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Designing for Heat at the Edge: Validating Surface Temperature Predictions for Air Barrier Tie-ins
Stan Gatland
Saint-Gobain / CertainTeed
AIA Continuing Education Provider
abaa EDUCATION

Designing for Heat at the Edge: Validating Surface Temperature Predictions for Air Barrier Tie-ins

Stan Gatland
Manager, Building Science + Comfort
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Learning Objectives

1. Explain the importance of accurate rooftop surface temperature prediction critical for selecting appropriate air and water barrier tie-in materials at roof-to-wall interfaces.
2. Describe a validated simulation workflow to estimate rooftop and parapet surface temperatures.
3. Analyze the impact of environmental variables on roof surface temperatures.
4. Interpret field study results and quantify the influence of reflected solar radiation on roof and parapet temperatures to inform resilient design strategies.

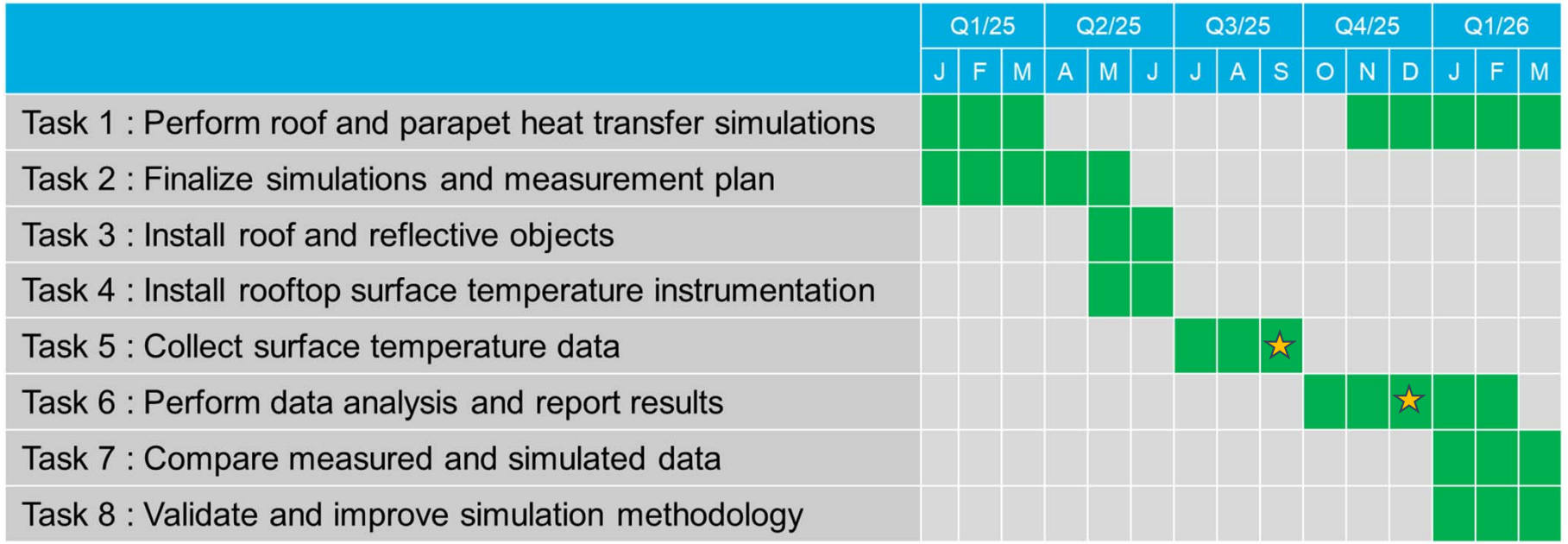
Introduction

- The roof-to-wall interface experiences extreme environmental loads
- Air and water control layers rely on flashings and tie-ins to maintain continuity between roofing and façade systems
- Upper service temperature limits range between 180°F and 300 °F
- Accurately predicting rooftop surface temperature extremes is critical for specifying appropriate membrane and flashing materials

Literature Survey

- Stephenson (1963) predicted a black roof membrane surface's temperature might exceed 230°F due to direct and reflected solar radiation
- Low slope roof surface temperature research limited to comparing black membranes with cool, green and adaptive roofing system technologies
- Dupuis (2014) published the most comprehensive low slope roof surface temperature study comparing measurements to a predictive heat transfer simulation

Research Project Timeline



air barrier abaa association of america

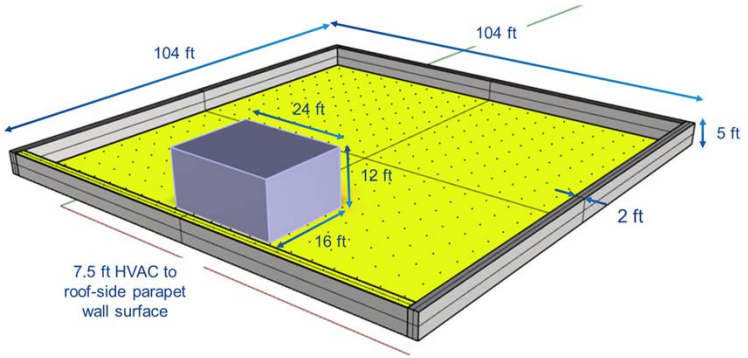
September 2025
Webinar

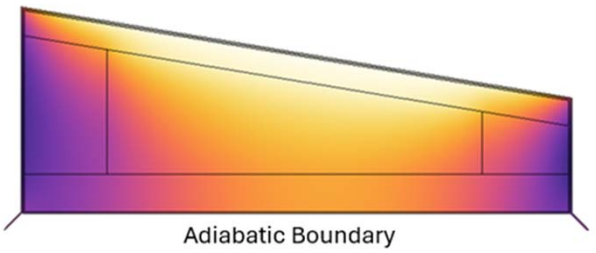
Buildings XVI Conference
December 8-11, 2025
Clearwater Beach, FL
ASHRAE Oak Ridge National Laboratory

December 2025
Conference

Surface Temperature Modeling (CS-FEA)

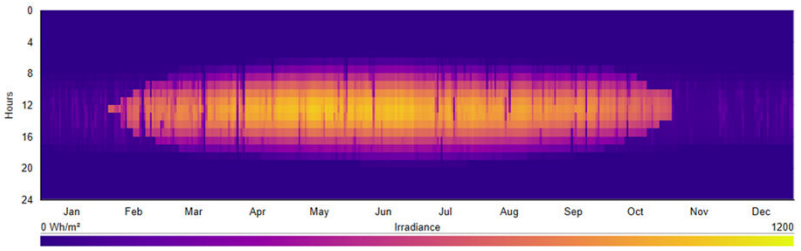
- Combination of a solar radiation map simulation workflow with finite element analysis heat transfer module to simulate rooftop surface temperature
- Create a 3D geometric model with specified surface material physical properties
- Solar radiation analysis generates total surface irradiance values using historical, typical meteorological year (TMY) weather data files
- Rooftop surface radiative heat flux values used as boundary conditions to perform 1D and 2D heat transfer simulations
- Predicts rooftop surface temperatures





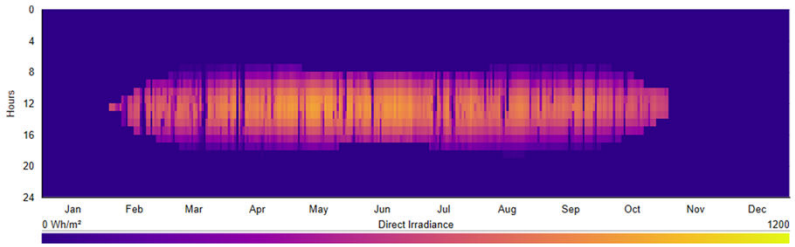
Solar Radiation Mapping (Location: Phoenix AZ - No Reflection)

Annual Total Solar Radiation



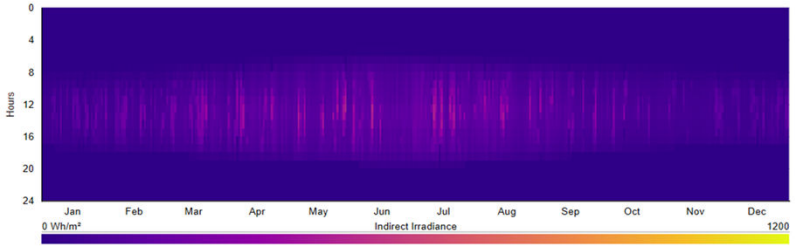
March 23 (12 pm) **911 Wh/m²**

Annual Direct Solar Radiation



March 23 (12 pm) **796 Wh/m²**

Annual Indirect Solar Radiation



March 23 (12 pm) **115 Wh/m²**

Dupuis Roof Membrane Temperature Research (2014)

Roof Membrane Comparison in Manhattan, KS (August 2010)

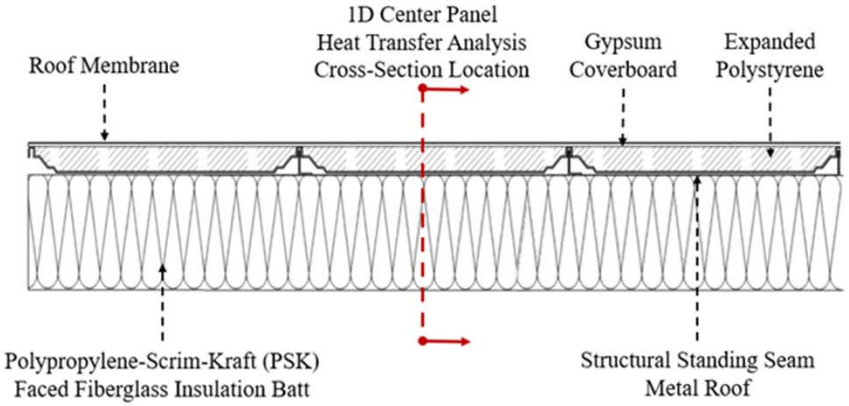


Figure 3 Test bed facility overview and roof membrane system assembly details – Manhattan, KS (Dupuis 2014).

Dupuis 2014, "Sensitivity Analysis of Error in a Roof Membrane Temperature Model Versus Input Data", PhD Dissertation, University of Wisconsin - Madison

Rooftop surface temperature model validation

Heat Transfer Analysis Simulation Matrix

Table 4. Heat Transfer Analysis Simulation Matrix

Method	Weather Data	Date/Hour	Total Surface Radiation G (W/m^2)	Air Temperature T_A (°C)	Wind Speed V_{10} (m/s)	CHTC Equation h_c (W/m^2)
A	Measured	Actual	CS Radiation Map	Measured	Measured	Dupuis (1)
B	TMY	Selected	CS Radiation Map	TMY	TMY	Lui + Harris (2)

$$h_c\ (W/m^2) = 1.773 * V_r + 7.1864 \quad (1)$$

$$h_c\ (W/m^2) = (0.90 * V_{10}) + 3.28\ (\text{leeward}) \quad (2)$$

TMY = typical meteorological year
CHTC (hc) = convective heat transfer coefficient [W m-2 or Btu h-1 ft-2]
Vr = wind speed measured 1 m above the roof surface [m s-1 or mi hr-1 (mph)]
V10 = wind speed measured 10 m above the ground [m s-1 or mph]
TA = outdoor air temperature [°C or °F]
Ts = rooftop surface temperature [°C or °F]

CS-FEA Surface Temperature Simulation Methods (A + B)

Model Validation with Dupuis Results (Black Roof)

