

Analyzing Passive House strategies for a desert climate using WUFI Plus

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Learning Objectives:

- To understand the benefits of using WUFI Plus for climates that have large diurnal temperature swings.
- Become accustomed to running WUFI modeling early in the design process so changes are possible, enabling the testing of building construction types, shading and insulation levels.
- Learn the benefits of running multiple simulations to test assumptions. How to check assumptions with similar tests.
- How to analyze results to get the most impact from design decisions.

Tucson, Arizona

32°N, 110°W

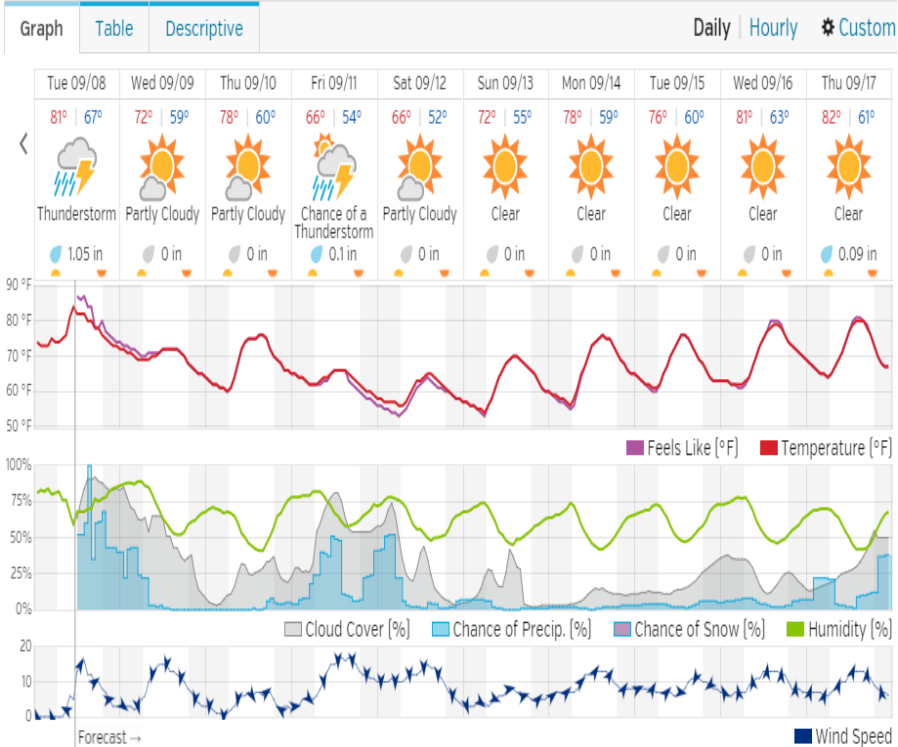
Heating degree days – 1,500; Cooling degree days – 2,900;

Percent of possible sunshine 85%;

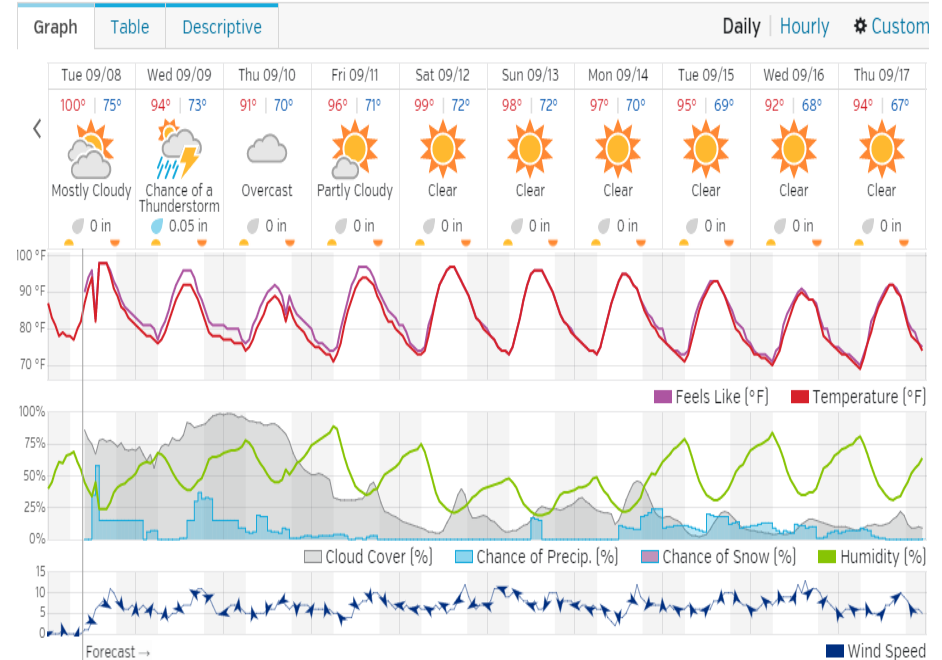


Comparative daily temperature swings – Chicago and Tucson

10-Day Weather Forecast

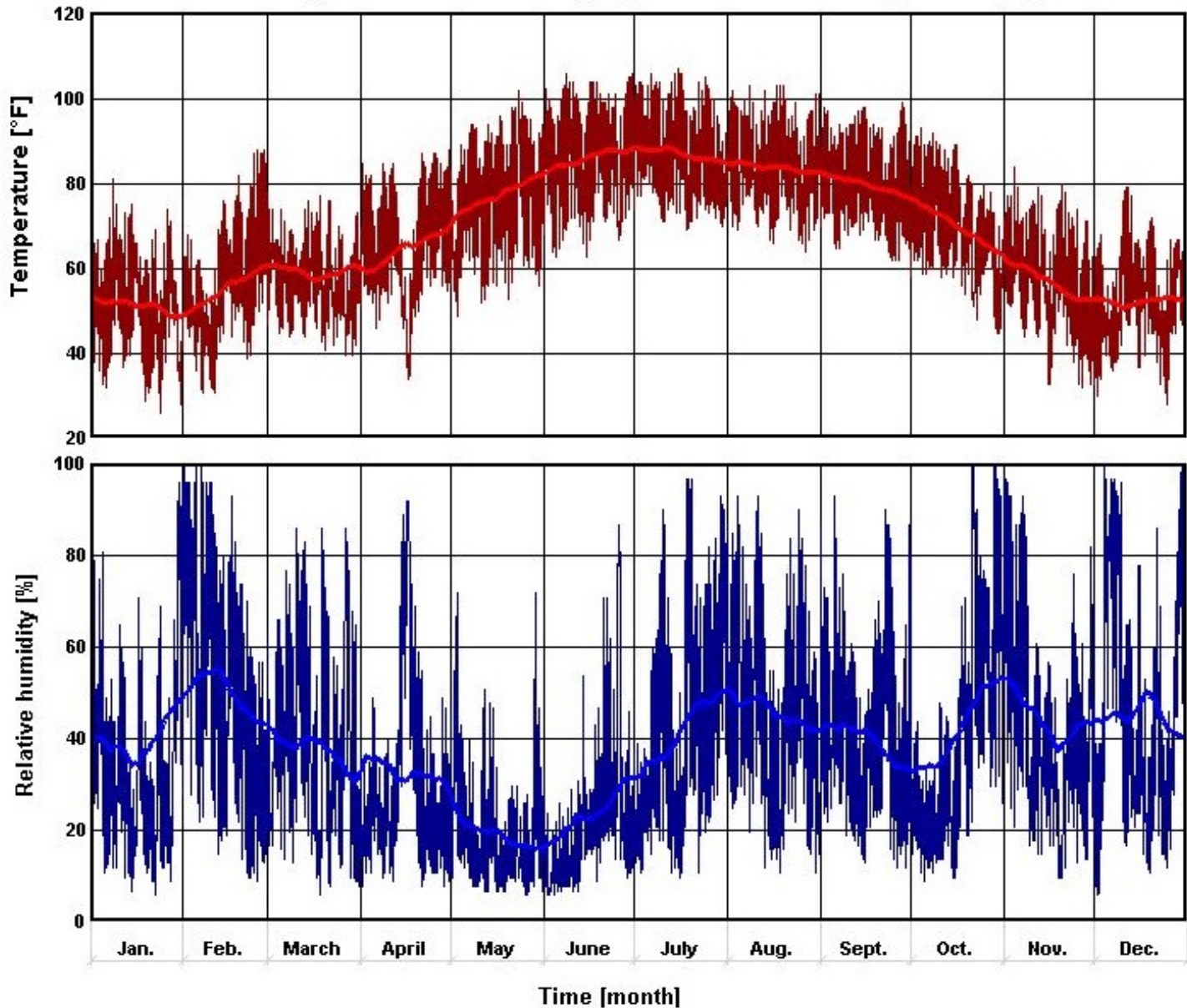


10-Day Weather Forecast



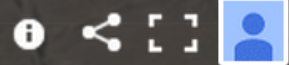
Tucson Climate

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



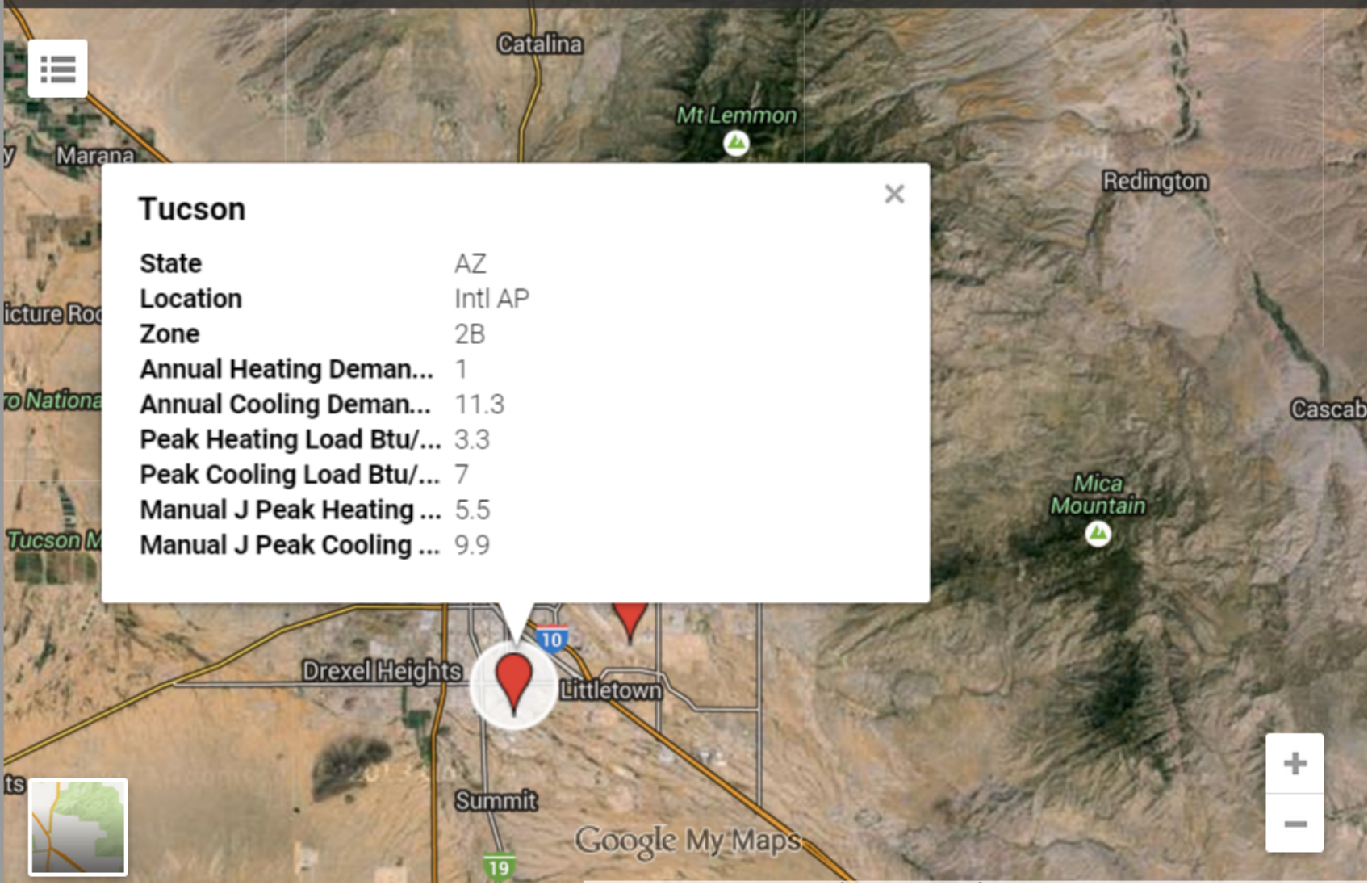
Temperature [°F]:
Max. 107.06
Mean. 68.75
Min. 26.06

