Assessing the Year-Round Thermal Benefits of a Green Roof

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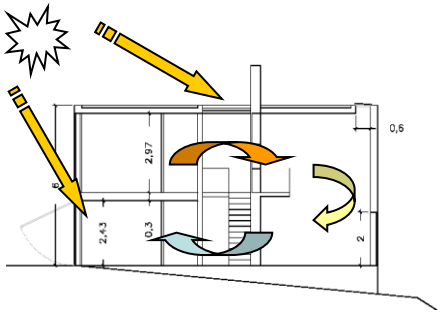
Green Roofs at Walmart

Lessons from Chicago Store #5402

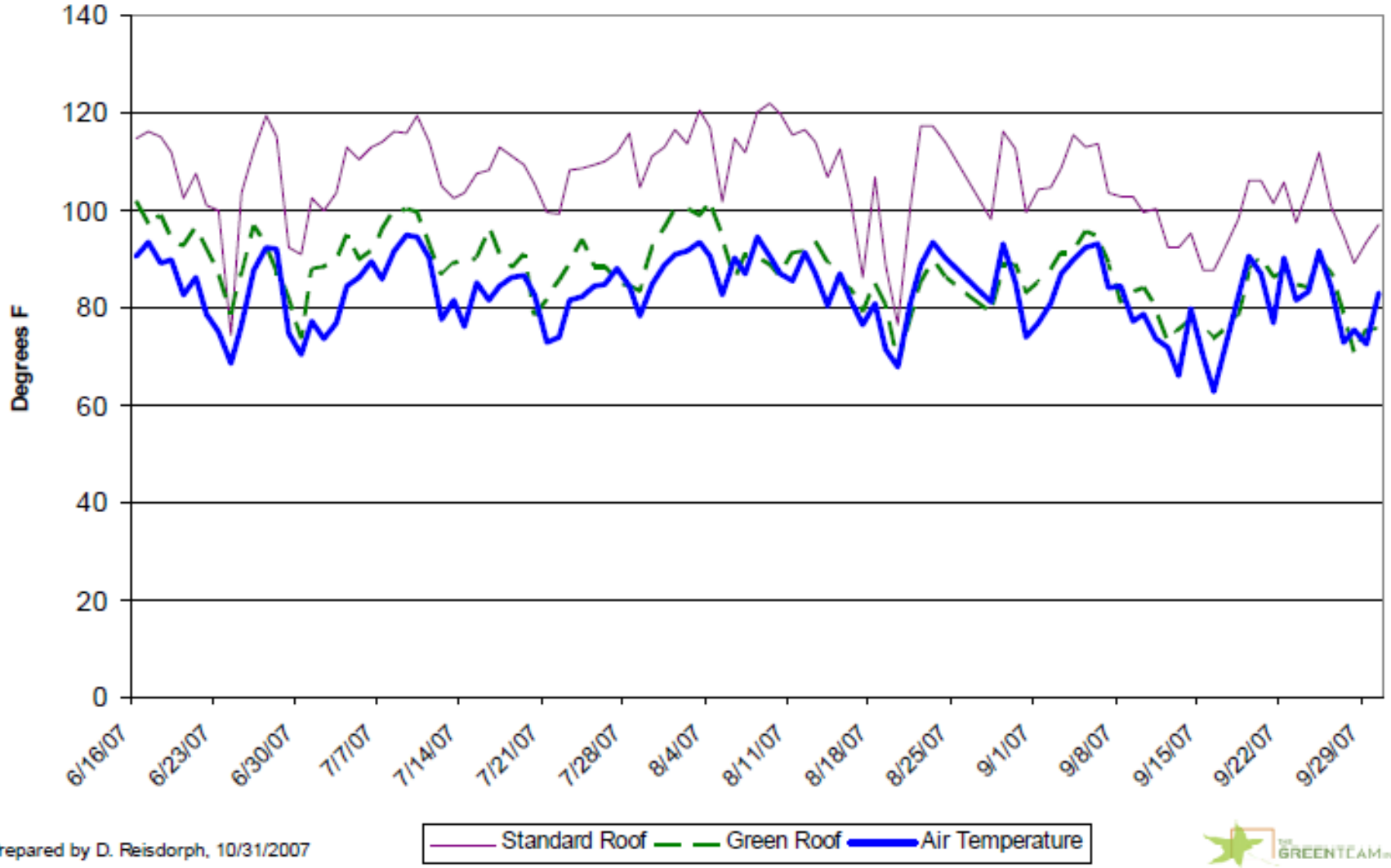
Green Roofs

What is the year-round potential for energy conservation?



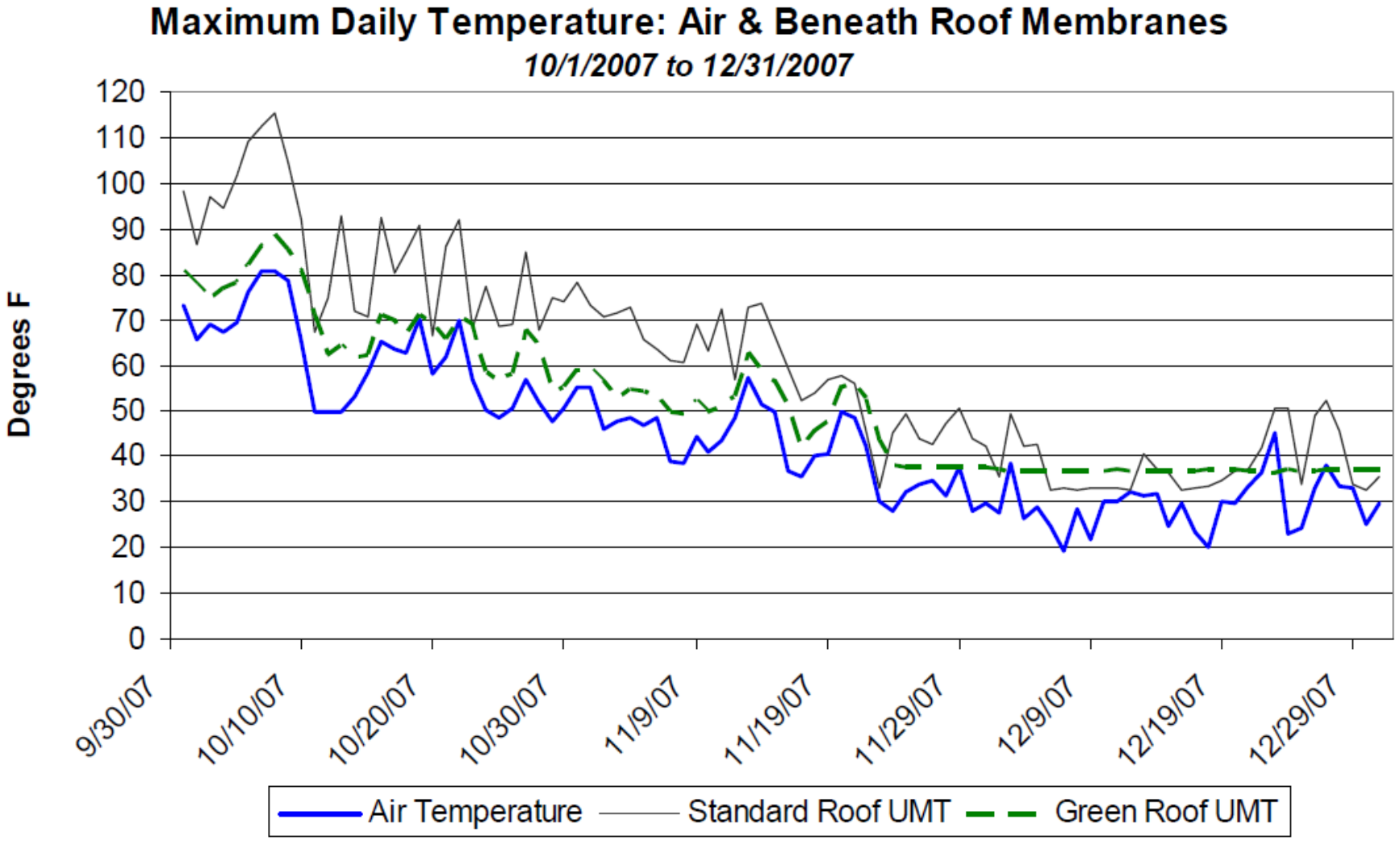
- To answer this question:
  - Data and modeling for each season
  - Impact on air intake temperatures
  - Potential for biodiverse roofs

