NET-ZERO LESSONS LEARNED:

Design, construction, and two years of living in a net-zero, high performance home.

BBD 2020

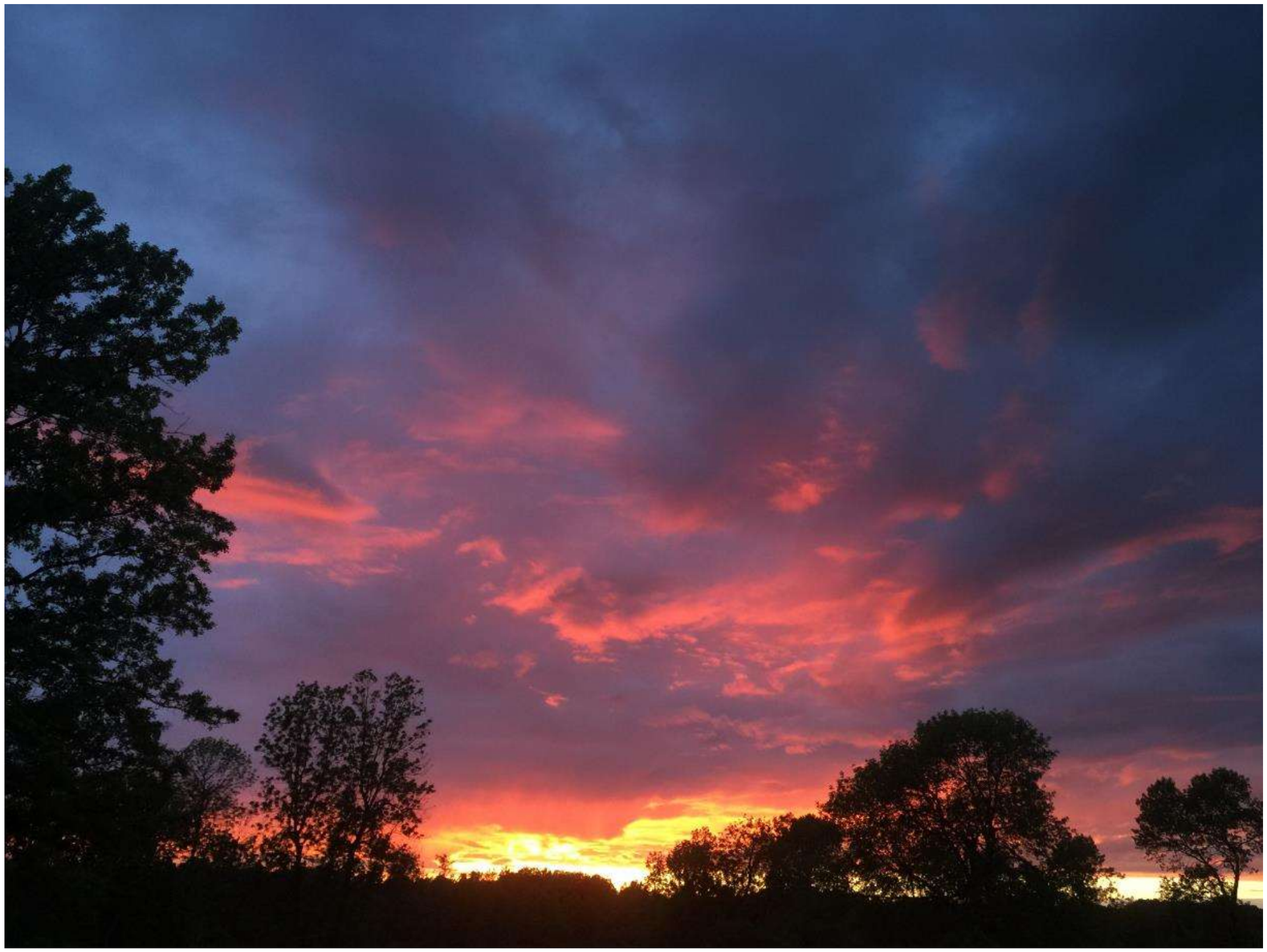
JEAN TERWILLIGER, AIA, CPHD;
VERMONT INTEGRATED ARCHITECTURE

OUTLINE

1. BACKGROUND AND DESIGN PROCESS
2. CONSTRUCTION DETAILS AND CONSTRUCTION
3. LIVING IN IT- LESSONS LEARNED

LEARNING OBJECTIVES

1. How design can affect building performance, how the High Performance Homes program meets 2030 climate goals, and how HP homes perform in real life.
2. Universal design principles for changing lives.
3. Construction details for thermal bridge free design and low-carbon materials.
4. MEP design and performance for high performance homes.



Why do we build?

Human nature to create “home”

“Machine for living”- Corbusier

“The ultimate form of human self-expression”

“Architecture begins to matter when it brings delight, sadness, perplexity and awe along with a roof over our heads.” – Paul Goldberger

“Buildings are inextricably linked to time and space. They are defined by their context.” - John Kampfner

Where and How should we build NOW?

"We are the authors of our out-of-control climate system… Now we all share the responsibility to write the next act… I know that there are climate horrors to come, but those horrors are not yet scripted. We are staging them by inaction, and by action can stop them."

– David Wallace-Wells, "The Uninhabitable Earth"

DESIGN PROCESS

SITE SELECTION PRIORITIES

LESS THAN 5 MILES BIKE RIDE TO TOWN

MOUNTAIN VIEWS- EAST OR WEST

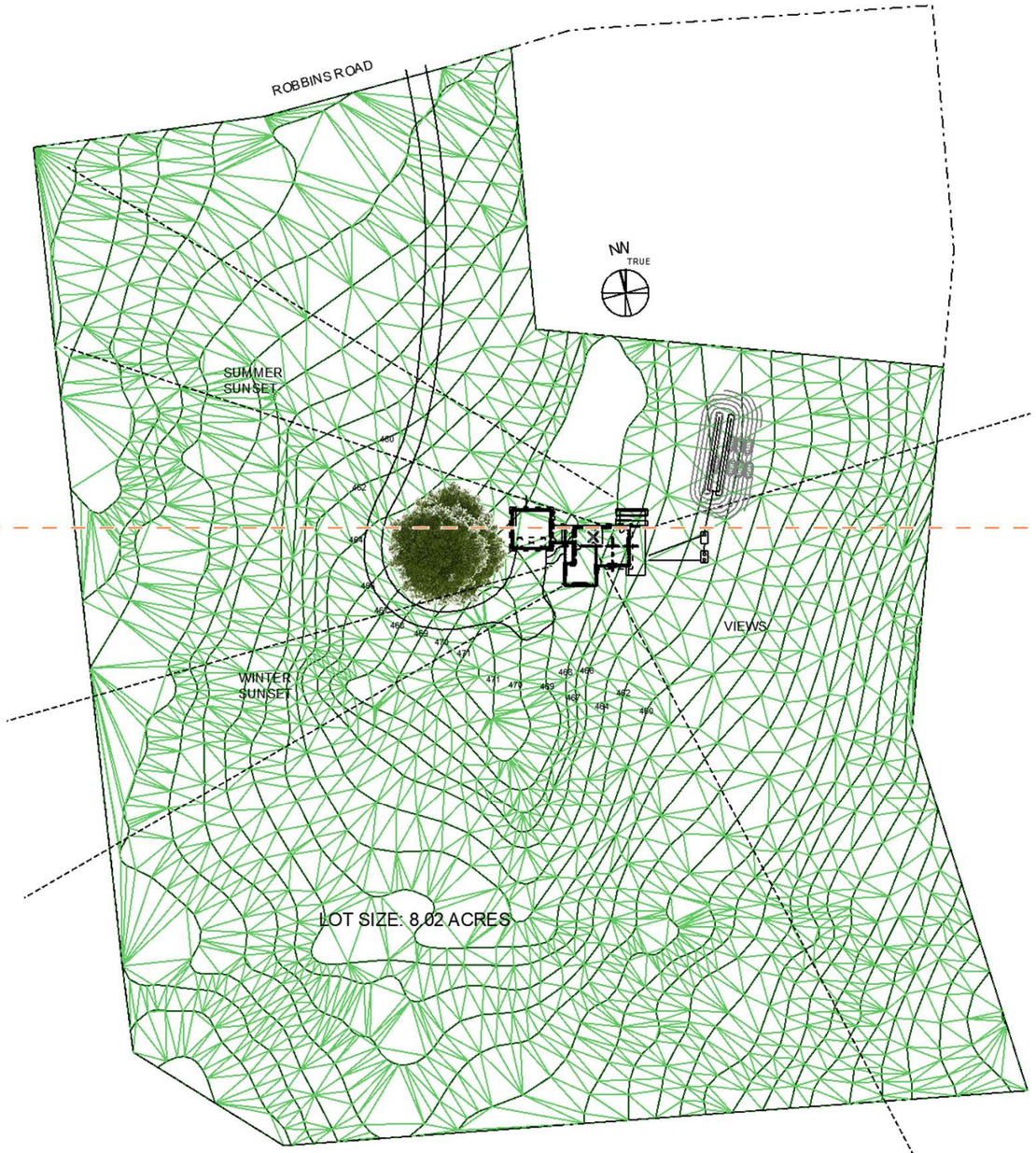
GOOD SOLAR EXPOSURE FOR PASSIVE DESIGN AND PV'S