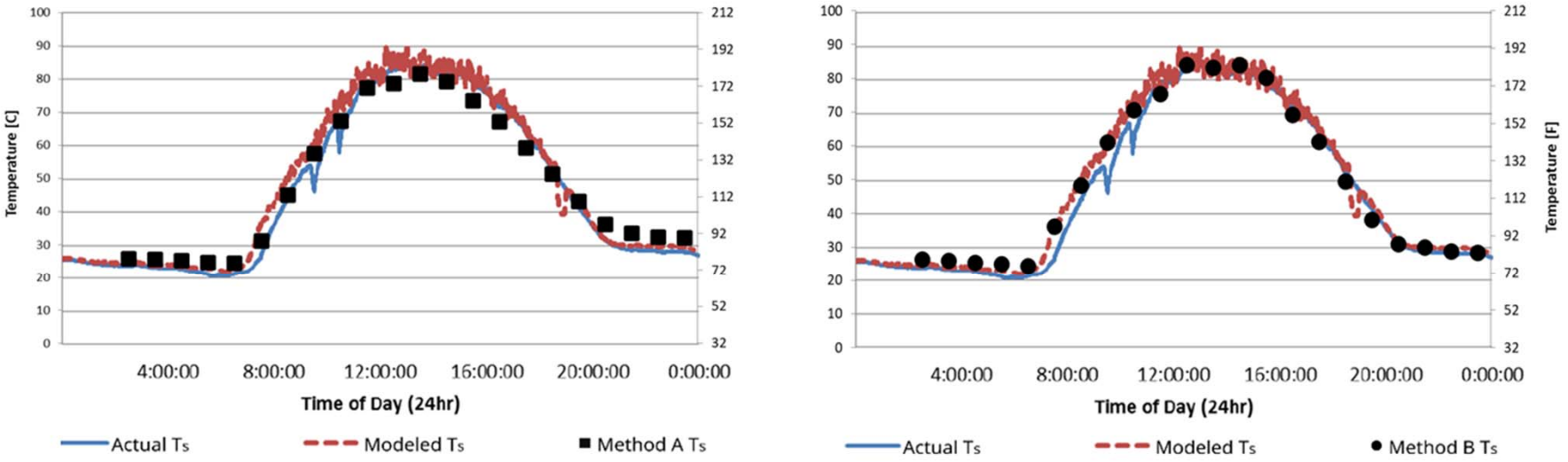


Figure 4 Black EPDM roof membrane surface temperature comparison, Actual and Modeled (Dupuis), Method A and B Simulated (CS-FEA)

CS-FEA Surface Temperature Simulation Methods (A + B)

Model Validation with Dupuis Results (White Roof)

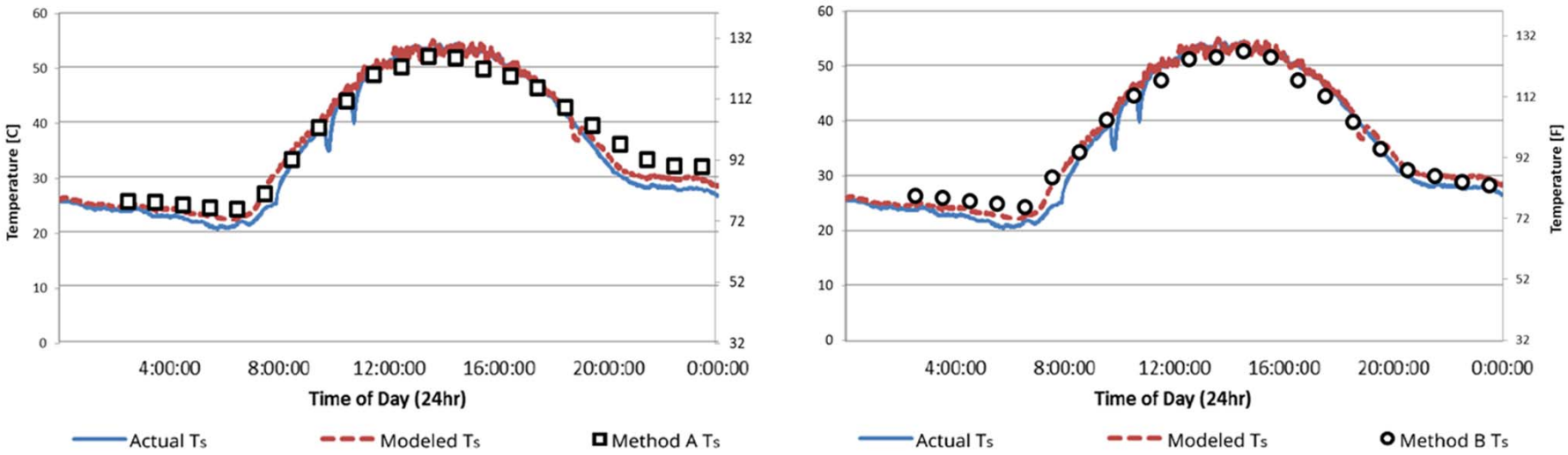


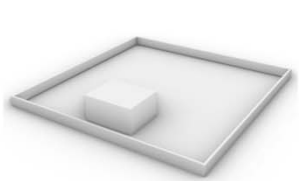
Figure 5 White 60 mil EPDM roof membrane surface temperature comparison, Actual and Modeled (Dupuis), Method A and B Simulated (CS-FEA)

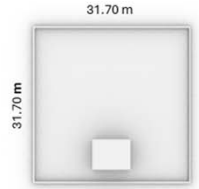
Surface Temperature Simulation Matrix

CS Radiation Mapping of Rooftop Surface with and without Reflective Object

Table 1. Roof Membrane and Parapet Coping Cover Extreme Surface Temperature Simulation Matrix

Location	Climate Zone	Roof Color	Reflective Object
Phoenix, AZ	2B	Black	Yes / No
		White	Yes / No
Colorado Springs, CO	5B	Black	Yes / No
		White	Yes / No





Aluminum Cladding
(64.7% reflectance)

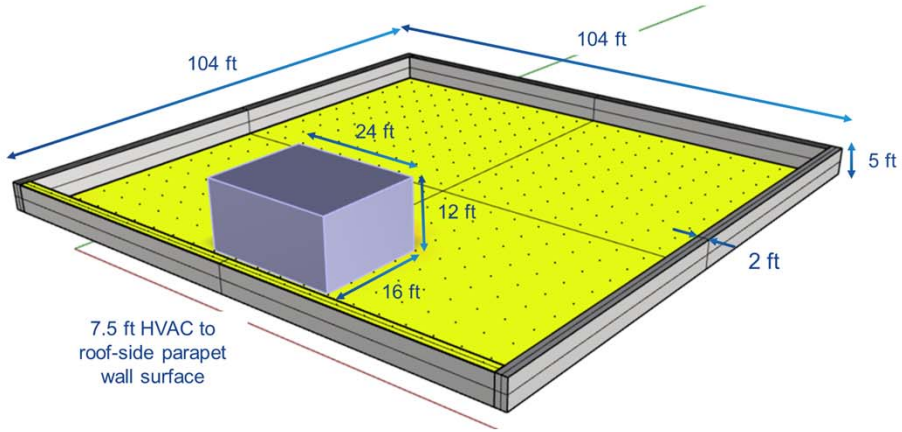
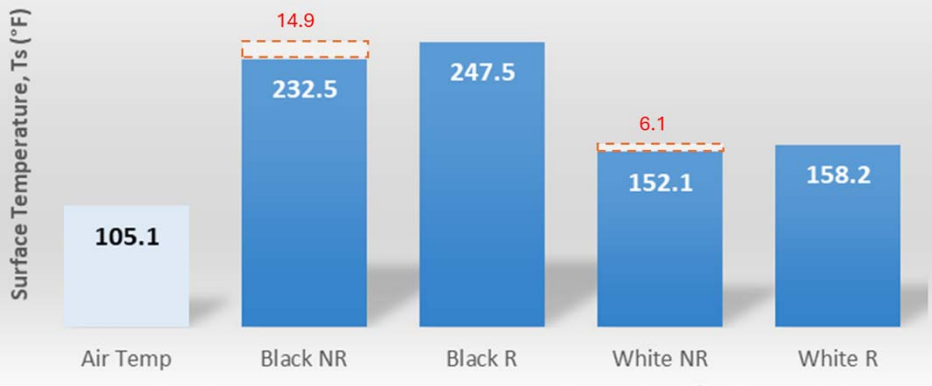
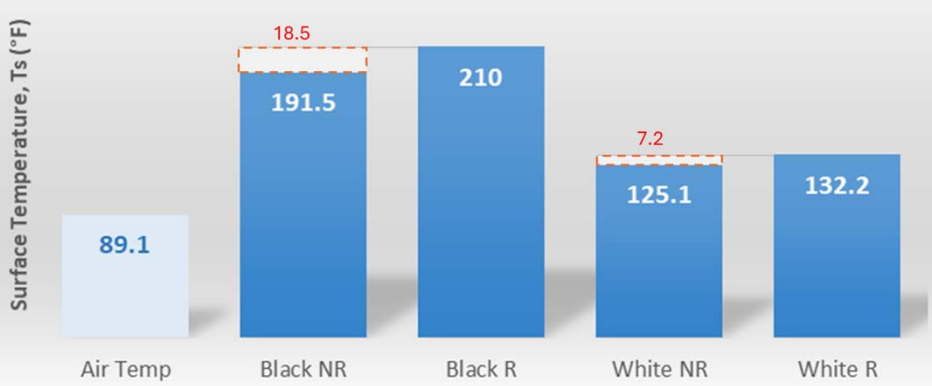


Table 6 Black and White Roof Membrane Surface Temperature Comparison (Phoenix, Arizona)



Roof Surface Membrane Conditions – No Reflection (NR) / Reflection (R)

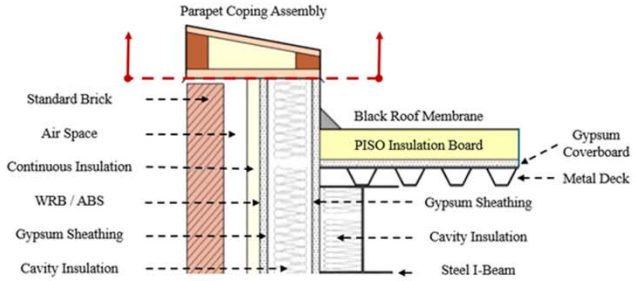
Table 6 Black and White Roof Membrane Surface Temperature Comparison (Colorado Springs, CO)



Roof Surface Membrane Conditions – No Reflection (NR) / Reflection (R)

2-D Parapet Coping assembly Heat Transfer Model

Coping Cover Surface Temperature



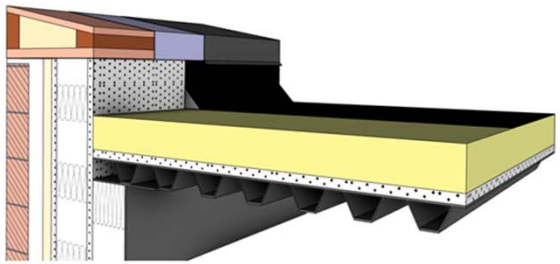
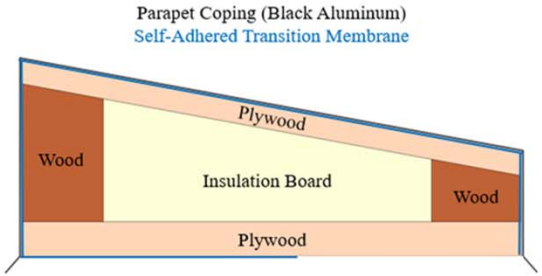


Figure 6 Parapet roof-wall intersection.