Maximum Daily Temperature: Air & Beneath Roof Membrane

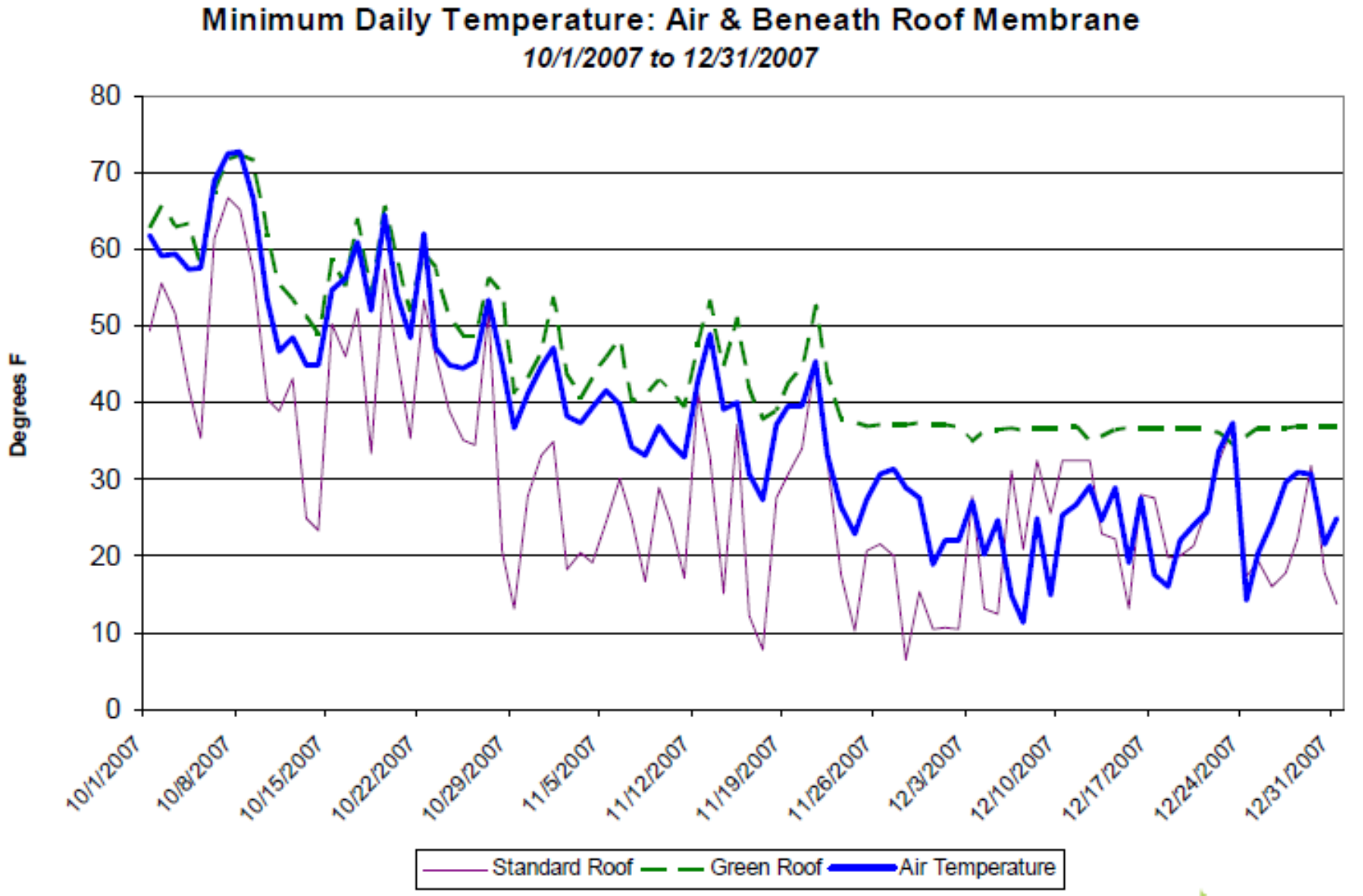


Prepared by D. Reisdorph, 10/31/2007

Temperature Oct – Dec 2007

