

Passive Building at 5,000+ Feet



Learning Objectives

01

Identify how high-elevation conditions impact Passive Building design assumptions.

02

Evaluate limitations of high-performance components such as skylights and IGUs.

03

Develop enclosure and foundation strategies for high-elevation sites.

04

Adapt design and construction approaches for remote locations with limited skilled labor.

Agenda

Introductions

What's changes above 5,000'?

Climate Data, Modeling, &
Certification

Case Studies w/ Lessons Learned

Wildewood @ 7990'

Glade Park @ 6870'

Peak 1 @ 8715'

EcoMod Chalet @ 9666'

Q&A





Morgan law, CPHC

Principal Architect & Co-founder

Shape Architecture focuses on buildings that minimize energy use and long-term costs, while maximizing comfort, durability, and connection to sites.

Morgan Law is founding principal and design director of Shape Architecture Studio. His work has included multi-family, restaurant, commercial, hospitality, and single-family, with a specialization in high performance and sustainable design.





WILLOW WIND

CONSTRUCTION

Jesse Zacher, Owner

Our philosophy has always been rooted in continuous improvement: with every house we build, we learn, refine, and make the next one a little better. Over time, that drive led us to rethink our materials, specifically focusing on eliminating petrochemical-based insulations wherever possible to create healthier, more sustainable environments.

Building better shouldn't mean pricing people out, so we are committed to keeping high-quality, forward-thinking construction truly affordable. To ensure strict quality and process control, our team remains on site throughout the entire project, performing as much of the build scope as possible ourselves.

When I'm not on the job site, you can usually find me outdoors, recharging by climbing or biking with my family.





John Loercher, CPHC

Building Performance Consultant

Northeast Projects is a building-performance consulting firm specializing in Phius certification, energy modeling, and high-performance enclosure design. The firm supports residential and commercial projects across diverse climates, with a focus on translating ambitious performance goals into practical, buildable solutions.

John Loercher, CPHC, is the principal of Northeast Projects. John is also a Phius Enclosure Specialist, Phius Certified Trainer, and Senior Lecturer at Rensselaer Polytechnic Institute. Through consulting, teaching, and professional training, he focuses on making building-science principles practical, understandable, and directly applicable to design and construction.

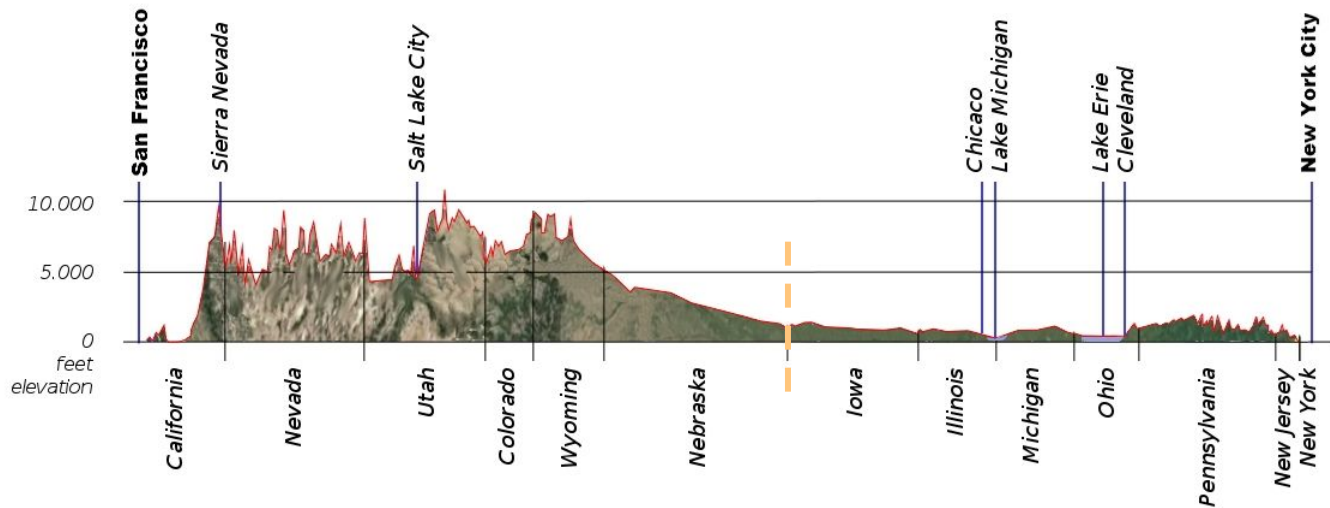


Westward Bound

~75% of Phius Certified Projects are East of Nebraska

01

Identify how high-elevation conditions impact Passive House design assumptions.



"US elevation profile from LA to NYC" - u/edsml via Reddit, 2014

What Changes Above 5,000'?

Climate & Modeling

- Climate Data Availability
- (Often) Intense tree cover
- Reduced air density
- Local Microclimates

Materials & Components

- Intense radiation / UV exposure
- IGU pressure
- Emissivity

Comfort & Resilience

- Phius comfort requirements ($\Delta 7.2^{\circ}\text{F}$)
- Condensation thresholds
- Grid resilience
- Winter overheating
- Introduction of cooling
- Increased wildfire risk

Mechanical Systems

- Adjusted Blower Door testing
- Peak Design Temps
- Air Equipment derating
- Ventilation commissioning

Construction Access

- Short building season
- Remote labor and deliveries
- Snow, wind and access
- Road closures

Climate Data

Default Phius Dataset (Boulder, CO):

US CUSTOMARY:

Month	1	2	3	4	5	6	7	8	9	10	11	12	Heating Load		Cooling Load
Days	31	28	31	30	31	30	31	31	30	31	30	31	Weather 1	Weather 2	Radiation
BROOMFIELD/JEFFCO [BOULDER - SURFRAD] CO	Latitude:	40.1	Longitude * East	-105.2	Altitude (ft)	5541.3	0	Daily temperature variation summer (F)		28.1	Radiation Data:		kBTU/(ft²*month)	Radiation: BtU/ft²*R	
Ambient Temp (°F)	31.6	33.1	40.8	49.6	57.0	66.2	73.4	71.1	62.2	50.9	40.3	29.1	8.8	20.5	75.6
North	9.5	9.5	12.0	13.9	17.4	18.4	17.4	13.3	9.8	7.9	6.7	8.9	13.6	12.7	25.0
East	20.9	21.9	30.1	33.0	36.8	39.3	41.8	38.0	31.4	25.7	17.8	18.7	24.1	16.2	63.4
South	45.0	40.6	41.8	33.6	27.9	23.5	25.0	30.7	38.4	43.7	41.5	45.0	65.9	36.5	36.5
West	18.4	20.3	25.7	30.4	33.0	33.3	29.5	27.3	26.6	21.2	16.8	18.4	31.7	22.2	50.1
Global	23.8	27.6	42.5	53.6	62.4	63.4	61.8	56.1	46.6	35.8	24.4	21.6	31.4	23.8	99.9
Dewpoint	15.4	18.1	24.3	30.0	36.5	42.8	45.3	48.9	37.9	27.3	20.3	12.9			
Sky temperature	-6.5	-0.6	7.5	15.1	24.4	32.9	38.1	40.8	27.5	14.5	4.5	-10.7			

Heating Load		Cooling Load
Weather 1	Weather 2	Weather 1
Ambient Temp (°F)		
8.8	20.5	75.6

Custom Phius Dataset (Silverthorne, CO):

US CUSTOMARY:

Month	1	2	3	4	5	6	7	8	9	10	11	12	Heating Load		Cooling Load
Days	31	28	31	30	31	30	31	31	30	31	30	31	Weather 1	Weather 2	Radiation
SILVERTHORNE_CO	Latitude	39.6	Longitude * East	-106.1	Altitude (ft)	8723.8	0	Daily temperature variation summer (F)		28.6	Radiation Data:		kBTU/(ft²*month)	Radiation: BTU/ft²*R	
Ambient Temp (°F)	19.4	21.9	29.8	37.6	46.2	57.0	61.5	58.6	52.0	40.3	28.8	19.6	2.1	15.8	65.1
North	5.1	6.0	9.2	11.7	16.5	18.7	17.8	13.3	9.5	7.6	5.7	4.9	6.7	6.3	19.7
East	18.4	21.2	30.4	34.9	38.7	40.9	39.3	37.1	33.3	24.1	18.7	16.2	24.1	15.8	42.4
South	48.8	45.6	45.0	33.9	29.2	26.9	27.9	32.7	40.3	46.0	46.0	47.2	64.7	38.4	30.4
West	19.0	21.9	30.7	31.1	37.4	38.4	37.4	33.6	30.4	26.3	18.7	16.8	23.5	15.2	36.5
Global	25.7	31.4	46.9	53.6	62.4	67.8	64.7	58.3	49.5	37.7	26.6	22.8	33.0	22.5	69.4
Dewpoint	9.0	10.4	14.5	19.2	25.2	29.3	39.2	38.8	31.3	22.6	14.5	9.5			
Sky temperature	-18.2	-15.3	-8.0	-0.4	8.6	15.6	27.1	25.5	15.8	3.9	-8.5	-17.1			

Heating Load		Cooling Load
Weather 1	Weather 2	Weather 1
Ambient Temp (°F)		
2.1	15.8	65.1

Phius Comfort & Condensation Requirements

Phius Window Comfort & Condensation Risk Assessment Tool

v25.1.2



Required input cells.	Requirement met.
Required dropdown menu inputs.	Requirement not met.
Calculated from another sheet.	Threshold.

