



NorthernSTAR

A Building America partner in research, innovation, and real home solutions.



U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



NorthernSTAR

UNIVERSITY OF MINNESOTA
Driven to DiscoverSM

MonoPath – The “Perfect Wall” Made Affordable

Rolf Jacobson, LEED AP, CPHC
Skandia Design & Consulting
University of Minnesota, NorthernSTAR



MonoPath Research Team –
Pat Huelman, U of M
Tom Schirber, U of M

Industry Partners –
MonoPath, <http://www.mono-path.com/>

Original partners also included...
Amherst H. Wilder Foundation
Center for Sustainable Building Research (U of M)
Cocoon Home Performance

DOE FOA Control #1117-1522

MonoPath

A Whole Building Approach to High-Performance Affordable Housing

Technical Areas A,B and C
Climate Zones Hot/Humid, Mixed Humid, Cold


NorthernSTAR Building America Team and Partners

Subrecipients CSI, LLC Urban Homeworks Center for Energy and Environment Energy Center of Wisconsin Building Knowledge, Inc ABT Systems (Armin Rudd)	Consultants Gary Klein and Associates Simply Green Design Skandia Design & Consulting Wilson Ventilation Services	Industry Partners Huber Engineered Woods Unico, Inc Panasonic Home and Environment Co
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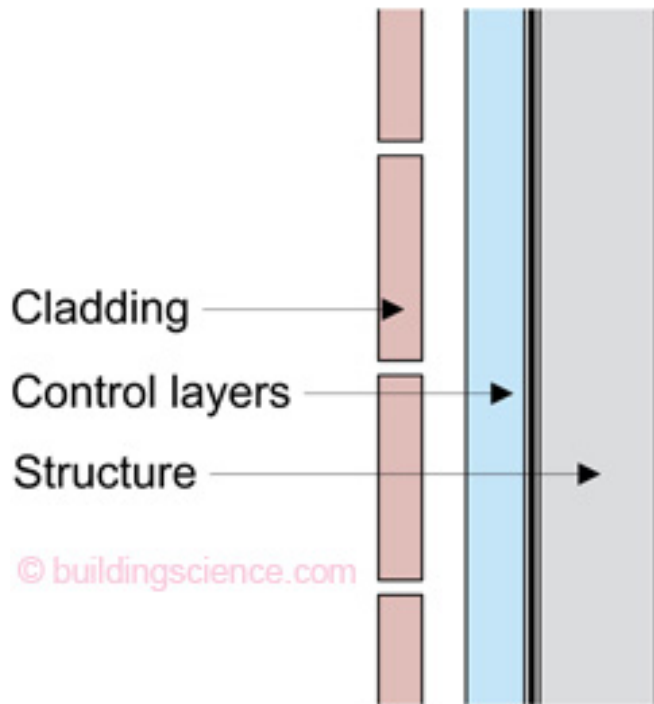
Day 1 → Day 6



Outline

- 1) Building science background – the perfect wall
- 2) Development of the MonoPath system
- 3) Adaptation to Passive House

Building Science Background



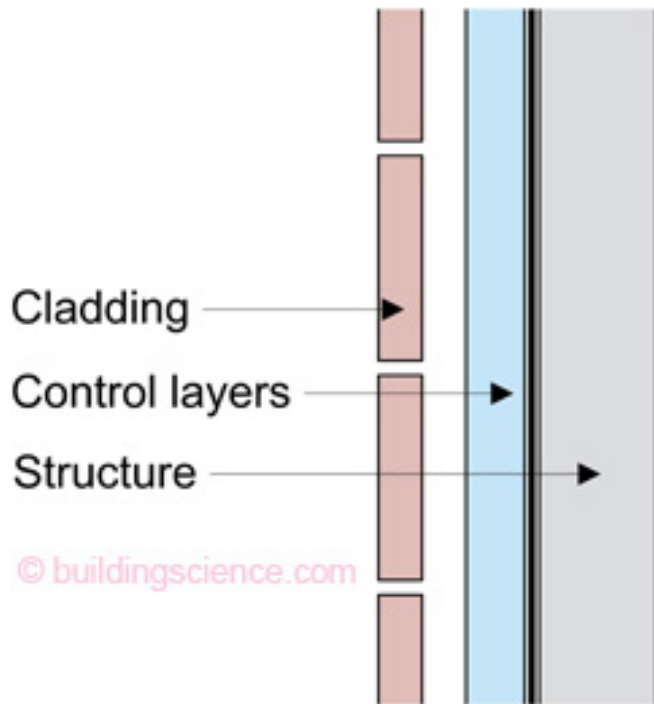
BSI-001 The Perfect Wall

Joseph Lstiburek, June 11, 2008

“The Perfect Wall—

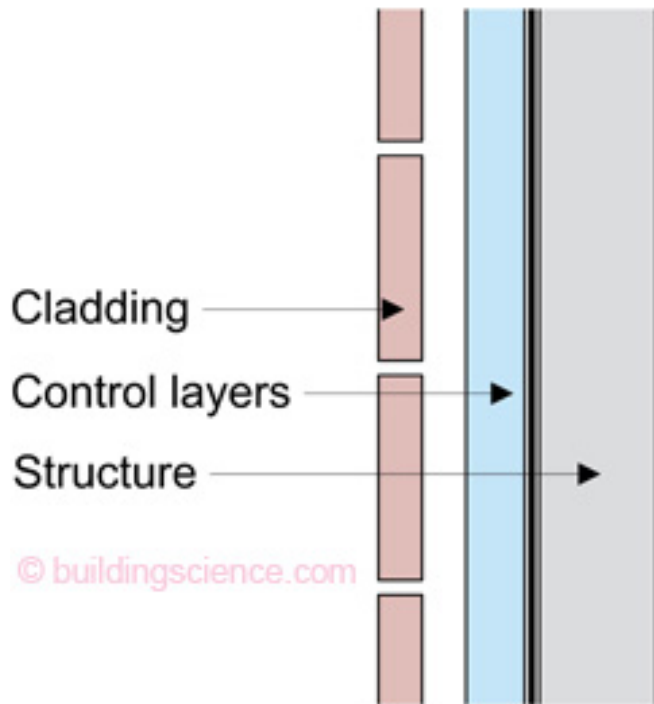
In concept the perfect wall has the rainwater control layer, the air control layer, the vapor control layer and the thermal control layer on the exterior of the structure. The cladding’s function is principally to act as an ultra-violet screen. Oh, and architects might consider the aesthetics of the cladding to be important.”

Building Science Background



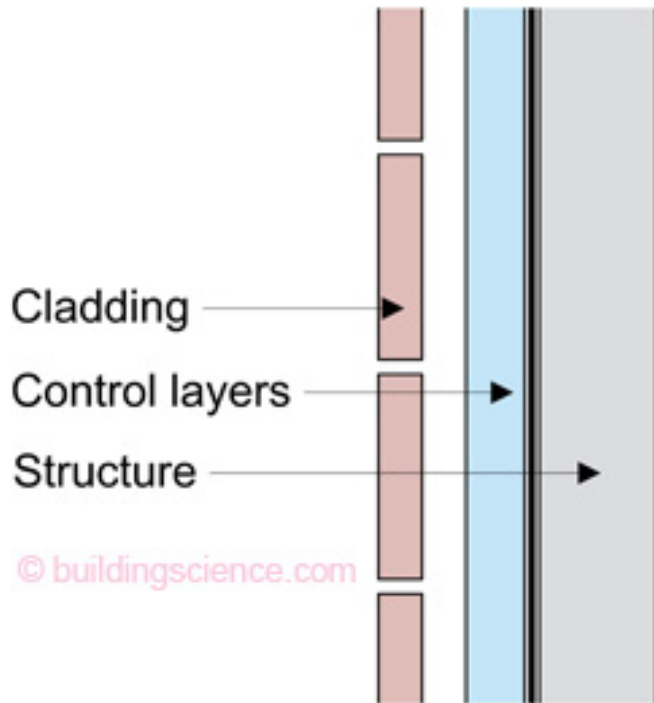
Structure is exposed to interior –
Structural elements are exposed directly to the interior
where ventilation and conditioned air can dry them
quickly and easily.

Building Science Background



Structure is kept warm –
Exterior insulation keeps structure at room temperature.
Heat drives off moisture and helps keep critical structural elements dry.

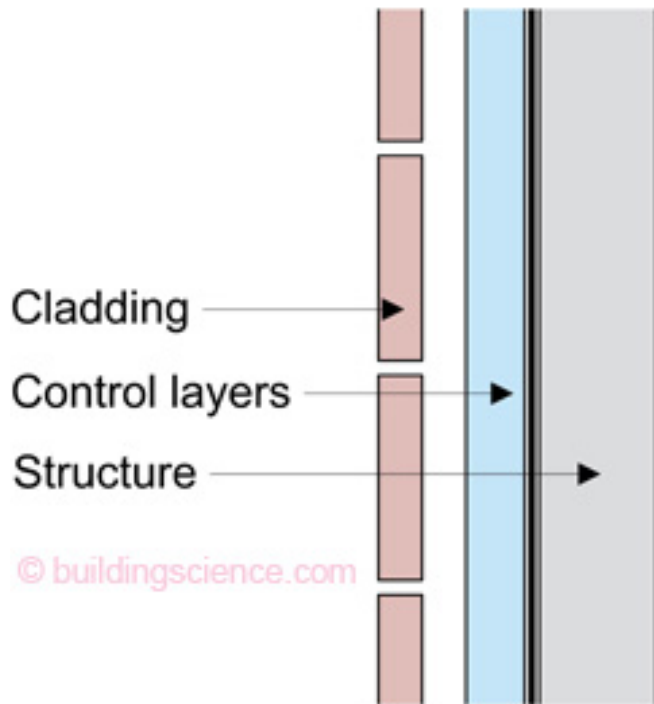
Building Science Background



Structure is kept at constant temperature –
Minimizes thermal stress and differential movement.

© buildingscience.com

Building Science Background



Cladding

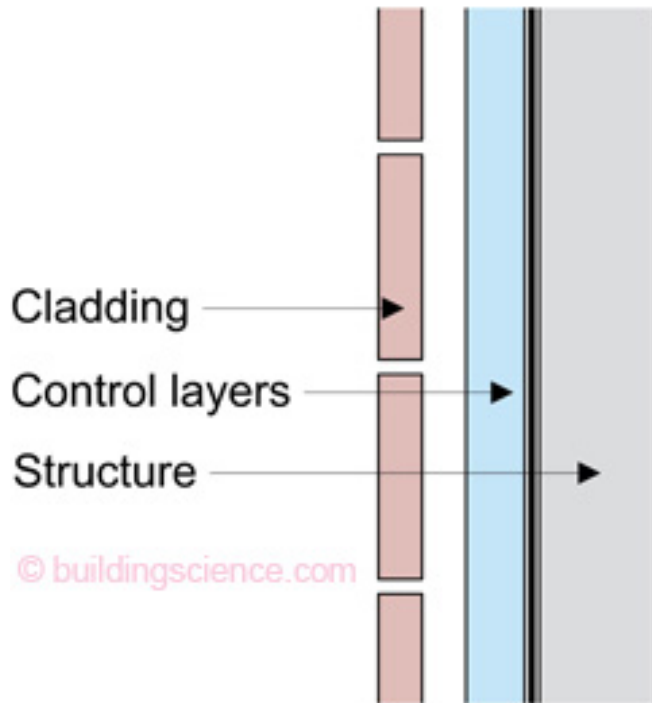
Control layers

Structure

© buildingscience.com

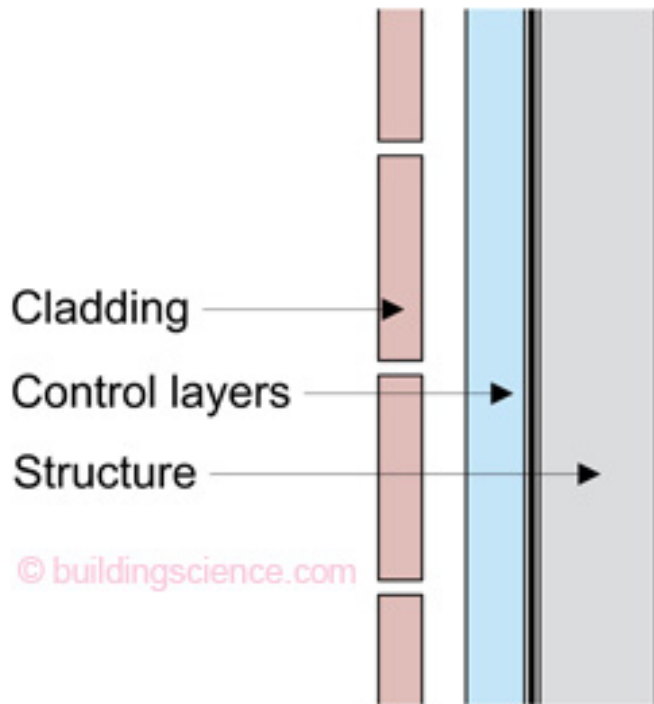
Critical control layers are protected— Vapor retarder, air barrier, and weather barrier are protected from radiation, temperature extremes, large amounts of water, and puncture.

