



Appendix A

# Green Roof Thermal Analysis

INCIDENT SOLAR RADIATION CALCULATIONS

**Average Peak Instantaneous Solar Radiation**

MONTH	n	$\delta$	$\Theta_z$	$G_{on}$ [W/m <sup>2</sup> ]	$G_b$ [W/m <sup>2</sup> ]	$G_d$ [W/m <sup>2</sup> ]	$G_{total}$ [W/m <sup>2</sup> ]
JANUARY	17	-20.92	59.80	1410.19	417.29	69.57	486.86
FEBRUARY	47	-12.95	51.83	1398.13	508.19	84.72	592.91
MARCH	75	-2.42	41.30	1379.46	609.61	101.63	711.24
APRIL	105	9.41	29.47	1356.42	694.67	115.81	810.48
MAY	135	18.79	20.09	1336.15	738.13	123.06	861.19
JUNE	162	23.09	15.79	1324.67	749.77	125.00	874.77
JULY	198	21.18	17.70	1323.49	741.65	123.65	865.30
AUGUST	228	13.45	25.43	1335.03	709.23	118.24	827.47
SEPTEMBER	248	6.18	32.70	1347.65	667.09	111.22	778.31
OCTOBER	288	-9.60	48.48	1377.96	537.29	89.58	626.87
NOVEMBER	318	-18.91	57.79	1398.13	438.34	73.08	511.41
DECEMBER	344	-23.05	61.93	1409.20	390.05	65.03	455.07

Location: Washington, DC

A [km] = 0.125

$\phi$  = 38.88

$\omega$  = 0

$\tau_b$  = 0.588

$a_0^*$  = 0.14033

$r_0$  = 0.97

$a_0$  = 0.13612

$\tau_d$  = 0.098

$a_1^*$  = 0.74731

$r_1$  = 0.99

$a_1$  = 0.73984

$G_{sc}$  [W/m<sup>2</sup>] = 1367.0

$k^*$  = 0.37590

$r_k$  = 1.02

$k$  = 0.38342

# ENERGY BALANCE CALCULATIONS FOR A TYPICAL ROOF, DAYTIME

**Average Daytime Peak Heat Gain (Cooling Load) Through Typical Roof**

Month →	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
Energy Flux Model													
Shortwave <sub>dn</sub> [W/m <sup>2</sup> ]	486.9	592.9	711.2	810.5	861.2	874.8	865.3	827.5	778.3	626.9	511.4	455.1	700.5
Shortwave <sub>up</sub> [W/m <sup>2</sup> ]	-97.4	-118.6	-142.2	-162.1	-172.2	-175.0	-173.1	-165.5	-155.7	-125.4	-102.3	-91.0	-140.1
Longwave <sub>dn</sub> [W/m <sup>2</sup> ]	209.0	215.2	234.2	253.8	273.1	291.4	299.9	296.3	281.4	258.6	237.6	217.1	255.8
Longwave <sub>up</sub> [W/m <sup>2</sup> ]	-328.0	-337.4	-366.1	-395.5	-424.4	-451.6	-464.1	-458.8	-436.7	-402.6	-371.2	-340.3	-398.3
Q <sub>conv</sub> [W/m <sup>2</sup> ]	-85.0	-87.7	-91.1	-88.4	-80.2	-77.5	-73.3	-71.8	-74.0	-76.1	-80.2	-82.3	-80.6
Q <sub>lat</sub> [W/m <sup>2</sup> ]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Q <sub>total</sub> [W/m <sup>2</sup> ]	185.5	264.4	346.0	418.3	457.5	462.2	454.8	427.6	393.4	281.4	195.3	158.6	337.3
Q <sub>total</sub> [BTU/hr-ft <sup>2</sup> ]	<b>58.8</b>	<b>83.8</b>	<b>109.7</b>	<b>132.6</b>	<b>145.0</b>	<b>146.5</b>	<b>144.2</b>	<b>135.6</b>	<b>124.7</b>	<b>89.2</b>	<b>61.9</b>	<b>50.3</b>	<b>106.9</b>