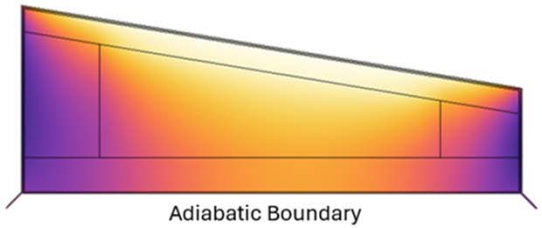
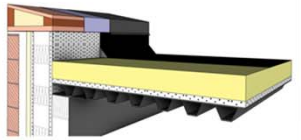
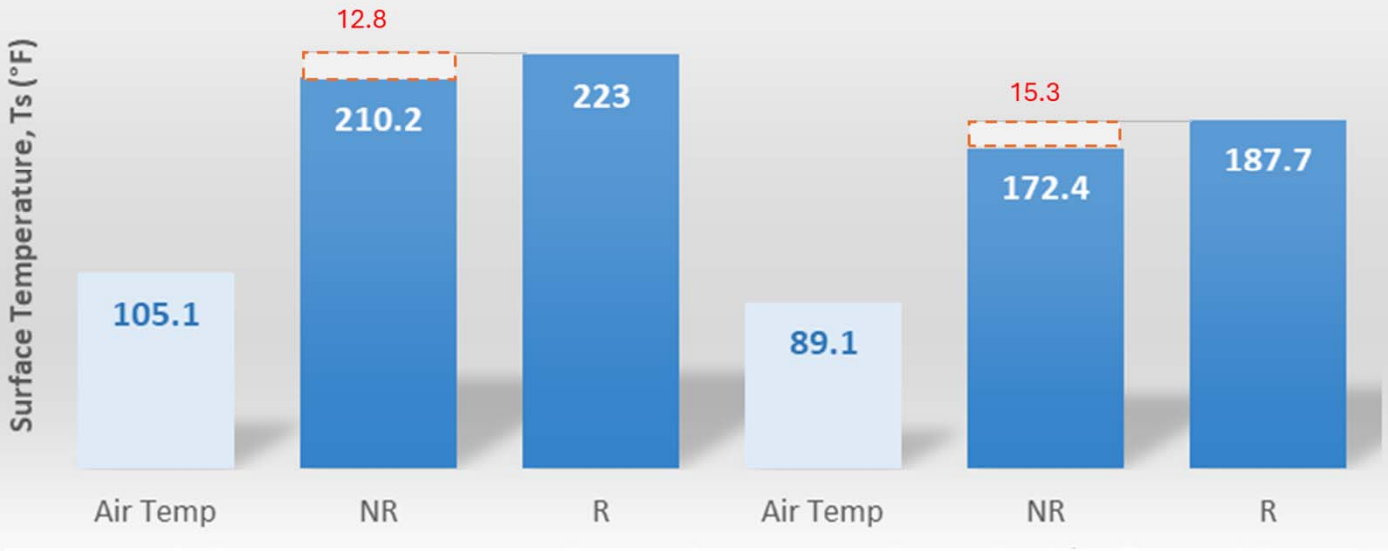


Figure 7 Parapet coping assembly model details and steady-state heat transfer simulation image.

Table 7

Black Matte Coping Cover Surface Temperature Comparison (Phoenix vs. Colorado Springs)

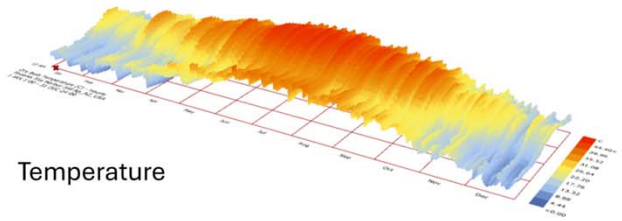


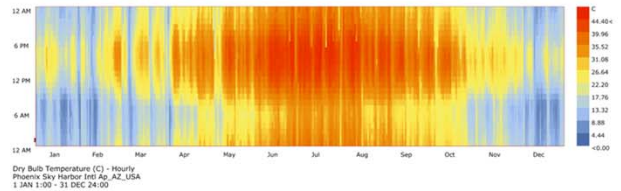


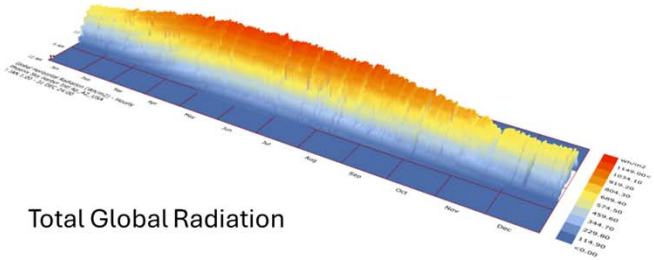
Black Matte Coping Cover Surface Conditions – No Reflection (NR) / Reflection (R)

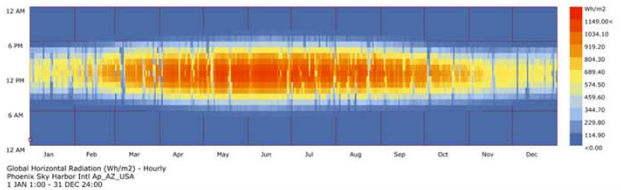
Visualizing Air Temperature & Solar Radiation