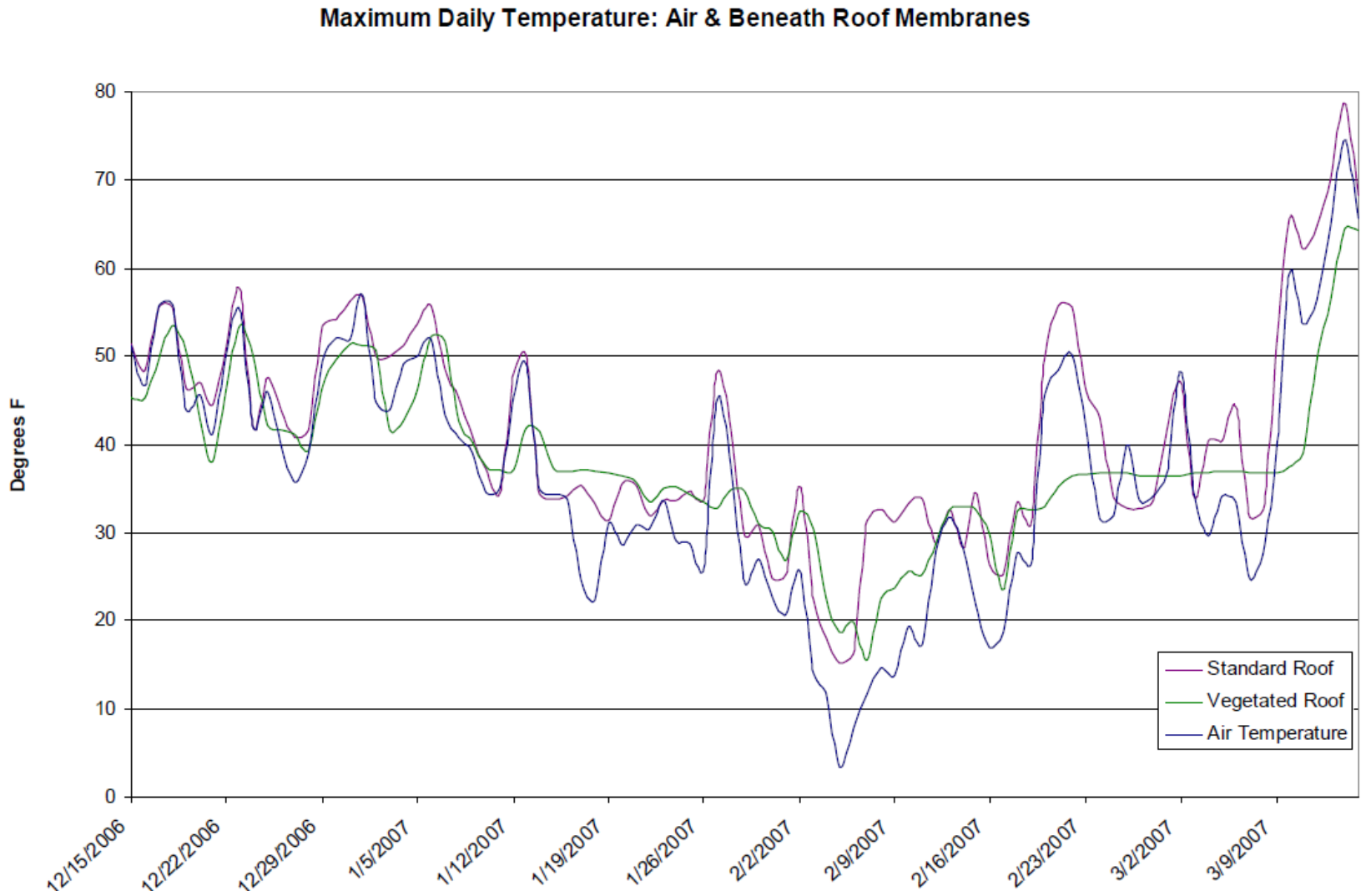


Temperature Oct – Dec 2007

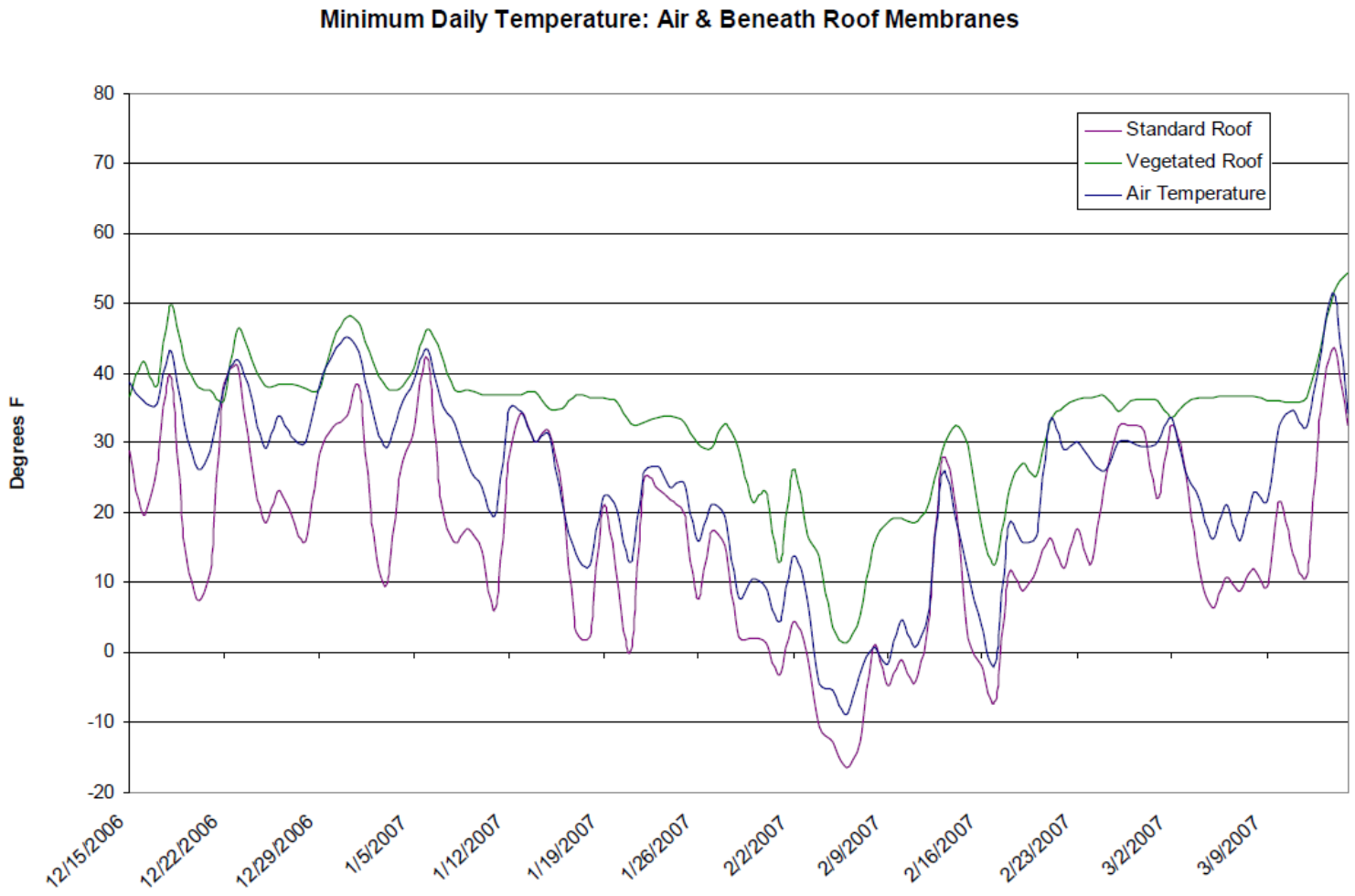


Prepared by D. Reisdorph, 2/8/2008

Dec 2006 through March 2007