**Ambient Conditions:**

T <sub>OA</sub> [K]	278.9	280.9	286.8	292.4	297.7	302.4	304.5	303.7	299.9	293.8	287.8	281.5	292.6
T <sub>OA</sub> [°F]	42.3	45.9	56.5	66.7	76.2	84.7	88.5	86.9	80.1	69.1	58.3	47	66.9
T <sub>roof</sub> [K]	283.2	285.2	291.0	296.7	302.0	306.7	308.8	307.9	304.2	298.0	292.0	286.8	296.8
T <sub>roof</sub> [°F]	50	53.6	64.2	74.4	83.9	92.4	96.2	94.6	87.8	76.8	66	54.7	74.6
T <sub>RA</sub> [K]	295.4	295.4	295.4	298.7	298.7	298.7	298.7	298.7	298.7	298.7	295.4	295.4	297.3
T <sub>RA</sub> [°F]	72	72	72	78	78	78	78	78	78	78	72	72	75.5

P <sub>vapor</sub> [millibars]	0.0089	0.0101	0.0151	0.0218	0.0298	0.0384	0.0426	0.0408	0.0336	0.0237	0.0161	0.0106	0.0244
U <sub>wind</sub> [m/s]	4.5	4.6	4.9	4.7	4.2	4.0	3.7	3.6	3.8	3.9	4.2	4.3	4.2

Direct Solar (G <sub>b</sub> )	417.29	508.19	609.61	694.67	738.13	749.77	741.65	709.23	667.09	537.29	438.34	390.05	600.4
Diffuse Solar (G <sub>d</sub> )	69.67	84.72	101.63	115.81	123.06	125	123.65	118.24	111.22	89.58	73.08	65.03	100.1

Hours of Sun/Day	10.3	11.3	12.2	13.1	14.0	14.9	14.0	13.1	12.2	11.3	10.3	9.43	4444.0
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Avg. Precipitation [in]	2.72	2.71	3.17	2.71	3.66	3.38	3.80	3.91	3.31	3.02	3.12	3.12	38.63
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**Properties/Constants:**

- albedo [α]: 0.20
- Stefan Boltzmann const. [σ]: 5.67E-08 [W/m<sup>2</sup>·K<sup>4</sup>]
- Thermal Conductivity [k]: 0.38 [W/m·K]
- Longwave Emissivity [ε<sub>l</sub>]: 0.9
- [γ<sub>l</sub>]: 12
- Convective Heat Transfer Coeff. [γ<sub>l</sub>]: 6 [W/m<sup>2</sup>·K]
- Convective Heat Transof Water [p]: 10 [W/m<sup>2</sup>·K]
- Evaporation Enthalpy [h<sub>e</sub>]: 2257 [J/kg]
- Bowen Ratio: 0.17

# ENERGY BALANCE CALCULATIONS FOR A COOL ROOF, DAYTIME

**Average Daytime Peak Heat Gain (Cooling Load) Through Cool Roof**

Month →	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
Energy Flux Model													
Shortwave <sub>in</sub> [W/m <sup>2</sup> ]:	486.9	592.9	711.2	810.5	861.2	874.8	865.3	827.5	778.3	626.9	511.4	455.1	700.5
Shortwave <sub>up</sub> [W/m <sup>2</sup> ]:	-379.8	-462.5	-554.8	-632.2	-671.7	-682.3	-674.9	-645.4	-607.1	-489.0	-398.9	-355.0	-546.4
Longwave <sub>in</sub> [W/m <sup>2</sup> ]:	209.0	215.2	234.2	253.8	273.1	291.4	299.9	296.3	281.4	258.6	237.6	217.1	255.8
Longwave <sub>up</sub> [W/m <sup>2</sup> ]:	-328.0	-337.4	-366.1	-395.5	-424.4	-451.6	-464.1	-458.8	-436.7	-402.6	-371.2	-340.3	-398.3
Q <sub>conv</sub> [W/m <sup>2</sup> ]:	-85.0	-87.7	-91.1	-88.4	-80.2	-77.5	-73.3	-71.8	-74.0	-76.1	-80.2	-82.3	-80.6
Q <sub>rad</sub> [W/m <sup>2</sup> ]:	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Q <sub>total</sub> [W/m <sup>2</sup> ]:	-96.9	-79.5	-66.5	-51.8	-42.0	-45.1	-47.1	-52.3	-58.0	-62.2	-101.3	-105.4	-69.0
Q <sub>total</sub> [BTU/hr-ft <sup>2</sup> ]:	<b>-30.7</b>	<b>-25.2</b>	<b>-21.1</b>	<b>-16.4</b>	<b>-13.3</b>	<b>-14.3</b>	<b>-14.9</b>	<b>-16.6</b>	<b>-18.4</b>	<b>-26.1</b>	<b>-32.1</b>	<b>-33.4</b>	<b>-21.86891</b>