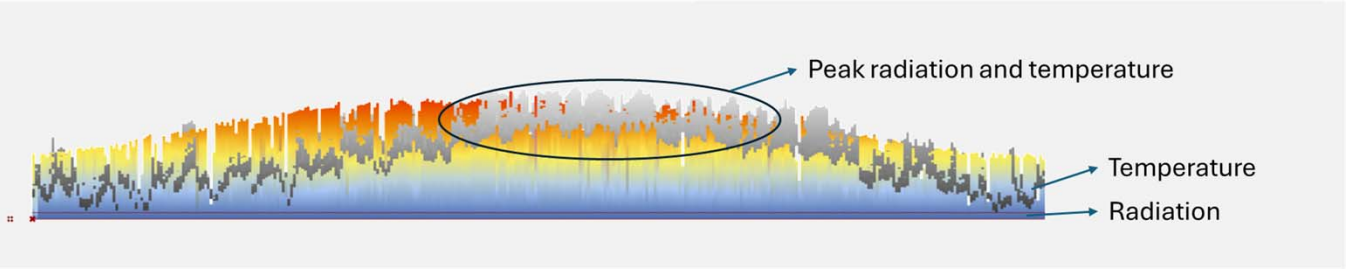
Phoenix, Arizona Example



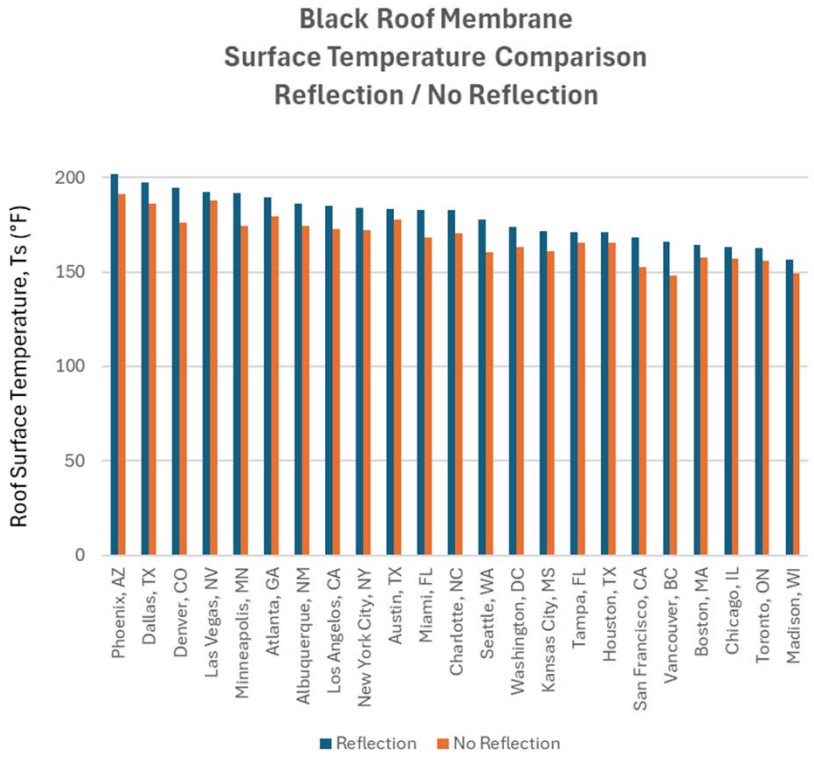


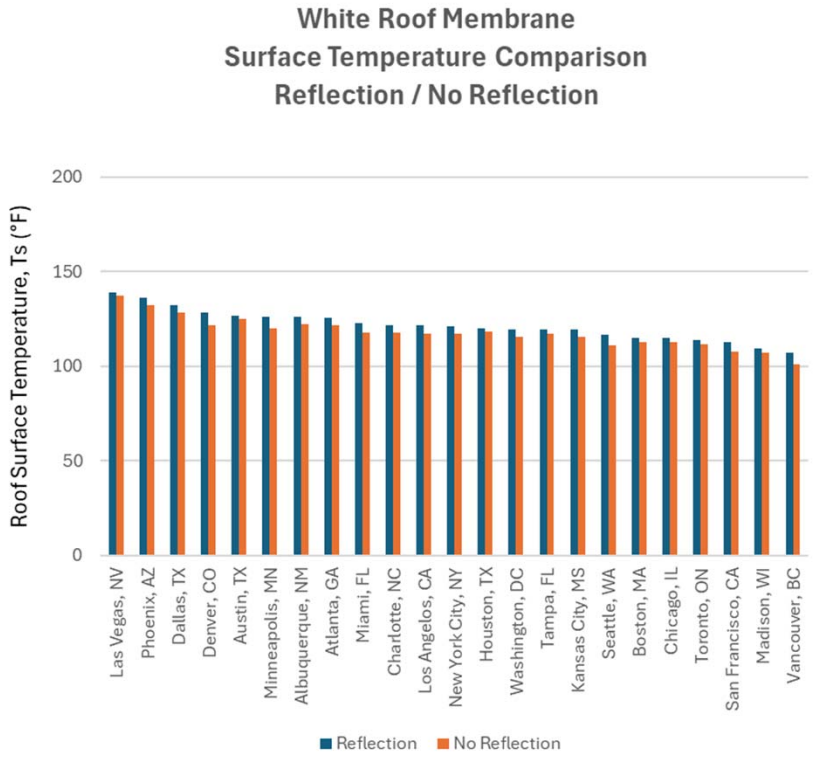




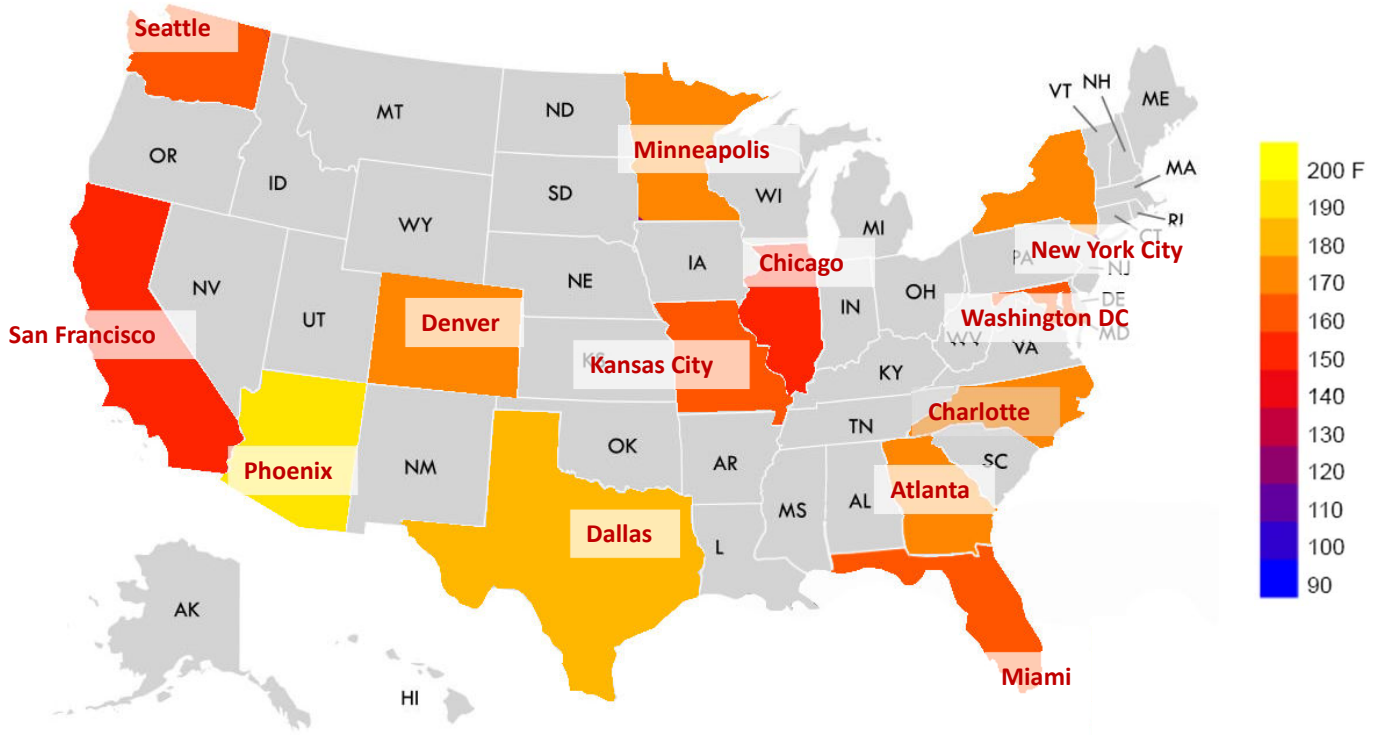


North American Parametric Analysis

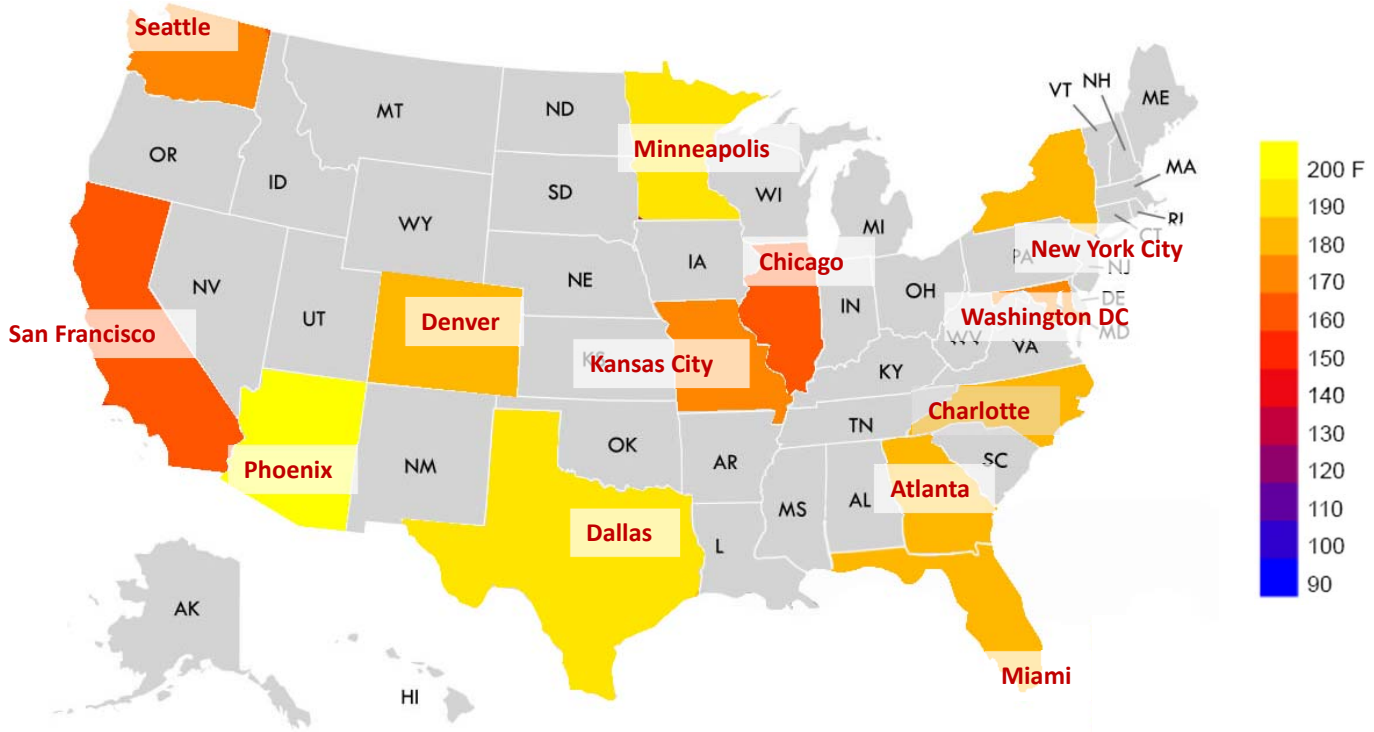




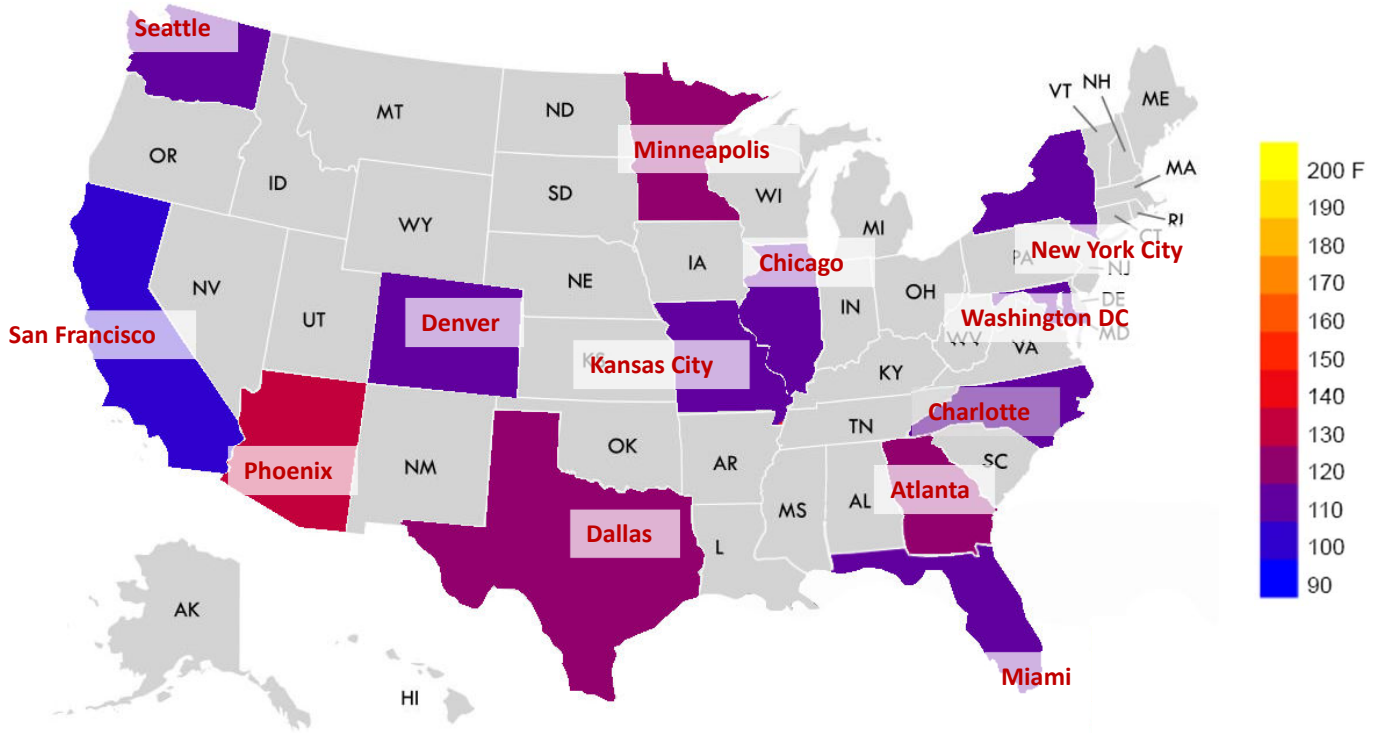
Black Roof / No Reflection (NR)



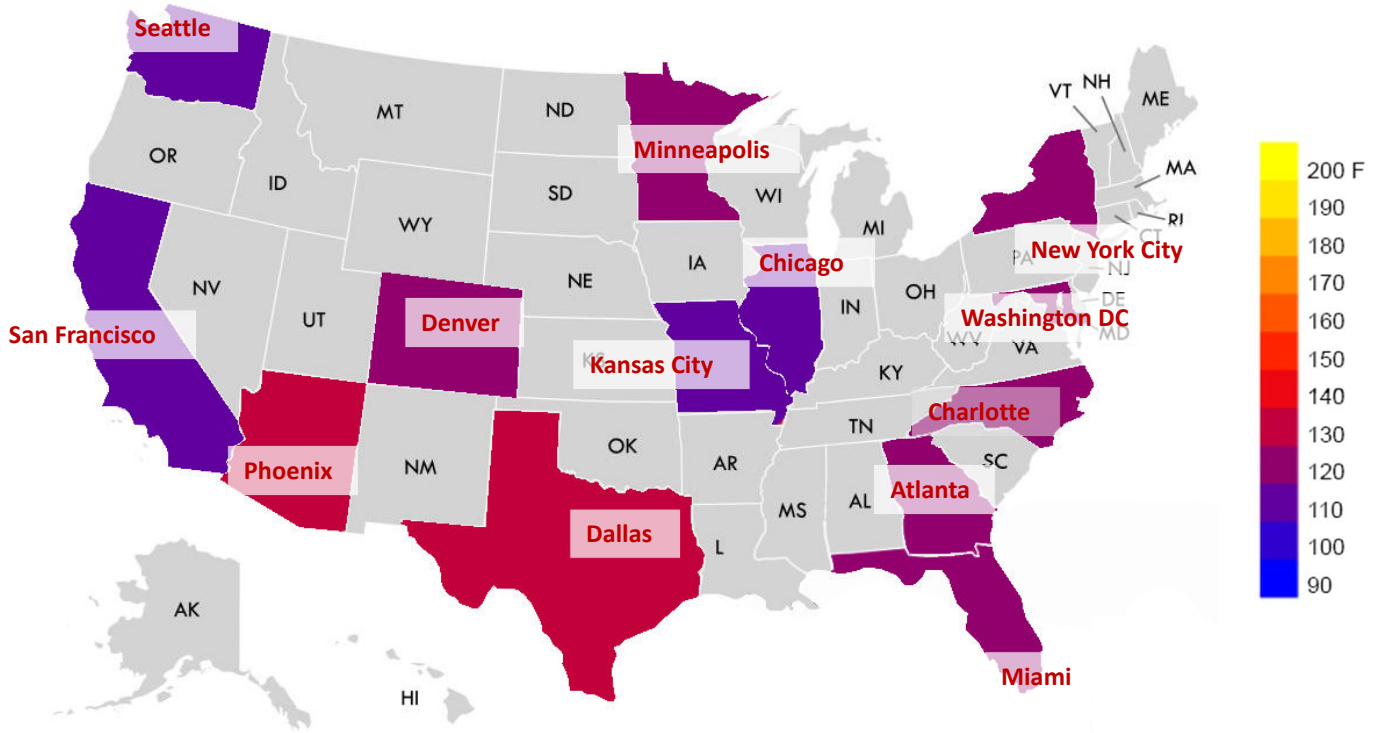
Black Roof / Reflection (R)



White Roof / No Reflection (NR)



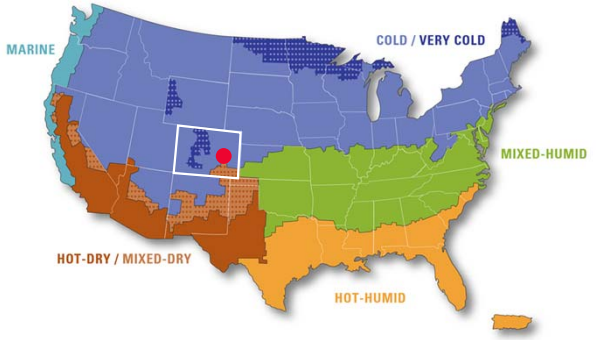
White Roof / Reflection (R)



Extreme Rooftop Surface Temperature

Research Project Partner Selection Process

- Partner with the Colorado School of Mines, Golden, Colorado (Denver)
- Cold and dry climate with high seasonal air temperatures and extreme solar radiation
- 30+ people involved (Building Science, Product Management, R&D, Sales, Finance, Engineering School, Facilities, EHS, Corporate Relations & Foundation, Roofing Contractor)