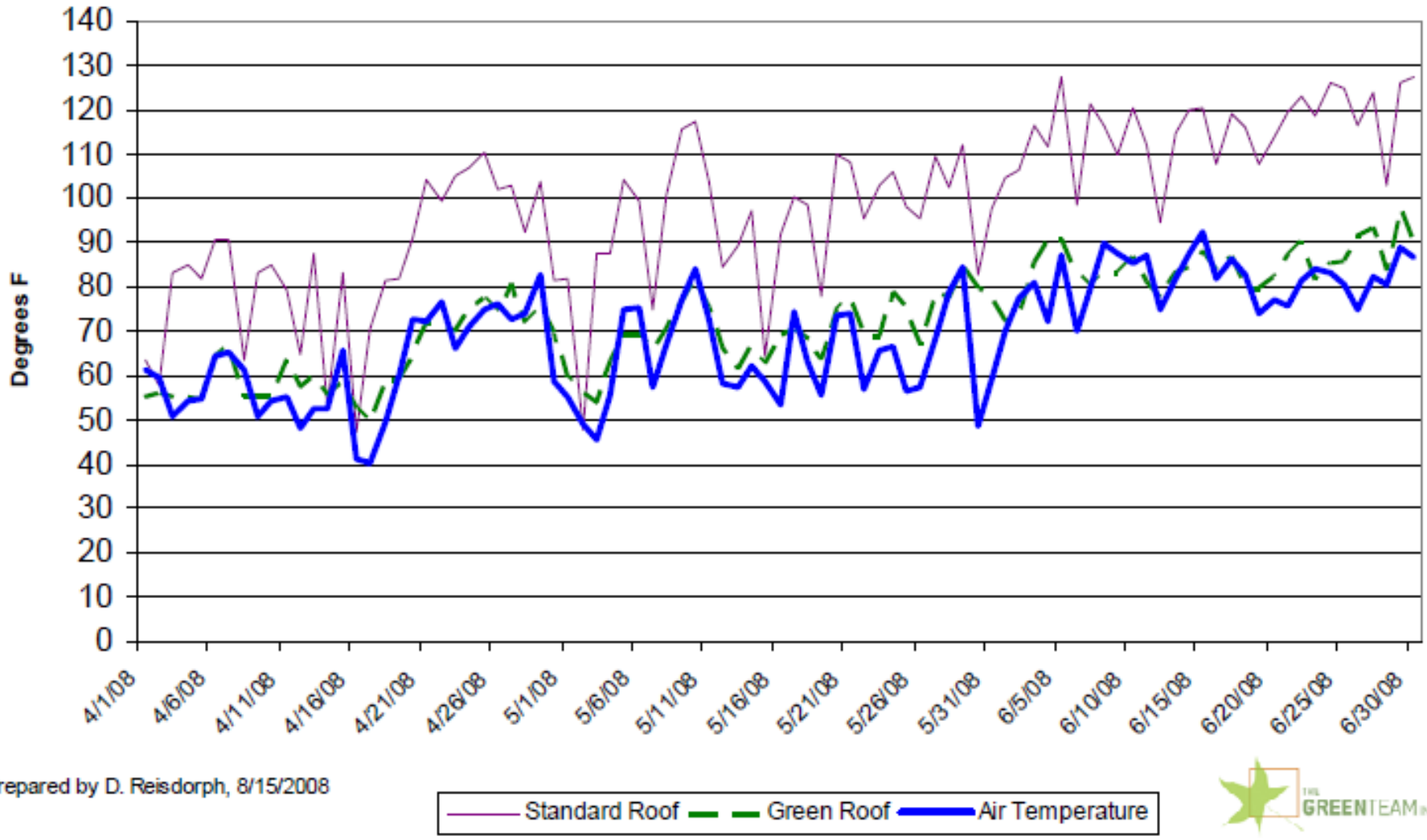


Dec 2006 through March 2007



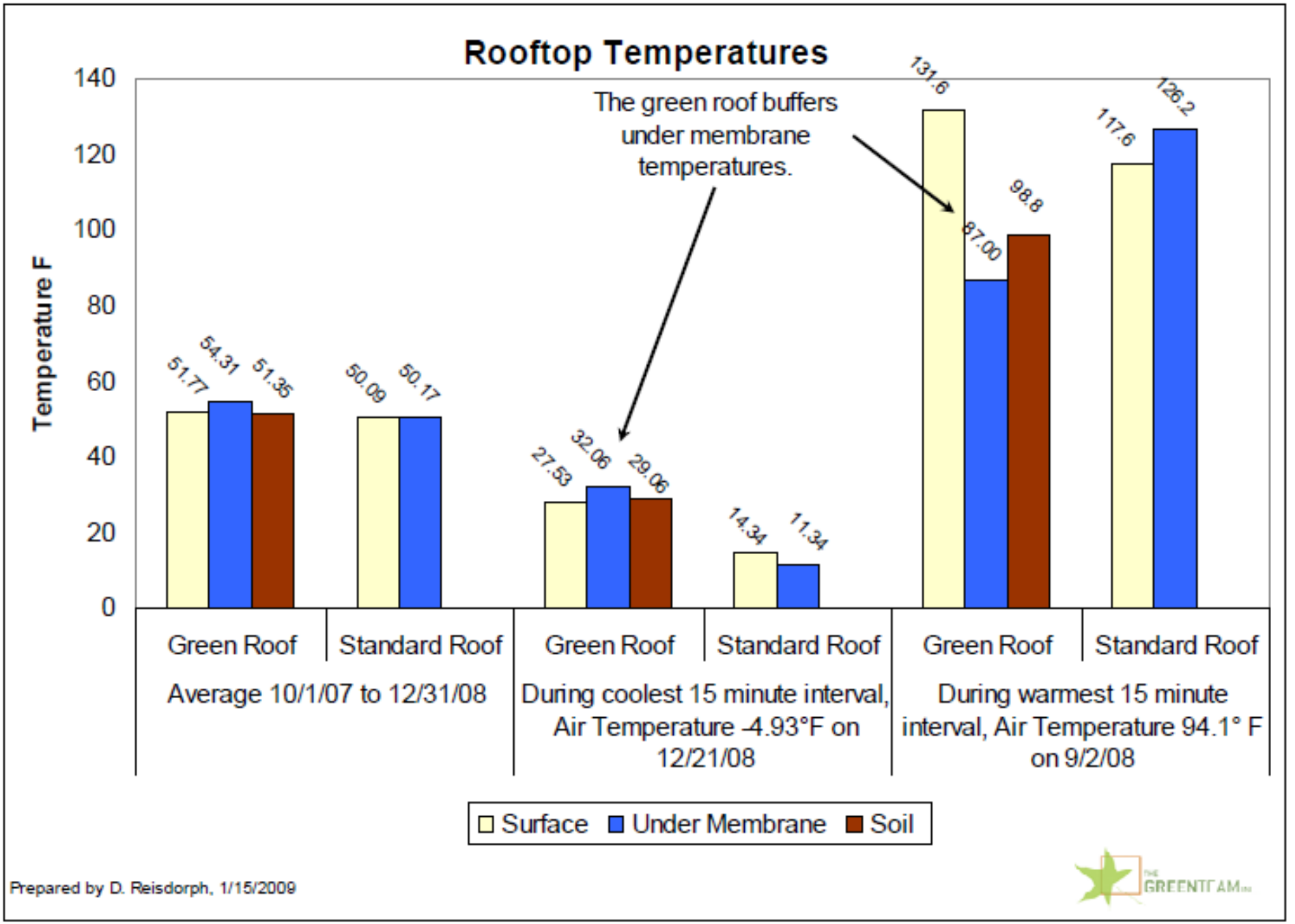
Maximum Daily Temperature: Air & Beneath Roof Membrane