**Ambient Conditions:**

T <sub>OA</sub> [K]:	278.9	280.9	286.8	292.4	297.7	302.4	304.5	303.7	299.9	293.8	287.8	281.5	292.6
T <sub>OA</sub> [°F]:	42.3	45.9	56.5	66.7	76.2	84.7	88.5	86.9	80.1	69.1	58.3	47	66.9
T <sub>roof</sub> [K]:	283.2	285.2	291.0	296.7	302.0	306.7	308.8	307.9	304.2	298.0	292.0	285.8	296.8
T <sub>roof</sub> [°F]:	50	53.6	64.2	74.4	83.9	92.4	96.2	94.6	87.8	76.8	66	54.7	74.6
T <sub>RA</sub> [K]:	295.4	295.4	295.4	298.7	298.7	298.7	298.7	298.7	298.7	298.7	295.4	295.4	297.3
T <sub>RA</sub> [°F]:	72	72	72	78	78	78	78	78	78	78	72	72	75.5

P <sub>vapor</sub> [millibars]:	0.0089	0.0101	0.0151	0.0218	0.0298	0.0384	0.0426	0.0408	0.0336	0.0237	0.0161	0.0106	0.0244
U <sub>wind</sub> [m/s]:	4.5	4.6	4.9	4.7	4.2	4.0	3.7	3.6	3.8	3.9	4.2	4.3	4.2
Direct Solar (G <sub>b</sub> ):	417.29	508.19	609.61	694.67	738.13	749.77	741.65	709.23	667.09	537.29	438.34	390.05	600.4
Diffuse Solar (G <sub>d</sub> ):	69.57	84.72	101.63	115.81	123.06	125	123.65	118.24	111.22	89.58	73.08	65.03	100.1
Hours of Sun/Day:	10.3	11.3	12.2	13.1	14.0	14.9	14.0	13.1	12.2	11.3	10.3	9.43	4444.0
Avg. Precipitation [in]:	2.72	2.71	3.17	2.71	3.66	3.38	3.80	3.91	3.31	3.02	3.12	3.12	36.63

**Properties/Constants:**

albedo (α):	0.78
Stefan Boltzmann const. (σ):	5.67E-08 [W/m <sup>2</sup> -K <sup>4</sup> ]
Thermal Conductivity (k):	3.62305194 [W/m-K]
Longwave Emissivity (ε <sub>l</sub> ):	0.9
Convective Heat Transfer Coeff. (h <sub>1</sub> ):	12
Convective Heat Transfer Coeff. (h <sub>2</sub> ):	6 [W/m <sup>2</sup> -K]
Density of Water (ρ):	10 [W/m <sup>2</sup> -K]
Evaporation Enthalpy (h <sub>fg</sub> ):	2257 [J/kg]
Bowen Ratio:	0.17

# ENERGY BALANCE CALCULATIONS FOR A GREEN ROOF, NIGHT

**Average Nighttime Base Heat Gain (Cooling Load) Through Green Roof**

Month →	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
Energy Flux Model													
Shortwave <sub>dn</sub> [W/m <sup>2</sup> ]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shortwave <sub>up</sub> [W/m <sup>2</sup> ]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Longwave <sub>dn</sub> [W/m <sup>2</sup> ]	184.2	187.7	201.4	216.1	234.4	253.4	263.2	260.4	245.6	222.9	207.0	191.7	222.5
Longwave <sub>up</sub> [W/m <sup>2</sup> ]	-289.9	-296.5	-318.8	-342.7	-372.0	-402.3	-418.8	-412.9	-389.0	-353.2	-327.5	-302.8	-352.5
Q <sub>conv</sub> [W/m <sup>2</sup> ]	-42.8	-45.6	-48.3	-51.1	-53.9	-56.7	-59.4	-56.7	-53.9	-51.1	-48.3	-45.6	-51.1
Q <sub>lat</sub> [W/m <sup>2</sup> ]	-122.2	-130.2	-138.1	-146.0	-154.0	-161.9	-169.8	-161.9	-154.0	-146.0	-138.1	-130.2	-146.1
Q <sub>total</sub> [W/m <sup>2</sup> ]	-270.7	-284.5	-303.9	-323.8	-345.5	-367.5	-384.8	-371.1	-351.3	-327.4	-306.9	-286.8	-327.2
Q <sub>total</sub> [BTU/hr-ft <sup>2</sup> ]	<b>85.8</b>	<b>90.2</b>	<b>96.3</b>	<b>102.6</b>	<b>109.5</b>	<b>116.5</b>	<b>122.0</b>	<b>117.6</b>	<b>111.4</b>	<b>103.8</b>	<b>97.3</b>	<b>90.9</b>	<b>-103.7</b>