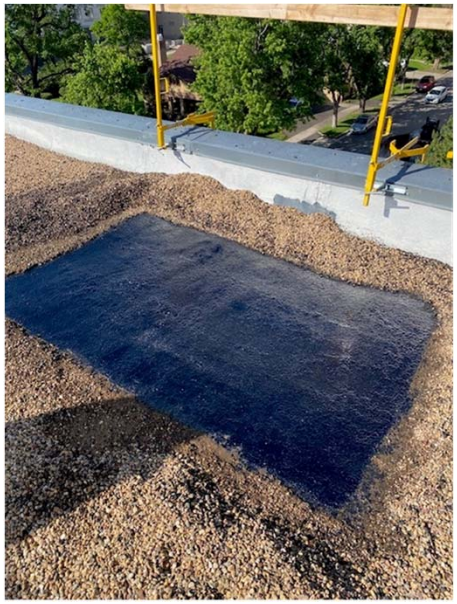


Continental USA Climate Zone Map Descriptions

Rooftop Experiment

Southeast Corner of Brown Building Rooftop

Parapet Coping Flashing Membrane Install and Roof Surface Preparation



Stone ballast and embedded stone removed, and asphalt surface torched

White + Black Roof Membranes

Parapet cap removed, surface coated with adhesive primer, tie-in flashing installed, and parapet cap replaced

Corner Roof Membrane
Parapet Coping Cap

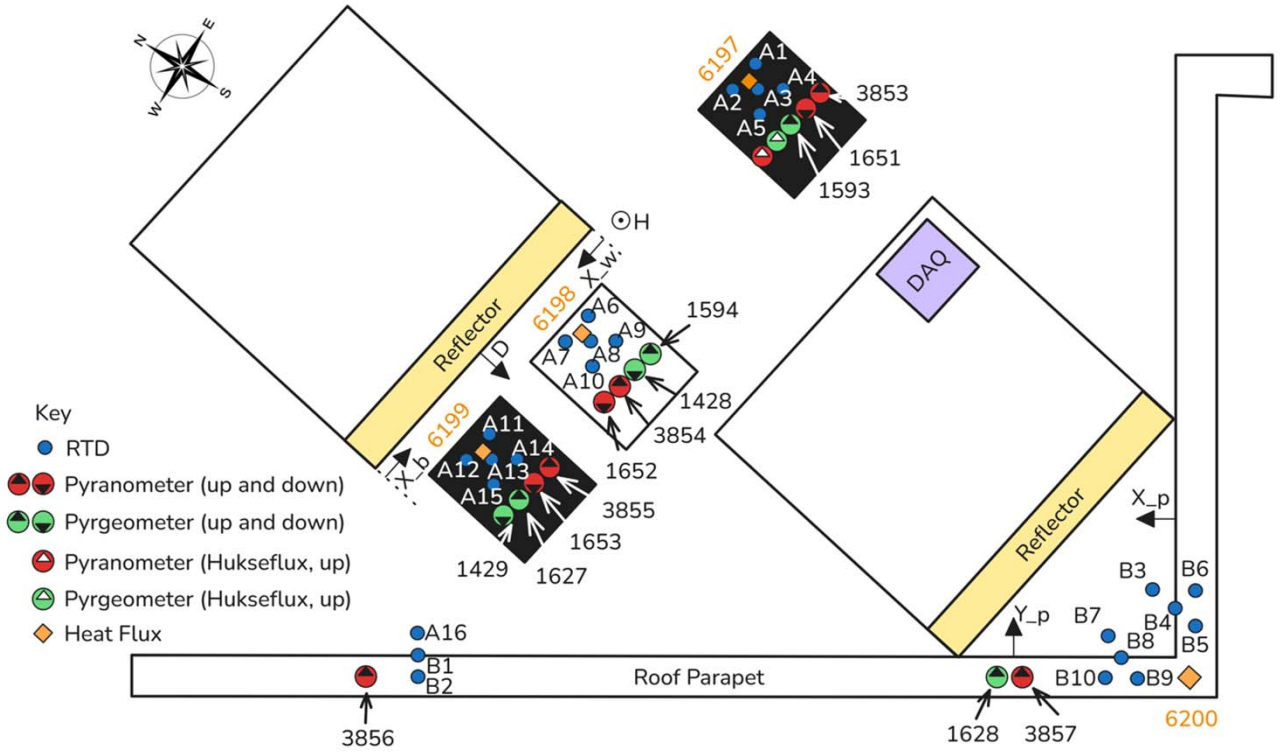
Roof Surface Measurement Sensors

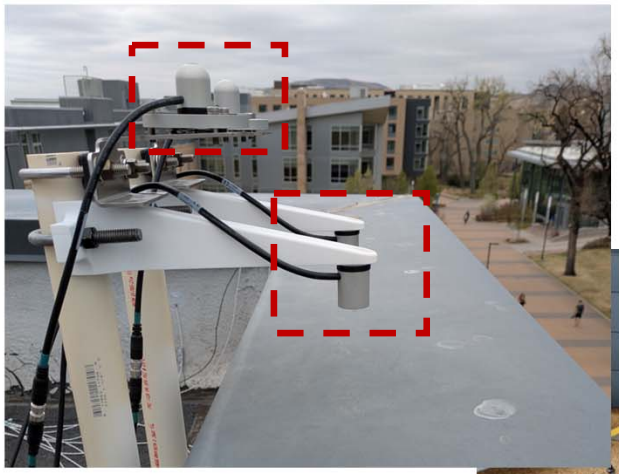
Brown Hall Engineering Building Rooftop Measurements

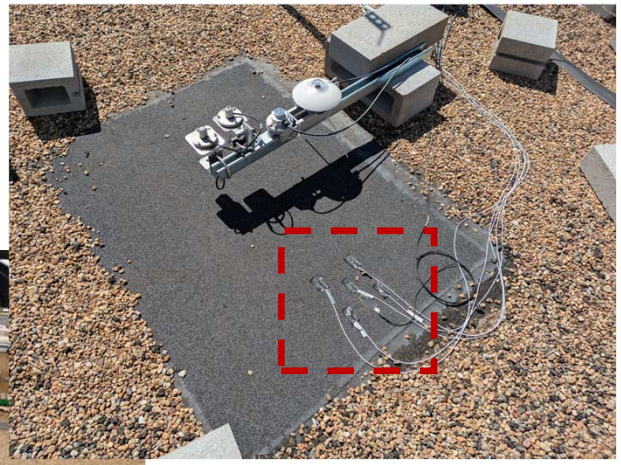
- Five (5) resistance temperature detectors
- One (1) heat flux sensor
- Solar (short-wave) radiation sensors
  - Two (2) pyranometers facing up (Incoming)
  - Two (2) pyranometers facing down (Reflected)
- Thermal (long-wave) radiation sensors
  - Two (2) pyrgeometers facing up (Incoming)
  - Two (2) pyrgeometers facing down (Emitted)
- Weather station
  - Air temperature
  - Relative humidity
  - Barometric pressure
  - Wind speed
  - Wind direction
  - Solar radiation

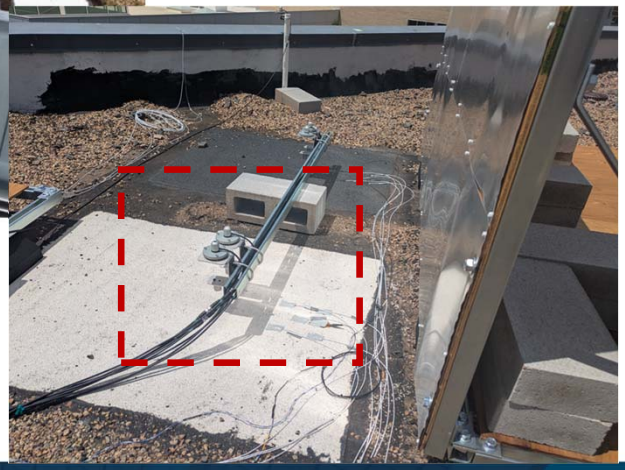
Colorado School of Mines – Dr. Paulo Tabares

Brown Hall Engineering Building Rooftop Measurements









Southeast Corner of Brown Building Rooftop

Measurement Locations for Parapet Coping Cover and Roof Surfaces

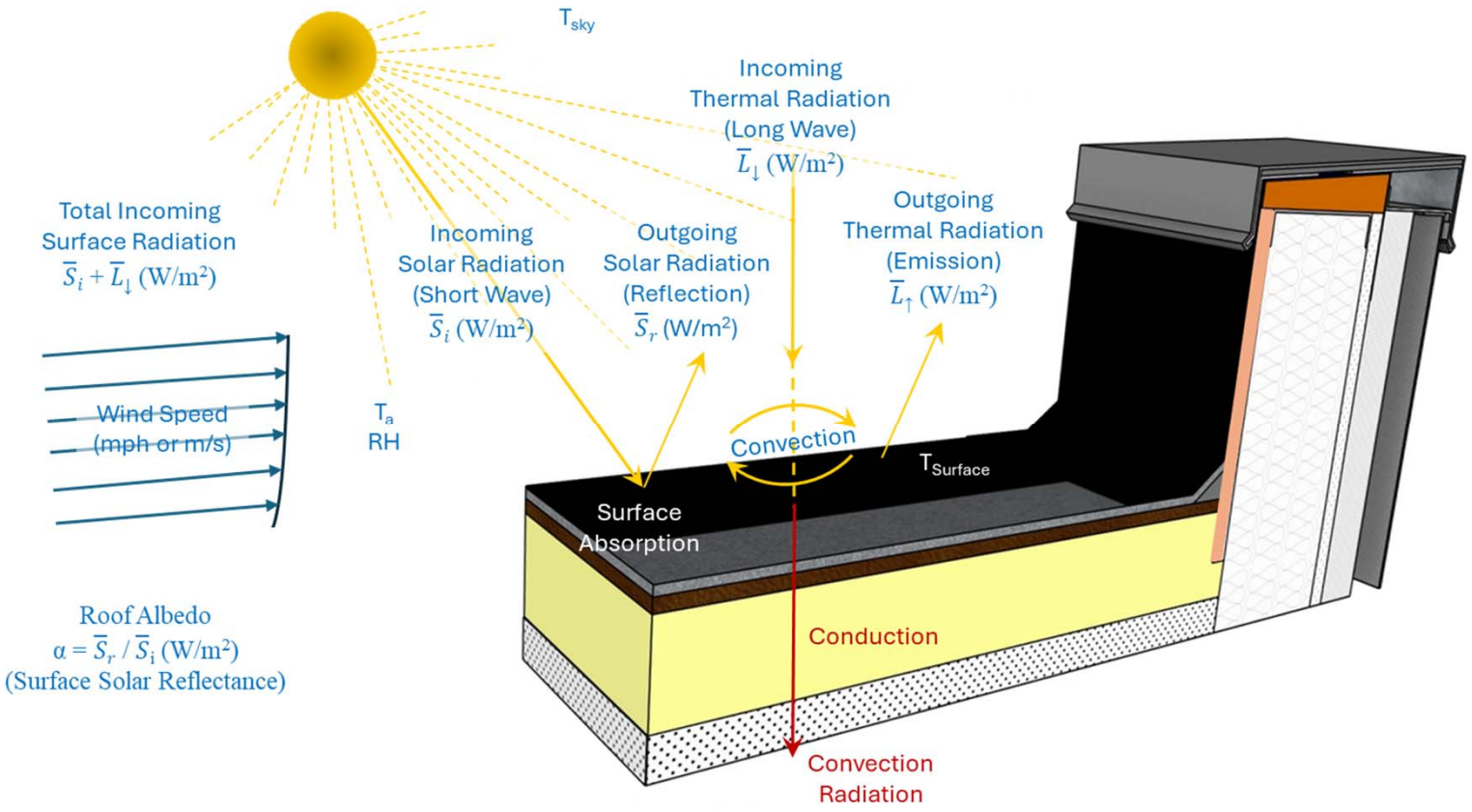
Vertical Reflective Surface
Mounting Frames on Unistrut Sleds

