In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

"This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1.5 hours** of credit toward **Building Officials and Residential Contractors code/ energy** continuing education requirements."

For additional continuing education approvals, please see your credit tracking card.

design coalition inc.

# The Root River House

## *A Net-Zero Project*

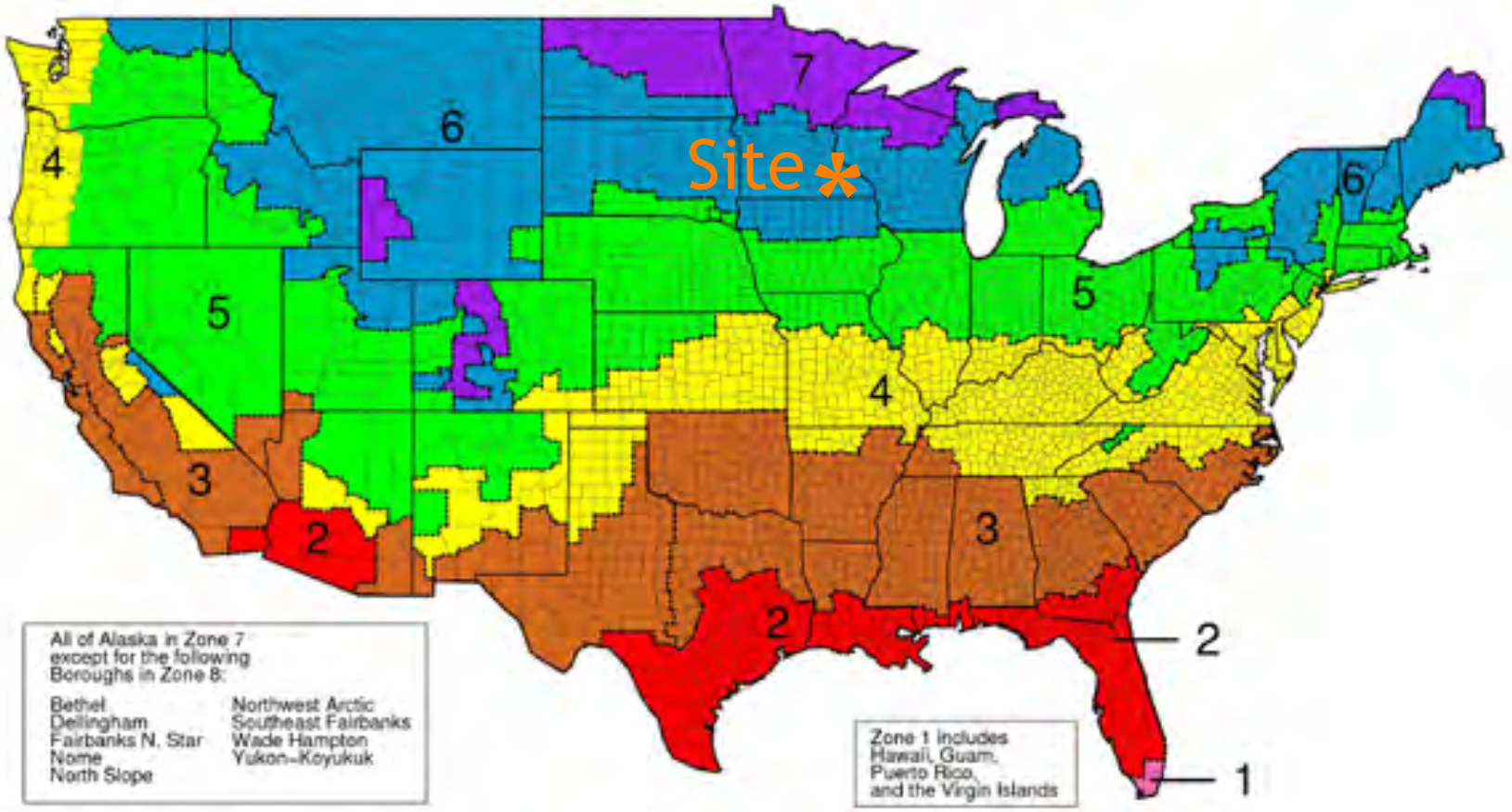
Christi Weber

*Building Designer & Certified Passive House Consultant*

Design Coalition Architects, Madison, WI

design coalition inc.

# Project Site & Building Layout




Climate Zone 6 -- Approximately 7700 HDD

design coalition inc.

# Project Site & Building Layout

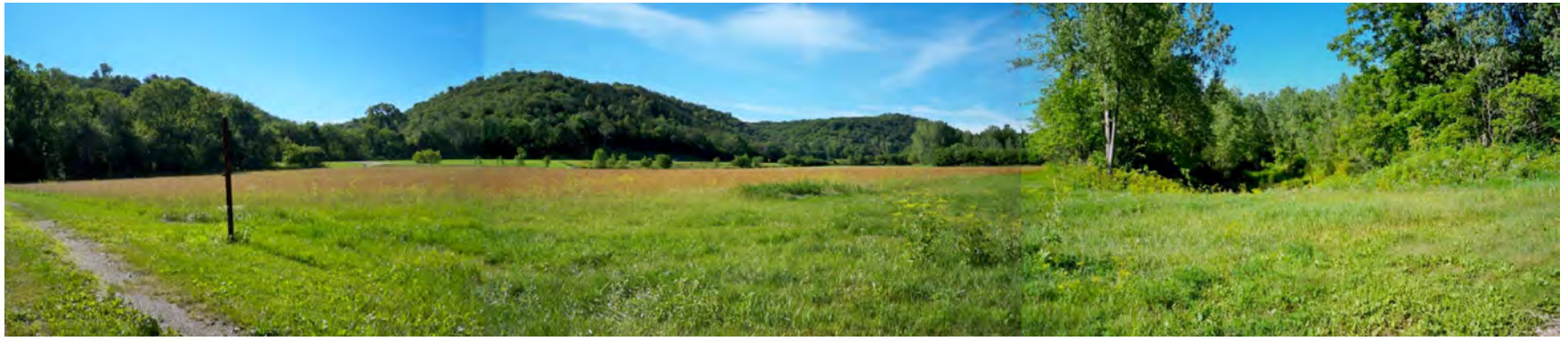

design coalition inc.

# Project Site & Building Layout

Root River:

Western Trees:

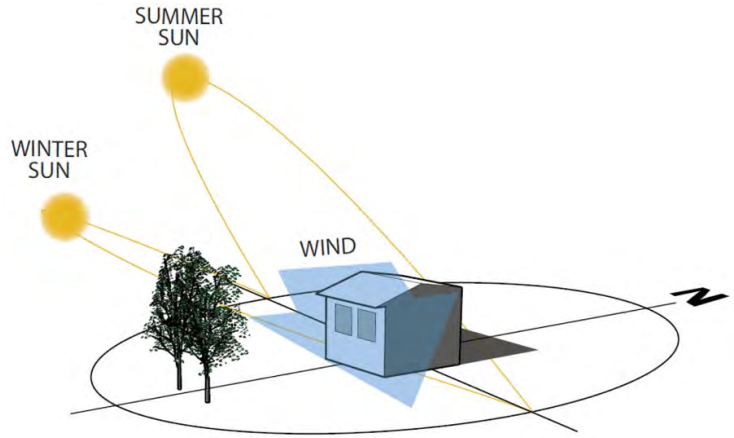
Panorama facing southeast:

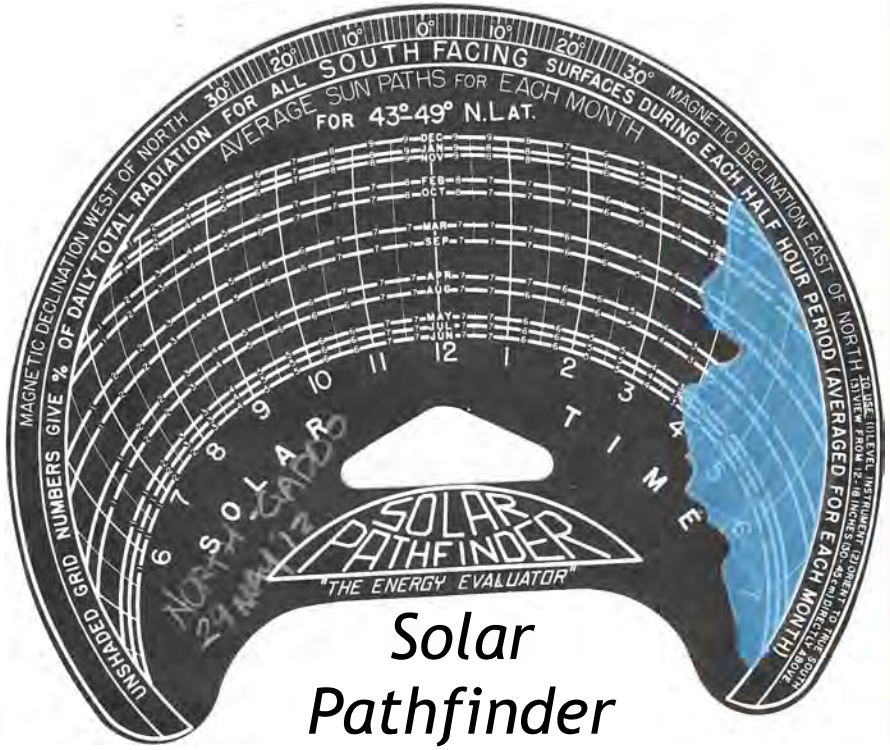


design coalition inc.

# Project Site & Building Layout

Solar access on site is great to south, but limited by western edge of trees.




*Solar Pathfinder*

design coalition inc.

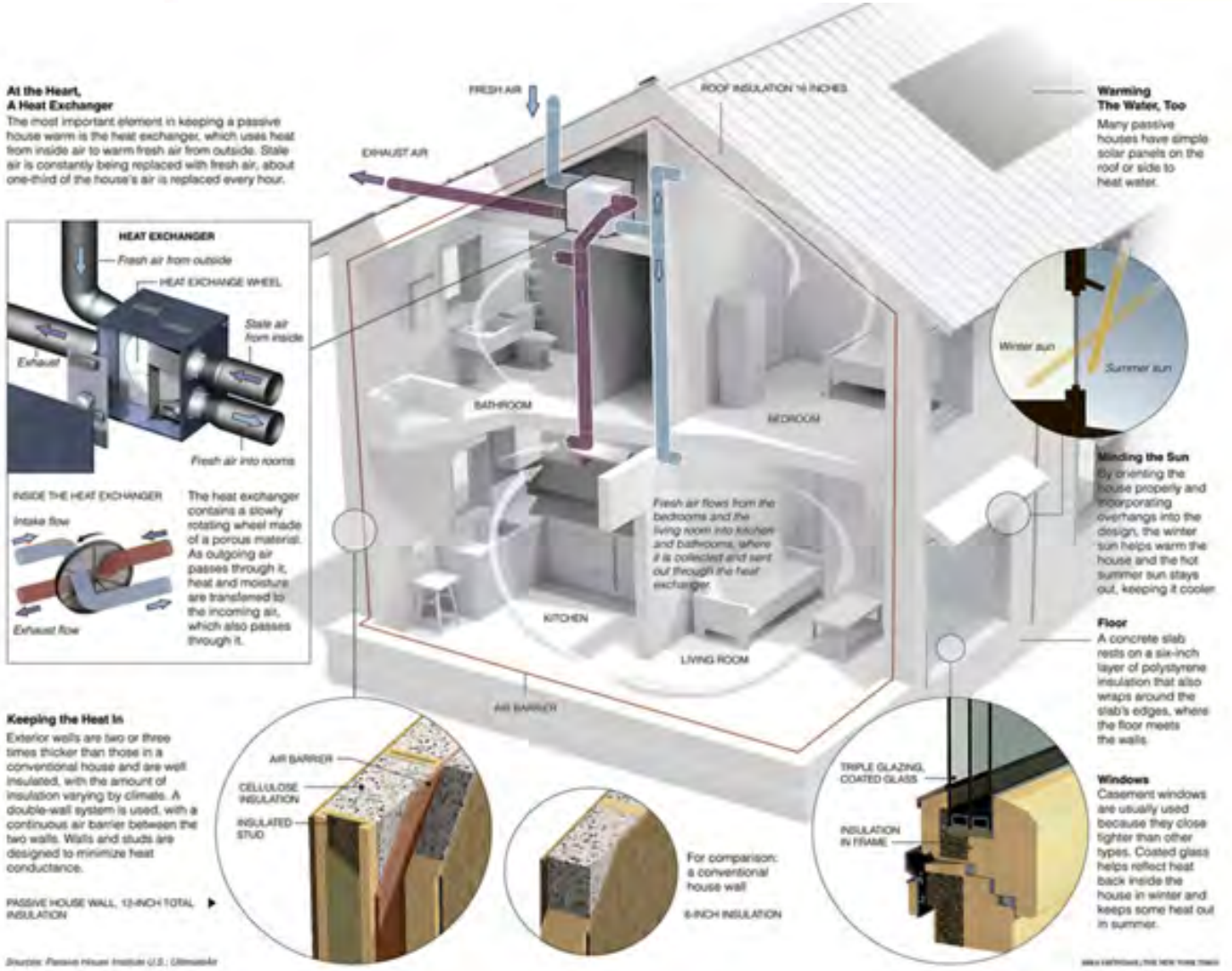
# Passive House Principles

## A brief review…

design coalition inc.

# What is Passive House?

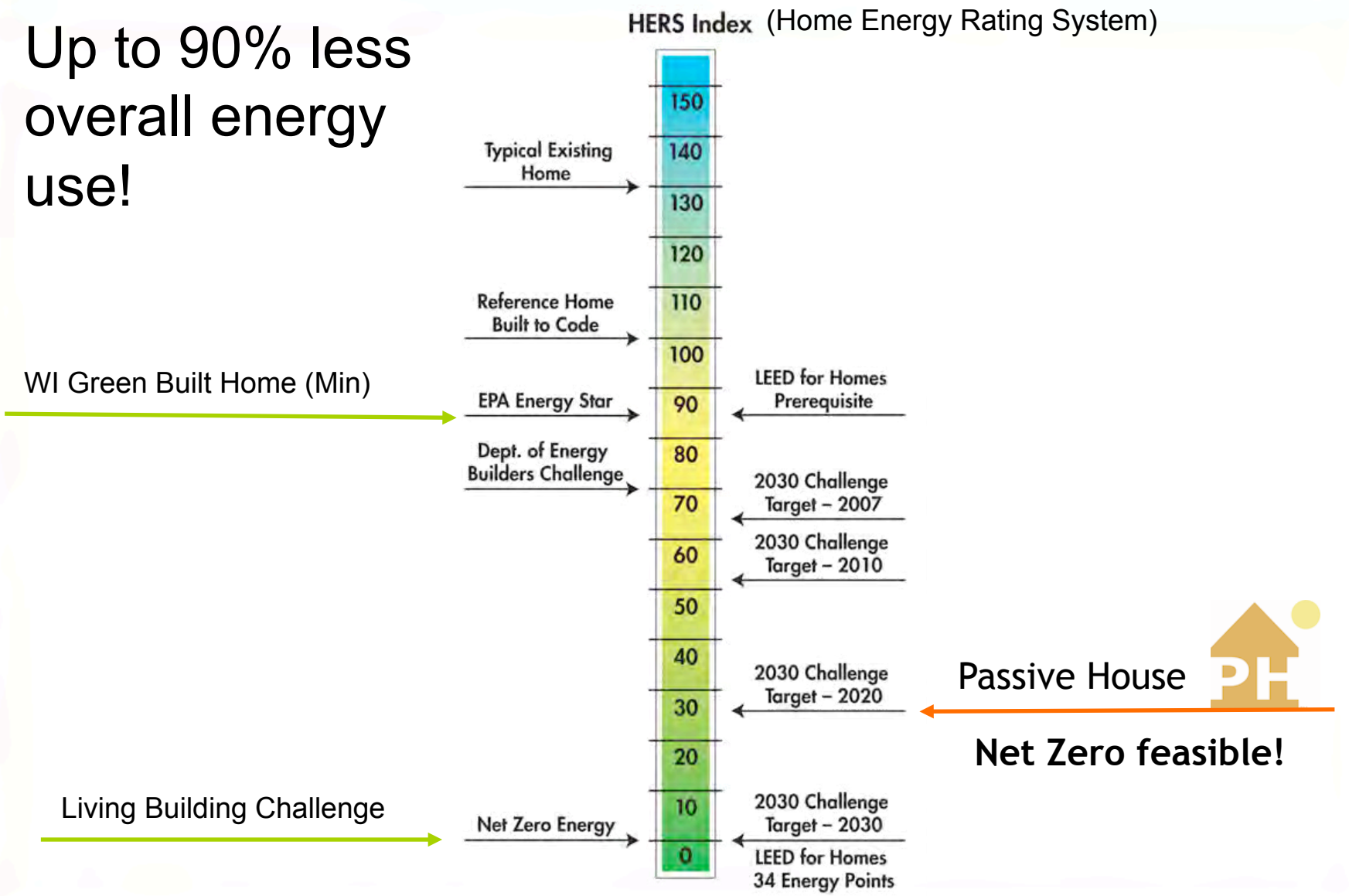
An integrated envelope and systems design.




design coalition inc.

# What is Passive House?

Up to 90% less overall energy use!

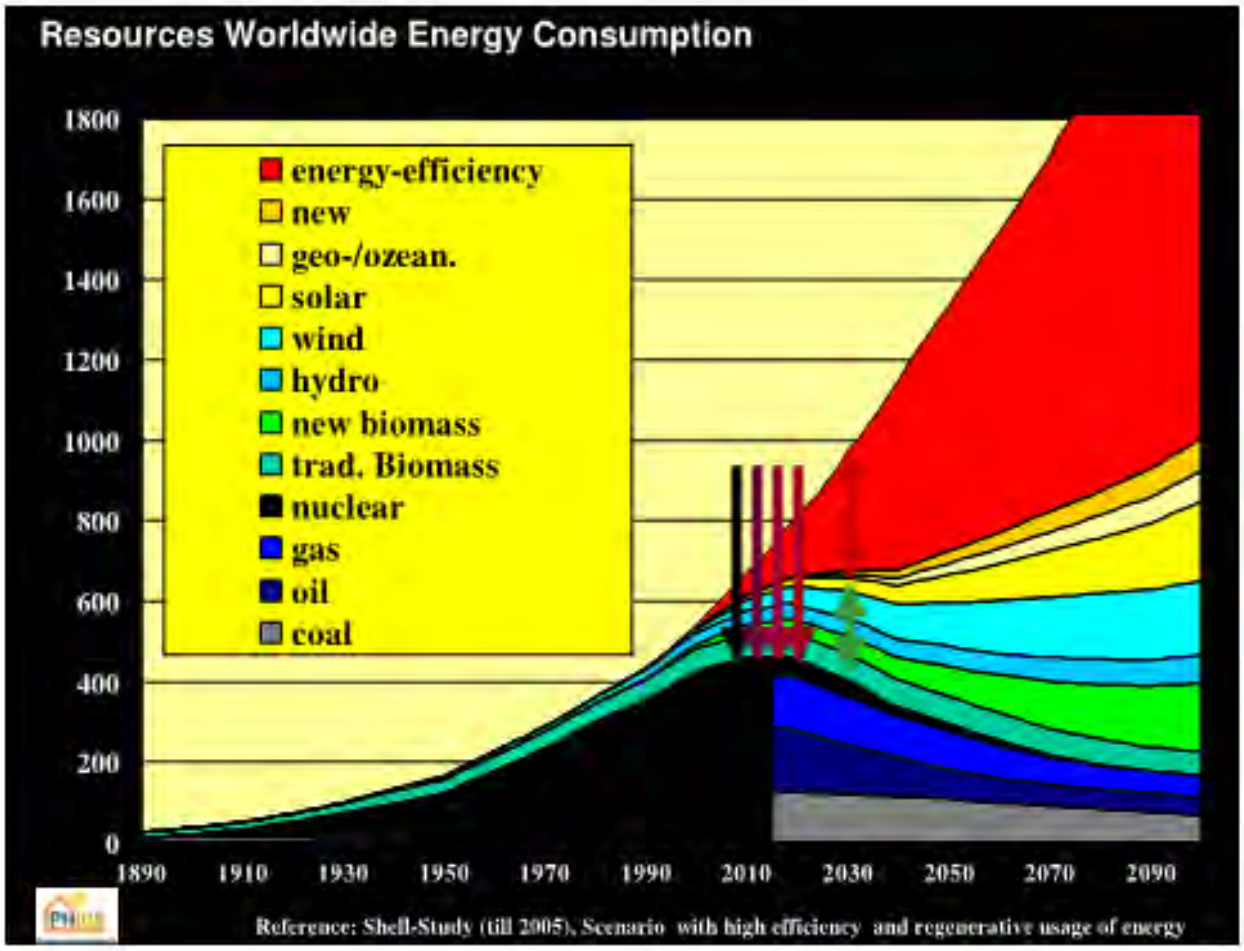



design coalition inc.