PEACEFUL, OFF MAIN ROAD

EASY ACCESS FOR EASY DEVELOPMENT

POTENTIAL FOR TRAILS , GARDENING

MAGIC- VIEWS! QUIET YET NOT TOO FAR FROM TOWN


ROBBINS ROAD
NW
TRUE
SUMMER
SUNSET
WINTER
SUNSET
VIEWS
LOT SIZE: 8.02 ACRES

SITE PLAN

HOUSE PRIORITIES

COMFORTABLE, SUNNY, INFORMAL

PLAYFUL, NOT PRECIOUS

NET-ZERO AND PASSIVE HOUSE OR ALMOST PASSIVE HOUSE

FLEXIBILITY OVER TIME- AGE IN PLACE, ROOM FOR GUESTS, FUTURE ONE LEVEL LIVING, USE ALL ROOMS

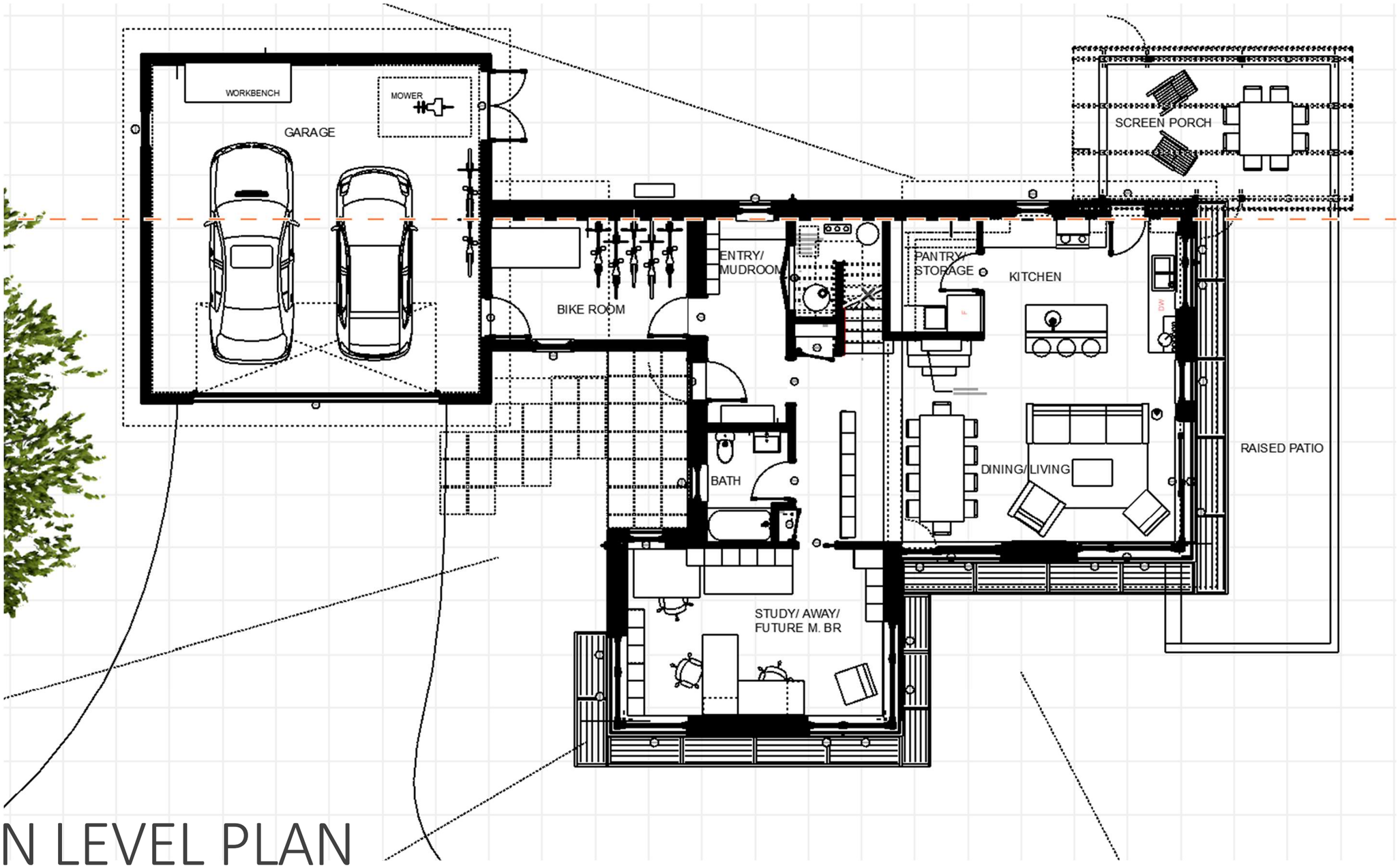
WORK FROM HOME FOR 1 OR 2

HOW MUCH SPACE IS TOO MUCH? NO UNUSED ROOMS

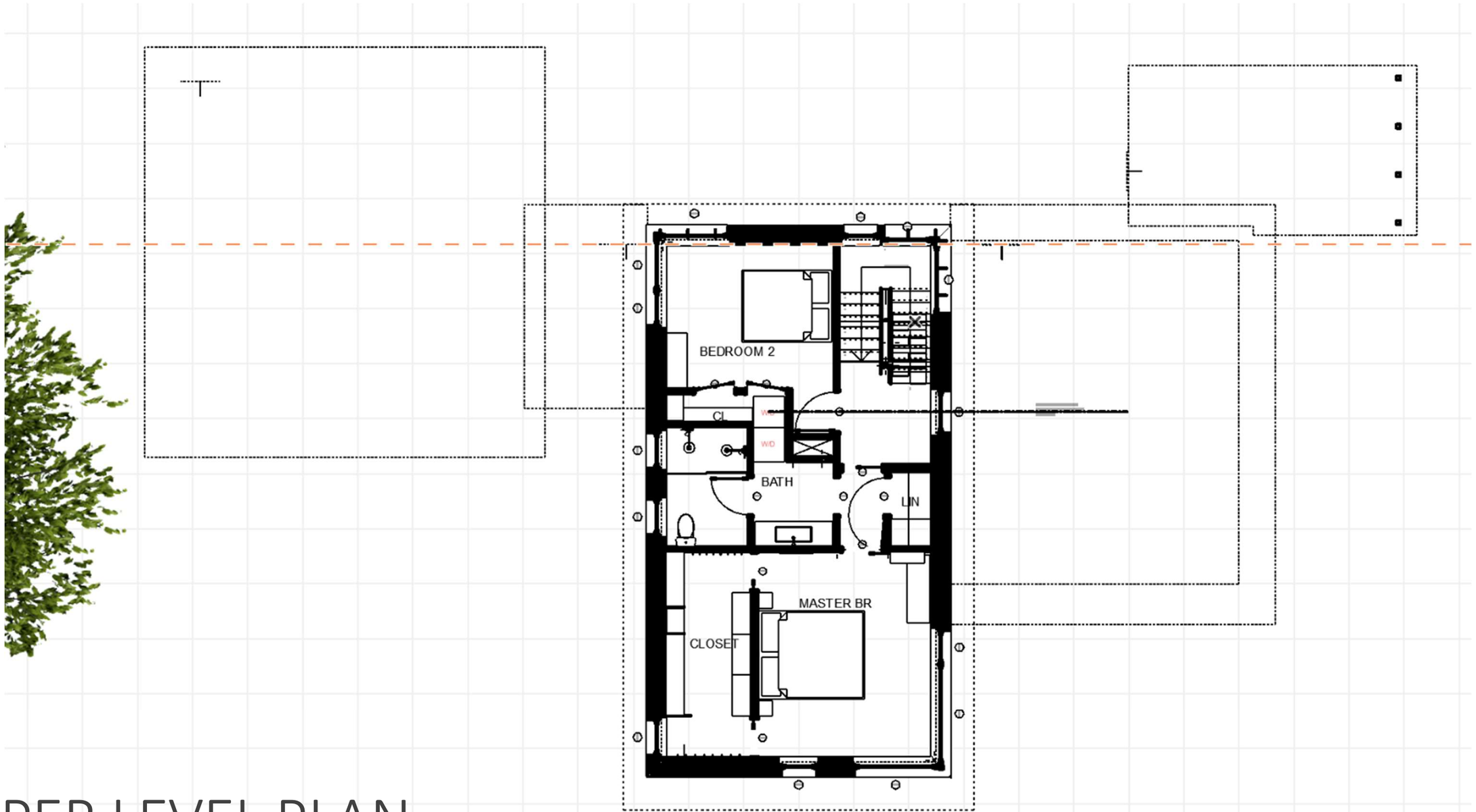
GOOD STORAGE W/ NO BASEMENT

BALANCE BETWEEN COST AND QUALITY/ PERFORMANCE

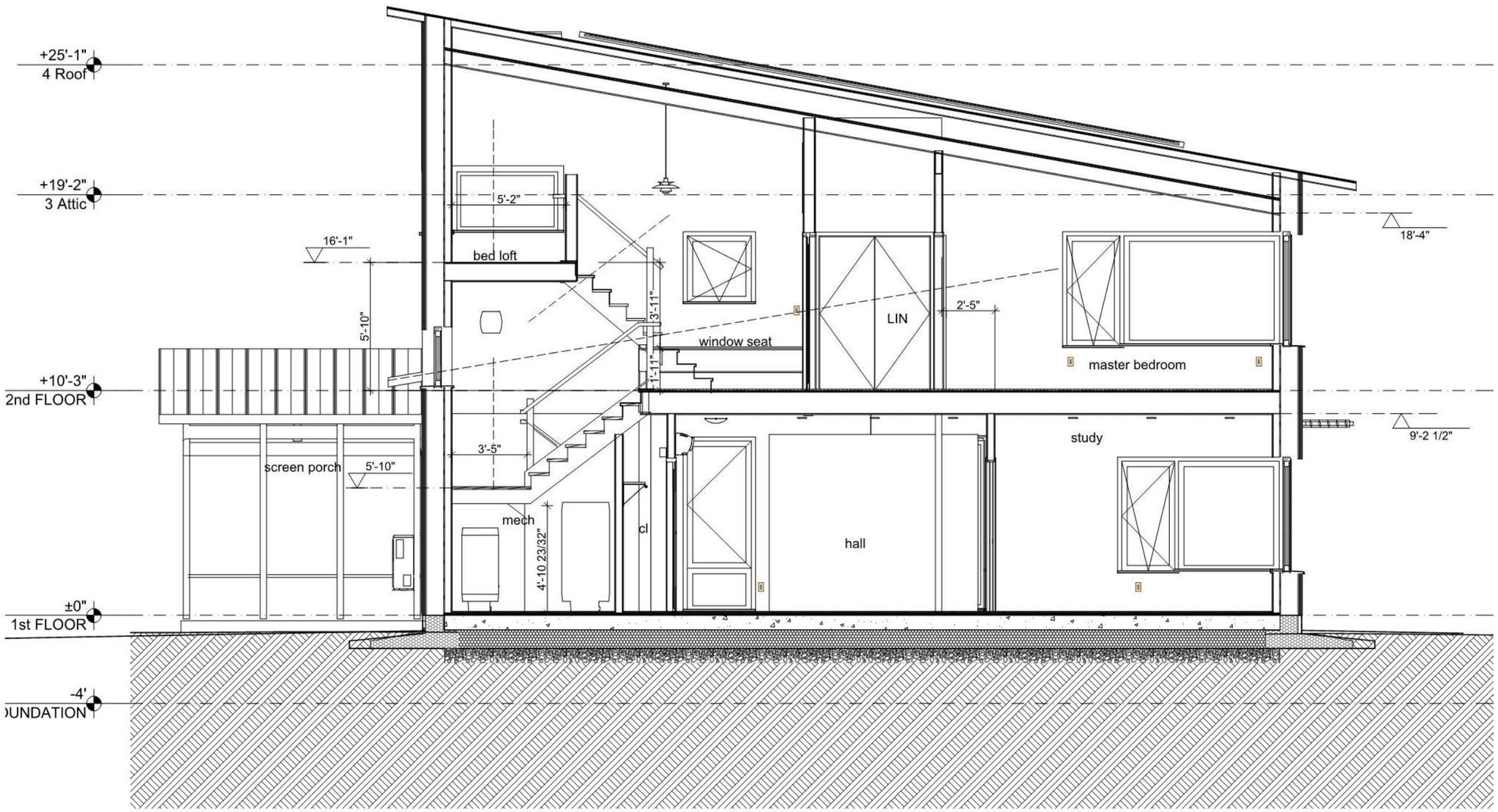
DELIGHT IN DETAILS AND FINISHES- WOOD FROM CHERRY TREES



MAIN LEVEL PLAN



UPPER LEVEL PLAN



2 SECTION

SCALE: 1/4" = 1'-0"

0 2' 4' 8'