4/1/2008 to 6/30/2008



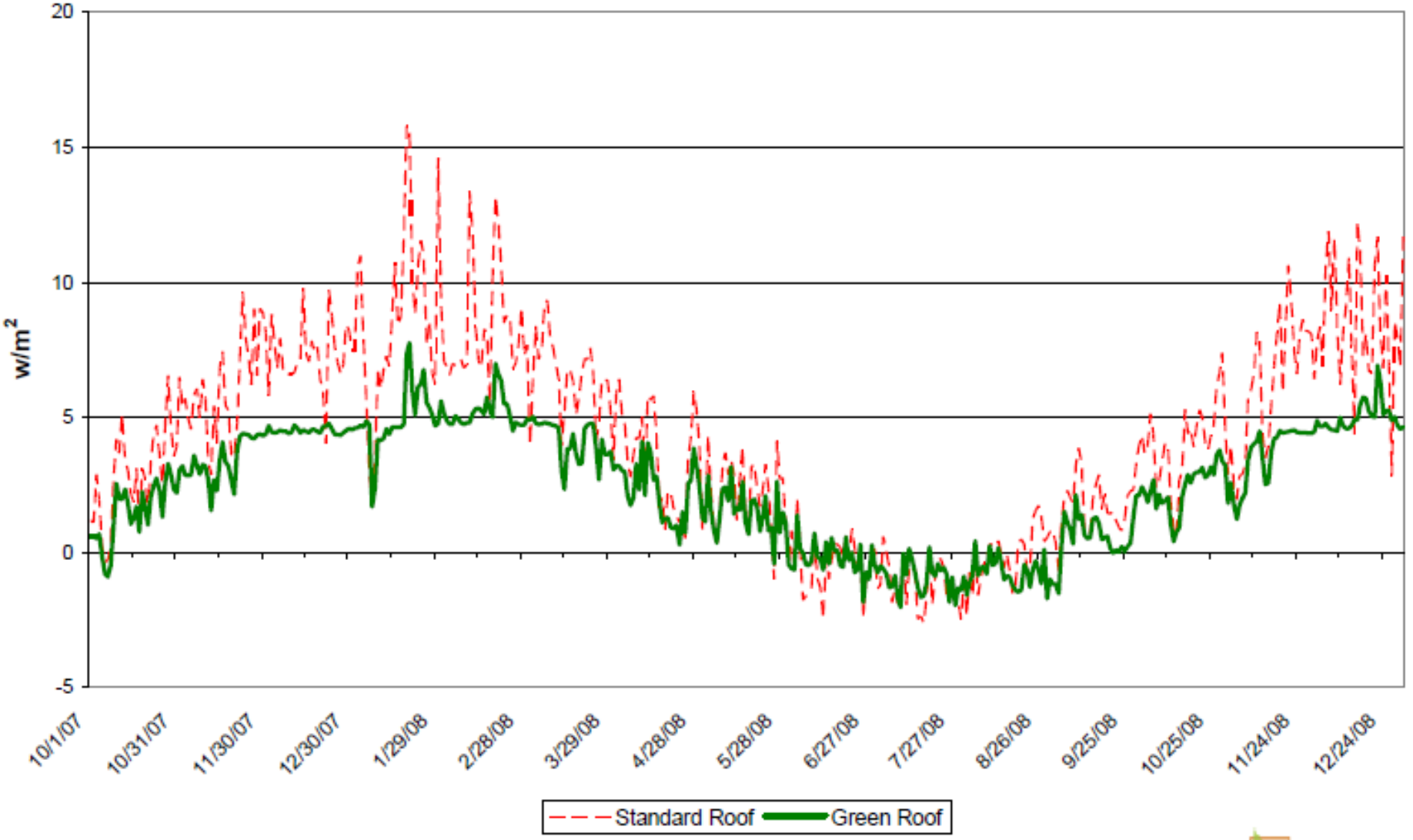
Prepared by D. Reisdorph, 8/15/2008

THE GREEN TEAM INC.


Rooftop Temperatures
Temperature F
140
120
100
80
60
40
20
0
The green roof buffers under membrane temperatures.
51.77
54.31
51.35
50.09
50.17
27.53
32.06
29.06
14.34
11.34
131.6
87.00
98.8
117.6
126.2
Green Roof
Standard Roof
Green Roof
Standard Roof
Green Roof
Standard Roof
Average 10/1/07 to 12/31/08
During coolest 15 minute interval, Air Temperature -4.93°F on 12/21/08
During warmest 15 minute interval, Air Temperature 94.1° F on 9/2/08
Surface
Under Membrane
Soil
Prepared by D. Reisdorph, 1/15/2009
THE GREENTEAM