**Ambient Conditions:**

T <sub>OA</sub> [K]:	270.3	271.5	276.3	281.2	286.8	292.3	295.0	294.3	290.1	283.3	278.2	273.0	282.7
T <sub>OA</sub> [°F]:	26.8	29.1	37.7	46.4	56.6	66.5	71.4	70	62.5	50.3	41.1	31.7	49.3
T <sub>roof</sub> [K]:	274.5	276.1	281.2	286.3	292.2	298.0	301.0	299.9	295.5	288.4	283.0	277.5	287.9
T <sub>roof</sub> [°F]:	34.5	37.3	46.4	55.6	66.3	76.7	82.1	80.2	72.2	59.5	49.8	39.9	58.5
T <sub>RA</sub> [K]:	293.2	293.2	293.2	300.9	300.9	300.9	300.9	300.9	300.9	300.9	293.2	293.2	297.7
T <sub>RA</sub> [°F]:	68	68	68	82	82	82	82	82	82	82	68	68	76.2

P <sub>vapor</sub> [millibars]:	0.0065	0.0066	0.0077	0.0103	0.0151	0.0217	0.0256	0.0244	0.0188	0.0119	0.0086	0.0068	0.0137
U <sub>wind</sub> [m/s]:	4.5	4.6	4.9	4.7	4.2	4.0	3.7	3.6	3.8	3.9	4.2	4.3	4.2

Direct Solar (G <sub>b</sub> ):	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Diffuse Solar (G <sub>d</sub> ):	0	0	0	0	0	0	0	0	0	0	0	0	0.0

Hours of Sun/Day:	10.3	11.3	12.2	13.1	14.0	14.9	14.0	13.1	12.2	11.3	10.3	9.43	4444.0
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Avg. Precipitation [in]:	2.72	2.71	3.17	2.71	3.66	3.38	3.80	3.91	3.31	3.02	3.12	3.12	38.63
Supp. Watering [in]:	0.00	0.00	0.00	0.68	0.92	0.85	0.95	0.98	0.83	0.00	0.00	0.00	5.19

0.009286

**Properties/Constants:**

albedo (α):	0.25
Stefan Boltzmann const. (σ):	5.67E-08 [W/m <sup>2</sup> ·K <sup>4</sup> ]
Thermal Conductivity (k):	0.38 [W/m <sup>2</sup> ·K]
Longwave Emissivity (ε <sub>l</sub> ):	0.9
convective Heat Transfer Coeff. (h <sub>1</sub> ):	6 [W/m <sup>2</sup> ·K]
convective Heat Transfer Coeff. (h <sub>2</sub> ):	10 [W/m <sup>2</sup> ·K]
Density of Water (ρ):	998 [kg/m <sup>3</sup> ]
Evaporation Enthalpy (h <sub>e</sub> ):	2257 [J/kg]
Bowen Ratio:	0.35

# ENERGY BALANCE CALCULATIONS FOR A GREEN ROOF, NIGHT

**Average Nighttime Base Heat Gain (Cooling Load) Through Cool Roof**

Month → Energy Flux Mode	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
Shortwave <sub>in</sub> [W/m <sup>2</sup> ]:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shortwave <sub>up</sub> [W/m <sup>2</sup> ]:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Longwave <sub>in</sub> [W/m <sup>2</sup> ]:	184.2	187.7	201.4	216.1	234.4	253.4	263.2	260.4	245.6	222.9	207.0	191.7	222.5
Longwave <sub>up</sub> [W/m <sup>2</sup> ]:	-289.9	-297.7	-321.4	-346.7	-377.7	-409.9	-428.1	-420.6	-394.9	-357.3	-330.1	-304.0	-356.8
Q <sub>conv</sub> [W/m <sup>2</sup> ]:	-85.0	-99.1	-114.8	-122.9	-121.9	-127.8	-130.3	-118.5	-112.4	-105.7	-101.1	-93.0	-111.1
Q <sub>lat</sub> [W/m <sup>2</sup> ]:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q <sub>total</sub> [W/m <sup>2</sup> ]:	-190.7	-209.2	-234.8	-253.5	-265.2	-284.3	-295.3	-278.7	-261.7	-240.0	-224.1	-205.2	-245.4
Q <sub>total</sub> [BTU/hr-ft <sup>2</sup> ]:	<b>-60.5</b>	<b>-66.3</b>	<b>-74.4</b>	<b>-80.3</b>	<b>-84.1</b>	<b>-90.1</b>	<b>-93.6</b>	<b>-88.4</b>	<b>-83.0</b>	<b>-76.1</b>	<b>-71.1</b>	<b>-65.1</b>	<b>-77.8</b>

