Sonoran Desert Passive House

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brubaker architects
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 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
Site and orientation
Site and orientation
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
Envelope: Sunscreen Wall System

SunScreen Walls
THE UMBRELLA
Envelope: Sunscreen Wall System

Wall Section Notes

1. 6" Mineral wool batts
2. 6" continuous mineral wool board - 2 layers (agreement 7" thick)
3. Class D fire rated, cool-slab membrane with 2" insulation
4. 6" EPS foam insulation
5. Wall: 12" thick, 2x6 stud, 3x6" wood plate
6. VELUX translucent skylights
7. 1/2" F1-68/60 support with sealant & flashing below
8. Typical wall: metal stud structural framing, interior stud chosen for barrier resistance and recycling quality
9. Glazed brick header only at larger exposure of living room windows
10. Metal roof panel for durability and rainwater harvesting
11. Synthetic sheathing on 1/2" glass mat fiber cement sheathing
12. Triple-glazed zinc aluminum clad wood windows
13. Sunscreen wall: ventilated air space, 6" airspace window module, 1 airspace on south-facing wing
14. 4" flashing on the exterior side to block summer sun
15a. Perforated stainless steel air vent at high and low level of wall
15b. Perforated metal air vents
16a. Temperature sensors embedded in clad deck and/or apron
16b. Temperature sensors embedded in routine in windows and behind continuous insulation
16c. DPC above in order to seal roof at flashing
17. 2x6 brick/wood frame with weather resistant barrier
18. Blinds
19. 3/8" glass for aesthetic/performative
20. Service distribution layer for lighting, power, water, etc.
21. Brick
22. Porcelain tile floor for kitchen performance
23. Radiant tubing in floor slab - only at exterior walls
24. Window and interior interior need to maintain shading of interior zones
25. Large window will permit solar reflector 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
Envelope: Sunscreen Wall System
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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
Envelope: Thermal Bridge Free Design
Envelopes: Thermal Bridge Free Design
Envelope: Insulation
Envelope: Insulation
Envelope: Insulation
Envelope: Insulation
Envelope: Insulation
Envelope: Insulation
Envelope: Insulation
Envelope: Sensors
Envelope: Sensors
Mechanical Systems

Radiant Cooling and Heating

VOLUMETRIC HEAT CAPACITY
kJ / °C m³

<table>
<thead>
<tr>
<th>Material</th>
<th>Btu/°F ft³</th>
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<tbody>
<tr>
<td>Water</td>
<td>4000</td>
</tr>
<tr>
<td>Concrete</td>
<td>1000</td>
</tr>
<tr>
<td>Gypsum</td>
<td>600</td>
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<tr>
<td>Brick</td>
<td>400</td>
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<tr>
<td>Adobe</td>
<td>200</td>
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<tr>
<td>Wood</td>
<td>100</td>
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<tr>
<td>Insulation</td>
<td>10</td>
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<tr>
<td>Air</td>
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Mechanical Systems

Radiant Cooling and Heating
Mechanical Systems

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Fresh Air System
Mechanical Systems

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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

Annual Ground Temperatures

- Outdoor daily average
- 2 feet below grade in sun
- 4 feet below grade
- 6.7 feet below grade
- 10 feet below grade
2019 06 30 Wall Temperatures in Bedroom Wing - F°
Electrical Systems

Solar
Electrical Systems

Solar
Electrical Systems

Solar
# Measured versus Energy Models

<table>
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<tr>
<th></th>
<th>Phius + 2015</th>
<th>Phius Core 2021 Zero</th>
<th>Measured</th>
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<tbody>
<tr>
<td></td>
<td>Target kWh</td>
<td>Core 2021 kWh</td>
<td>3 year average kWh</td>
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<tr>
<td>Heating Demand</td>
<td>1.00</td>
<td>3.1</td>
<td>1.8</td>
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<tr>
<td>Cooling Demand</td>
<td>8.89</td>
<td>15.4</td>
<td>9.6</td>
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<tr>
<td>Total HVAC</td>
<td>10,540.36</td>
<td>15,853.38</td>
<td>6,414.71</td>
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<tr>
<td>Site Energy</td>
<td>6,200 kwh/ person</td>
<td>5,500 kwh/ person</td>
<td>13,838.58</td>
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<td>WUFI Monthly Report</td>
<td>10,932.00</td>
<td>11,188.00</td>
<td>10,405.00</td>
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</table>
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
- WUF1 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