# What is Passive House?

Energy demand is rising and will continue to rise.

(Renewables account for only a small portion of that increase.)

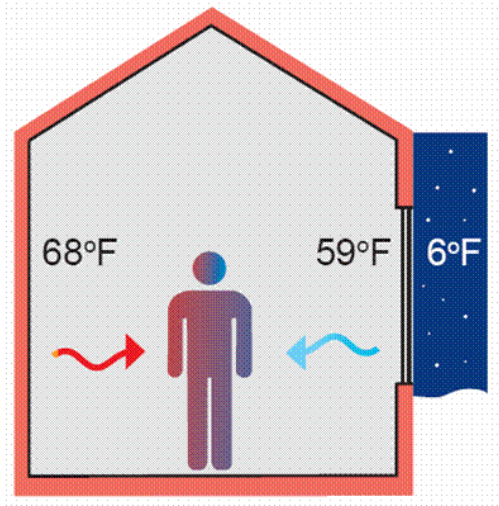



If we simply conserve, we can greatly offset emissions.

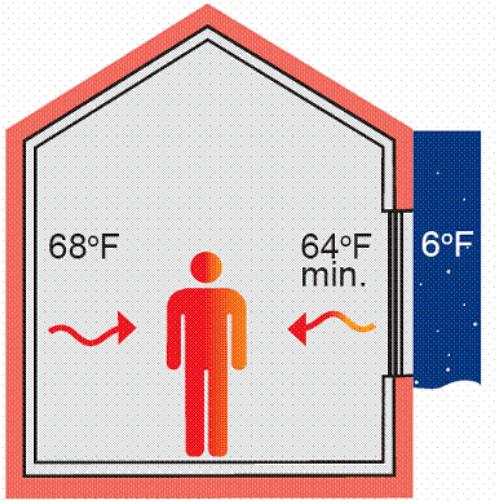
# What is Passive House?

## Superior comfort!

- No drafts, no condensation, no cold spots.
- Warm interior surfaces (no more than 4˚F colder than the interior air temperature).
- No drastic temperature swings.
- More “usable” square footage in the winter.




Conventional
Envelope & Windows



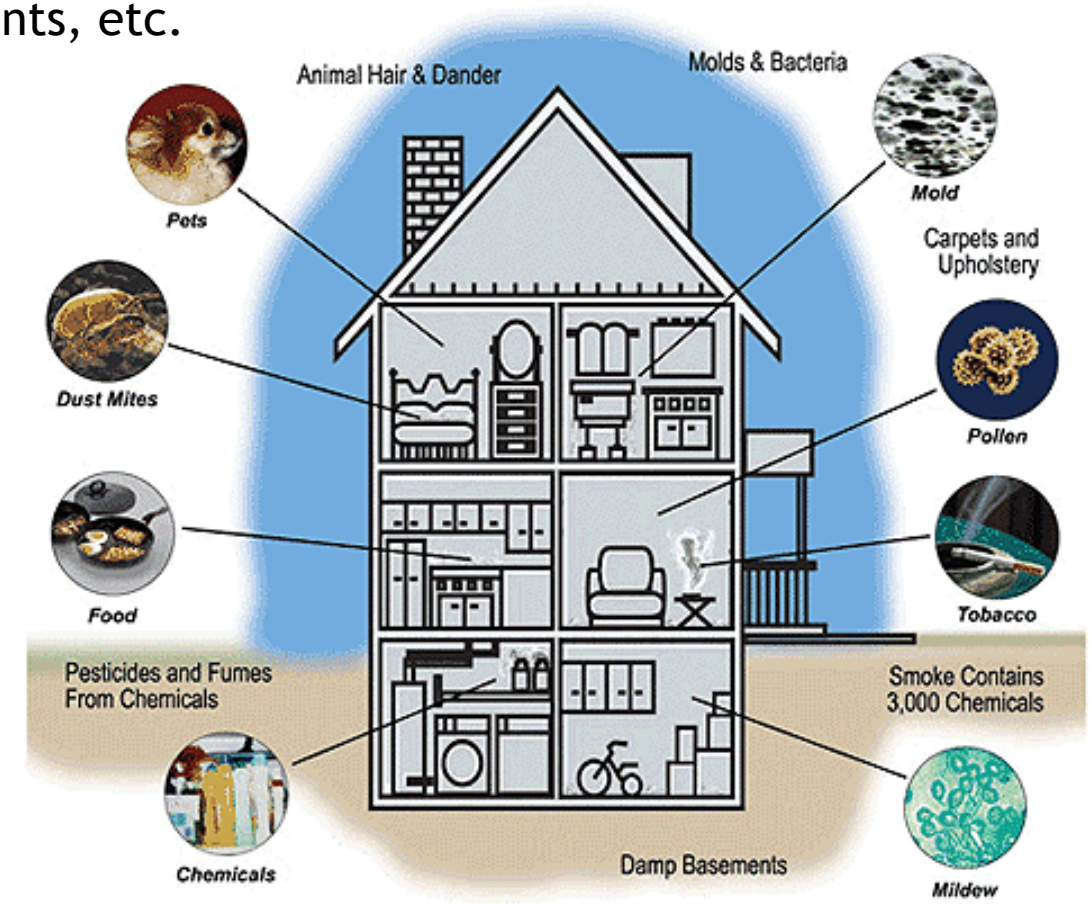

PH Envelope &
Windows

Source: Informationsgemeinschaft Passivhaus D,
Broschure “Aktiv fur mehr Behaglichkeit.”

# What is Passive House?

## Superior indoor air quality!

- Constant, low-velocity, filtered fresh air
- Reduced allergens, pollutants, etc.
- Lower $CO_2$ levels



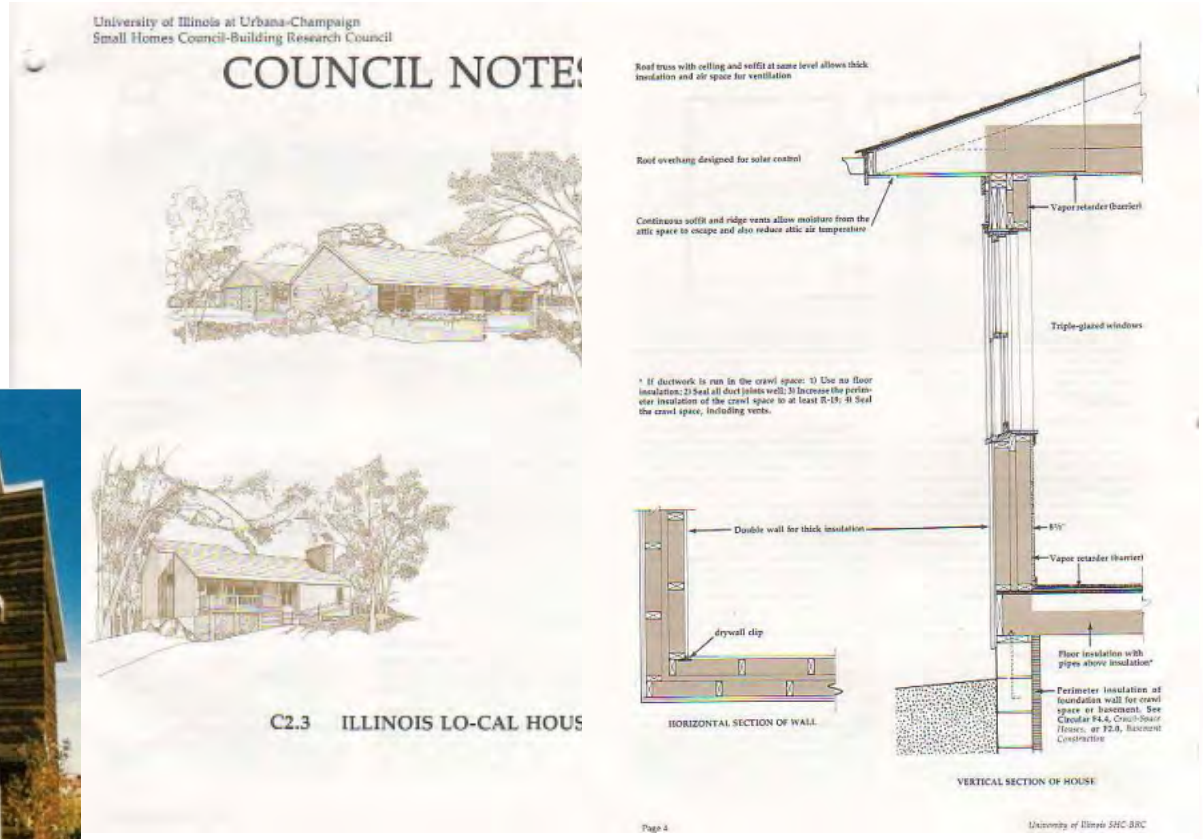

Source: EPA

# History of Passive House

## Passive House has roots in the U.S. and Canada

*Energy-efficiency in response to 1970's energy crisis.*

**Saskatchewan Conservation House**, Canada, 1977




**Super-insulated"Lo-Cal House"**, Wayne Schick, U of I Small Homes Council

design coalition inc.

# Passive House Principles

Conservation Approach -- Minimize Losses, Maximize Gains

Building Orientation -- Solar Gain, Daylighting, Shading

Thermal Envelope --

Continuous Insulation, Thermal Bridge Free,
High Performance Windows & Doors

Air-tightness --

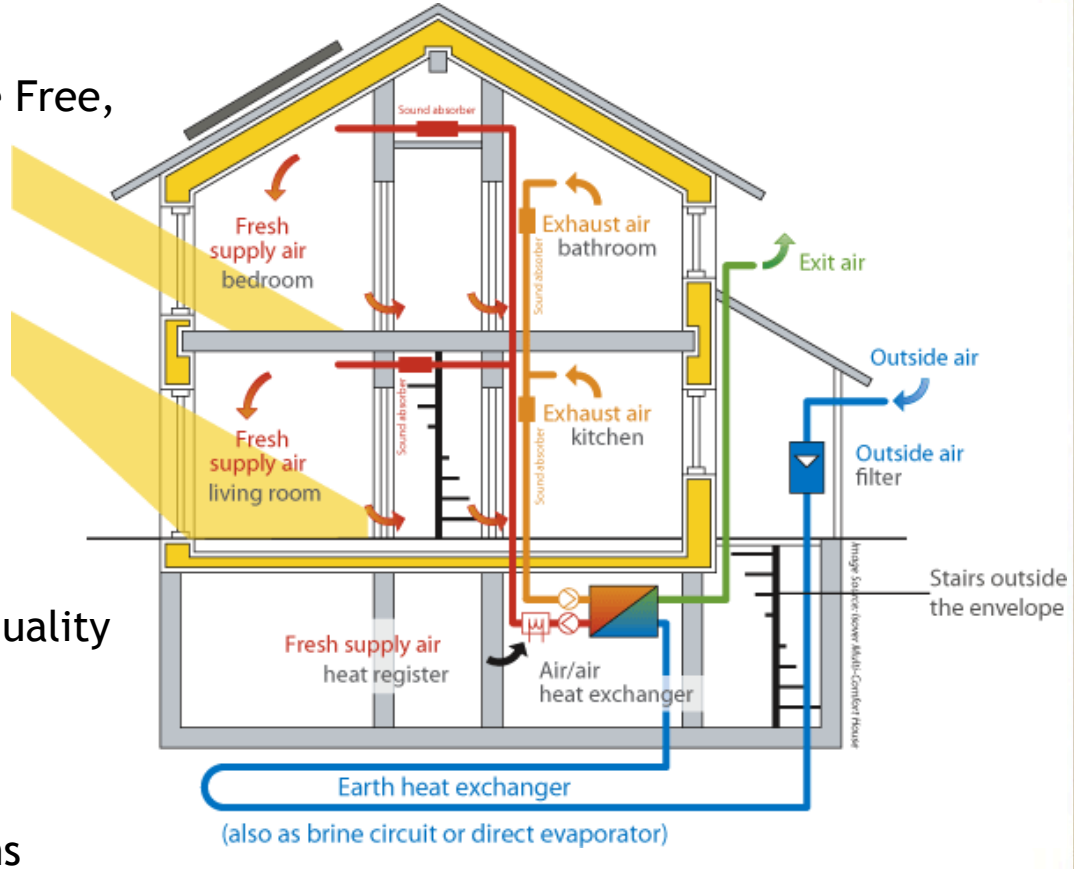
Minimize heat loss & moisture
diffusion into wall assembly.

Balanced Ventilation with
Heat Recovery --

Continuous fresh air, exceptional air quality

Minimal Mechanical System –

Free of a traditional furnace – mostly
heated by solar and internal heat gains



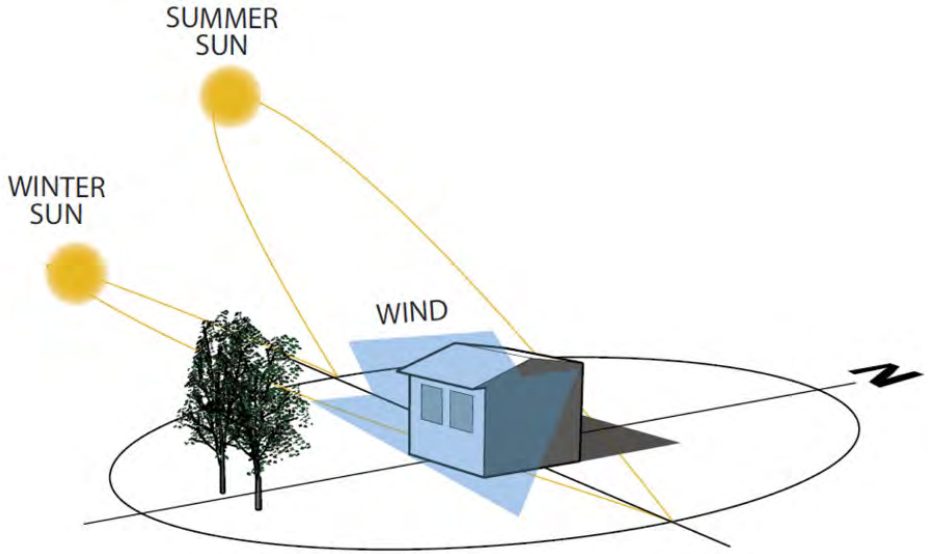

*Above example courtesy of PHAUS.*

design coalition inc.

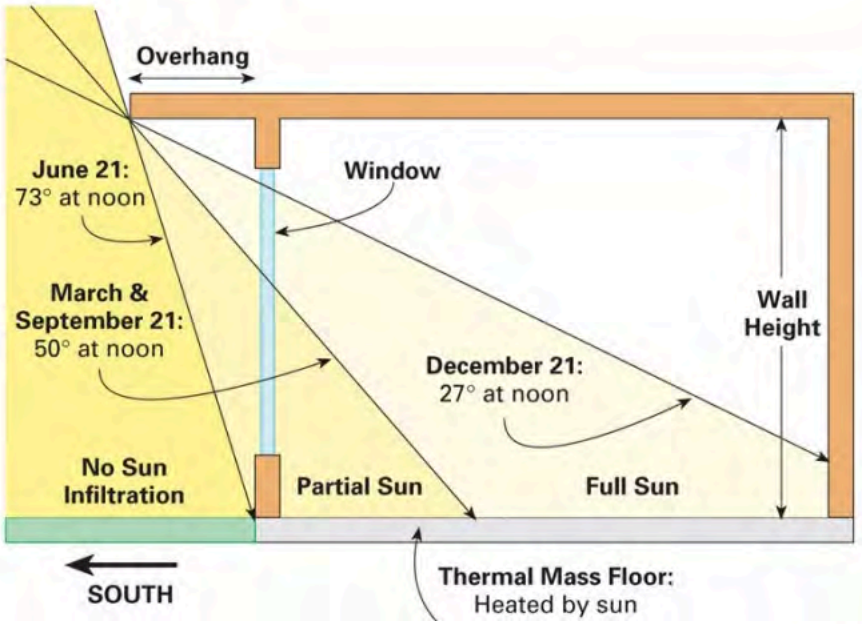
# Passive House Principles

## Building Orientation:

- Solar heat gain in winter
- Summer shading
- Adjacent trees and buildings




Graphic: Lighthouse Sustainable Center
Source: Passive Design Tool Kit

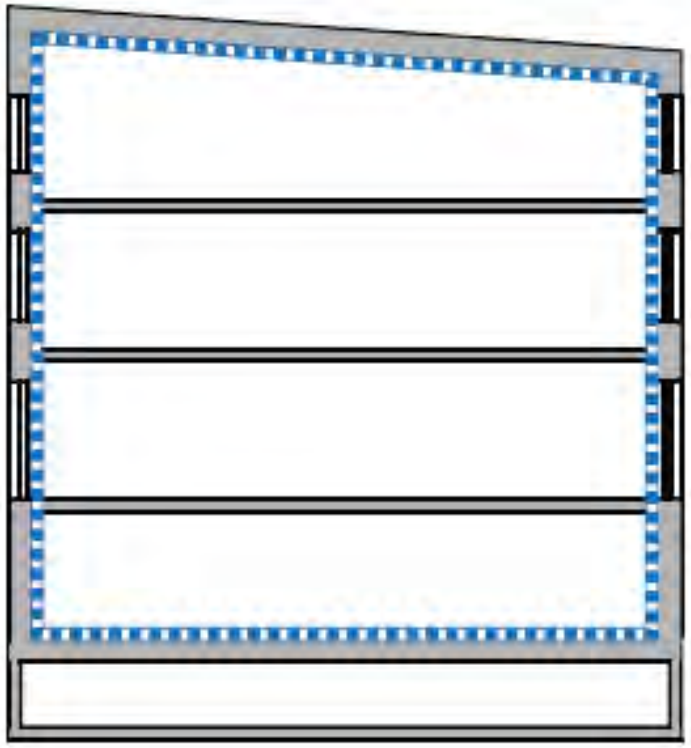


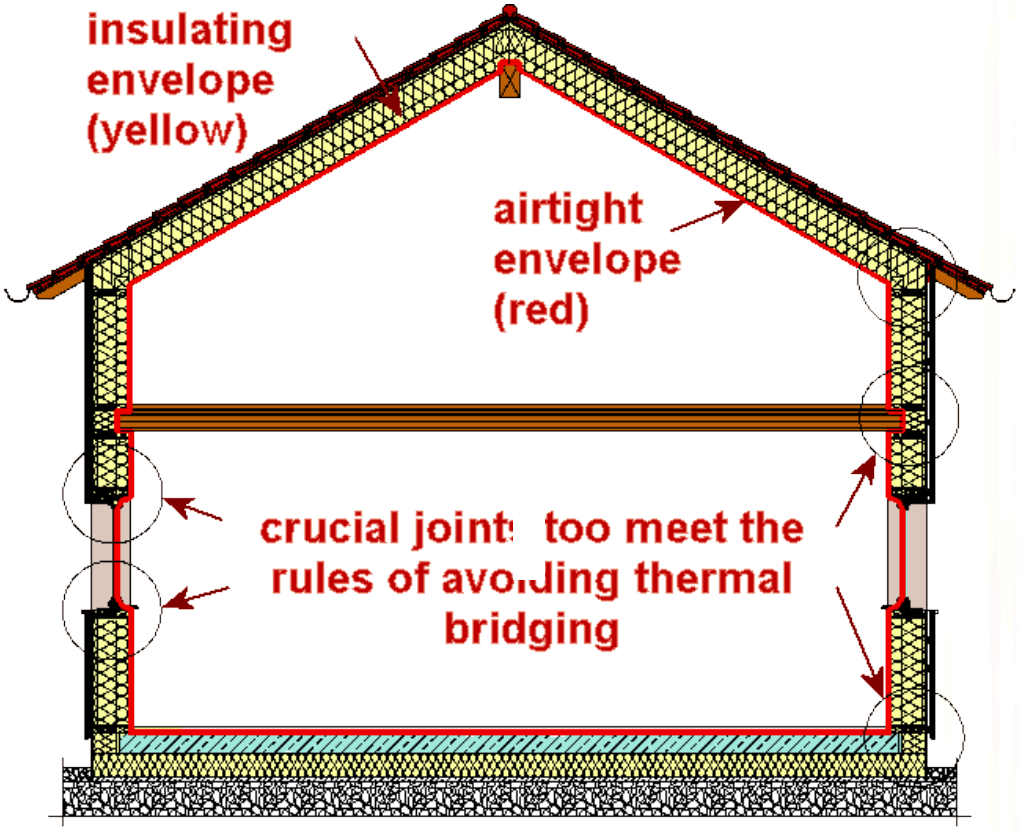

Source: Homepower.org

# Passive House Principles

## Envelope Goals:

- Continuous Insulation
- Continuous Air-Tight Enclosure
- Eliminate Thermal Bridges