**Ambient Conditions:**

T <sub>OA</sub> [K]:	270.3	271.5	276.3	281.2	286.8	292.3	295.0	294.3	290.1	283.3	278.2	273.0	282.7
T <sub>OA</sub> [°F]:	26.8	29.1	37.7	46.4	56.6	66.5	71.4	70	62.5	50.3	41.1	31.7	49.3
T <sub>roof</sub> [K]:	274.5	276.4	281.7	287.1	293.3	299.4	302.7	301.3	296.6	289.3	283.6	277.8	288.7
T <sub>roof</sub> [°F]:	34.5	37.8	47.4	57.1	68.3	79.2	85.1	82.7	74.2	61	50.8	40.4	60.0
T <sub>RA</sub> [K]:	293.2	293.2	293.2	300.9	300.9	300.9	300.9	300.9	300.9	300.9	293.2	293.2	297.7
T <sub>RA</sub> [°F]:	68	68	68	82	82	82	82	82	82	82	68	68	76.2

P <sub>vapor</sub> [millibars]:	0.0065	0.0066	0.0077	0.0103	0.0151	0.0217	0.0256	0.0244	0.0188	0.0119	0.0086	0.0068	0.0137
U <sub>wind</sub> [m/s]:	4.5	4.6	4.9	4.7	4.2	4.0	3.7	3.6	3.8	3.9	4.2	4.3	4.2

Direct Solar (G <sub>b</sub> ):	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Diffuse Solar (G <sub>d</sub> ):	0	0	0	0	0	0	0	0	0	0	0	0	0.0

Hours of Sun/Day:	10.3	11.3	12.2	13.1	14.0	14.9	14.0	13.1	12.2	11.3	10.3	9.43	4444.0
Avg. Precipitation [in]:	2.72	2.71	3.17	2.71	3.66	3.38	3.80	3.91	3.31	3.02	3.12	3.12	38.63
Supp. Watering [in]:	0.00	0.00	0.00	0.68	0.92	0.85	0.95	0.98	0.83	0.00	0.00	0.00	5.19

**Properties/Constants:**

albedo [α]:	0.78
Stefan Boltzmann const. [σ]:	5.67E-08 [W/m <sup>2</sup> ·K <sup>4</sup> ]
Thermal Conductivity [k]:	0.38 [W/m <sup>2</sup> ·K]
Longwave Emissivity [ε <sub>l</sub> ]:	0.9
convective Heat Transfer Coeff. [γ <sub>1</sub> ]:	6 [W/m <sup>2</sup> ·K]
convective Heat Transfer Coeff. [γ <sub>2</sub> ]:	10 [W/m <sup>2</sup> ·K]
Density of Water [ρ]:	998 [kg/m <sup>3</sup> ]
Evaporation Enthalpy [h <sub>g</sub> ]:	2257 [J/kg]
Bowen Ratio:	0.17

# ENERGY BALANCE CALCULATIONS FOR A GREEN ROOF, NIGHT, MONTHLY

Average Daily Roof Heat Flux

	GREEN ROOF											
	January	February	March	April	May	June	July	August	September	October	November	December
Peak (Day)	-107.47	-89.19	-71.46	-45.12	-18.24	-11.78	-6.15	-11.51	-25.54	-62.58	-95.80	-110.39
Average 24hr	-96.64	-89.69	-83.90	-73.87	-63.88	-64.14	-64.07	-64.58	-68.44	-83.18	-96.55	-100.65
Base (Night)	-85.81	-90.20	-96.33	-102.62	-109.51	-116.50	-121.99	-117.64	-111.35	-103.77	-97.29	-90.90
Δ Heat Flux	21.66	1.01	24.87	57.51	91.27	104.71	115.84	106.13	85.81	41.19	1.49	19.60