Rel. humidity [%]:
Max. 100
Mean. 38.49
Min. 6

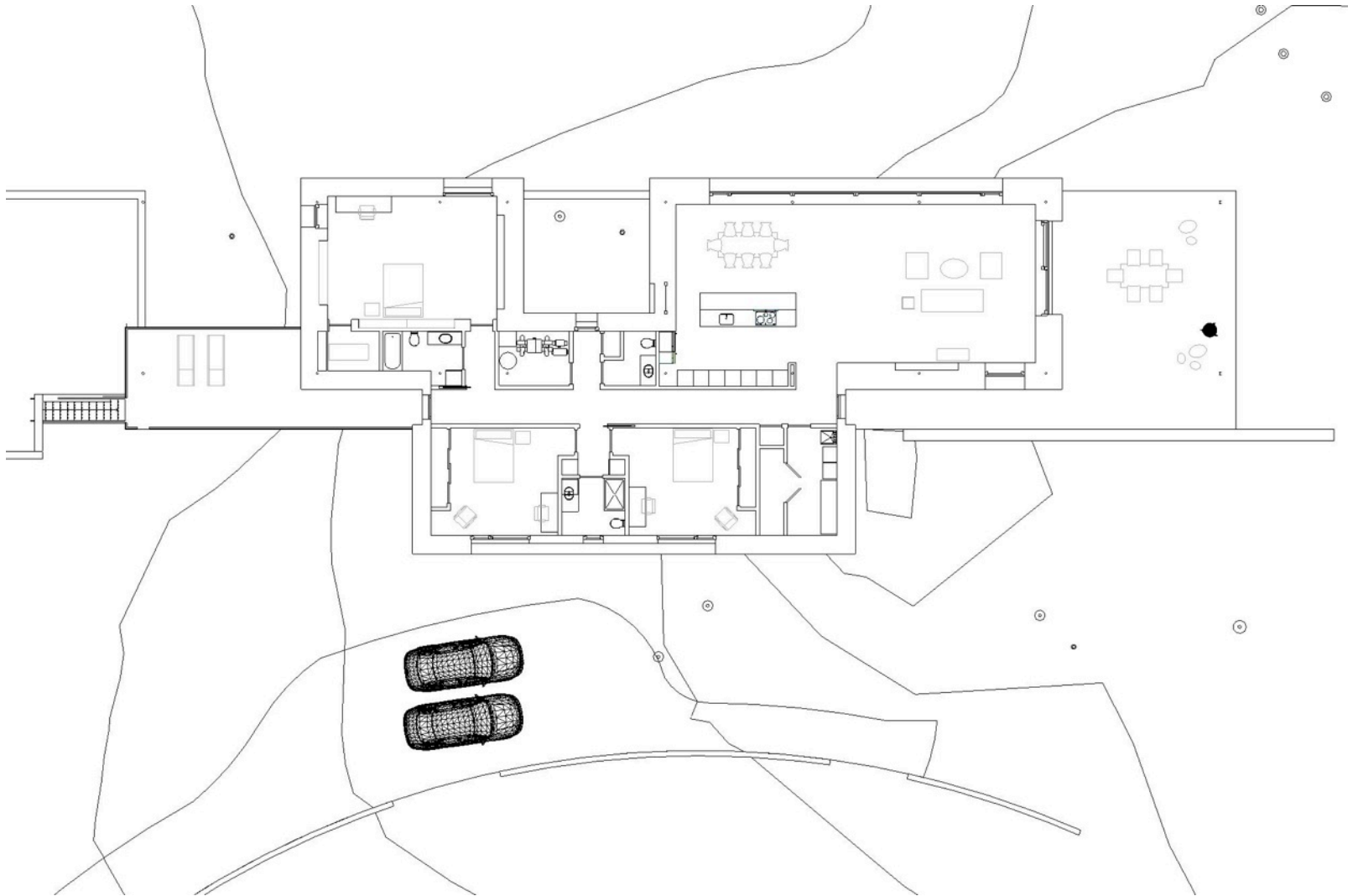


Tucson ✕

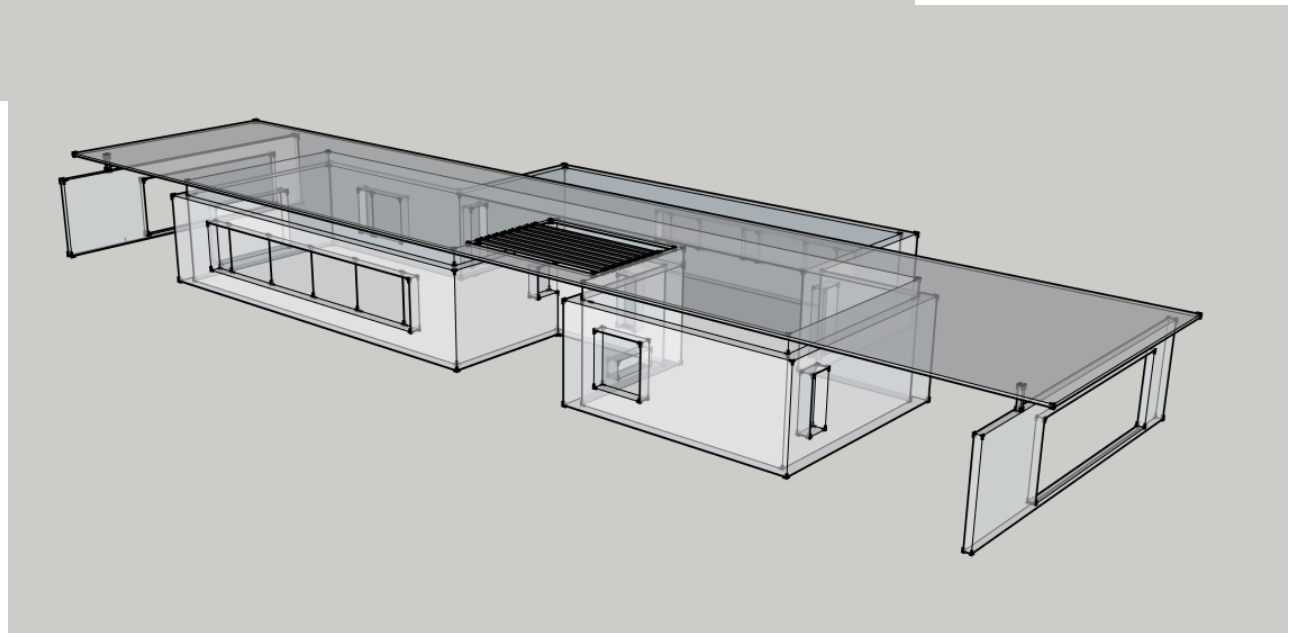
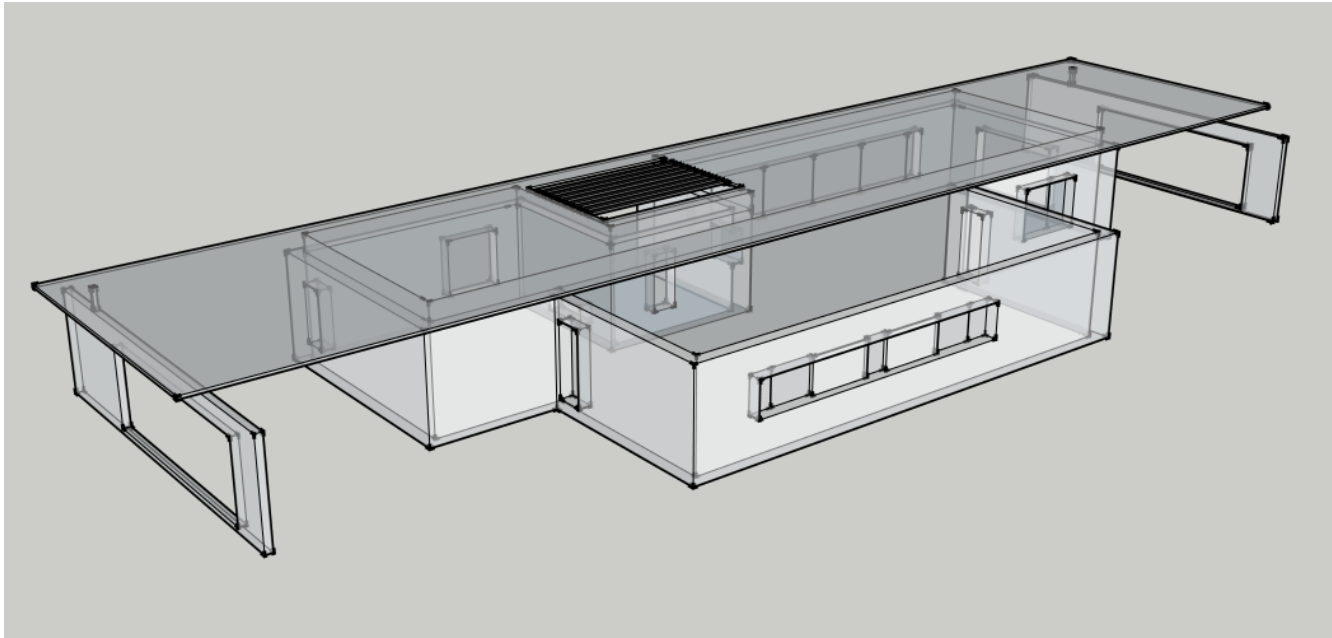
State	AZ
Location	Intl AP
Zone	2B
Annual Heating Deman...	1
Annual Cooling Deman...	11.3
Peak Heating Load Btu/...	3.3
Peak Cooling Load Btu/...	7
Manual J Peak Heating ...	5.5
Manual J Peak Cooling ...	9.9



Plan



Sketchup model



Wall Section

“Perfect Wall Variation”

Sun screen layer

Ventilation layer

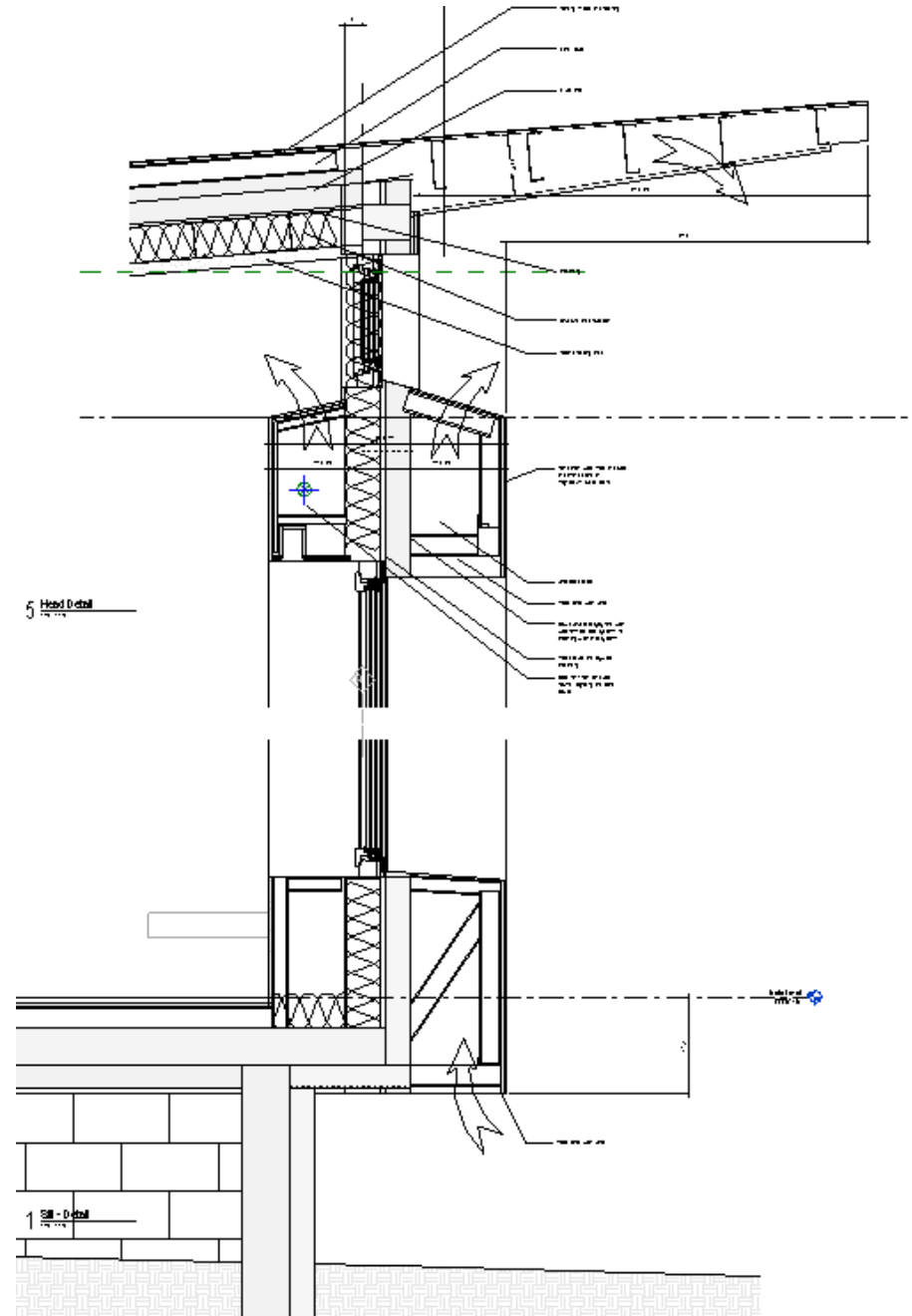
Continuous Insulation Layer

Air Barrier

Structure

Utilities

Interior Finish



Case 1: RI2 WI2:

- Localization/Climate: TUCSON INTERNATIONAL AP AZ
- Building
 - PH case: Passive house: Residential
 - Zone 1: Internal Zone
 - Visualized components
 - Component 1
 - Component 2
 - Component 3
 - Component 4
 - Component 5
 - Component 6
 - Component 7
 - Component 8: West Door
 - Component 9
 - Component 10
 - Component 11: South Fixed BR
 - Component 12: South TT BR
 - Component 13
 - Component 14: East Lift Slide
 - Component 15
 - Component 16
 - Component 17: South Fixed LR
 - Component 18
 - Component 19
 - Component 20
 - Component 21
 - Not visualized components
 - Internal Loads/Occupancy
 - Ventilation/Rooms
 - Thermal bridges
 - Attached zones
 - Remaining elements
 - Systems
 - System 1 (User defined)

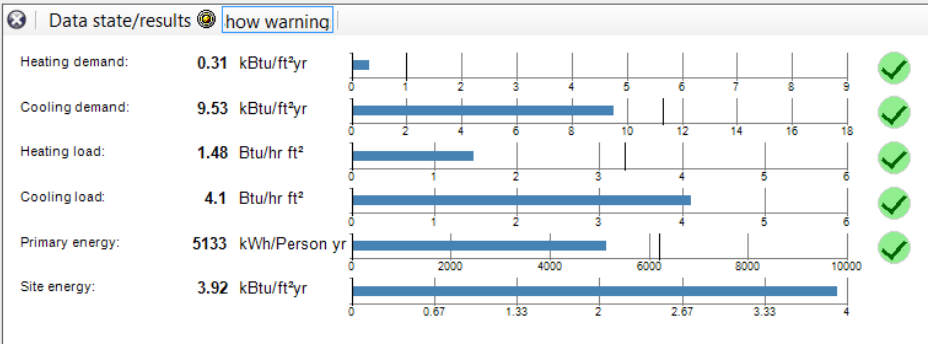
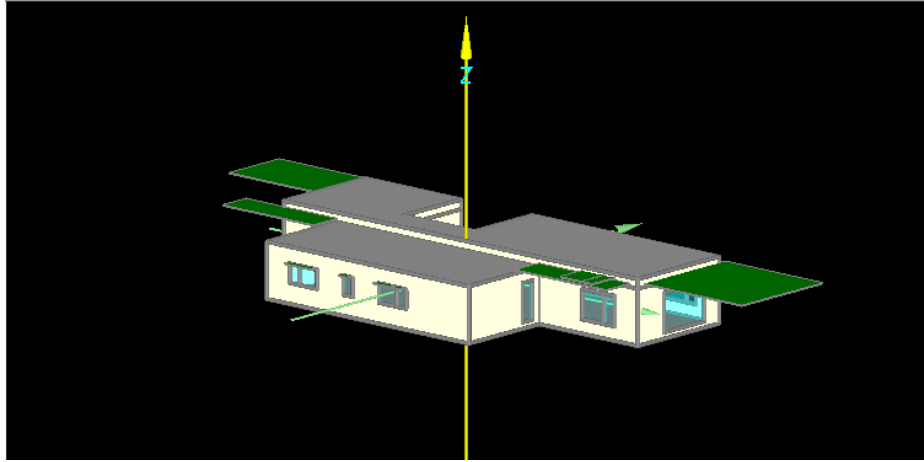
Occupant quantity [-]	4
Number of Bedrooms [-]	3
Humidity sources [lb/(ft²hr)]	0.00041

Device list

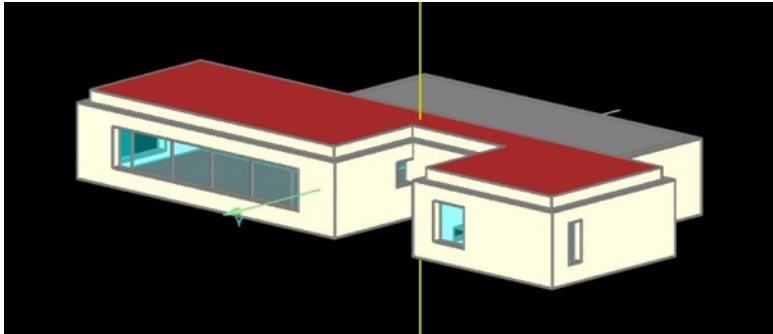
Device/End use	Reference quantity	Quantity	In conditioned space	Additio
Kitchen dishwasher	PH case occupants		<input checked="" type="checkbox"/>	DHW connection
Laundry - washer	PH case occupants		<input checked="" type="checkbox"/>	DHW connection; Utiliz
Laundry - dryer	PH case occupants		<input checked="" type="checkbox"/>	Condensation dryer; R
Kitchen refrigerator	PH case Units	1	<input checked="" type="checkbox"/>	
Kitchen freezer	PH case Units	1	<input checked="" type="checkbox"/>	
Kitchen cooktop	PH case occupants		<input checked="" type="checkbox"/>	Cooking with electricity
User defined	User defined	1	<input checked="" type="checkbox"/>	Resnet MELs
User defined	User defined	1	<input checked="" type="checkbox"/>	80% resnet interior ligh
User defined	User defined	1	<input type="checkbox"/>	garage lighting