Roof membranes with adjacent vertical reflective panel surface

Rooftop Drone Photos

Colorado School of Mines Brown Engineering Building

Roof Surface Energy Balance



Roof Surface Energy Balance

Solve for Surface Temperature, T_s

$$\dot{Q}_{rad} - \dot{Q}_{conv} - \dot{Q}_{cond} = 0$$

$$\dot{Q}_{rad} = (1 - \rho)\, A\, \overline{Si} - \varepsilon\, \sigma\, A \left(T_s^4 - T_{sky}^4\right)$$

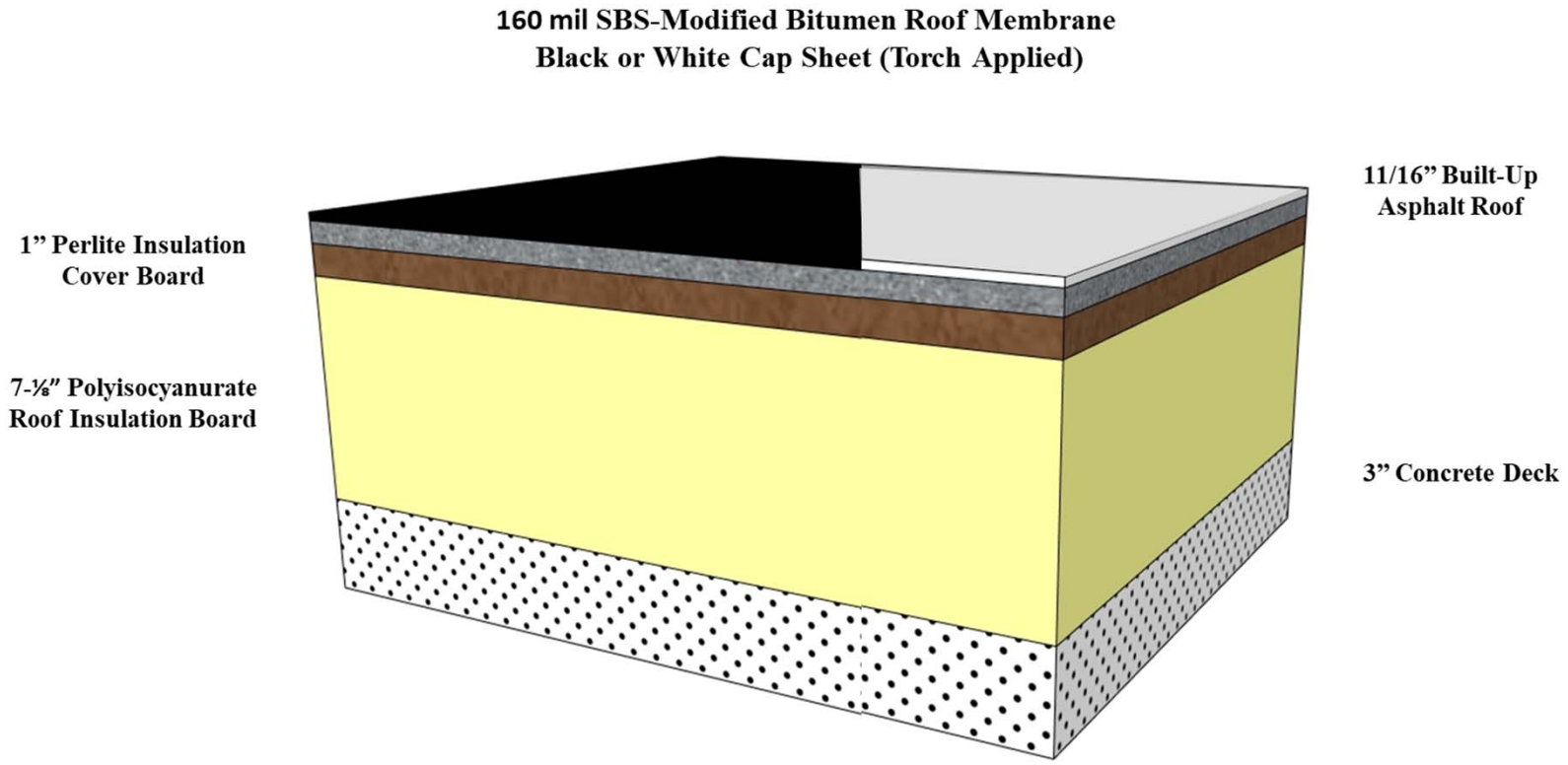
$$\dot{Q}_{conv} = h\, A\, (T_s - T_{sky})$$

$$h = (0.90\, V_{10}) + 3.28$$

$$\dot{Q}_{cond} = -k\, A\, (T_s - T_i) \neq 0 \text{ (negligible)}$$

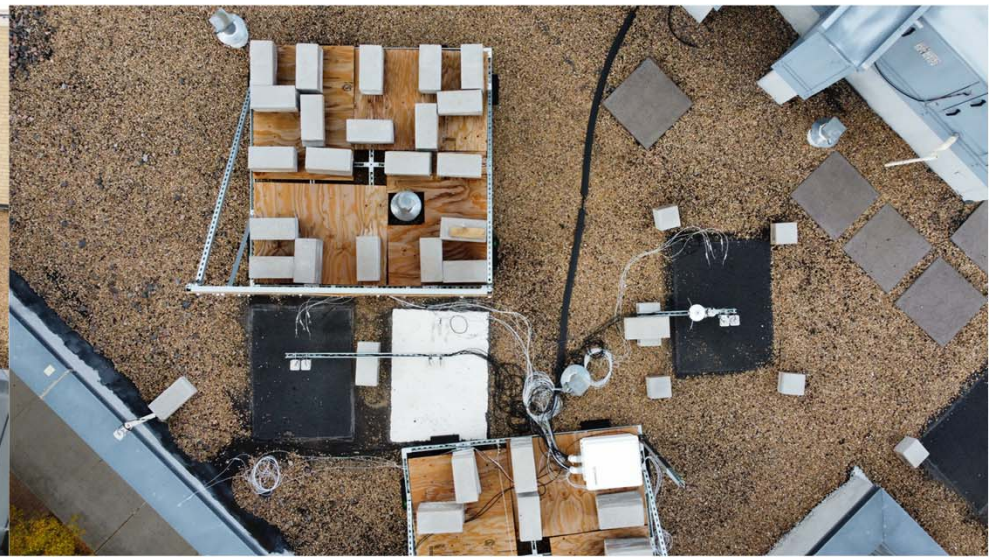
$$(1 - \rho)\, A\, \overline{Si} - \varepsilon\, \sigma\, A \left(T_s^4 - T_{sky}^4\right) - ((0.90\, V_{10}) + 3.28)) * (T_s - T_{sky}) = 0$$