Hour of Day	GREEN ROOF											
	January	February	March	April	May	June	July	August	September	October	November	December
0	-100.79	-89.88	-88.66	-84.87	-81.34	-84.18	-86.24	-84.88	-84.86	-91.06	-96.83	-104.38
1	-103.24	-90.00	-91.47	-91.37	-91.66	-96.01	-99.33	-96.88	-94.56	-95.71	-97.00	-106.58
2	-105.23	-90.09	-93.76	-96.68	-100.08	-105.68	-110.02	-106.68	-102.48	-99.52	-97.14	-108.38
3	-106.65	-90.16	-95.39	-100.43	-106.04	-112.51	-117.58	-113.60	-108.08	-102.20	-97.23	-109.65
4	-107.38	-90.19	-96.23	-102.38	-109.12	-116.05	-121.49	-117.19	-110.98	-103.59	-97.28	-110.31
5	-107.38	-90.19	-96.23	-102.38	-109.12	-116.05	-121.49	-117.19	-110.98	-103.59	-97.28	-110.31
6	-106.65	-90.16	-95.39	-100.43	-106.04	-112.51	-117.58	-113.60	-108.08	-102.20	-97.23	-109.65
7	-105.23	-90.09	-93.76	-96.68	-100.08	-105.68	-110.02	-106.68	-102.48	-99.52	-97.14	-108.38
8	-103.24	-90.00	-91.47	-91.37	-91.66	-96.01	-99.33	-96.88	-94.56	-95.71	-97.00	-106.58
9	-100.79	-89.88	-88.66	-84.87	-81.34	-84.18	-86.24	-84.88	-84.86	-91.06	-96.83	-104.38
10	-98.06	-89.76	-85.52	-77.62	-69.83	-70.97	-71.63	-71.50	-74.04	-85.86	-96.64	-101.92
11	-95.23	-89.63	-82.27	-70.12	-57.92	-57.31	-56.51	-57.65	-62.84	-80.49	-96.45	-99.37
12	-92.50	-89.60	-79.14	-62.87	-46.41	-44.10	-41.91	-44.27	-52.02	-75.29	-96.26	-96.91
13	-90.05	-89.38	-76.33	-56.37	-36.09	-32.27	-28.81	-32.27	-42.32	-70.64	-96.09	-94.71
14	-88.05	-89.29	-74.03	-51.06	-27.67	-22.60	-18.12	-22.48	-34.40	-66.84	-95.96	-92.91
15	-86.64	-89.23	-72.41	-47.31	-21.71	-15.77	-10.56	-15.55	-28.80	-64.15	-95.86	-91.64
16	-85.91	-89.19	-71.57	-45.36	-18.63	-12.23	-6.65	-11.96	-25.90	-62.76	-95.81	-90.98
17	-85.91	-89.19	-71.57	-45.36	-18.63	-12.23	-6.65	-11.96	-25.90	-62.76	-95.81	-90.98
18	-86.64	-89.23	-72.41	-47.31	-21.71	-15.77	-10.56	-15.55	-28.80	-64.15	-95.86	-91.64
19	-88.05	-89.29	-74.03	-51.06	-27.67	-22.60	-18.12	-22.48	-34.40	-66.84	-95.96	-92.91
20	-90.05	-89.38	-76.33	-56.37	-36.09	-32.27	-28.81	-32.27	-42.32	-70.64	-96.09	-94.71
21	-92.50	-89.60	-79.14	-62.87	-46.41	-44.10	-41.91	-44.27	-52.02	-75.29	-96.26	-96.91
22	-95.23	-89.63	-82.27	-70.12	-57.92	-57.31	-56.51	-57.65	-62.84	-80.49	-96.45	-99.37
23	-98.06	-89.76	-85.52	-77.62	-69.83	-70.97	-71.63	-71.50	-74.04	-85.86	-96.64	-101.92
24	-100.79	-89.88	-88.66	-84.87	-81.34	-84.18	-86.24	-84.88	-84.86	-91.06	-96.83	-104.38

