Sonoran Desert Passive House

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brubaker architects

phius con HOUSTON 2023

Learning Objectives:

Learning Objective #1

Energy use comparison:
- As modeled in WUFI Passive
- Three years of monitored data
- Using the house as a thermal battery to reduce load on grid

Learning Objective #2

Discussion of building siting, shape, thermal mass, insulation, shade and common hot dry climate misconceptions.

Learning Objective #3

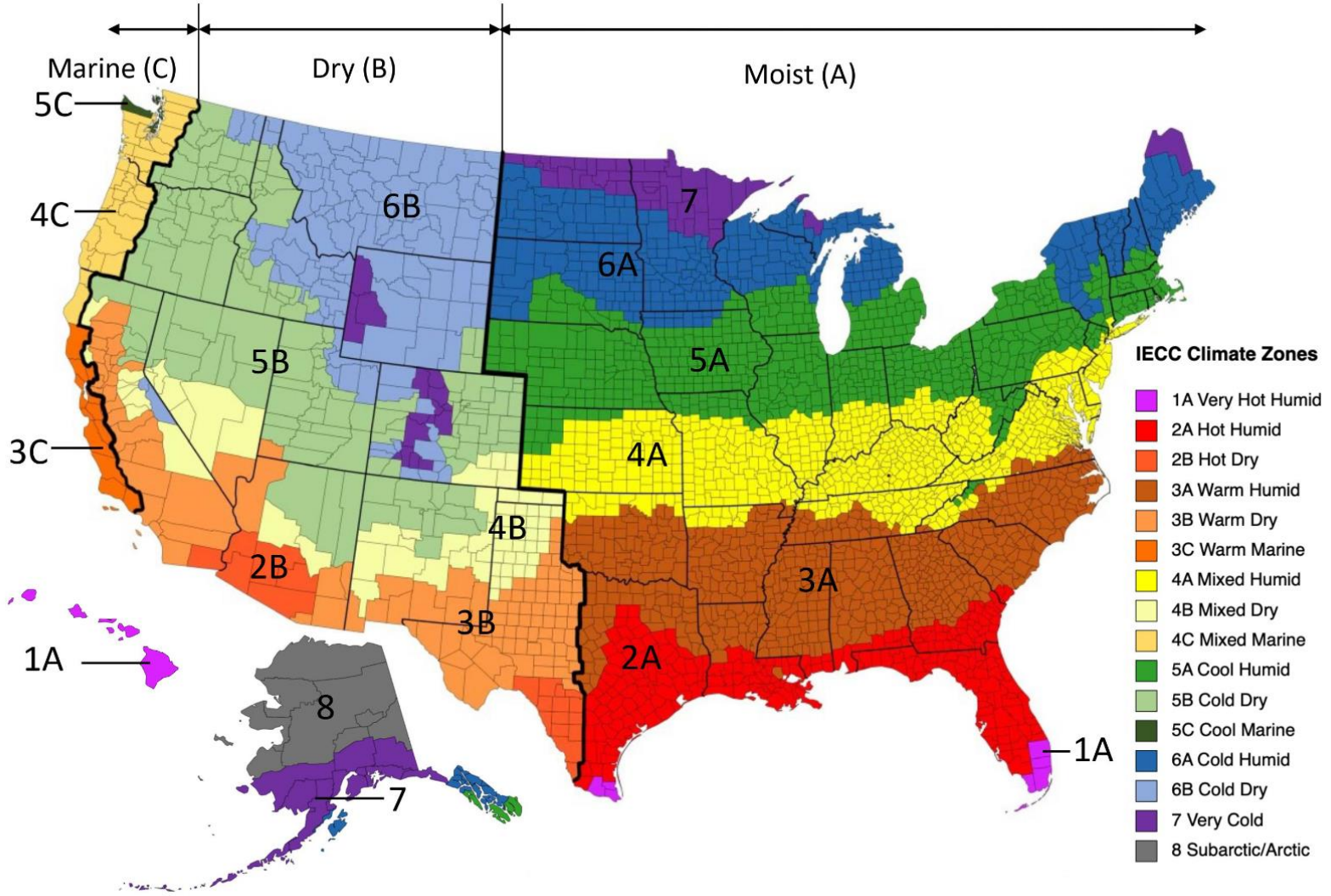
Mechanical discussion for hot regions
- Radiant cooling benefits in a dry climate.
- ERV summer humidity issues and how to solve them.

Learning Objective #4
- Lessons learned

Tucson, Arizona

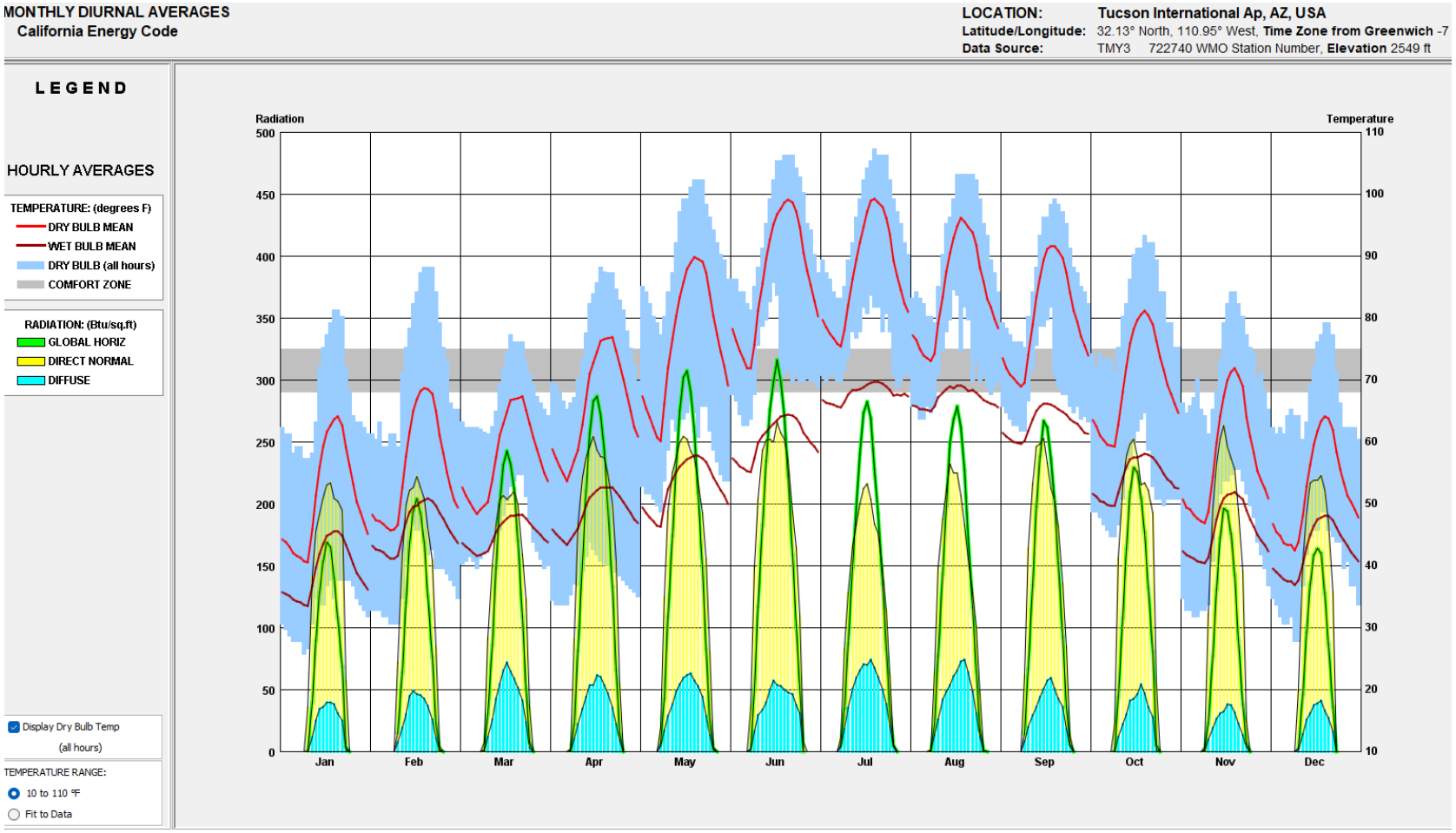
Tucson Climate

32°N, 110°W
Heating degree days – 1,850
Cooling degree days – 3,500;
Percent of possible sunshine 85%;



Tucson Climate

Days with min Temp below freezing 17
Days with Max Temp 90°F or higher – 143
Average annual relative humidity 43.5
Climate Zone 2B



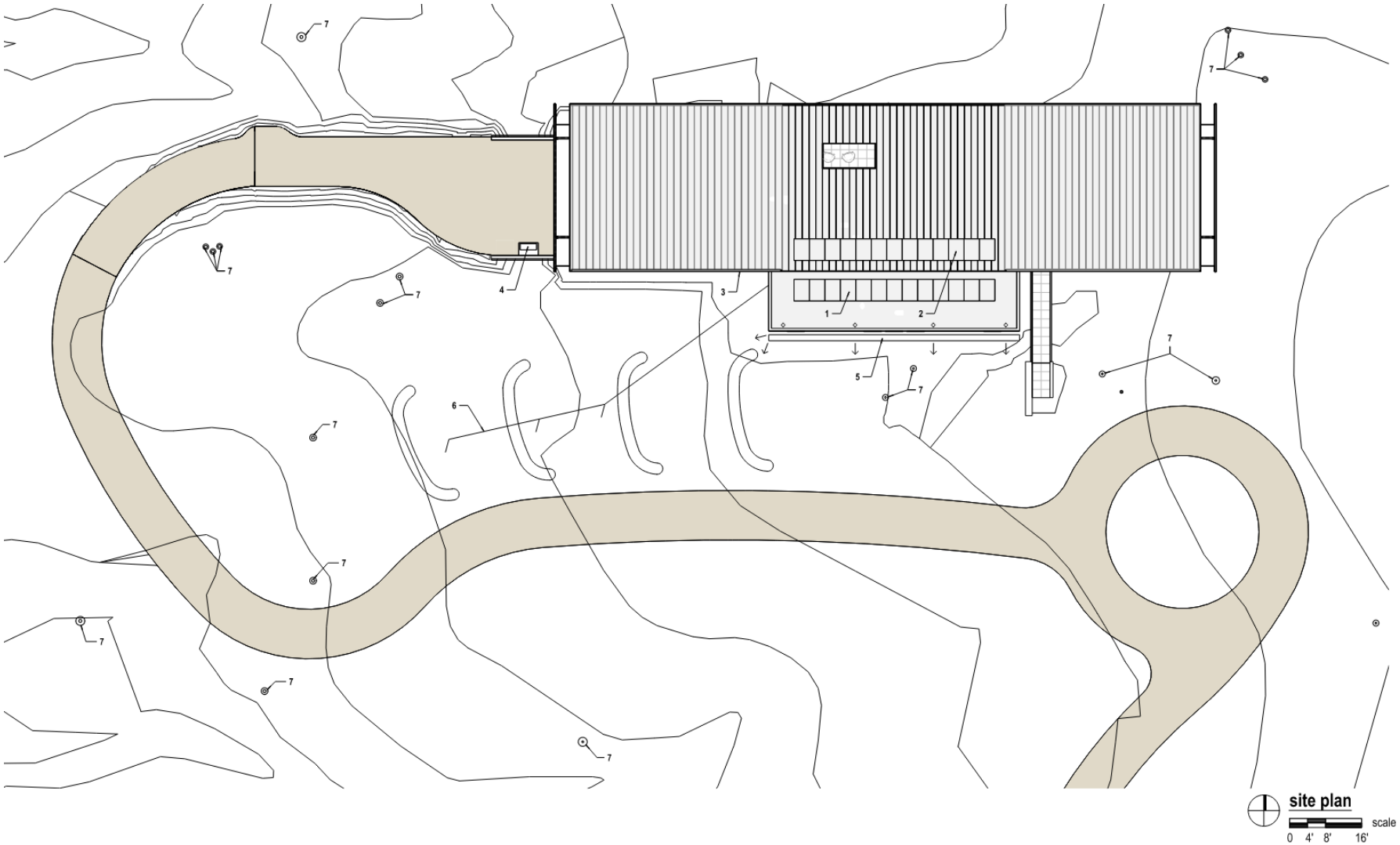
Goals

- To design a minimalist, serene environment
- To create a piece of architecture that evokes the spirit of the place
- To connect to the natural landscape and views
- To optimize a Passive House Principles for the Sonoran Desert's harsh environment
- Preservation of the natural landscape

Site Selection

- Must be wide enough in east-west direction to stretch out building to minimize west facing afternoon sun
- No Home Owner's Associations
  - To ensure that design is not getting dictated by another entity
- No visible telephone lines
- Preferably views to the north
  - Best orientation for glass in this climate
- Disturb as little as possible of native landscape
  - Site building between existing saguaros and mesquite trees
  - Keep construction area tight to structure