Settings

Language

English

Measurement System

Imperial (IP)

Project Information

Phius Project #

2906

Project Name

Ecomod Chalet

Window or Door Label

Pivot Alu7 Door_36 SHGC

Climate Information

Type of Climate Data

Phius - Custom

Country

USA

State

CO

Climate Location

La Plata Peak, Twin Lakes

ASHRAE 99% Design Temperature

-9.4

[°F]

HDD65 > CDD50?

☒

Check box if true.

Average Monthly Temperatures

[°F]	1	2	3	4	5	6	7	8	9	10	11	12
Ambient	18.0	18.5	25.3	32.4	41.2	52.3	56.3	53.4	47.3	36.7	25.7	17.8
Dewpoint	5.7	6.3	10.8	16.2	22.5	26.4	36.9	36.5	28.6	19.4	10.4	5.9

Condensation Risk Assessment

ISO 13788: Low Thermal Inertia Elements

Input Data:

Select Fenestration Type

3. Any other type of fenestration.

Class 2 typical

Select Humidity Class

2. Offices, dwellings with normal occu

Frame U-Value

0.3

BTU/hr.sF

Safety Factor

15%

Typical = 15%. Minimum = 1%.

Result:

Maximum U-value

0.49

BTU/hr.sF

Risk acceptably low?

YES (Pass)

Exceptions:

- Pet doors are not required to pass the condensation resistance test.
- Exterior doors with ADA, egress, fire rating requirements may use the uninstalled whole door U-value.

Comfort Requirements

Window Head-Height-From Sill (HHS)

10.00

feet

Maximum Temperature Difference (TA)

7.3

[°F]

Required Whole Window U-value*

0.14

BTU/hr.sF

Assigned window type		
Name	Uw [Btu/hr ft² °F]	
Pivot Alu7 Lift and slide_36 SHGC_fixed	0.1945	X
Available window types		
Pivot Alu7 Fixed_36 SHGC	0.1423	X
Pivot Alu7 Operable_36 SHGC	0.1547	X
Pivot Alu7 Door_36 SHGC	0.2164	X
Pivot Alu7 Fixed_54 SHGC	0.1423	X
Pivot Alu7 Operable_54 SHGC	0.1547	X
Pivot Alu7 Lift and slide_36 SHGC_slide	0.2328	X

Introduction of Cooling

Dominant Culture: No cooling necessary in the mountains

- **Problem 1:** Phius requires cooling
- **Problem 2:** Super-insulated enclosure drives cooling load upwards (specifically slab insulation)

Perimeter Slab Insulation only:*

Cooling load

specific: 0.43 Btu/hr ft²
target: 3 Btu/hr ft²
total: 605.96 Btu/hr



Continuous Slab Insulation:*

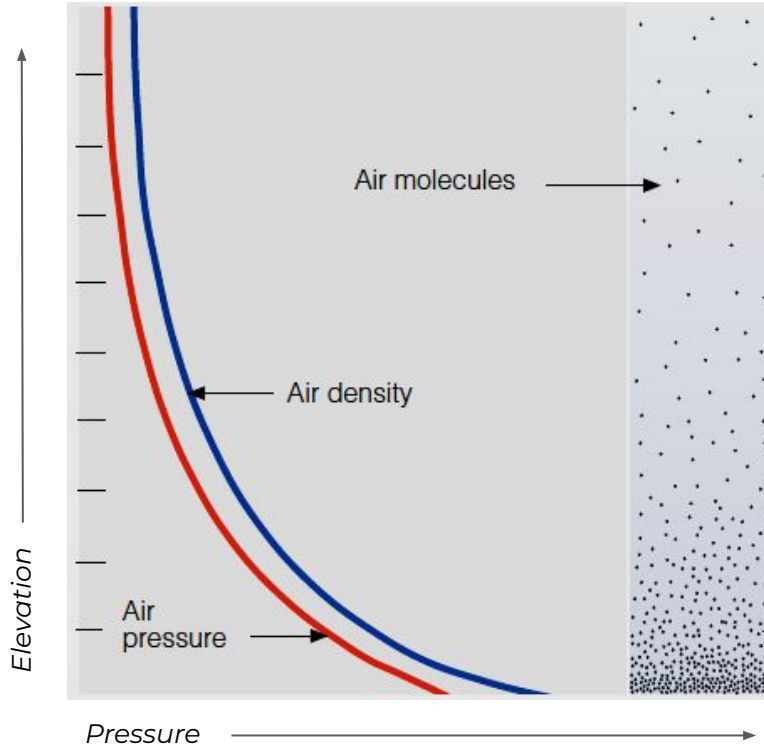
Cooling load

specific: 1.45 Btu/hr ft²
target: 3 Btu/hr ft²
total: 2,063.96 Btu/hr



* WUFI is known to underestimate cooling, always perform a manual J

Reduced Air Density



Impact on buildings:

- Lower air density = less heat carried per CFM
- Ventilation systems require altitude adjustment
- HVAC equipment lose capacity and efficiency
- Less convective heat transfer
- Material and Assembly pressure tolerances

Adjusted Blower Door Results

Uncorrected blower-door results appear better than they are.

*At ~9,000 ft, correcting to standard air density can increase reported leakage by roughly 5%**

Simplified correction method:

Altitude factor: $1 + (0.000006 \times \text{ft. elev})$

9,000 ft: $1 + (0.000006 \times 9,000) = 1.054$

500 CFM50 →	~527 CFM50 corrected
0.060 CFM50/ft ² →	~0.063 CFM50/ft² corrected

**RESNET*

WILDEWOOD

Nederland, CO

Phius CORE 2021 Certified

7,990'



PEAK LOAD	17,473 BTU / HOUR	ANNUAL HEATING	4.57 kBtu / SF / YEAR
PRIMARY ENERGY	43.62 kBtu / SF / YEAR	ANNUAL COOLING	0.30 kBtu / SF / YEAR

VENTILATION

89% % EFFICIENT

R-VALUES

39.0 WALLS
82.0 ROOF
0.0 FLAT ROOF
26.0 SLABS

WINDOWS & DOORS

0.56 SHGC
0.12 U-VALUE GLASS
0.15 U-VALUE FRAME
0.16 U-VALUE UNIT

AIR TIGHTNESS

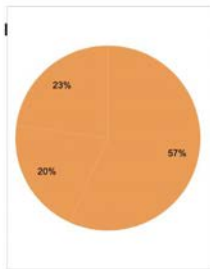
0.82 ACH50

GLAZING % OF TFA

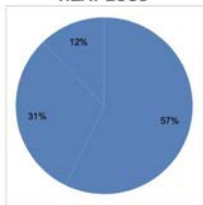
WINDOW ENERGY **11,594** kBtu / YEAR

TOTAL KW

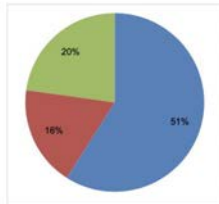
PV PANELS 17



HEAT LOSS



SHELL LOSSES



SOLAR GAINS: 57%
INTERNAL GAINS: 20%
MECHANICAL HEATING: 23%

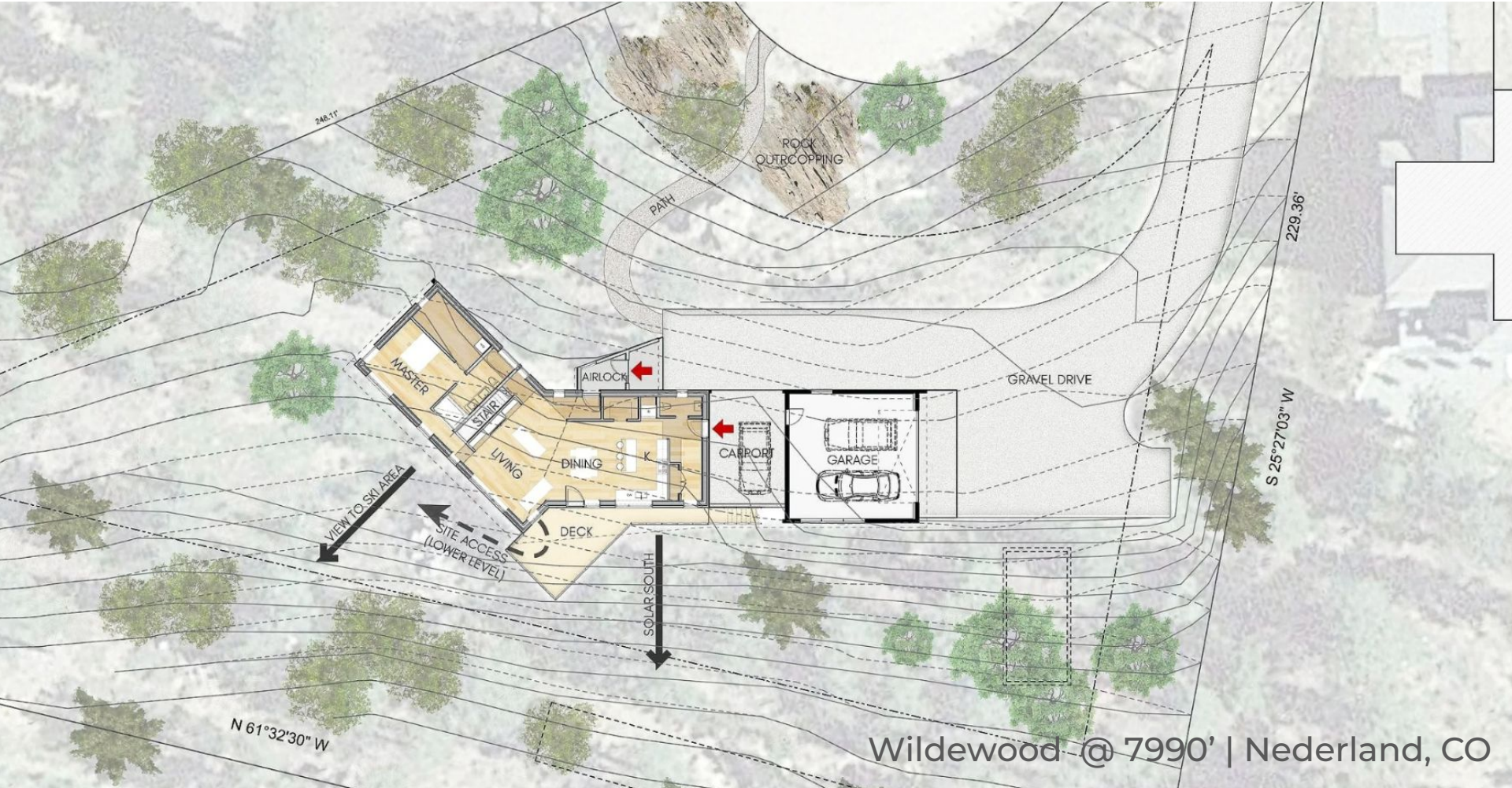
BUILDING SHELL: 57%
WINDOWS: 31%
VENTILATION & AIR LEAKS: 12%

WALLS: 51%
ROOF: 16%
FLOOR SLAB: 20%

The last of the dinosaurs!