	TYPICAL ROOF											
	January	February	March	April	May	June	July	August	September	October	November	December
Peak (Day)	58.79	83.81	109.67	132.59	145.01	146.52	144.15	135.56	124.70	89.19	61.91	50.27
Average 24hr	-0.84	8.76	17.63	26.12	30.47	28.20	25.28	23.60	20.88	6.55	-4.57	-7.39
Base (Night)	-60.46	-66.30	-74.42	-80.35	-84.07	-90.11	-93.59	-88.36	-82.95	-76.09	-71.05	-66.06
Δ Heat Flux	119.26	150.11	184.09	212.93	229.09	236.62	237.74	223.91	207.66	165.27	132.96	115.33

Hour of Day	TYPICAL ROOF											
	January	February	March	April	May	June	July	August	September	October	November	December
0	-43.00	-44.32	-47.46	-49.16	-50.52	-55.45	-58.77	-55.57	-52.54	-51.88	-51.58	-48.17
1	-52.48	-56.24	-62.09	-66.08	-68.73	-74.26	-77.66	-73.36	-69.04	-65.01	-62.14	-57.33
2	-58.43	-63.74	-71.28	-76.72	-80.17	-86.07	-89.54	-84.54	-79.41	-73.27	-68.79	-63.09
3	-60.46	-66.30	-74.42	-80.35	-84.07	-90.11	-93.59	-88.36	-82.95	-76.09	-71.05	-65.06
4	-58.43	-63.74	-71.28	-76.72	-80.17	-86.07	-89.54	-84.54	-79.41	-73.27	-68.79	-63.09
5	-52.48	-56.24	-62.09	-66.08	-68.73	-74.26	-77.66	-73.36	-69.04	-65.01	-62.14	-57.33
6	-43.00	-44.32	-47.46	-49.16	-50.52	-55.45	-58.77	-55.57	-52.54	-51.88	-51.58	-48.17
7	-30.65	-28.77	-28.39	-27.11	-26.80	-30.95	-34.15	-32.38	-31.04	-34.77	-37.81	-36.22
8	-16.27	-10.67	-6.19	-1.44	0.82	-2.42	-5.49	-5.38	-6.00	-14.84	-21.78	-22.32
9	-0.84	8.76	17.63	26.12	30.47	28.20	25.28	23.60	20.88	6.55	-4.57	-7.39
10	14.60	28.18	41.45	53.67	60.12	58.83	56.05	52.58	47.75	27.94	12.63	7.53
11	28.98	46.28	63.65	79.35	87.74	87.36	84.72	79.58	72.79	47.87	28.67	21.44
12	41.33	61.83	82.71	101.40	111.46	111.86	109.33	102.76	94.29	64.98	42.44	33.38
13	50.80	73.76	97.34	118.32	129.67	130.67	128.23	120.56	110.79	78.12	53.00	42.55
14	56.76	81.25	106.54	128.96	141.11	142.48	140.10	131.74	121.17	86.37	59.64	48.31
15	58.79	83.81	109.67	132.59	145.01	146.52	144.15	135.56	124.70	89.19	61.91	50.27
16	56.76	81.25	106.54	128.96	141.11	142.48	140.10	131.74	121.17	86.37	59.64	48.31
17	50.80	73.76	97.34	118.32	129.67	130.67	128.23	120.56	110.79	78.12	53.00	42.55
18	41.33	61.83	82.71	101.40	111.46	111.86	109.33	102.76	94.29	64.98	42.44	33.38
19	28.98	46.28	63.65	79.35	87.74	87.36	84.72	79.58	72.79	47.87	28.67	21.44
20	14.60	28.18	41.45	53.67	60.12	58.83	56.05	52.58	47.75	27.94	12.63	7.53
21	-0.84	8.76	17.63	26.12	30.47	28.20	25.28	23.60	20.88	6.55	-4.57	-7.39
22	-16.27	-10.67	-6.19	-1.44	0.82	-2.42	-5.49	-5.38	-6.00	-14.84	-21.78	-22.32
23	-30.65	-28.77	-28.39	-27.11	-26.80	-30.95	-34.15	-32.38	-31.04	-34.77	-37.81	-36.22
24	-43.00	-44.32	-47.46	-49.16	-50.52	-55.45	-58.77	-55.57	-52.54	-51.88	-51.58	-48.17