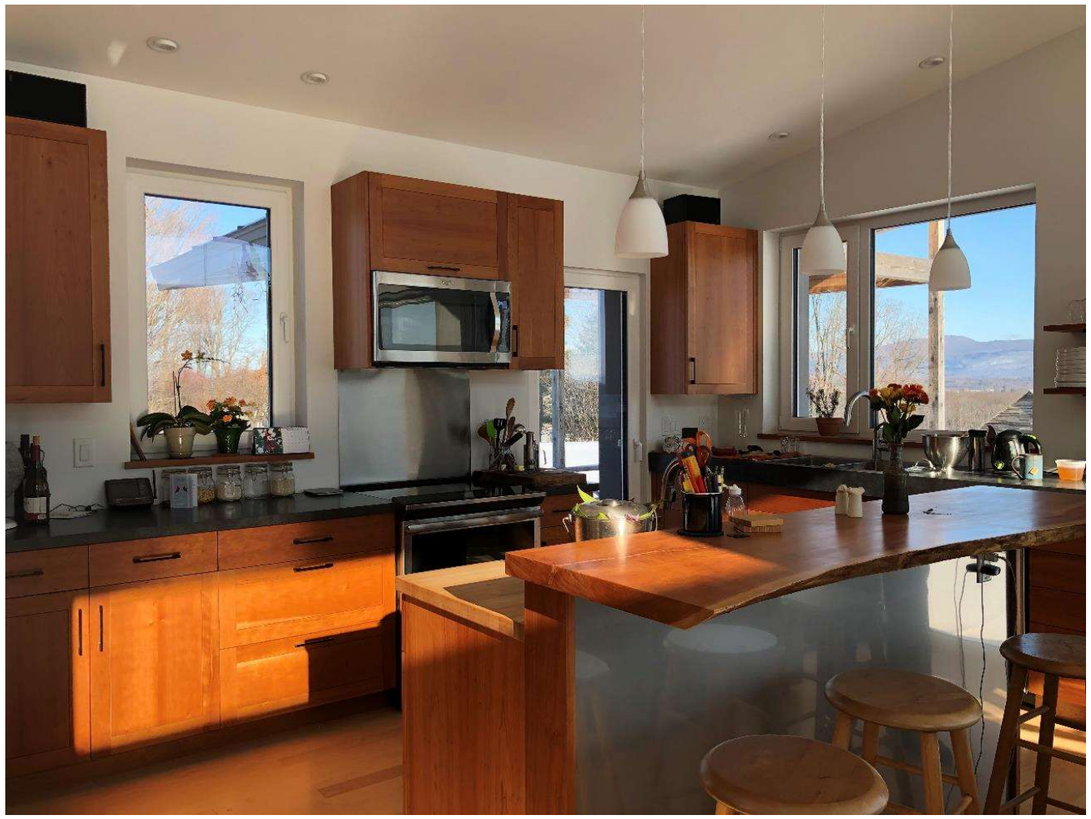
VIEW FROM NW- FROM ROAD

VIEW FROM SW- ENTRY

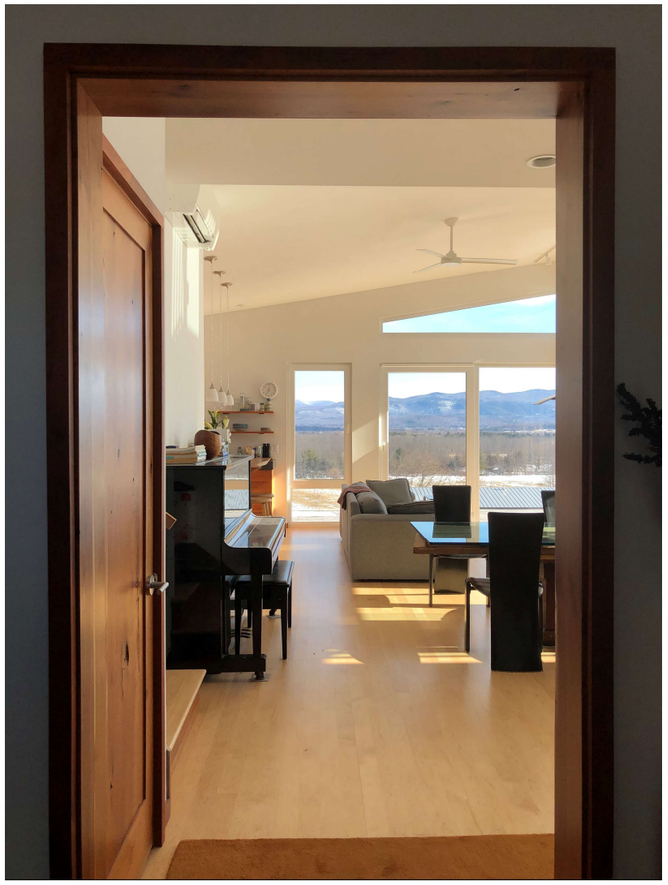
VIEW FROM SOUTHEAST

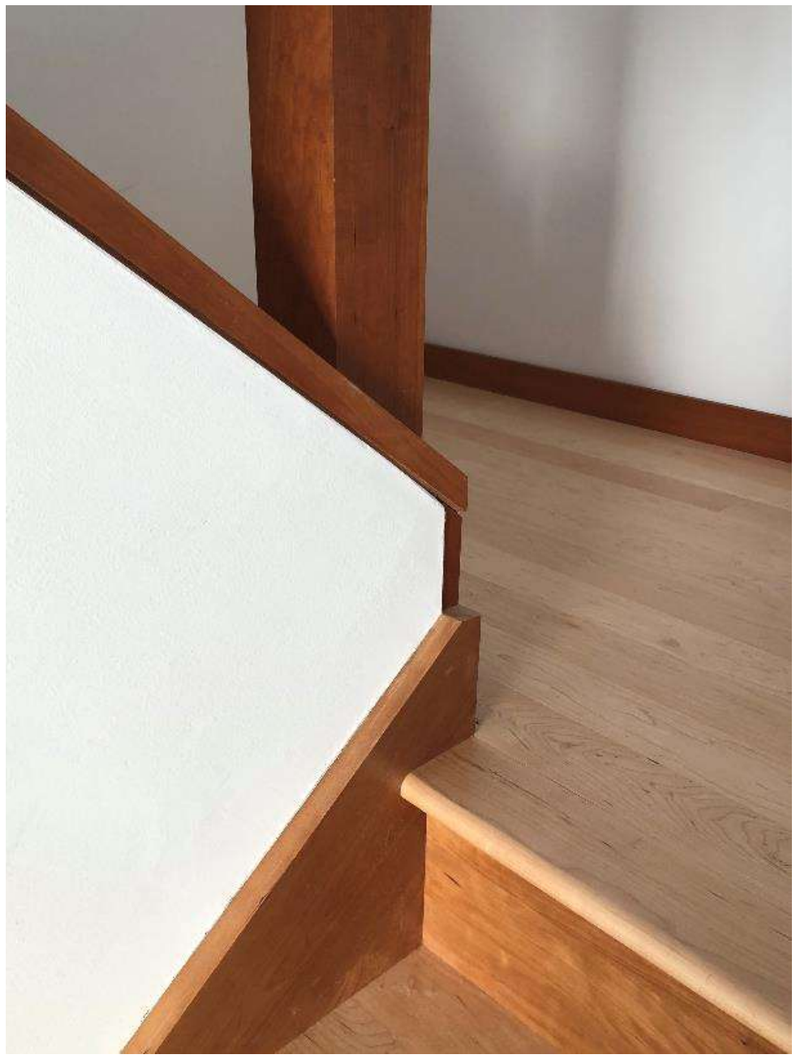
OPEN LIVING SPACE

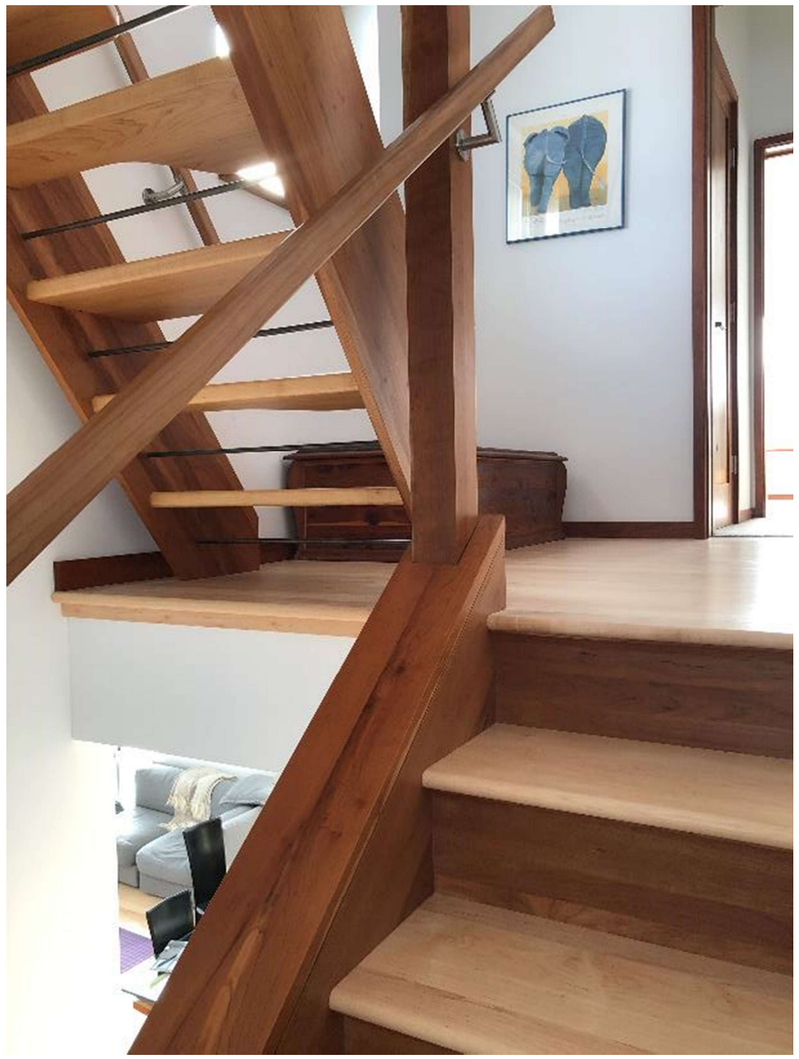
KITCHEN

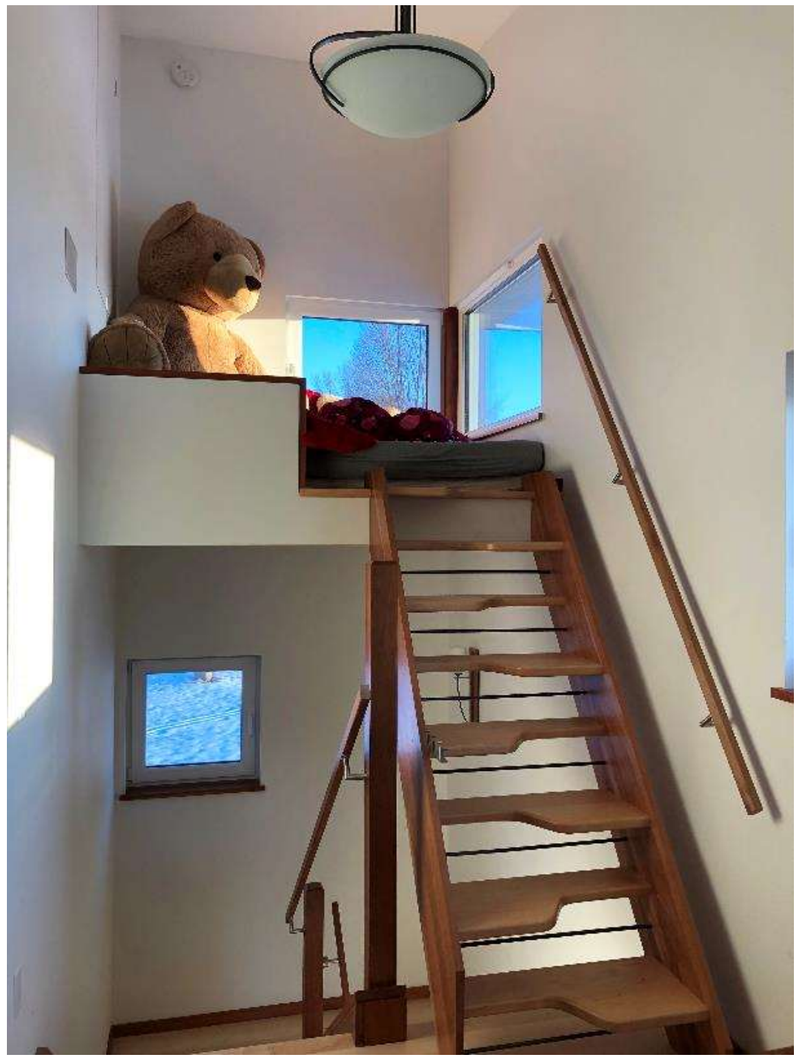


CONNECTED SPACES









STAIRS- CHERRY AND MAPLE

CONNECTED SPACES

HP SPECS

ENVELOPE:

R-40 EPS UNDER AND AROUND SLAB

R-45 WALLS- 9.5” I-JOIST W/ CELLULOSE OUTSIDE OF 2X4 STRUCTURAL WALL W/ MIN. WOOL.