# Passive House Principles

## High Performance Windows and Doors:

Typical American:

- Double Paned
- Metal Spacers
- Un-insulated Frames
- 1 Air Seal Gasket
- SHGC less than 0.50
- DH or Casement

Marvin

Typical Passive House:

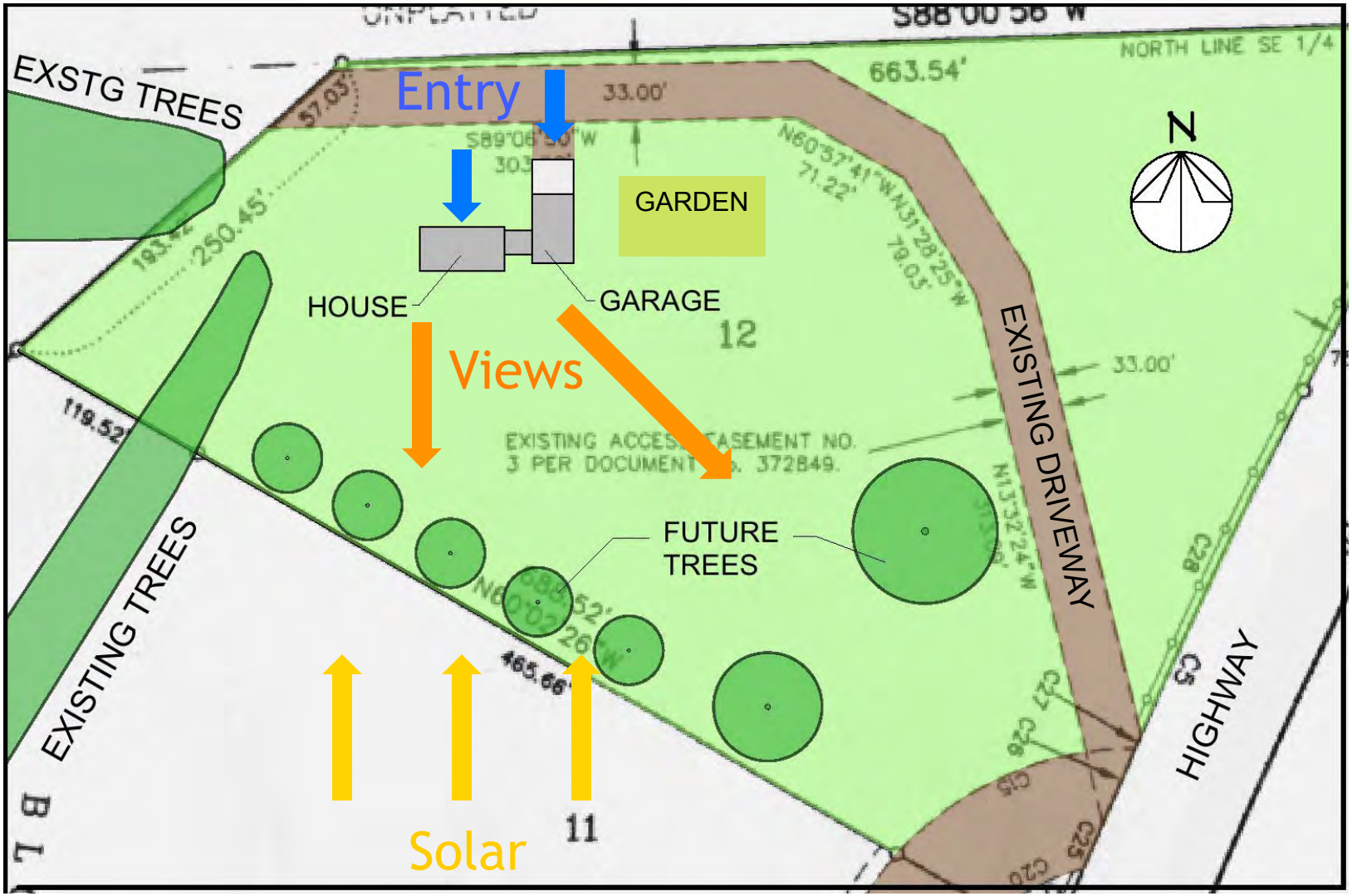
- Triple Paned
- Warm Edge Spacers
- Insulated Frames
- 3 Air Seal Gaskets
- SHGC 0.50 or more
- Typically Tilt/Turn

Energate

# Applying Passive House principles….

design coalition inc.

# Root River House Site Plan

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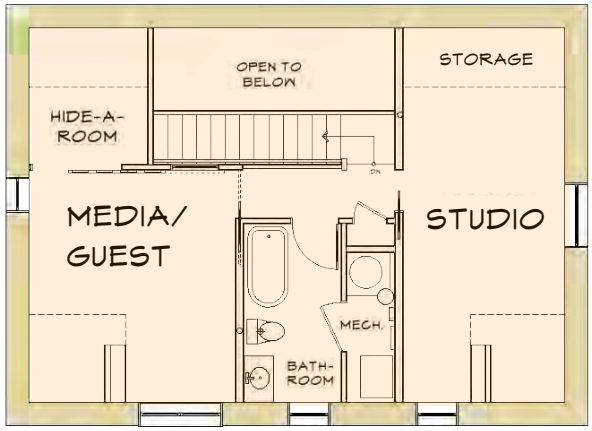
# Program & Building Layout

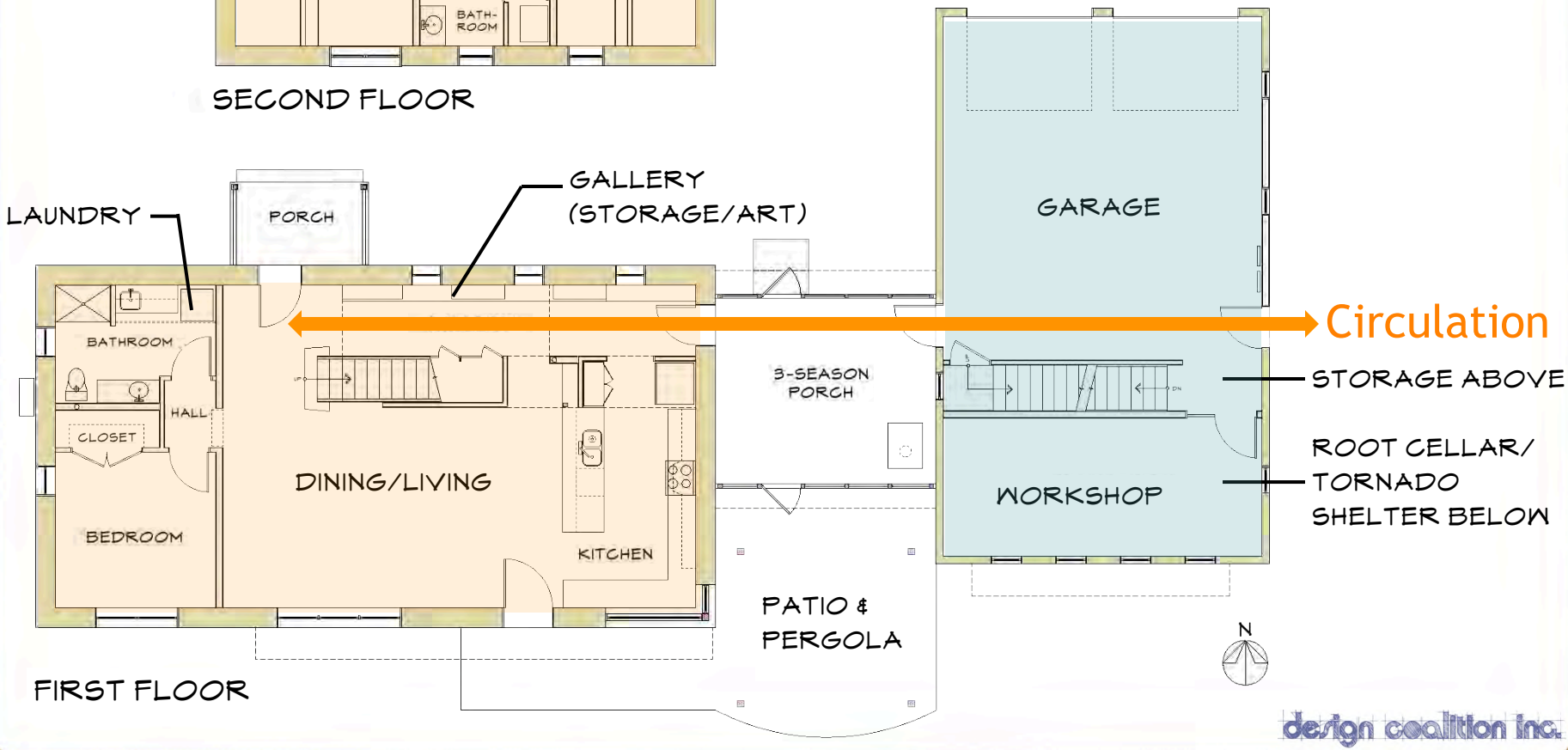



SECOND FLOOR

House Size: Net 1,514 SF; Gross 2,210 SF

CONDITIONED SPACE/PASSIVE HS ENVELOPE

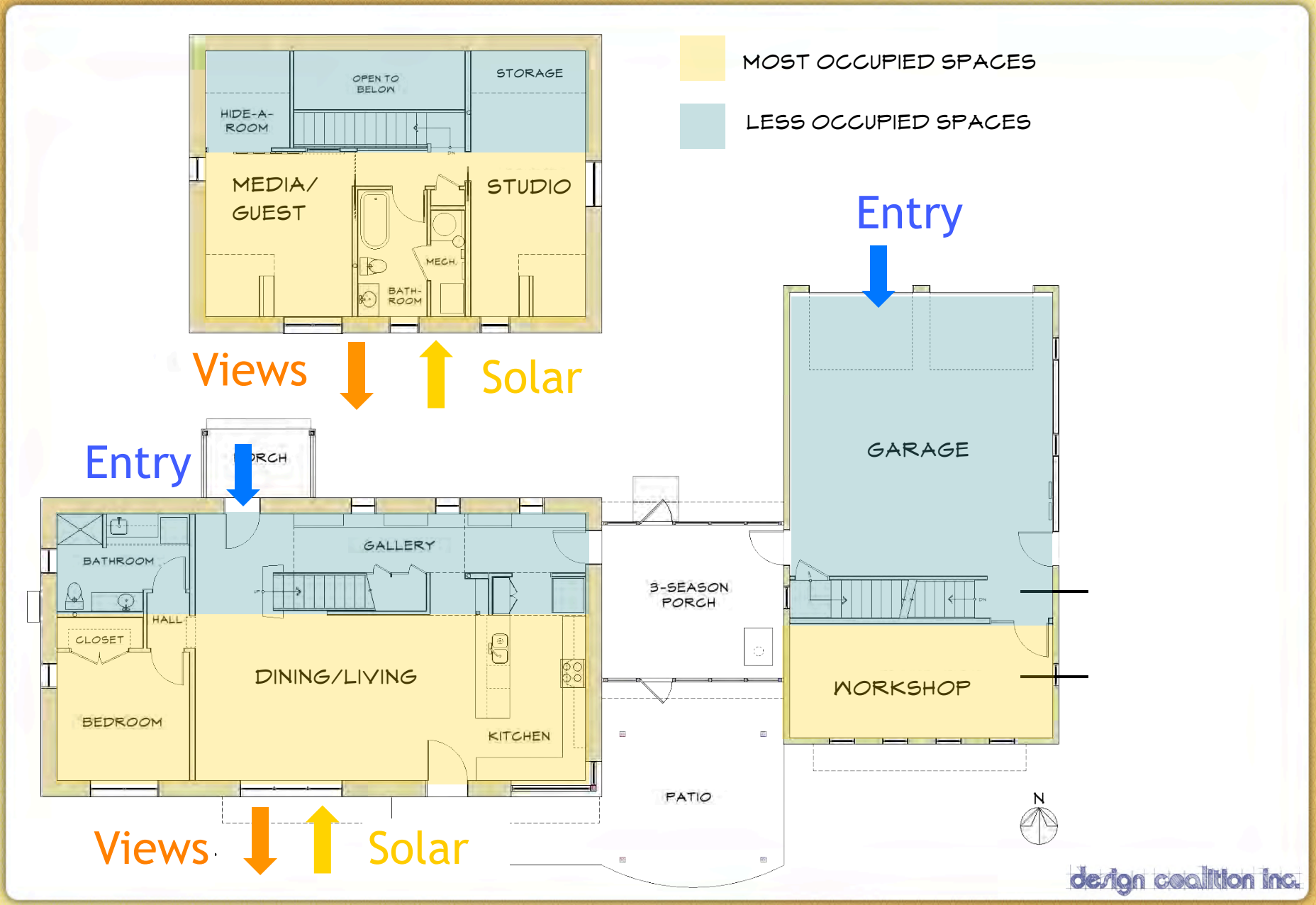
UNCONDITIONED SPACE




FIRST FLOOR

design coalition inc.

# Program & Building Layout



# Program & Building Layout

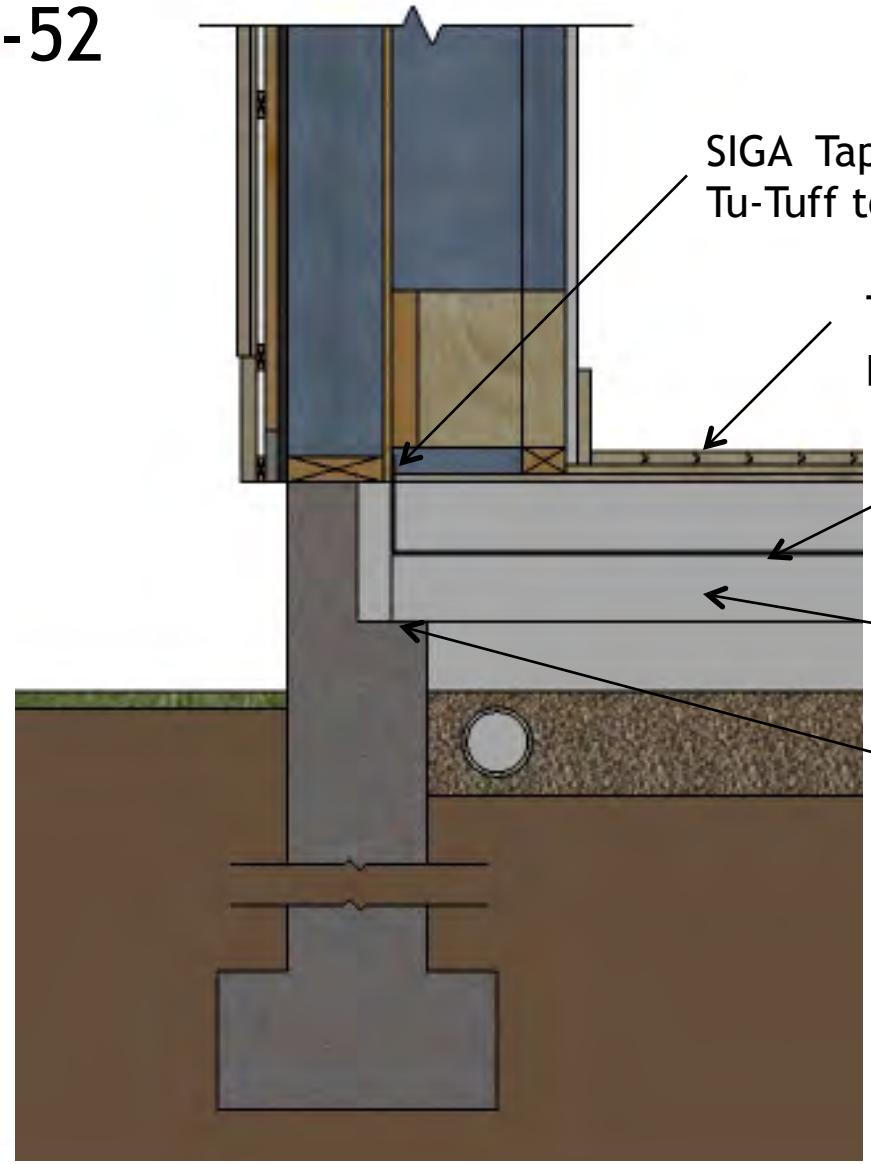
South Facade

North Facade

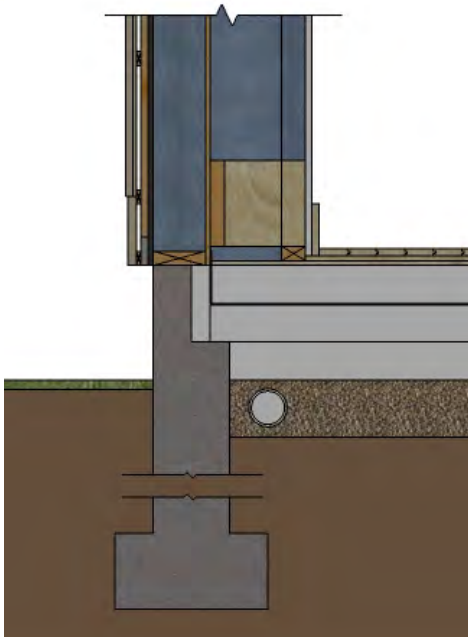
design coalition inc.