Average Daily Heat Flux

10/1/2007 to 12/31/2008

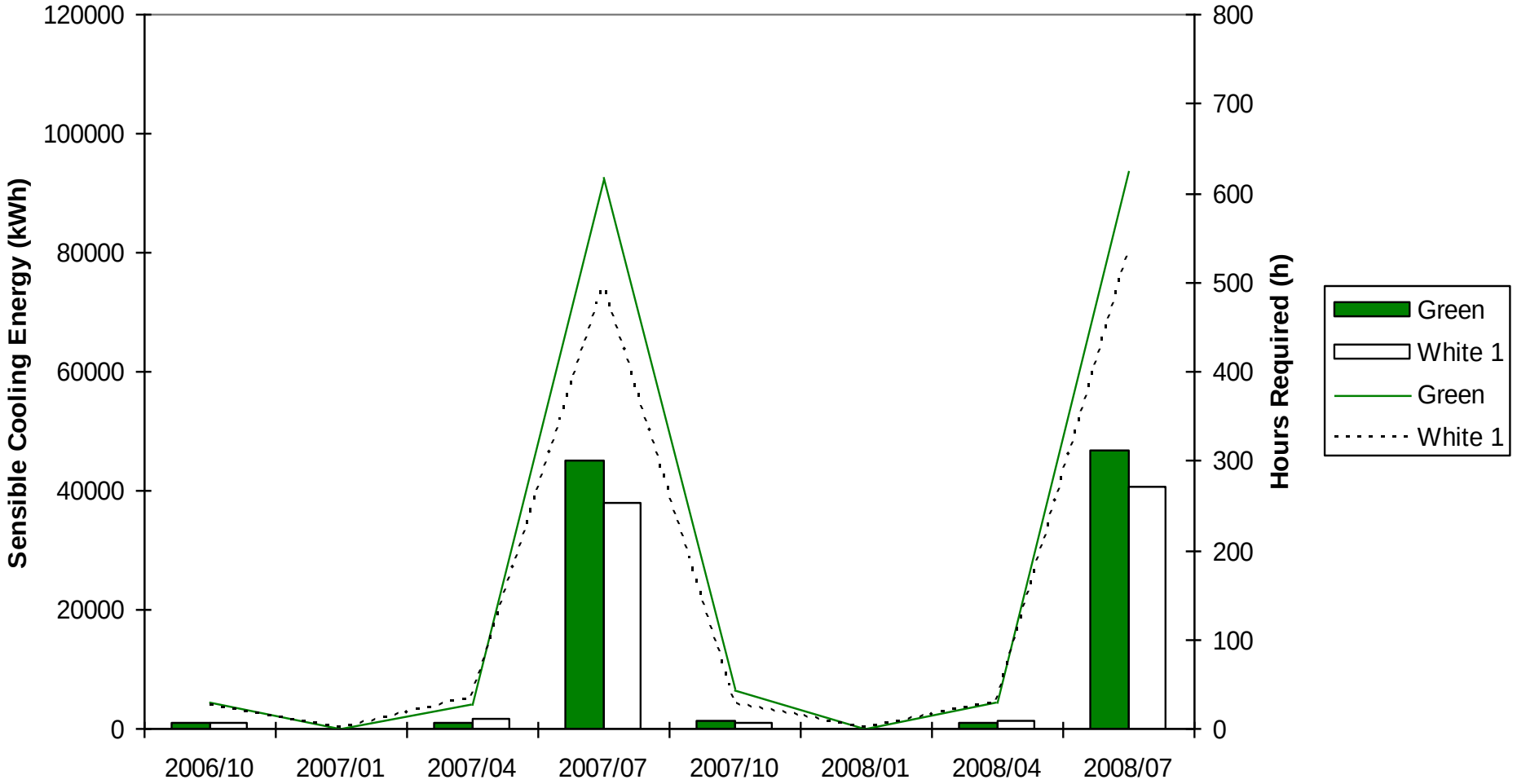


Prepared by D. Reisdorph, 1/15/2009

Simulated Cooling on a Representative Volume

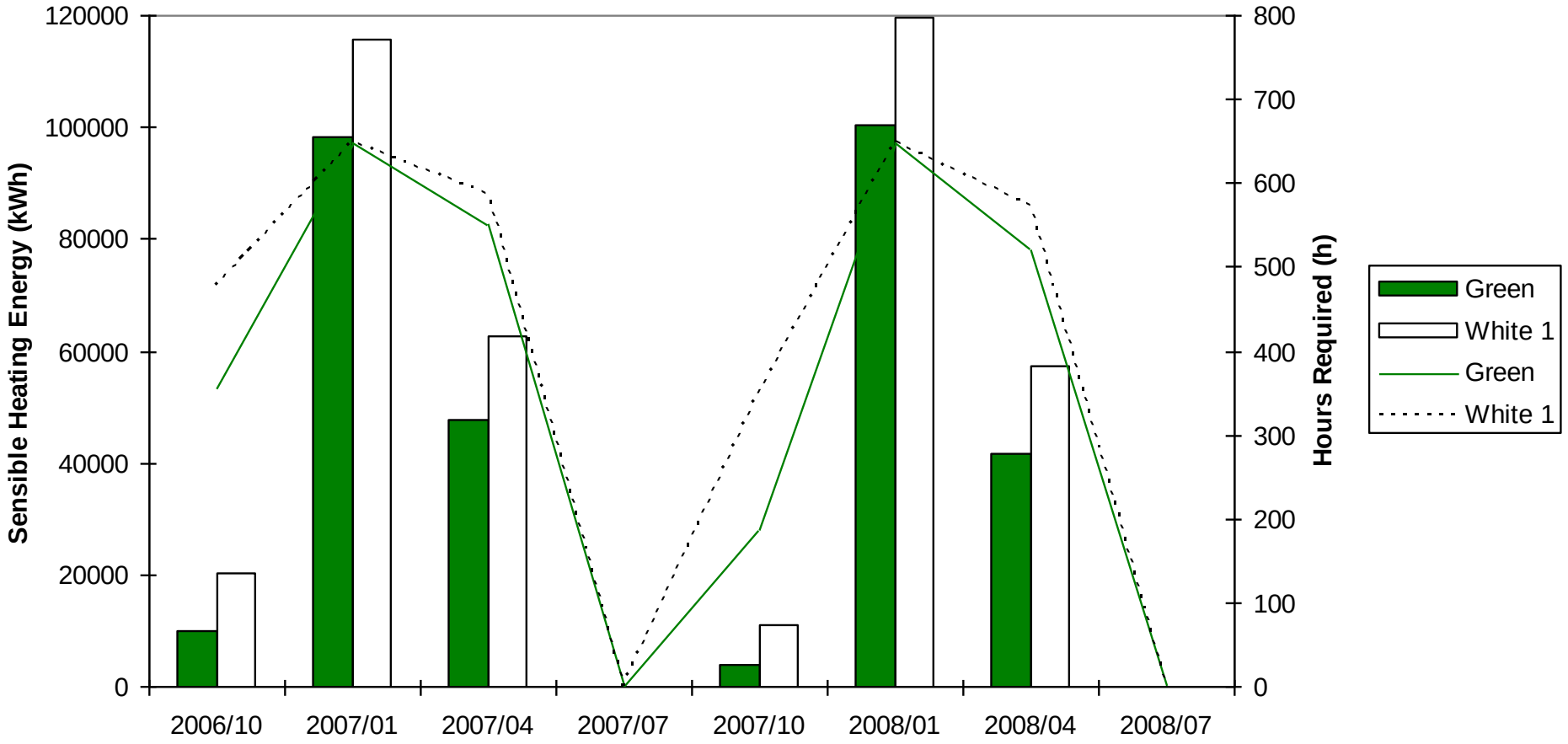
Comparisons between the Green and White Roof

Based on Measured Heat Fluxes (bars represent loads; lines represent hours of operation)