Additional data: Kitchen dishwasher

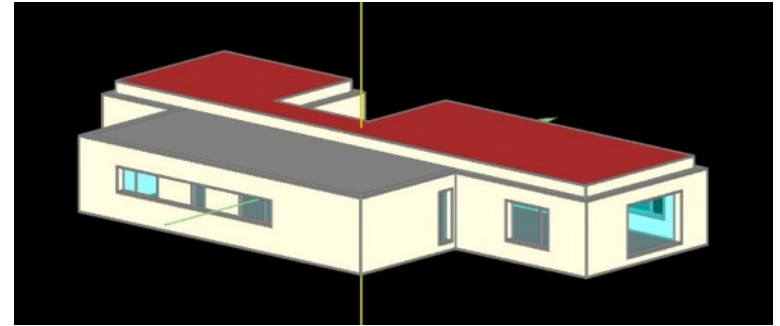
Choice	DHW connection
Energy demand (norm) [kWh/Use]	1.3
Comment	



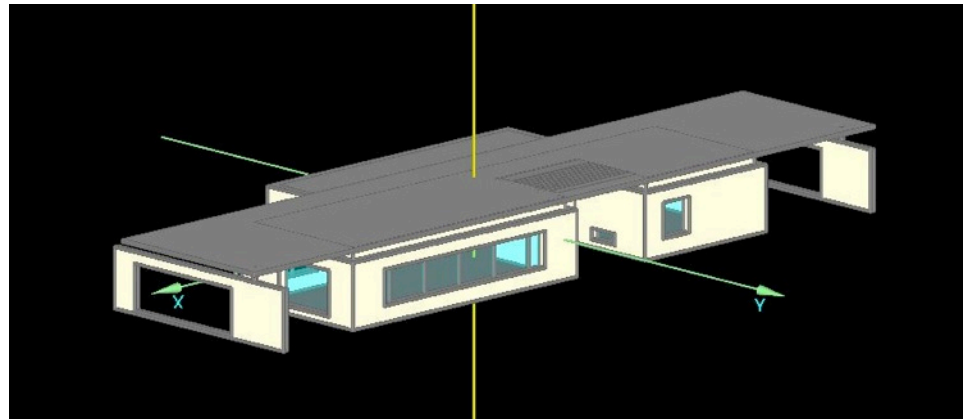
WUFI modeling



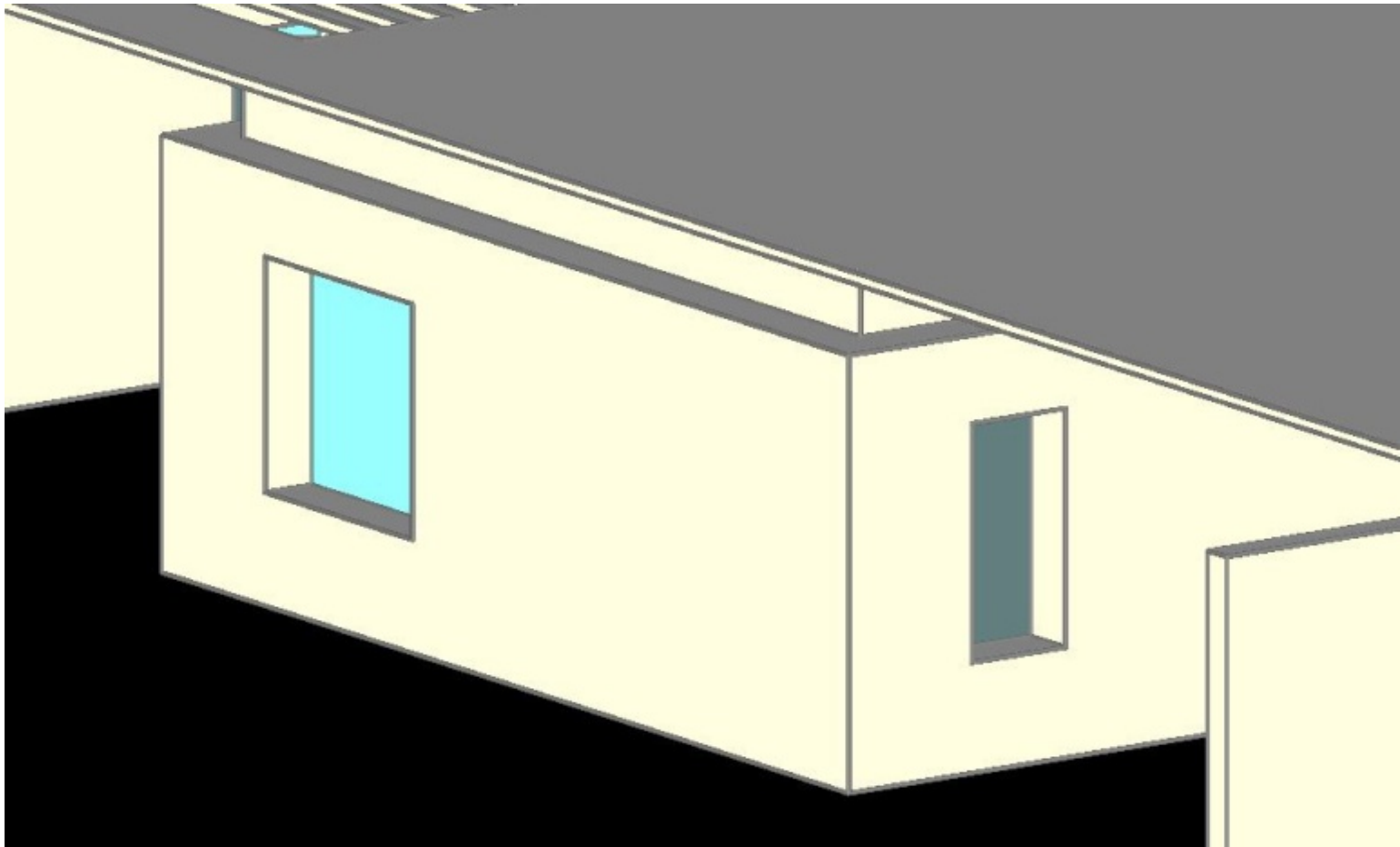
View from the northwest, without the roof overhang and with the double skin wall.



View from the southeast, without the roof overhang and with the double skin wall. Simulations were also run without the double skin wall.



View from the northeast, with the roof overhang and the double skin wall. The roof overhang, and sunscreen wall were modeled as separate simulated zones so that they would provide shading to the interior zone. Only the results from the interior zone were used.



View from the northwest, with the roof overhang and a close up of the double skin wall. The double skin wall provides shading for the windows both from above and from the sides. The double skin wall is modeled with 20 air changes per hour.

Table of Assembly types

(WI1 means wall; insulation; version 1, All lists have the exterior material at the top. These lists show the basic wall types, the sunscreen walls have a 15" air layer versus a 1.5" air layer.)

I Walls – Walls using insulation between studs and continuous insulation on exterior of studs

Walls (Code Min R13)	I1	I1.5	I2	I3	I4	I4.5	I5	I6	I7	I8
Regular Portland Stucco	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875
Gypsum Board Exterior	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
Air Layer	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
Extruded Polystyrene Insulation	6.000	5.000	4.000	4.000	4.000	3.500	4.000	3.000	2.000	1.000
Plywood	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Mineral Wool	6.000	6.000	6.000	4.000	2.000	2.000	0.000	0.000	0.000	0.000
Air Space	0.000	0.000	0.000	2.000	4.000	4.000	6.000	6.000	6.000	6.000
Gypsum Board (USA)	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
Thermal Resistance (hrft ² F/Btu)	59.064	53.295	47.526	41.345	35.164	32.279	28.982	23.213	17.444	11.675
Thermal Mass (Btu/ft ² F)	21.396	20.769	20.143	18.721	17.300	16.986	15.878	15.252	14.625	13.999

G Walls – Identical to I walls except 2 layers of gypsum board on interior for increased thermal mass

Walls (Code Min R13)	G1	G2	G3	G4	G5	G6	G7	G8
Regular Portland Stucco	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875
Gypsum Board Exterior	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
Air Layer	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
Extruded Polystyrene Insulation	6.000	4.000	4.000	4.000	4.000	3.000	2.000	1.000
Plywood	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Mineral Wool	6.000	6.000	4.000	2.000	0.000	0.000	0.000	0.000
Air Space	0.000	0.000	2.000	4.000	6.000	6.000	6.000	6.000
Gypsum Board (USA)	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Thermal Resistance (hrft ² F/Btu)	59.617	48.079	41.898	35.717	29.535	23.766	17.997	12.228
Thermal Mass (Btu/ft ² F)	28.360	27.107	25.685	24.264	22.842	22.216	21.589	20.963

M Walls – Uses brick as structure to provide thermal mass

Walls (Code Min R13)	M1	M2	M3	M4	M5	M6
Regular Portland Stucco	0.875	0.875	0.875	0.875	0.875	0.875
Gypsum Board Exterior	0.625	0.625	0.625	0.625	0.625	0.625
Air Layer	1.500	1.500	1.500	1.500	1.500	1.500
Extruded Polystyrene Insulation	6.000	4.000	3.000	2.000	1.000	0.000
Brick (old)	12.000	12.000	12.000	12.000	12.000	12.000
Gypsum Board (USA)	0.625	0.625	0.625	0.625	0.625	0.625
Thermal Resistance (hrft ² F/Btu)	29.664	23.895	18.126	12.357	6.587	41.202
Thermal Mass (Btu/ft ² F)	267.216	265.963	265.336	264.710	264.083	263.457

RE Walls – Uses rammed earth as structure

Walls (Code Min R13)	RE1	RE1.5	RE2	RE3	RE4	RE4.5	RE5	RE6
Regular Portland Stucco	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875
Gypsum Board Exterior	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
Air Layer	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
Extruded Polystyrene Insulation	6.000	5.000	4.000	3.000	2.000	1.500	1.000	0.000
Adobe	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000
Mud Plaster	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875
Gypsum Board (USA)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Resistance (hrft ² F/Btu)	43.404	37.635	31.866	26.097	20.328	17.443	14.559	8.790
Thermal Mass (Btu/ft ² F)	338.248	337.622	336.995	336.369	335.742	335.429	335.116	334.489

CMU Walls – Uses solid grouted concrete masonry units as structure and for thermal mass

Walls (Code Min R13)	CMU1	CMU1.5	CMU2	CMU3	CMU3.5	CMU4	CMU5	CMU6
Regular Portland Stucco	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875
Gypsum Board Exterior	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
Air Layer	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
Extruded Polystyrene Insulation	6.000	5.000	4.000	3.000	2.500	2.000	1.000	0.000
Concrete Blocks, pumice aggregate	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
Mortar	5.750	5.750	5.750	5.750	5.750	5.750	5.750	5.750
Concrete Blocks, pumice aggregate	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
Air Space	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875
Gypsum Board (USA)	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
Thermal Resistance (hrft ² F/Btu)	42.744	36.974	31.205	25.436	22.552	19.667	13.898	8.129
Thermal Mass (Btu/ft ² F)	177.709	177.082	176.456	175.829	175.516	175.203	174.576	173.950

Roof Types

I Roof – Uses insulation between light gauge metal framing and continuous insulation above studs

Roof (Code Min R38)	I1	I2	I3	I4	I5	I6	I7	I8
Steel2	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
Plywood (USA)	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
Air Layer	3.625	3.625	3.625	3.625	3.625	3.625	3.625	3.625
Extruded Polystyrene Insulation	6.000	4.000	4.000	4.000	4.000	3.000	2.000	1.000
Plywood	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Mineral Wool	8.000	8.000	6.000	2.000	0.000	0.000	0.000	0.000
Air Space	0.000	0.000	2.000	6.000	8.000	8.000	8.000	8.000
Gypsum Board (USA)	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Thermal Resistance (hrft ² F/Btu)	66.530	54.992	48.811	34.278	27.374	21.605	15.836	10.067
Thermal Mass (Btu/ft ² F)	21.4631	20.2101	18.7885	15.9453	14.5237	13.8972	13.2707	12.644

G Roof – Uses insulation between light gauge metal framing and continuous insulation above studs. Adds additional layer of gypsum board for thermal mass.

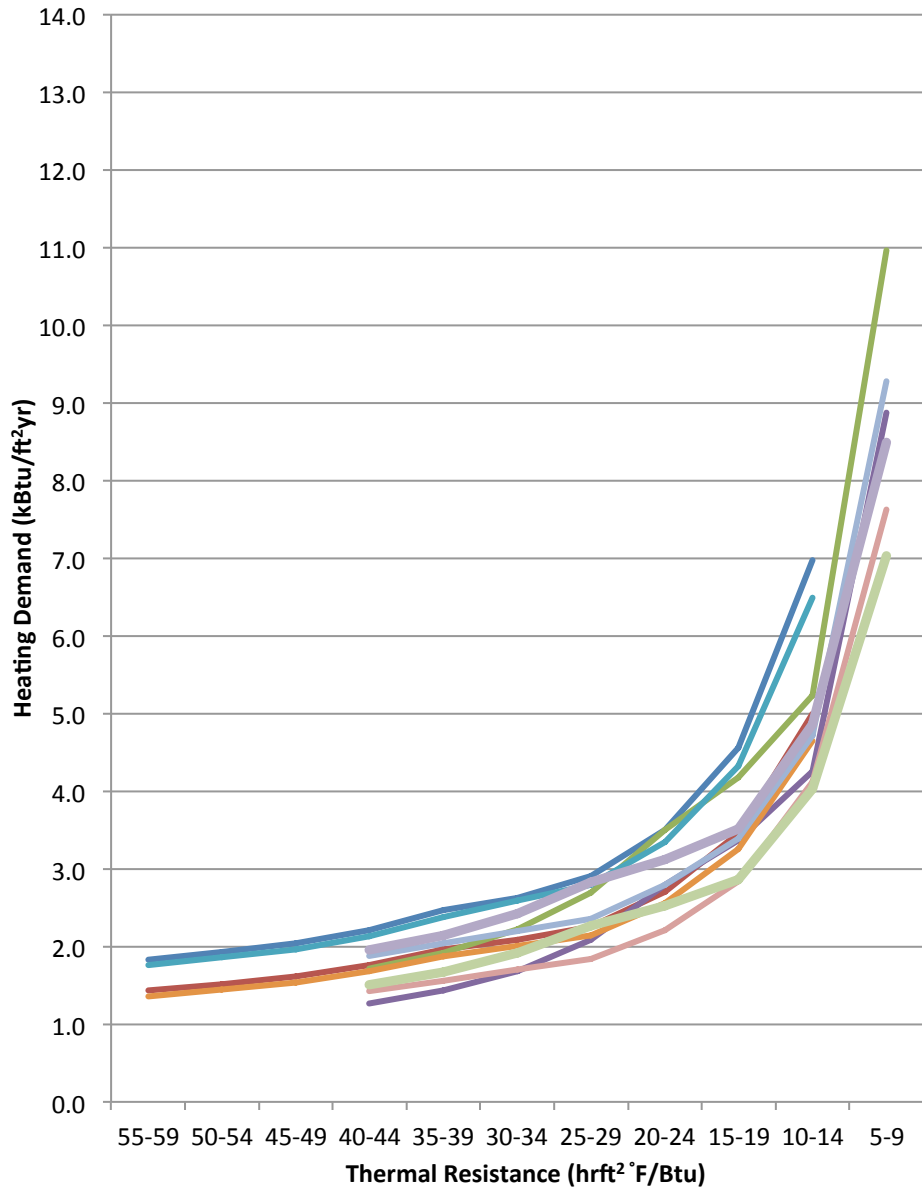
Roof (Code Min R38)	G1	G2	G3	G4	G5	G6	G7	G8
Steel2	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
Plywood (USA)	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
Air Layer	3.625	3.625	3.625	3.625	3.625	3.625	3.625	3.625
Extruded Polystyrene Insulation	6.000	4.000	4.000	4.000	4.000	3.000	2.000	1.000
Plywood	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Mineral Wool	8.000	8.000	6.000	2.000	0.000	0.000	0.000	0.000
Air Space	0.000	0.000	2.000	6.000	8.000	8.000	8.000	8.000
Gypsum Board (USA)	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Thermal Resistance (hrft ² F/Btu)	67.194	55.656	49.475	34.942	28.038	22.268	16.499	10.730
Thermal Mass (Btu/ft ² F)	29.820	28.567	27.145	24.302	22.881	22.254	21.628	21.001

Slab Types

S Slab – Uses mineral wool insulation below the slab. Foam insulation was not used due to termites. There is also a stud layer above the slab for utilities and future renovations.