Building Science Background



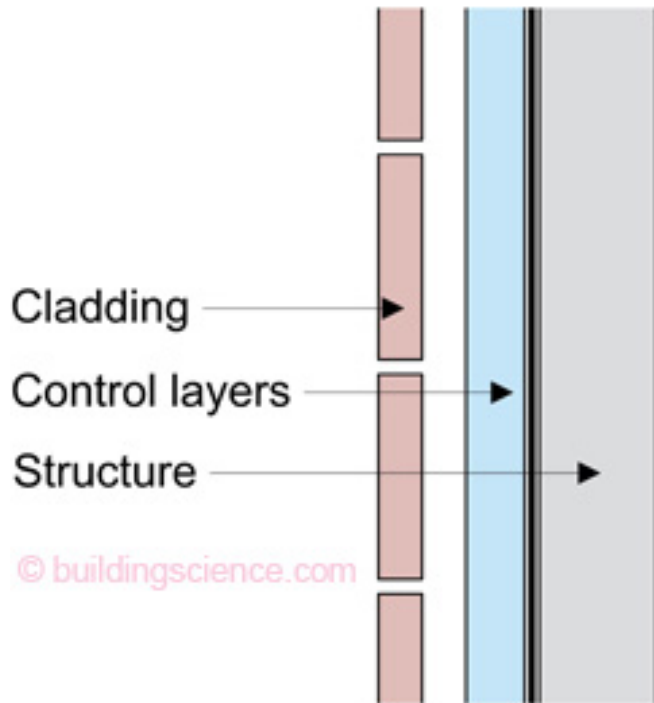
Critical control layers are simplified—
Installation of 3 layers (vapor retarder, air barrier, and weather barrier) is reduced to 1 membrane, either peel + stick, liquid or spray applied, or factory applied.

Building Science Background



Critical control layers are simplified—
Complex and sometimes unanticipated interactions
between vapor retarder, air barrier, and weather barrier
are eliminated as multiple layers are reduced to one.

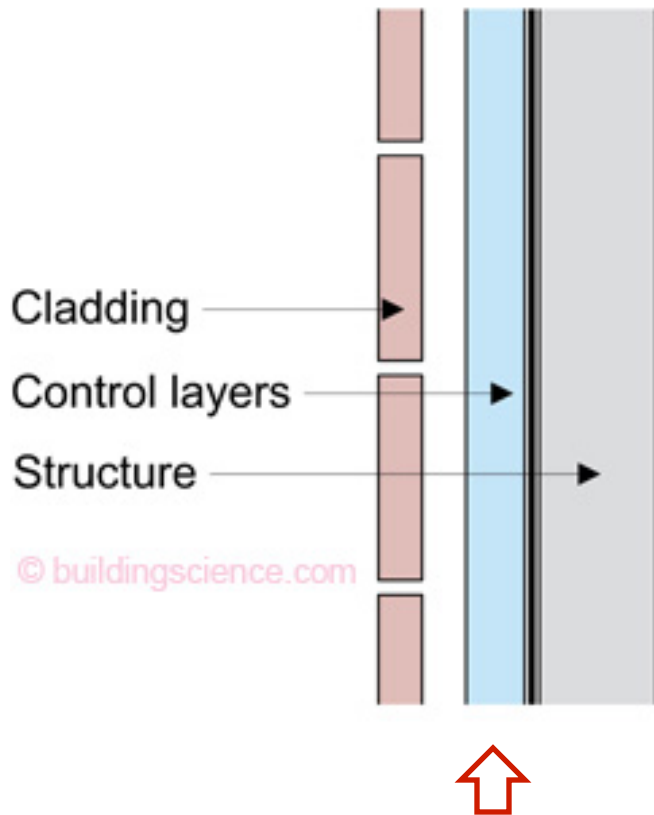
Building Science Background



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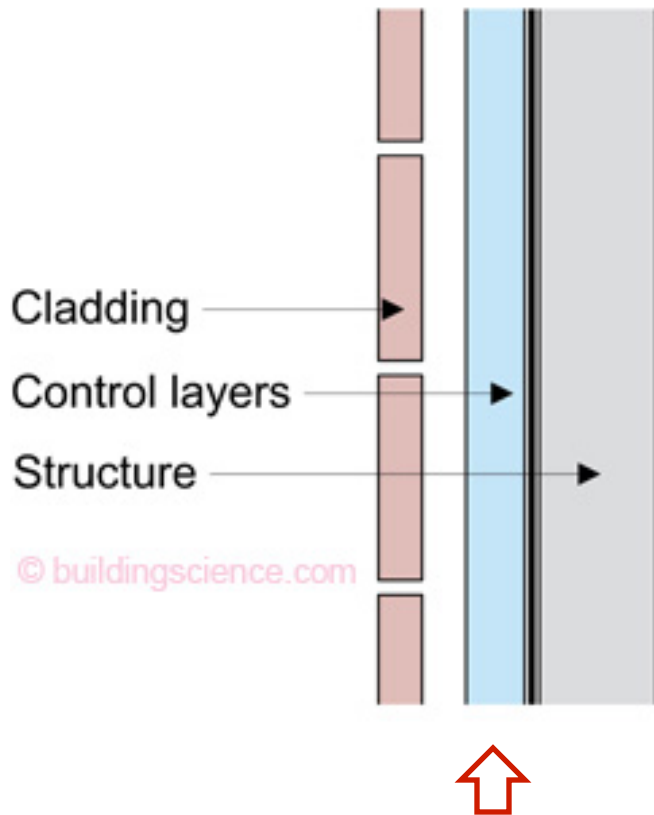
Critical control layers are simplified—
One QA/QC check can verify the integrity of all three
control layers.

Building Science Background



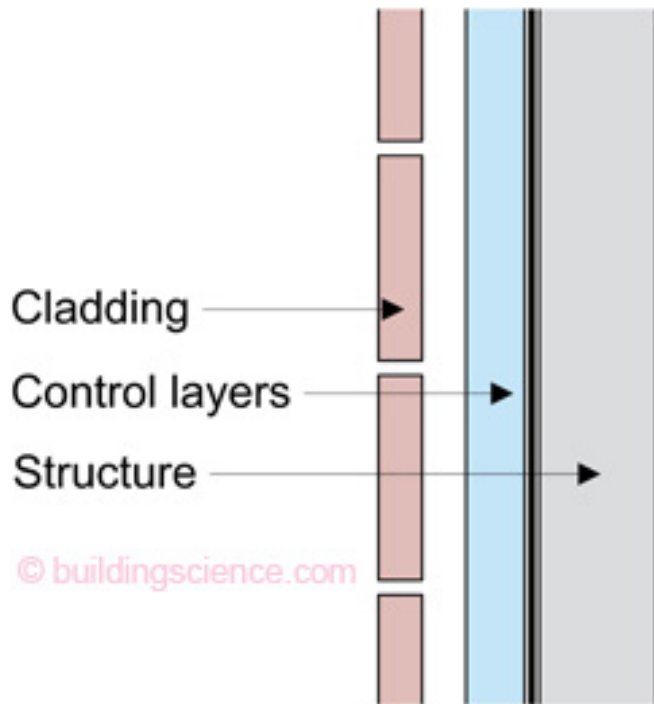
Exterior insulation is continuous –
Heat loss from thermal bridging is eliminated.

Building Science Background



Exterior insulation is continuous –
Winter-time condensation on cold sheathing is
eliminated.

Building Science Background

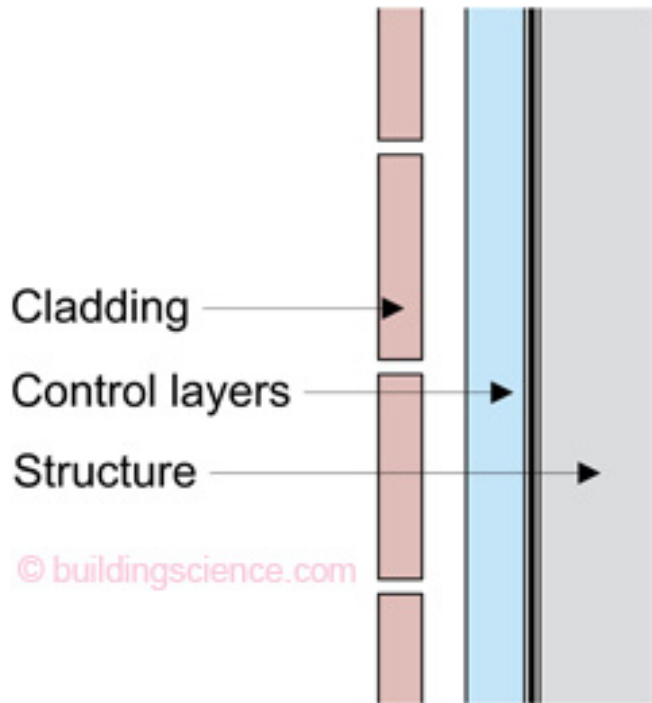


Air gap improves performance of insulation and durability of cladding –

Air gap has five-fold functionality:

- allows drainage of bulk water that penetrates cladding or roofing
- reduces pressure of wind driven rain
- prevents wet siding and roofing from contacting the sheathing (capillary action)
- assists evaporative drying of both siding and insulation
- reduces penetrations through the weather barrier

Building Science Background

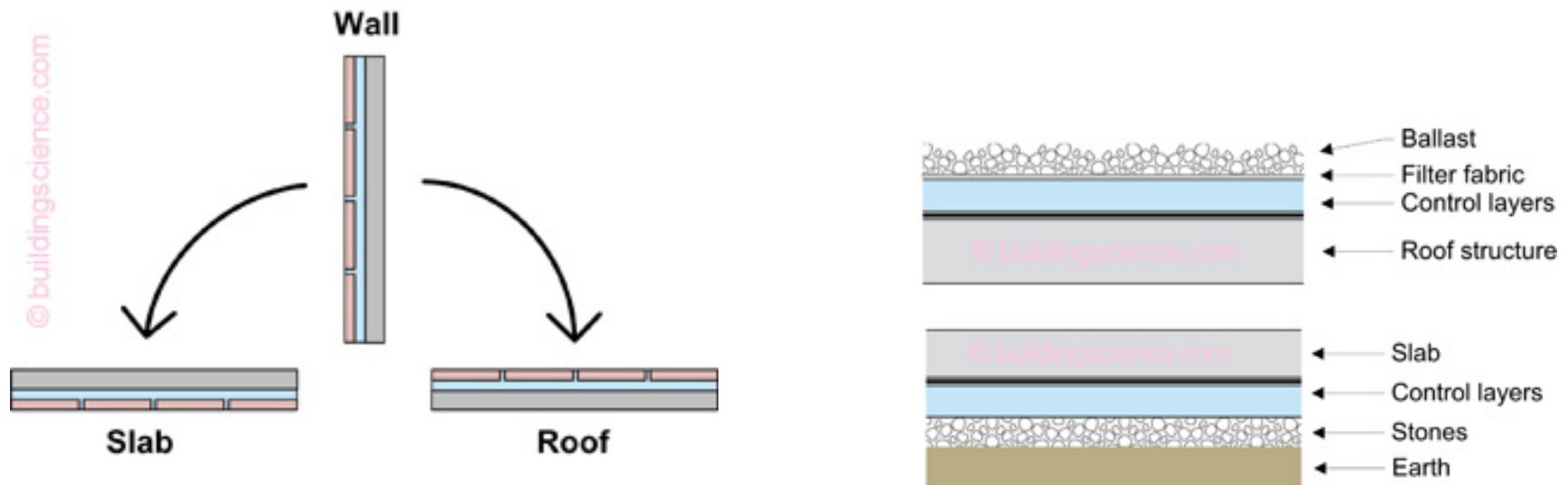


The Perfect Wall can be used in any climate zone –
(As long as insulation is moisture safe)

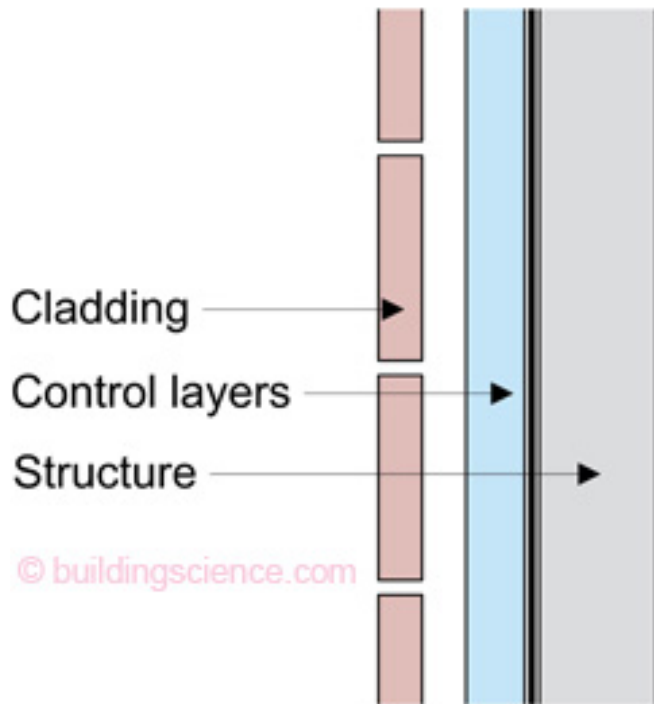
Building Science Background

“In a beautiful bit of elegance and symmetry if you lie the perfect wall down you get the perfect roof and then when you flip it the other way you get the perfect slab. The physics of walls, roofs and slabs are pretty much the same —no surprise.”

— Joe L.



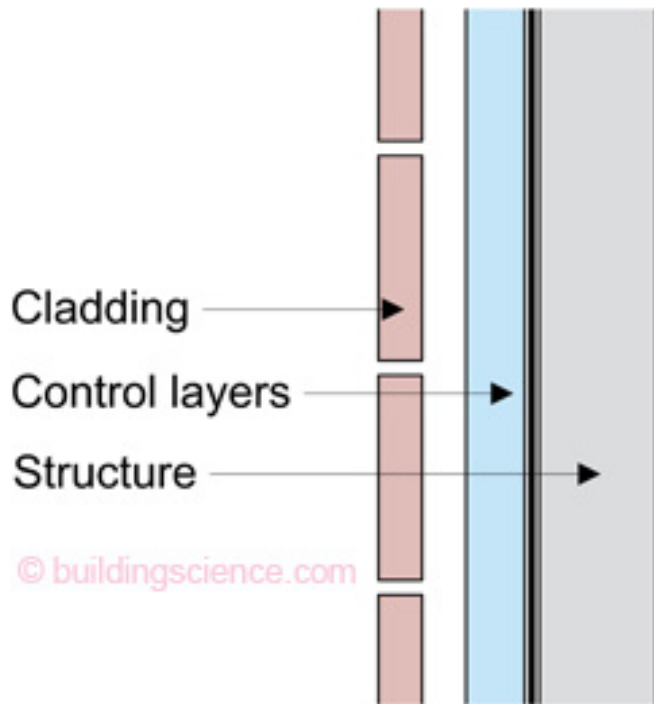
Building Science Background



Benefits:

- Structure is kept warm
- Structure is kept at constant temperature
- Structure is kept dry
- Critical control layers are protected
- Critical control layers are simplified
- Insulation is continuous
- Air gap improves performance of insulation and durability of cladding.
- The Perfect Wall can be used in any climate zone.