# Envelope

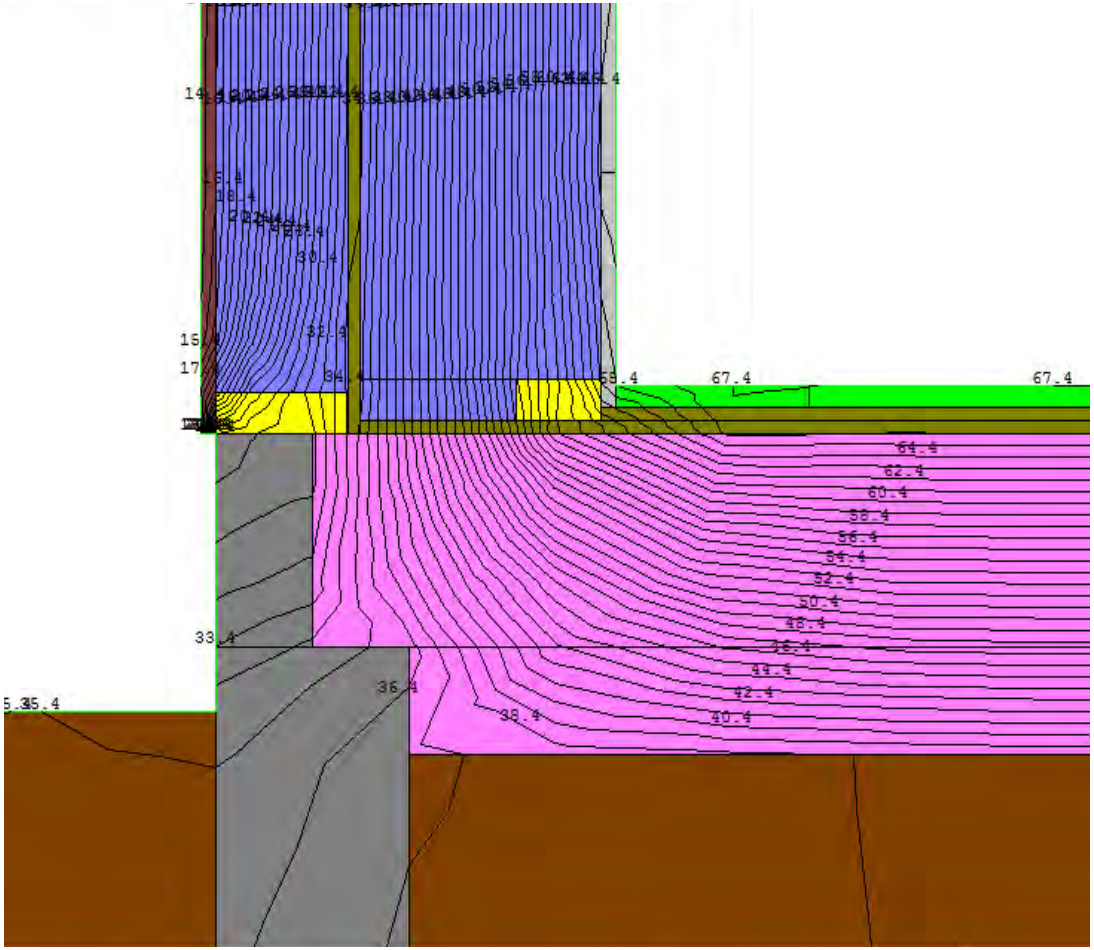
## Floor: R-52



# Envelope



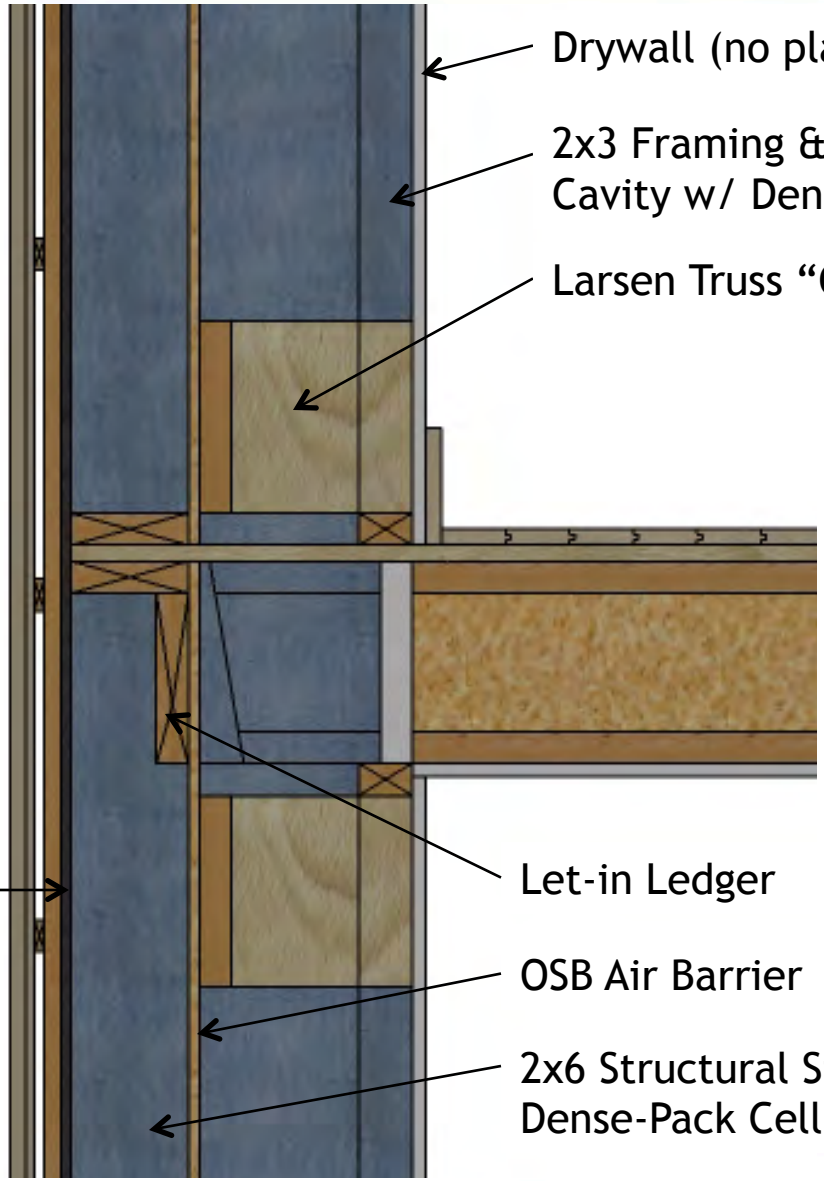
Wall Section




THERM Model

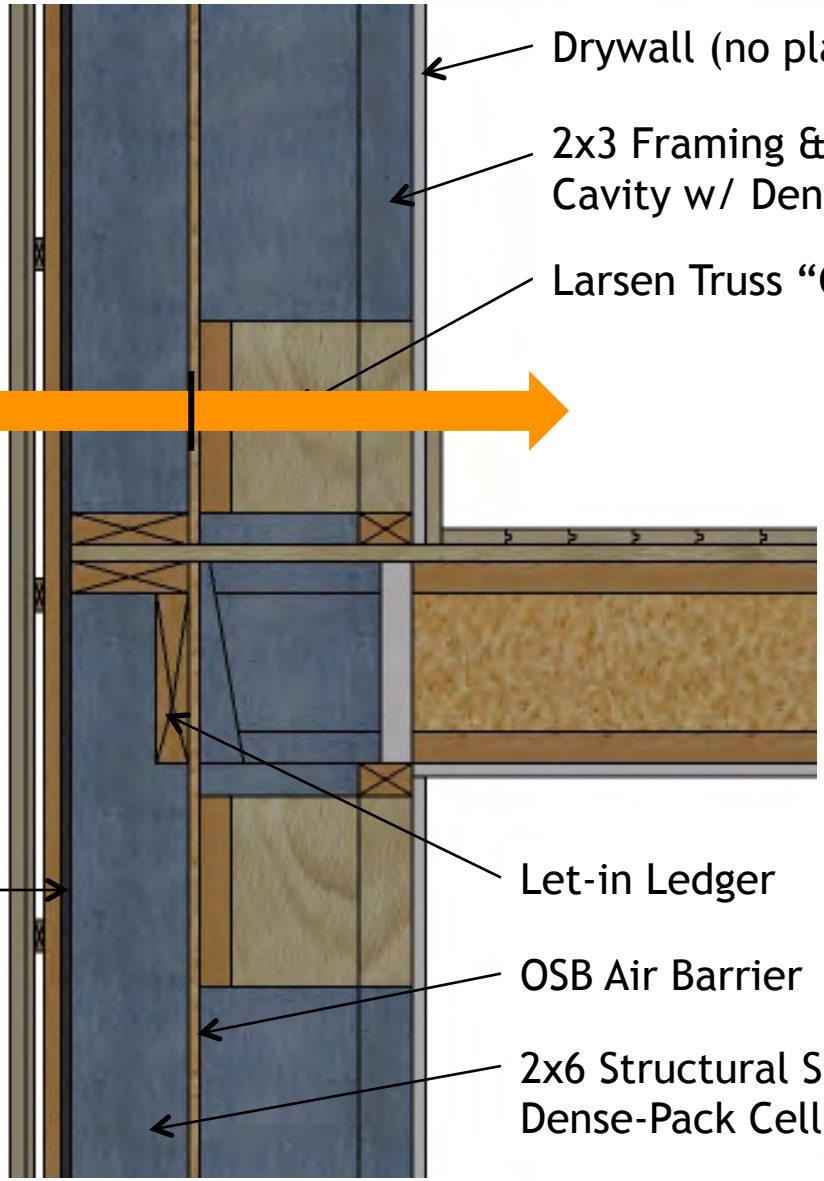
# Envelope

## Walls: R-61



# Envelope

## Walls: R-61



Drywall (no plastic vapor barrier!!)

2x3 Framing & Larsen Truss
Cavity w/ Dense-Pack Cellulose

Larsen Truss “Cleat”

Drying to
both sides

Fiberboard
Sheathing

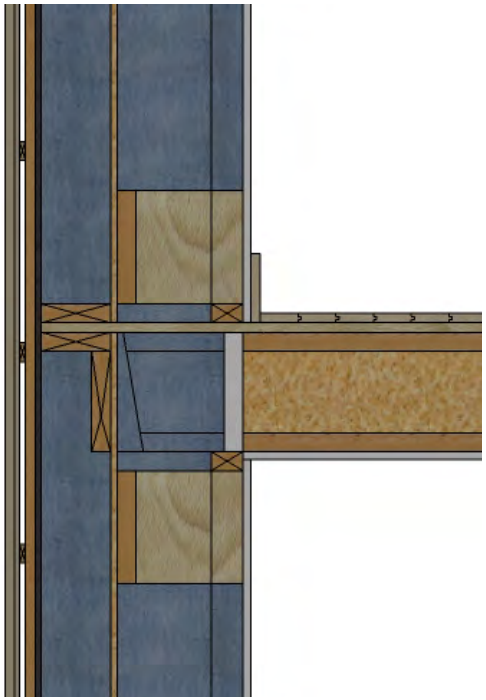
Let-in Ledger

OSB Air Barrier

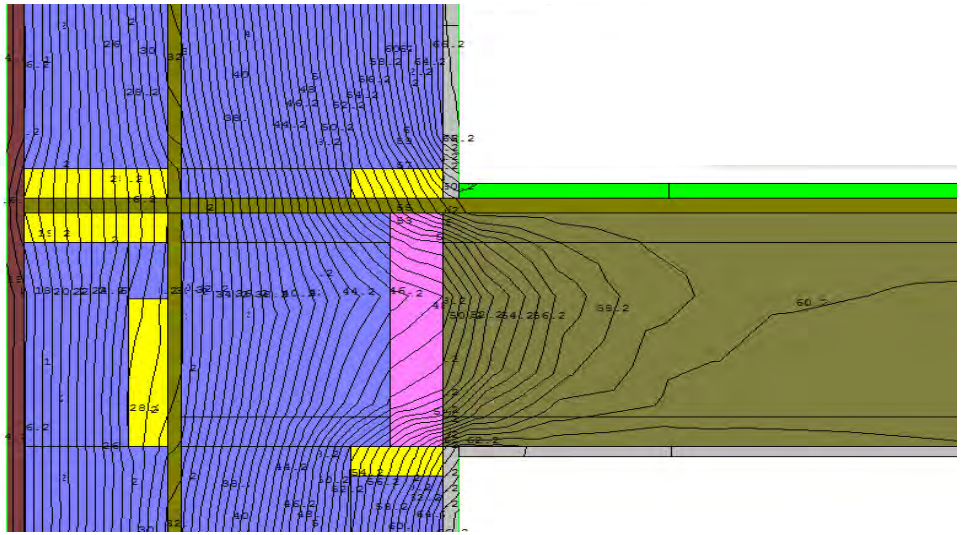
2x6 Structural Stud w/
Dense-Pack Cellulose

design coalition inc.

# Envelope



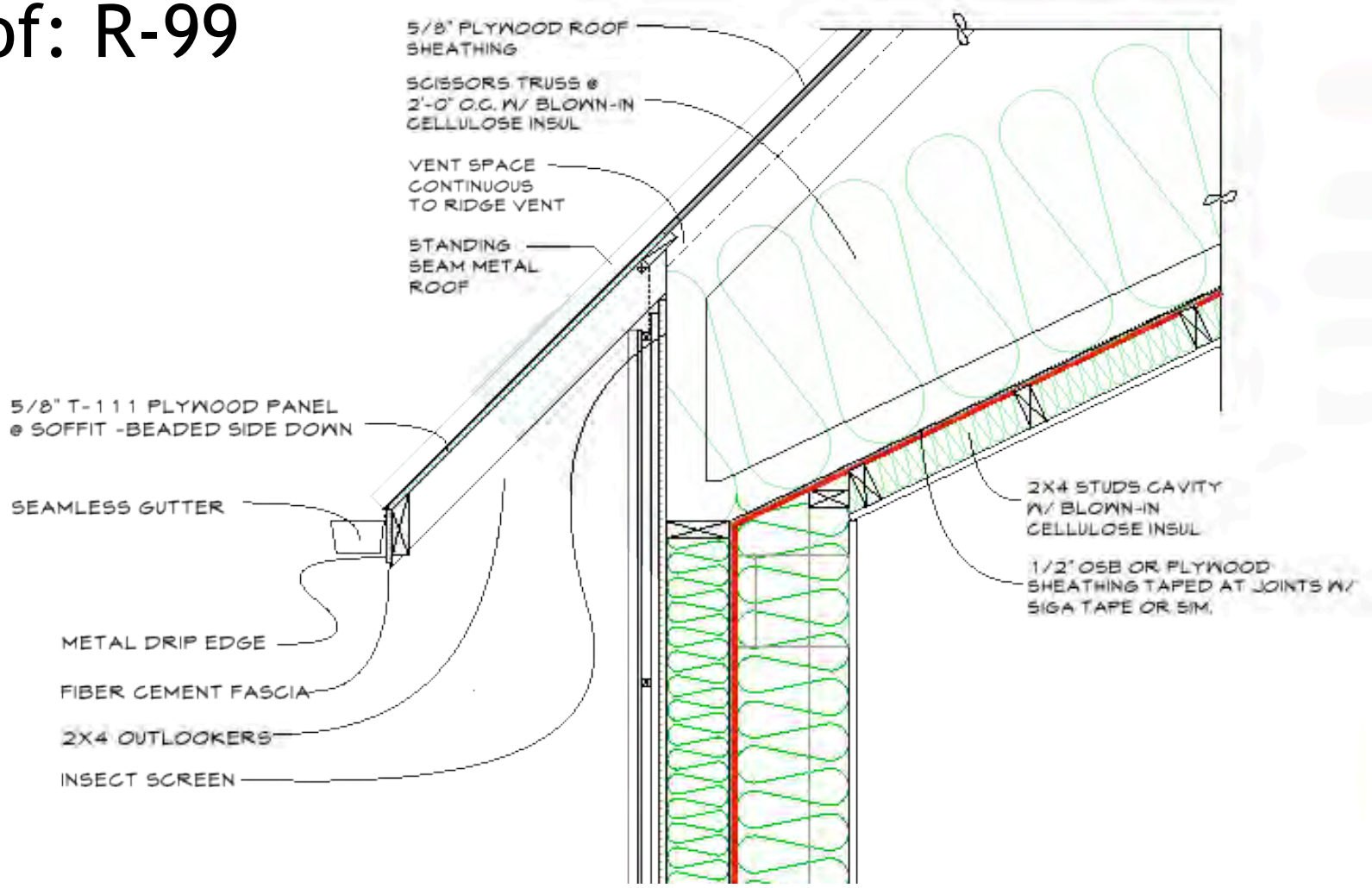
Wall Section



THERM Model

# Envelope

## Roof: R-99




design coalition inc.

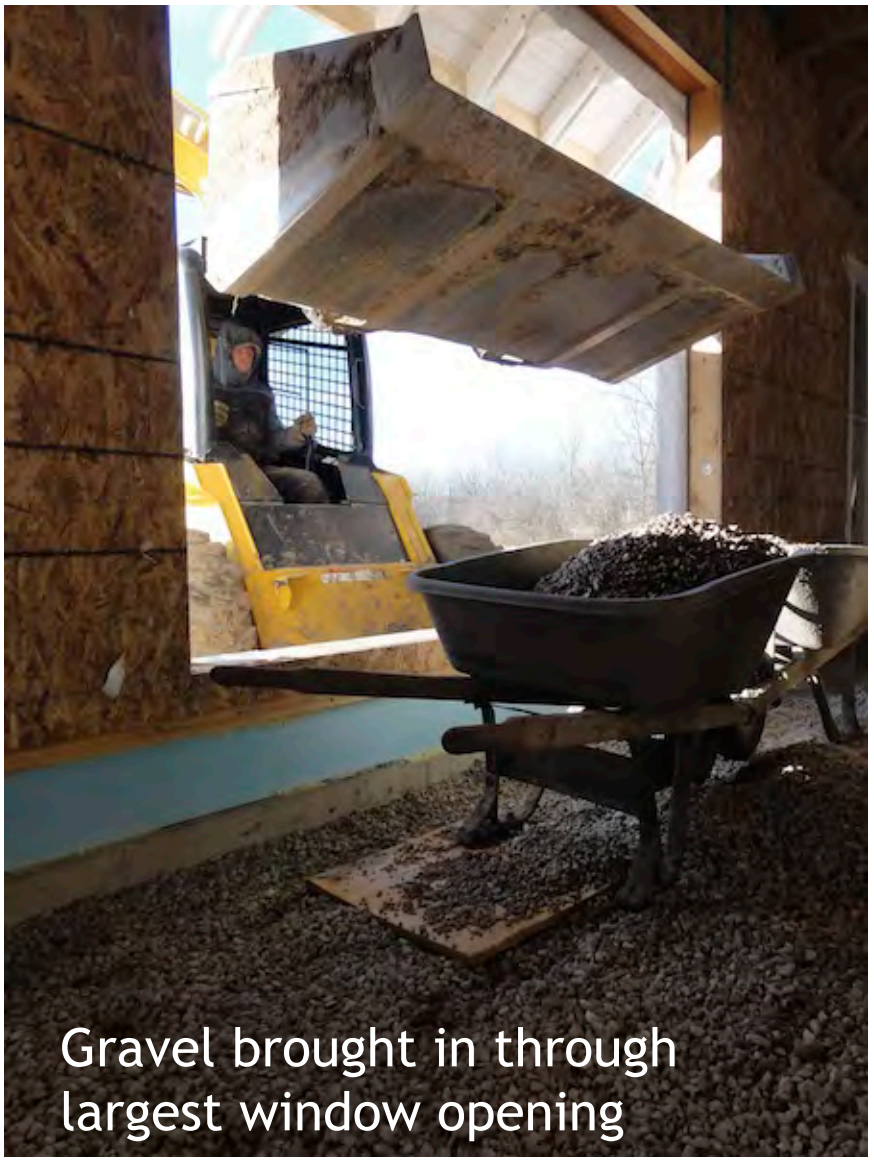
# Envelope

Floor installation after framing to keep floor dry

Concrete Ledge

design coalition inc.

# Envelope



Gravel brought in through largest window opening

# Envelope

Installation of high density EPS insulation – 3 perpendicular layers

design coalition inc.

# Envelope

Taping of EPS joints

All penetrations sealed with SIGA tape.


SIGA Tape connecting Tu-Tuff to OSB

design coalition inc.

# Envelope

2 layers perpendicular plywood floor sheathing

design coalition inc.

# Envelope

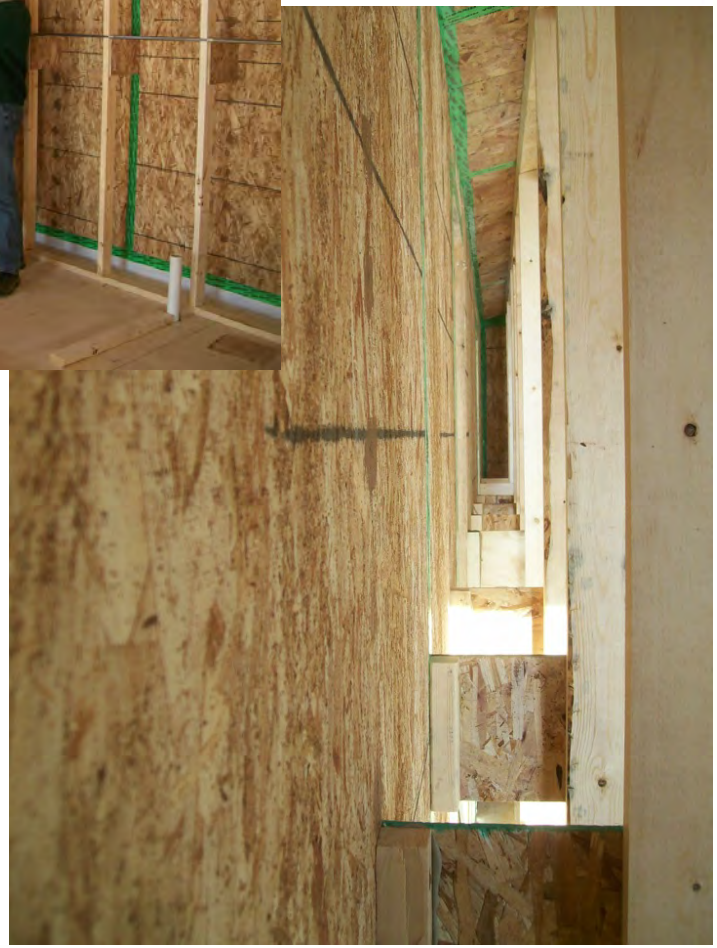
Joist & Hanger @ OSB


2x6 Framing & OSB Air Barrier

# Envelope

Larsen truss and window bucks framed out after window installation.