45° angle in design to be perfectly south oriented and also capture SW views. Site is steep & wooded.





Wildewood @ 7990' | Nederland, CO

- Athena Sustainable Materials Institute



Lessons Learned

- ICFs: carbon intensive, but simplifies air sealing
- Airtightness: 0.049 CFM 50/ft²

Wildewood @ 7990' | Nederland, CO

Lessons Learned, cont.

- **Embrace the misfits** Owner as first time GC/ builder with an Extremely windy site
- Extra support required for non-experienced passive house builders

Wildewood @ 7990' | Nederland, CO

- **Radiant Heat for the win!** Air-to-water heat pump heat due to thin air derating, dry cold climate



Wildewood @ 7990' | Nederland, CO

● **Don't be a hero!** (hire an energy modeler)



Wildewood @ 7990' | Nederland, CO

PINION PASSIVE

6,870'

Glade Park, CO

Phius CORE 2024, Design Certified
Construction Cert Pending





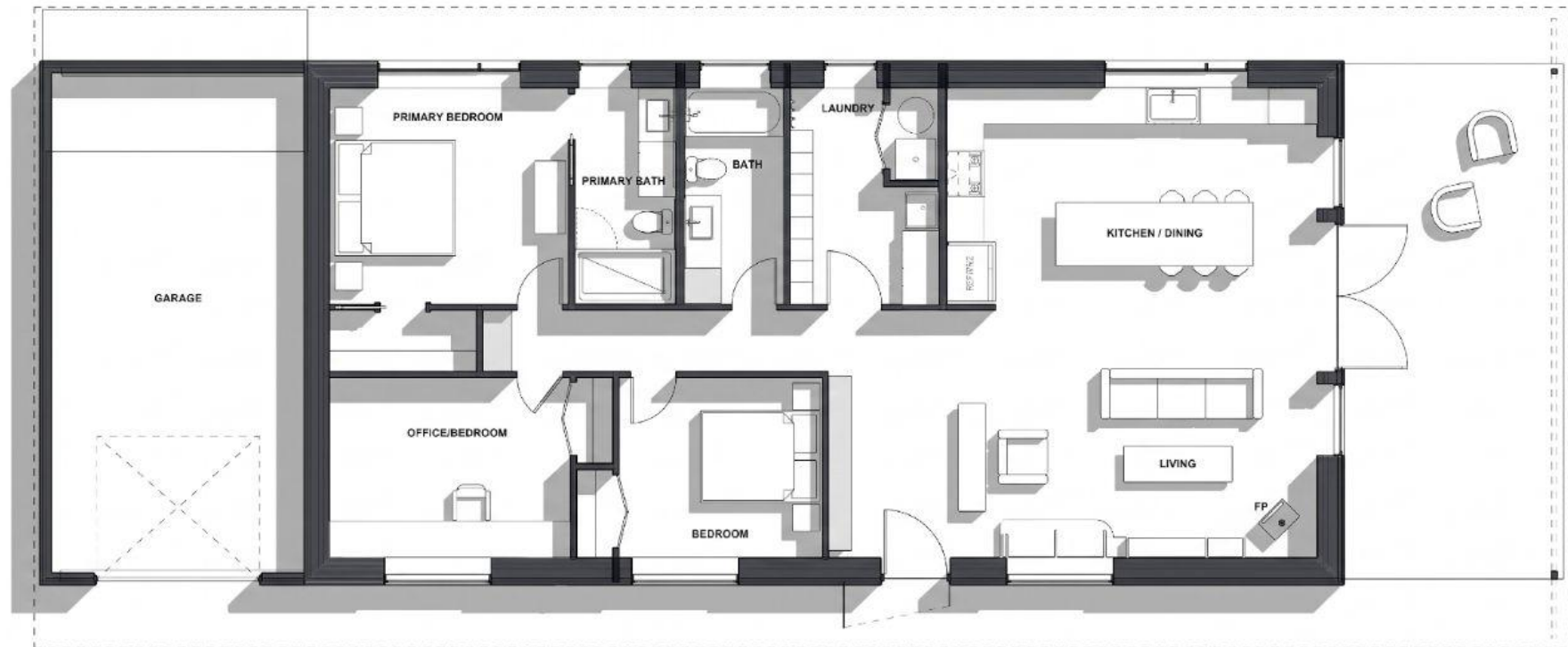
Glade Park @ 6870' | Glade Park, CO

Should I explore alternative green building approaches? Earth bags?

No, build a close to Passive House; it's better for resale!



If it quacks like a duck....maybe it could be..



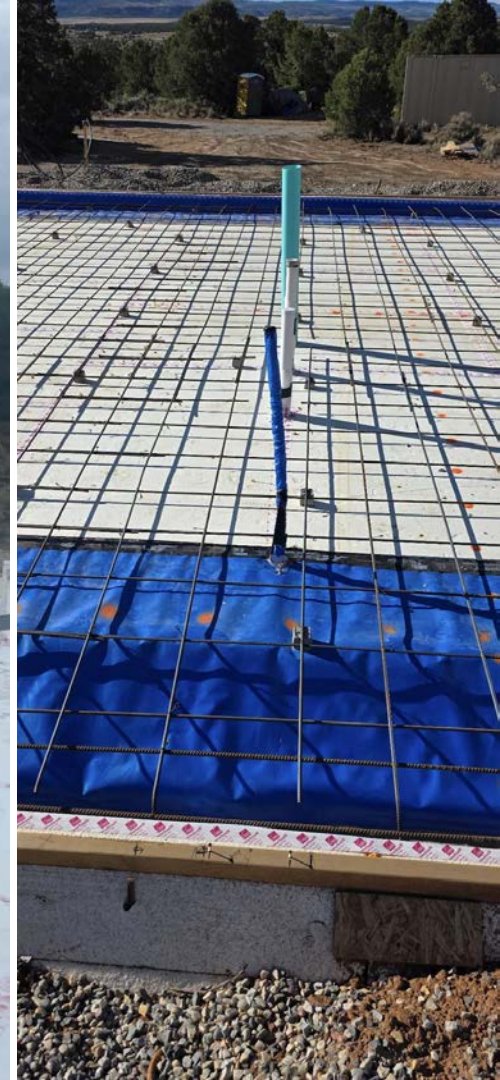
Glade Park @ 6870' | Glade Park, CO

A certified duck!

Concessions were made by the team
(someone call the rater)



Glade Park @ 6870' | Glade Park, CO

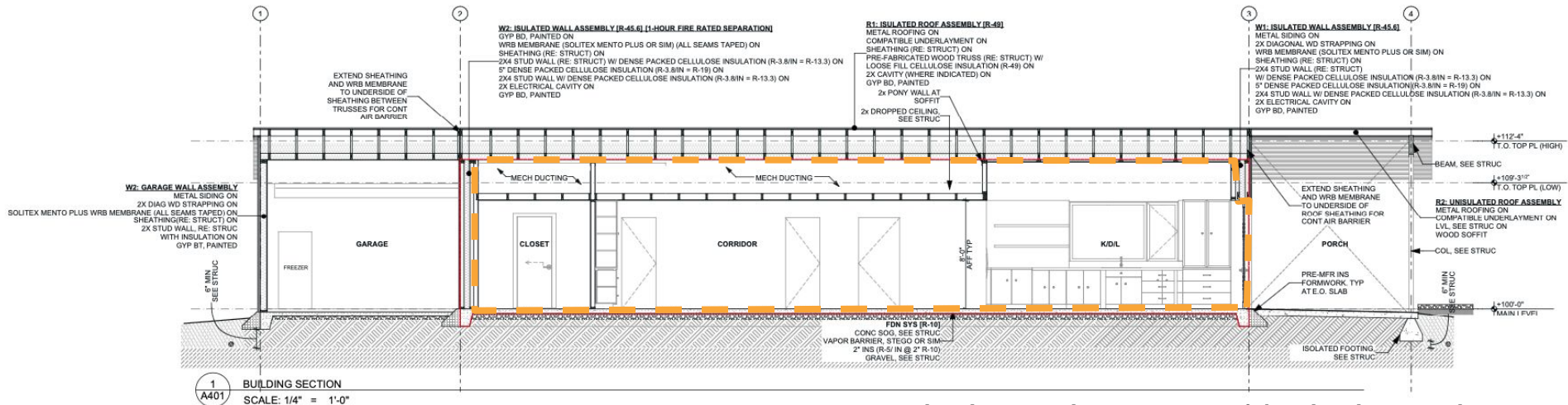


Not the textbook approach!