Site and orientation



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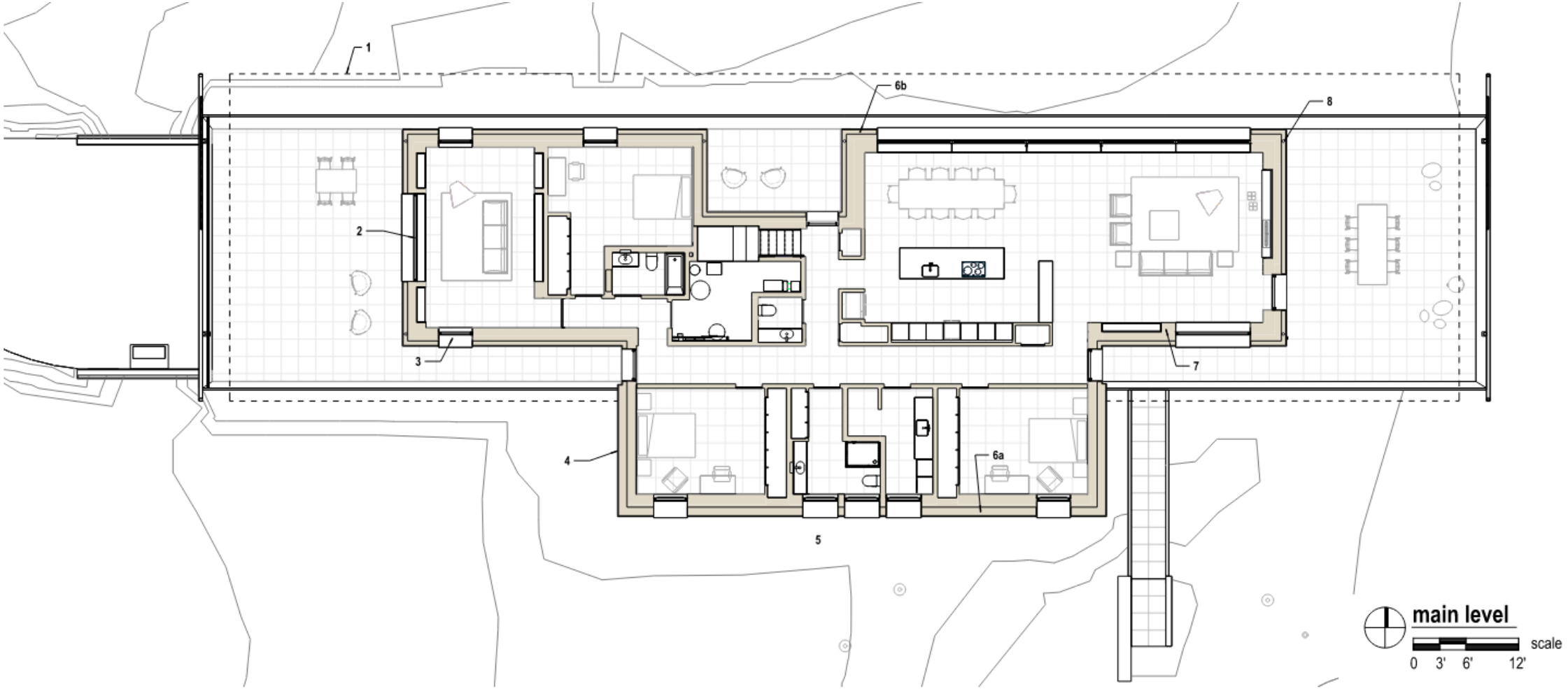

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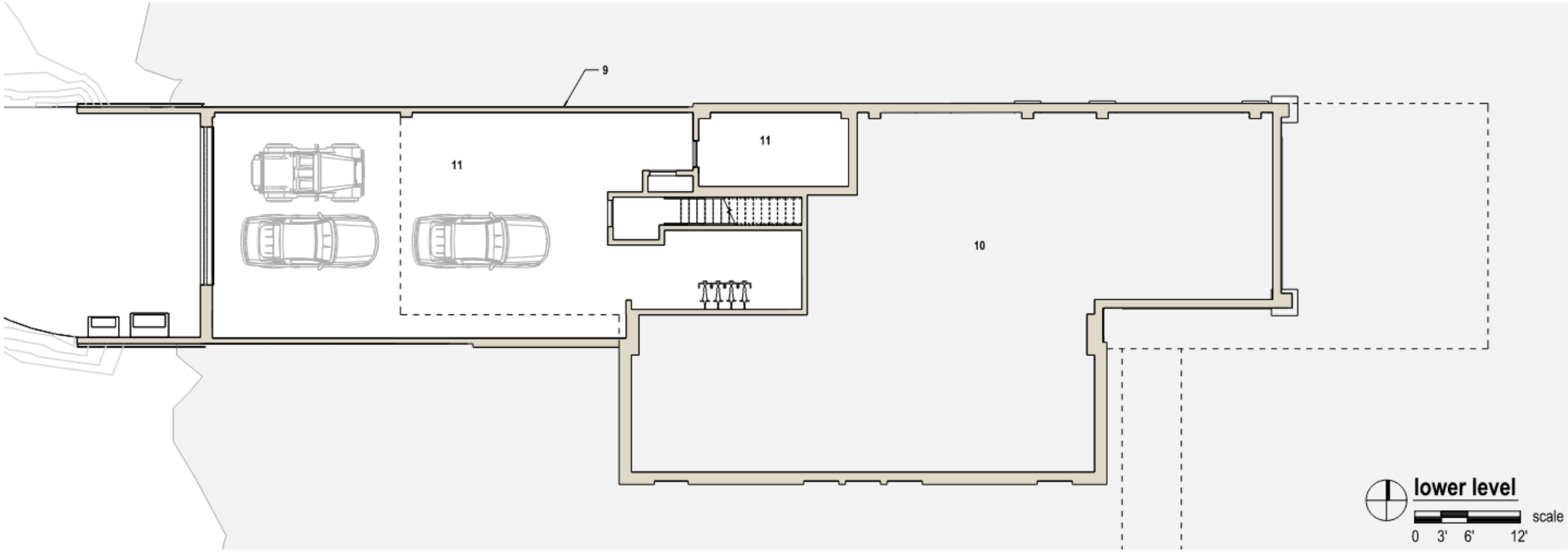