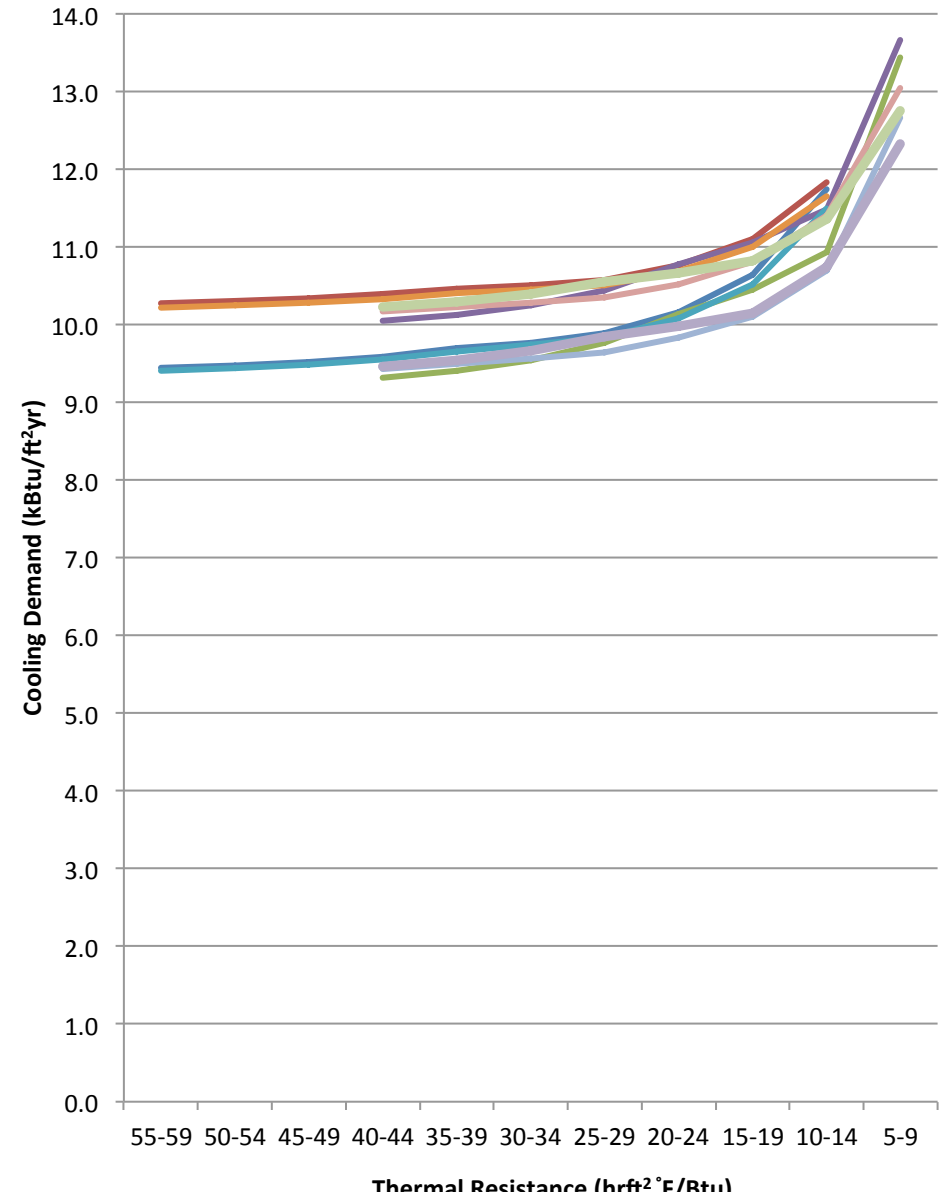
Slab on Grade	S1	S2	S3
Mineral Wool	8	4	0
vapor retarder (0.1 perm)	0.039	0.039	0.039
Concrete	4.000	4.000	4.000
Air Layer	3.625	3.625	3.625
Plywood	0.750	0.750	0.750
Oak, radial	0.750	0.750	0.750
Thermal Resistance (hrft ² F/Btu)	31.932	17.509	3.086
Thermal Mass (Btu/ft ² F)	127.0542	124.0542	121.0542

1: Heating Demand vs. Wall, Conventional and Sun Screen Walls, No Roof Overhang, Sun Screen Roof



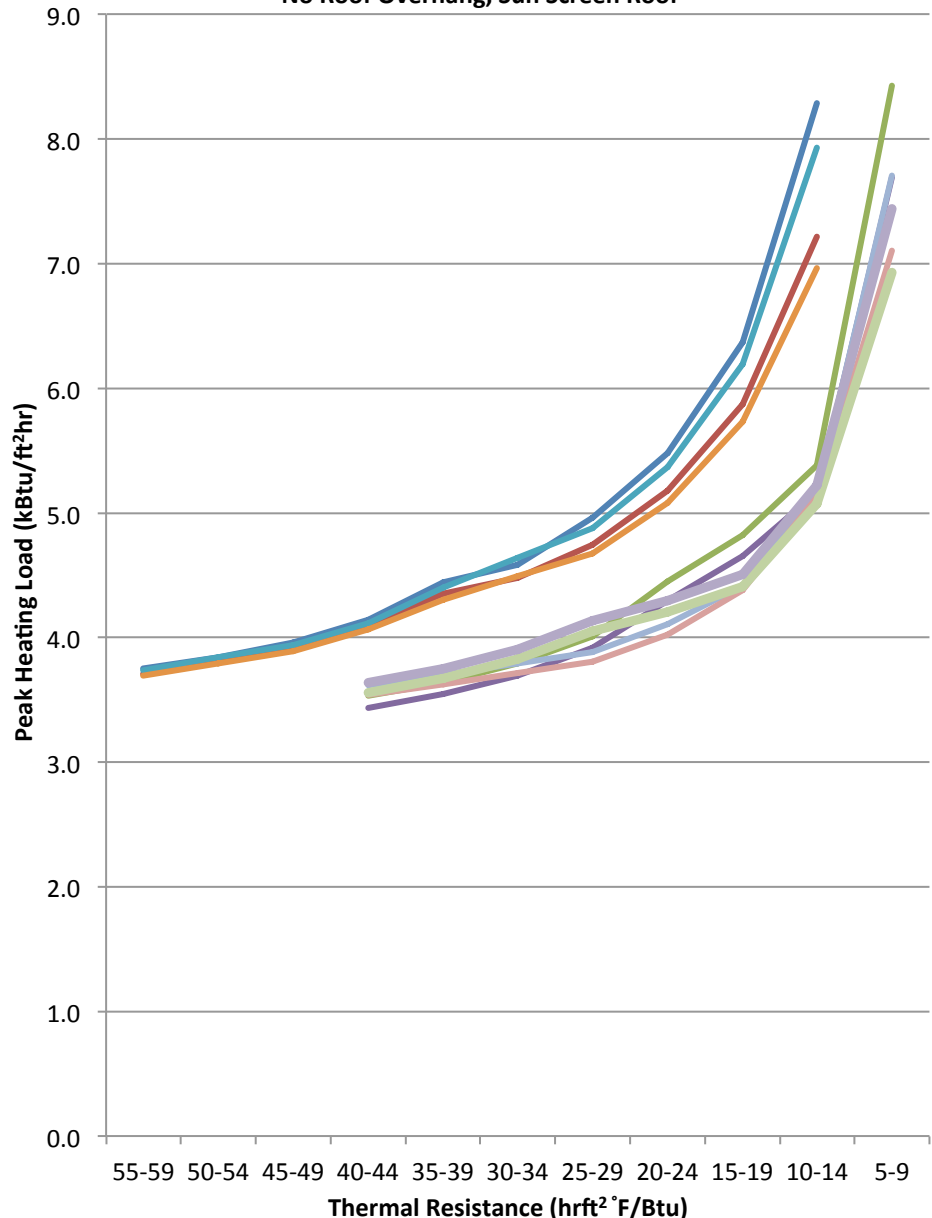
- | | | |
|-------------------|------------------|--------------------|
| — I Sun Screen | — I Conventional | — RE Sun Screen |
| — RE Conventional | — G Sun Screen | — G Conventional |
| — M Sun Screen | — M Conventional | — CMU Conventional |
| — CMU Sun Screen | | |

2: Cooling Demand vs. Wall, Conventional and Sun Screen Walls, No Roof Overhang, Sun Screen Roof

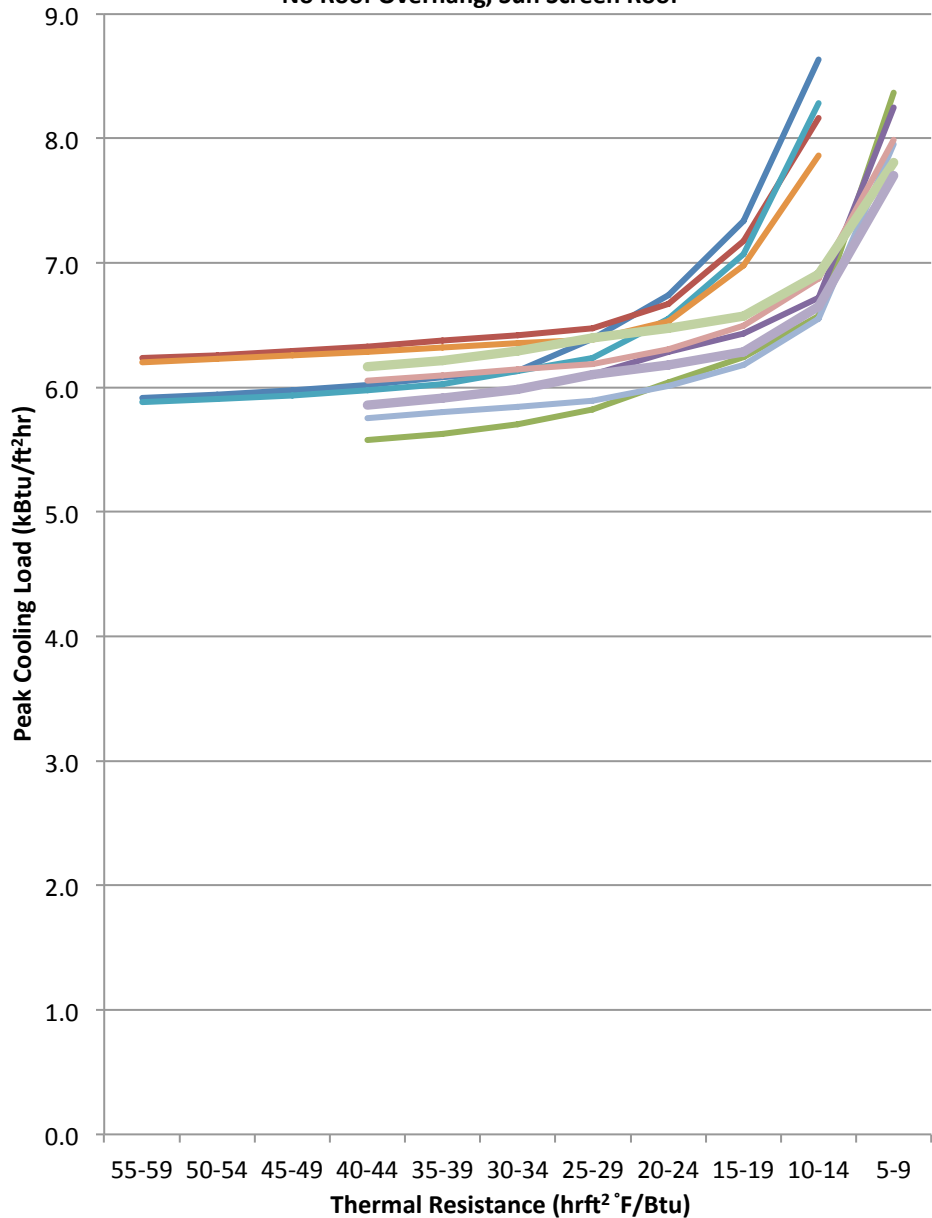


- | | | |
|---|------------------|--------------------|
| Thermal Resistance (hrft²°F/Btu) | | |
| — I Sun Screen | — I Conventional | — RE Sun Screen |
| — RE Conventional | — G Sun Screen | — G Conventional |
| — M Sun Screen | — M Conventional | — CMU Conventional |
| — CMU Sun Screen | | |

**3: Peak Heating Load vs. Wall, Conventional and Sun Screen Walls,
No Roof Overhang, Sun Screen Roof**



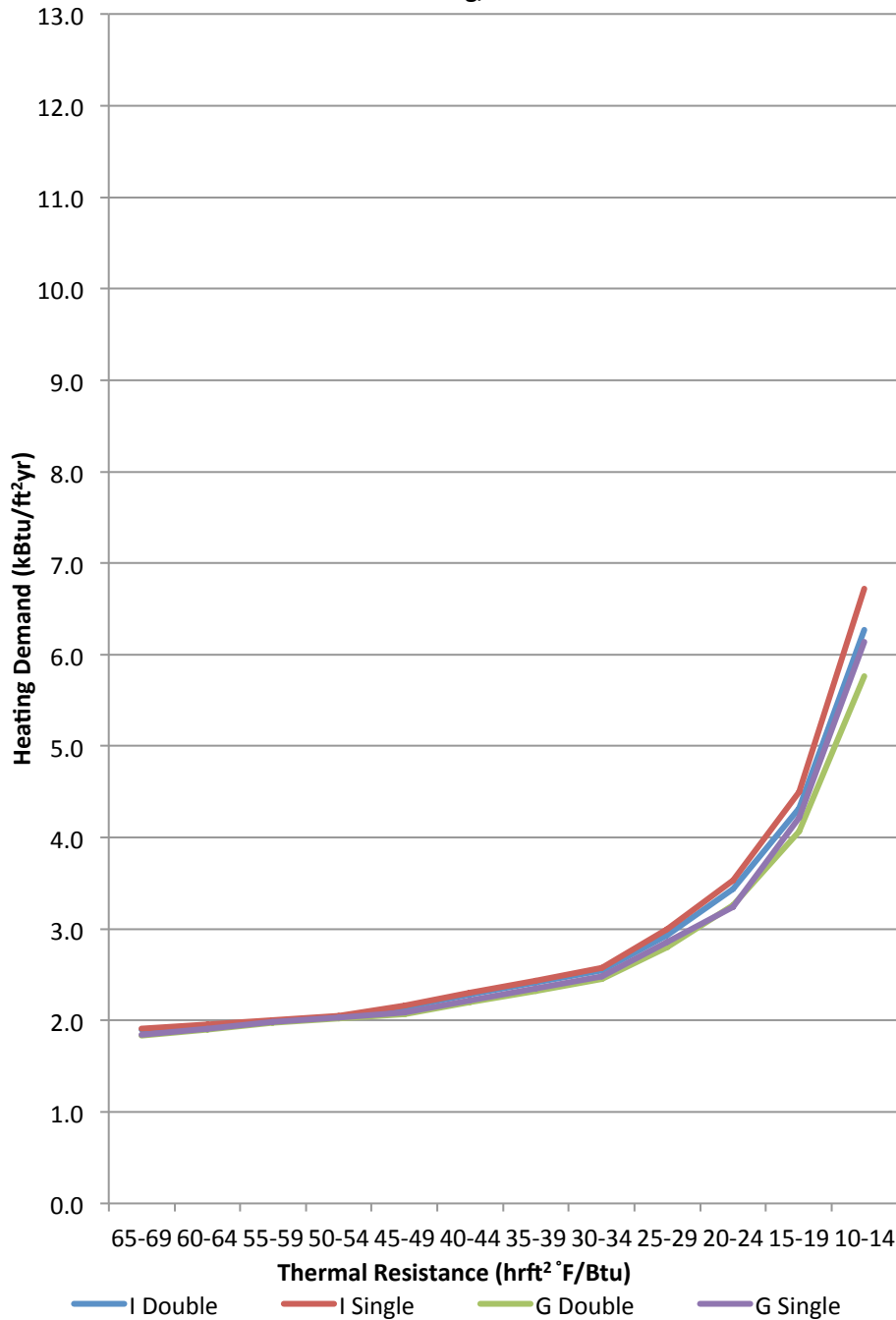
**4: Peak Cooling Load vs. Wall, Conventional and Sun Screen Walls,
No Roof Overhang, Sun Screen Roof**