Building Science Background

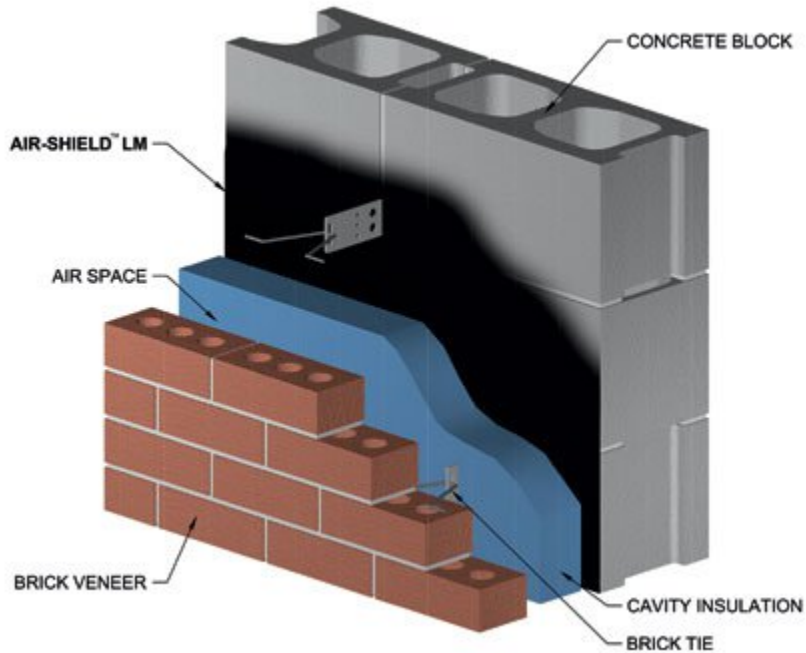


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- The Perfect Wall can be used in any climate zone.

The Perfect Wall is the most robust, durable wall we know how to build.

Building Science Background



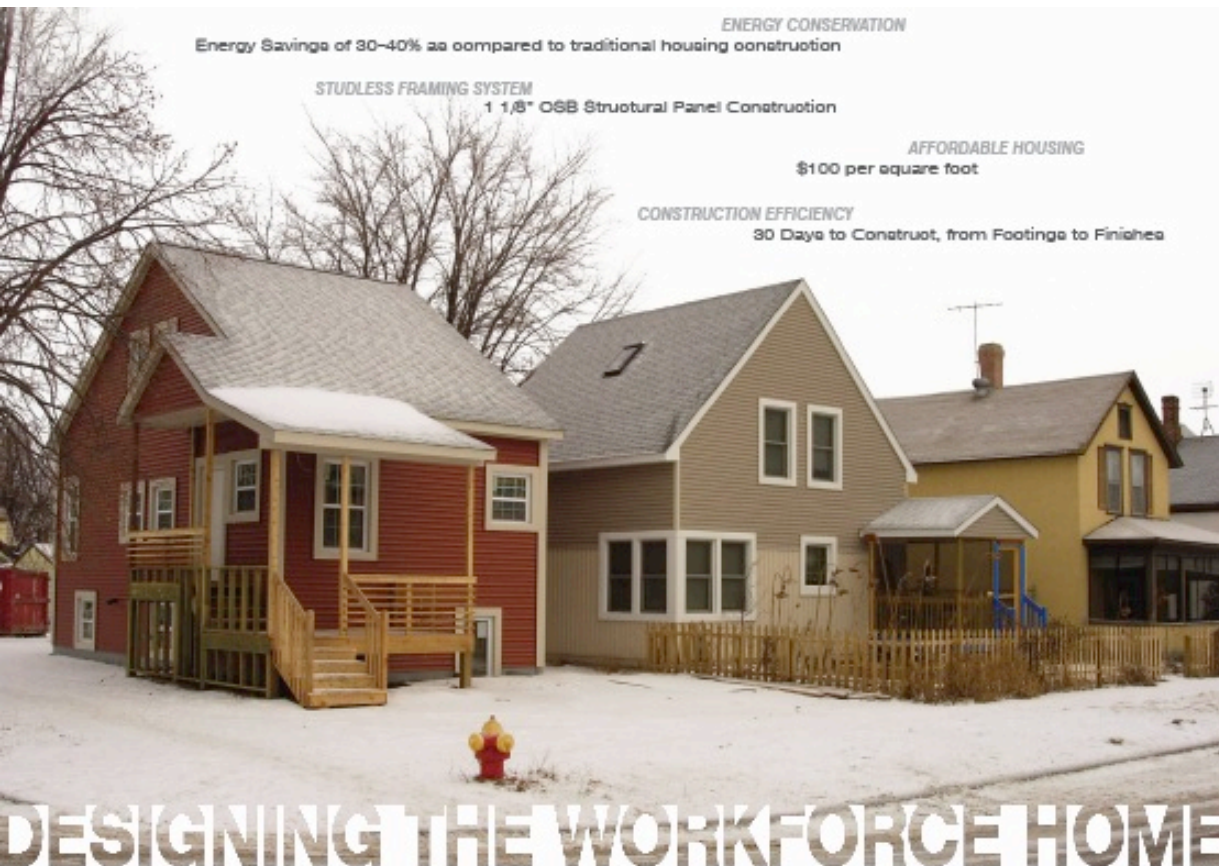
Of course, nothing this good ever comes cheap:
Problem with the Perfect Wall: EXPENSE



Development of the MonoPath System

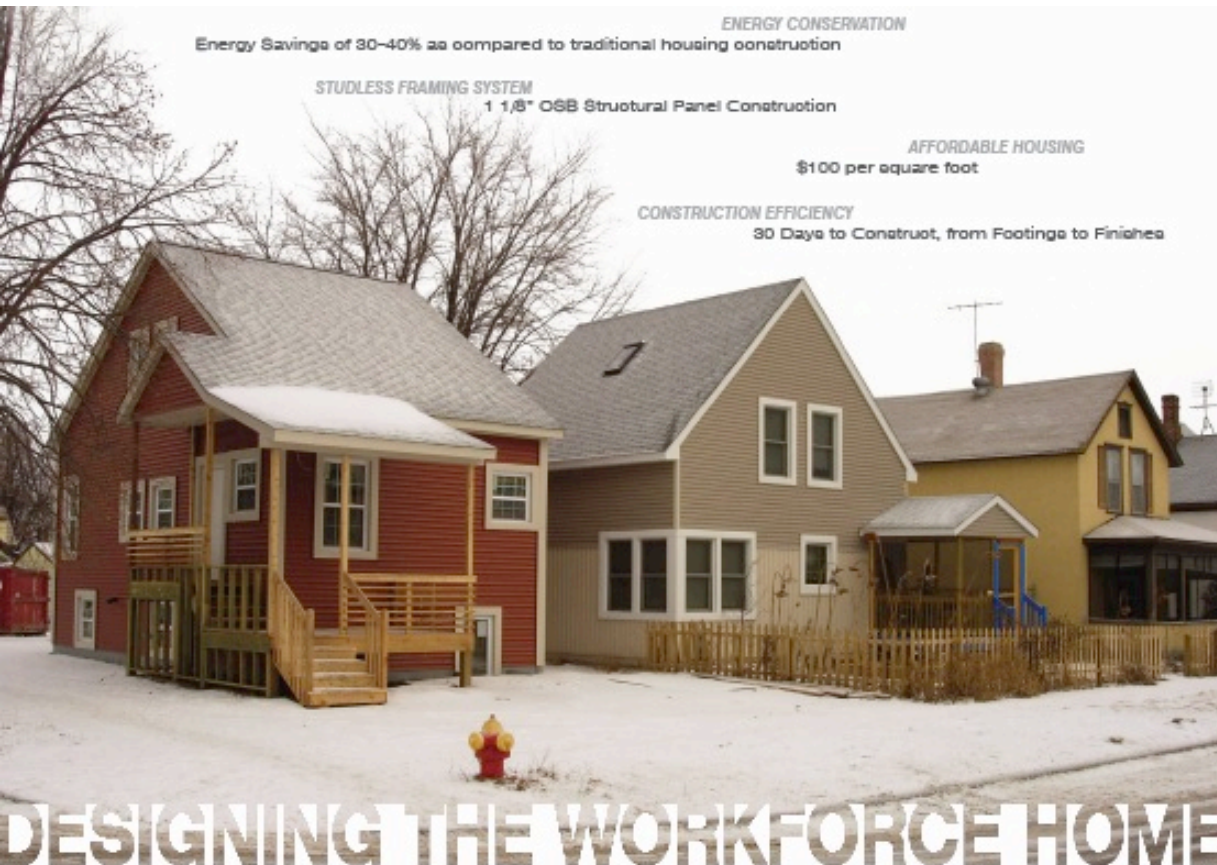
What if we could get the energy, hygrothermal, and durability benefits provided by the perfect wall AND make it affordable for housing?

Development of the MonoPath System



In early 2000's U of M researchers teamed with the Wilder Foundation to develop a prototype wall for affordable housing. Goals:

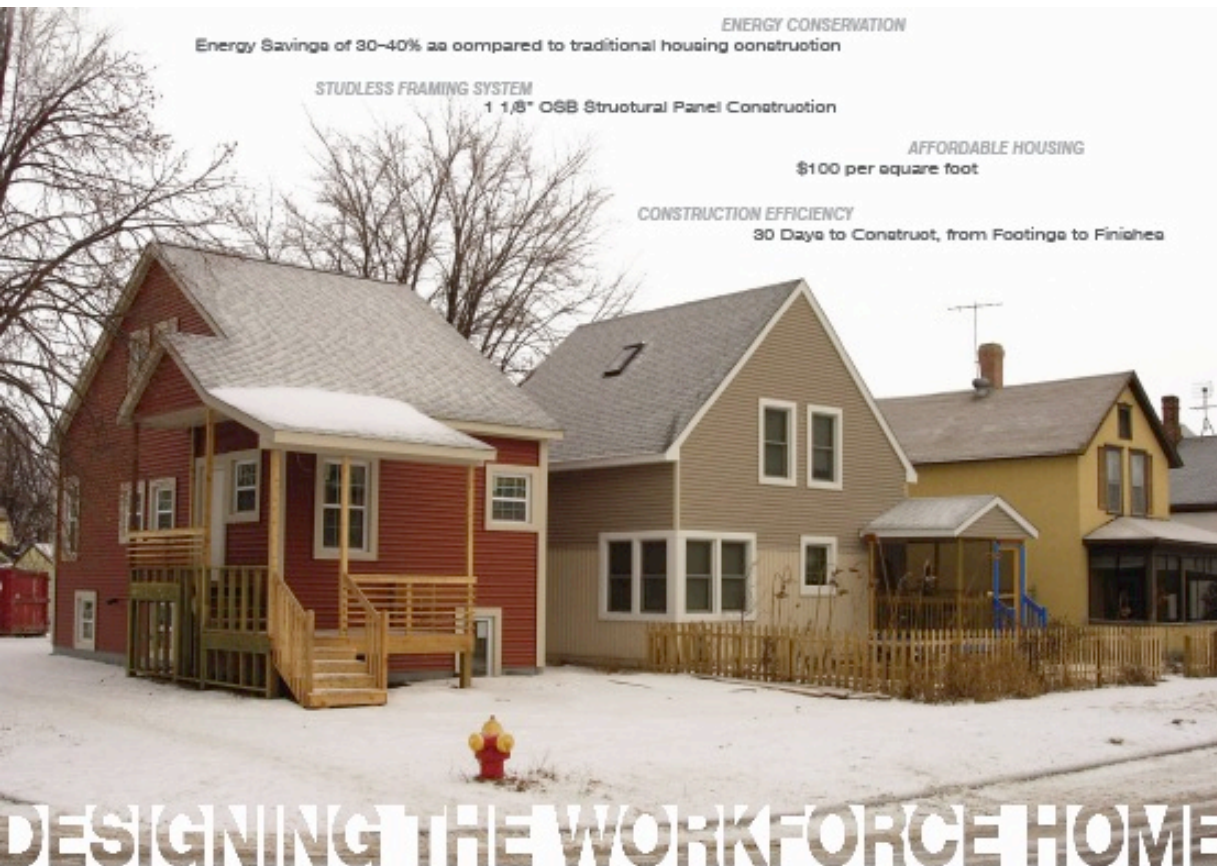
Development of the MonoPath System



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1. energy efficient (whole house savings of 30-40%)

