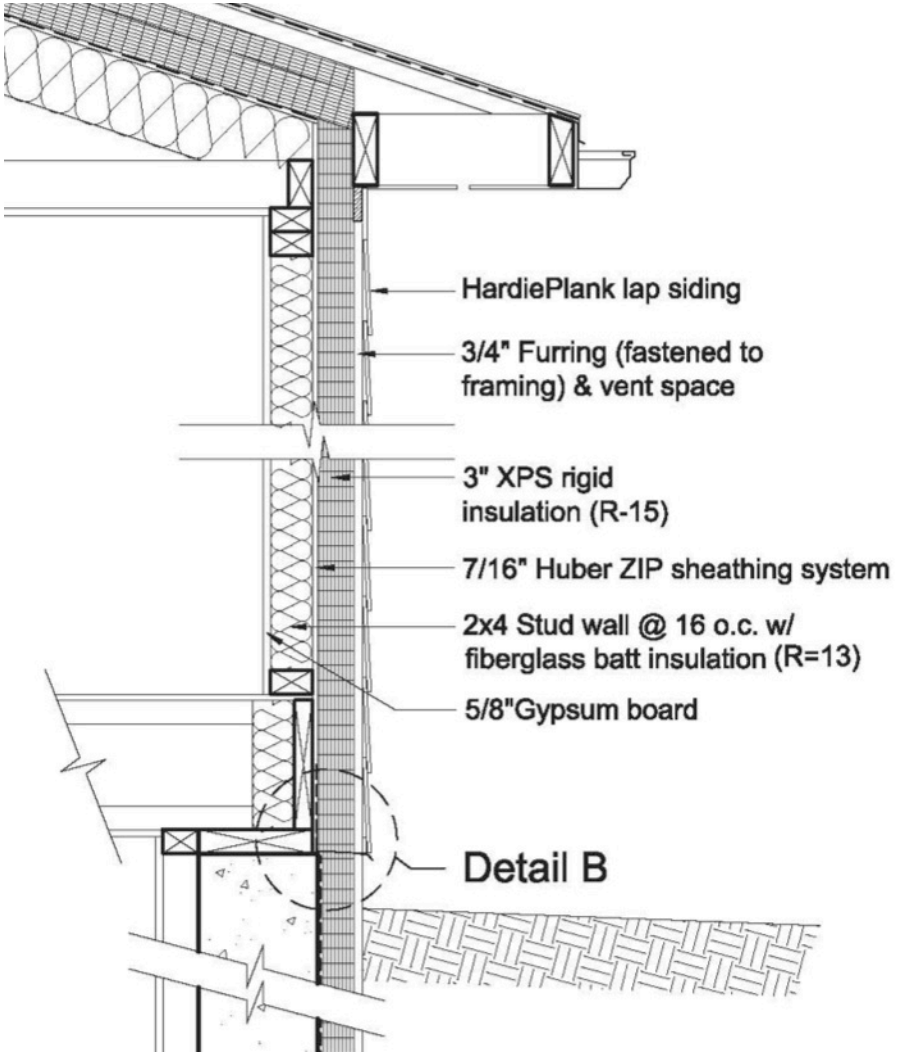
FOUNDATION STRATEGY | Airtight, Dry, & Warm

- Exterior waterproofing and insulation
  - Slab is R-10
  - Footing is R-10
  - Foundation wall is R-15
- Good drainage
- Capillary breaks



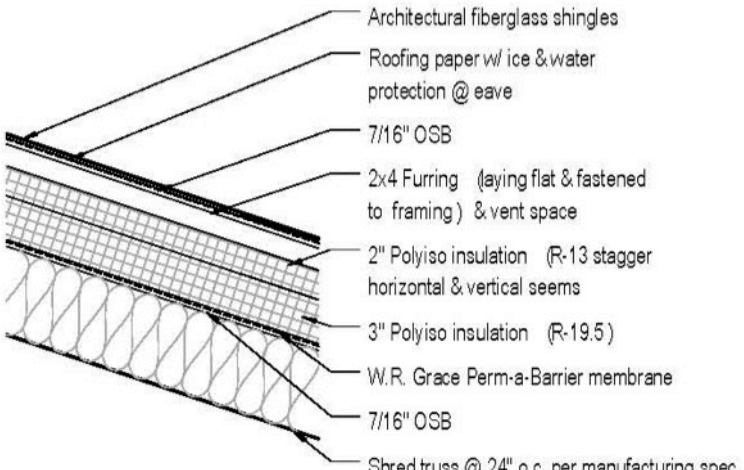
HYBRID WALL STRATEGY | Robust & Easy to Construct

- The air, water, and vapor control layer is over a traditional wood-frame wall
- Then rigid insulation, vented rainscreen, and siding is added to the exterior
- This approach limits moisture movement, yet facilitates bi-directional drying