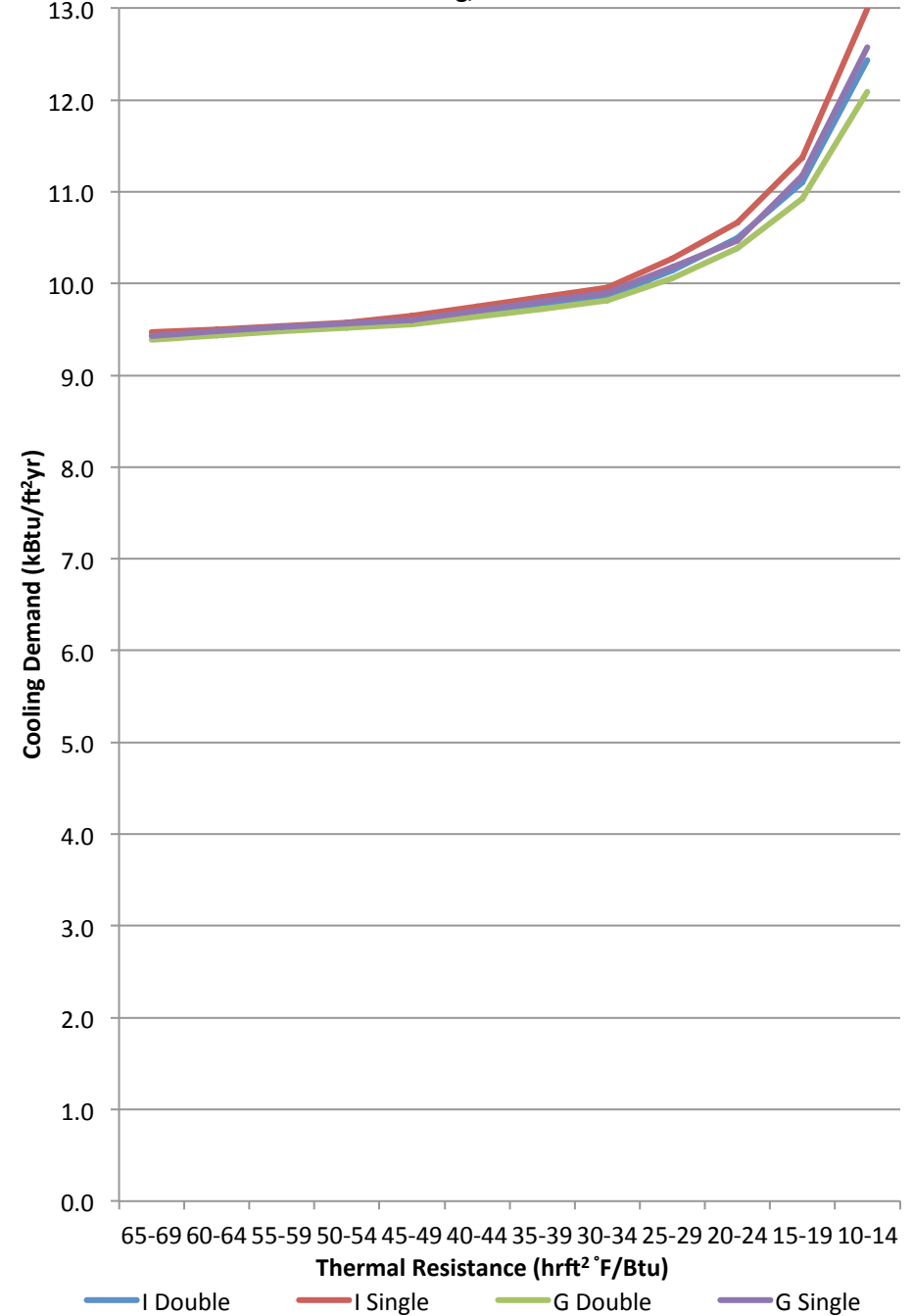
- I Sun Screen
- RE Conventional
- M Sun Screen
- CMU Sun Screen
- I Conventional
- G Sun Screen
- M Conventional
- RE Sun Screen
- G Conventional
- CMU Conventional

- I Sun Screen
- RE Conventional
- M Sun Screen
- CMU Sun Screen
- I Conventional
- G Sun Screen
- M Conventional
- RE Sun Screen
- G Conventional
- CMU Conventional

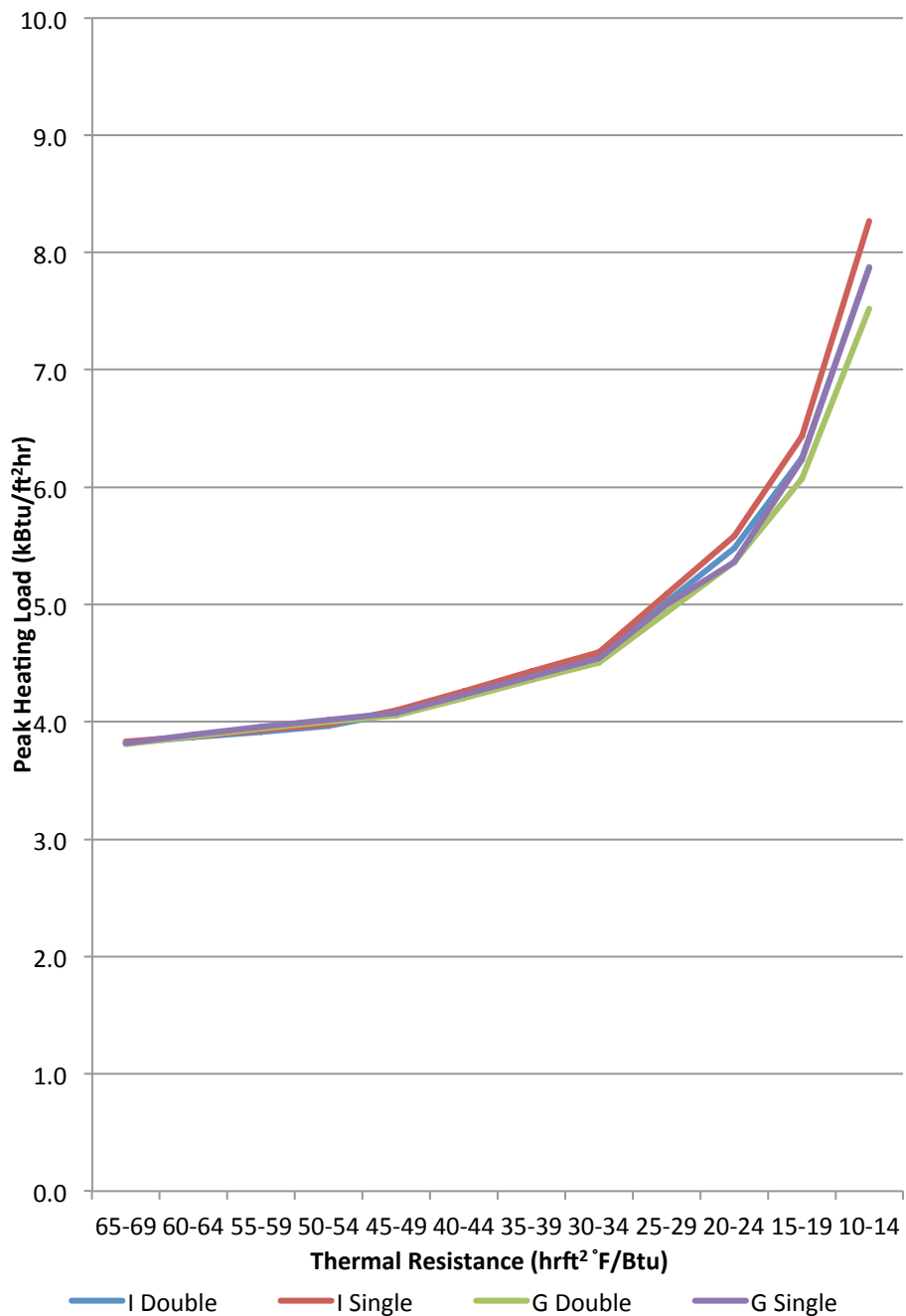
5: Heating Demand vs. Roofs, Conventional and Sun Screen Roof, No Roof Overhang, Sun Screen Wall



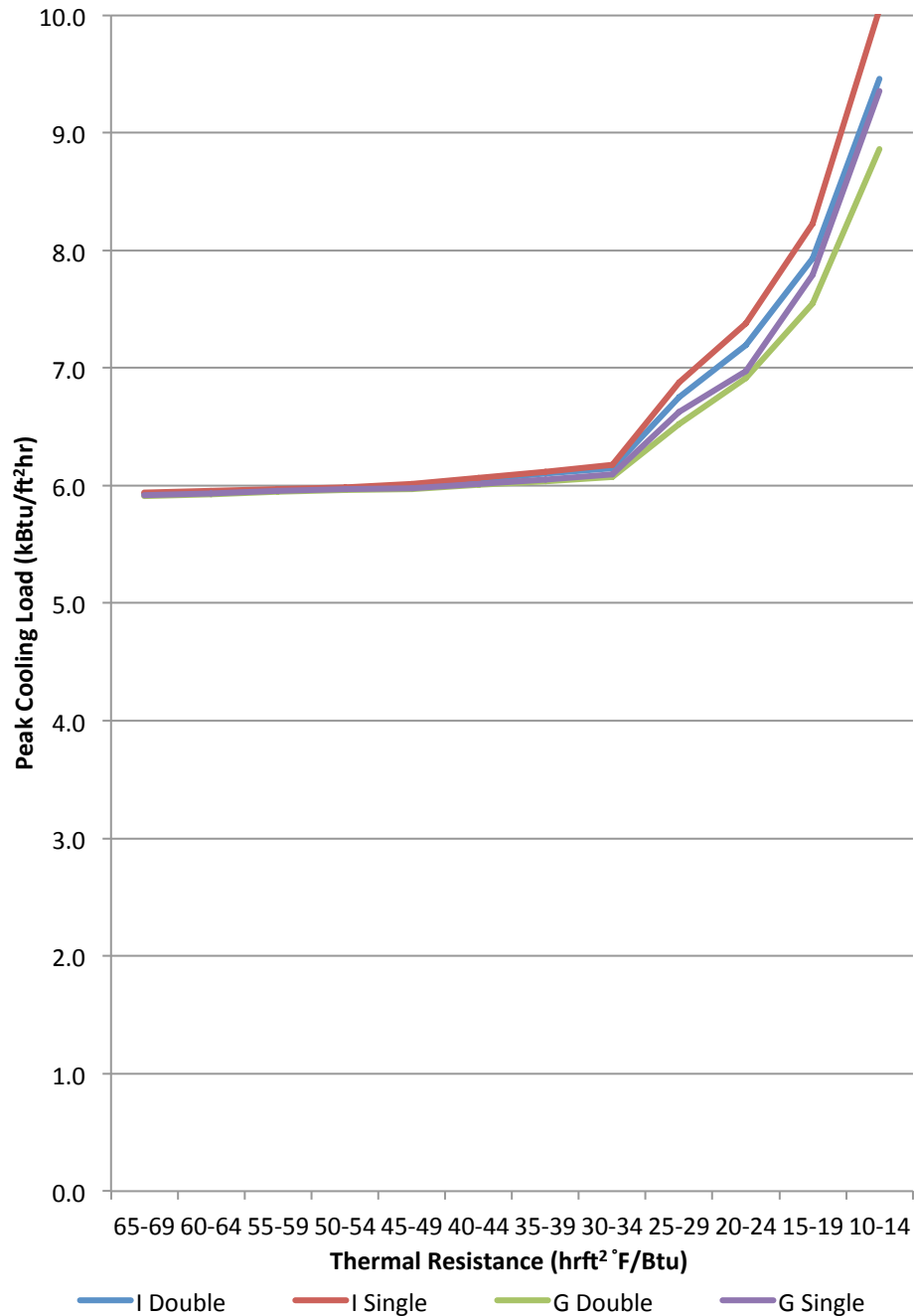
6: Cooling Demand vs. Roofs, Conventional and Sun Screen Roof, No Roof Overhang, Sun Screen Wall