**Anything is possible
with an excellent
builder & a collaborative building
performance consultant, certifier,
and architect!**

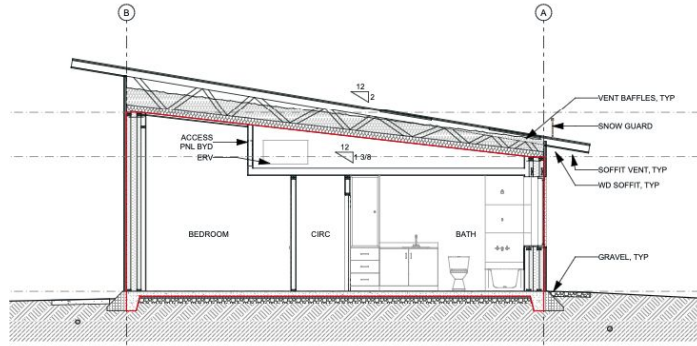
Glade Park @ 6870' | Glade Park, CO



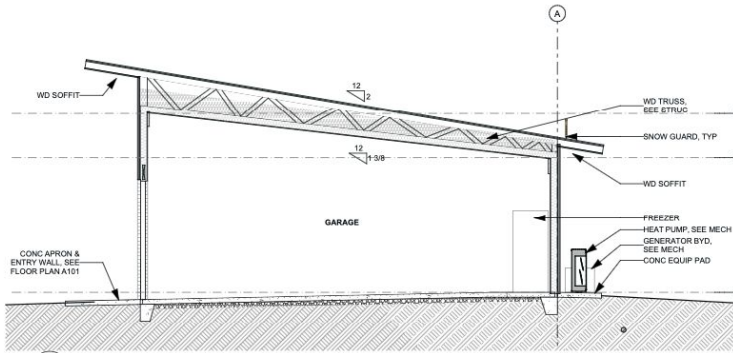
Glade Park @ 6870' | Glade Park, CO



Glade Park @ 6870' | Glade Park, CO



3
A401 NS SECTION THROUGH BATH & BED
SCALE: 1/4" = 1'-0"



2
A401 N-S SECTION THROUGH GARAGE
SCALE: 1/4" = 1'-0"



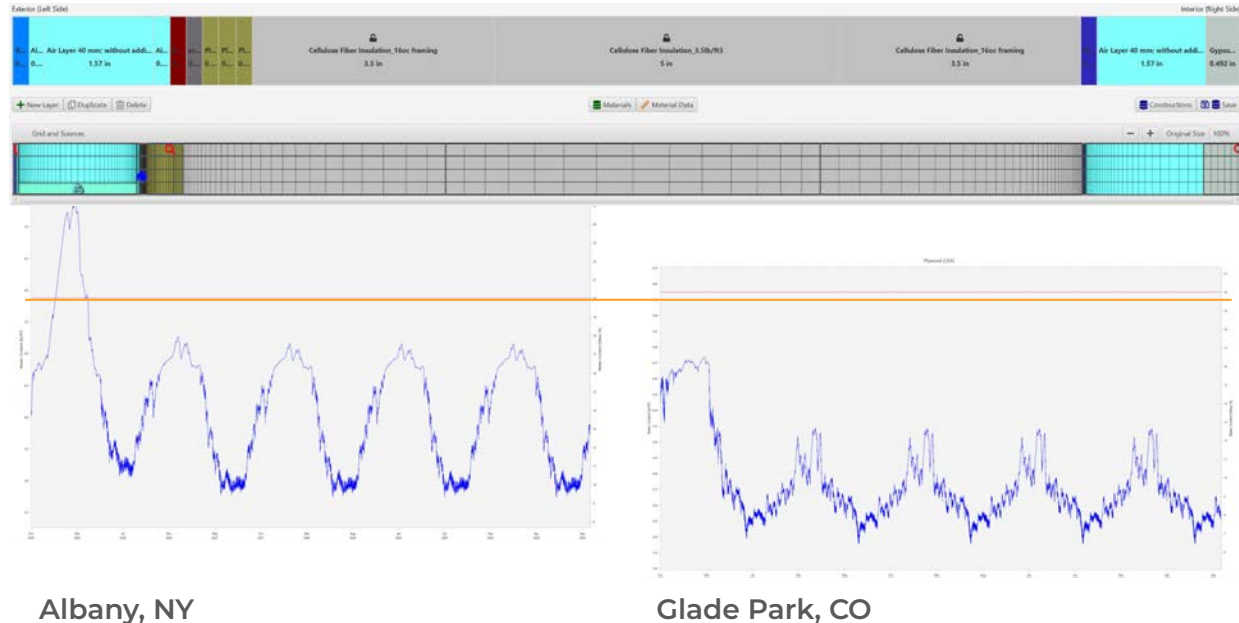
Glade Park @ 6870' | Glade Park, CO

Lessons Learned

- Enhanced wall durability with drier air
- Assembly dries out quickly & stabilizes
- Less seasonal moisture variability in condensing layer (plywood)

Wall Assembly: 12"
double stud wall w/
DP cellulose

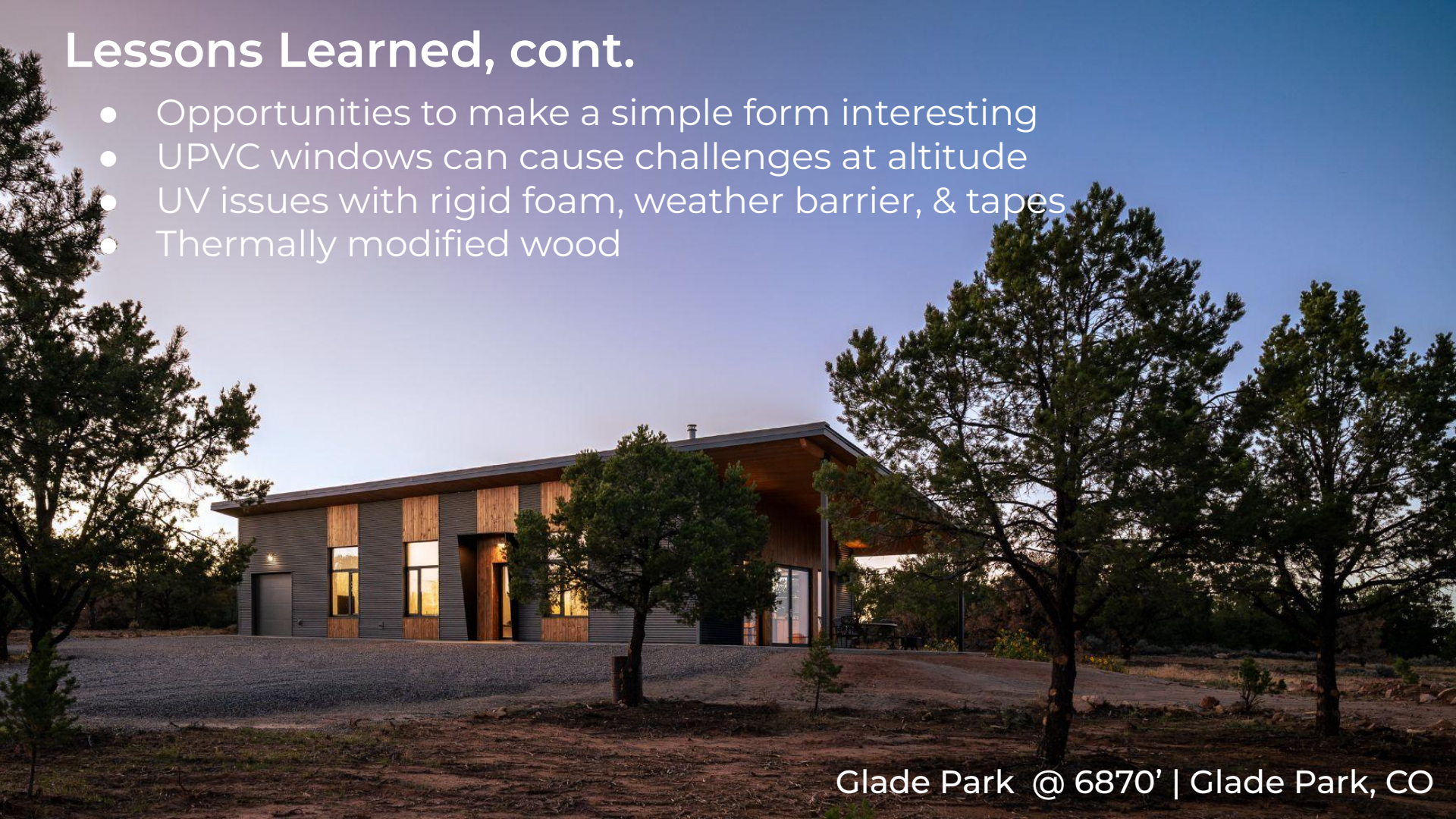
WUFI Pro Phius
hygrothermal
modeling protocol