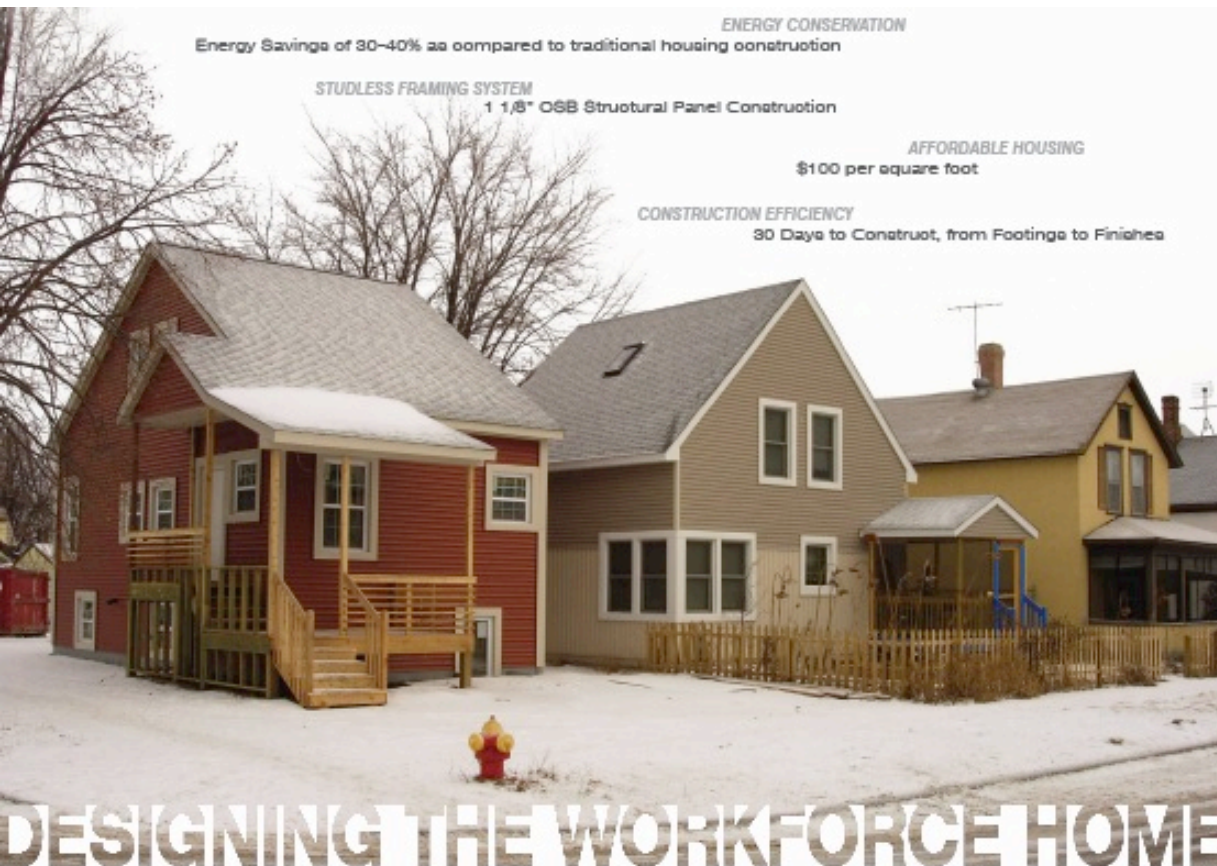
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2. fast, prefab construction (30 days to construct from footings to finishes)

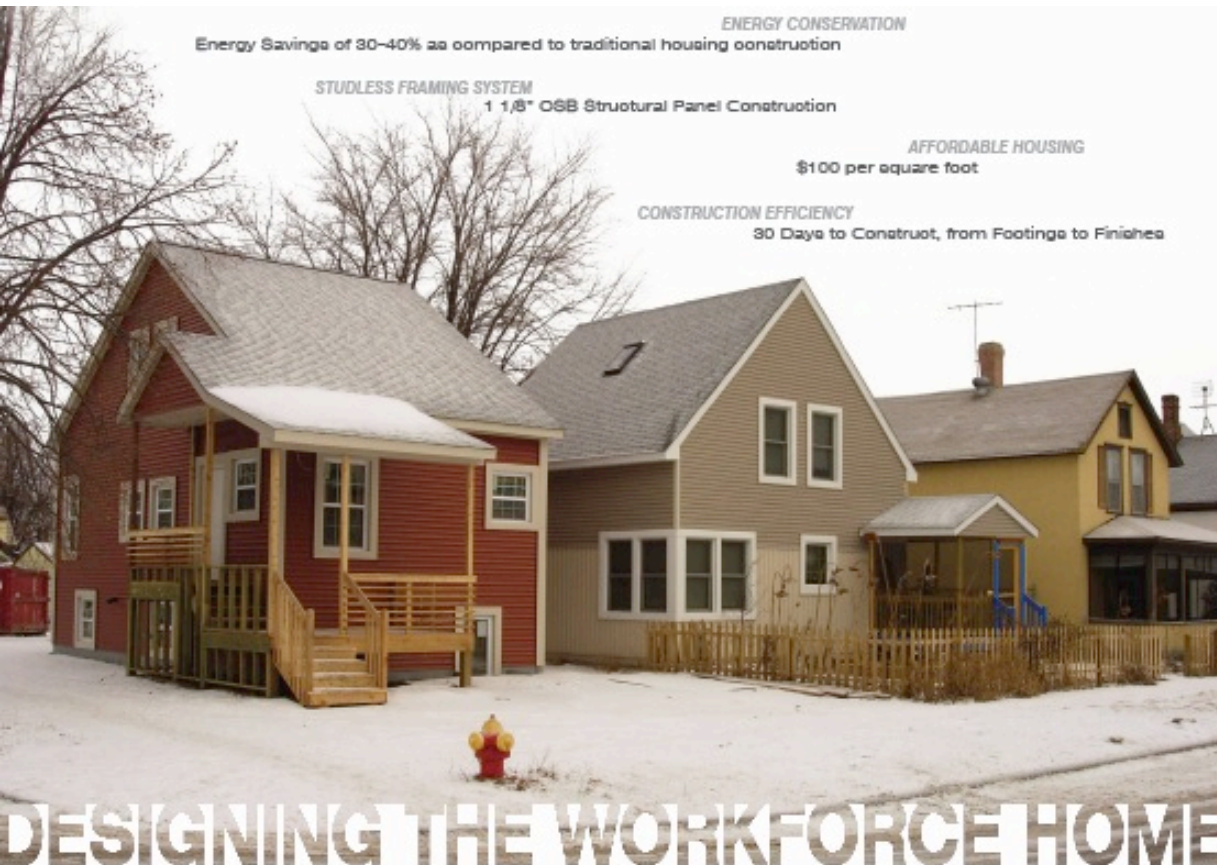
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Development of the MonoPath System



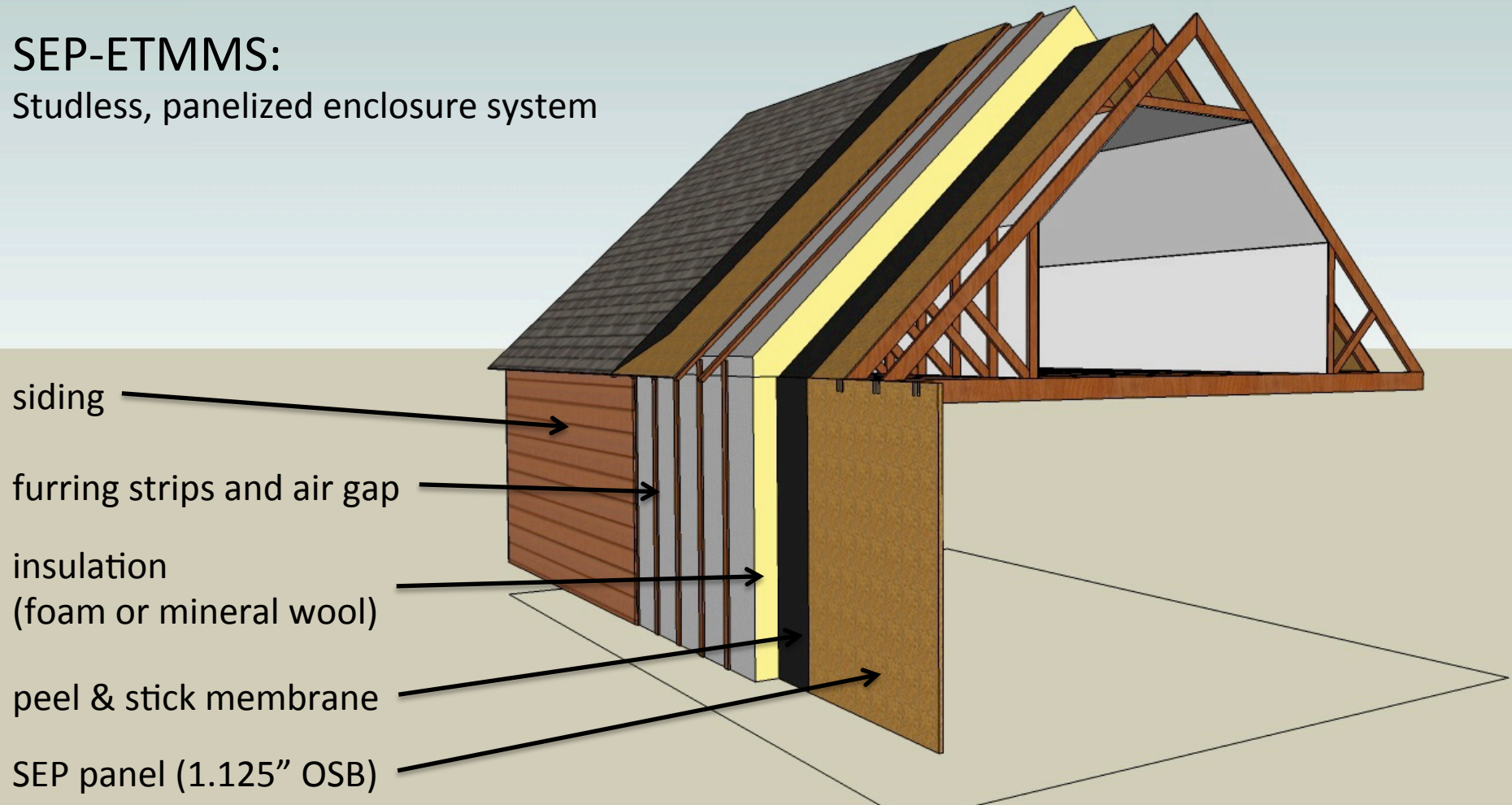
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2. fast, prefab construction (30 days to construct from footings to finishes)
3. affordable (\$100/sf)
4. robust, moisture safe construction (modeled on Perfect Wall principles)

Development of the MonoPath System

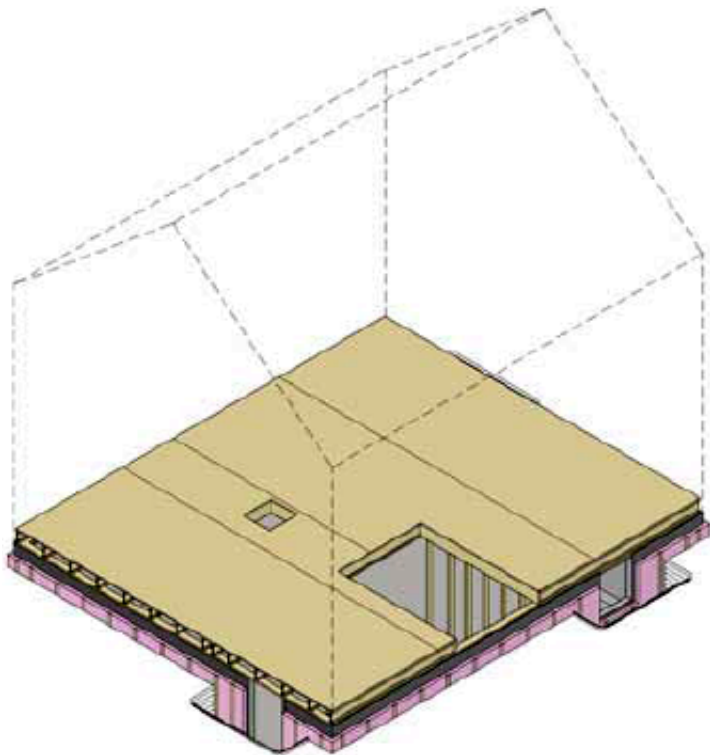
SEP-ETMMS:

Studless, panelized enclosure system



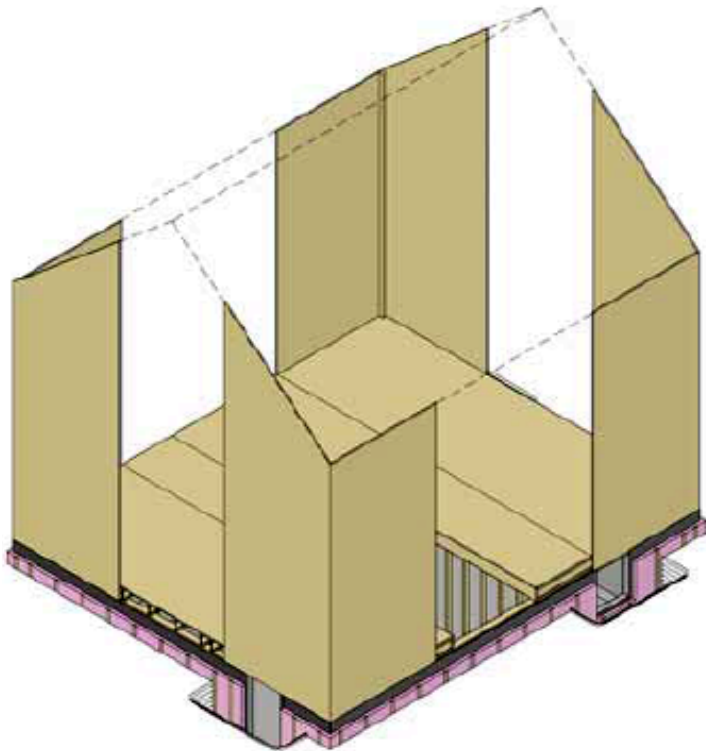
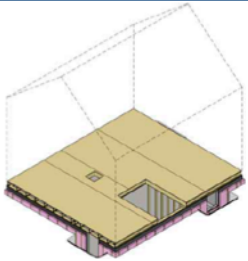
Development of the MonoPath System