R-70 ROOF- 24” TRUSSES WITH 21” MEDIUM DENSE-PACK CELLULOSE

U-.18 PVC TILT AND TURN WINDOWS- ALL .5 SHGC- MOSTLY MID-WALL INSTALLATION, EXTERIOR INSULATION

.5 ACH 50 AIR LEAKAGE (MEETS PASSIVE HOUSE LEVELS)

EFFICIENT SYSTEMS:

ZEHNDER ERV (OWNER INSTALLED)

1- 18,000 BTU LOW TEMP HEAT PUMP (ADDITIONAL LINESET INSTALLED FOR FUTURE SECOND FLOOR COOLING)

HEAT PUMP HOT WATER HEATER

PASSIVE HOUSE PHPP MODELING

PHI: 4.75 kBTU/sf-yr max. heating demand (9.51 kBTU/sf-yr for low energy building)

.6 ACH 50 min. volume air tightness

PHIUS:- ~10.9 kBTU/sf-yr heating demand for Rutland, VT. 9 BTU/sf-hr max. heat load

.05 ACH 50/SF surface min. air tightness

MODEL VS. REALITY

This House:

~5 kbtu/sf-yr heating demand (no multiplier)

~10 BTU/sf-hr heat load

237 cfm50= .5 ACH 50

Architecture:	Vermont Integrated Architecture	**Mechanical engineer:**	none	
Street:	P.O. Box 862	Street:		
Postcode/City:	05753 Middlebury	Postcode/City:		
Province/Country:	Vermont US-United States of America	Province/Country:		
Energy consultancy:	Efficiency Vermont- Li Ling Young	**Certification:**		
Street:		Street:		
Postcode/City:		Postcode/City:		
Province/Country:		Province/Country:		
Year of construction:	2018	Interior temperature winter [°F]:	68.0	Interior temp. summer [°F]: 77.0
No. of dwelling units:	1	Internal heat gains (IHG) heating case [BTU/(hr.ft²)]:	0.76	IHG cooling case [BTU/(hr.ft²)]: 0.80
No. of occupants:	3.0	Specific capacity [BTU/F per ft² TFA]:	10.6	Mechanical cooling: x

Specific building characteristics with reference to the treated floor area

				Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area ft²	1897				
Space heating	Heating demand kBTU/(ft²yr)	11.64	≤	9.51	-	no
	Heating load BTU/(hr.ft²)	9.01	≤	-	-	
Space cooling	Cooling & dehum. demand kBTU/(ft²yr)	2.92	≤	9.51	-	yes
	Cooling load BTU/(hr.ft²)	6.10	≤	-	-	
	Frequency of overheating (> 77 °F) %	-	≤	-		-
	Frequency of excessively high humidity (> 0.012 lb/lb) %	0.0	≤	10		yes
Airtightness	Pressurization test result n_{50} 1/hr	0.5	≤	1.0		yes
Non-renewable Primary Energy (PE)	PE demand kBTU/(ft²yr)	32.50	≤	-		-
	PER demand kBTU/(ft²yr)	15.36	≤	24	24	yes
Primary Energy Renewable (PER)	Generation of renewable energy (in relation to pro-jected building footprint area) kBTU/(ft²yr)	25.99	≥	-	-	

[2] Empty field: Data missing; '-': No requirement

I confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification.

PHI Low Energy Building? no

Task: First name: Surname: Signature:

Issued on: City:

2030 CHALLENGE

2030 challenge goals for 2020:

80% reduction in operational carbon

40% reduction in embodied carbon

Baseline for Single family operational carbon:

Site EUI= 36 kBTU/sf-yr

2020 80% reduction goal: 7.2 kBTU/sf-yr

This house: Site EUI= 9.8 kBTU/sf-yr before solar, -6 kBTU/sf-yr with solar

Embodied carbon: ???

BUDGET:

WHAT WE TOOK OUT

PASSIVE HOUSE SPECS: ADDITIONAL INSULATION, BETTER WINDOW FRAMES, GROUND LOOP FOR ERV

SKYLIGHT

NORTHWEST SUNSHADE (MORE DECORATIVE THAN FUNCTIONAL)

CUSTOM BOOKCASE AND STORAGE CUBBIES (MIGHT STILL GET BUILT)

BY OWNER ITEMS

CONSTRUCTION

OCTOBER 2017-
MAY 2018

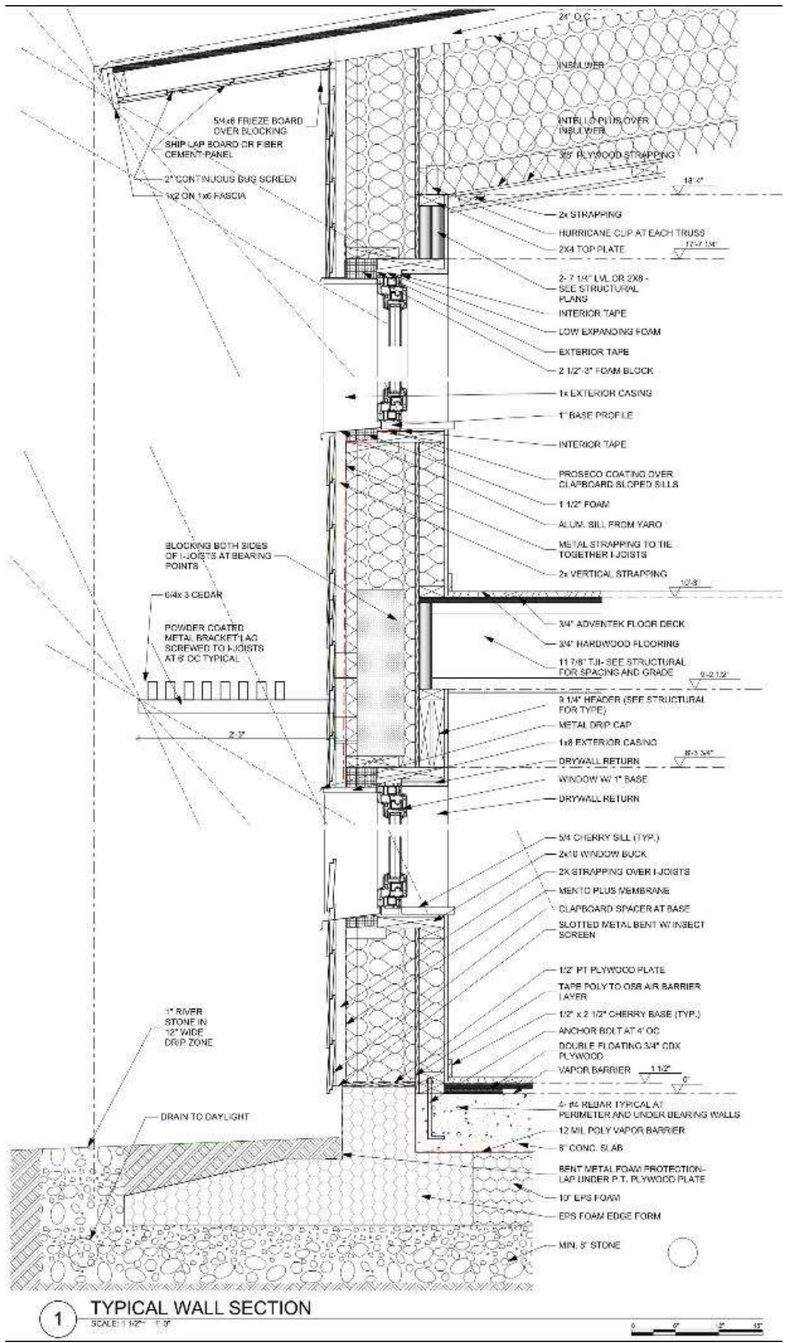
OVERVIEW

“Architecture is the art of organizing space, but it is by construction that it expresses itself.”

– August Perret

BUILT BY:

NORTHERN TIMBERS CONSTRUCTION (LED BY ALEX CARVER AND CHRIS NORTH)

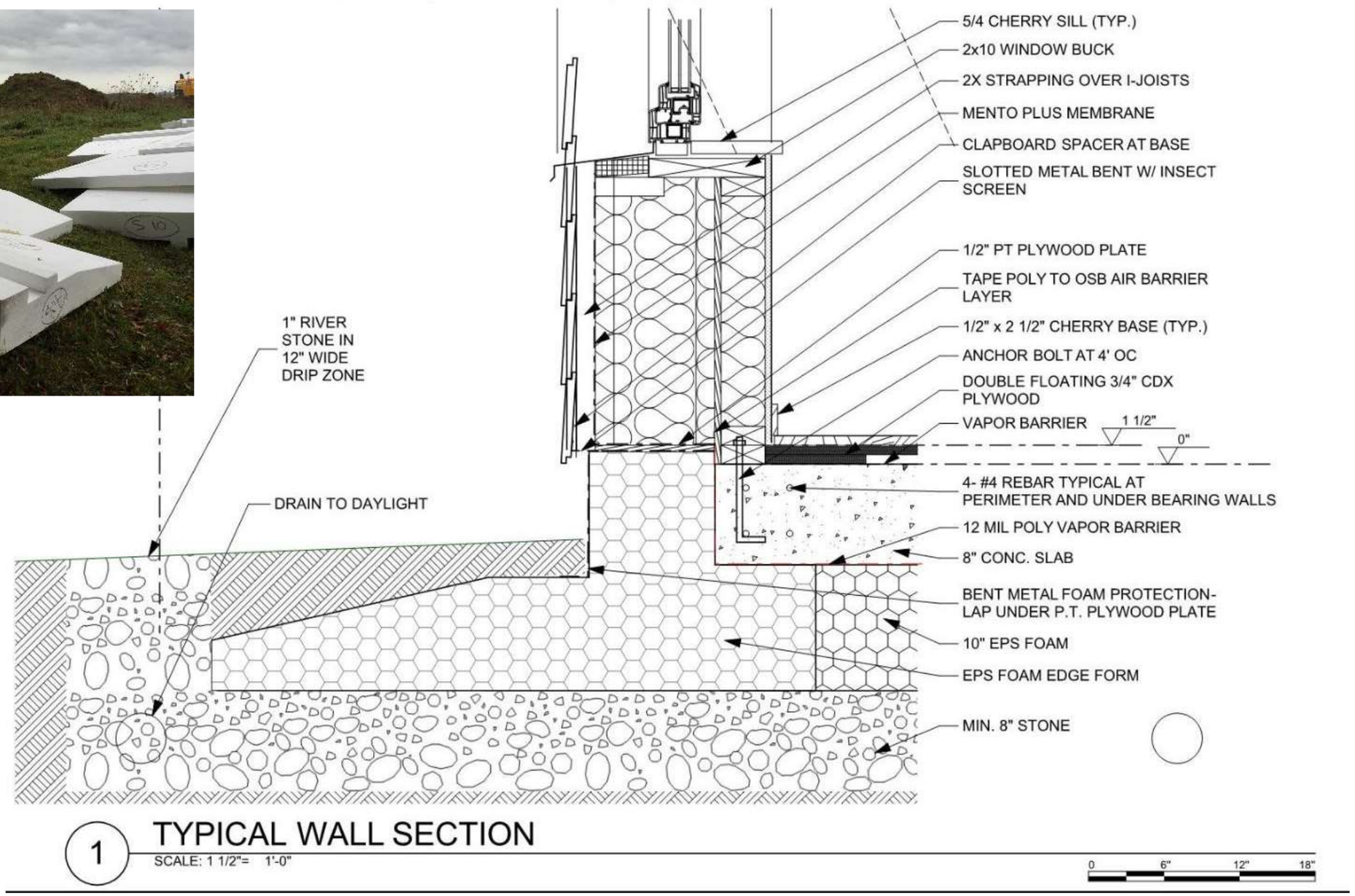


BETTER BUILDINGS BY DESIGN 2020

FOUNDATION

FROST WALL AT GARAGE AND PATIO

RAFT SLAB


1" RIVER STONE IN 12" WIDE DRIP ZONE
DRAIN TO DAYLIGHT
5/4 CHERRY SILL (TYP.)
2x10 WINDOW BUCK
2X STRAPPING OVER I-JOISTS
MENTO PLUS MEMBRANE
CLAPBOARD SPACER AT BASE
SLOTTED METAL BENT W/ INSECT SCREEN
1/2" PT PLYWOOD PLATE
TAPE POLY TO OSB AIR BARRIER LAYER
1/2" x 2 1/2" CHERRY BASE (TYP.)
ANCHOR BOLT AT 4' OC
DOUBLE FLOATING 3/4" CDX PLYWOOD
VAPOR BARRIER
1 1/2"
0"
4- #4 REBAR TYPICAL AT PERIMETER AND UNDER BEARING WALLS
12 MIL POLY VAPOR BARRIER
8" CONC. SLAB
BENT METAL FOAM PROTECTION- LAP UNDER P.T. PLYWOOD PLATE
10" EPS FOAM
EPS FOAM EDGE FORM
MIN. 8" STONE
1
TYPICAL WALL SECTION
SCALE: 1 1/2"= 1'-0"
0
6"
12"
18"