20% MC

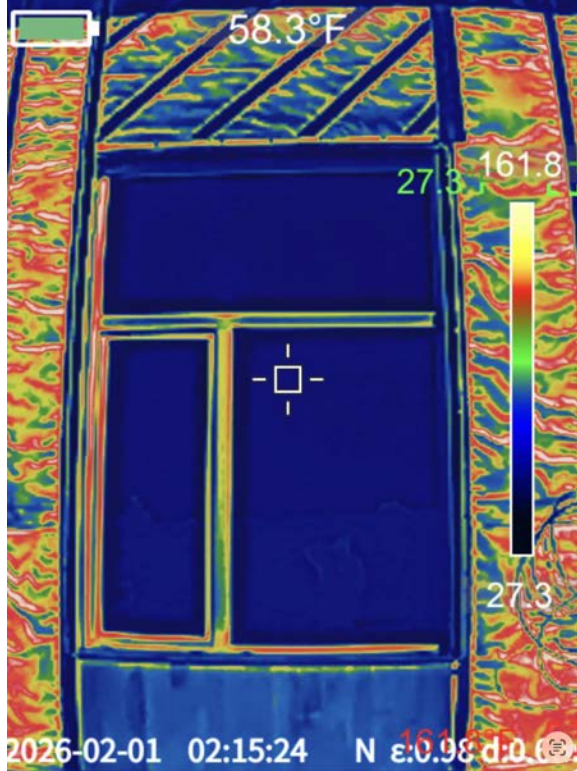
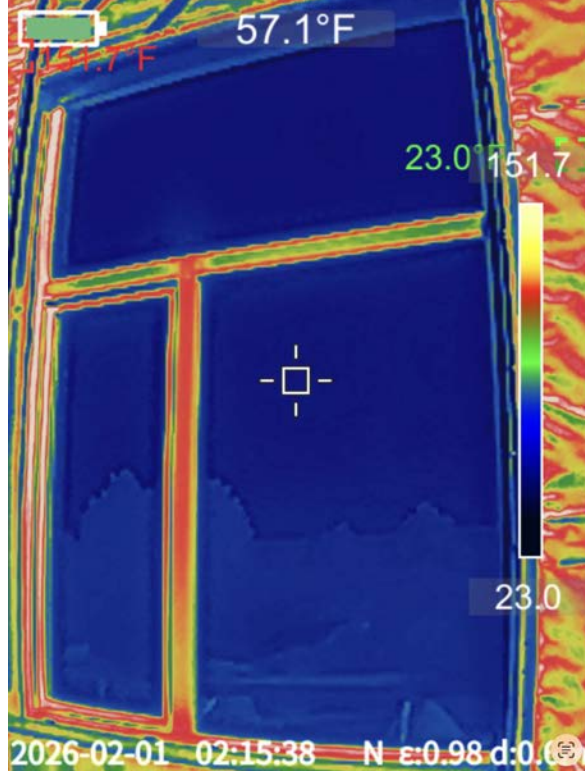
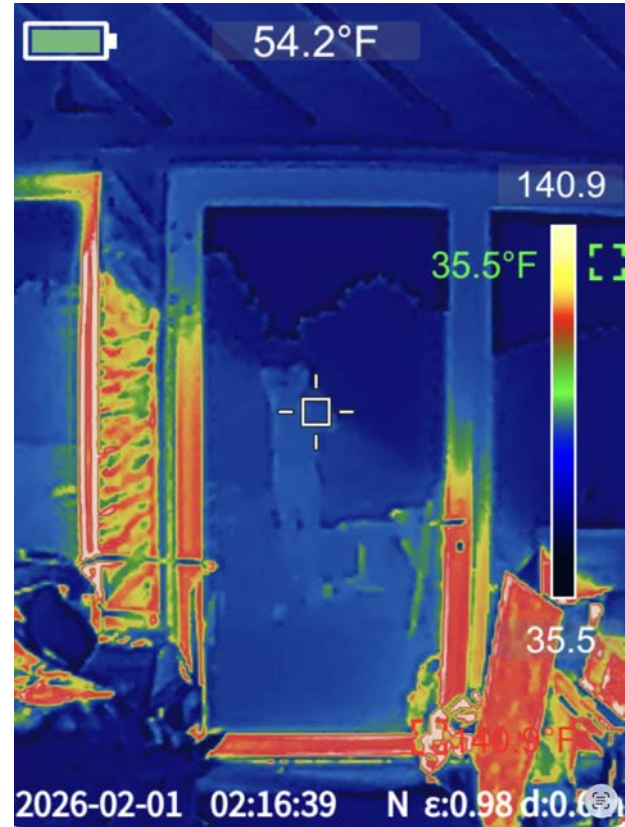
Lessons Learned, cont.

- Opportunities to make a simple form interesting
- UPVC windows can cause challenges at altitude
- UV issues with rigid foam, weather barrier, & tapes
- Thermally modified wood



Glade Park @ 6870' | Glade Park, CO





38° ambient temp.

10:00am.

Frame temp? 156° already.

Lessons Learned, cont.

Existing well → make passive house pump shed

Shallow frost protected slab selected based on existing bedrock and desire for minimal site disturbance

Purchasing equipment for dense packed insulation

UFER with monoslab and significant insulation/vapor barrier



Glade Park @ 6870' | Glade Park, CO

Lessons Learned, cont.

- PHIUS raters are hard to come by in rural areas. This can increase costs & timelines.
- Maybe have that PH convo *before* breaking ground



Glade Park @ 6870' | Glade Park, CO

Cost Summary

Phase One

\$500K | \$243/sf

A very efficient home w/ basic interiors & exterior. Held this budget and strategy until framing started.

Phase Two

\$540K | \$263/sf

A more efficient home to potentially meet PH. Included ERV upgrade, certification cost, HVAC modifications, timber fill ILO cellulose, PH compatible wood stove

Phase Three

\$565K | \$275/sf

Passive House certified with design upgrades including exterior materials, bathrooms, kitchen, and fireplace surround

*2,025 SF house
w/ garage and porch @ 50% area*

Glade Park @ 6870' | Glade Park, CO





(insert girlfriend here)

Glade Park @ 6870' | Glade Park, CO

PEAK ONE

8,715'