Envelope: Air tight

Zip system with zip tape

Envelope: Air tight

Zip system with zip tape

Envelope: Air tight

Zip system with zip tape

Sealing between base and sheathing

Envelope: Air tight

Zip system with zip tape

Sealing between base and sheathing

Envelope: Air tight

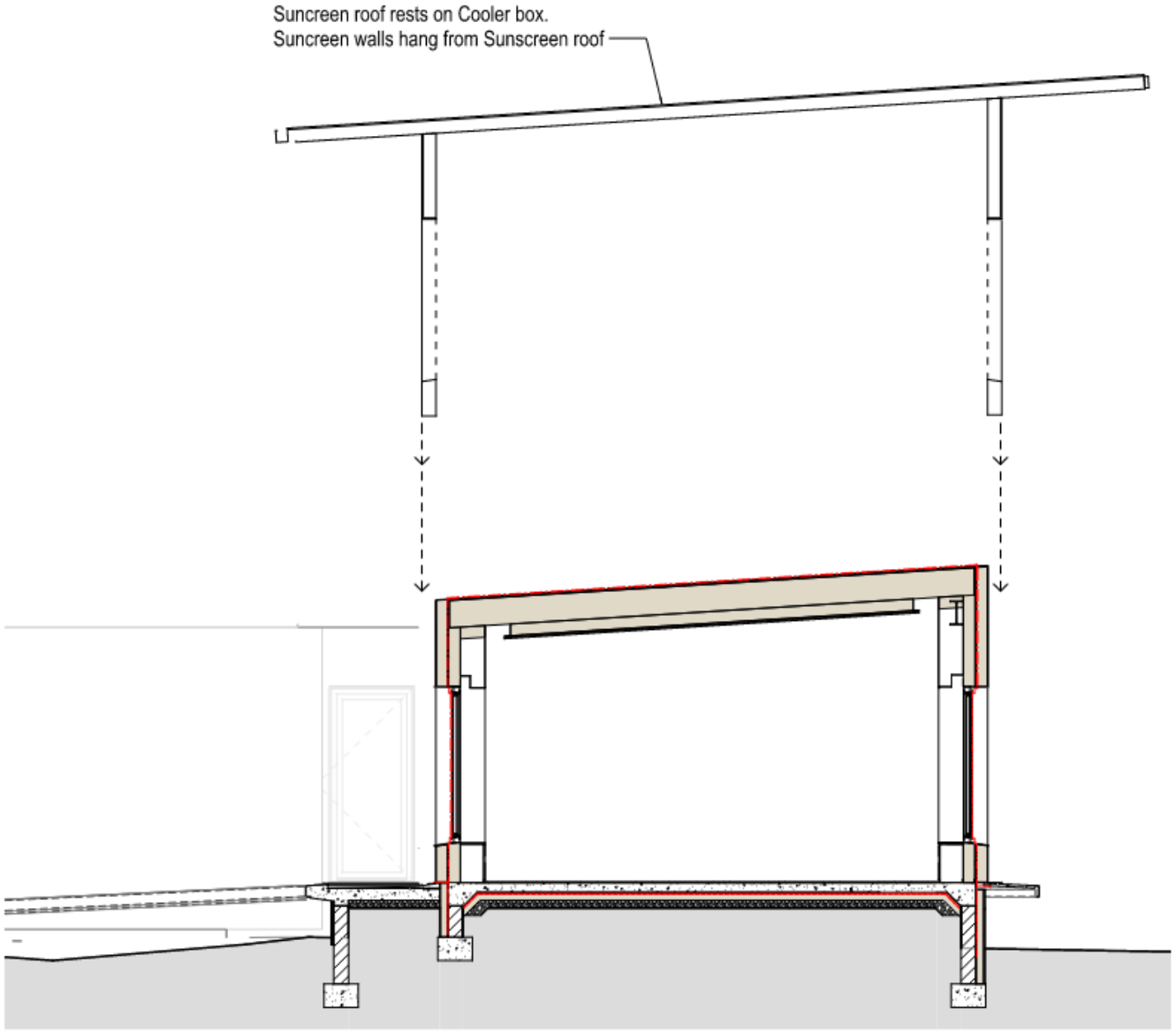
Zip system with zip tape

Sealing at windows

Envelope: Insulated box

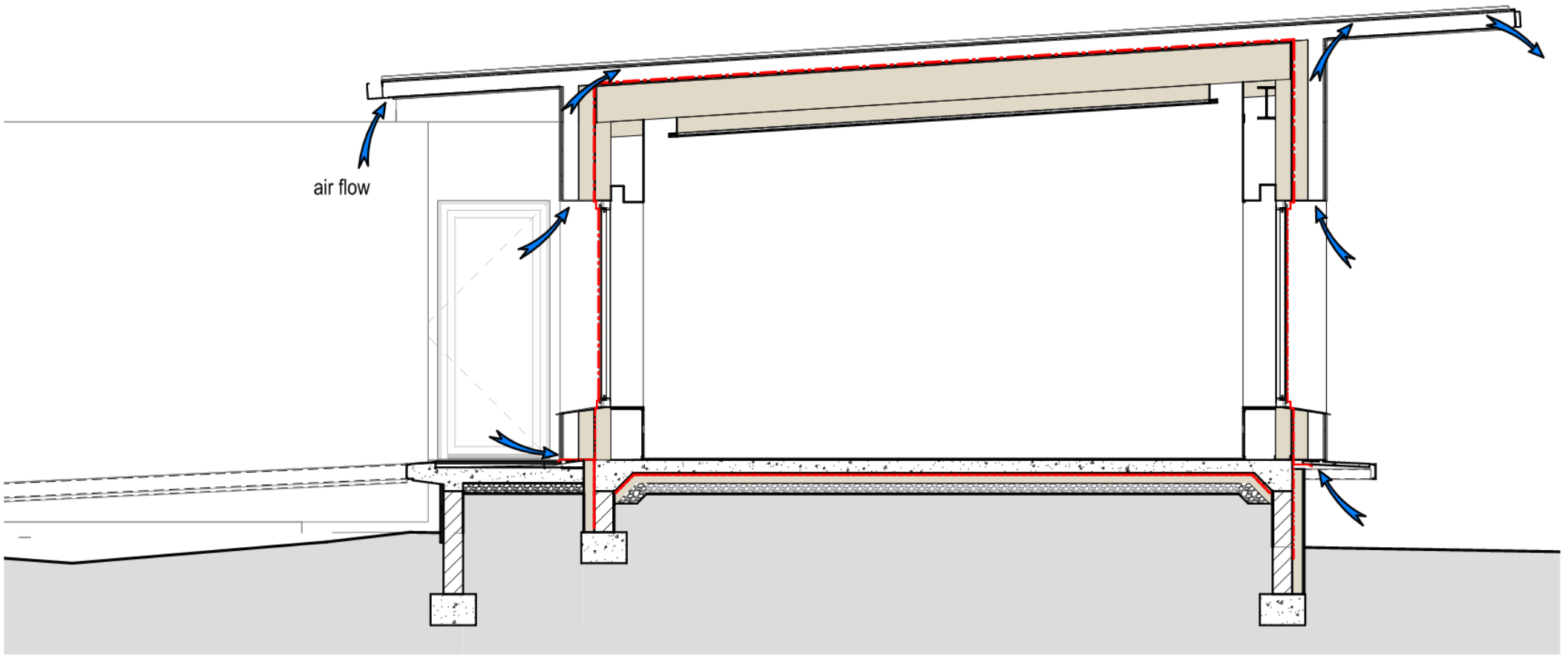
Zip system with zip tape

Sealing between base and sheathing



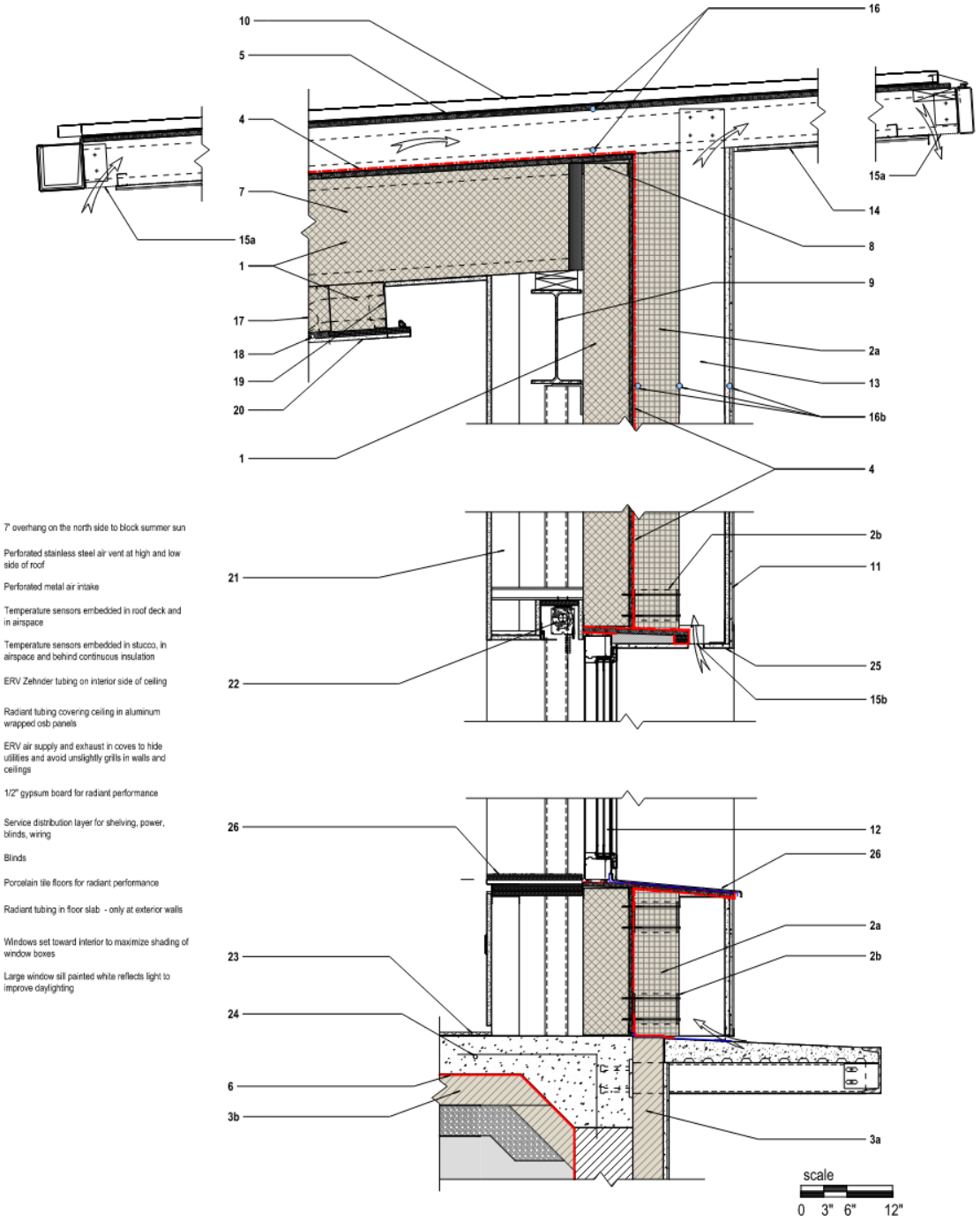
Insulated Box
THE COOLER

Envelope: Sunscreen Wall System



SunScreen Walls
THE UMBRELLA

Envelope: Sunscreen Wall System



Wall Section Notes

1 6" Mineral wool batts

2a 6" continuous mineral wool board - 2 layers staggered 3" thick

2b Cascadia clip 6" - used to connect suncreeen wall stud to structural stud and prevent thermal bridge

3a 4" EPS foam foundation insulation extends down 4' below grade

3b 4" EPS foam slab insulation with termite resistant polystyrene

4 Zip board fully taped air and weather resistant barrier

5 Plywood with waterproof membrane

6 Termite shield vapor barrier

7 14" TJI roof support with metal stud framing below for cove support

8 Typical walls - metal stud structural framing. Metal studs chosen for termite resistance and recycling ability

9 Steel beam header only at large expanse of living room windows

10 Metal roof painted white for durability and rainwater harvesting

11 Synthetic stucco on 5/8" glass mat exterior gypsum sheathing

12 Triple glazed Zola aluminum clad wood windows

13 Sunscreen wall - ventilated air space. 6" air space under main roof, 1' airspace on south bedroom wing

14 7' overhang on the north side to block summer sun

15a Perforated stainless steel air vent at high and low side of roof

15b Perforated metal air intake

16a Temperature sensors embedded in roof deck and in airspace

16b Temperature sensors embedded in stucco, in airspace and behind continuous insulation

17 ERV Zehnder tubing on interior side of ceiling

18 Radiant tubing covering ceiling in aluminum wrapped osb panels

19 ERV air supply and exhaust in coves to hide utilities and avoid unslightly grills in walls and ceilings

20 1/2" gypsum board for radiant performance

21 Service distribution layer for shelving, power, blinds, wiring

22 Blinds

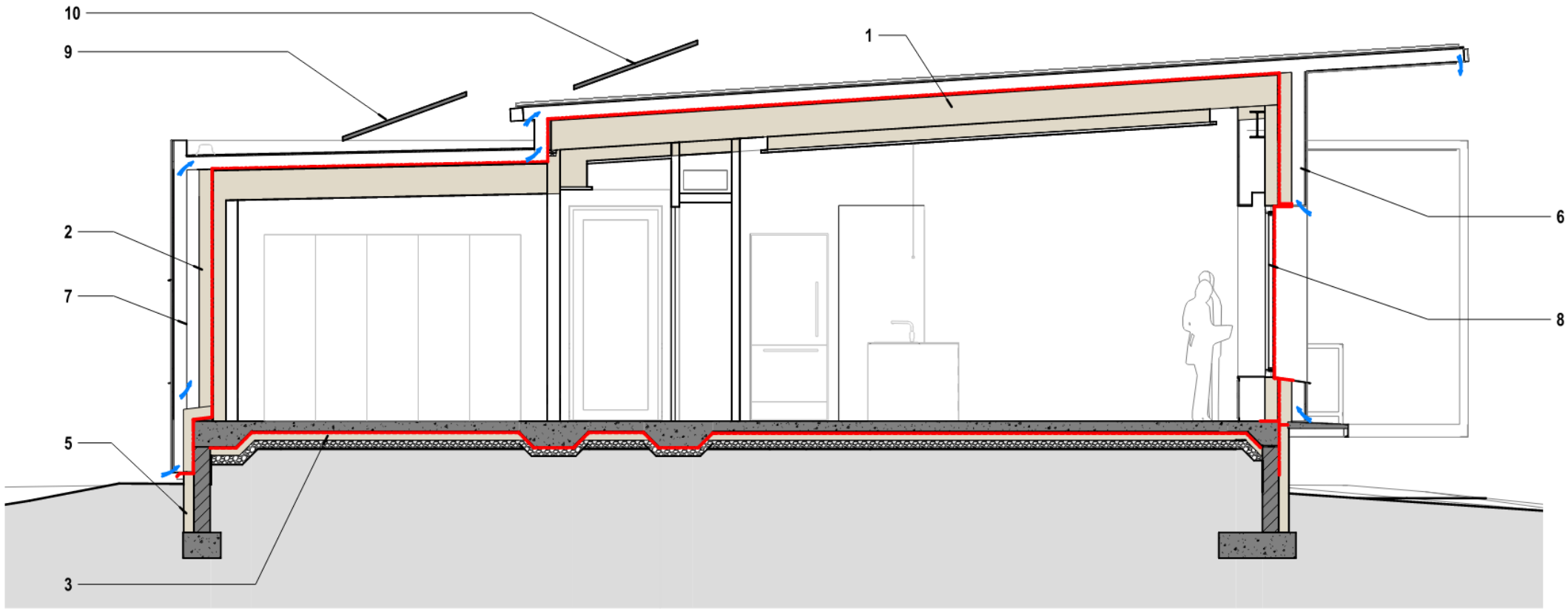
23 Porcelain tile floors for radiant performance