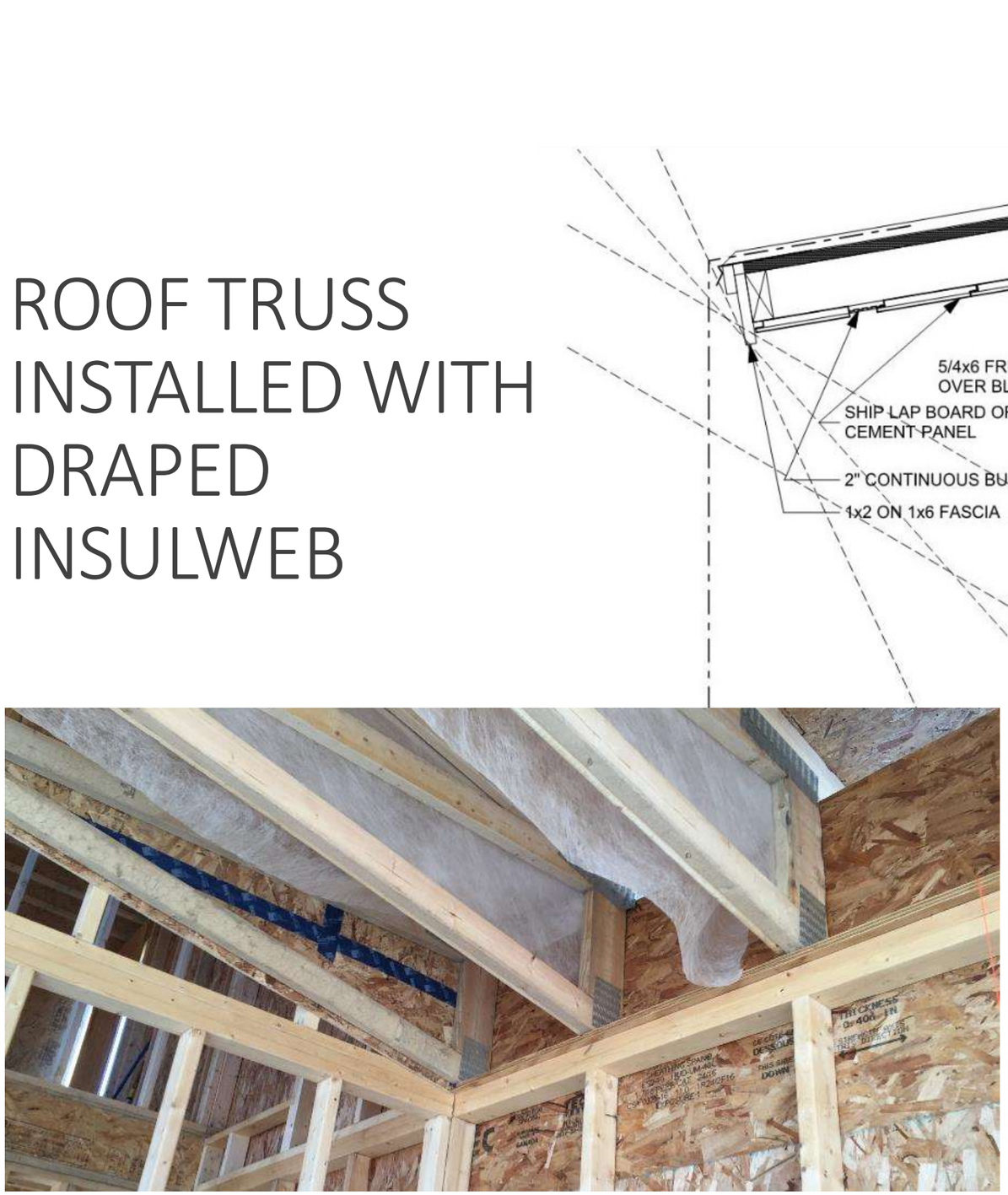
ROUGH-IN AND VAPOR BARRIER

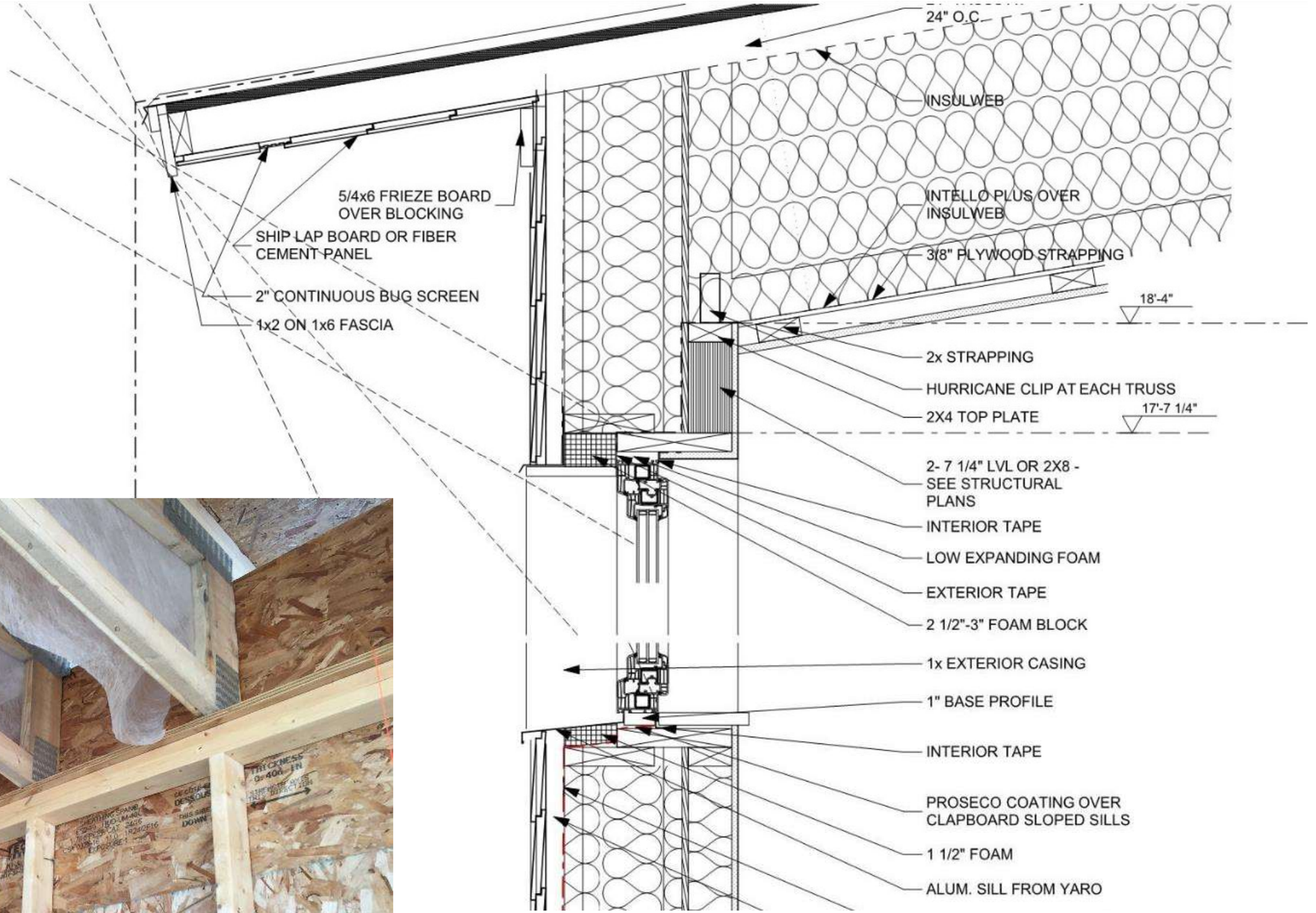
FRAMING

FOUNDATION MEETING WALL- STANDING SEAM ROOF

WATER, WATER EVERYWHERE- LET IT DRY OUT, KEEP IT OUT

ROOF TRUSS INSTALLED WITH DRAPED INSULWEB





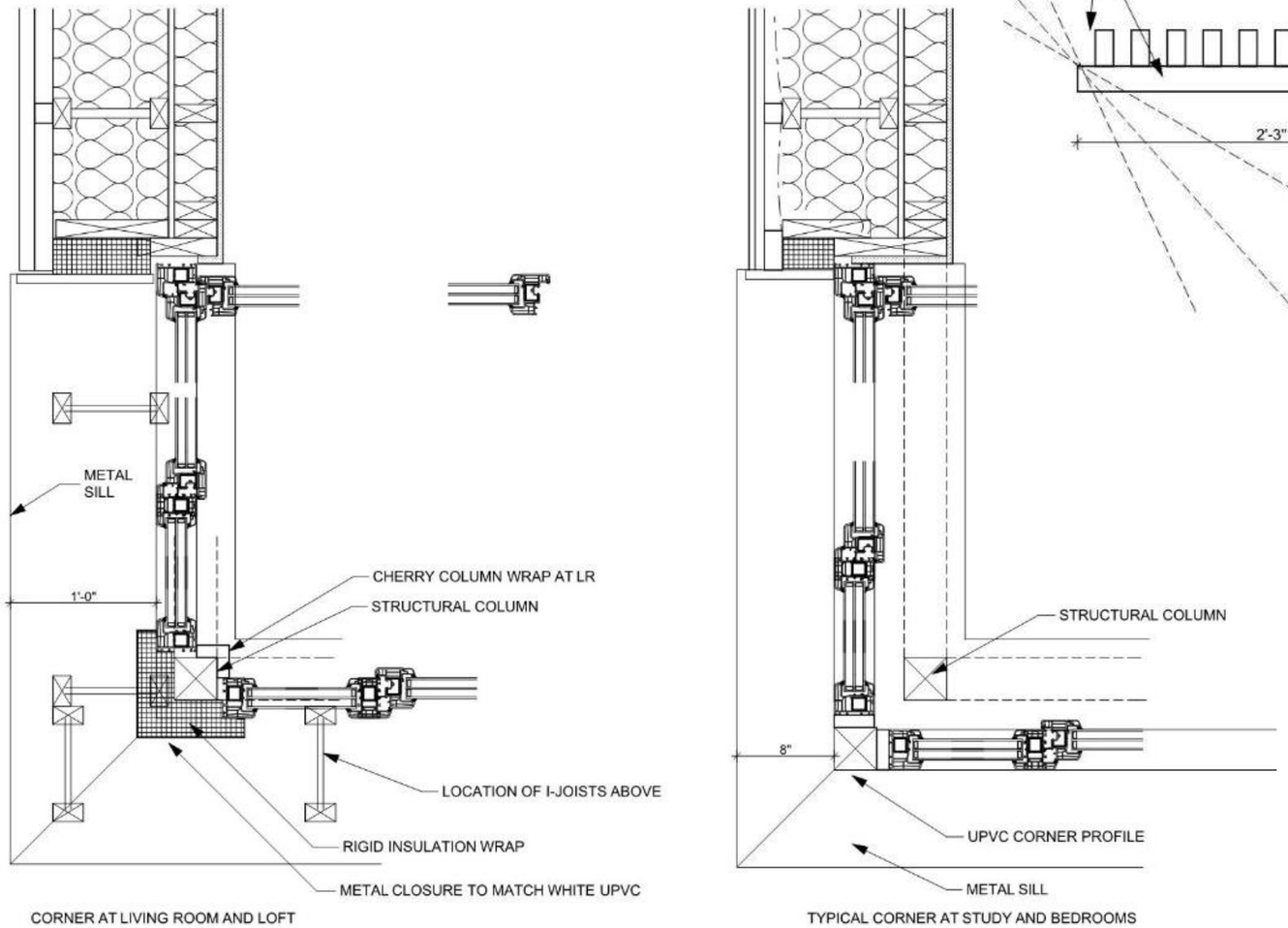
INSULWEB, INTELLO, STRAPPING

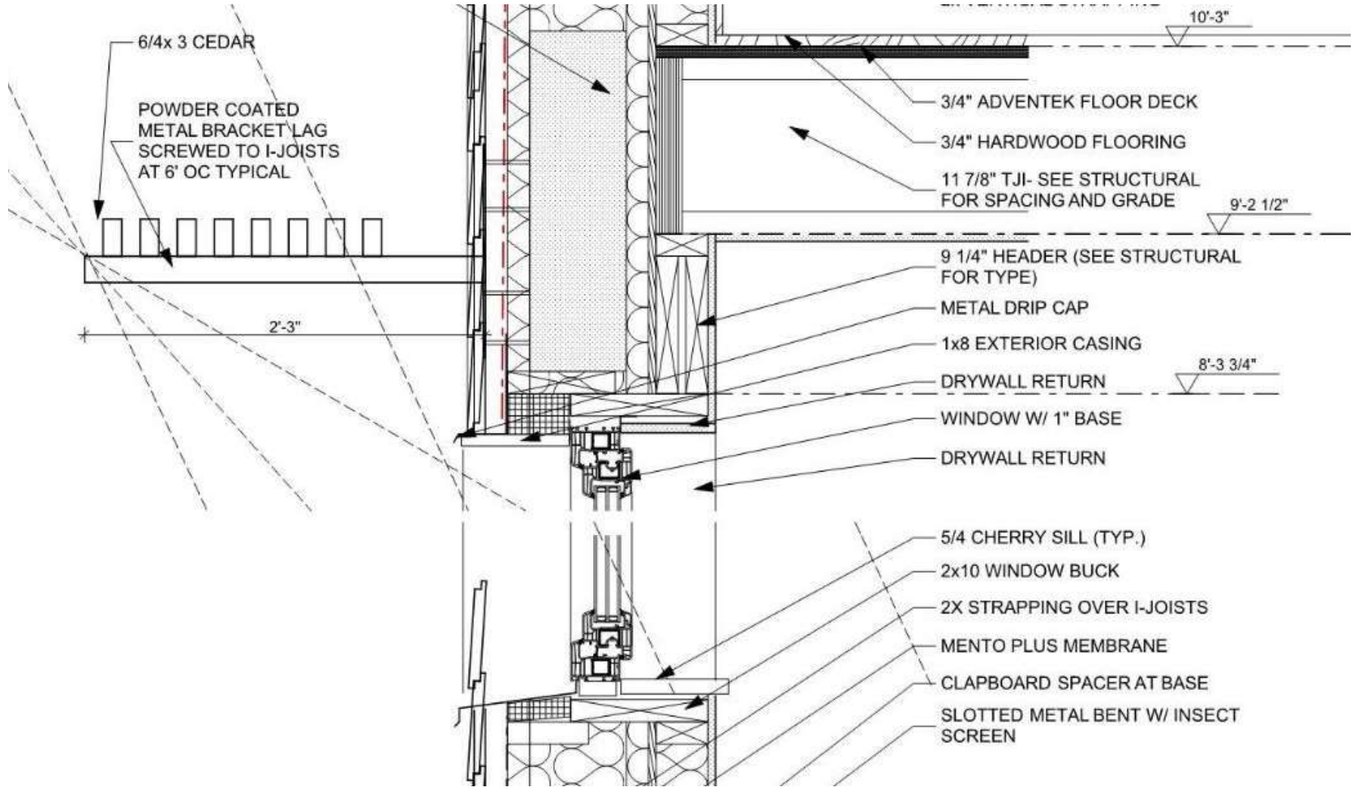
2X4 SHELL W/ ROOF, BUCKS, I-JOIST, MENTO PLUS