Original SEP-ETTMS construction sequence



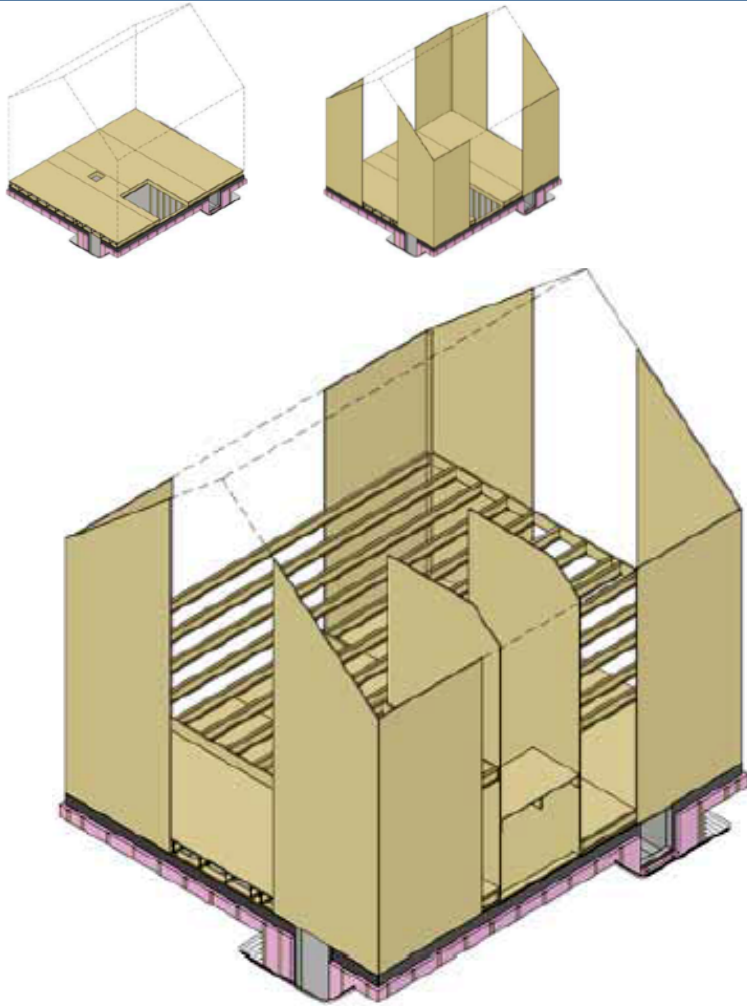
Begin with standard construction below grade.

Development of the MonoPath System



Crane tilts wall corners up first. Panels are up to 8' x 24' in size. Panels are attached at the bottom to the rim joist with screws and to each other using 4x4 posts.

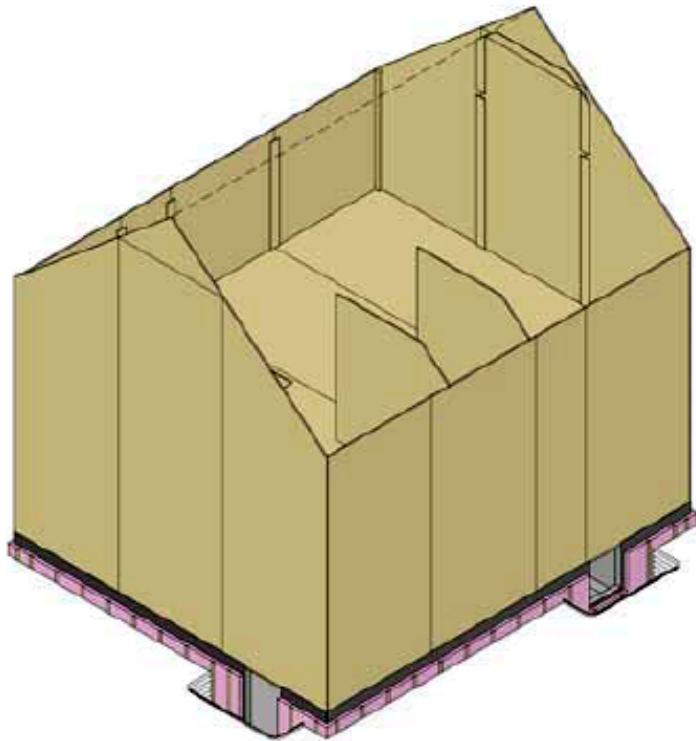
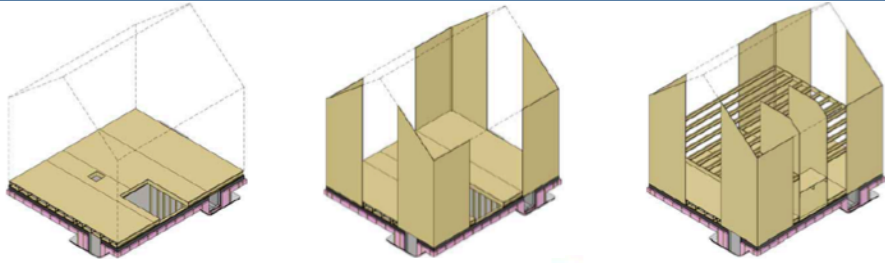
Development of the MonoPath System



Continuous ledger board links each corner. Connection between wall panels and floor diaphragm provides shear strength. Floor joists hung on metal hangers.

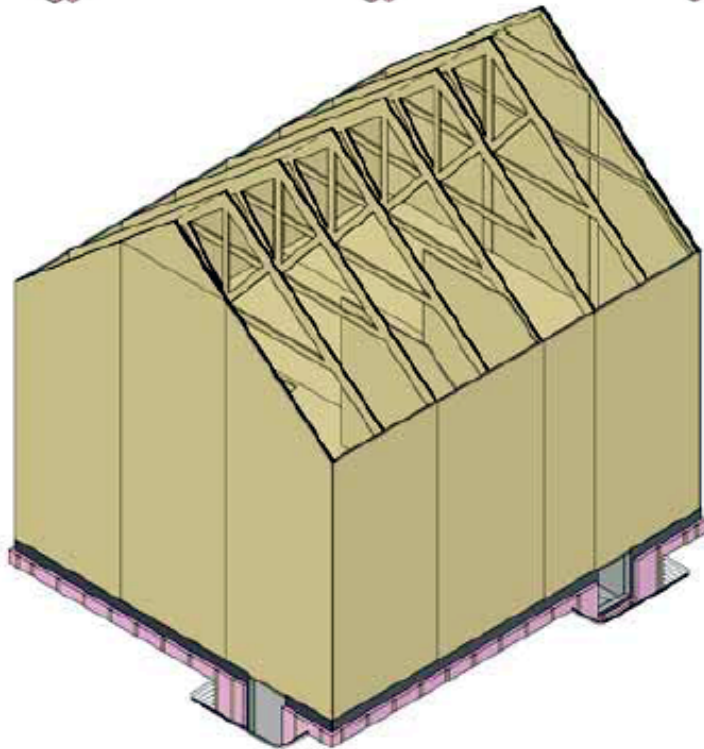
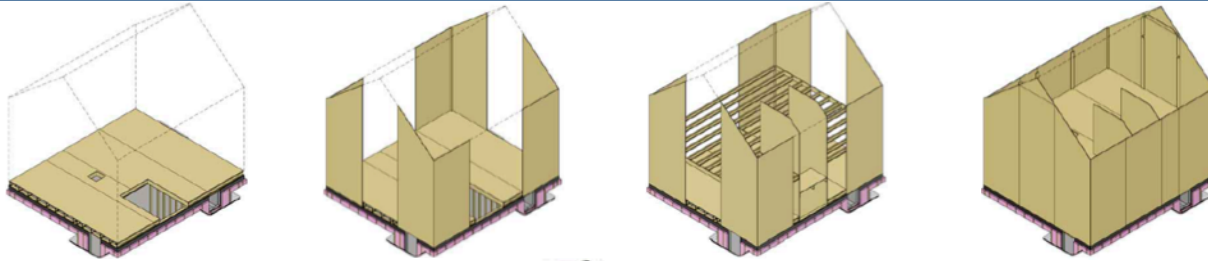
Structure begins to stiffen.

Development of the MonoPath System



Mid-wall sections and wall tops are lifted into place. Mid-wall panels are connected to each other with battens.

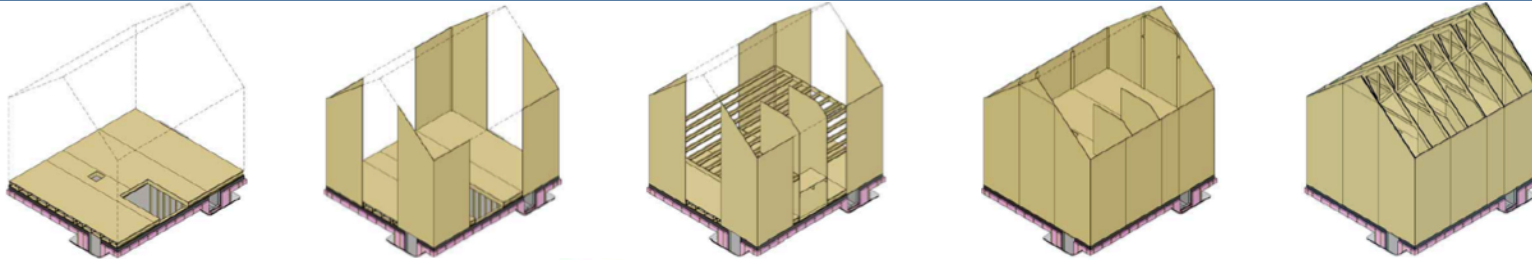
Development of the MonoPath System



Second ledger board for roof trusses link wall panels at the top.

Roof trusses are lifted into place with crane and installed with metal hangers.

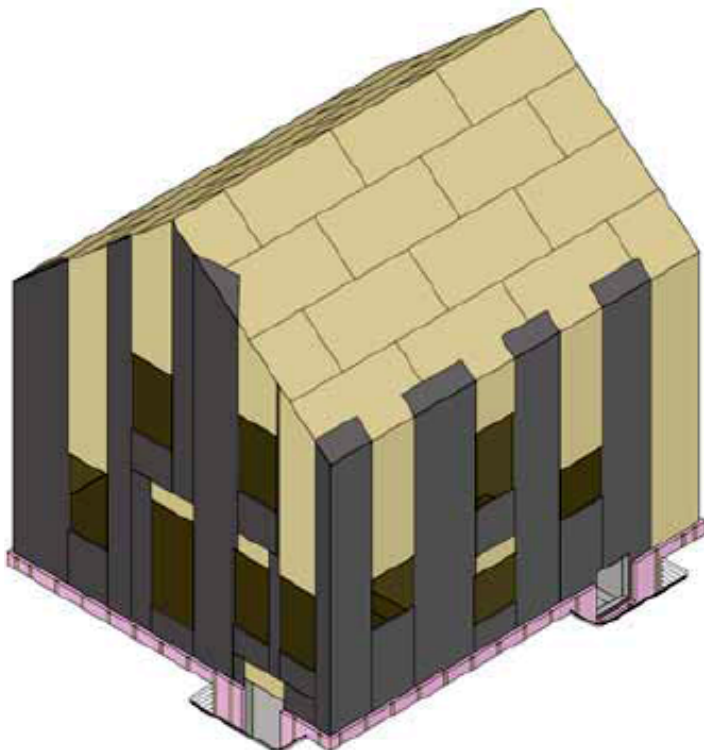
Development of the MonoPath System



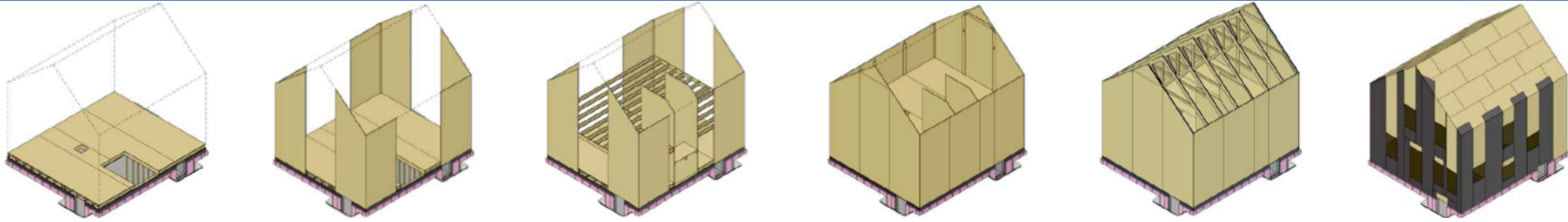
Roof deck is completed with standard 7/16" OSB. Structure is complete and full strength.

Window openings are cut (if not pre-cut in factory).

Peel & stick membrane (water, vapor, and air control layer) is installed up to windows sills.