24 Radiant tubing in floor slab - only at exterior walls

25 Windows set toward interior to maximize shading of window boxes

26 Large window sill painted white reflects light to improve daylighting

Envelope: Sunscreen Wall System



Envelope: Sunscreen Wall System

Building Section Notes

1 Roof with mineral wool insulation R-83

2 Walls with mineral wool insulation R-38

3 Underslab insulation R-9

4 6" mineral wool batt insulation

5 Foundation insulation

6 6" air space, typ

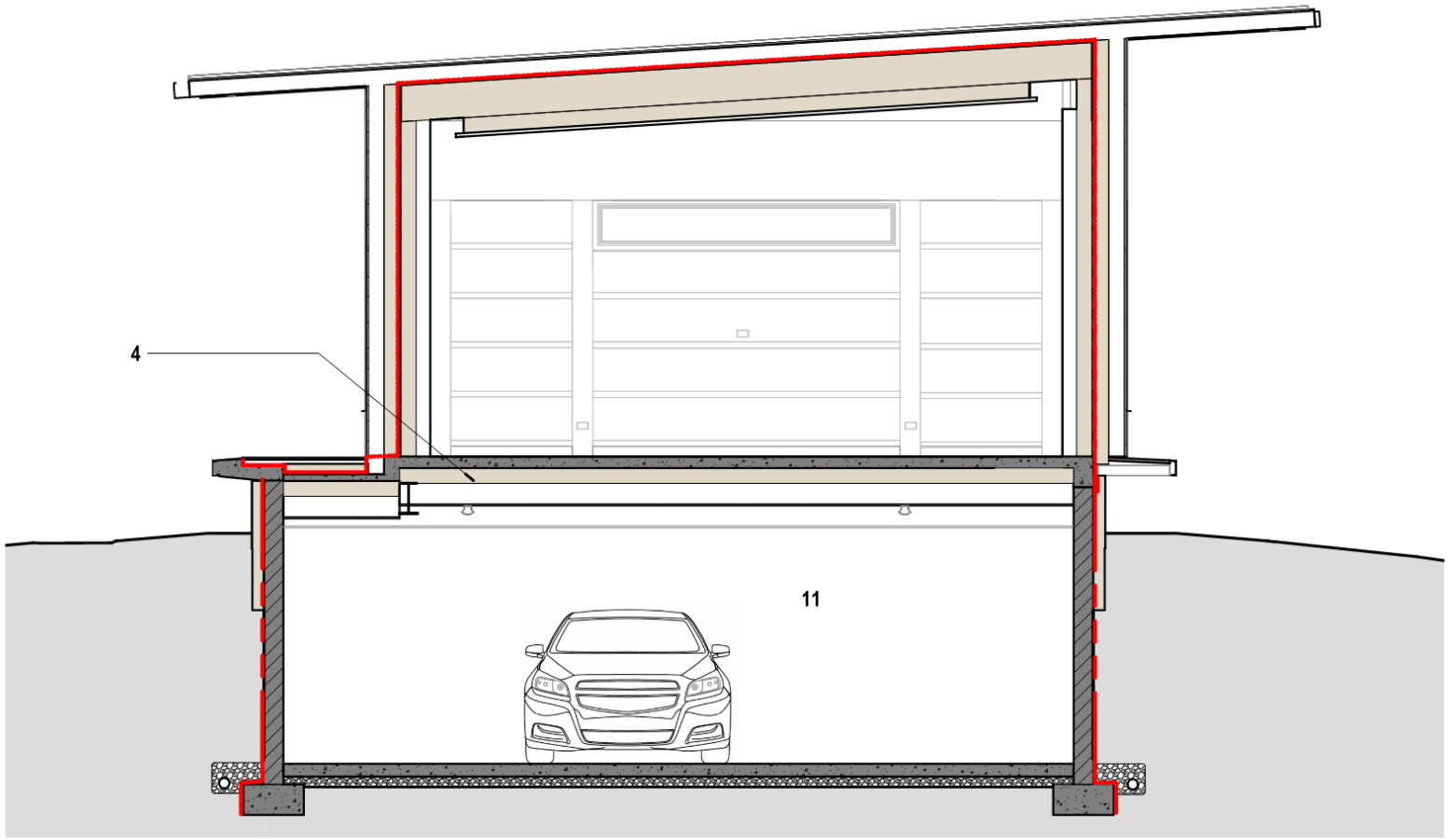
7 12" air space

8 Triple glazed windows

9 Original photovoltaic panels

10 Photovoltaic panels added in 2022

11 Unconditioned space



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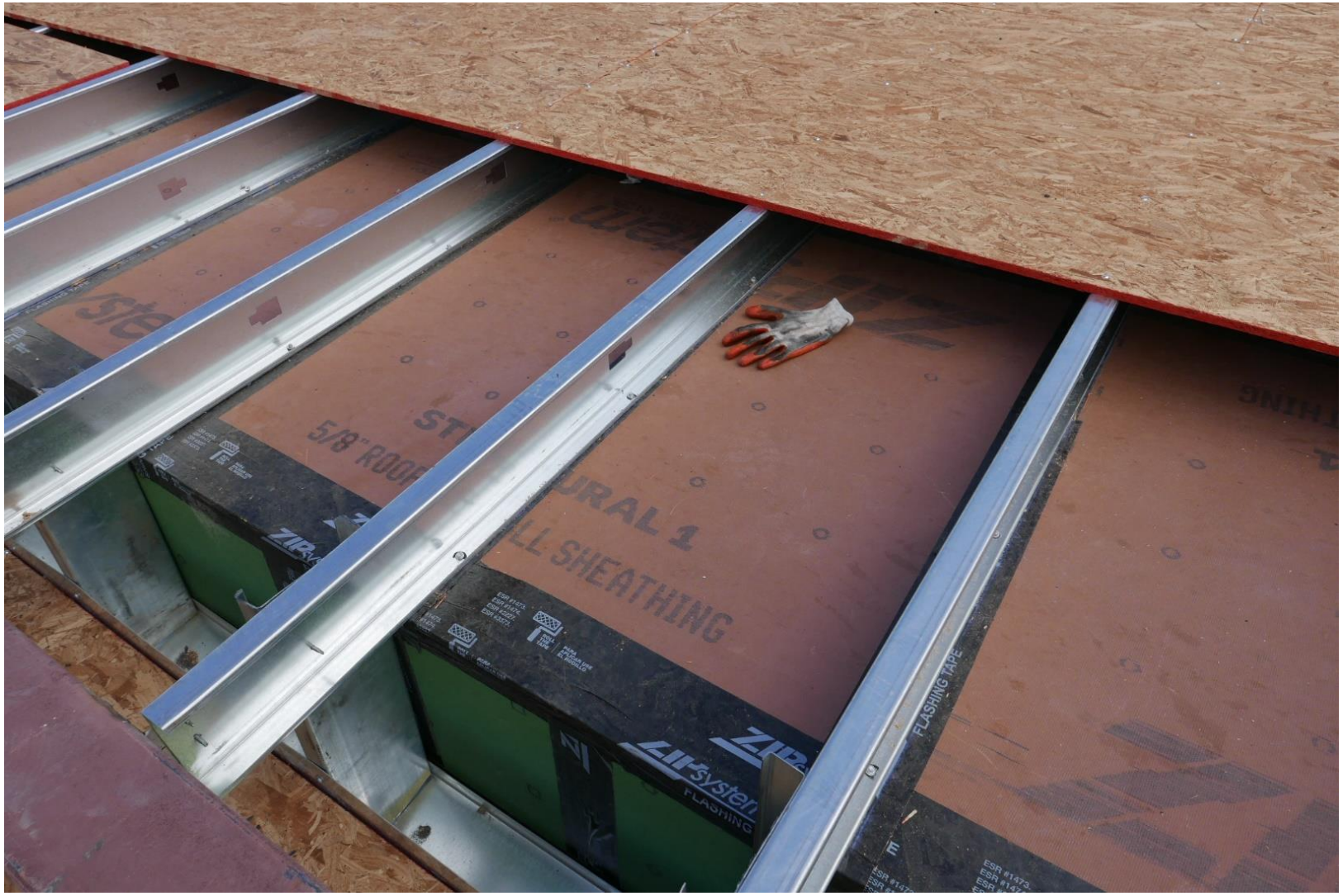

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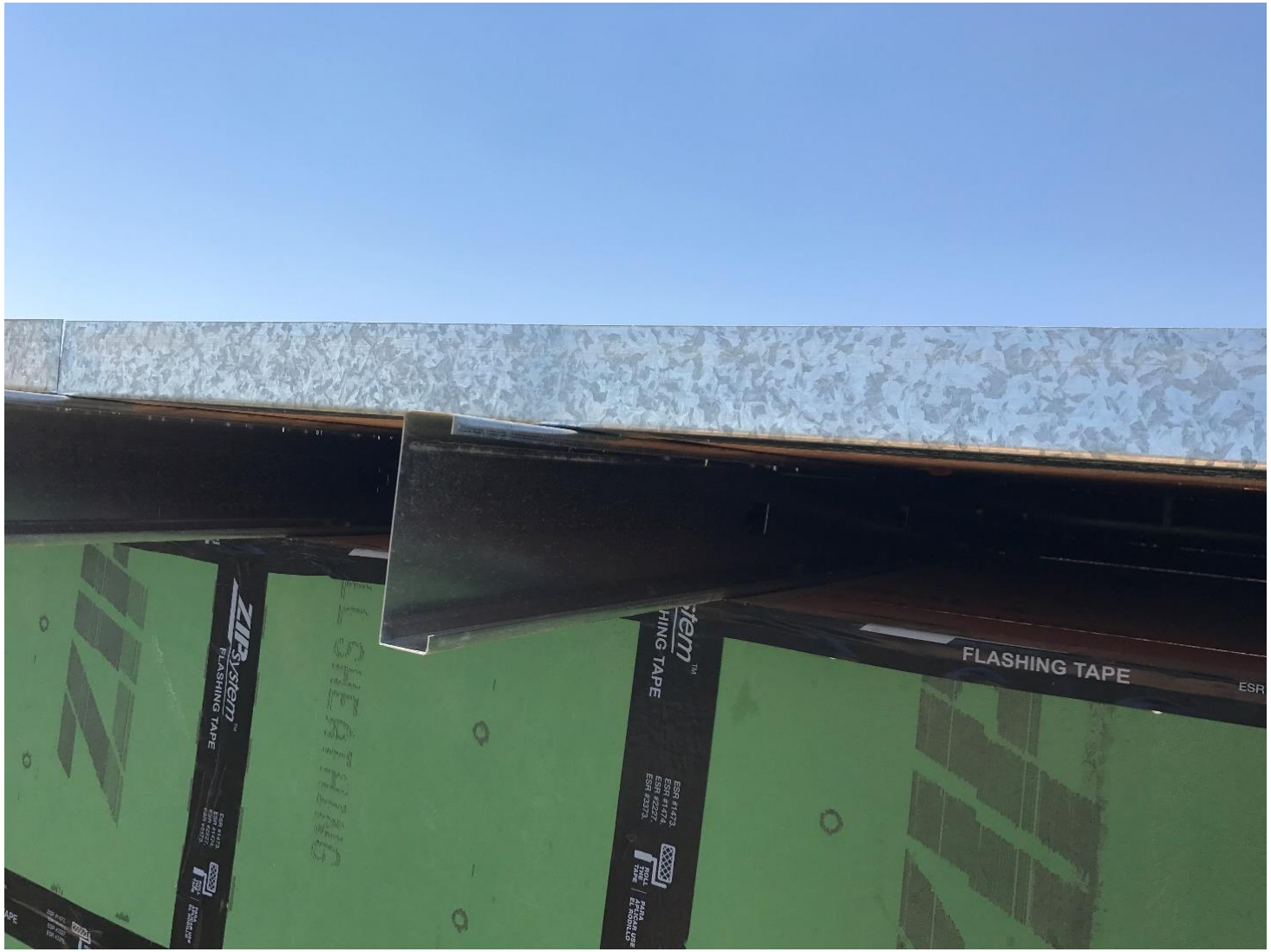

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July 8, 6:20 am, 73°F on
the way to 100°F

Envelope: Sunscreen Wall System

July 8, 6:25 am, 73°F on the way to 100°F

Envelope: Sunscreen Wall System

August 4, 12:51 pm, 103°F, sun angle - about 75°

Envelope: Thermal Bridge Free Design

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Envelope: Insulation

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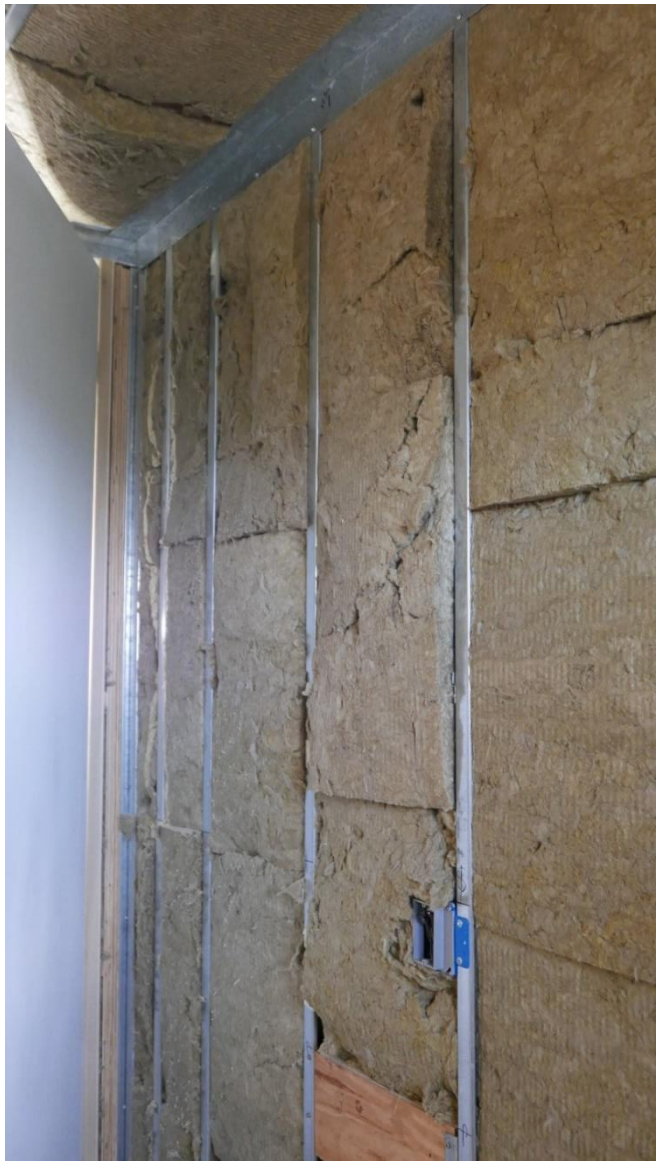
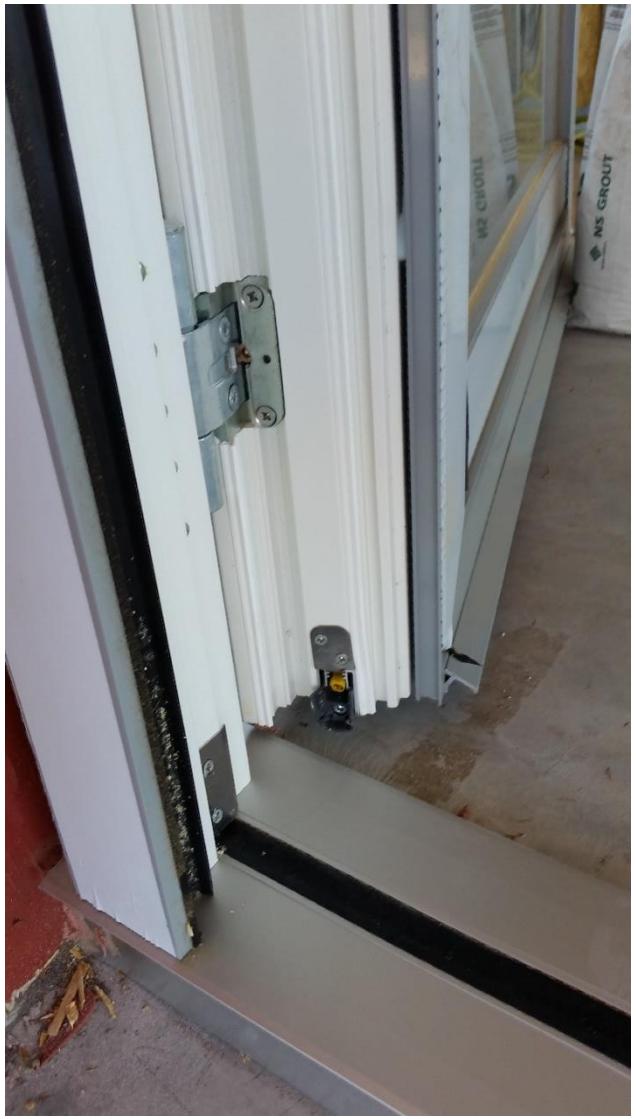
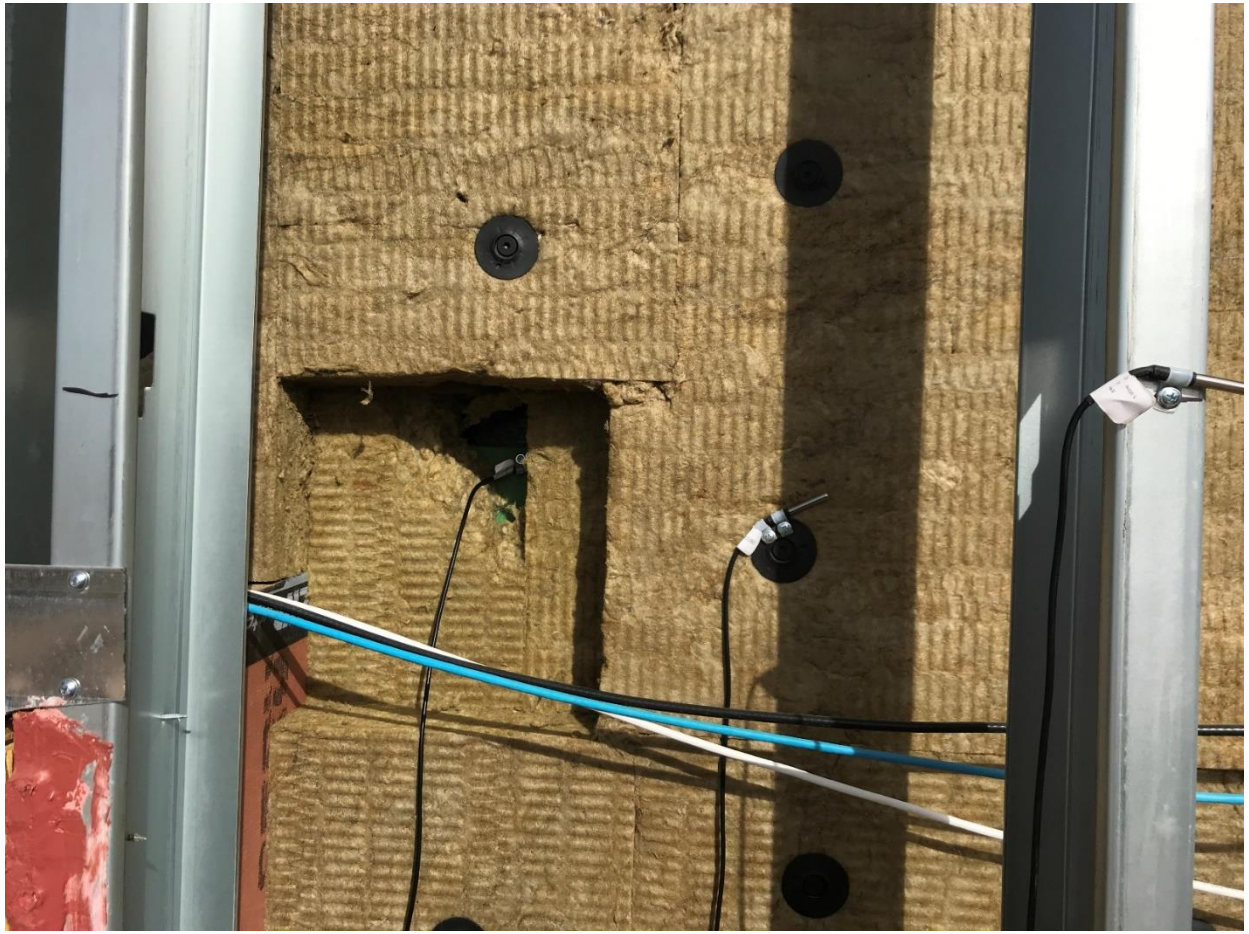
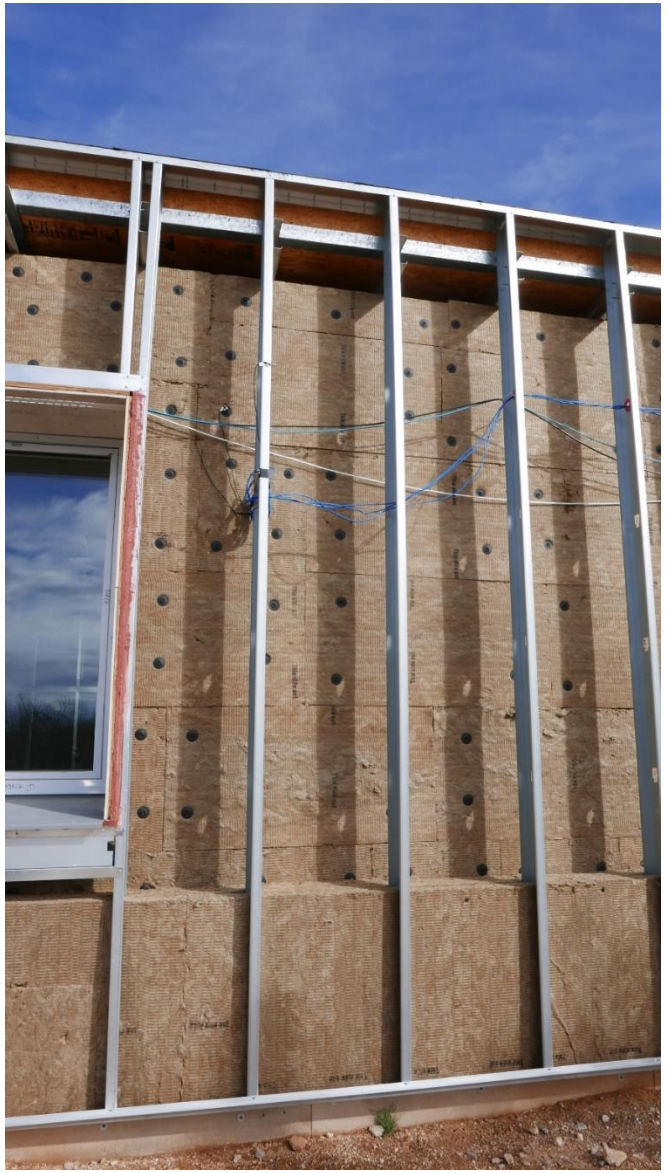