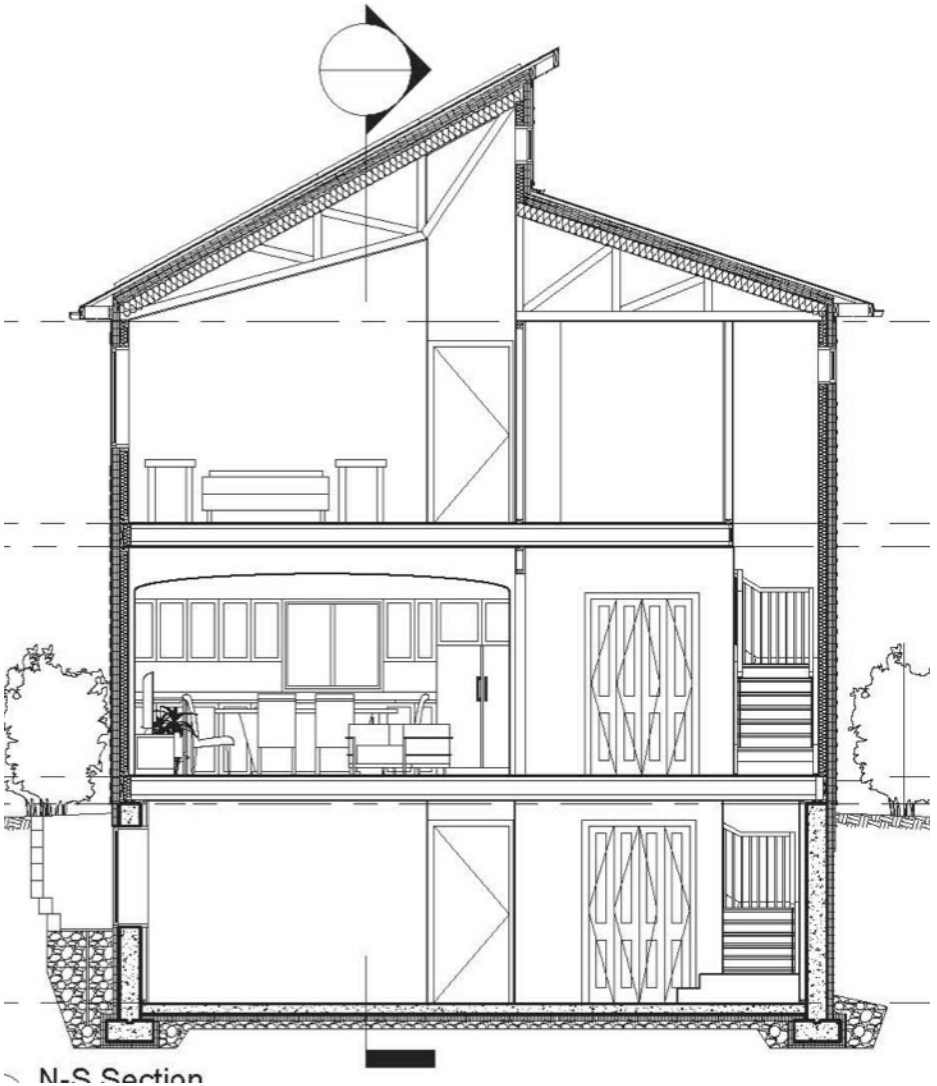
HYBRID ROOF STRATEGY | Adds Flexible Space & Robust

- Provides additional space for design, living, storage, & mechanicals
- Manages moisture & mitigates ice dams much better than traditional sloped ceilings



NORTH ROOF DETAIL

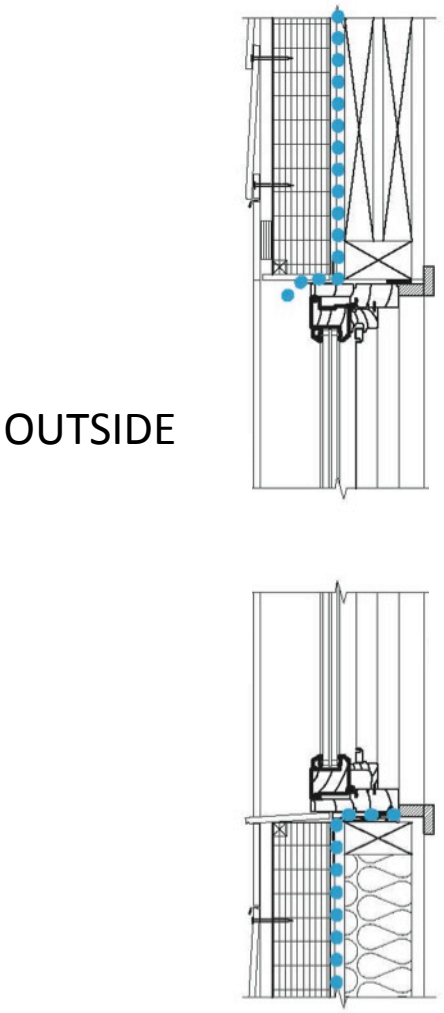
Total R-value = 53
Insulation 60/40 Ratio