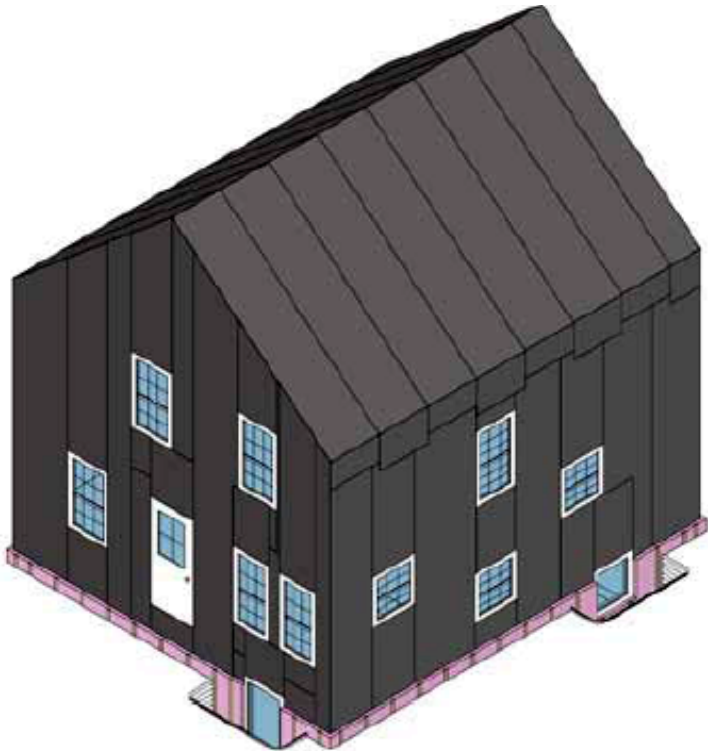
Development of the MonoPath System



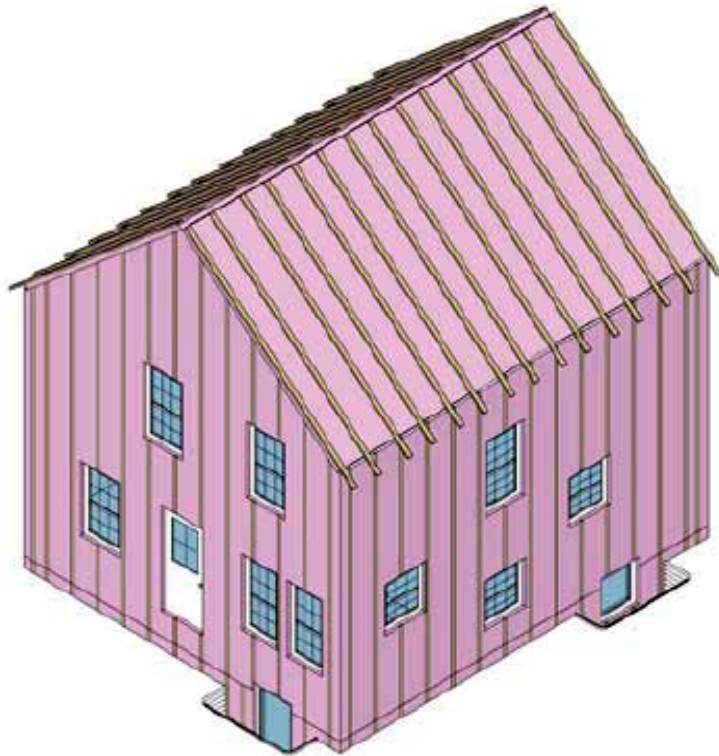
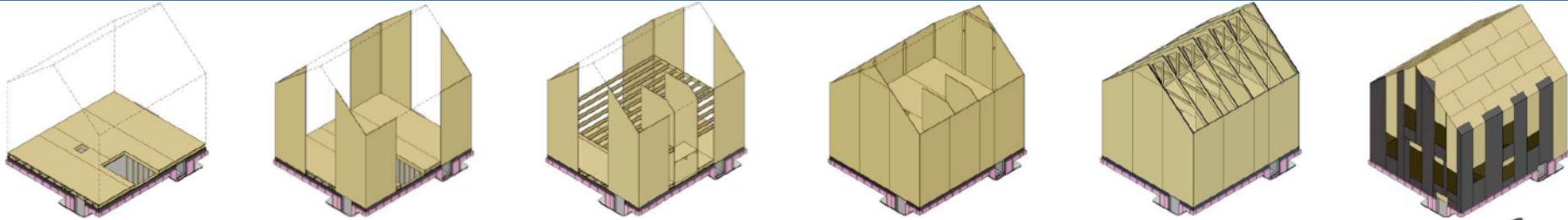
Flanged windows and doors installed.

Peel & stick membrane installation continues. Membrane laps over flange at window head and is continued up to roof peak, shingle fashion.

Structure is now essentially air and water tight.

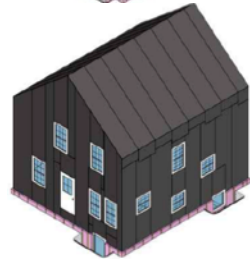


Development of the MonoPath System

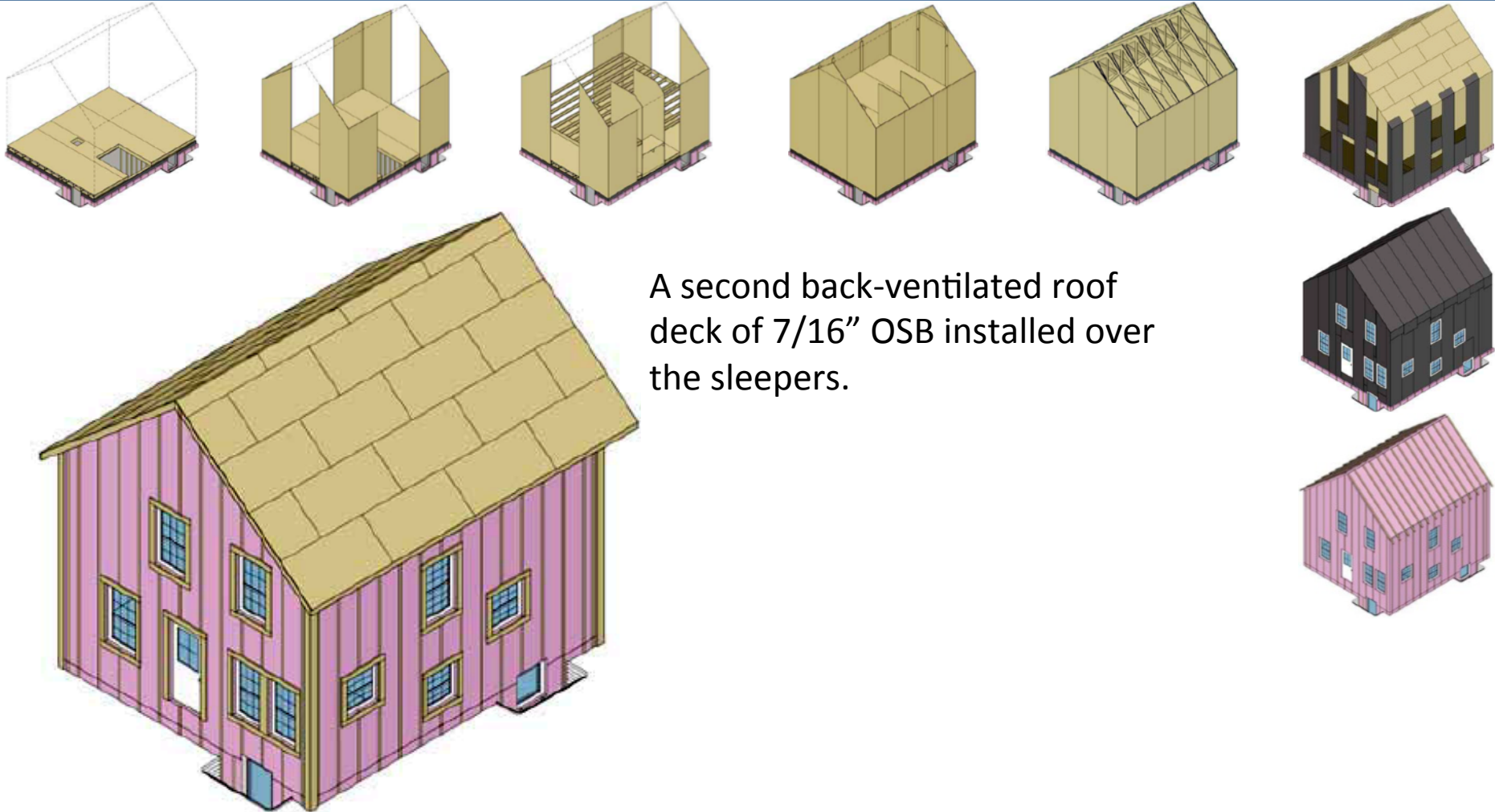


Exterior insulation is applied. Vertical laps in peel & stick membrane provide tiny pathways to drain water that migrates behind the insulation.

Furring strips and sleepers installed over insulation, cinching it down and providing drainage behind cladding.

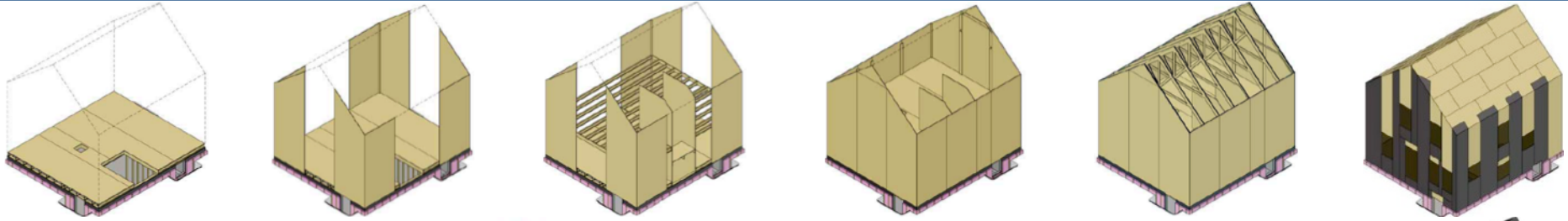


Development of the MonoPath System

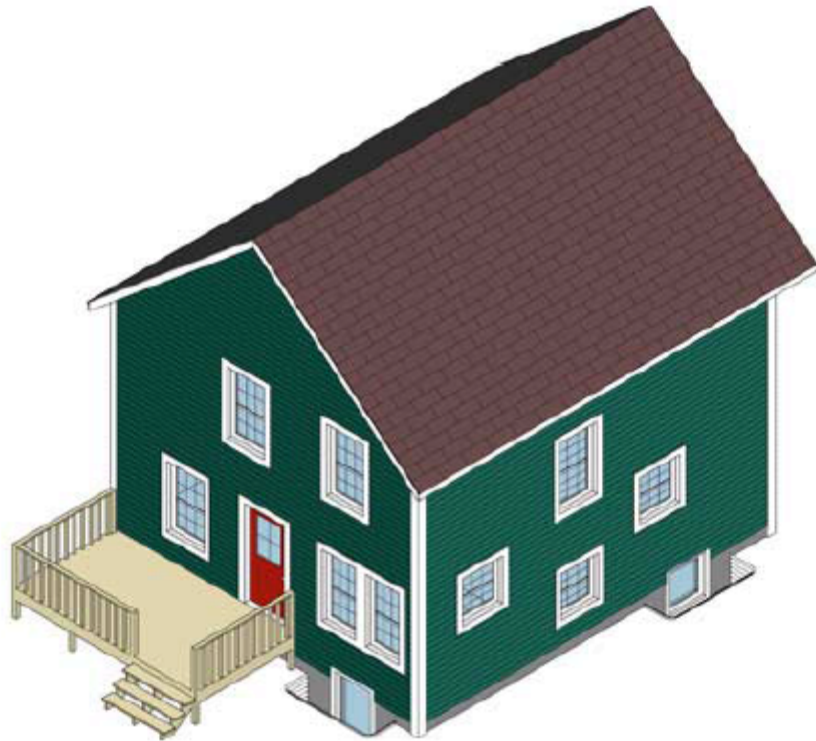


A second back-ventilated roof deck of 7/16" OSB installed over the sleepers.

Development of the MonoPath System



Back-ventilated siding and roofing finishes the exterior.



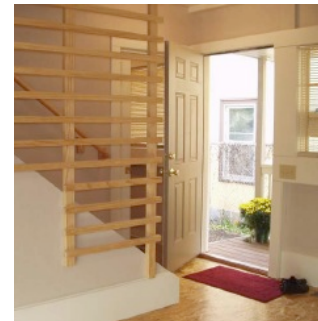
Development of the MonoPath System



Day 1, structure complete



Week 1, house water tight



Month 1, house complete

Development of the MonoPath System

First round of construction – 2003/2004

- 4 homes built for affordable housing partner
- Experimented with a variety of house sizes and shapes
- Average airtightness: 0.8 ACH@50Pa
- Achieved all of the goals, except for affordability target \$100/sf

House 1, 1.5-story



House 2, split level



House 3, 2-story



House 4, 1 story



Development of the MonoPath System

House 4 – SEP panels at the factory. Panels are high density, water resistant OSB 1 1/8" thick.



Development of the MonoPath System

House 4 –
insulated crawl
space foundation
and bottom plate.



Development of the MonoPath System

House 4 – setting first SEP panel.



Development of the MonoPath System

House 4 – SEP
structure
complete.



Development of the MonoPath System

House 4 – peel & stick membrane (vapor retarder, air barrier, and WRB) installation complete.



Development of the MonoPath System

House 4 –
installing exterior
insulation.



Development of the MonoPath System

House 4 –
installing siding
over furring strips.