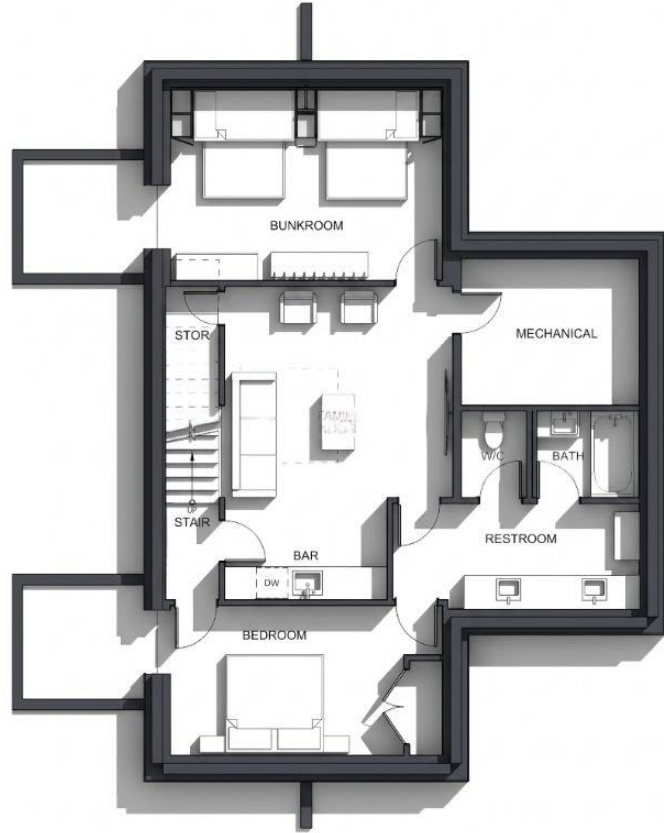
Silverthorne, CO

Phius CORE 2024, Design Certified
Construction Cert Pending

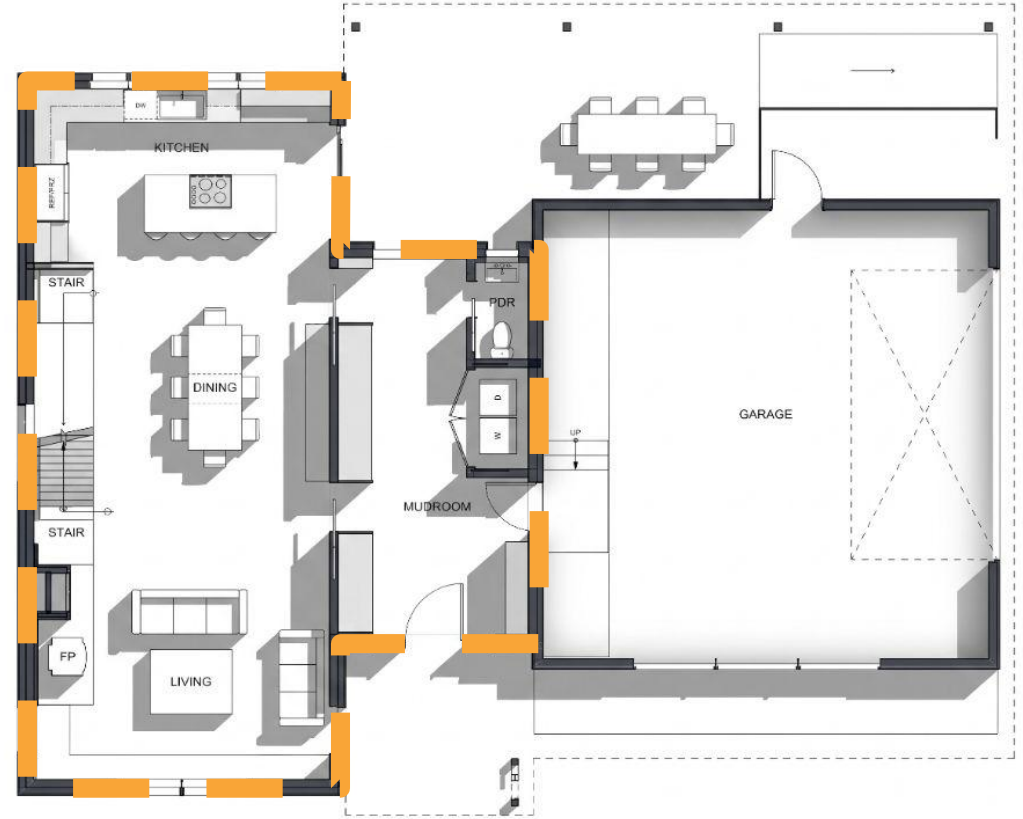




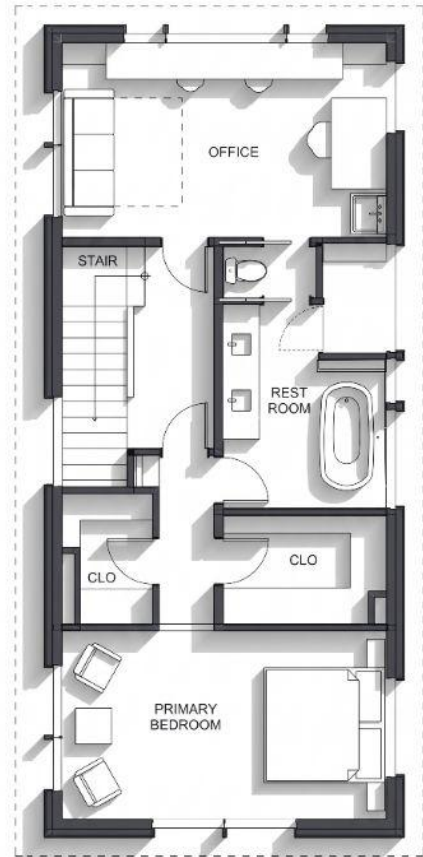
Peak One @ 8715' | Silverthorne, CO



LOWER LEVEL PLAN



MAIN LEVEL PLAN



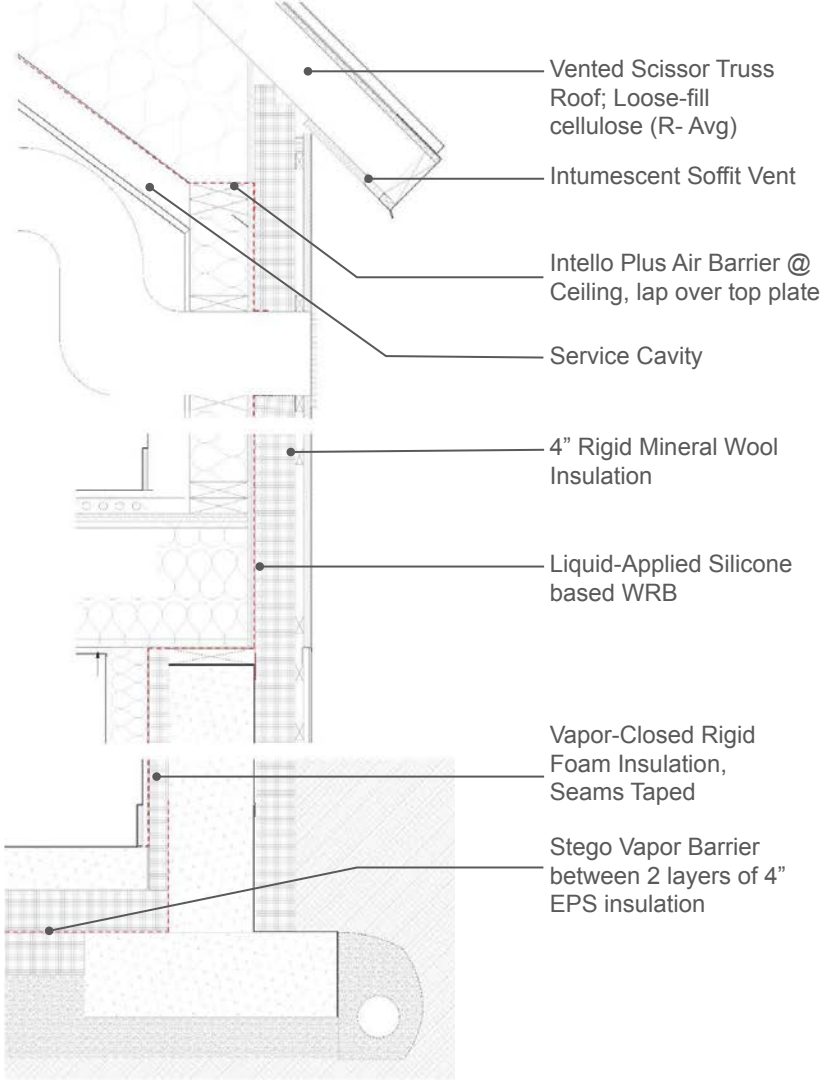
UPPER LEVEL PLAN

Peak One @ 8715' | Silverthorne, CO



Keep a buffer in certain categories

Peak One @ 8715' | Silverthorne, CO

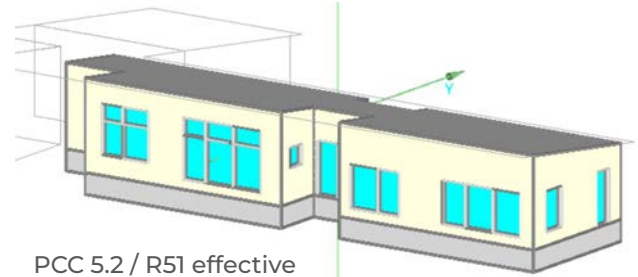
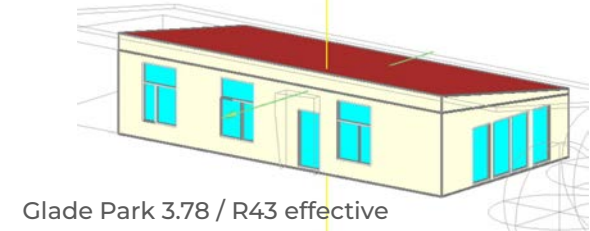




Peak One @ 8715' | Silverthorne, CO

Lessons Learned

- In cold-climates, form is critical; achieving the standards requires careful consideration of form factor
- Strong form factors reduce R-value requirements for assemblies
- Transmission heat loss can be reduced with usable sub-grade space



Lessons Learned, Cont.



Design team was challenged with sourcing a skylight that met the requirements for a high slope roof, high altitude site, & U-values

Peak One @ 8715' | Silverthorne, CO

Lessons Learned, Cont.

Air-to-water heat pump avoids thin air penalty.

Fan coils can be added for a low per/unit cost to future proof against warming temps.

Detail extents of silicone WRB to ensure proper window taping.



Peak One @ 8715' | Silverthorne, CO

Cost Summary

Additional Passive House Construction Costs

Insulation & Air Barrier:	\$42,123
Windows:	\$34,050
ERV:	\$30,000
Air to Water Heating:	\$20,000
<u>Misc Labor:</u>	<u>\$10,000</u>
Total:	\$136,173

Additional cost/SF: \$33 (5.8%)

Additional Fire Resistant Construction Costs

Fire retardant siding:	\$16,000
Soffit fire retardant:	\$8,000
<u>Vulcan Vent & caulking:</u>	<u>\$7,000</u>
Total:	\$31,000

Additional cost/SF: \$7.50 (1.3%)



Peak One @ 8715' | Silverthorne, CO



Peak One @ 8715' | Silverthorne, CO



Peak One @ 8715' | Silverthorne, CO

LA PLATA PASSIVE

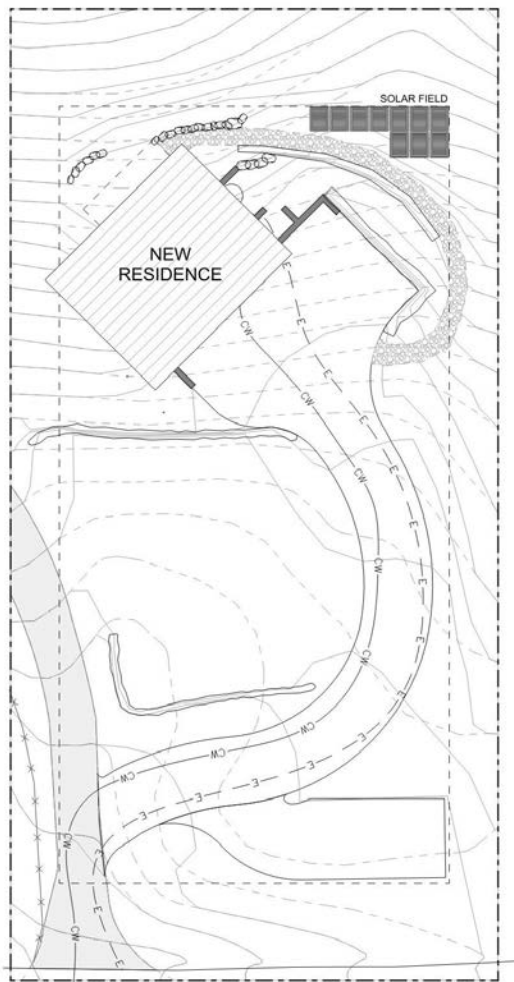
9,666'