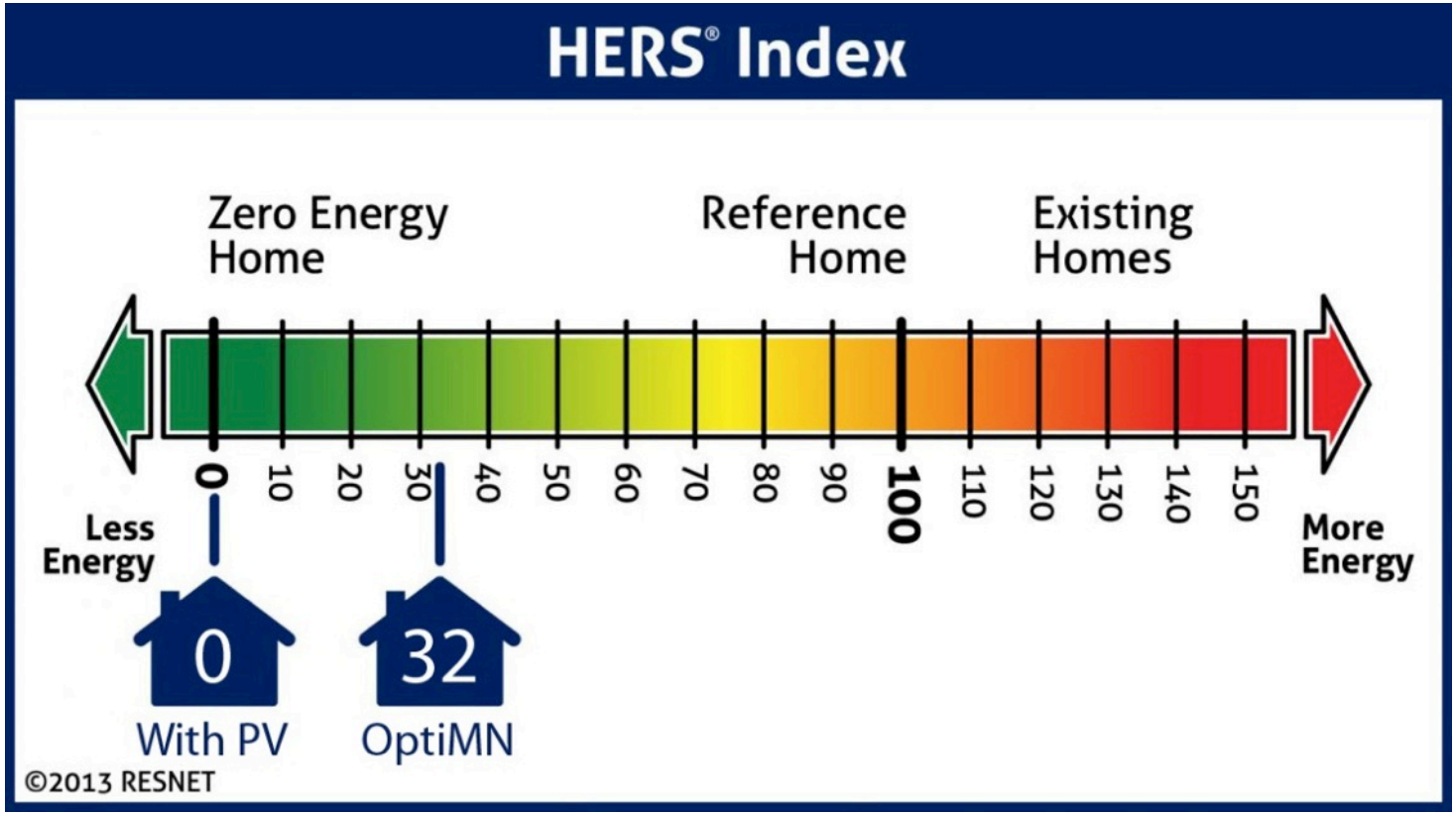
N-S Section

FENESTRATION STRATEGY | Efficient & Affordable

- Used high-performance double-pane, low emissivity, gas filled windows
  - U-value = .27
  - SHGC = .20
- Cost less than triple or quad pane and still achieved our performance goals



PERFORMANCE



Heating, cooling, and water heating costs is approximately **$420 / year**

CONCLUSION | IMPACT Home by Team OptiMN

Department of Energy's CHALLENGE
to build a Zero Energy Ready Home

→ **HERS score of 32** without PV
HERS score of 0 with PV

Urban Homeworks' MISSION
to produce equitable, dignified, communities

→ **An affordable house design that is larger, more flexible, and higher performance.**

Green Homes North INITIATIVE
to revitalize North Minneapolis neighborhoods with affordable, sustainable, and quality homes

→ **Giving new life to a vacant lot with a highly efficient home design for the future**

Team OptiMN's GOAL
is to design a home that makes an **IMPACT** by achieving all of the above

→ **We successfully met these goals by creating an affordable, high-performance home that truly benefits the owner, the community, and the environment**