Development of the MonoPath System

House 4 –
complete



Development of the MonoPath System

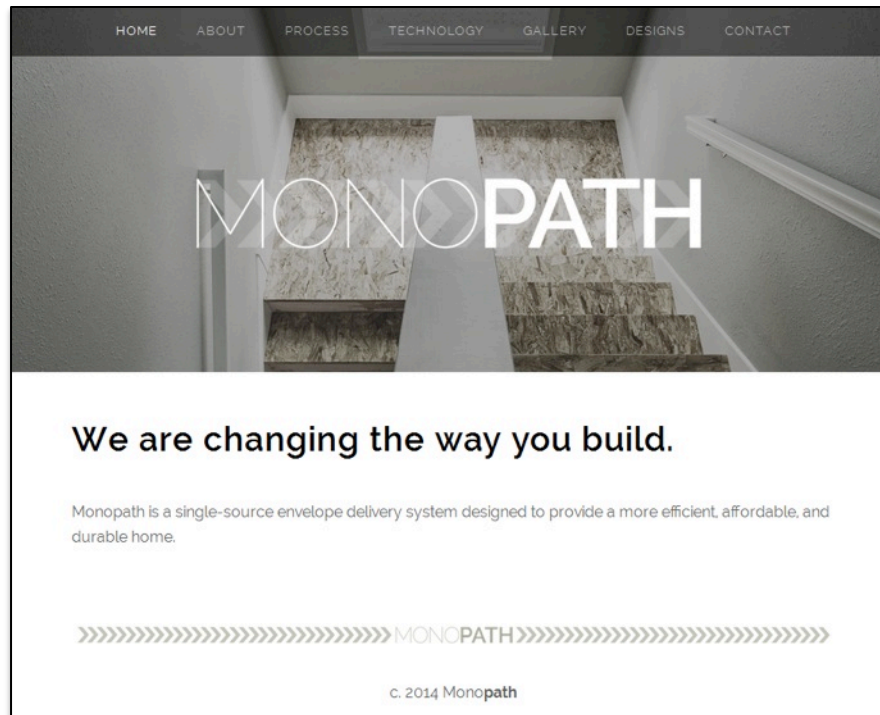
House 4 –
complete



Development of the MonoPath System

Second round of construction – 2013/2014

- 8 affordable homes constructed based on set of standardized plans
- Arrival of MonoPath concept and company, several important innovations:



Development of the MonoPath System

Second round of construction – 2013/2014

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 - 1) entire above grade envelope (interior to exterior) delivered by one contractor
 - reduced construction costs
 - simplified construction management
 - clear accountability (one party responsible)
 - improved quality

Development of the MonoPath System

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 - 2) roof changed to ventilated attic
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 - simplified enclosure and saved construction time
 - doubled R-value of roof to R-60

Development of the MonoPath System

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 - 2) roof changed to ventilated attic
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 - simplified enclosure and saved construction time
 - doubled R-value of roof to R-60
 - 3) cross lamination panels
 - stabilized/strengthened structure
 - eliminated need for battens to connect mid-wall panels
 - interior panel MDO overlay, can be painted directly

Development of the MonoPath System

MonoPath house, 2014



Development of the MonoPath System



Development of the MonoPath System

Third round of construction – 2016

- 10 affordable homes in contract negotiations for 2016
- Additional innovations under development:

Development of the MonoPath System

Third round of construction – 2016

- 10 affordable homes in contract negotiations for 2016
- Additional innovations under development:
 - 1) factory-applied WRB on outside face of SEP panels
 - eliminates necessity for peel & stick membrane
 - reduced construction costs, time, and aggravation!

Development of the MonoPath System

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 - 2) SEP-ETTMS foundation walls
 - eliminates need for poured/block foundation walls
 - reduced construction costs and time
 - simplified construction management



Development of the MonoPath System

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 - simplified construction management
 - 3) Alternate design versions (split level)
 - optimal configuration for maximizing basement space
 - further reduction in cost/sf

Development of the MonoPath System

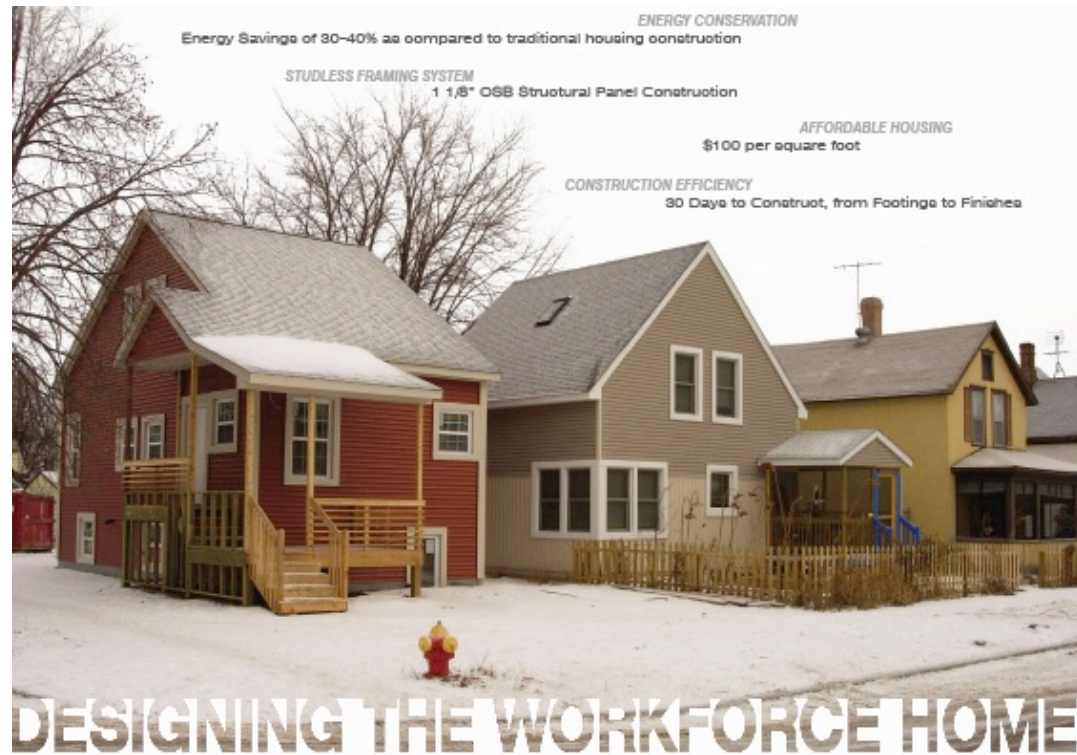
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Development of the MonoPath System

Original project goals met?

1. Robust, moisture safe enclosure?
2. Energy efficient?
3. Fast construction ?
4. Affordable?

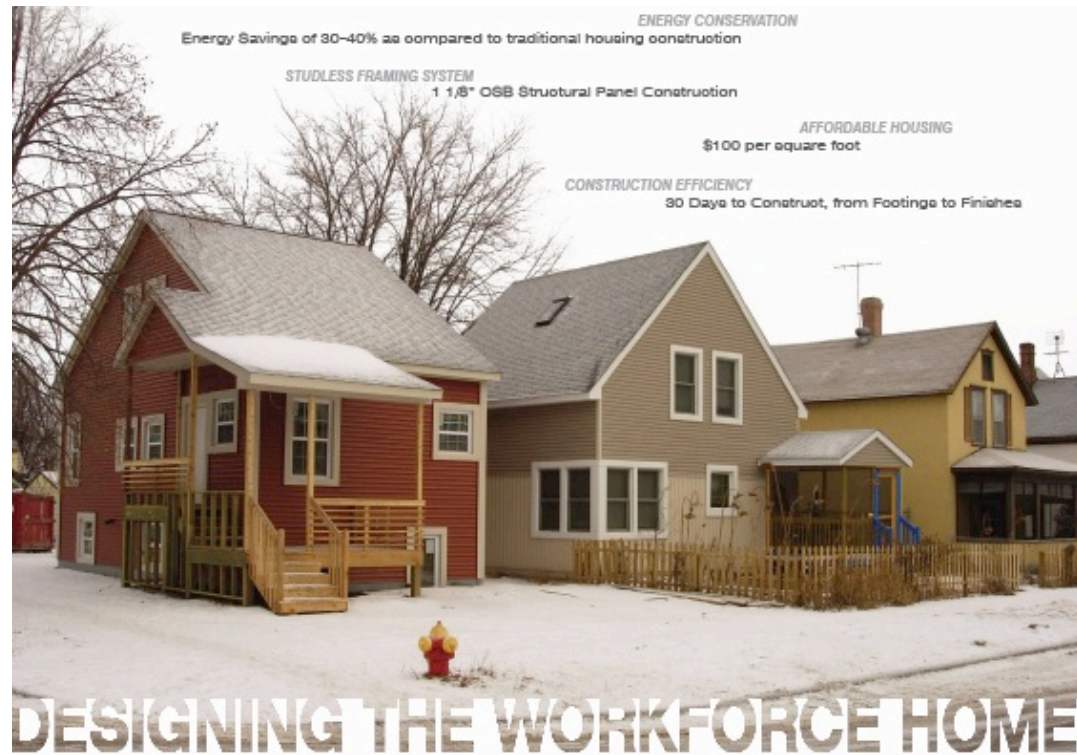


Development of the MonoPath System

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MonoPath is a “perfect wall” assembly, provides all associated benefits for moisture safety and durability.



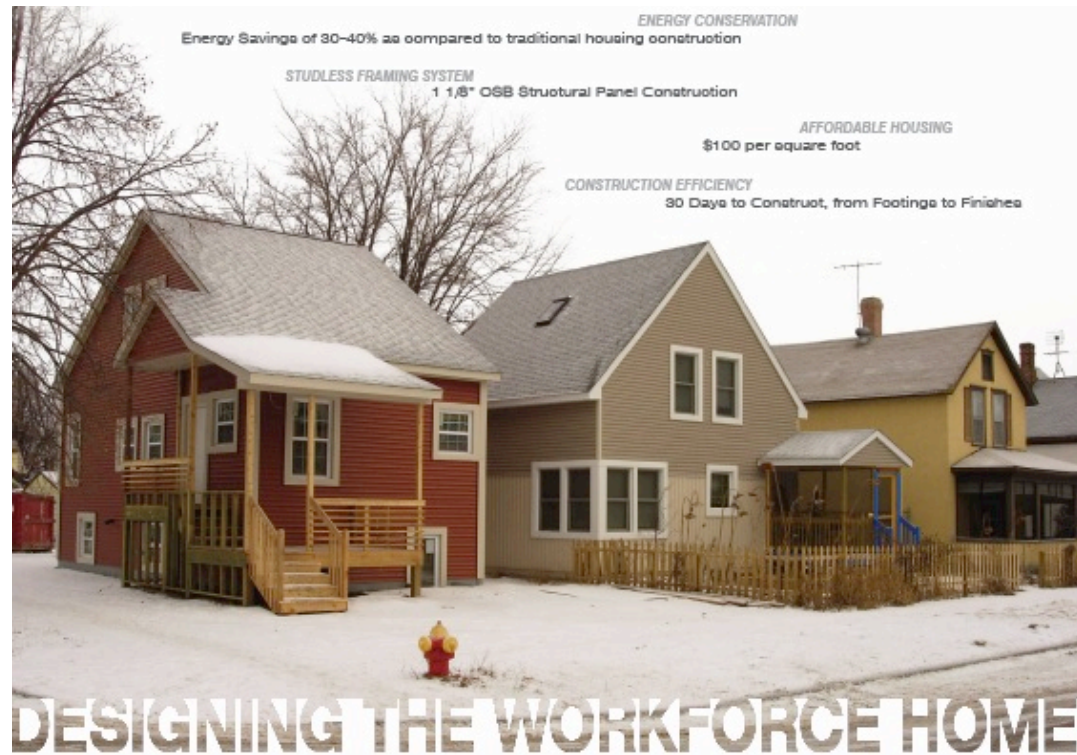
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2014 homes: 20% energy savings compared to 2009 IECC, mostly from reduction in thermal bridging, air leakage, and roof heat loss.

Greater savings definitely possible.



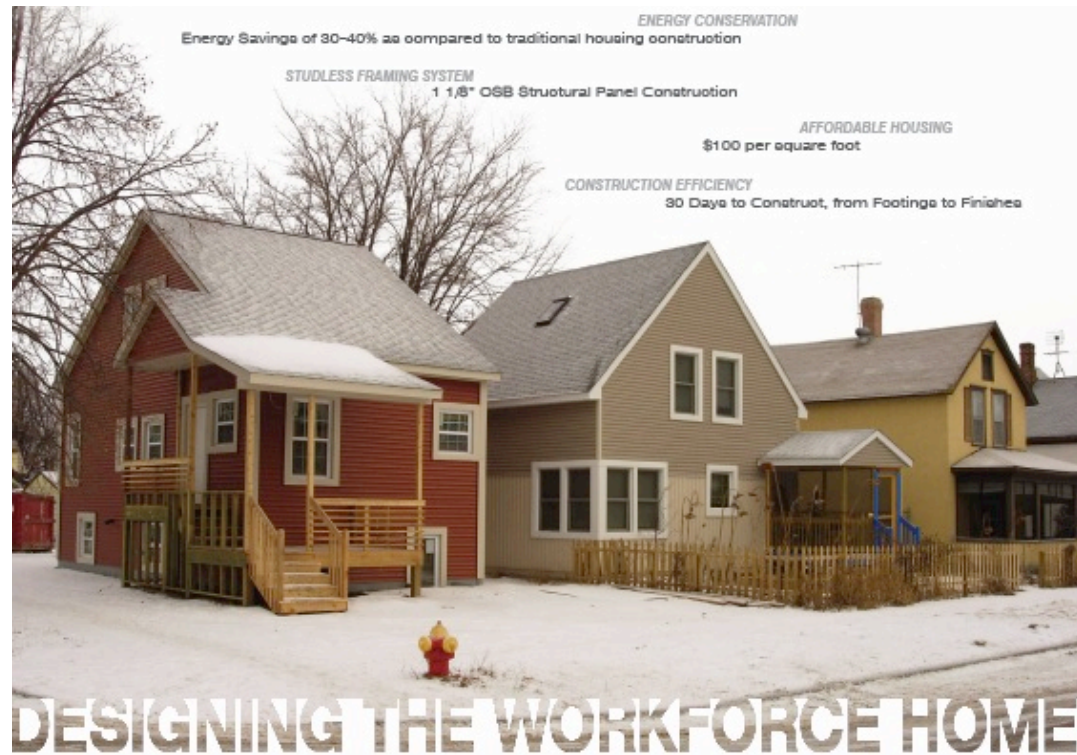
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Structure typically completed in 1 day,
and “dried in” in 5 days.

With innovations, next round of construction will be even faster.