Envelope: Insulation



Envelope: Sensors





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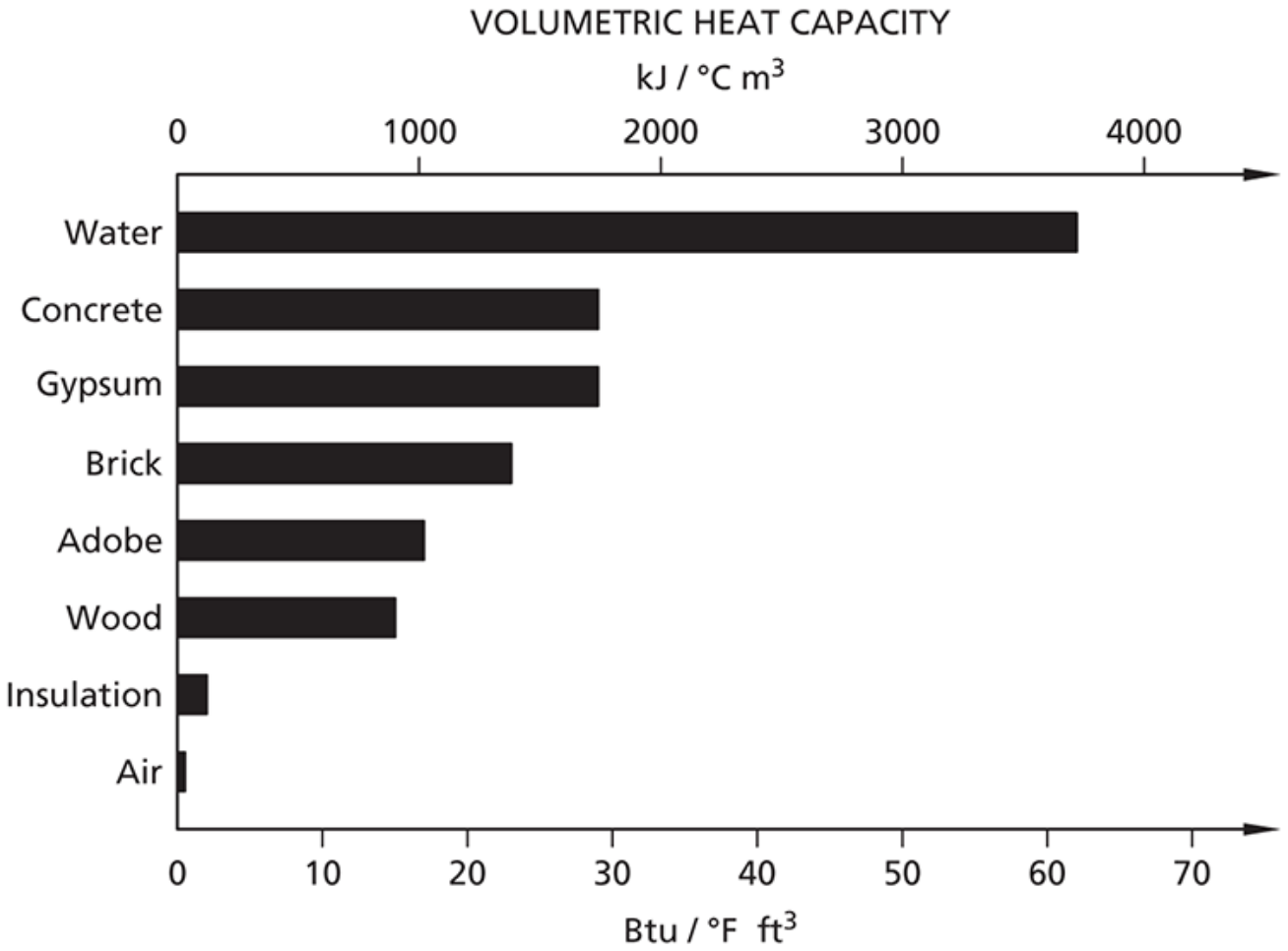
Mechanical Systems

Radiant Cooling and Heating



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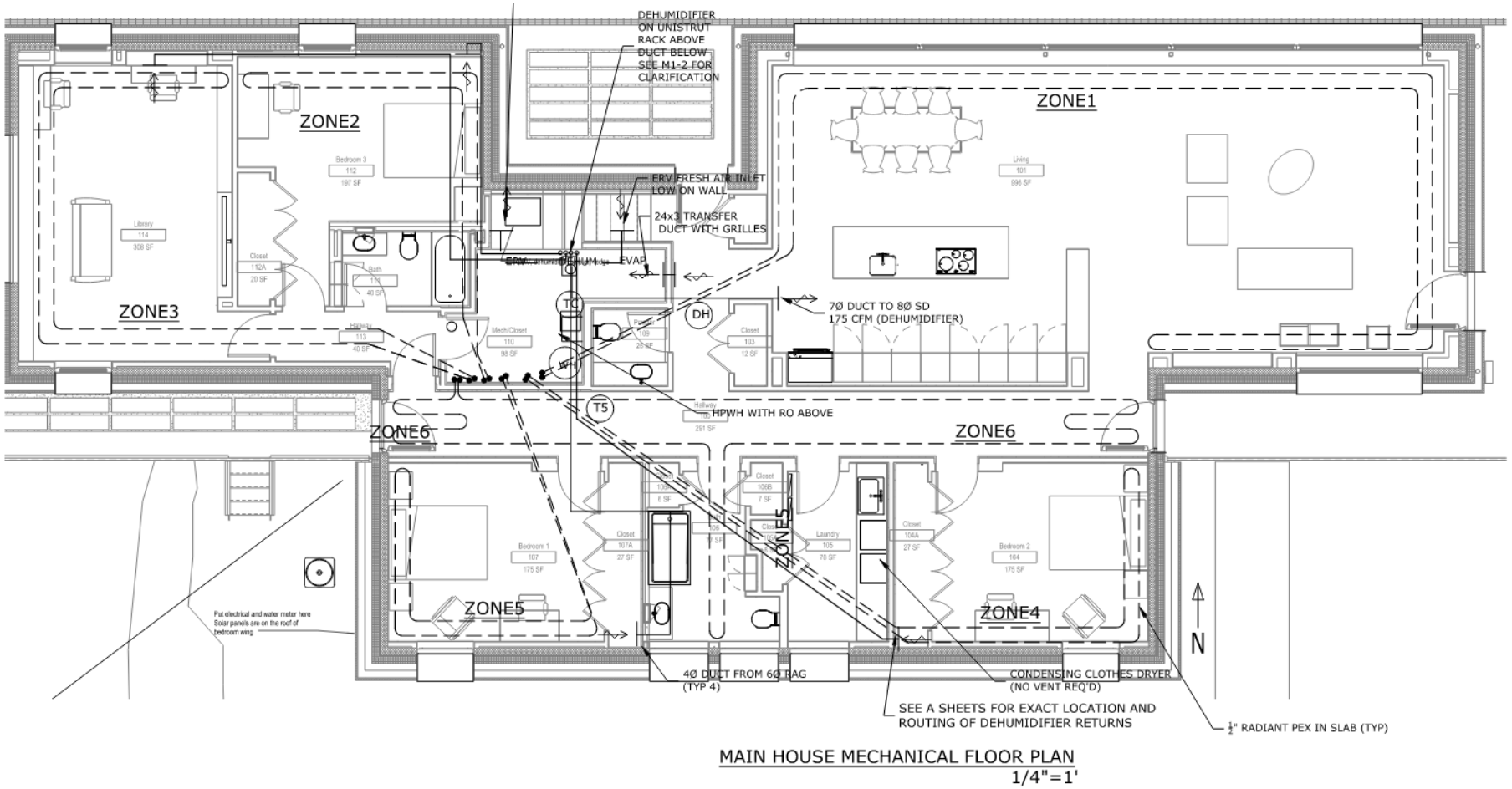
Radiant Cooling and Heating