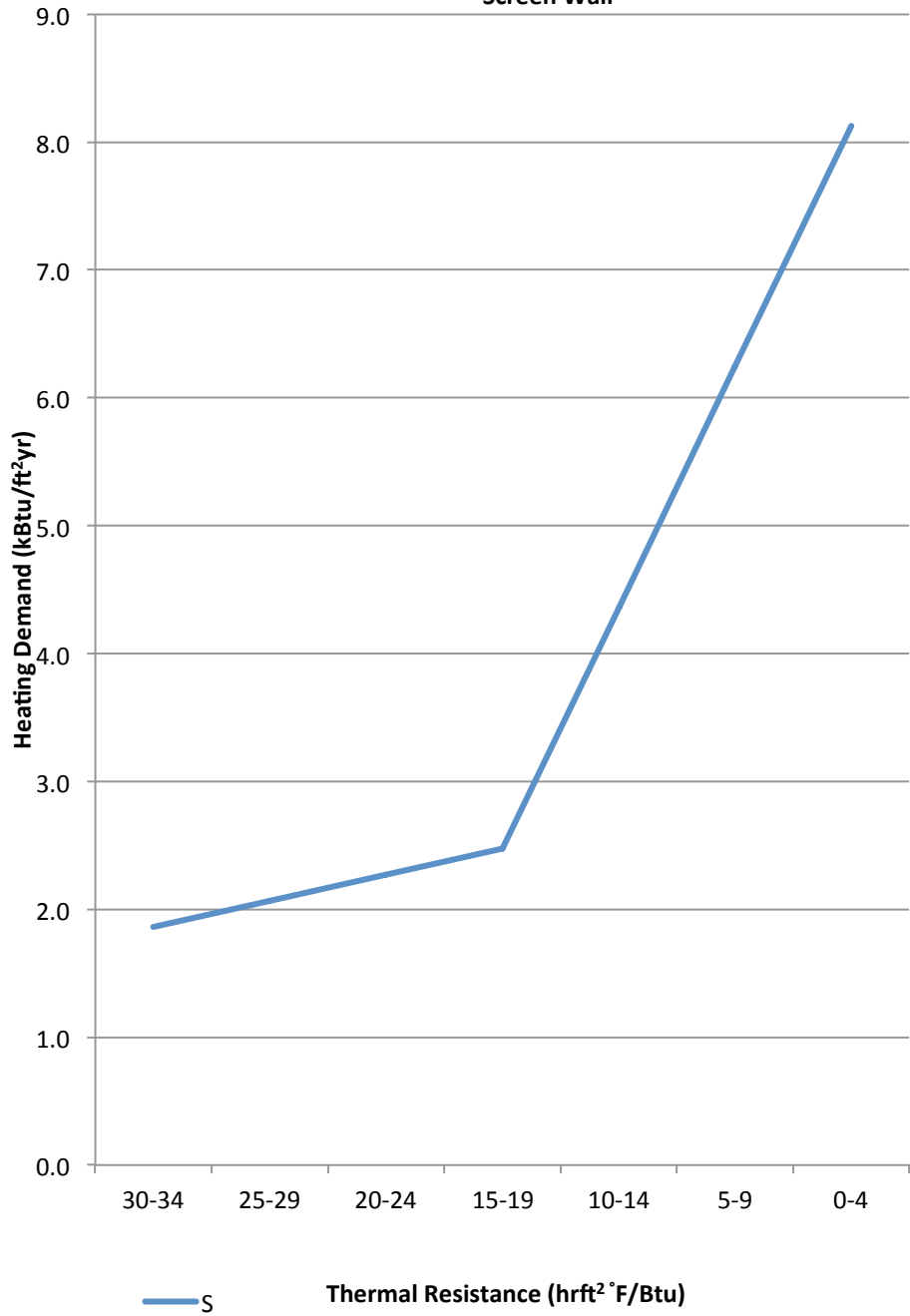
7: Peak Heating Load vs. Roofs, Conventional and Sun Screen Roof, No Roof Overhang, Sun Screen Wall



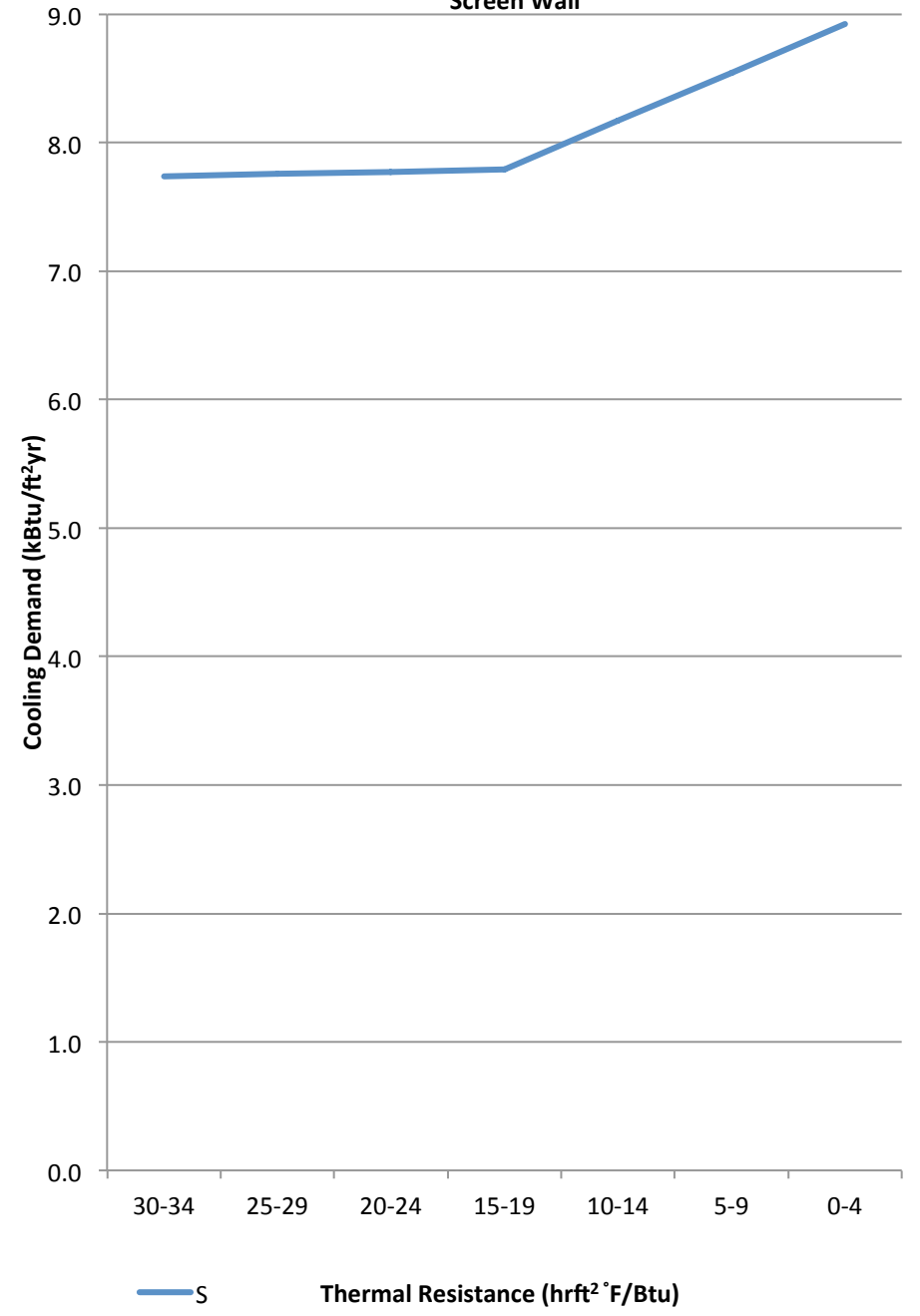
8: Peak Cooling Load vs. Roofs, Conventional and Sun Screen Roof, No Roof Overhang, Sun Screen Wall



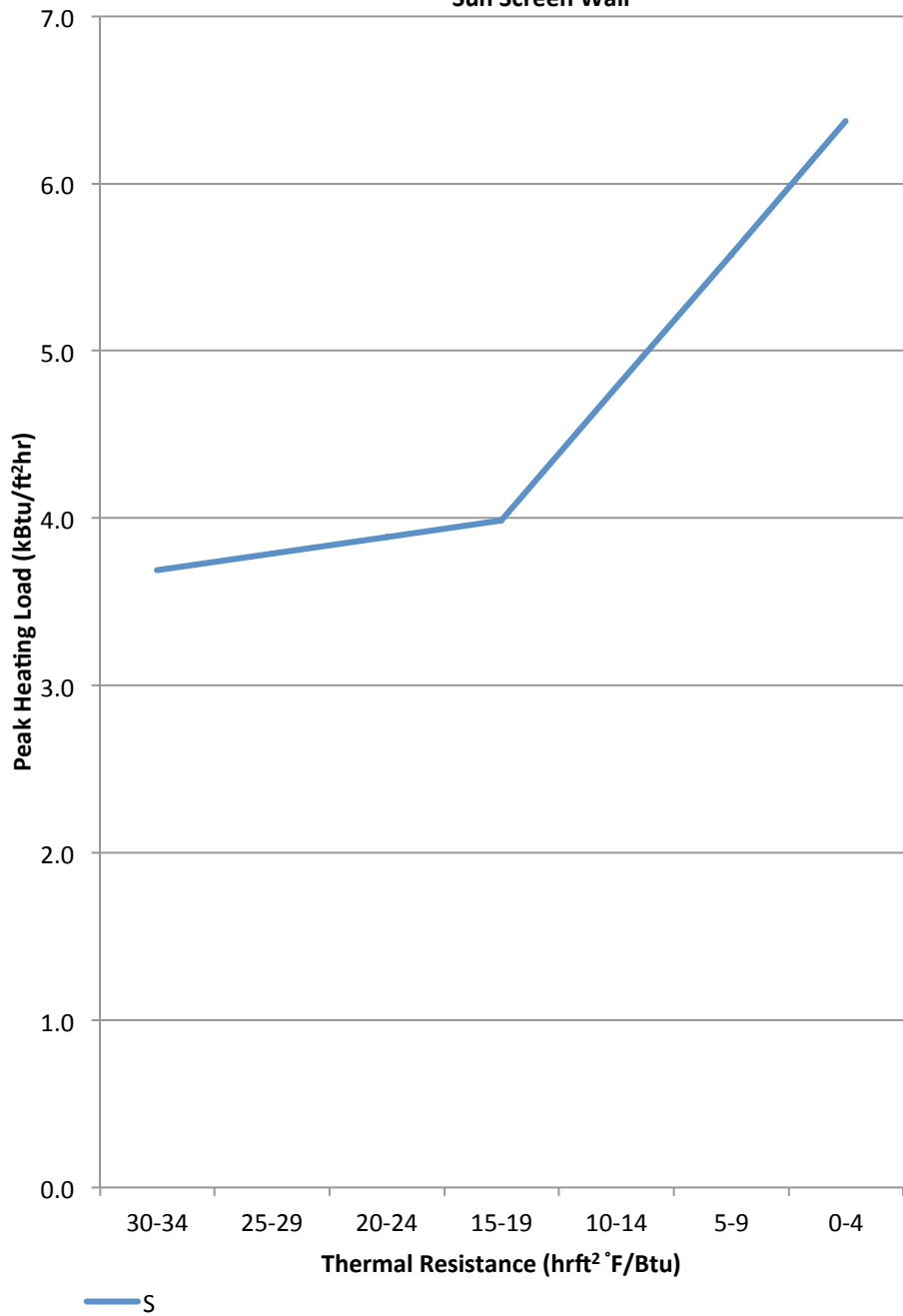
9: Heating Demand vs. Slab, Roof Overhang, Sun Screen Roof, Sun Screen Wall



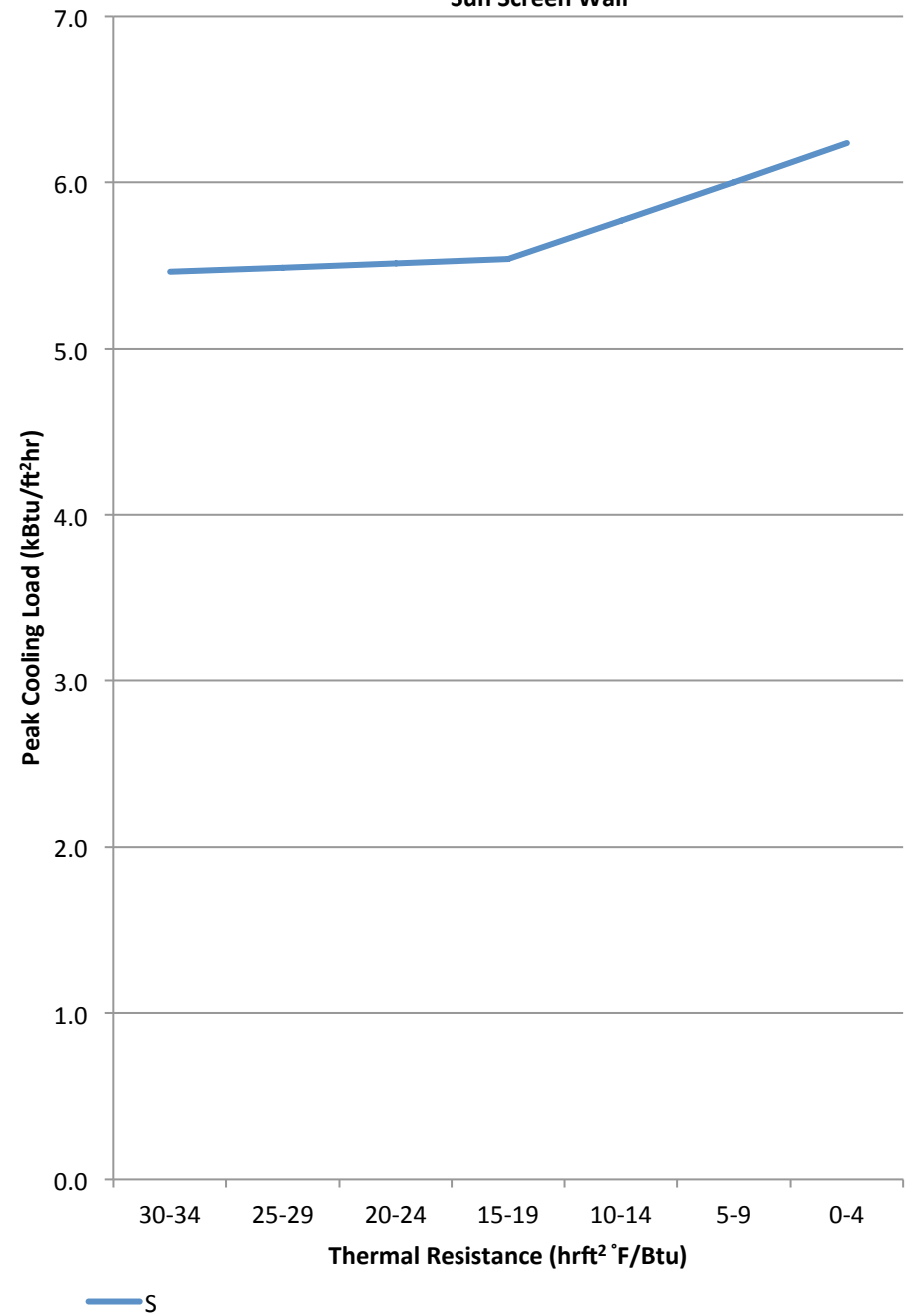
10: Cooling Demand vs. Slab, Roof Overhang, Sun Screen Roof, Sun Screen Wall