Twin Lakes, CO
Phius CORE 2024, Design Certified
Construction Cert Pending





Ecomod Chalet @ 9666' | Twin Lakes, CO



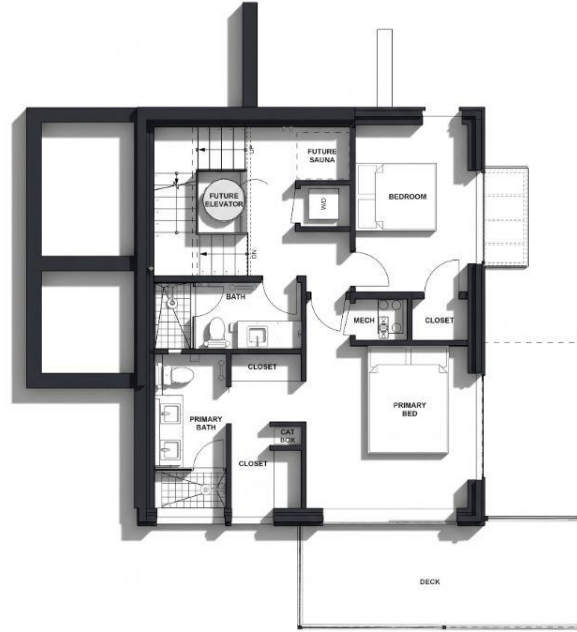
MAIN LEVEL PLAN



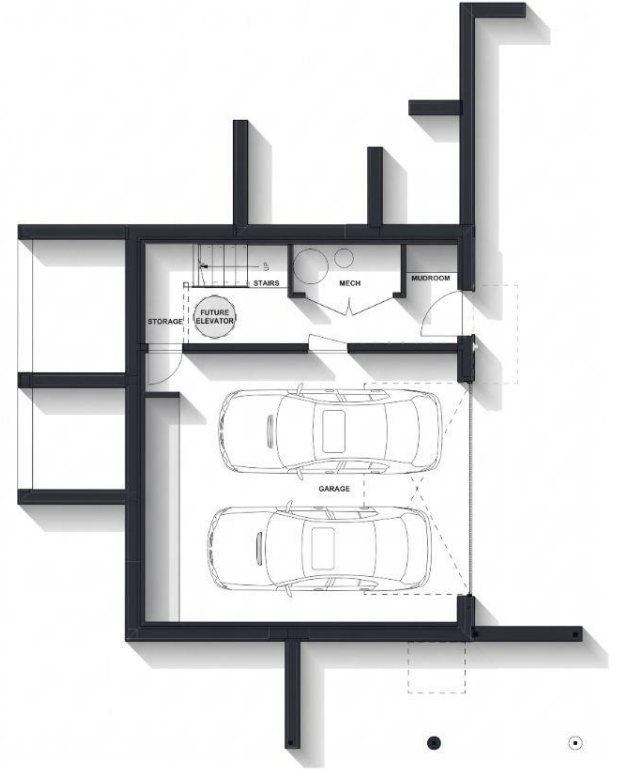
Ecomod Chalet @ 9666' | Twin Lakes, CO



UPPER LEVEL PLAN

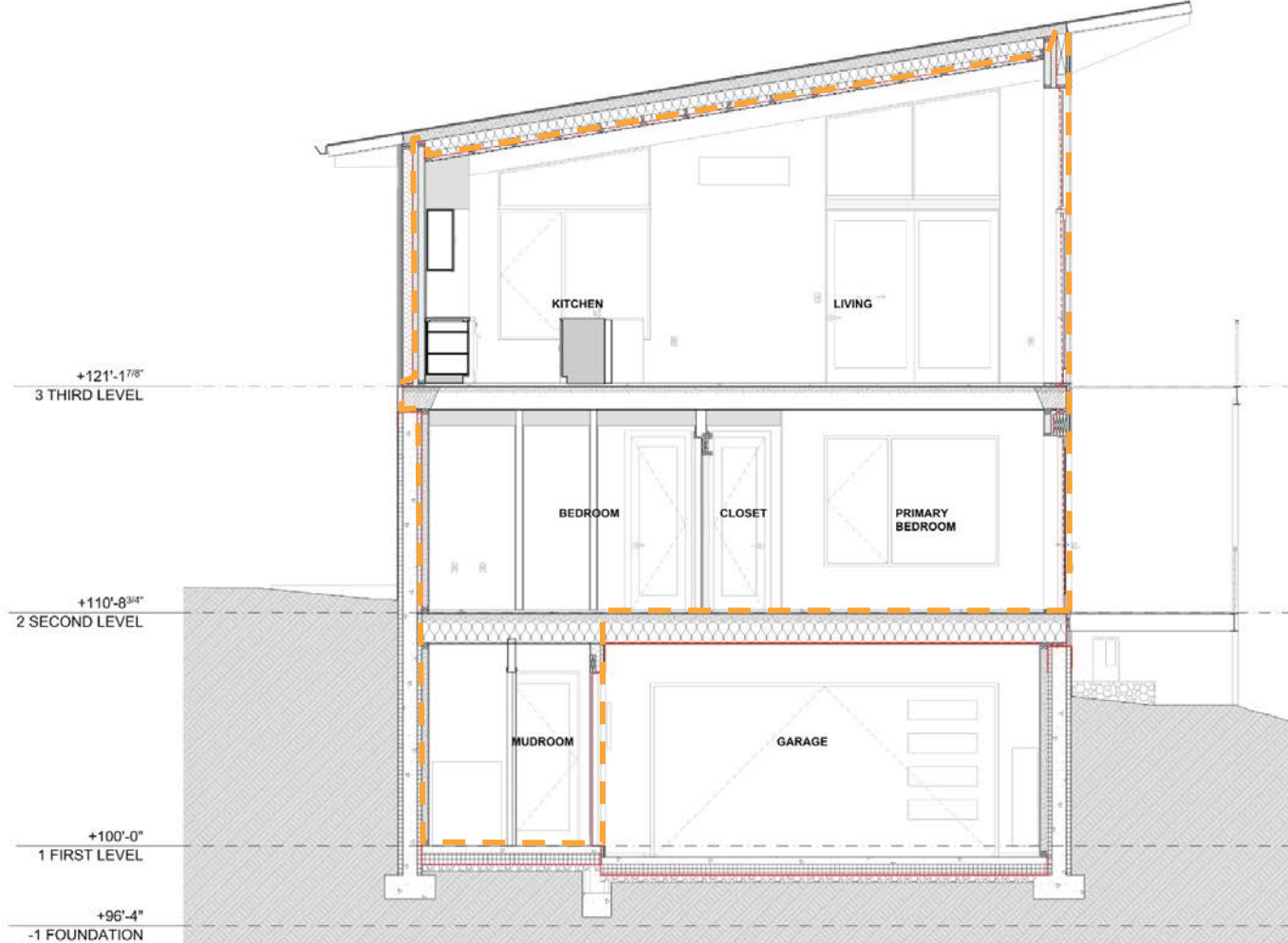


MAIN LEVEL PLAN



LOWER LEVEL PLAN

Ecomod Chalet @ 9666' | Twin Lakes, CO

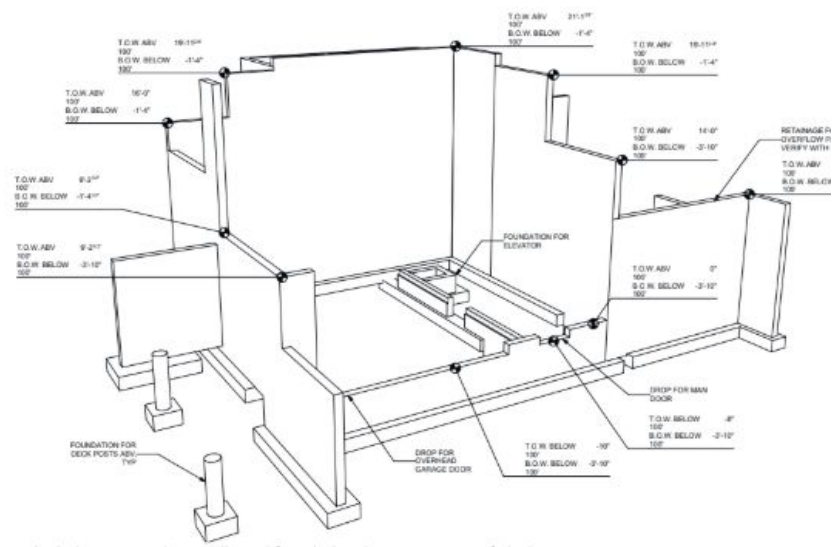


Ecomod Chalet @ 9666' | Twin Lakes, CO



Ecomod Chalet @ 9666' | Twin Lakes, CO

Phius protocol has really improved to allow for more complexity - foundation this complex due to steep site could not have been certified in the past



Ecomod Chalet @ 9666' | Twin Lakes, CO

Lessons Learned

- Complicated foundations can be done! But plan to iterate
- Interior continuous insulation allows for continuous stem / retaining walls
- Avoid complicated / expensive thermal break concrete details



Ecomod Chalet @ 9666' | Twin Lakes, CO

Lessons Learned, Cont.