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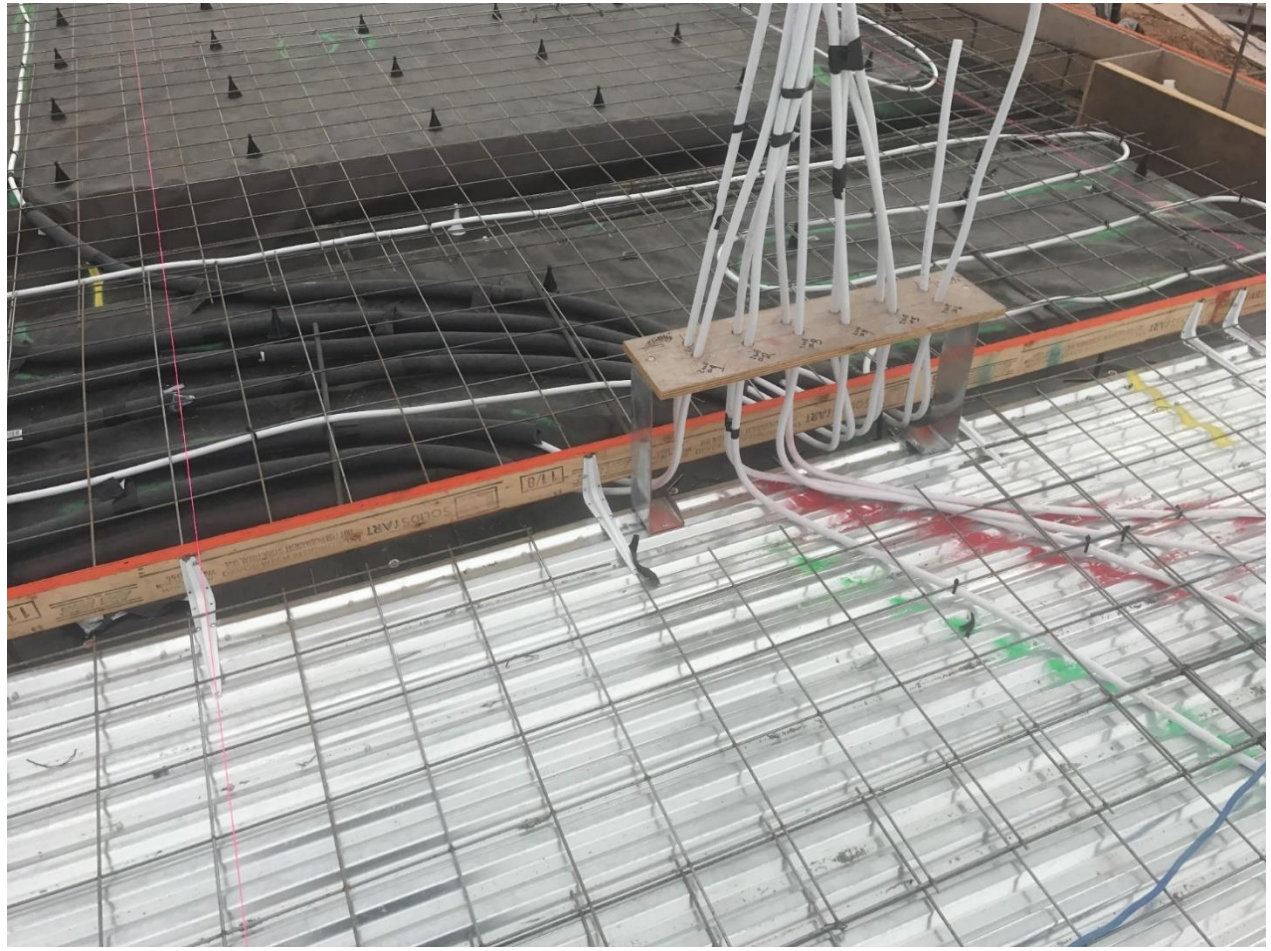

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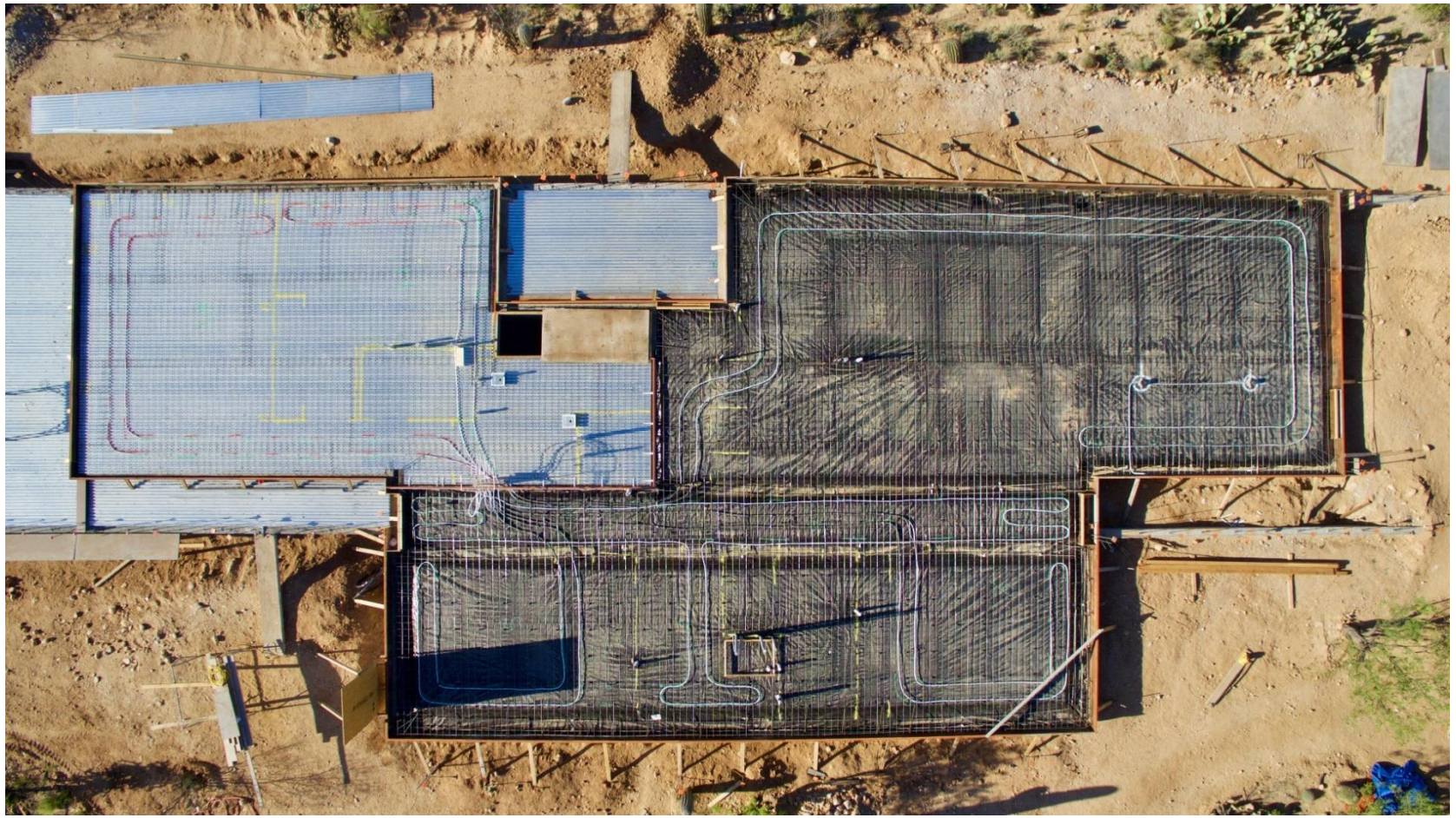

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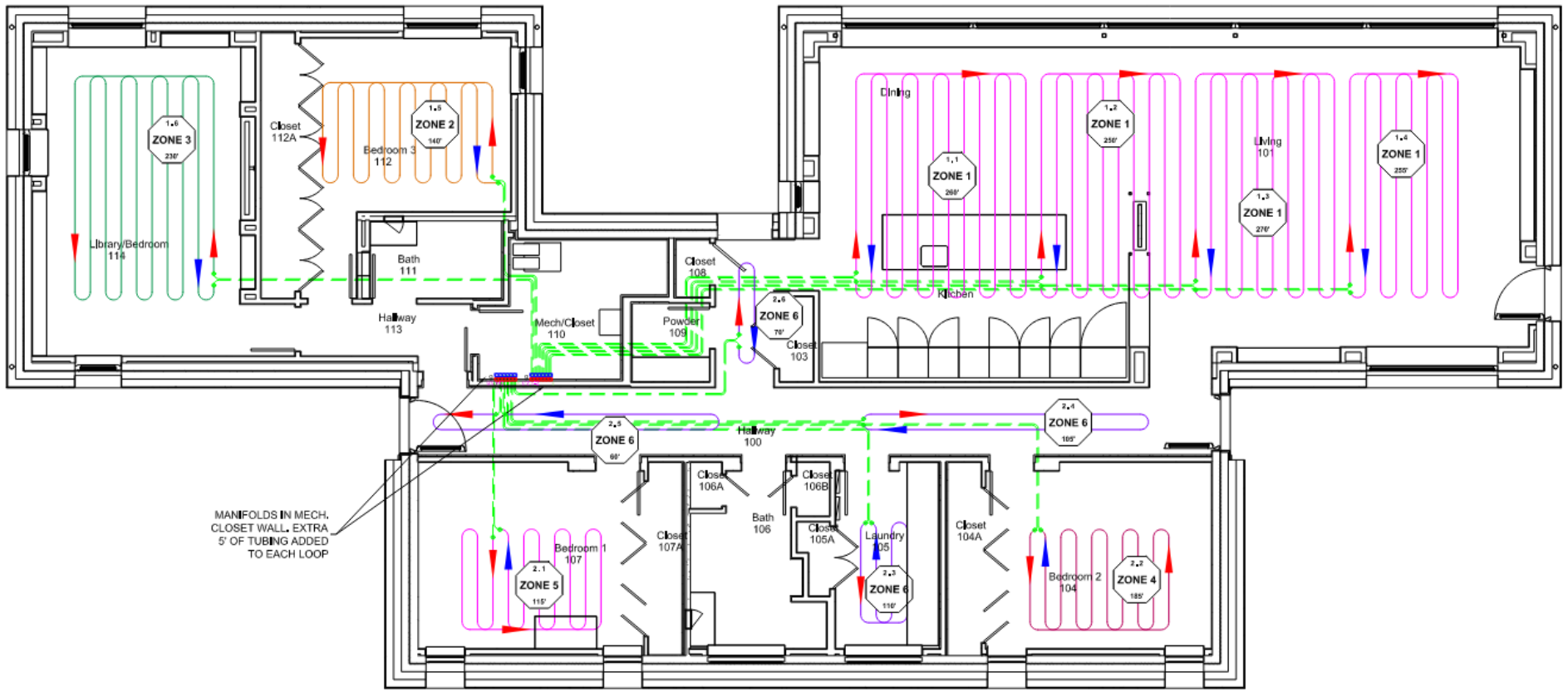

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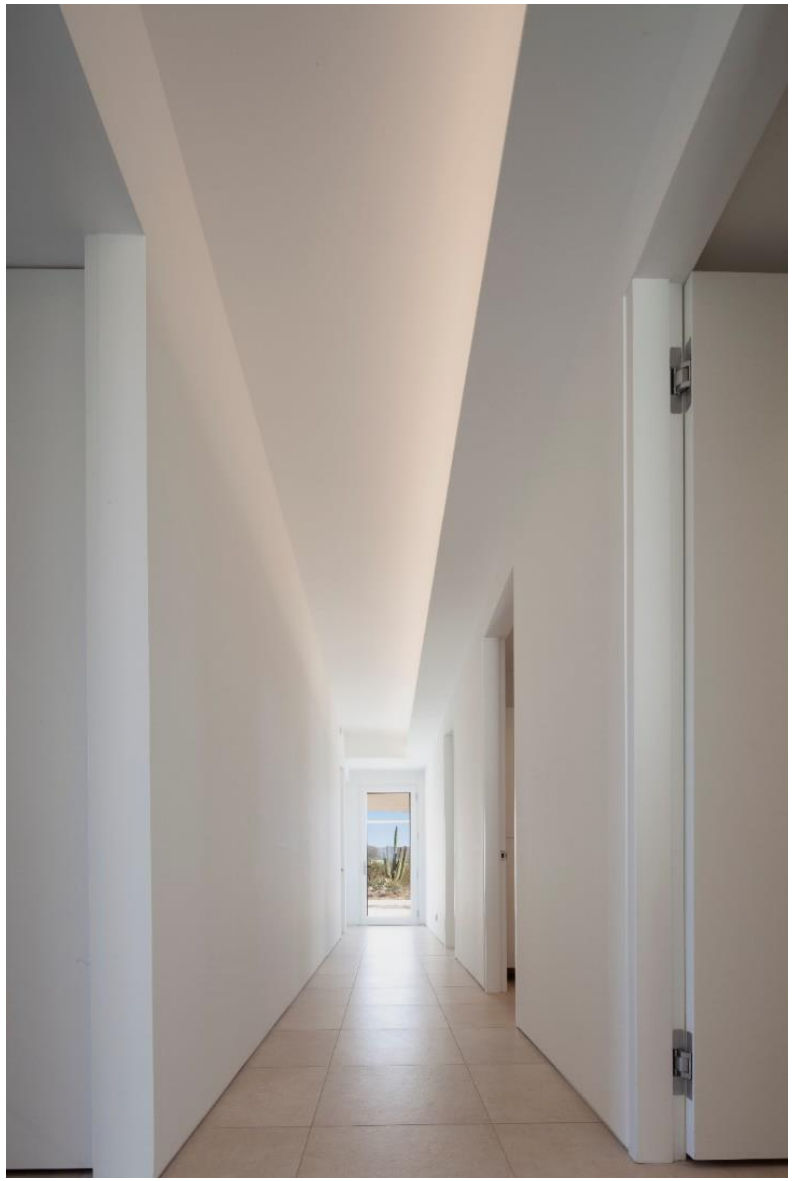
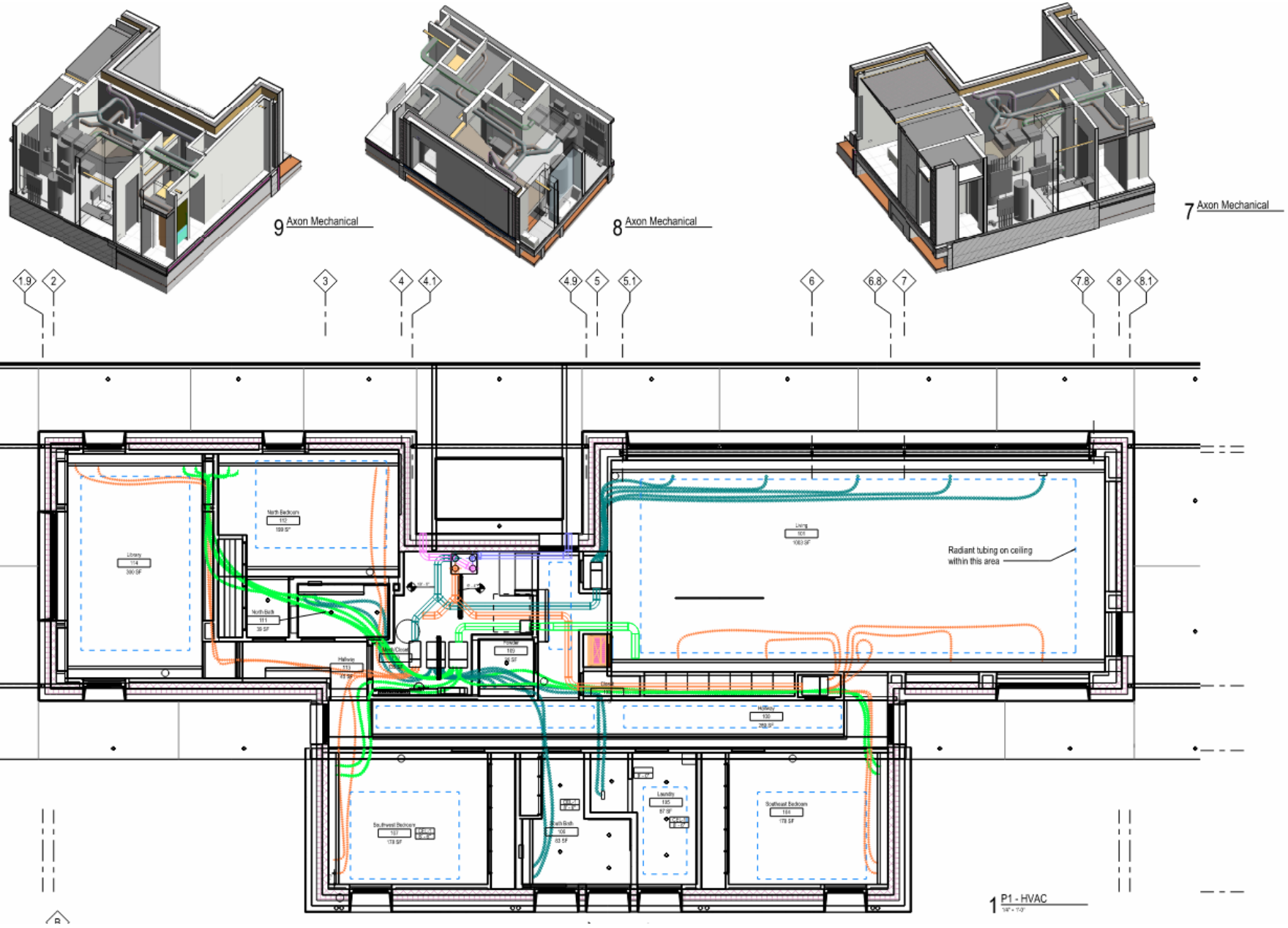