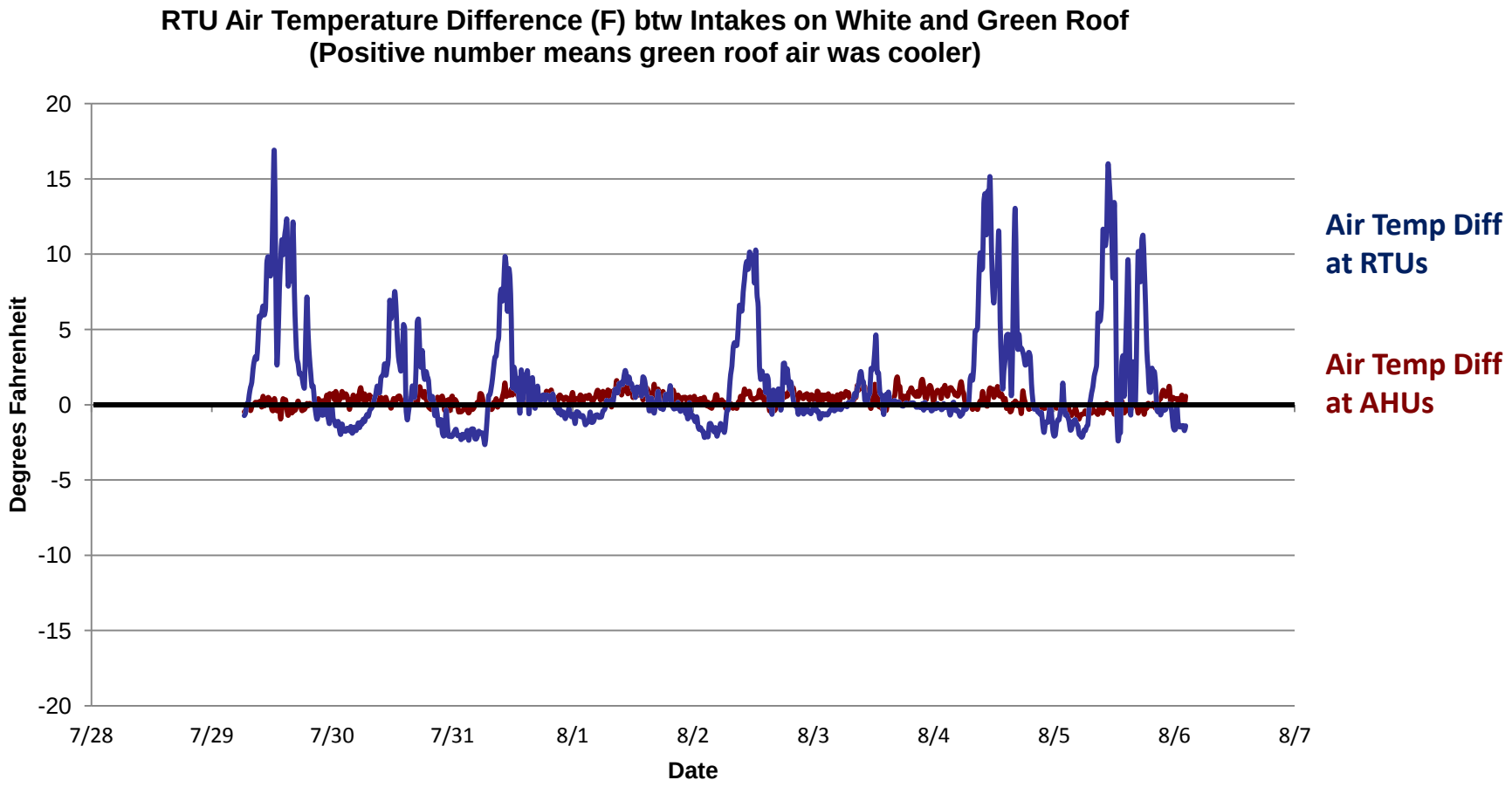


Simulated Heating on a Representative Volume
Comparisons between the Green and White Roof

Based on Measured Heat Fluxes (bars represent loads; lines represent hours of operation)

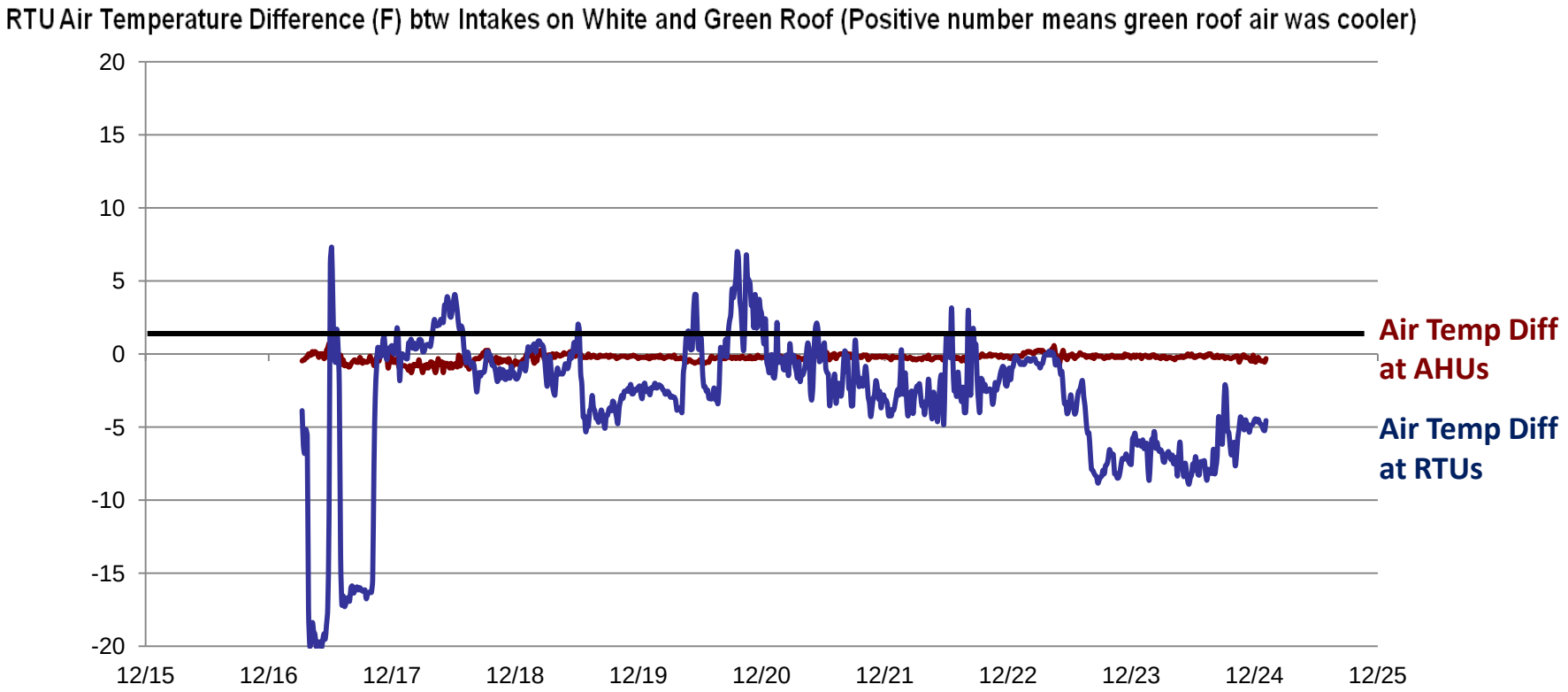


Summer Air Temperature on Chicago Walmart Roof



- **Summer data show signficantly cooler air at RTUs on green roof side**
- **Translates to energy savings in space conditioning**