Larsen truss cleat



# Envelope

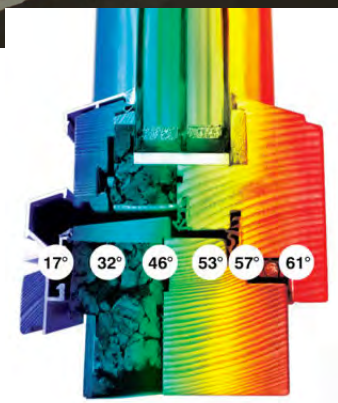

Air sealing of OSB joints, window connections and all penetrations.


# Envelope

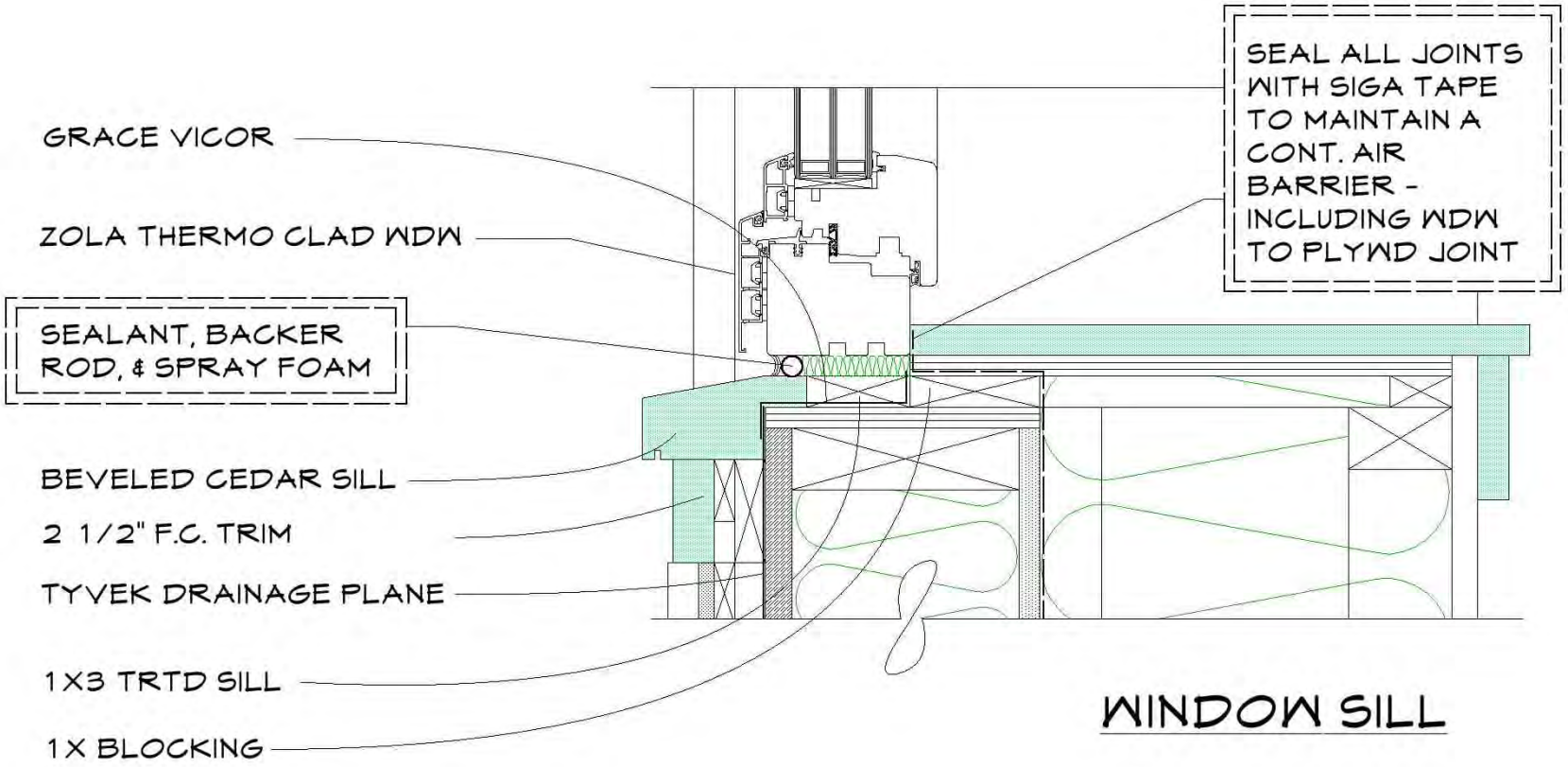

# Windows & Doors

## Zola ThermoClad European Windows

- Tilt-n-turn Operation
- Glass U-0.09 (R-11)
- Frame U-0.19 (R-5)
- 0.5 SHGC
- Most affordable
- Insect Screens




# Windows & Doors



# Windows & Doors

## Flashing/Waterproofing


# Windows & Doors

Heavy!! But, extremely well made.

# Blower door tests for air-tightness

1st Test: 0.550 $ACH_{50}$ (before insulation)

2nd Test: 0.320 $ACH_{50}$ (after sealing up two unsealed plumbing vents)

3rd Test: 0.305 $ACH_{50}$ (after insulation)

**Passive House Criteria: 0.6 $ACH_{50}$*

***Average new North American home: 4.0-5.0 $ACH_{50}$*

# Envelope

InsulWeb and cellulose insulation at Larsen Truss

design coalition inc.

# Envelope

InsulWeb, cellulose insulation and fiberboard at exterior

design coalition inc.

# Windows & Doors

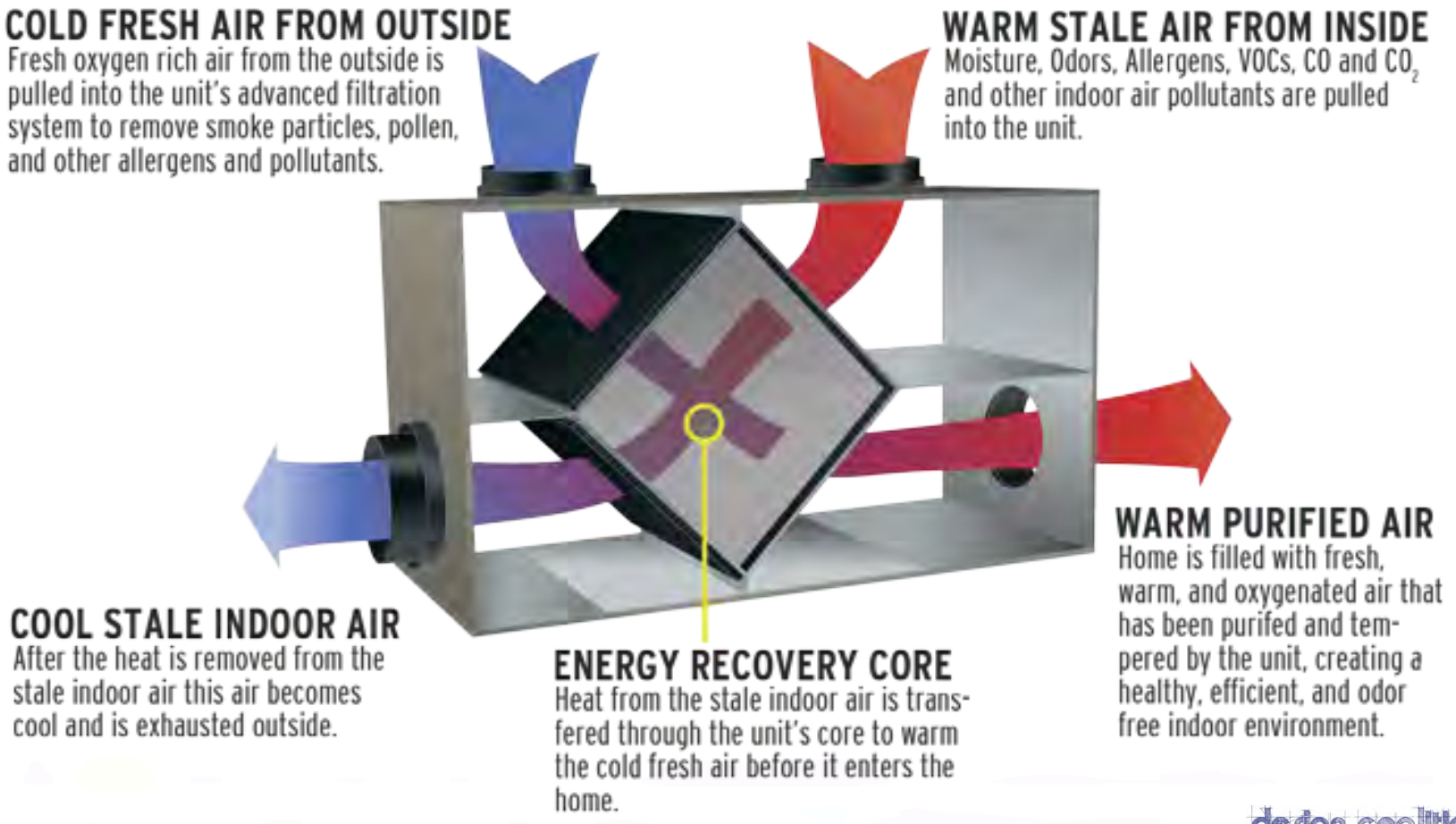

Shading w/ roof overhangs & canopies


Late March

# Mechanical Ventilation

## Energy Recovery Ventilation:

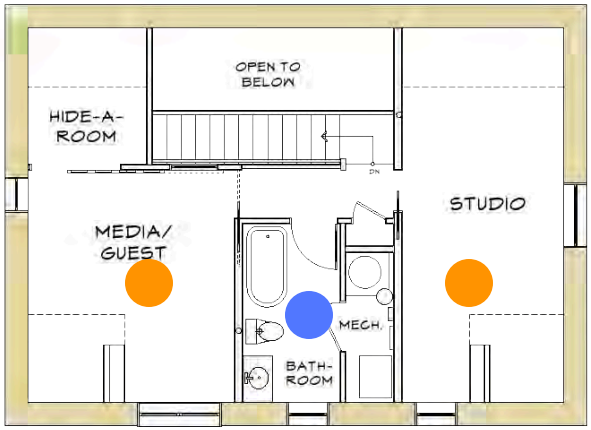
- Provides constant fresh air for people to breath in a really tight house
- Heat recovery



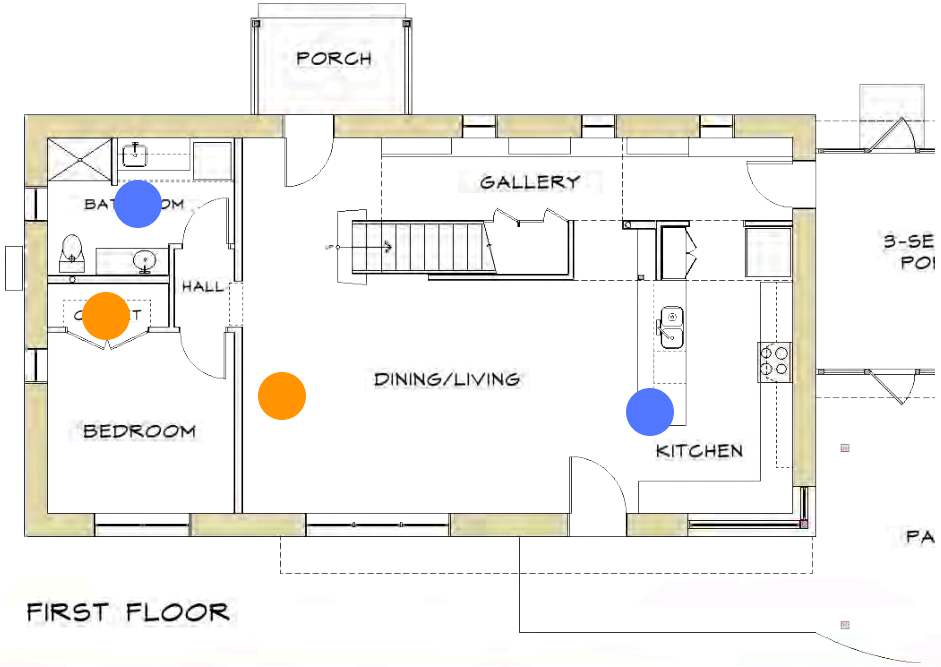
# Mechanical Ventilation

Supply

Exhaust




SECOND FLOOR




FIRST FLOOR

zehnder

ComfoAir 350 ERV

design coalition inc.

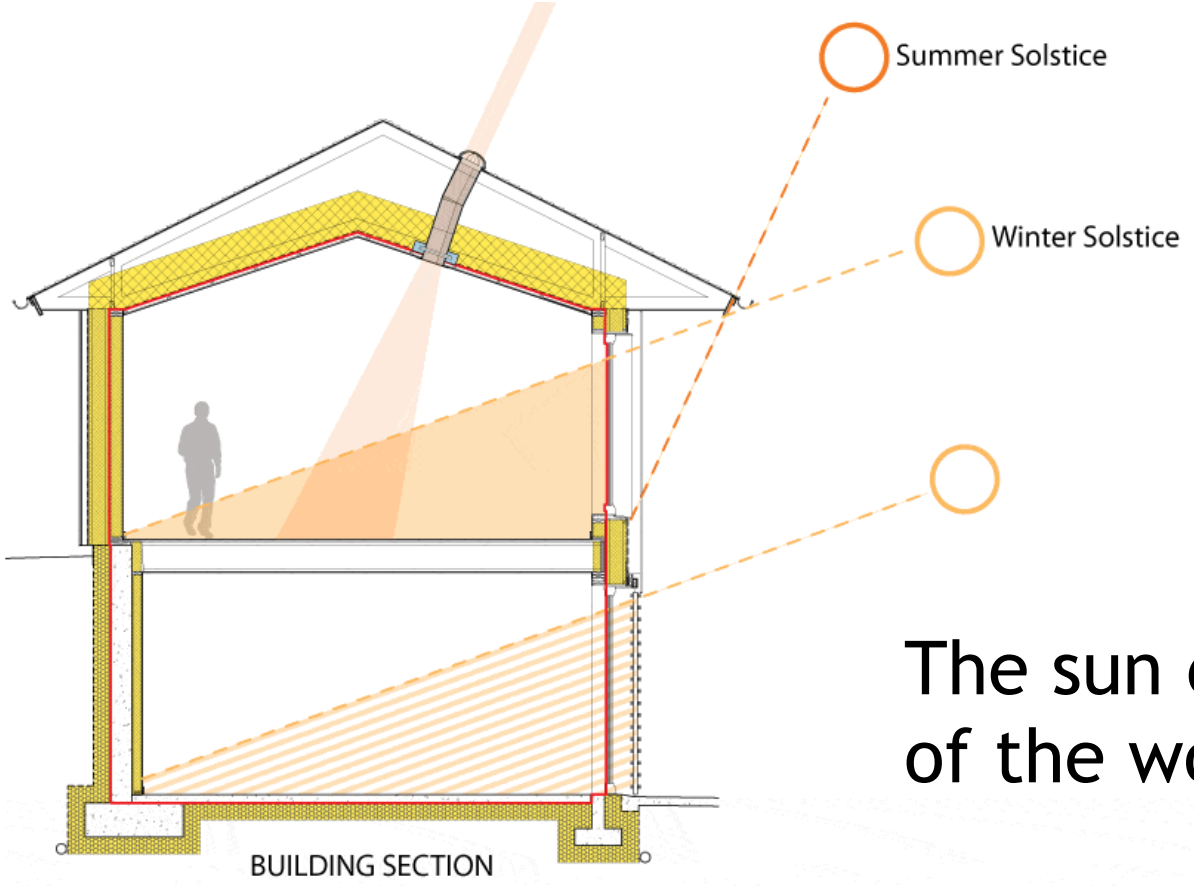
# Mechanical Ventilation



# Mechanical Heating & Cooling

## Root River House Mechanical Heat Load: 6,503 BTU/hr

*(Smallest available furnace = 35,000 - 40,000 BTU/hr = Total overkill*



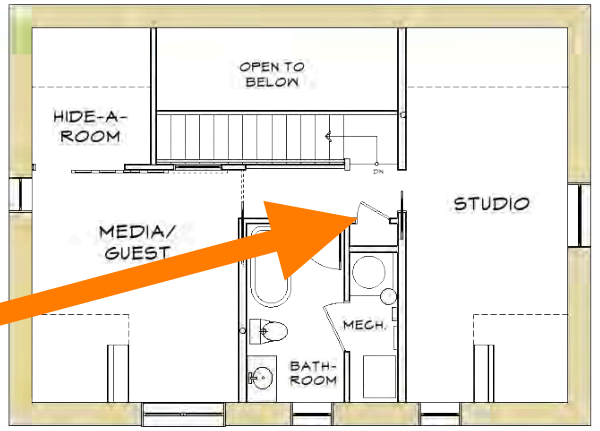

The sun does most of the work!

Hammer & Hand. Pumpkin Ridge

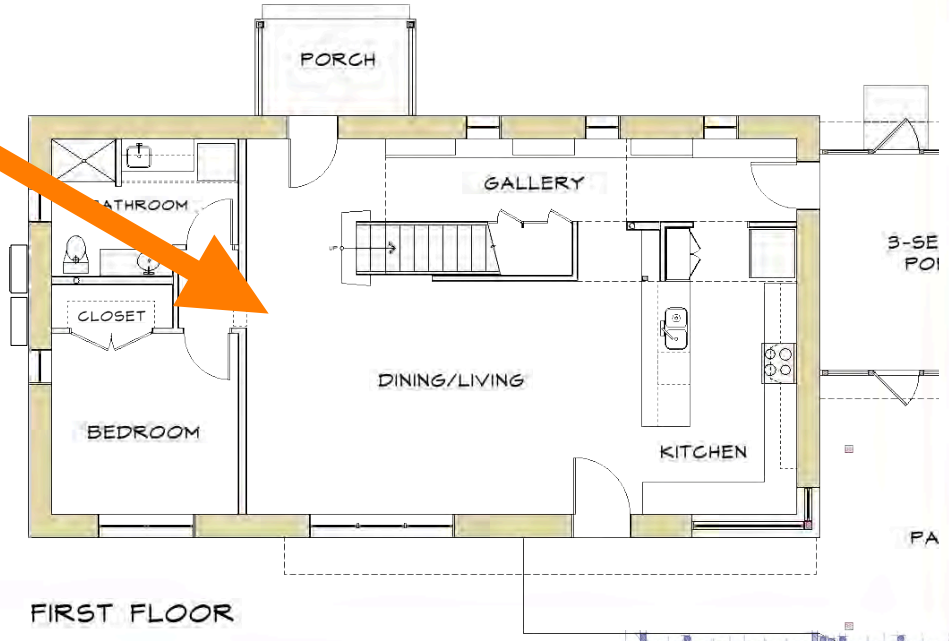
design coalition inc.