MENTO, STRAPPED, DENSE-PACKED, LAP SIDING

WINDOW FRAMING- 2x12 bucks, FIR CORNERS

WINDOWS



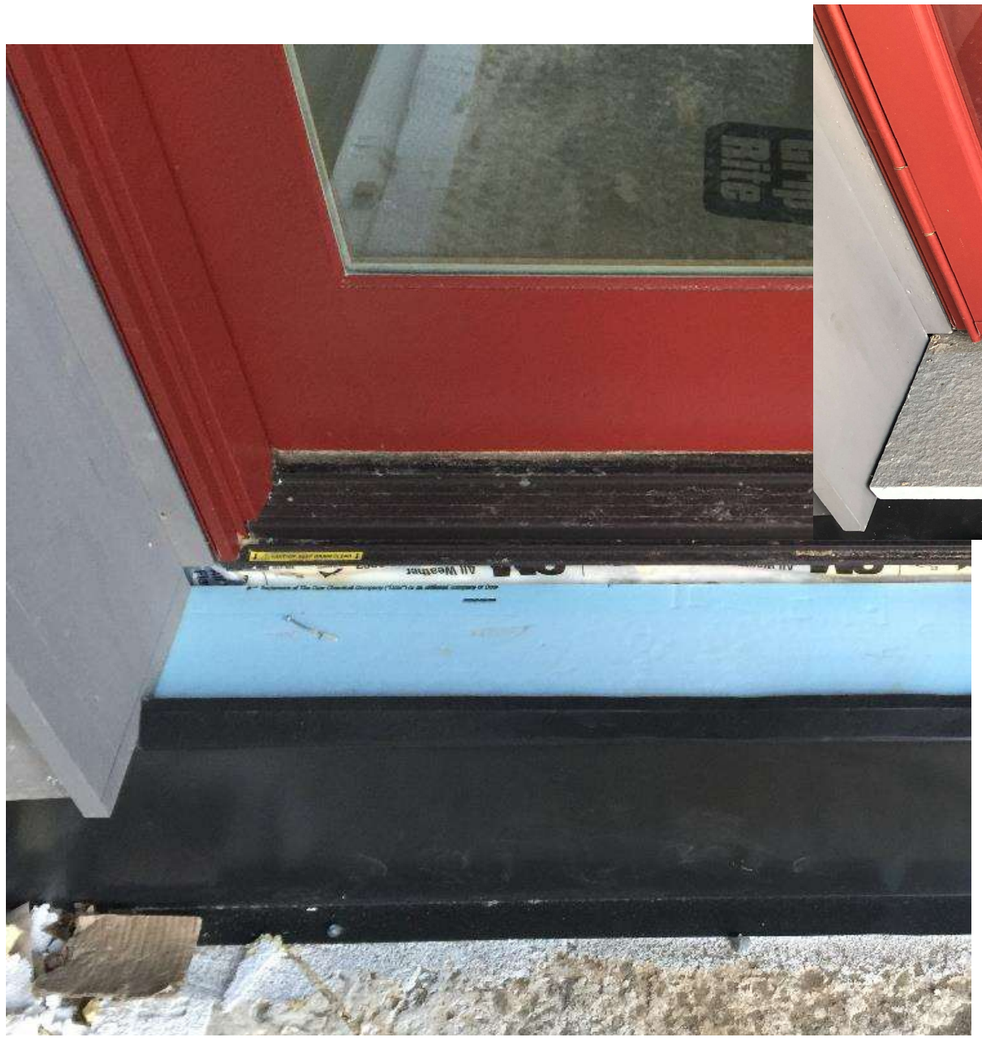


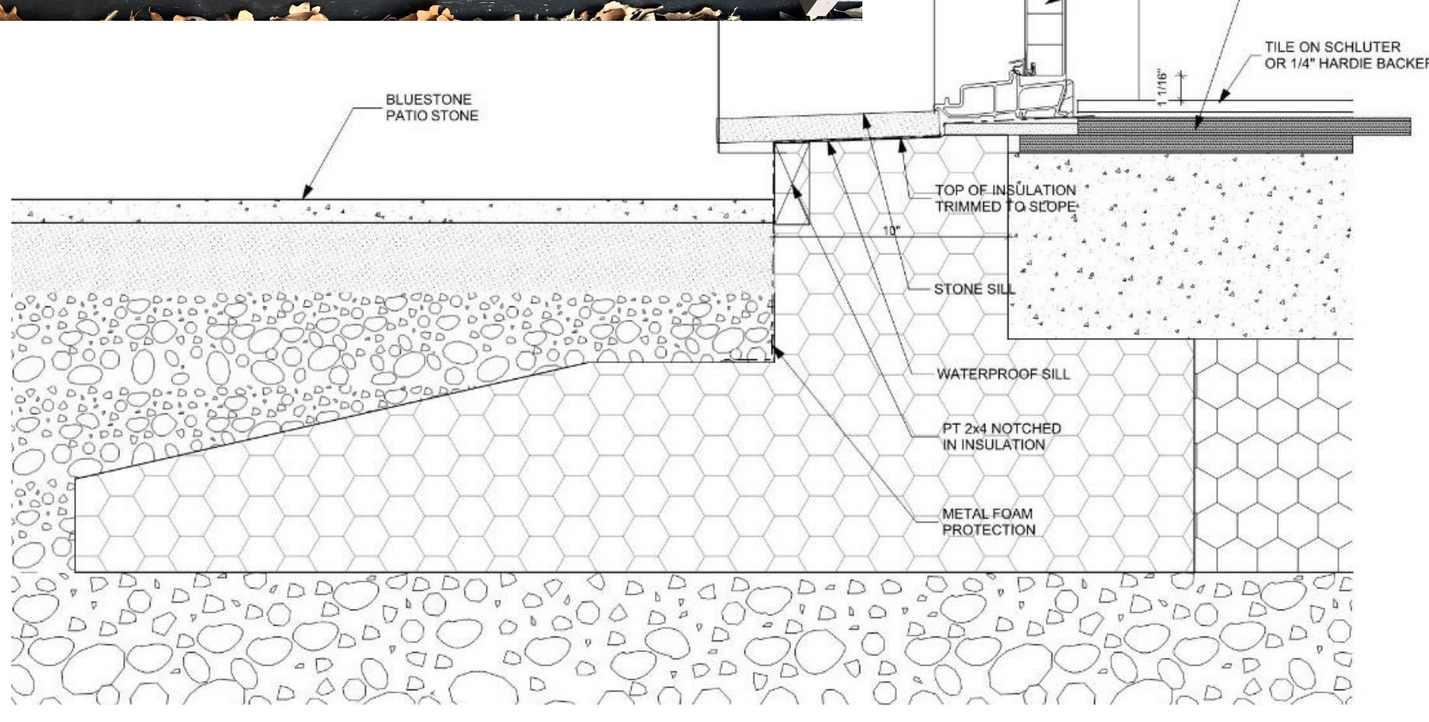
1 CORNER WINDOWS AND JAMBS
SCALE: 1 1/2"= 1'-0"

WINDOW INSTALL: center of wall, corner, sill

WINDOW HEAD DETAIL- INSULATION

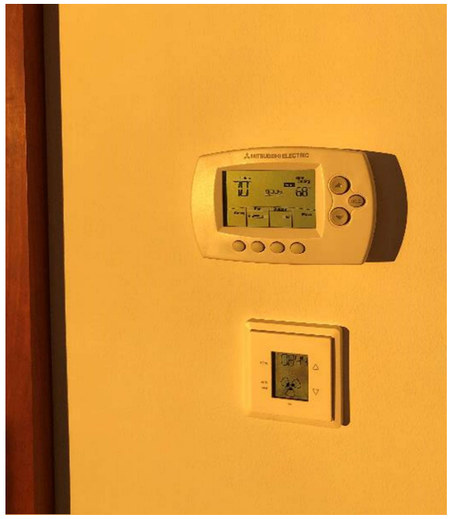
WINDOW SILL- EARLY WATER LEAK!