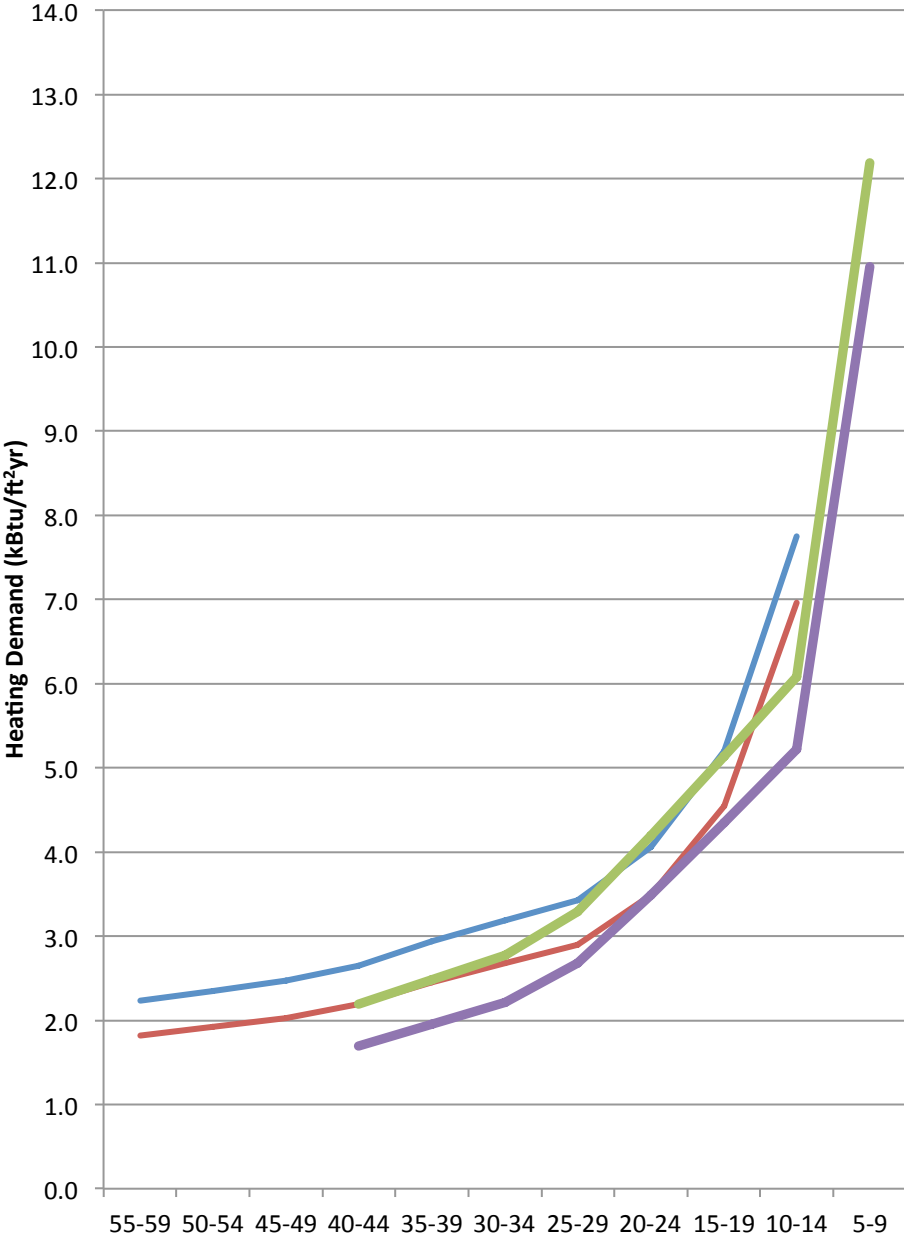
11: Peak Heating Load vs. Slab, Roof Overhang, Sun Screen Roof, Sun Screen Wall



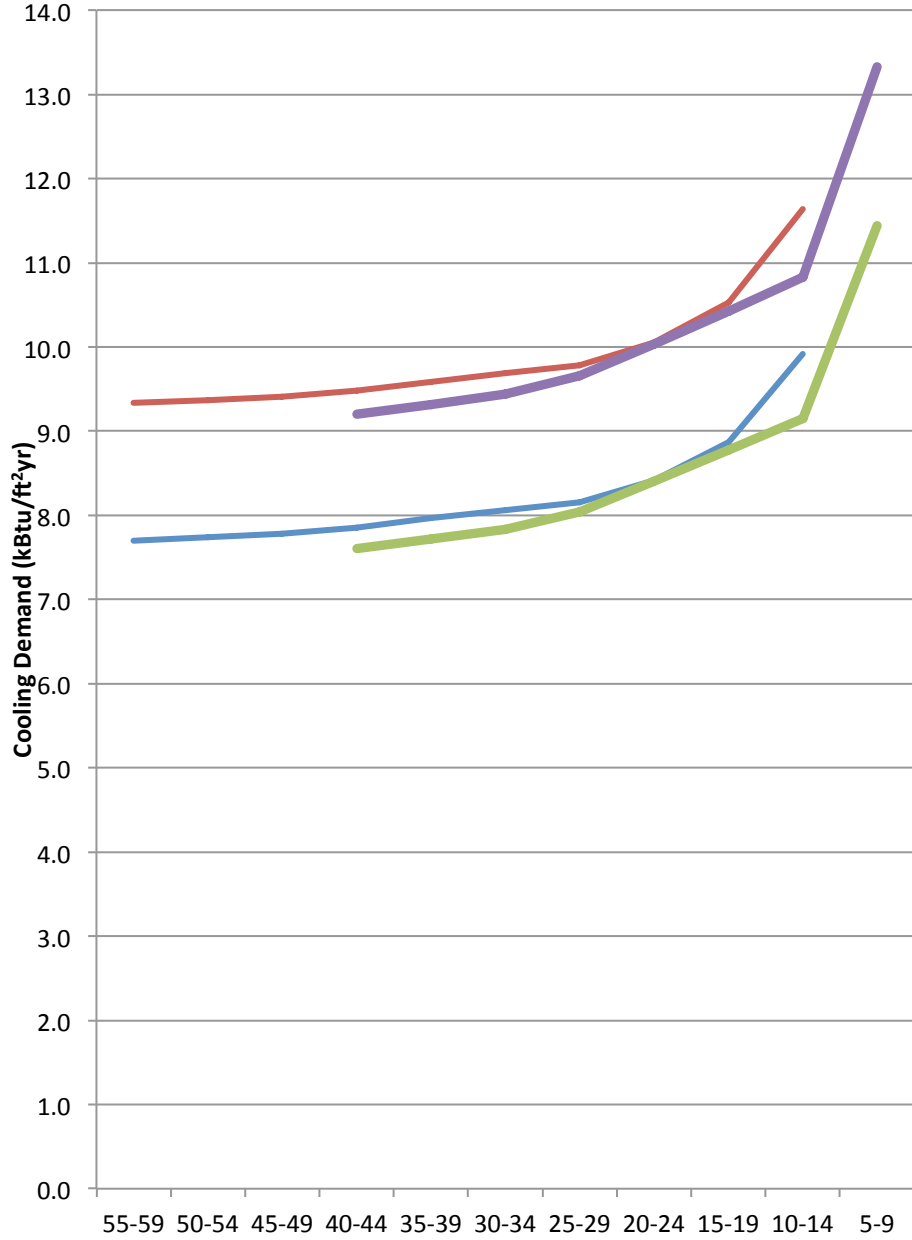
12: Peak Cooling Load vs. Slab, Roof Overhang, Sun Screen Roof, Sun Screen Wall



13: Heating Demand vs. Wall, Roof Overhang and No Roof Overhang, Sun Screen Wall, Sun Screen Roof



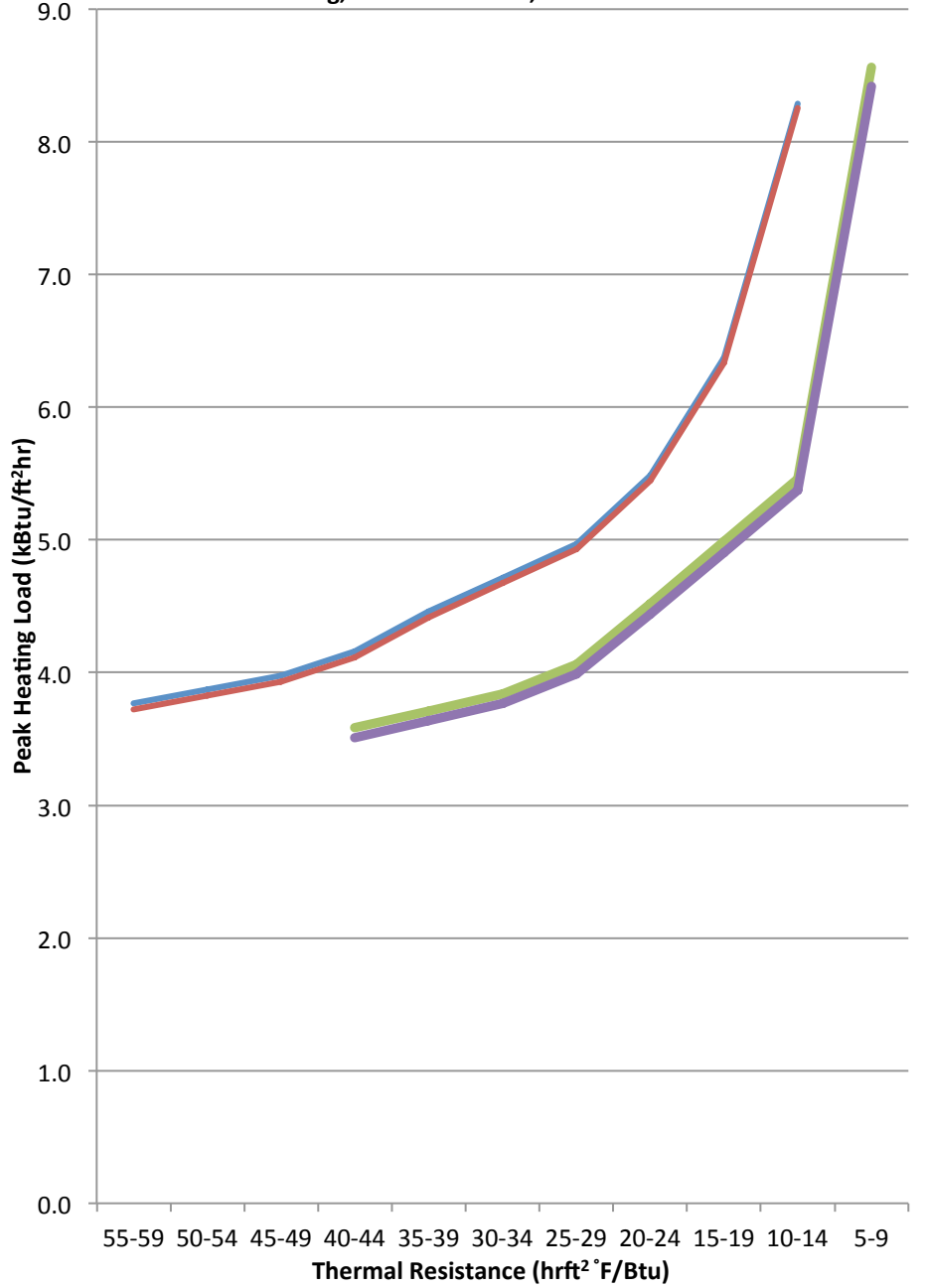
14: Cooling Demand vs. Wall, Roof Overhang and No Roof Overhang, Sun Screen Wall, Sun Screen Roof



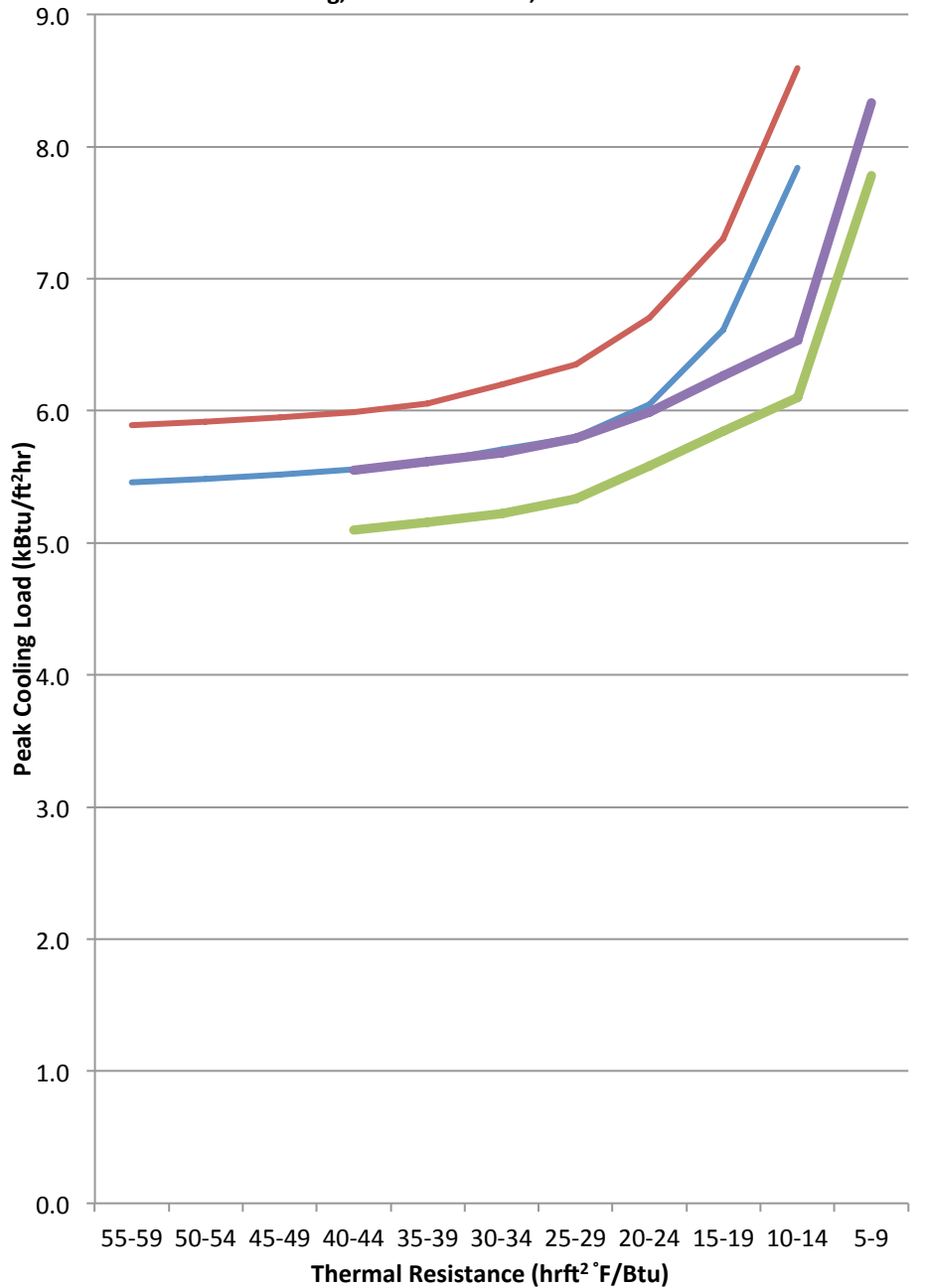
I Overhang I No Overhang RE Overhang RE No Overhang

I Overhang I No Overhang RE Overhang RE No Overhang

15: Peak Heating Load vs. Wall, Roof Overhang and No Roof Overhang, Sun Screen Wall, Sun Screen Roof