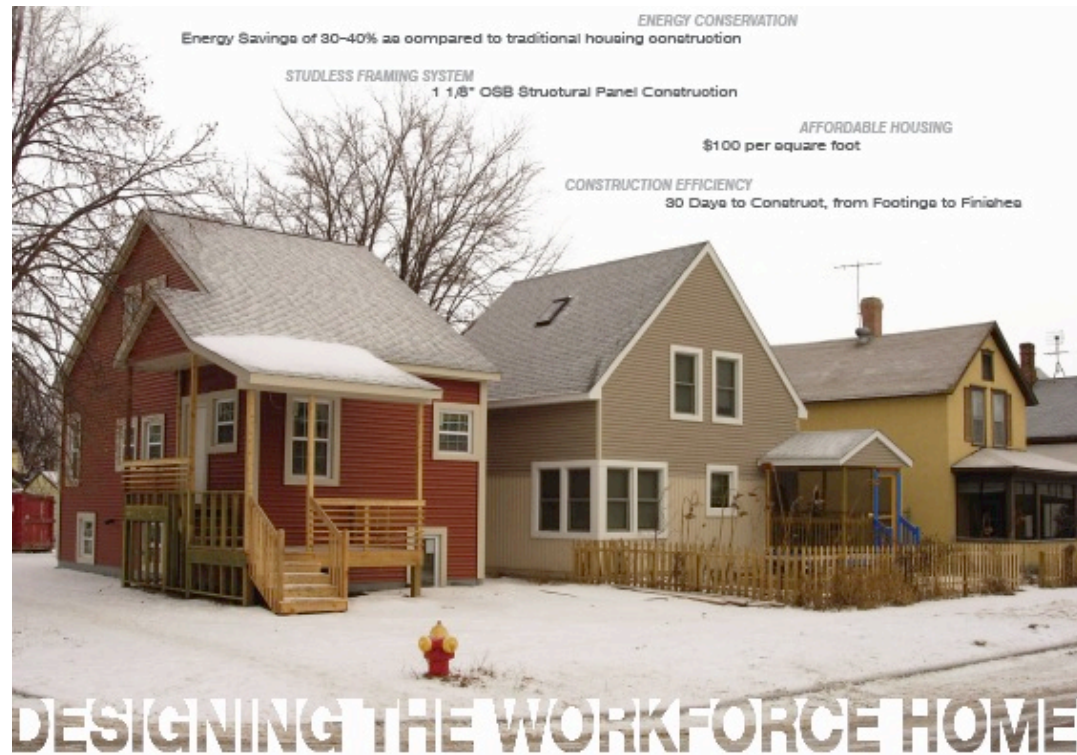
Development of the MonoPath System

Original project goals met?

- ✓ 1. Robust, moisture safe enclosure?
- ✓ 2. Energy efficient?
- ✓ 3. Fast construction ?
- ✓ 4. Affordable?

25% savings on cost of envelope.
Amounts to \$30,000 or more on
typical project. Achieves \$100/sf
target.

With innovations, next round promises further significant cost savings.



Adaptation to Passive House

To date, MonoPath homes have not been built to superinsulated standards. Current design:

- R-15 wall insulation
- R-60 roof insulation
- U-0.3 windows (standard double-hung vinyl windows)
- Conventional mechanical system

Adaptation to Passive House

The system offers significant advantages for Passive House construction:

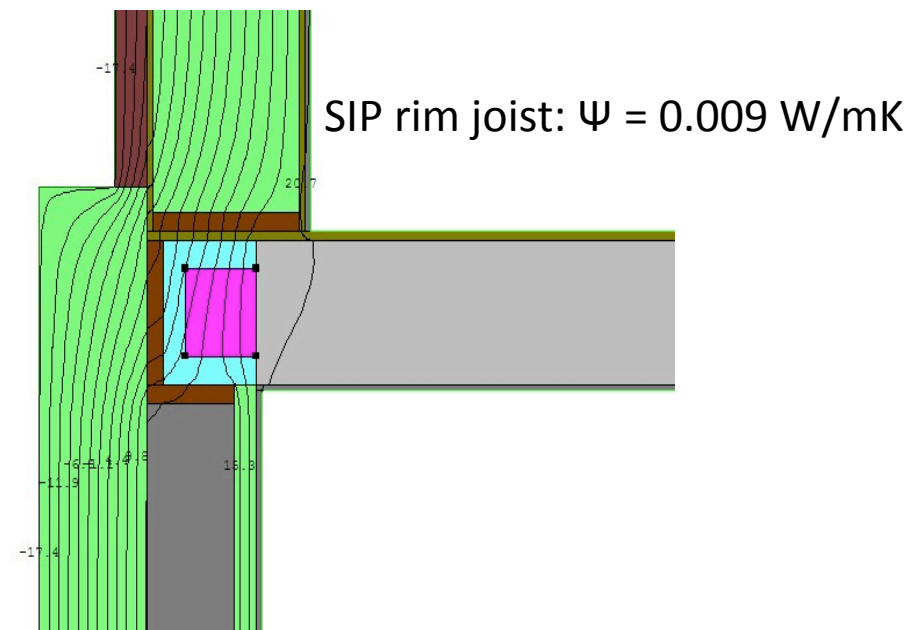
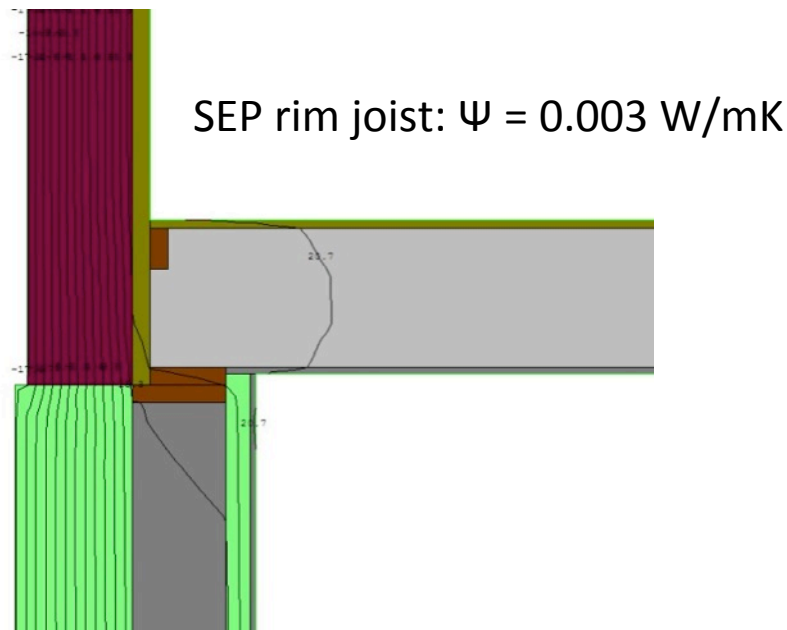
1. Screws battening down exterior insulation can be driven anywhere (no “missing the stud”)



Adaptation to Passive House

The system offers significant advantages for Passive House construction:

2. Thermal bridging minimized: no window headers (panels act as headers), continuous insulation at wall corners, rim joists, and grade



Adaptation to Passive House

The system offers significant advantages for Passive House construction:

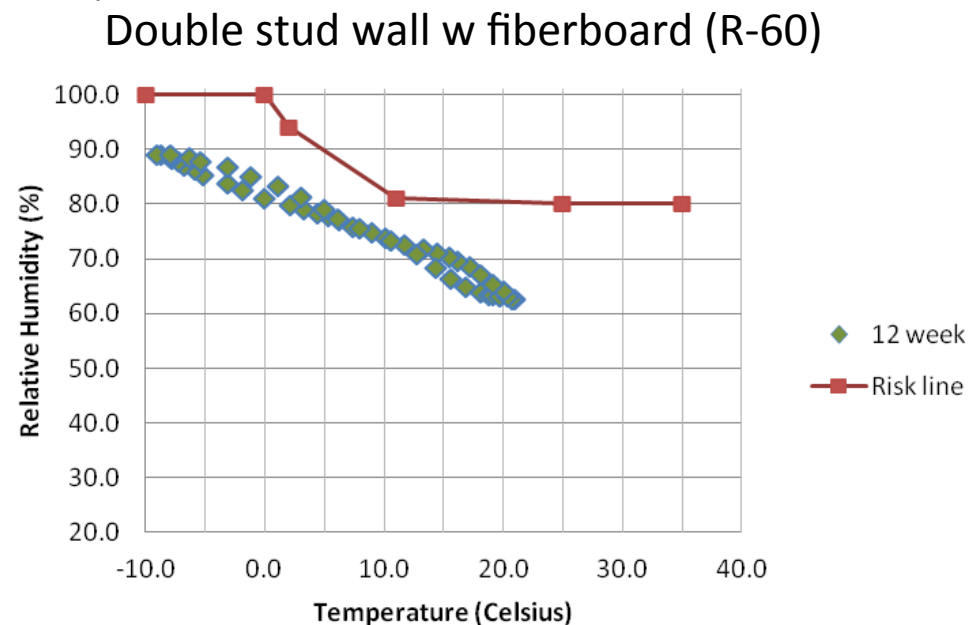
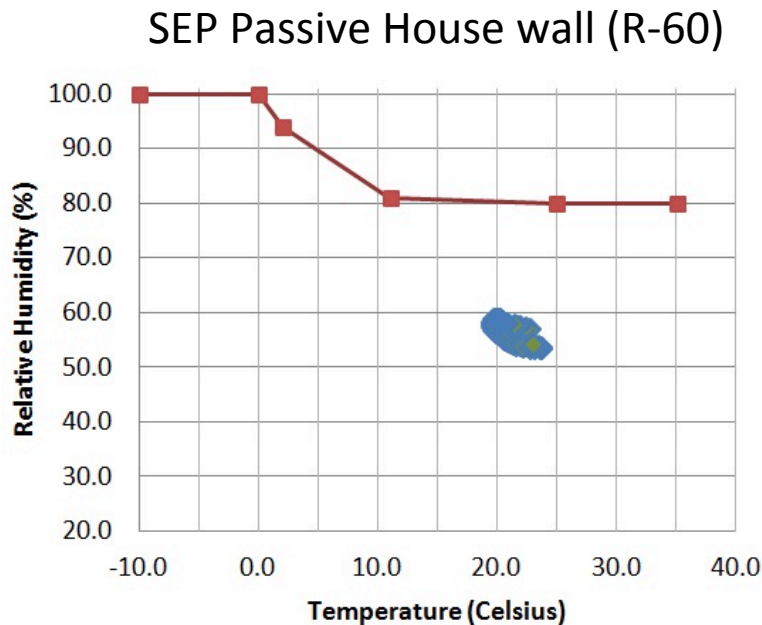
3. Enclosure design is incredibly air tight and air barrier is well-protected from puncture and degradation.



Adaptation to Passive House

The system offers significant advantages for Passive House construction:

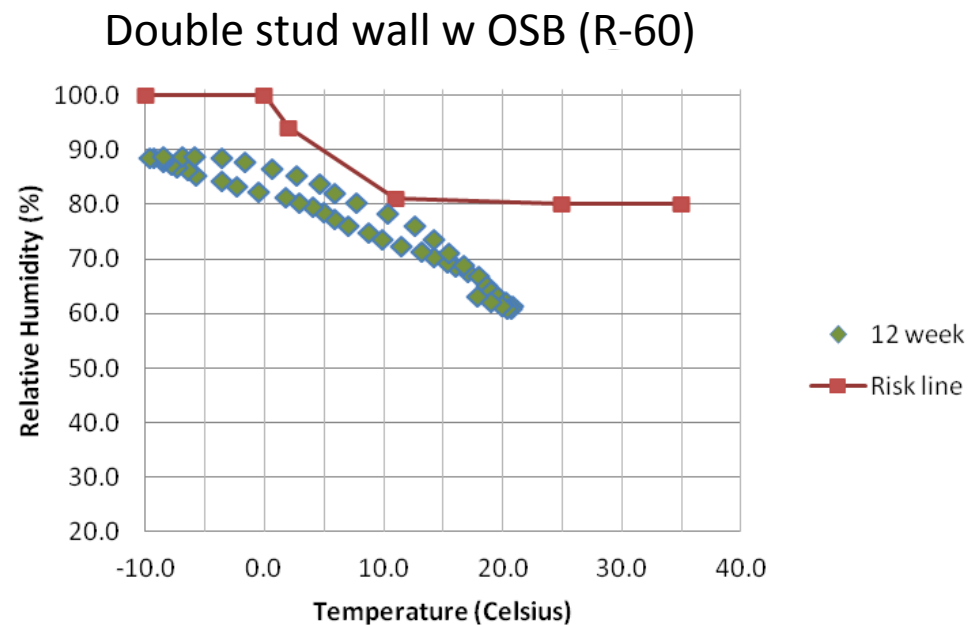
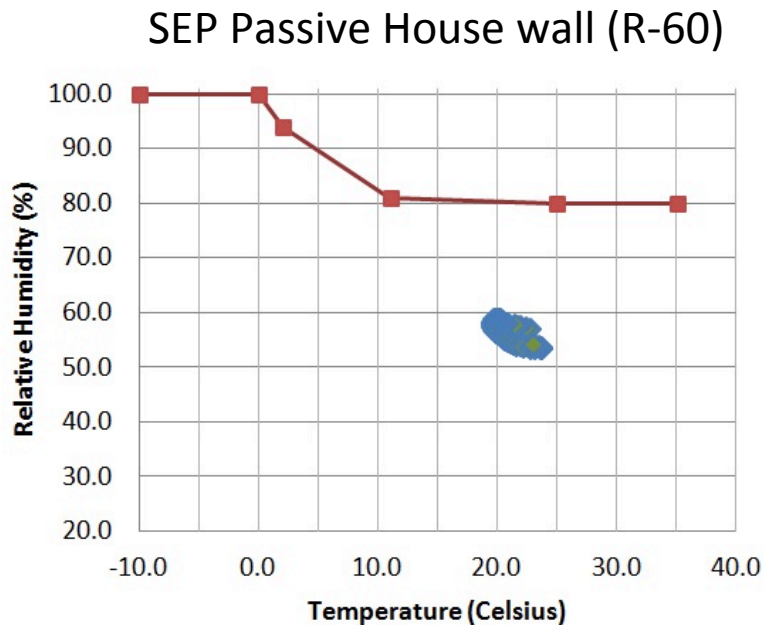
4. Moisture-safe for super insulated assemblies



Adaptation to Passive House

The system offers significant advantages for Passive House construction:

4. Moisture-safe for super insulated assemblies



Adaptation to Passive House

The system offers significant advantages for Passive House construction:

5. Very substantial enclosure cost savings could be applied to expensive Passive House components such as windows, additional insulation, and/or solar panels

\$30,000 =



+