One-Dimensional Geometric Roof Model

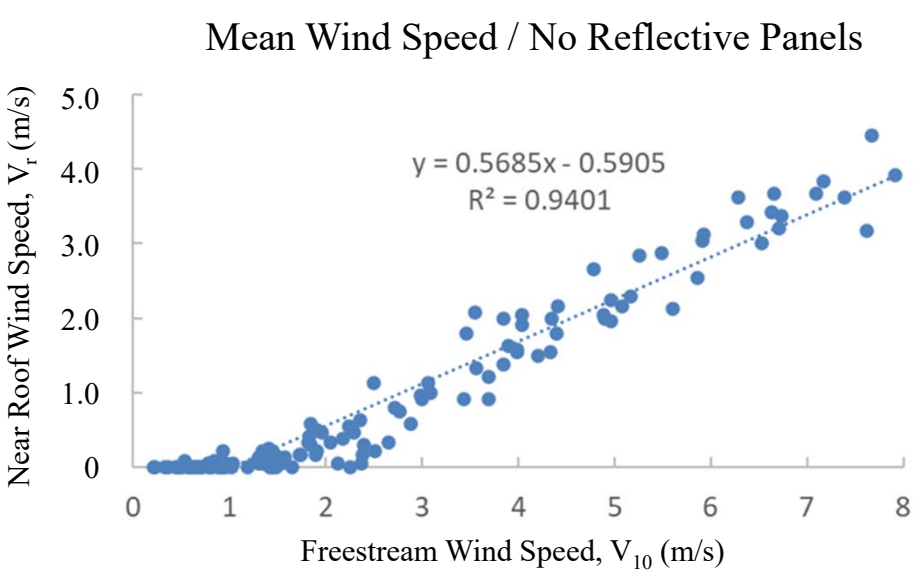


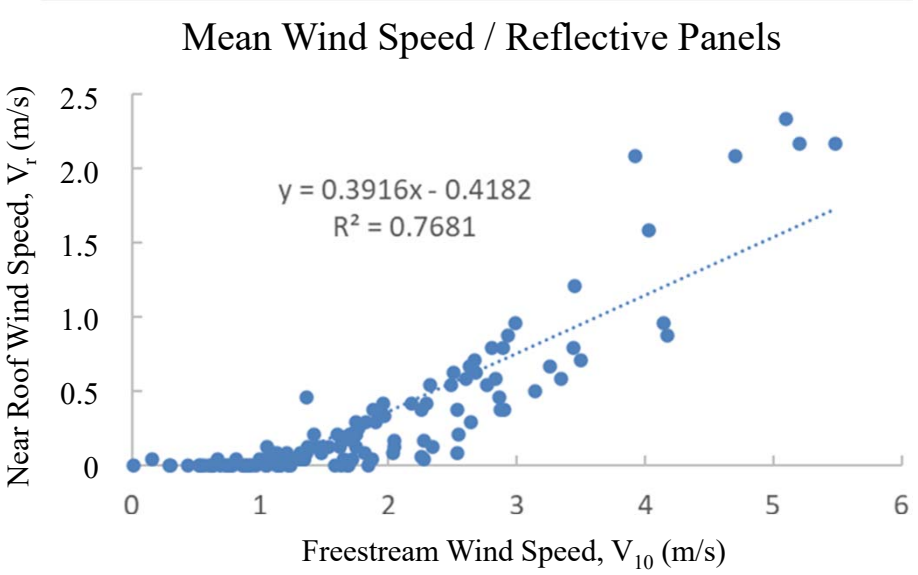
Rooftop Experimental Setup

Colorado School of Mines Brown Engineering Building



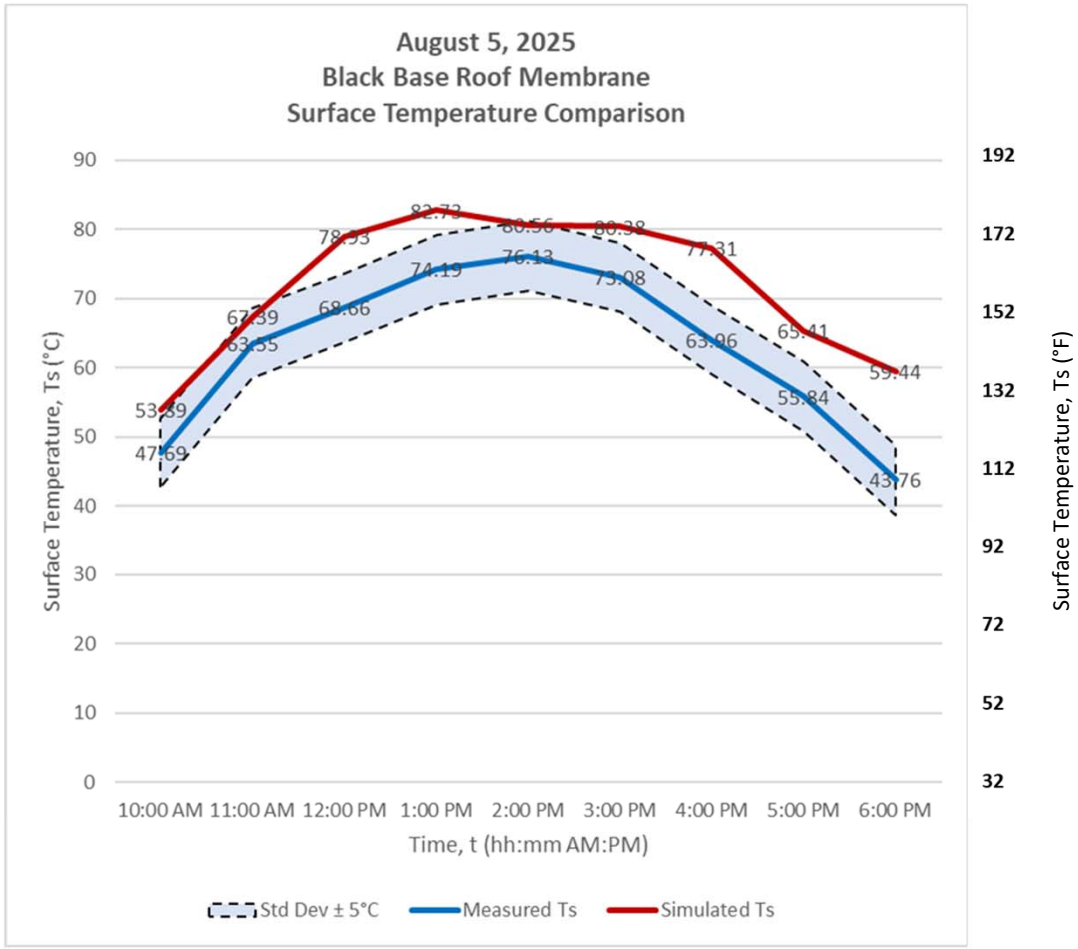
Wind Speed Correction

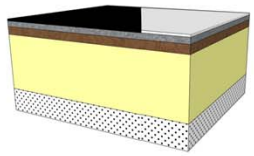


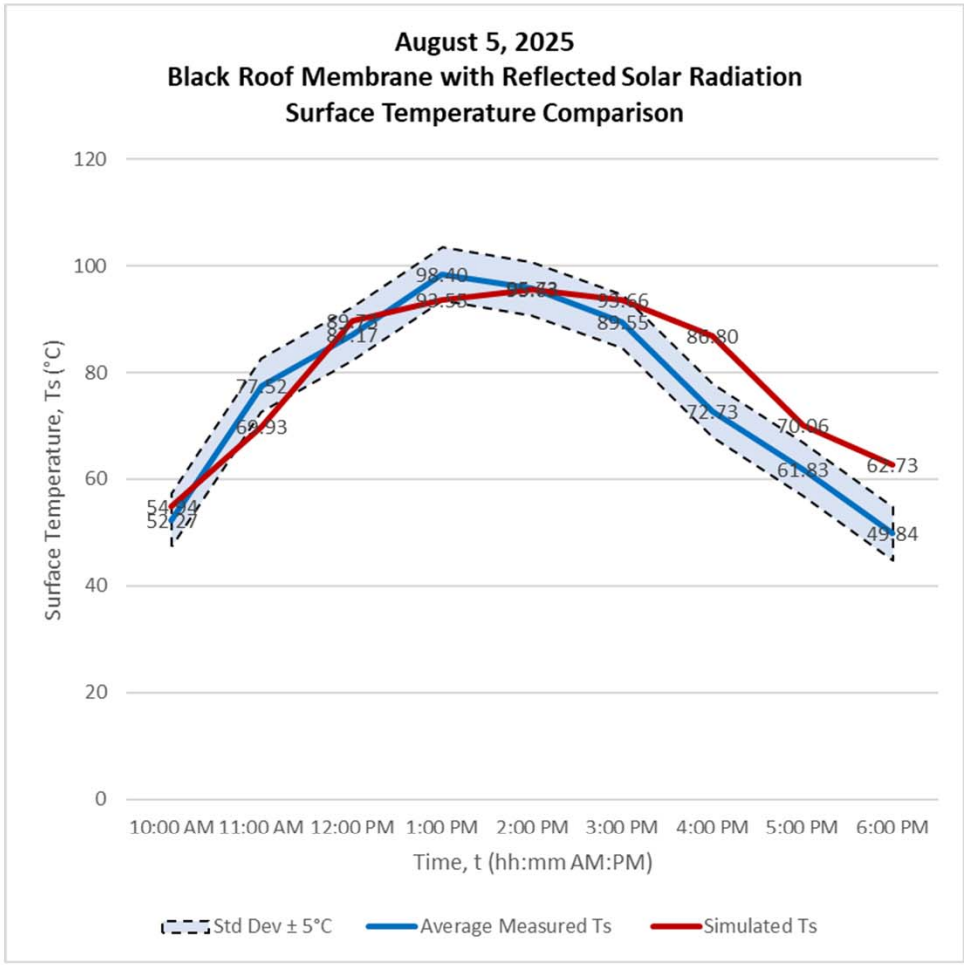


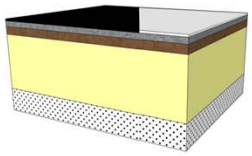
212
192
172
152
132
112
92
72
52
32

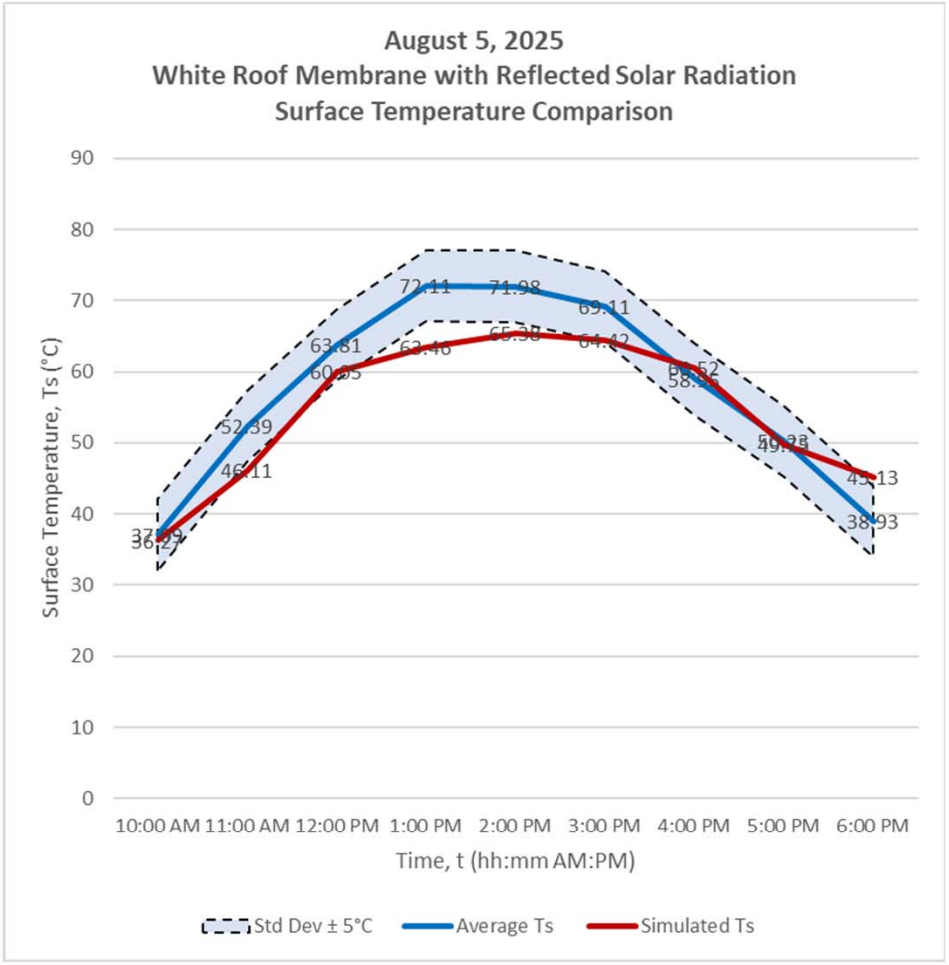
Temperature [F]

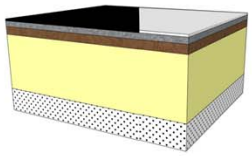




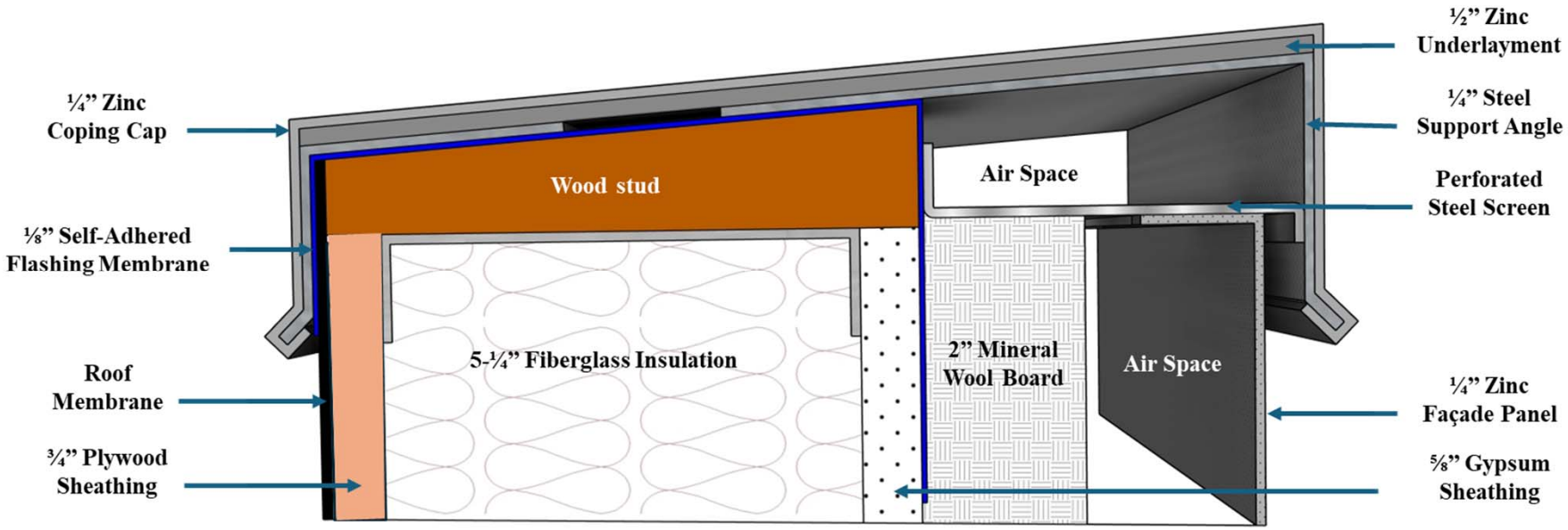

August 5, 2025
Black Roof Membrane with Reflected Solar Radiation
Surface Temperature Comparison
Surface Temperature, Ts (°C)
Surface Temperature, Ts (°F)
120
100
80
60
40
20
0
252
232
212
192
172
152
132
112
92
72
52
32
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
Time, t (hh:mm AM:PM)
Std Dev ± 5°C
Average Measured Ts
Simulated Ts