Mechanical Systems

Fresh Air System



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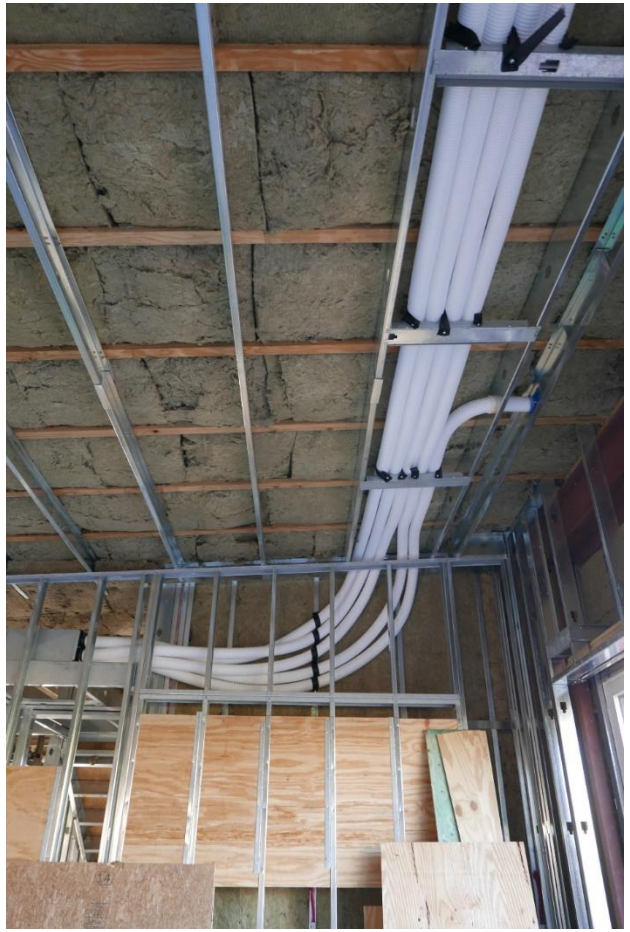

Mechanical Systems

Fresh Air System

Mechanical Systems

Fresh Air System

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Fresh Air System

Mechanical Systems

Dehumidification System

Mechanical Systems

Dehumidification System

Mechanical Systems

Domestic Hot Water System

Rainwater Harvesting

Rainwater Harvesting

Rainwater Harvesting

Electrical Systems

Solar

2022 - System expanded from 4.4 kW system to 10 kW system

Results

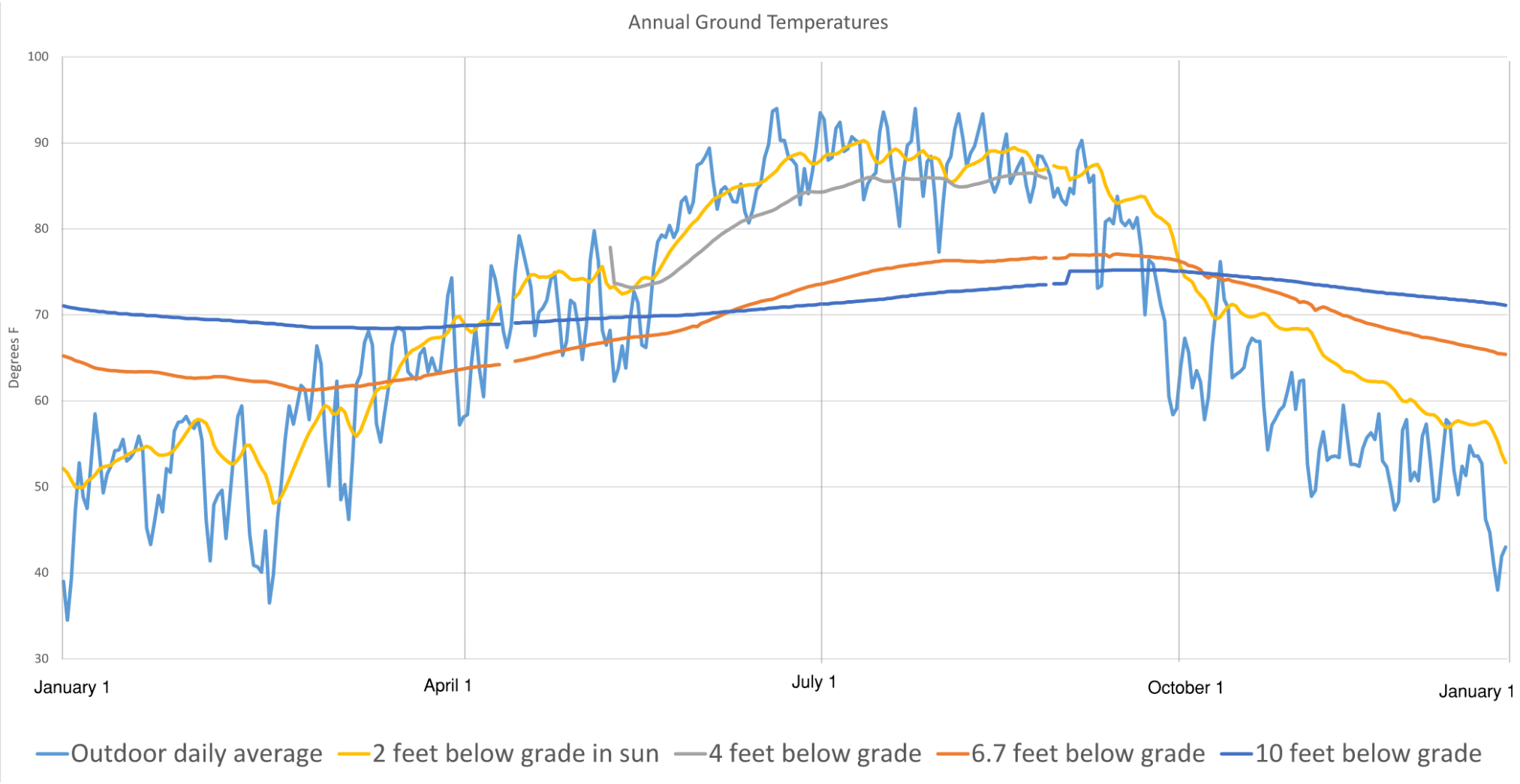
Building envelope and insulation concepts versus WUFI, versus monitored data

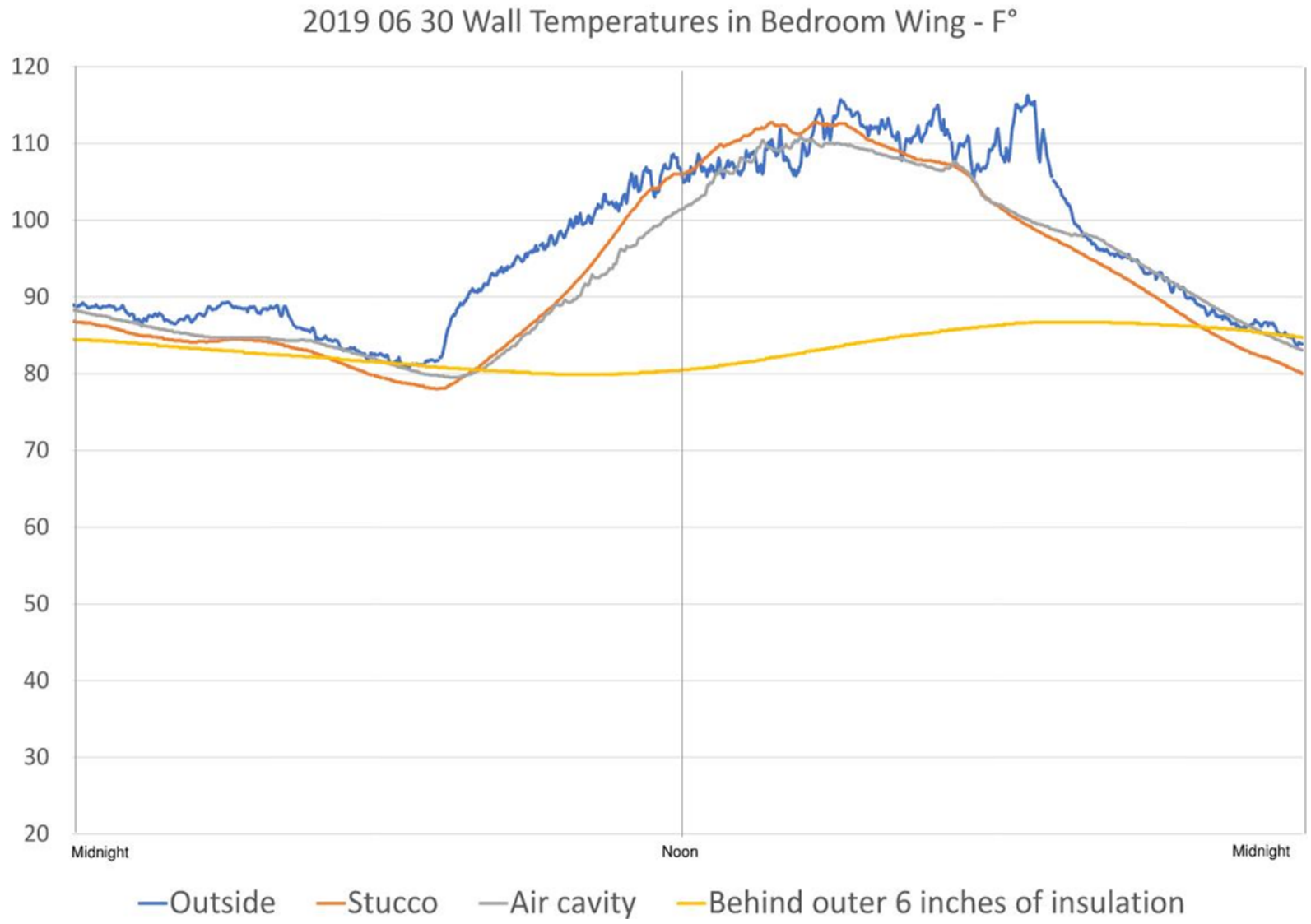
Shaded walls versus non-shaded walls measurements