# Mechanical Heating & Cooling

2 Mitsubishi Hyper-heat Mini-split heat pumps *(9,000 BTU/hr each)* provide back up heating & cooling




SECOND FLOOR

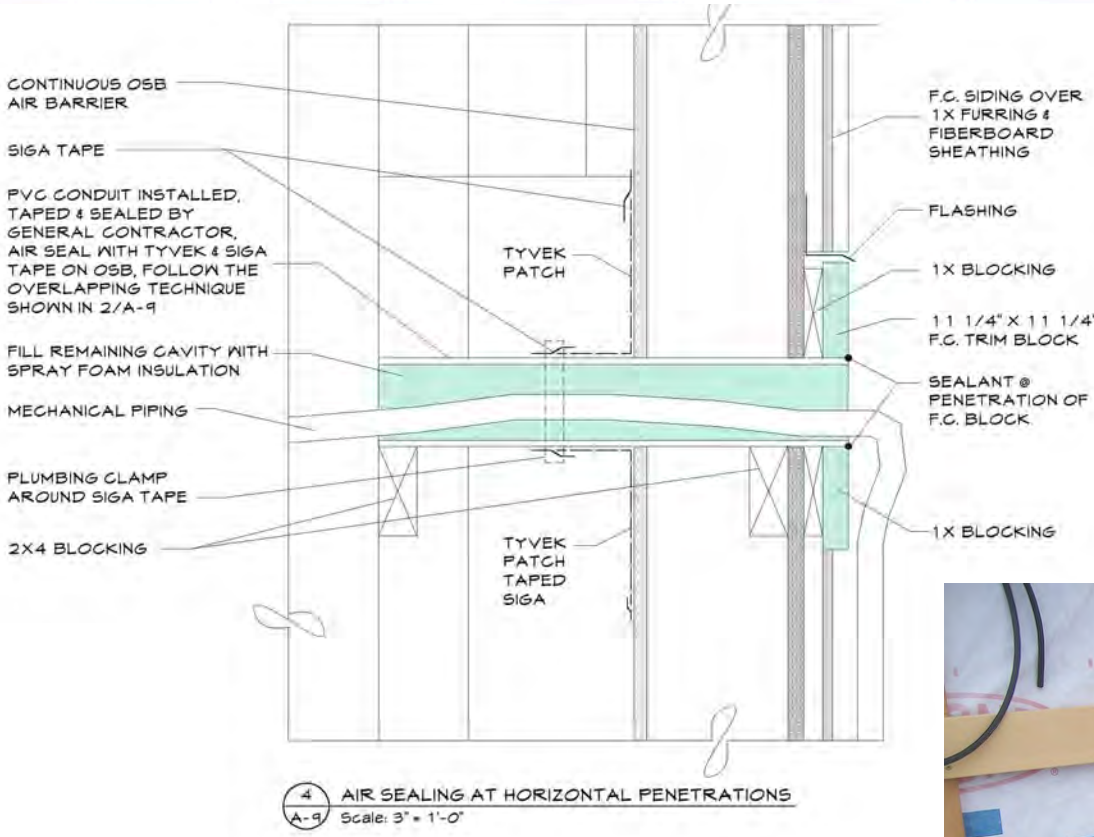



FIRST FLOOR

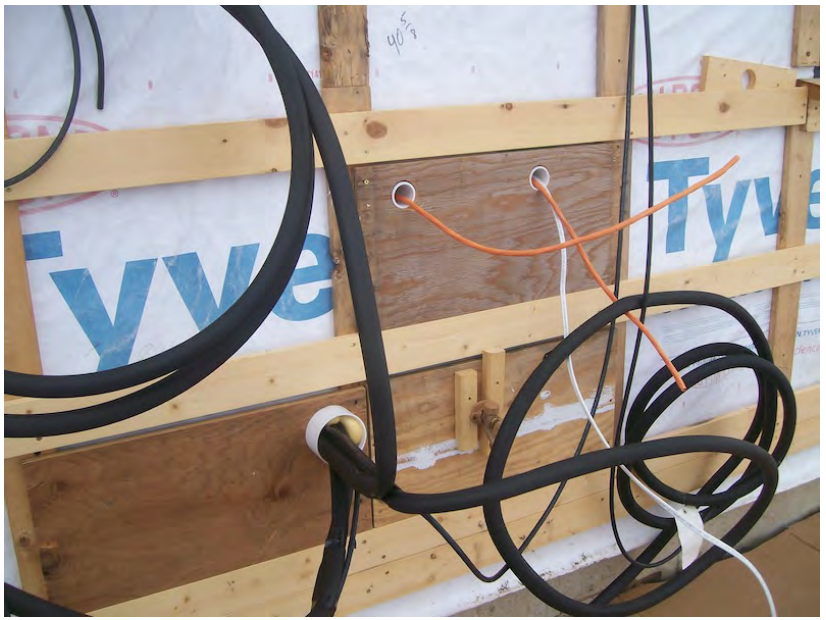
design coalition inc.

# Mechanical Heating & Cooling

# Mechanical Heating & Cooling




4 / A-9 AIR SEALING AT HORIZONTAL PENETRATIONS
Scale: 3" = 1'-0"




design coalition inc.

# Mechanical Heating & Cooling

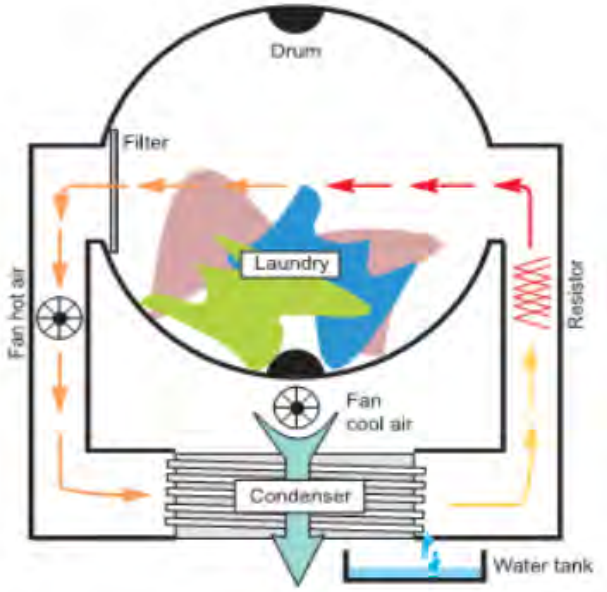
Backup for the backup

ecoheater®
warm never felt so good™

# Appliances (Special considerations for Passive House envelopes)

## Clothes Dryer:

Condensing Dryer within envelope vs. Direct Vent Dryer outside the envelope




Bosch Ventless
Condensation Dryer

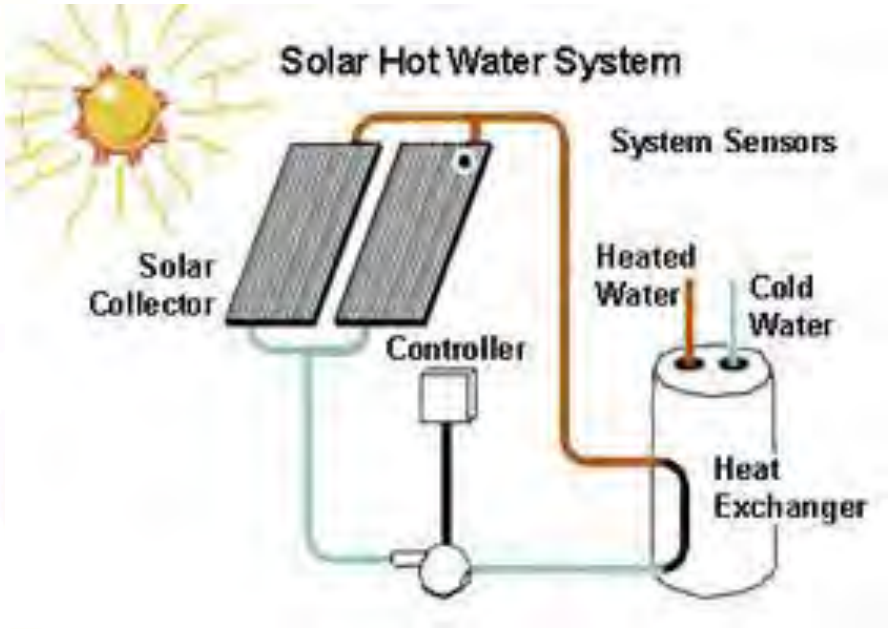
## Range & Vent Hoods:

Electric Range w/ Recirculating Vent vs. Gas Range w/ Direct Vent

# Domestic Water Heating

Solar Thermal (satisfies about 80% of DHW needs)

- SunMaxx Solar Thermal Collector System
  *(panel, controller/pump-station, expansion tank)*
- 75-gal Schuco solar storage tank
  *with electrical heating element as backup*

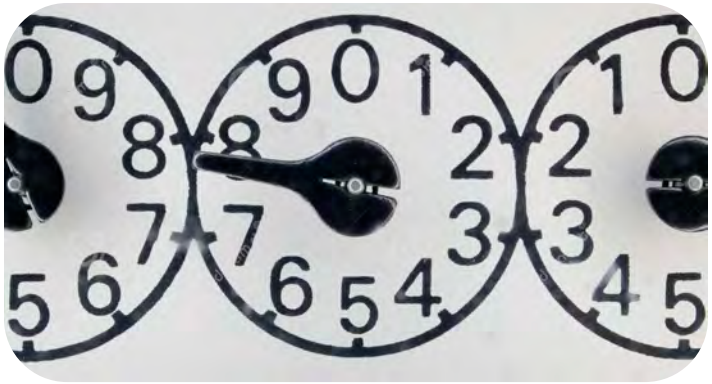



# Solar Electric Array

7 KW PV Array (more than the 3-4 KW system needed for projected energy use)


design coalition inc.

# Performance Results



# Passive House Certification?

## Passive House Criteria:

Heat Demand: 4.75 kBTU/sf/yr

Cooling Demand: 4.75 kBTU/sf/yr

Air Tightness: 0.6 ACH50

Primary Energy Demand: 38 kBTU/sf/yr

## Projected House Performance:

6.72 kBTU/sf/yr

0.44 kBTU/sf/yr

0.305 ACH50 *(actual field test)*

11.7 kBTU/sf/yr

**6,500 BTU/hr Peak Heat Load*

design coalition inc.

# Passive House Certification?

To meet PH heat demand criteria:

- Add 2” insulation to wall and 1” to roof
- Add subsoil heat exchanger
- Remove glazing from north-facing door
- Remove 1-2 north windows
- Air-tightness of better than 0.3 ACH 50
- Change L-shape massing

Decided not to go for Passive House certification.

-Not willing to compromise aesthetics, interior layout, daylight & natural ventilation goals, construction timeline, and/or budget.

-We knew the house would be net-zero or net-positive and PH strategies got us most of the way there.

# Performance Results

Building operations began in July 2014.

July through October = Net Positive!

November & December:
-Consumed more energy than produced.
-Included long stretches of below-zero temps & the some of the cloudiest weeks on record.

Total energy costs for first 6 months = $80
(plus $32/mo. to power co-op for grid connection)

# Performance Results

## Stories from Construction…

Builder used 80% of one propane tank for temporary heating vs. 3-5 tanks on a typical project.

During the “polar vortex” of 2013-2014: No temporary heat required for days at a time and the temp. never got below 40°F (even though only a third of the insulation had been installed).

In late March, the interior of the house felt comfortable and the heating system hadn’t even been installed yet.

# Performance Results

## Stories from the Homeowners…

*“Everyone who comes to the house, particularly those who studied the plans, say it feels bigger than they expected. The windows not only produce heat, but create a sense of space and fill the house with beautiful light, even on cloudy days.”*

*“The house is quiet, and the air isn't as dry as we've experienced in past winters. We see it in our skin, which is less dry, and we have few dry weather nosebleeds. When we go places with forced air heat, the difference is startling and uncomfortable.”*

Happy Homeowners

# Performance Results

## Other notes from the Homeowners…

-On sunny or partially sunny days, the main rooms get into the mid-60s or even 70s (ex: when it was 9 degrees outside, it was 76 degrees inside).

-Overnight, with no heat, temps drop back into mid-60s (or upper-50s during cloudy days).

-Without the drafts of a conventional house, interior temps in the low 60s feel warmer.

-The house holds temps well (by comparison, the workshop will lose 20-25 degrees overnight.)

-When heat is needed, mini-split on first floor suffices.

Winter at the
Root River House

# Upgrading to Net-Zero:
# The money question….

# Construction Costs

## Root River House

| Construction Costs | |
|---|---|
| Total Construction Cost of House & Garage | $445,000 |
| House Construction Cost (no GC Fee)* | $348,700 |
| House Construction Cost (w/ 10% GC Fee)* | $383,570 |
| Gross Square Feet | 2210 |
| Cost per Square Foot | $173.56 |

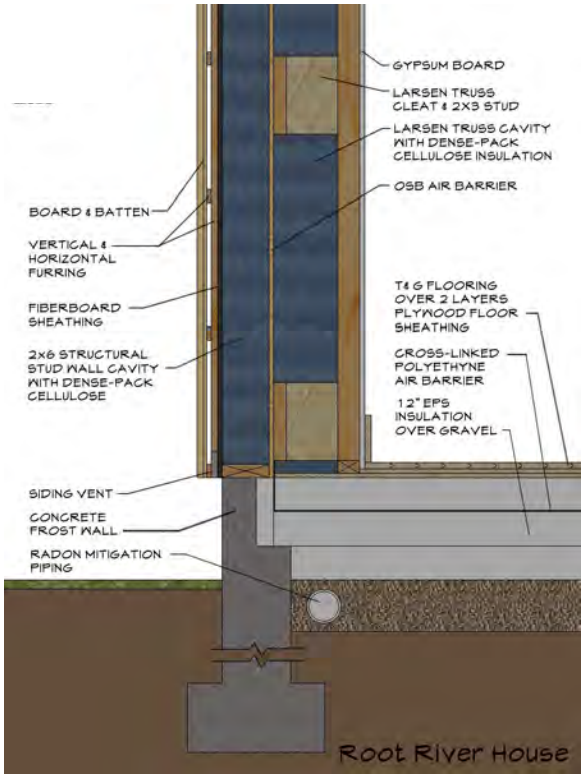
*Includes solar and solar tax credits.

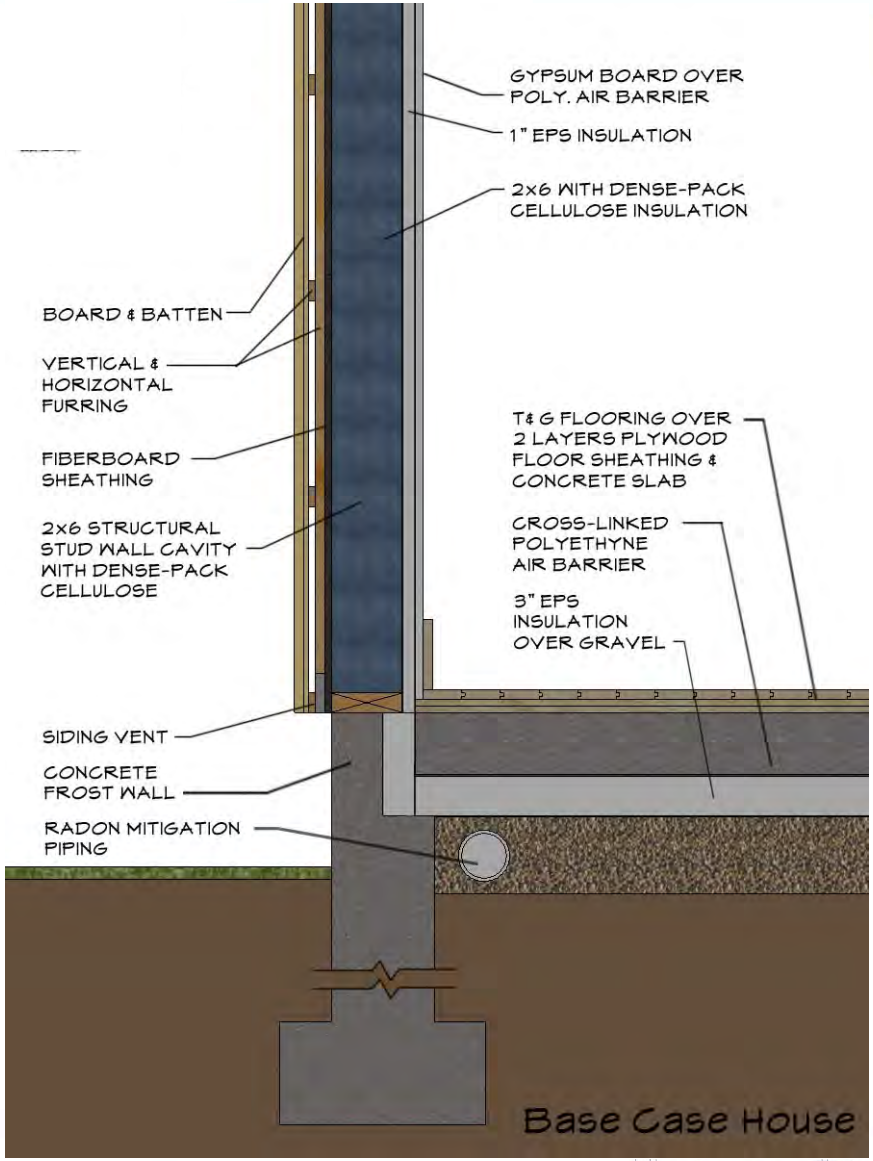
*Does not include land cost, design fees, well, septic system, driveway, utility connection or landscaping.

# Base Case Comparison

Base Case House Assumptions:

-Slightly better than code
-Little to no attention to solar orientation
-Conventional gas furnace w/ no ERV
-Conventional gas water heater
-Fiberglass double-glazed casement windows
-Air tightness: 4 ACH50
-Approx. $220/month energy bills

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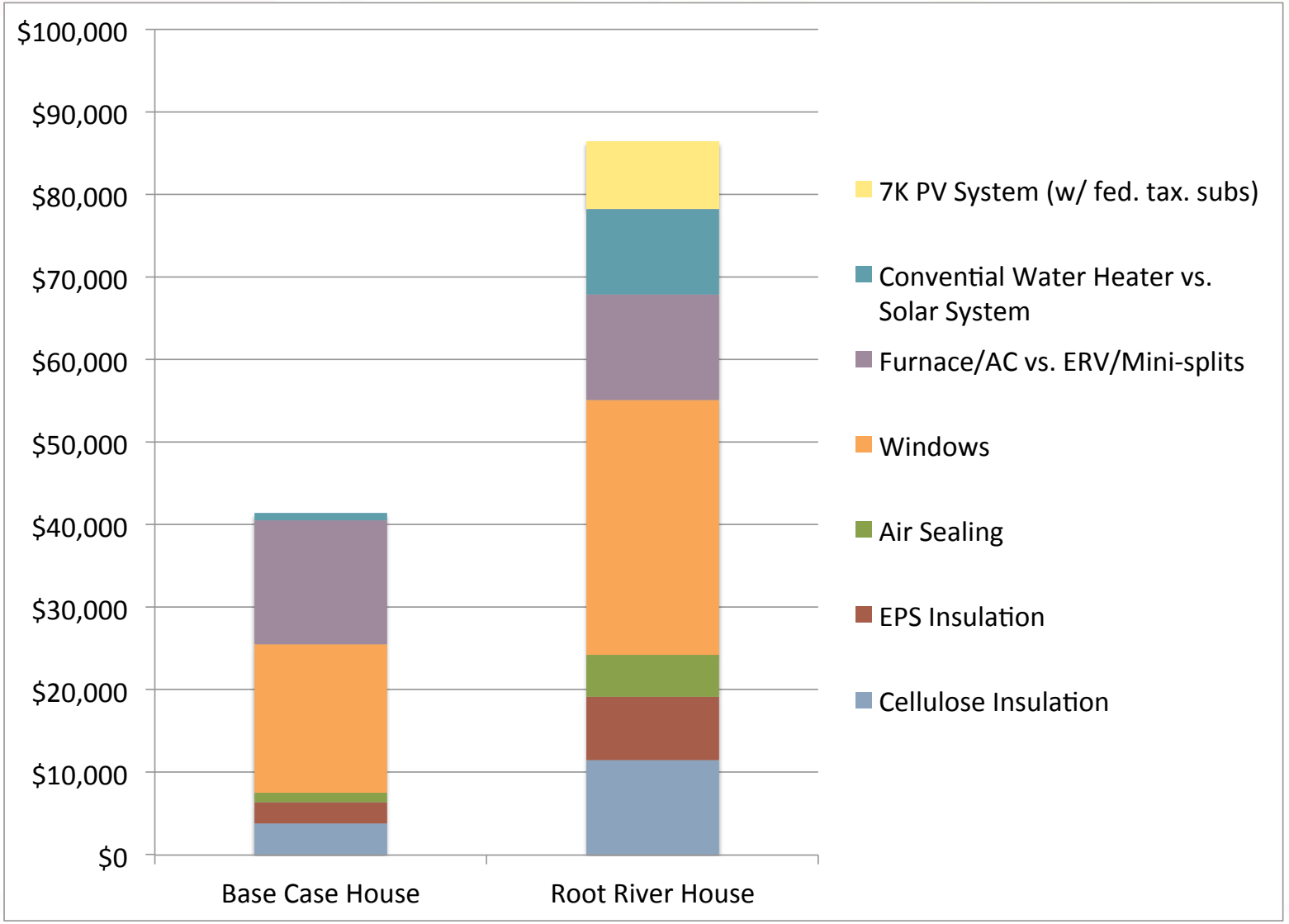
# Base Case Comparison

## Envelope & Mechanical Upgrades from Base Case = Approx. $45,000

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# Base Case Comparison

## Monthly expense comparison

| | Base Case House | Root River House |
|---|---|---|
| Total Construction Cost | $338,610 | $383,570 |
| 20% Downpayment | $67,722 | $76,714 |
| 80% Financed (30 yr. Mortgage @ 4.25% interest) | $270,888 | $306,856 |
| Monthly Mortgage Payment (P&I) | $1,332 | $1,409 |
| Approx. Monthly Energy Bill* | $220 | $45 |
| **Total Monthly Cost** | $1,552 | $1,454 |

*Grid connection charge from power co-op is $32/mo.