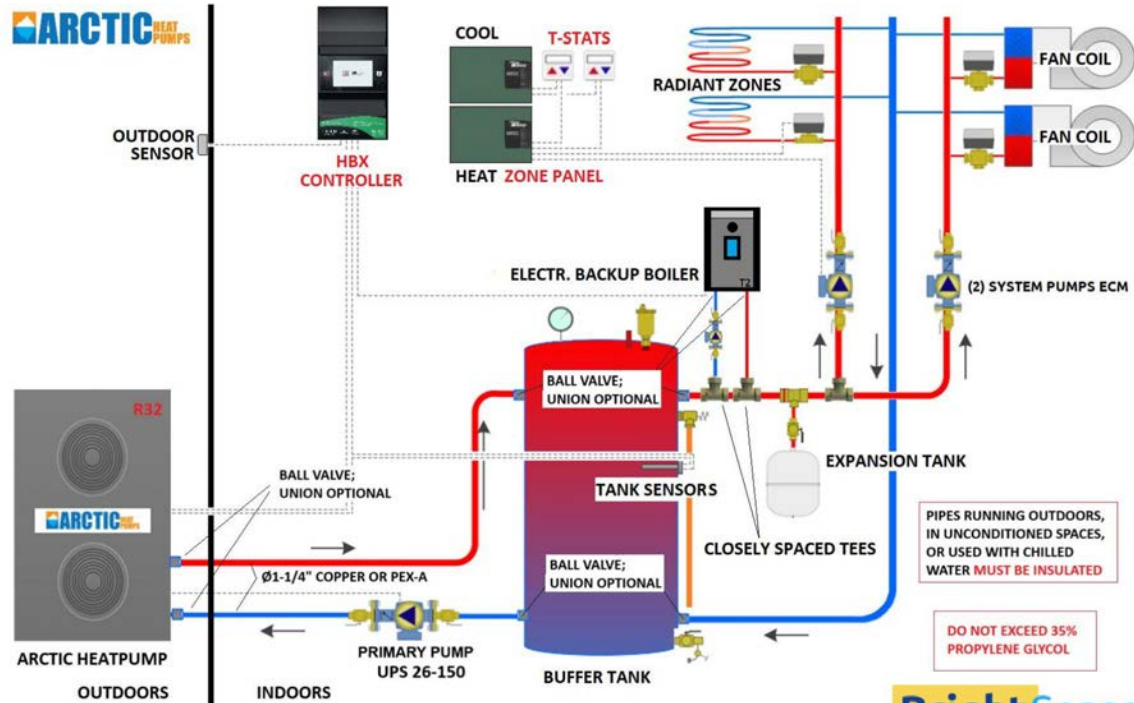


Figure 10 – Conceptual hydronic system schematic

- In-floor radiant heating enables path through comfort requirements

Phius Guidebook Appendix N-3: “Where window comfort cannot be met through the performance U-value, providing active heat at the perimeter may be used to meet the comfort criteria.”

- Helps control strict window criteria (\$\$)

BrightSense



Ecomod Chalet @ 9666' | Twin Lakes, CO



Ecomod Chalet @ 9666' | Twin Lakes, CO

LESSONS LEARNED



Utility Incentives from Xcel

Current Xcel Residential Rebates

- All electric, <1.5 ach50: \$22,000
- Passive House Certified: \$25,000

Xcel serves over half of the Colorado population.

To continue to scale the number of certified projects:

- All electric, <1.5 ach50: **\$12,000**
- Passive House Certified: **\$35,000**
10k for certification costs + \$25k for mechanical & envelope upgrades

Insurance Incentives

Lessons Learned from a client in Arvada, CO

The biggest discounts, in order of magnitude were:

1. Compliance with FEMA Marshall Fire protection guidelines,
2. Roof Fire, Hail, and Wind protection as a system, not just tiles or sheets
3. **Passive House construction (we got an extra door & window protection discount on top of our greater deductible risk assumption for roof, frame & foundation).**
4. Electrification discount (heat pumps, no gas, EV-to-House capability or dedicated battery backup - claiming EV capability right now),
5. Connected umbrella policy discount for accessibility, and
6. Multi-product discount (home, auto, umbrella, renter's)

Our focus on wildfire risk mitigation thus was the biggest driver of our insurance discounts, while passive house construction allowed us to assume greater deductible risk on roof, frame, and foundation.

How we make it happen:

1. Utilize Xcel grant where possible
2. Split the cost of the feasibility study to showcase commitment (sssh don't tell all of our clients that)
3. Donate time to facilitating the certification process
4. Combine clients' fire residency goals with PH certification
5. Work with builders who build beyond code as their standard
6. Find a compatible PH consultant and Rater and refine the process
7. Continue to find ways to make the certification process less expensive
8. The Phius climate-specific passive building standards are essential for making high altitude homes achievable and attainable.
9. Re-sale-ability?



NEXT PROJECTS



Thank you! Questions?



OUTLINE

Intro / prez outline - 2 mins

Team intros - 5 mins (jesse's could feature rvr)

John L - 10 mins Climate data, PHPP / wufi / certifying implications

NED - 1-2 slides ~floor plan~

Brook - 10 mins (shape and John) ~floor plan~

Glade Park - 10 mins (JESSE shape and John) Morgan intro and then hand to Jesse (john provided a discount for the certification process - jesse / shape / client - split the cost of John and dave and phius fee) fire mitigation changed over the course ~floor plan~

EMC - 10 mins (shape and John) ~floor plan~

NSL - one slide - shading from steep valley, need for cooling, having to model the mountains

Lessons learned: ventilation commissioning, insurance savings, utility rebates

Questions - 8 mins with a cool slide of other PH projects in CO Parks, NZDH, Paonia, FLI, SMH, RHH, NSL, 209, PHH, sunflower. Ogden

Phius CEUs

CONFERENCE EVENT

PhiusCon 2026

Passive House at 5000+ feet

CREDIT VALUE

XXCEU Credits

REPORTING INFORMATION

How to Claim Credits

Please note that credit codes will be provided post-event.

infoSelf Report Code Coming Later

CREDENTIAL MAINTENANCE

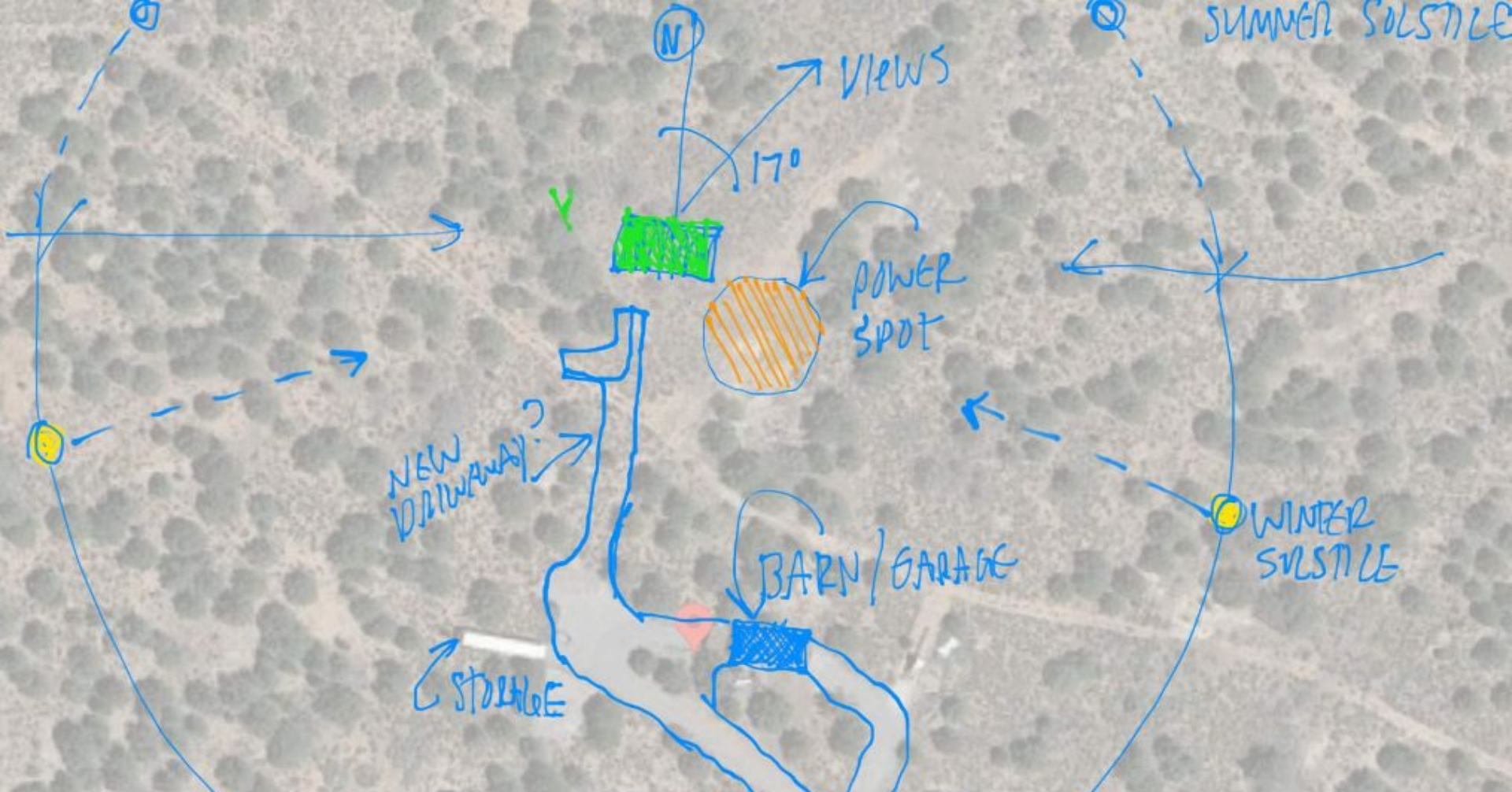
phius.org/.../maintain-credentials 



Wildewood @ 7990' | Nederland, CO



Wildewood @ 7990' | Nederland, CO



Glade Park @ 6870' | Glade Park, CO



Ecomod Chalet @ 9666' | Twin Lakes, CO

Site Plan



Peak One @ 8715' | Silverthorne, CO