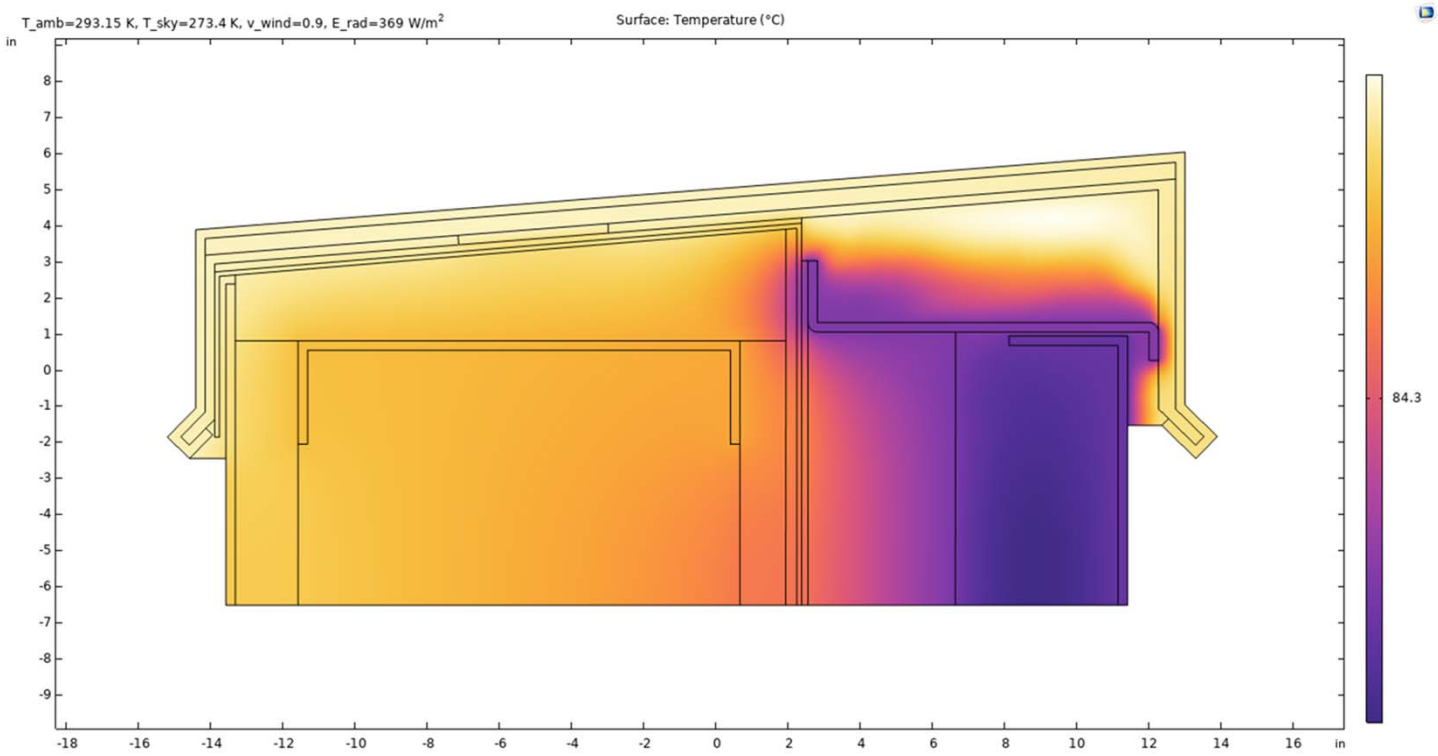

August 5, 2025
White Roof Membrane with Reflected Solar Radiation
Surface Temperature Comparison
Surface Temperature, Ts (°C)
Surface Temperature, Ts (°F)
90
80
70
60
50
40
30
20
10
0
192
172
152
132
112
92
72
52
32
72.11
71.98
69.11
63.81
63.46
65.38
64.42
60.85
52.39
46.11
38.93
10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM
Time, t (hh:mm AM:PM)
Std Dev ± 5°C
Average Ts
Simulated Ts

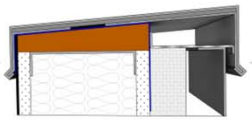


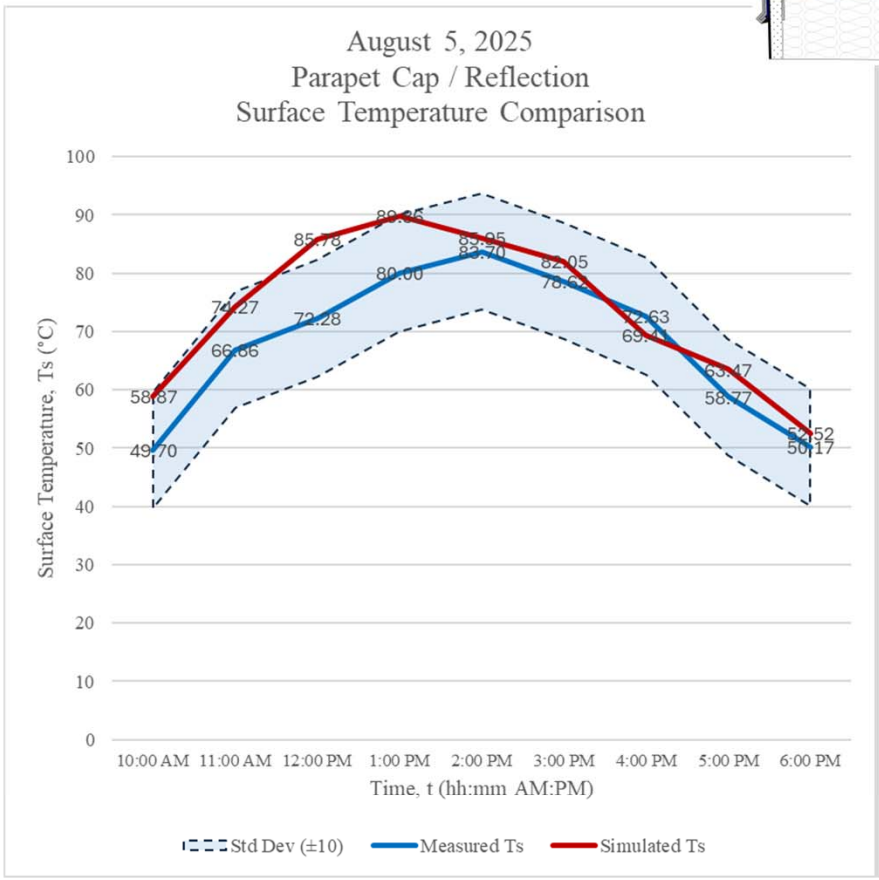
Two-Dimensional Parapet Geometric Model

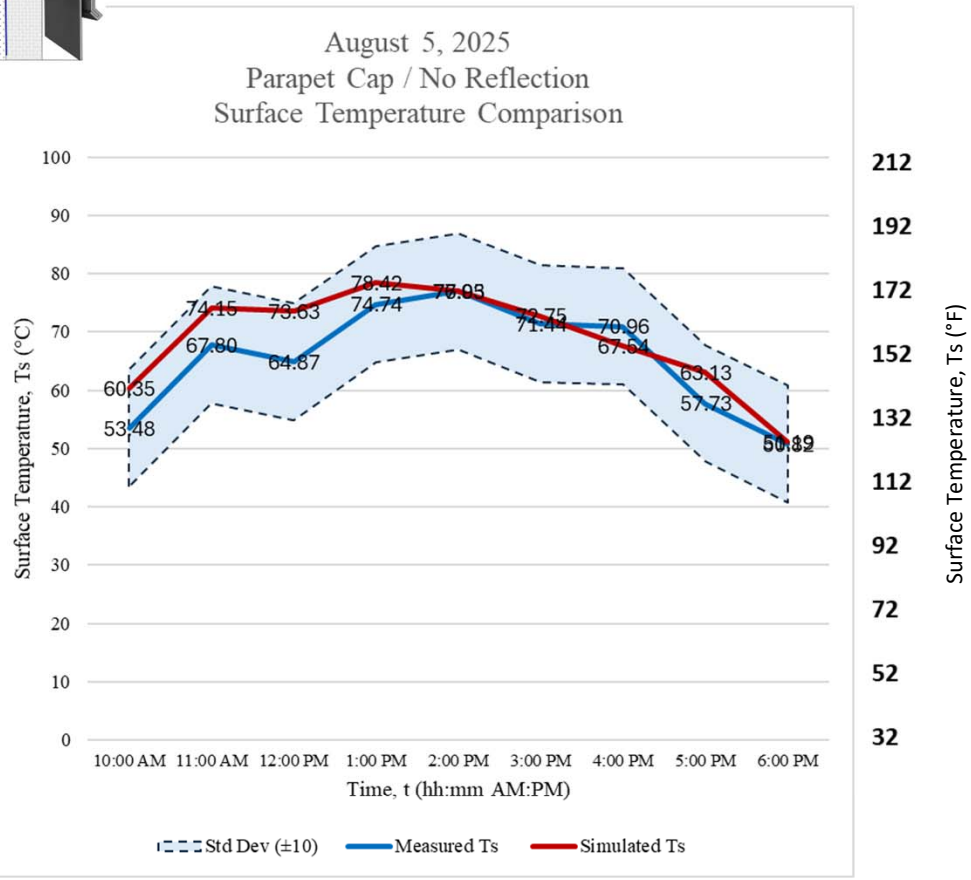


Two-Dimensional Geometric Model - Parapet






August 5, 2025
Parapet Cap / Reflection
Surface Temperature Comparison
Surface Temperature, Ts (°C)
100
90
80
70
60
50
40
30
20
10
0
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
Time, t (hh:mm AM:PM)
58.87
74.27
85.78
89.96
85.95
82.05
72.63
63.47
52.52
49.70
66.66
72.28
80.00
83.70
78.62
69.44
58.77
50.17
Std Dev (±10)
Measured Ts
Simulated Ts


August 5, 2025
Parapet Cap / No Reflection
Surface Temperature Comparison
Surface Temperature, Ts (°C)
100
90
80
70
60
50
40
30
20
10
0
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
Time, t (hh:mm AM:PM)
74.15
73.63
78.42
76.98
71.41
70.96
63.13
60.35
67.80
64.87
74.74
71.44
67.54
57.73
53.48
Std Dev (±10)
Measured Ts
Simulated Ts
212
192
172
152
132
112
92
72
52
32
Surface Temperature, Ts (°F)

Conclusions

- CS-FEA rooftop surface temperature simulation methodology can successfully predict surface temperatures impacted by extreme conditions
- CS-FEA simulation method was validated and optimized with the measured data from the rooftop surface temperature experiment
- Reflected solar radiation significantly increases surface temperature up to 18.5°F during peak conditions
- Surface color, air temperature and wind speed influence the final roof surface conditions
- Locations with similar solar radiation exposure can have very different surface temperatures due to air temperature and wind speed
- Identifying the parameters controlling climate specific, rooftop surface temperature extremes will help designers specify the thermal performance requirements for flashing membranes

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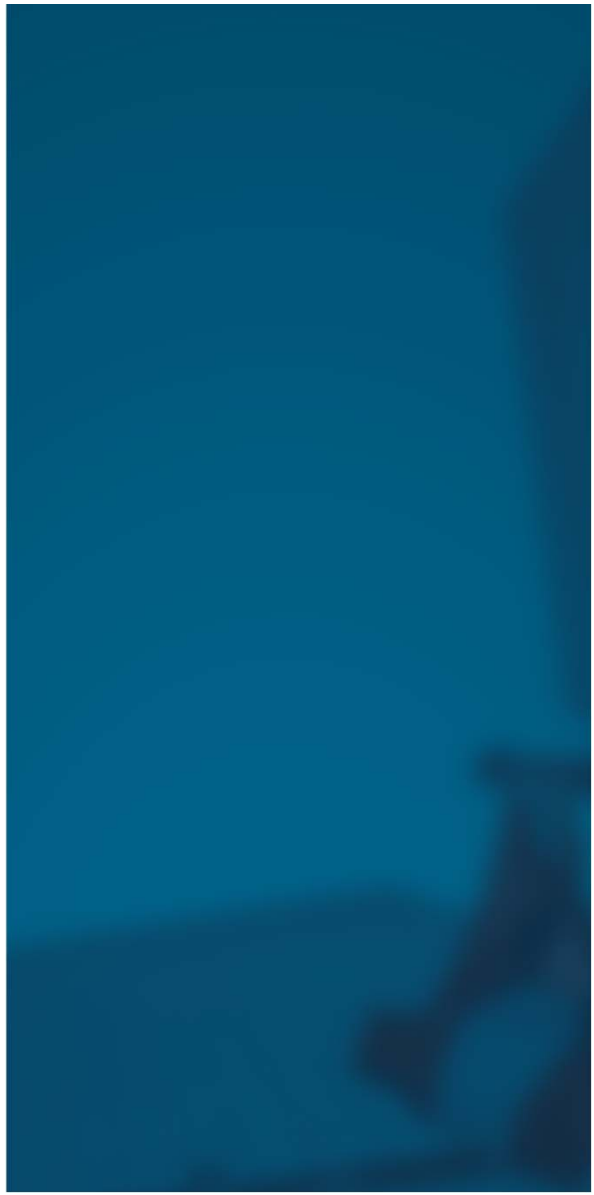


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