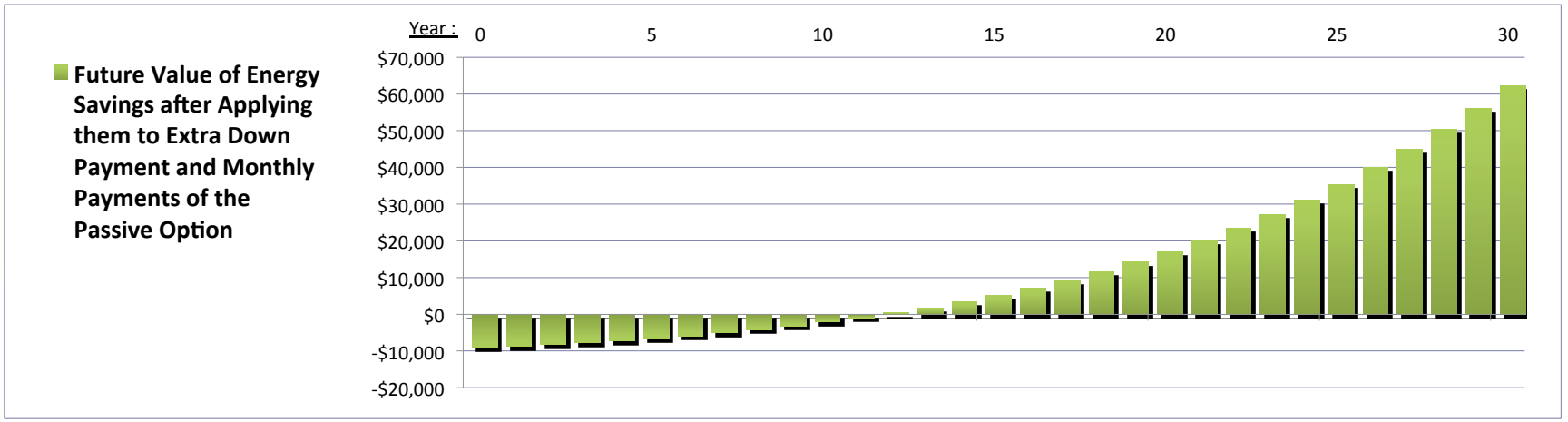
## $98 savings/month for the first year of mortgage

# Return on Investment

## Future Value & Rising Energy Costs

| Cost of Home Options | Cost of Baseline Home | Cost to Upgrade to Passive House | Cost of Passive House |
|---|---|---|---|
| | 338,610 | 13.28% | 383,577 |

| | |
|---|---|
| Energy Cost, Baseline Home ($ per month) | 220 |
| Annual Rate of increase in Energy Costs Projected | 3% |
| Energy Reduction from Passive House Approach (%) | 93% |




**Areas below zero indicate that the extra down and monthly payments exceed the value of the energy savings to date.**

**When the value reaches zero, it's all gravy - and the energy savings each month will add up to a substantial sum!**

INFORMATION PRESENTED BY: Christi Weber, Design Coalition, Inc.

# Return on Investment

## Beyond the financial - the **REAL** ROI

-No drafts, cold spots, or large temperature swings - surfaces are warm

-Healthy air

-Daylight and views to outside

-Acoustical benefits

-No fear (or less fear) of the unknown
*(weather, energy prices, power grid)*

-Reduction of personal ecological footprint

# Return on Investment

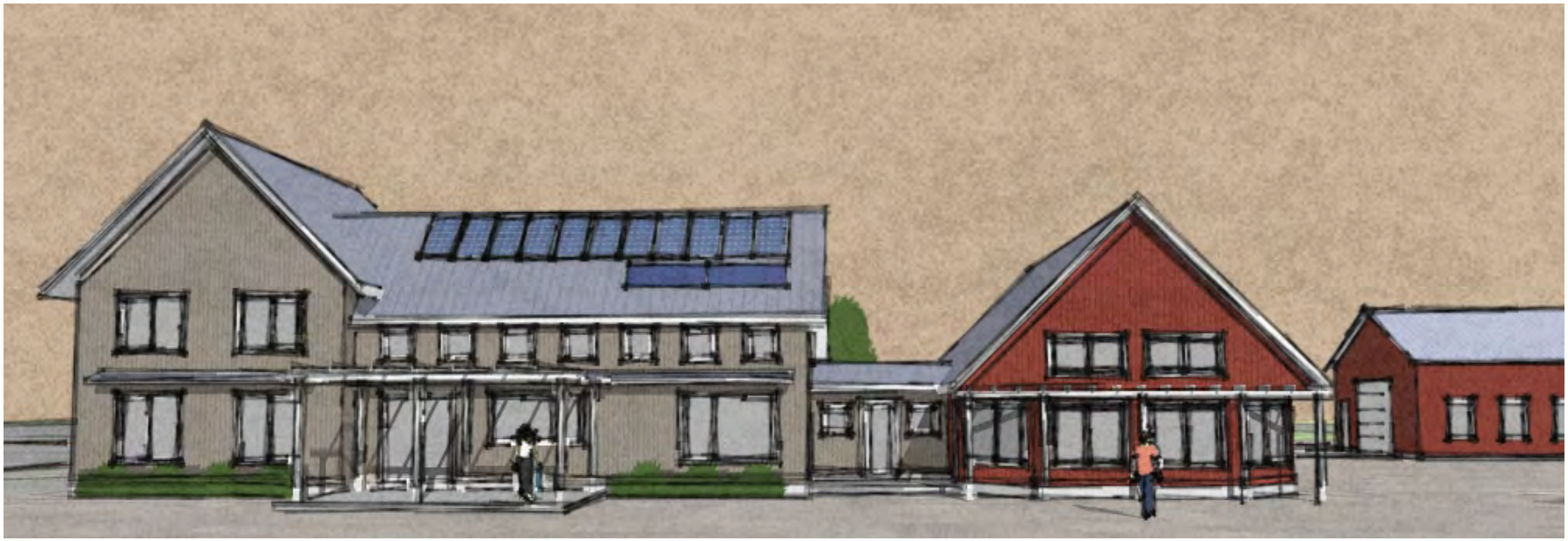
## Energy-efficient homes have higher values.

- Market value of a home increases $20 for every $1 decrease in annual energy costs. - *The Appraisal Journal*
- Newly constructed homes with a HERS rating in Portland sold for 8% more, existing homes for 30% more. - *Earth Advantage Institute*

## Energy-efficient homes sell faster.

*- Earth Advantage Institute*

# On the Boards



One Seed Farmhouse

*Located just outside Madison, WI*

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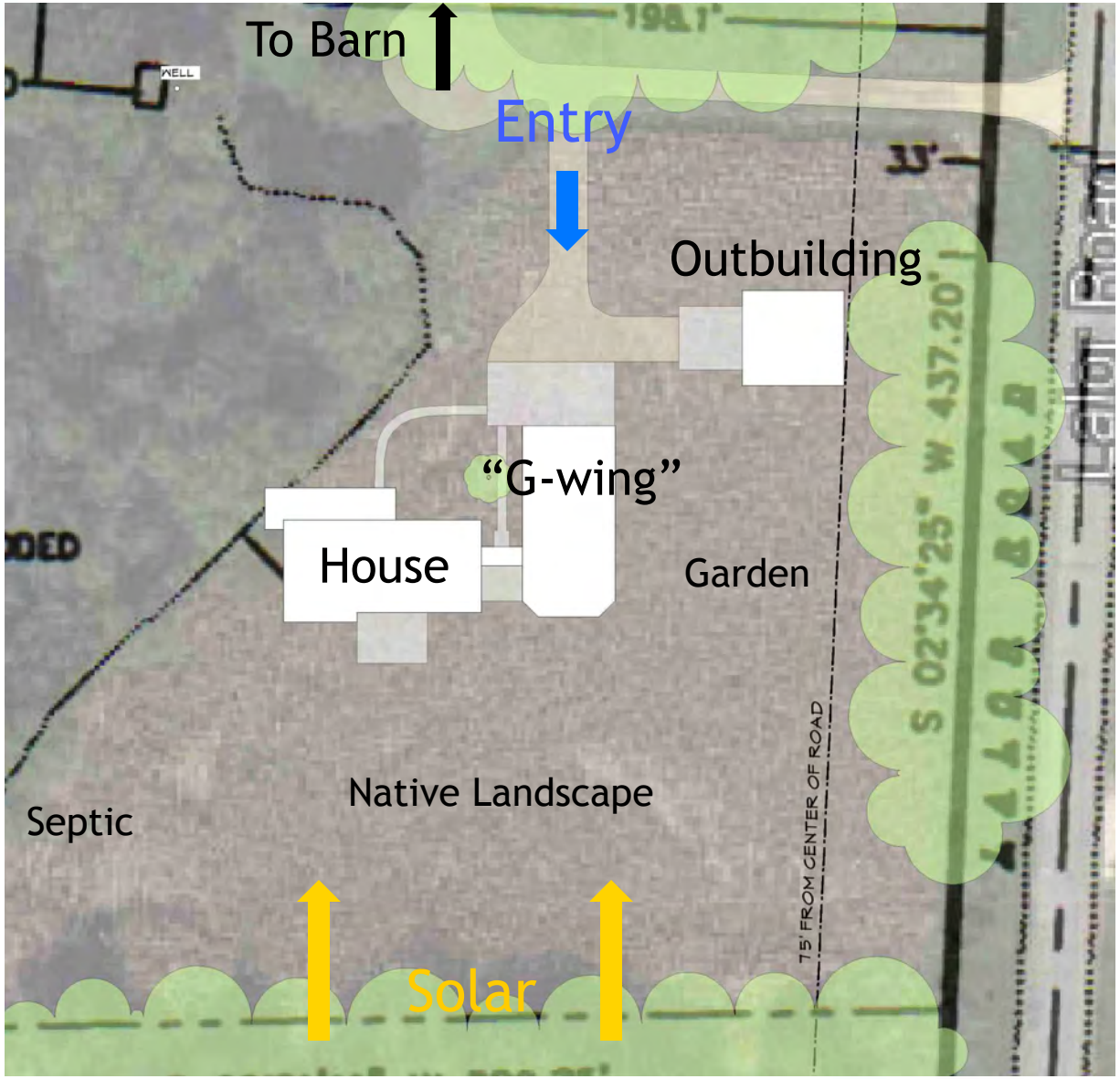
# One Seed Farmhouse




House with an Agricultural and Educational Purpose

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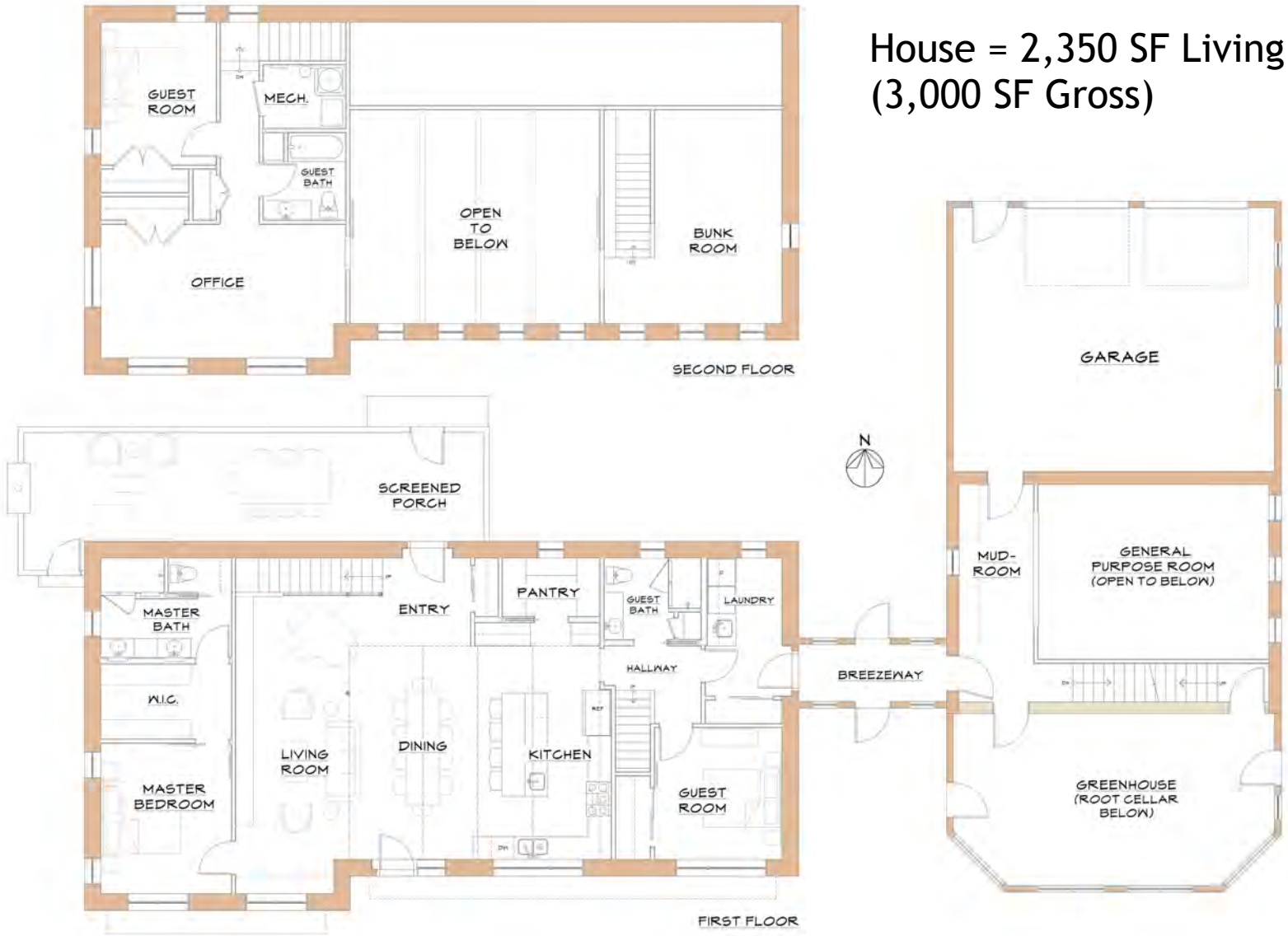
# One Seed Farmhouse

House = 2,350 SF Living Space
(3,000 SF Gross)

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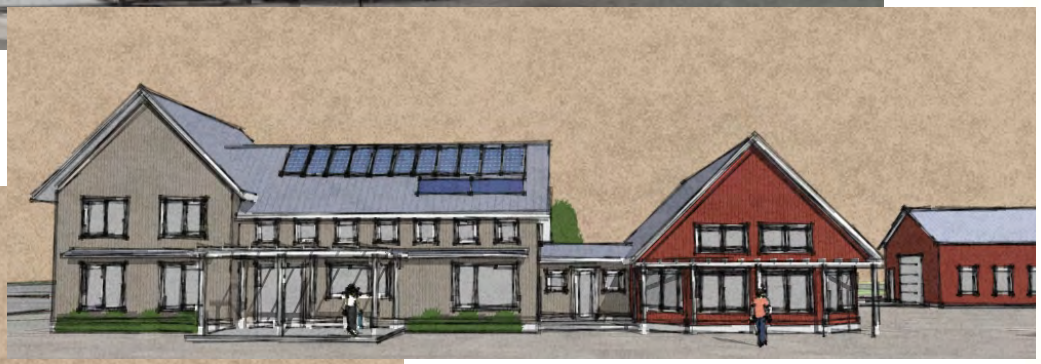
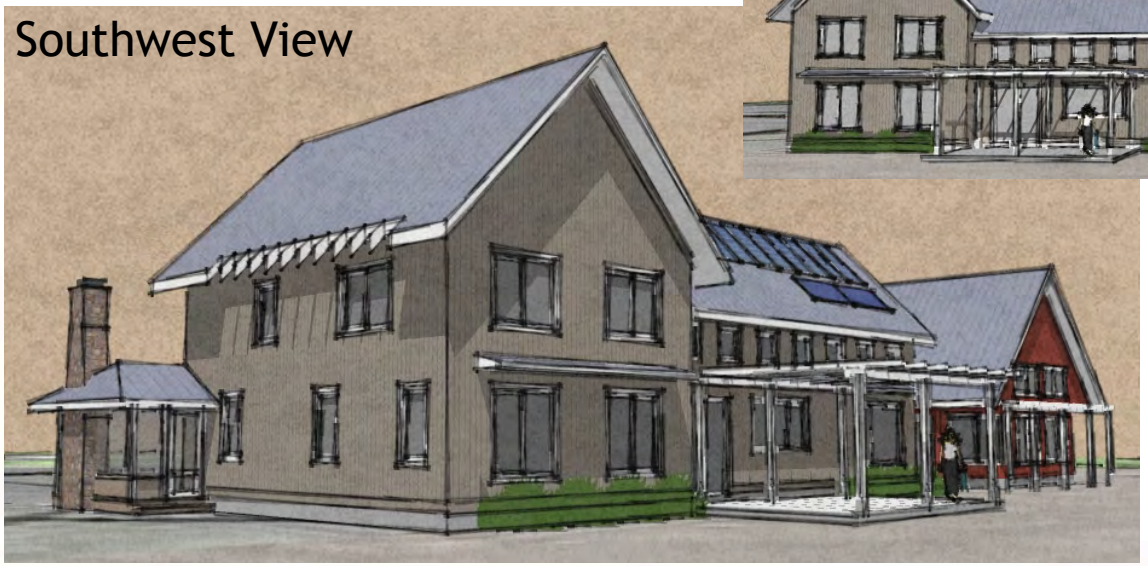
# One Seed Farmhouse

North Facade



South Facade

Southwest View



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# One Seed Farmhouse

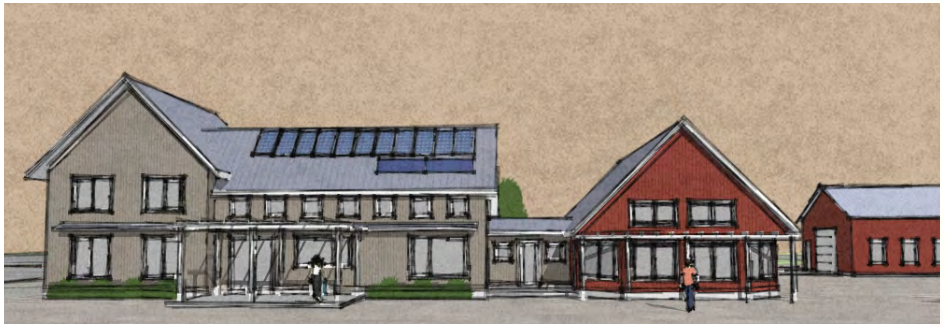
## Key Observations:

1. Net-zero CAN be cost-effective (Root River House).
2. Passive House Heat Demand criteria difficult to achieve in cold climates even with very large amounts of insulation.
3. PHIUS is currently re-examining it's own standard. Initial studies show that PH criteria isn't too far off the mark when it comes to cost-effectiveness as compared with the cost of PV. (See "Climate-Specific Passive Building Standards")
4. Energy modeling is key – One size fits all approaches do not lead to cost optimization (ex. The 5-10-20-40-60 approach)
5. Simple economic analysis is needed for net-zero projects.