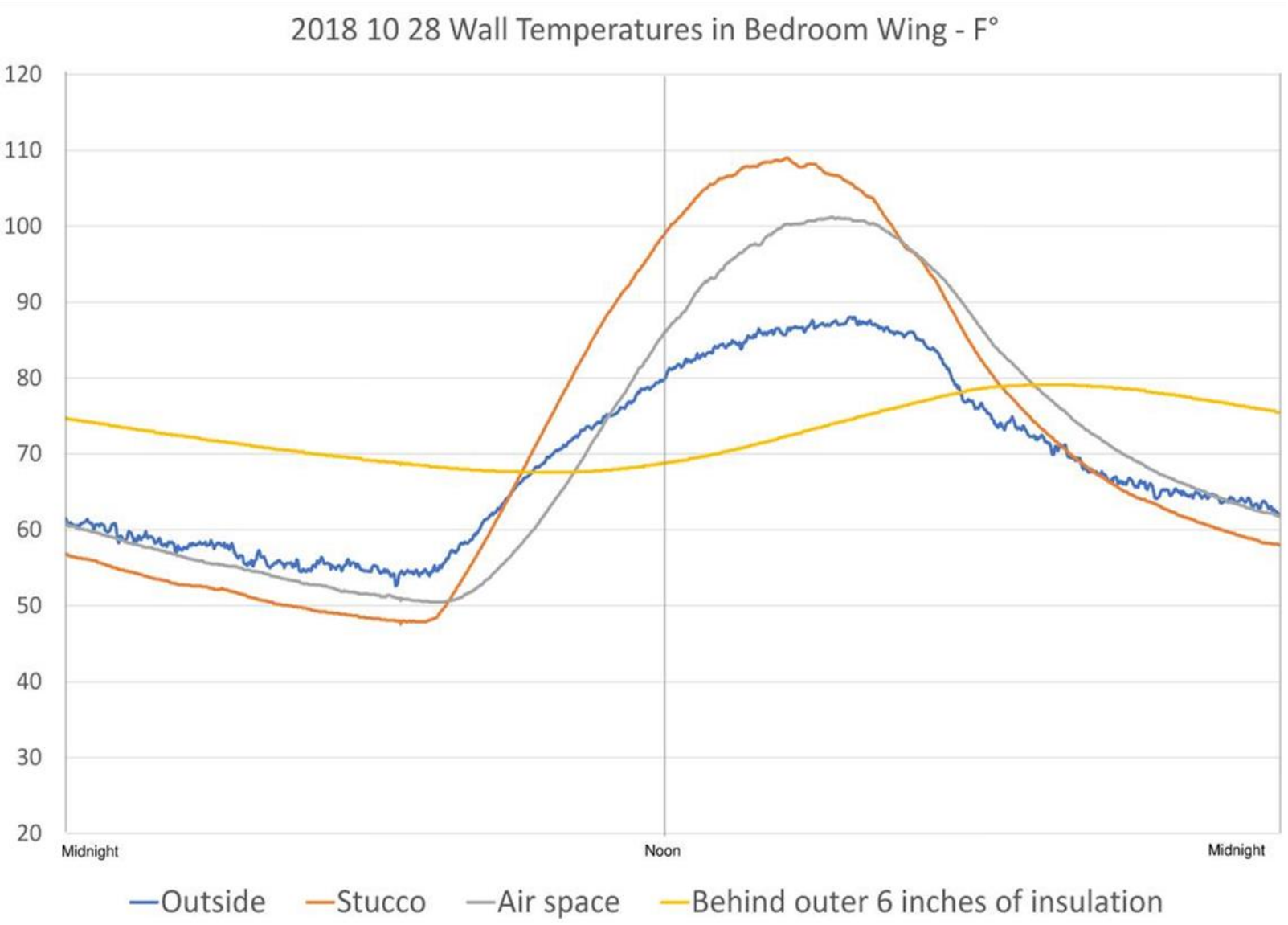
Mechanical system concepts versus measured performance

All circuits are individually monitored

Measured Ground Temperatures




2019 06 30 Wall Temperatures in Bedroom Wing - F°
120
110
100
90
80
70
60
50
40
30
20
Midnight
Noon
Midnight
Outside
Stucco
Air cavity
Behind outer 6 inches of insulation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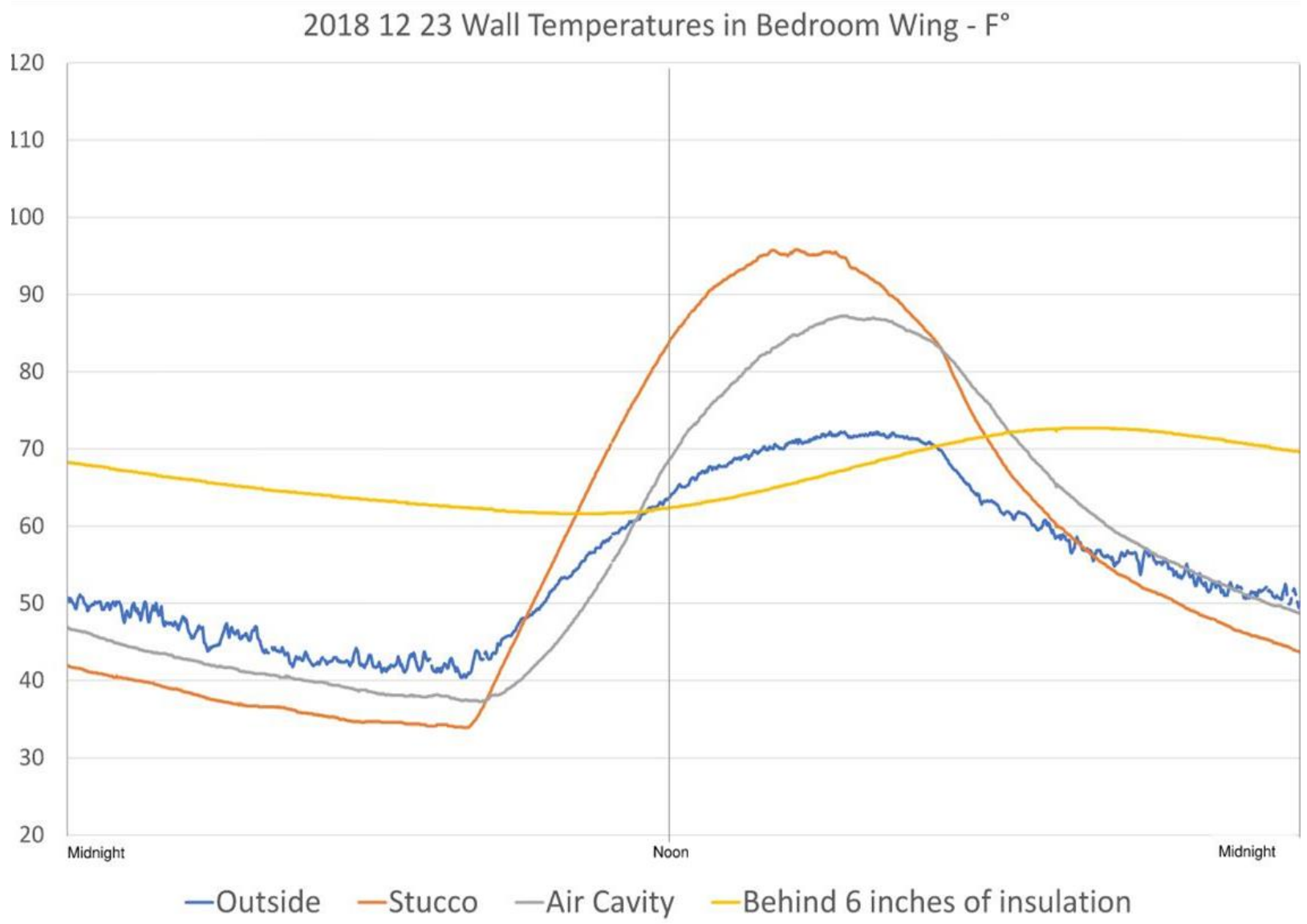
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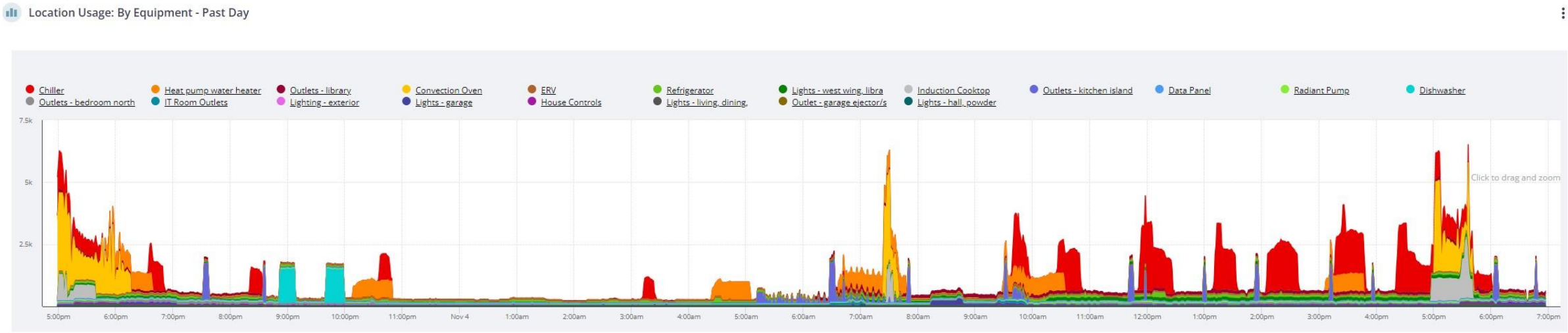
Electrical Systems

Solar



Electrical Systems

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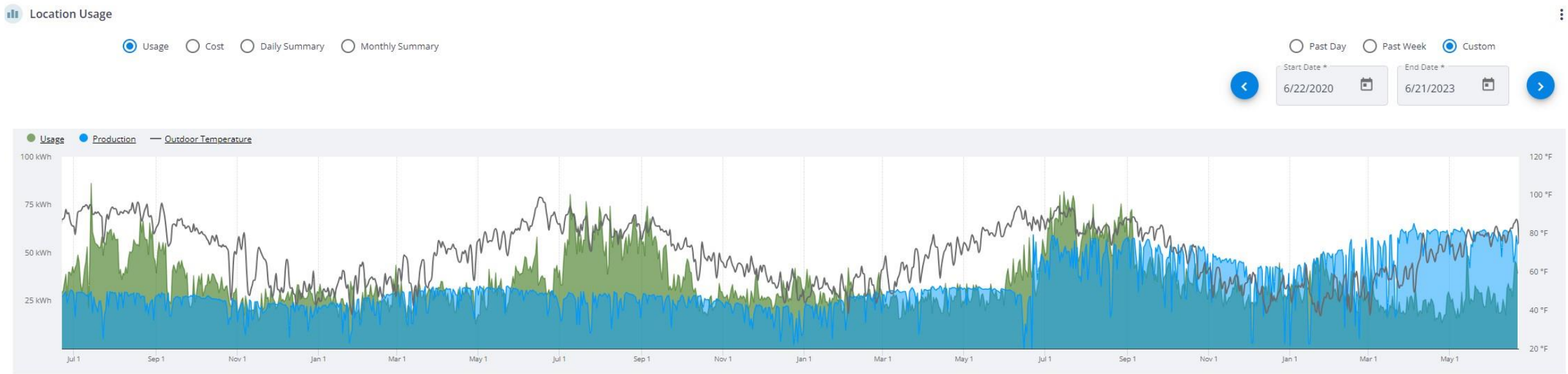

Measured versus Energy Models

	Phius + 2015						Phius Core 2021 Zero				Measured
	Target kBtu/ft2yr	Target kWh	WUFI kBtu/ft2yr	WUFI kWh/yr	WUFI kBtu/ft2yr Temp set to 74/75	WUFI kWh/yr Temp set to 74/75	Core 2021 Target kBtu/ft2yr	Core Target kWh/yr	Core 2021 kBtu/ft2yr	Core kWh/yr Temp set to 74/75	3 year average - Temp set 74 Heating 75 Cooling
Heating Demand	1.00	856.94	0.42	359.91	1.93	1,653.89	3.1	2,656.51	1.8	1,542.49	
Cooling Demand	11.30	9,683.42	8.89	7,618.19	9.62	8,243.76	15.4	13,196.87	9.6	8,226.62	
Total HVAC		**10,540.36**		**7,978.11**		**9,897.65**		**15,853.38**		**9,769.11**	**6,414.71**
Site Energy	**6,200 kWh/ person**	**24,800.00**		**10,932.00**		**11,188.00**	**5,500 kWh/ person**	**22,000.00**		**10,872.00**	**13,838.58**
WUFI Monthly Report										10,405.00	

Lessons Learned

With radiant system, internal dewpoint must be kept below 55°.

- Between mid-July and mid-September, the external dewpoint is often above 55°.
- Dehumidifier creates heat – noticeable if all of it is put into one room and running often
- PHIUS guidelines recommend that the ventilation system is capable of 0.3 ACH at least. 0.3 ACH brings in a lot of humidity
- Added coil from radiant tank to dehumidifier supply stream - brings dehumidified air down to 60°.

Add cooling coil from the radiant system to fresh air supply stream

- On hot dry days the ERV brings the temperature down from 112° outside to 78°.
- Added coil to ERV supply stream brings down fresh air to 60°.

Radiant system allows control

- Can add coils to ERV and dehumidifier
- Can adjust water temperature per season
- Adapts well to requirements of each zone during the day
- WUFI needs improvement for radiant systems

Conclusions:

- Cooling load is about 5 times heating load so decisions should be made that favor the cooling benefits.
- Dehumidification is critical even in the desert.
- Shading is important and will reduce amount of insulation required, but has a slight penalty in heating season.
- Slab insulation is beneficial.
- Sunscreen walls are beneficial and will reduce the max temperature that the insulation must overcome
- WUFI passive is accurate and can be trusted to get close to goals

Passive House Principles allow for comfort and connection with nature

- Even temperatures
- Less radiation to outside walls
- Radiant system is very comfortable - less blowing air