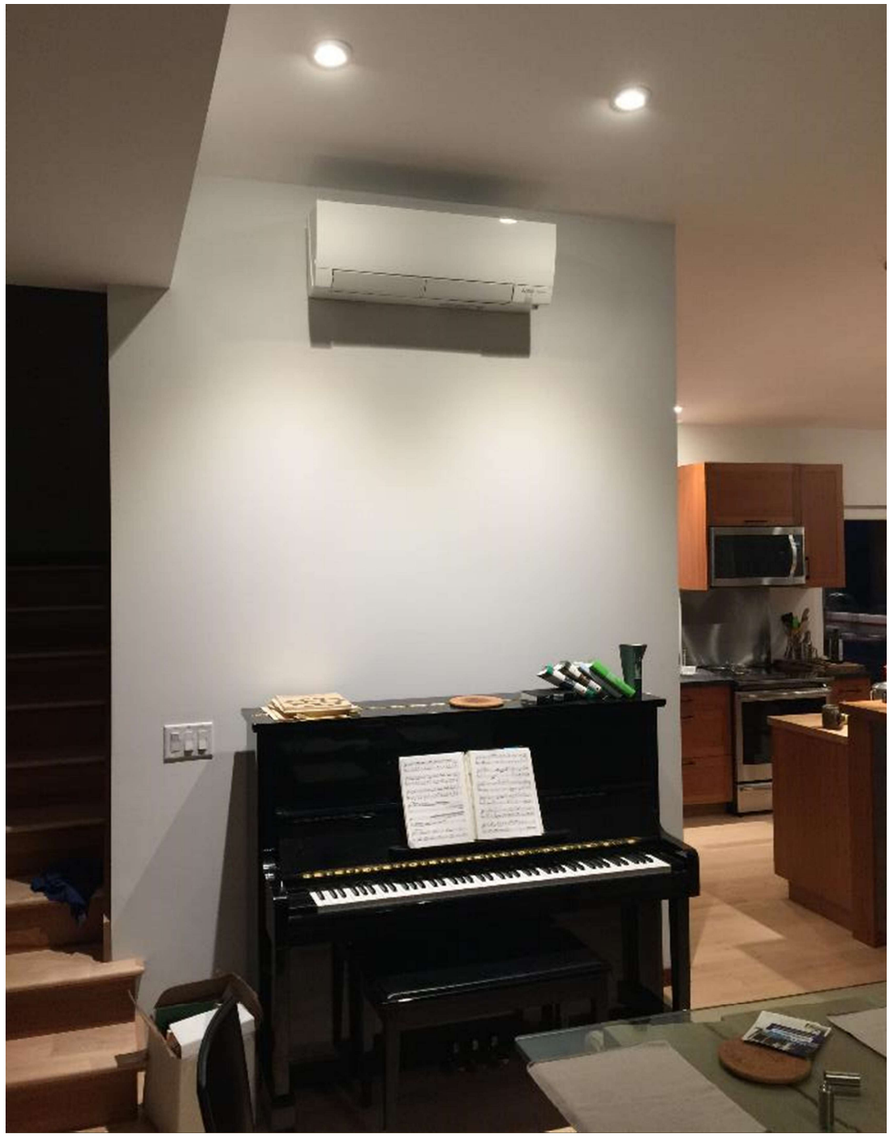



MARVIN ULTIMATE DOOR
2 LAYERS 3/4" PLYWOOD
TILE ON SCHLUTER OR 1/4" HARDIE BACKER
1 1/16"
BLUESTONE PATIO STONE
TOP OF INSULATION TRIMMED TO SLOPE
10"
STONE SILL
WATERPROOF SILL
PT 2x4 NOTCHED IN INSULATION
METAL FOAM PROTECTION

DOOR SILL

SYSTEMS

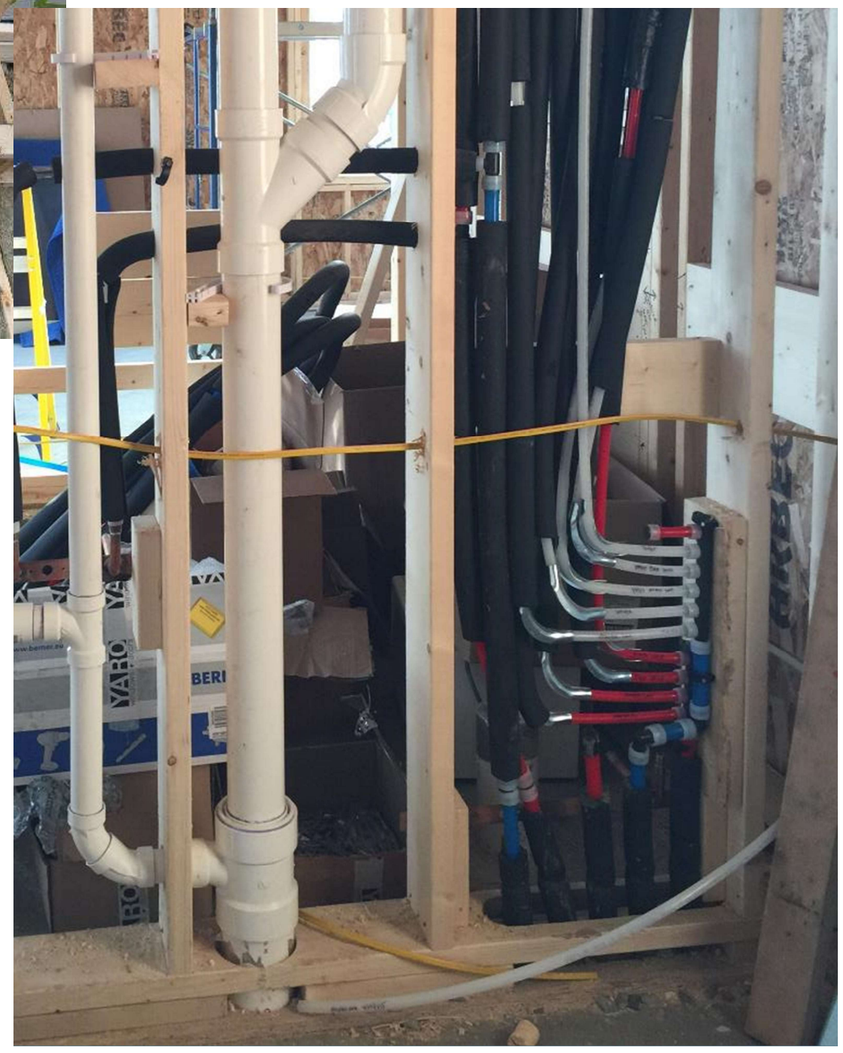




HEAT PUMP- wall hung in and out

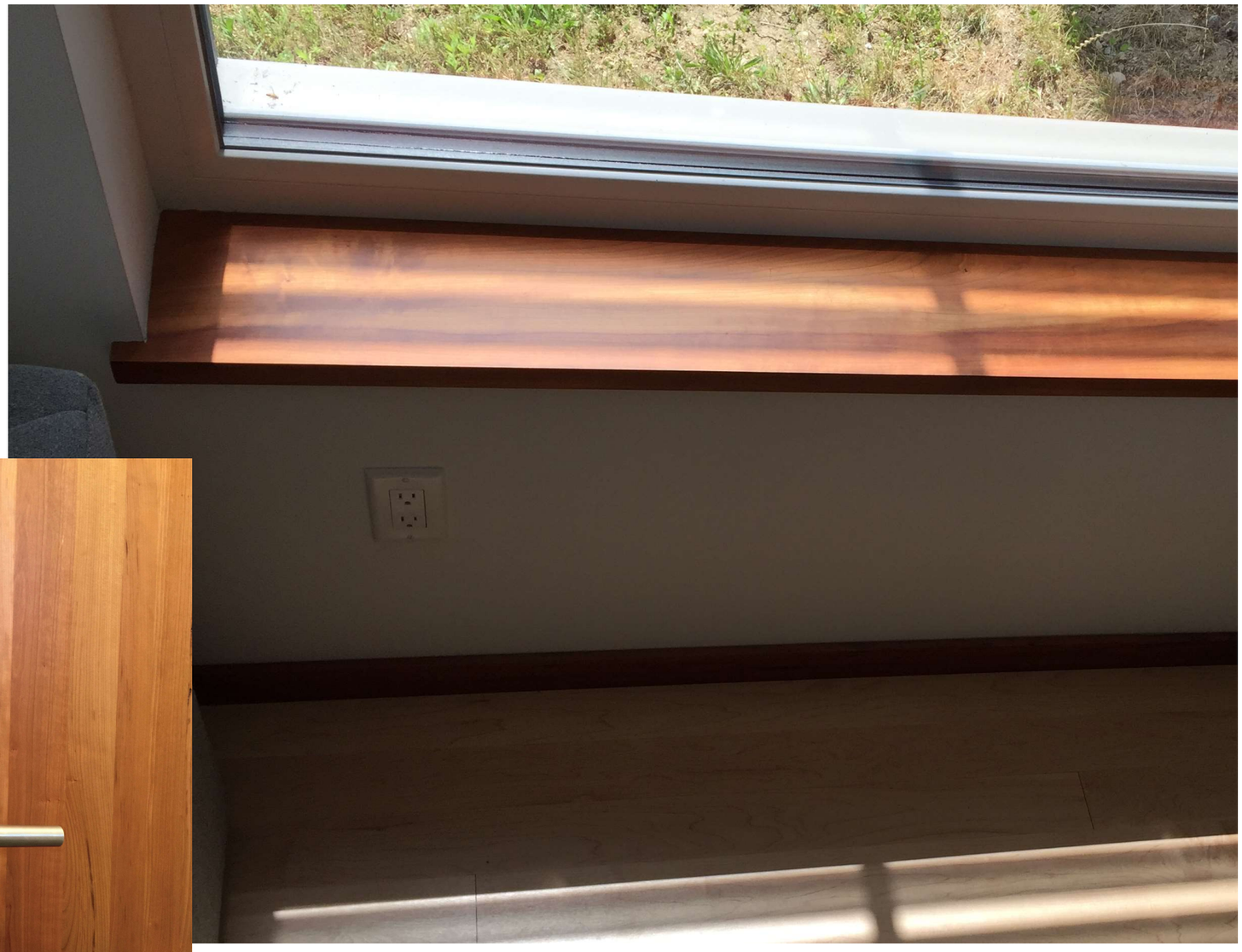
ZEHNDER ERV- by owner

CHASE SPACE:
make your life easier



WATER ROOM- DUCTED HEAT PUMP HWH

LIGHTING- lensed GIMBAL LED
Nothing penetrating air/vapor membrane



FINISHES: CHERRY

LIVING IN IT –

LESSONS LEARNED

PERFORMANCE

2019

SOLAR POWER GENERATED: 11,350 kWh

TOTAL ENERGY USED: 9720 kWh

ENERGY FROM GRID: 6800 kWh

ENERGY USED FOR CHARGING CAR:

~3900 kWh

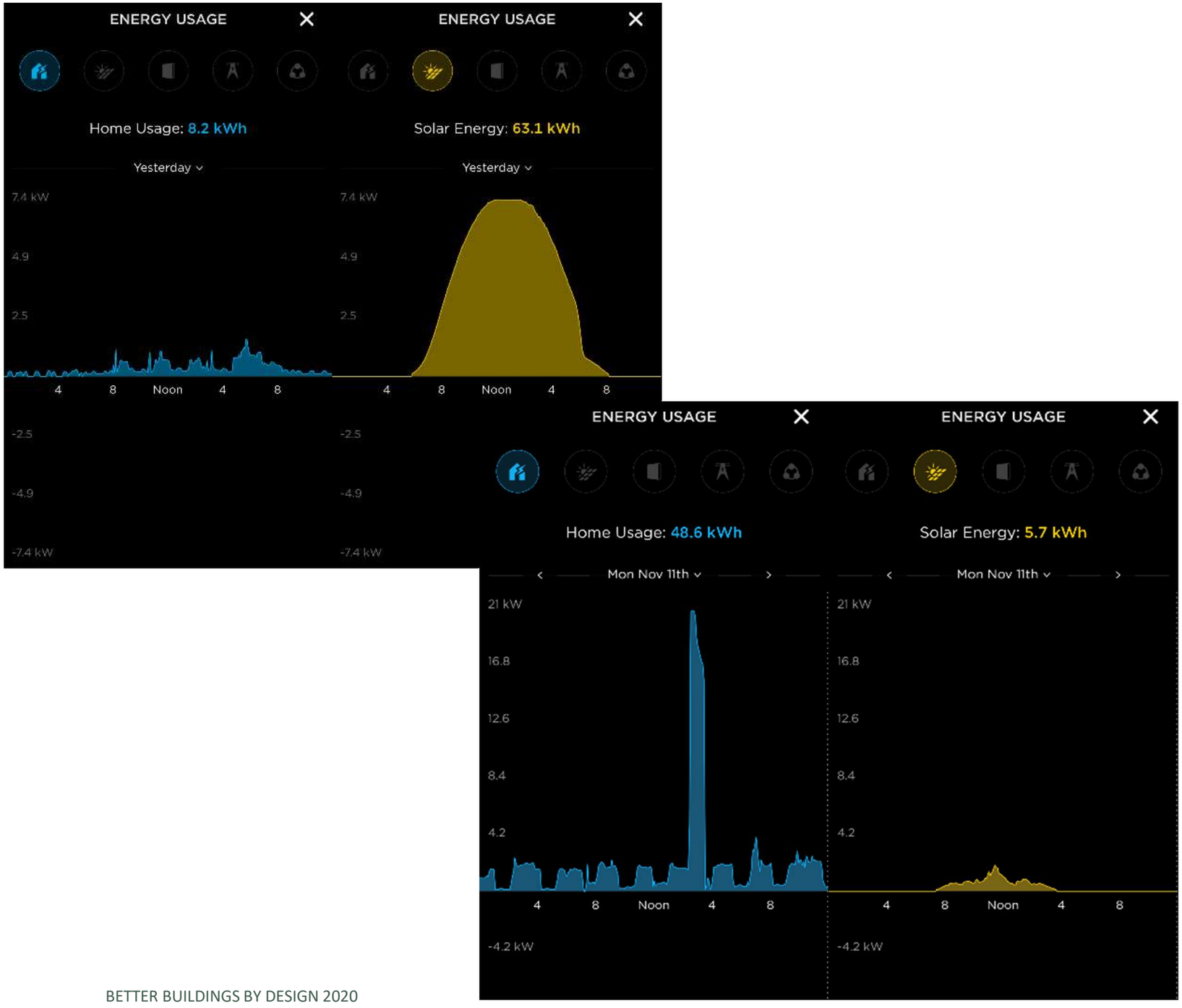
ENERGY USED FOR HOUSE WITH HEAT:

~5820 kWh, EUI= 9.5 kbtu/sf/yr

ENERGY USED FOR HEATING:

~2820 kWh, EUI= 4.6 kbtu/sf/yr

NET ADJUSTED EUI: -9.4 kBTU/sf-yr



OBSERVATIONS AND LESSONS LEARNED

COMFORT

HEAT PUMP- SET IT AND FORGET IT

ENJOY THE 5 DEGREE TEMP. DIFFERENCE BETWEEN MAIN LEVEL AND UPPER LEVEL BEDROOMS.

ERV- STABLE HUMIDITY- 40- 45% HUMIDITY ALL WINTER LONG

BELIEVE THE PHPP MODEL WHEN IT SAYS THE HOUSE WILL OVERHEAT

SO QUIET!!

REFRIGERATOR IS THE LOUDEST EQUIPMENT IN THE HOUSE

BARELY HEAR WIND AND RAIN UNLESS WINDOWS ARE OPEN

OBSERVATIONS AND LESSONS LEARNED

OWNER PERFORMED WORK

CAUTION! WE TOOK ON:

ZEHNDER INSTALL

TILED TUB SURROUND

CORIAN MASTER BATH COUNTER

MASTER CLOSET SHELVING INSTALL

SHAPING AND FINISHING RAILINGS AND ISLAND SLAB

PATIO PAVERS INSTALL

TILED 3’X 6’ SHOWER- BACKER AND TILE

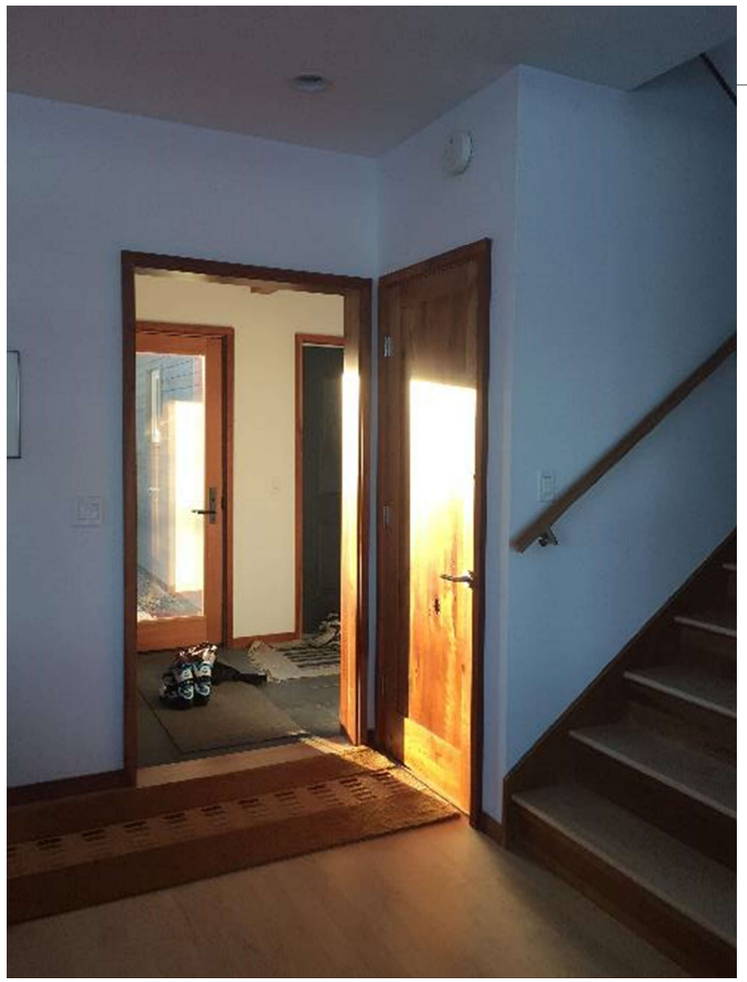
MOIST SITE- FOGGED/FROSTED WINDOW EXTERIORS

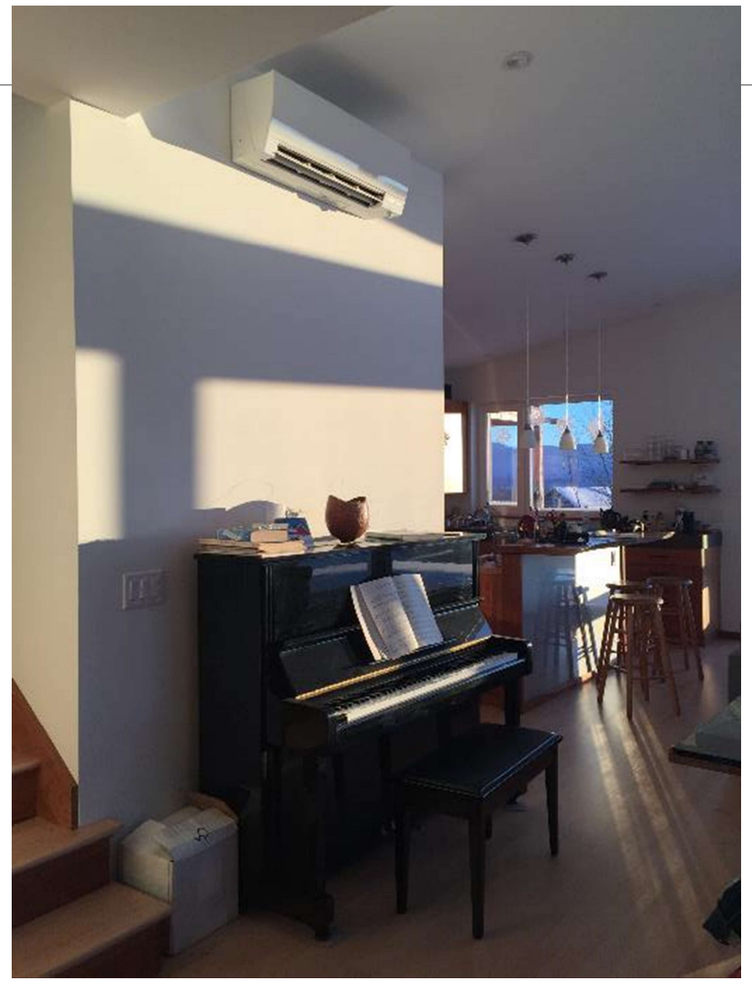
OBSERVATIONS AND LESSONS LEARNED

ENJOY SERENDIPIDOUS DESIGN ACCIDENTS

UNEXPECTED PLEASURES:
Great storage!

SUN- Path and Bounce





Solar Shading works!

October 20

June 10

FINAL THOUGHTS

LISTEN TO THE SITE

LISTEN TO THE CLIENTS

UNDERSTAND AND CLARIFY DREAMS AND PRIORITIES

CREATE BEAUTY

HIGH PERFORMANCE AND NET-ZERO READY NOW!

THANK YOU!

OBSERVATIONS AND LESSONS LEARNED

<u>UNEXPECTED TOXICS-</u>

WOOL CARPET OFF-GASSING

TILE THIN-SET AND GROUT- BREATHING HAZARD

WATER TEST- HIGH GROSS ALPHA- REVERSE OSMOSIS FILTER

<u>POSITIVES:</u>

CATALIZED LOW VOC POLYURETHANE HARDWOOD FLOOR FINISH

NATURAL HARD OIL FOR VERTICAL TRIM

MARMOLEUM- WARM UNDERFOOT

SHOP FINISHED SILLS WITH DULL RUB URETHANE- ONLY THING THAT STOOD UP TO WATER

OBSERVATIONS AND LESSONS LEARNED

BIG AND SMALL THINGS

CONSIDER MOVABLE EXTERIOR SHADING AT EAST AND WEST

HOUSE DOES NOT HOLD HEAT OF THE WINTER SUN- MORE THERMAL MASS

UNHEATED BIKE ROOM NEEDS VENTILATION TO CONTROL HUMIDITY

OWNER BEHAVIOR MATTERS AS MUCH AS ENVELOPE

DRIFT LOADING AND WIND BLOWN SNOW

FINISHES: CABINETRY

BACKGROUND

1995- Western MA house

A bit beyond Code building- 2x6 walls, extra insulation: R-60 cellulose in attic.

2008- VT Lake House- LEED Gold

Close to “High Performance”

2014- Passive House Training