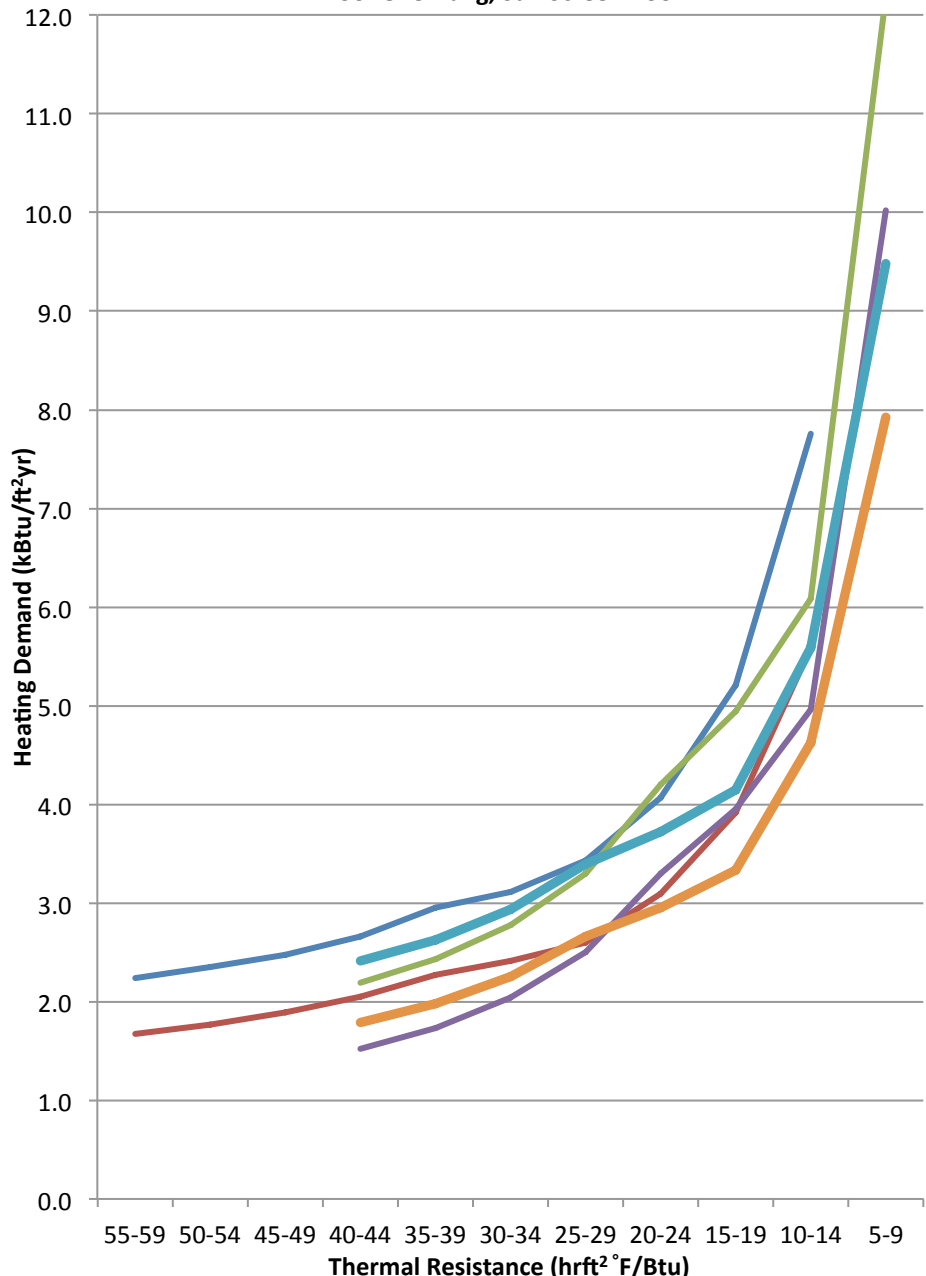
16: Peak Cooling Load vs. Wall, Roof Overhang and No Roof Overhang, Sun Screen Wall, Sun Screen Roof



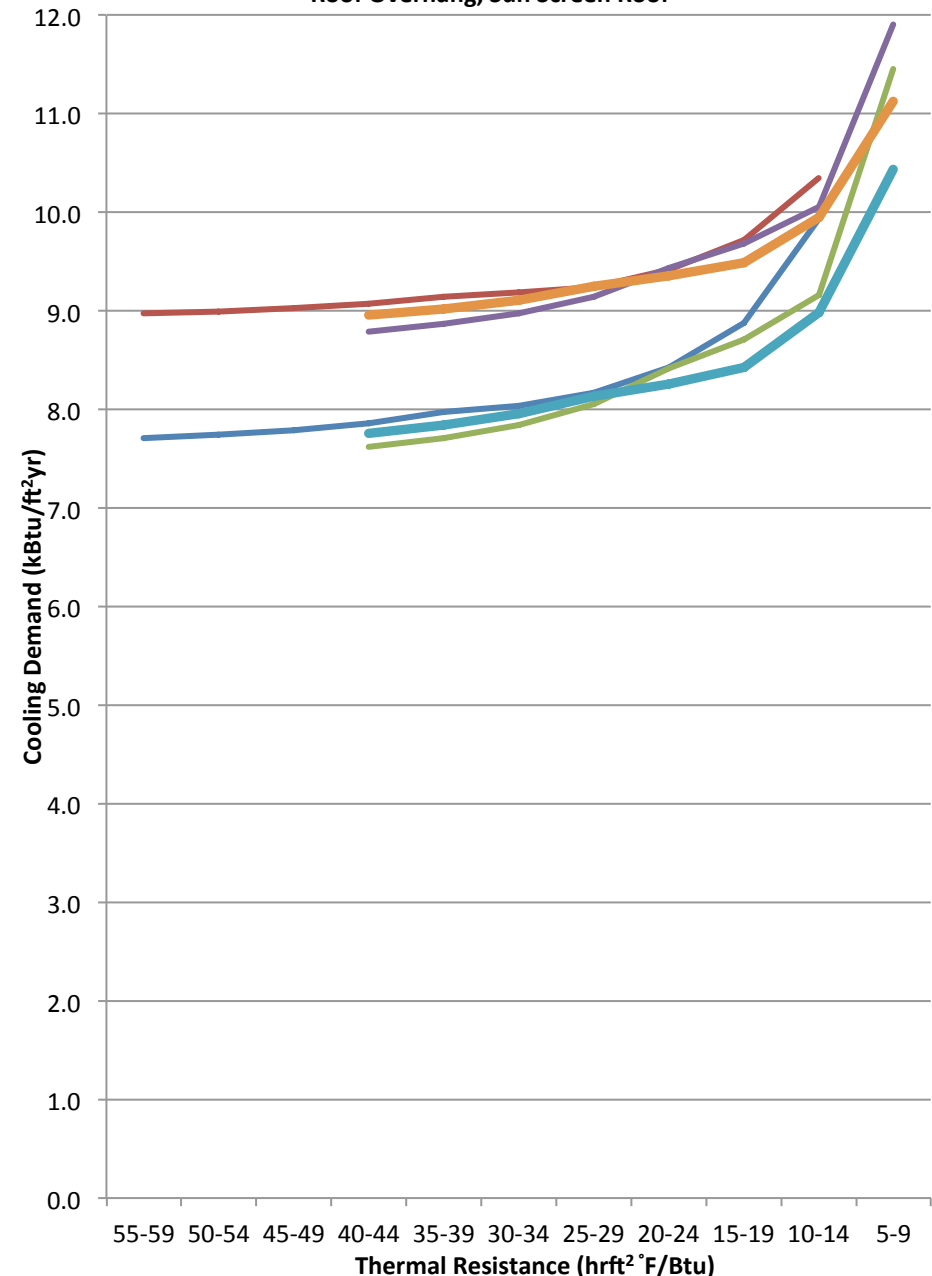
I Overhang I No Overhang RE Overhang RE No Overhang

I Overhang I No Overhang RE Overhang RE No Overhang

17: Heating Demand vs. Wall, Conventional and Sun Screen Walls, Roof Overhang, Sun Screen Roof



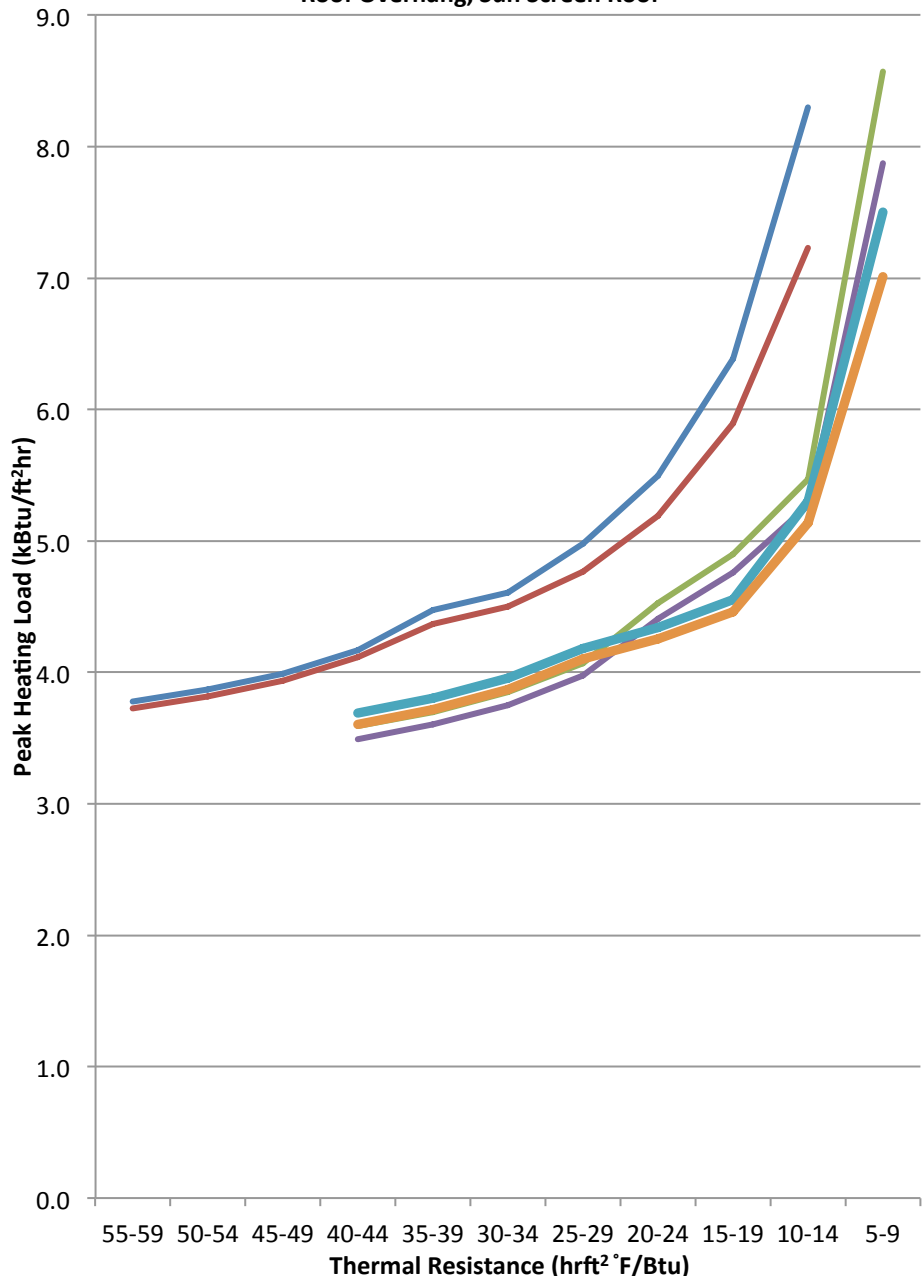
18: Cooling Demand vs. Wall, Conventional and Sun Screen Walls, Roof Overhang, Sun Screen Roof



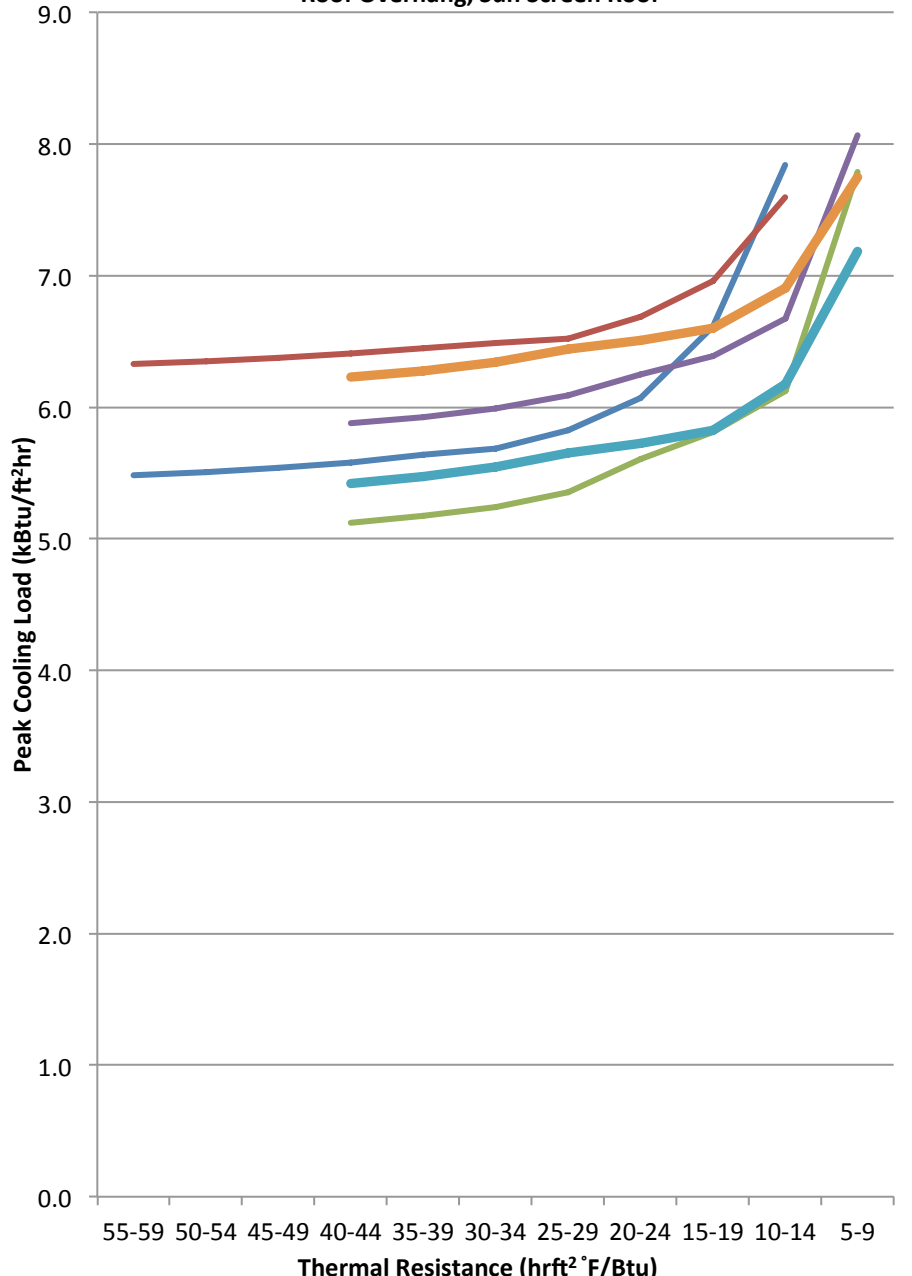
— I Sun Screen — I Conventional — RE Sun Screen
— RE Conventional — CMU Sun Screen — CMU Conventional

— I Sun Screen — I Conventional — RE Sun Screen
— RE Conventional — CMU Sun Screen — CMU Conventional

19: Peak Heating Load vs. Wall, Conventional and Sun Screen Walls, Roof Overhang, Sun Screen Roof



20: Peak Cooling Load vs. Wall, Conventional and Sun Screen Walls, Roof Overhang, Sun Screen Roof



— I Sun Screen — I Conventional — RE Sun Screen
— RE Conventional — CMU Sun Screen — CMU Conventional

— I Sun Screen — I Conventional — RE Sun Screen
— RE Conventional — CMU Sun Screen — CMU Conventional

Conclusions:

- Cooling load is about 3x heating load so decisions should be made that favor the cooling benefits.
- Thermal mass helps with heating and cooling, but only if insulated on the exterior.
- A cost analysis for the particular project should be done to decide if construction dollars should be spent on insulation or thermal mass.
- Insulation can be reduced by about 50% if 8"+ of thermal mass is used and insulated on the exterior side.
- Insulation levels of over R20-25 will have diminishing returns for cooling. For heating, insulation levels above R30 have diminishing returns.
- Shading is important and will reduce amount of insulation required, but has a slight penalty in heating season.
- Slab insulation is beneficial up to about R16.
- Sunscreen walls are beneficial and will reduce the cooling loads.