# One Seed Farmhouse

## Key Re-examinations of the Envelope:

1. Quantity of Insulation (vs. PV to get to net-zero)
2. Sizes and types of windows (vs. PV to get to net-zero)
3. Tweaks to the wall section



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# One Seed Farmhouse

## Envelope upgrades vs. PV?

-Use the super-simplified BEOpt approach.

-At what point do you hit diminishing returns on insulation and windows and it makes sense to invest in PV?

-Comparison between envelope upgrades and PV in order to achieve end goal of net-zero energy use.

## Preliminary Energy Model:

-12” EPS @ Floor (R-50)

-16” Cellulose @ Wall (R-60)

-22” Cellulose @ Roof (R-82)

-Peak Heat Load: 10,200 BTU/hr

# One Seed Farmhouse

## Envelope upgrades vs. PV?

| Scenario | Associated Heat Load (BTU/hr) compared to Base | Equivalent PV needed for Net-Zero (kW) | Cost of Scenario ($) | Cost of PV ($) | Total Cost of upgrade & PV ($) |
|---|---|---|---|---|---|
| | | | | | |
| **Floor** | | | | | |
| 6" EPS Insulation (Base) | | | | | |
| 8" EPS Insulation | | | | | |
| 10" EPS Insulation | | | | | |
| 12" EPS Insulation | | | | | |
| | | | | | |
| **Wall** | | | | | |
| 12" Cellulose Insulation (Base) | | | | | |
| 14" Cellulose Insulation | | | | | |
| 16" Cellulose Insulation | | | | | |
| | | | | | |
| **Roof** | | | | | |
| 16" Cellulose Insulation (Base) | | | | | |
| 18" Cellulose Insulation | | | | | |
| 20" Cellulose Insulation | | | | | |
| 22" Cellulose Insulation | | | | | |
| | | | | | |
| **Windows** | | | | | |
| H Window (Base) | | | | | |
| Zola European Windows | | | | | |
| 20% Reduction- South Wdws | | | | | |

# One Seed Farmhouse

## Wall section tweaks:

-We are always looking for ways to improve

-OSB and issues as an air barrier

-More recognizable to typical builder – repeatability

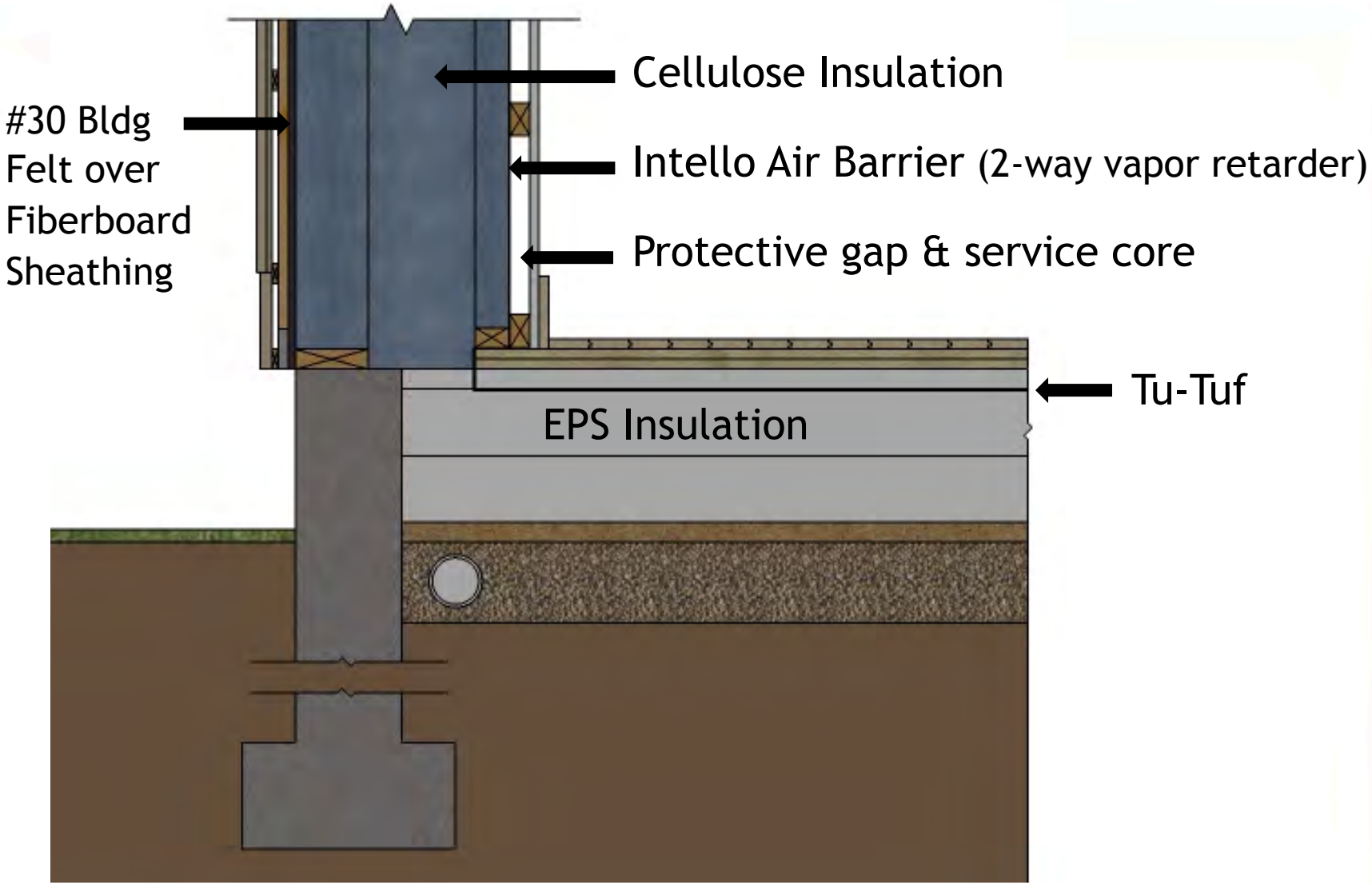
-Increased buildability (concrete ledge, panelized walls, sequencing)

-Air barrier at interior – even better vapor profile

-Preserve protection of air barrier

-Preserve continuity at second floor framing

# One Seed Farmhouse




Wall Section @ Fdn

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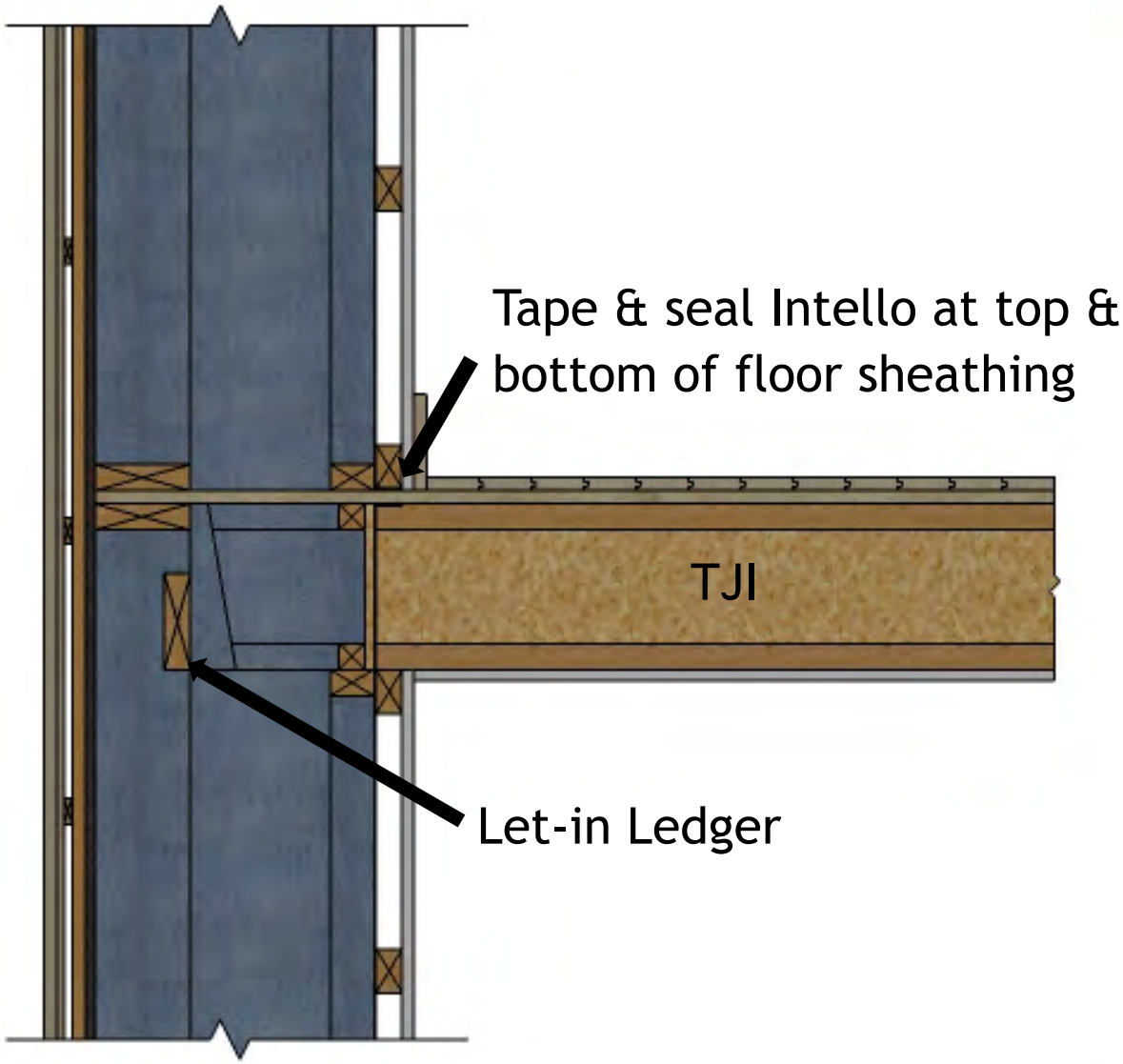
# One Seed Farmhouse




Wall Section @ Floor Framing

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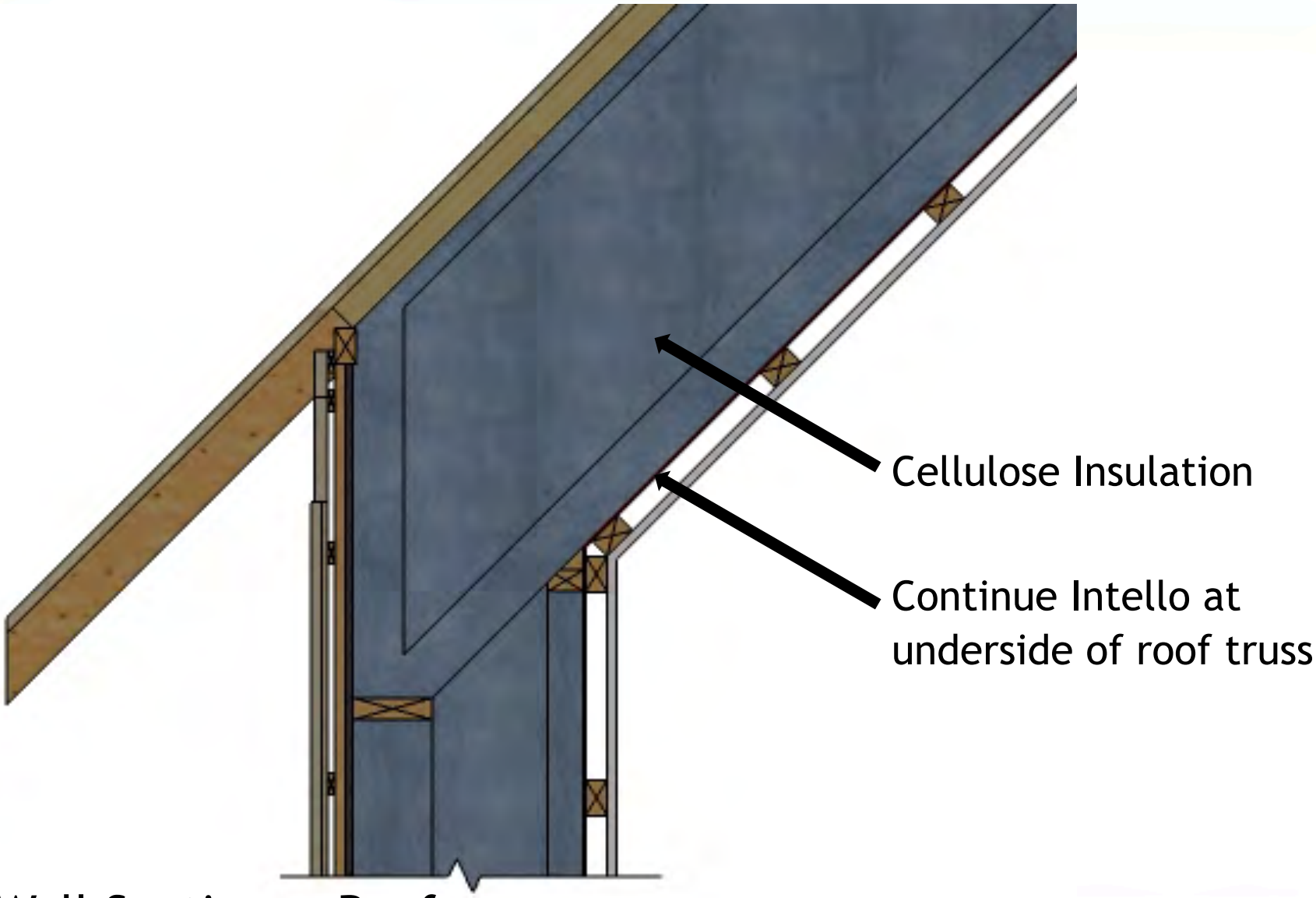
# One Seed Farmhouse




Wall Section @ Roof

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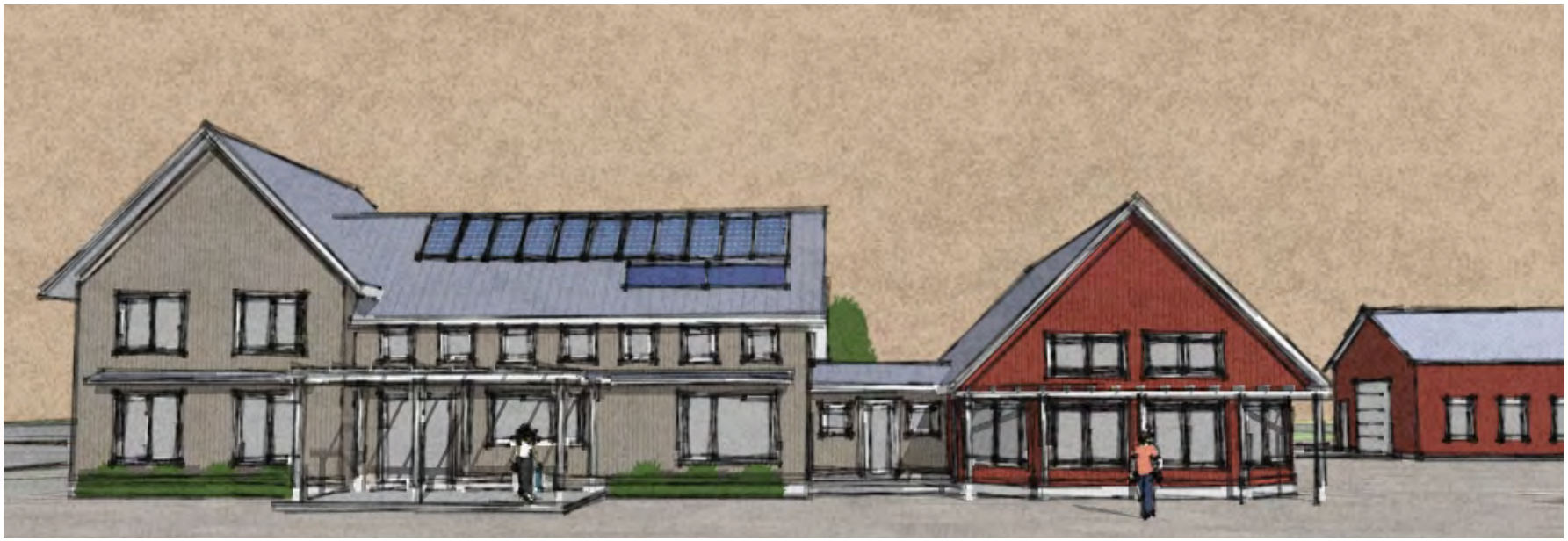
# One Seed Farmhouse



-Currently in Preliminary Cost Estimating

-Construction starts Summer 2015

-More on that next year!

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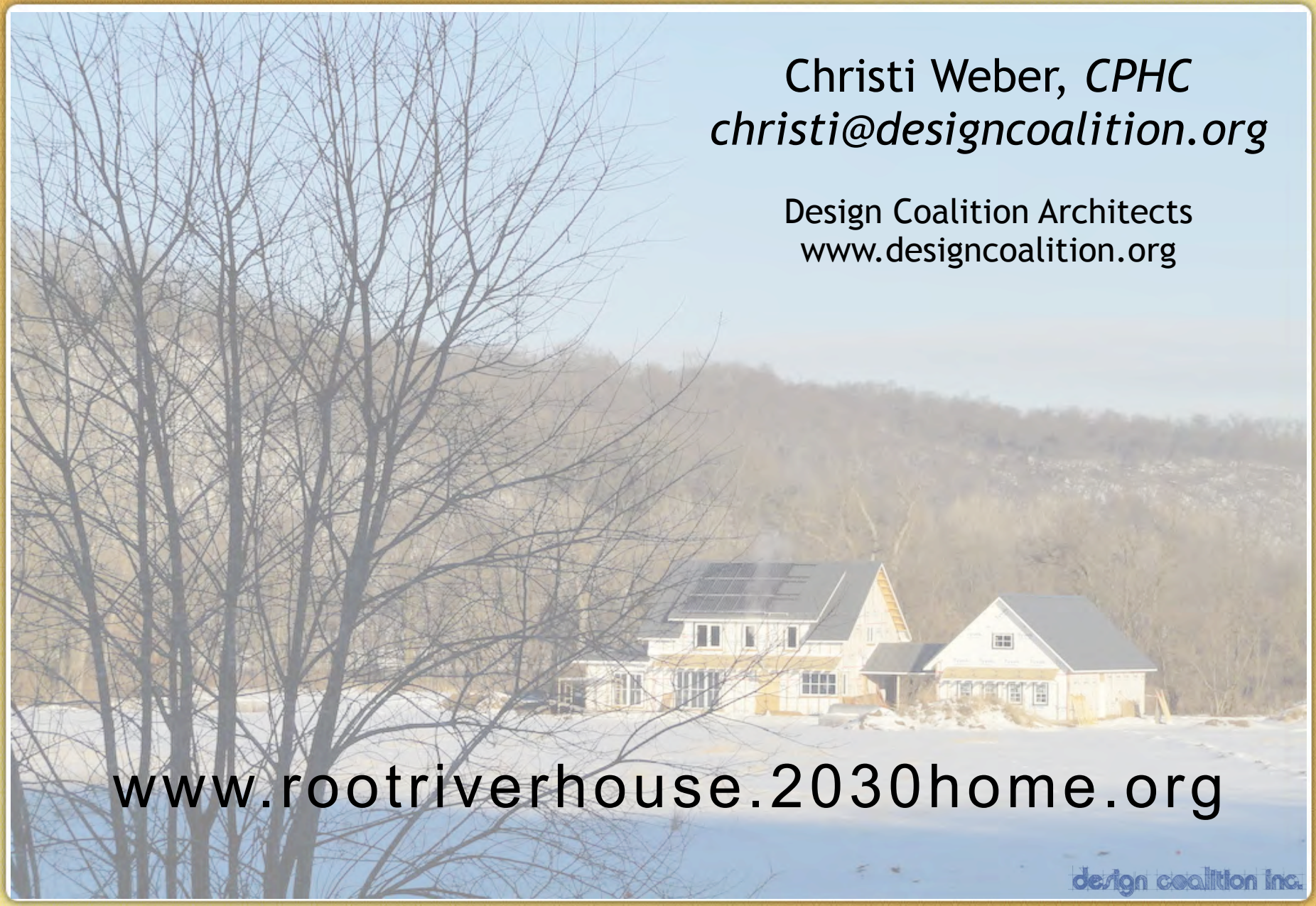
# Thank you!!!!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