ORIGINAL ROOF												
	January	February	March	April	May	June	July	August	September	October	November	December
Peak (Day)	-30.72	-25.20	-21.09	-16.42	-13.32	-14.31	-14.93	-16.57	-18.39	-26.06	-32.12	-33.40
Average 24hr	-45.59	-45.75	-47.75	-48.38	-48.69	-52.21	-54.26	-52.47	-50.67	-51.07	-51.58	-49.23
Base (Night)	-60.46	-66.30	-74.42	-80.35	-84.07	-90.11	-93.59	-88.36	-82.95	-76.09	-71.05	-65.06
Δ Heat Flux	29.75	41.10	53.33	63.93	70.76	75.80	78.66	71.78	64.56	50.02	38.93	31.66

ORIGINAL ROOF												
Hour of Day	January	February	March	April	May	June	July	August	September	October	November	December
0	-56.11	-60.28	-66.61	-70.99	-73.71	-79.01	-82.07	-77.85	-73.50	-68.76	-65.35	-60.42
1	-58.47	-63.55	-70.84	-76.07	-79.33	-85.03	-88.32	-83.55	-78.63	-72.73	-68.44	-62.94
2	-59.96	-65.60	-73.51	-79.26	-82.87	-88.81	-92.25	-87.14	-81.85	-75.23	-70.39	-64.52
3	-60.46	-66.30	-74.42	-80.35	-84.07	-90.11	-93.59	-88.36	-82.95	-76.09	-71.05	-65.06
4	-59.96	-65.60	-73.51	-79.26	-82.87	-88.81	-92.25	-87.14	-81.85	-75.23	-70.39	-64.52
5	-58.47	-63.55	-70.84	-76.07	-79.33	-85.03	-88.32	-83.55	-78.63	-72.73	-68.44	-62.94
6	-56.11	-60.28	-66.61	-70.99	-73.71	-79.01	-82.07	-77.85	-73.50	-68.76	-65.35	-60.42
7	-53.03	-56.02	-61.08	-64.37	-66.38	-71.16	-73.93	-70.41	-66.81	-63.58	-61.32	-57.14
8	-49.44	-51.07	-54.65	-56.66	-57.85	-62.02	-64.44	-61.76	-59.02	-57.55	-56.62	-53.32
9	-45.59	-45.75	-47.75	-48.38	-48.69	-52.21	-54.26	-52.47	-50.67	-51.07	-51.58	-49.23
10	-41.74	-40.43	-40.85	-40.11	-39.54	-42.40	-44.08	-43.18	-42.31	-44.60	-46.55	-45.13
11	-38.15	-35.47	-34.42	-32.40	-31.01	-33.26	-34.60	-34.52	-34.53	-38.57	-41.85	-41.31
12	-35.07	-31.22	-28.90	-25.78	-23.68	-25.41	-26.45	-27.09	-27.84	-33.39	-37.82	-38.03
13	-32.71	-27.95	-24.66	-20.70	-18.06	-19.39	-20.20	-21.38	-22.71	-29.41	-34.72	-35.52
14	-31.22	-25.90	-22.00	-17.51	-14.52	-15.60	-16.27	-17.80	-19.49	-26.91	-32.78	-33.93
15	-30.72	-25.20	-21.09	-16.42	-13.32	-14.31	-14.93	-16.57	-18.39	-26.06	-32.12	-33.40
16	-31.22	-25.90	-22.00	-17.51	-14.52	-15.60	-16.27	-17.80	-19.49	-26.91	-32.78	-33.93
17	-32.71	-27.95	-24.66	-20.70	-18.06	-19.39	-20.20	-21.38	-22.71	-29.41	-34.72	-35.52
18	-35.07	-31.22	-28.90	-25.78	-23.68	-25.41	-26.45	-27.09	-27.84	-33.39	-37.82	-38.03
19	-38.15	-35.47	-34.42	-32.40	-31.01	-33.26	-34.60	-34.52	-34.53	-38.57	-41.85	-41.31
20	-41.74	-40.43	-40.85	-40.11	-39.54	-42.40	-44.08	-43.18	-42.31	-44.60	-46.55	-45.13
21	-45.59	-45.75	-47.75	-48.38	-48.69	-52.21	-54.26	-52.47	-50.67	-51.07	-51.58	-49.23
22	-49.44	-51.07	-54.65	-56.66	-57.85	-62.02	-64.44	-61.76	-59.02	-57.55	-56.62	-53.32
23	-53.03	-56.02	-61.08	-64.37	-66.38	-71.16	-73.93	-70.41	-66.81	-63.58	-61.32	-57.14
24	-56.11	-60.28	-66.61	-70.99	-73.71	-79.01	-82.07	-77.85	-73.50	-68.76	-65.35	-60.42