Winter Air Temperature on Chicago Walmart Roof



- **Winter data show warmer air at RTUs on green roof side**
- **Translates to energy savings in heating**

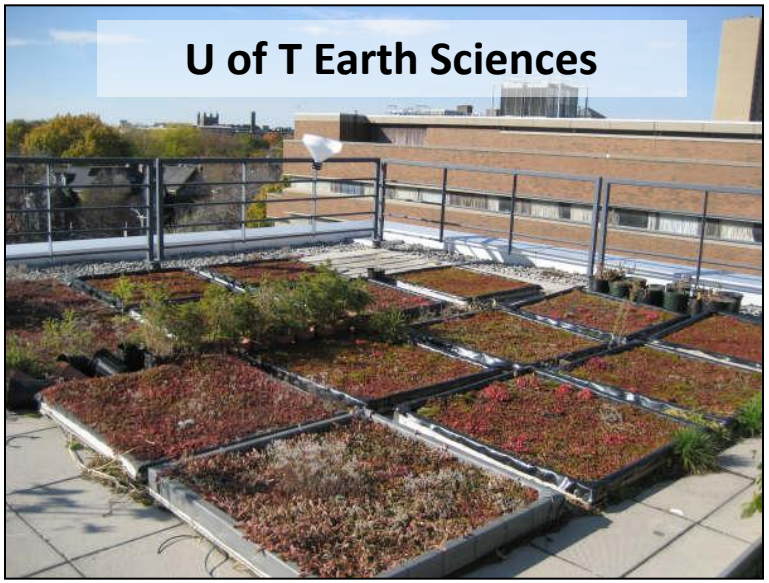
Improved Simulated Performance
Green Roof vs. Standard (White) Roof
(includes impact of cooler air temperatures at RTU)

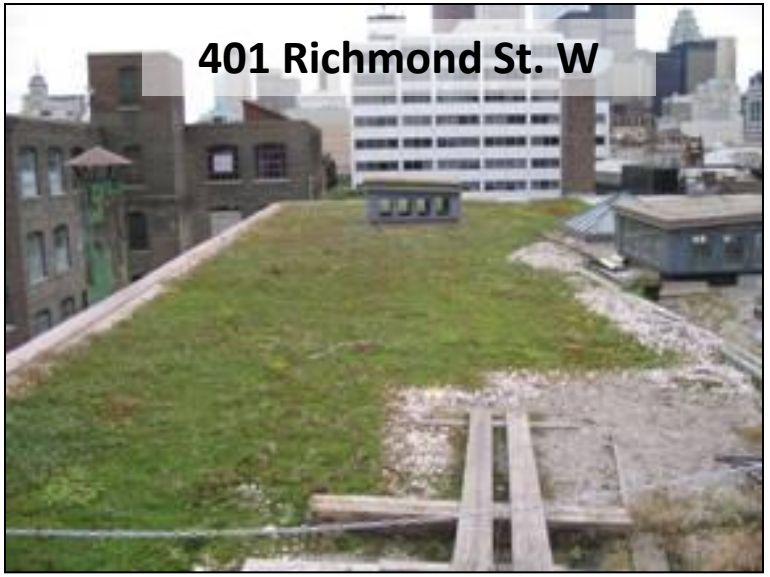
	Houston	Chicago
	% REDUCTION	**% REDUCTION**
COOLING	**10%**	**15%**
HEATING (GAS)	**12%**	**11%**
TOTAL REDUCTION	**3.1%**	**5.3%**

Energy Results (conclusions)

- Recent data show increasing savings from green roof. Higher cooling savings from green roof expected as white roof becomes weathered/dirty (likely since power washing is too expensive to pay back quickly)
- For full green roof, 0.5 – 5.3% annual savings expected in a range of climates
- Much of the savings came from heating
- Greater savings achieved in modelling southern location


Green Roof Sites
Sedum



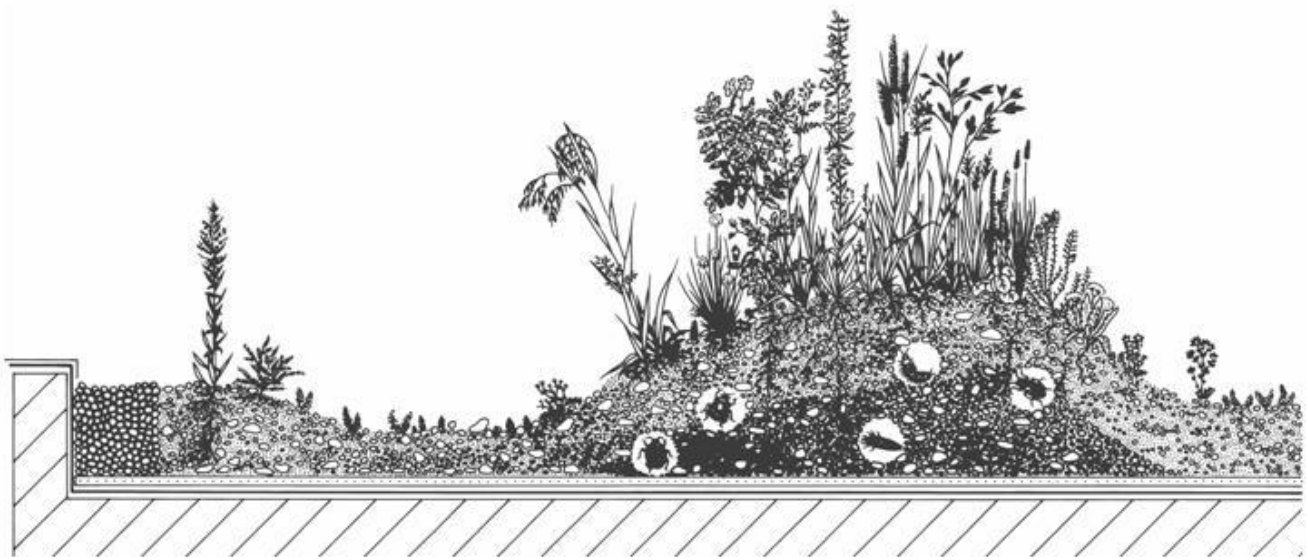
Green Roof Study Sites
Broadleaf / Mixed

The basic principle to improve the habitat quality for the most species:

GREEN ROOFS For Healthy Cities

www.greenroofs.org

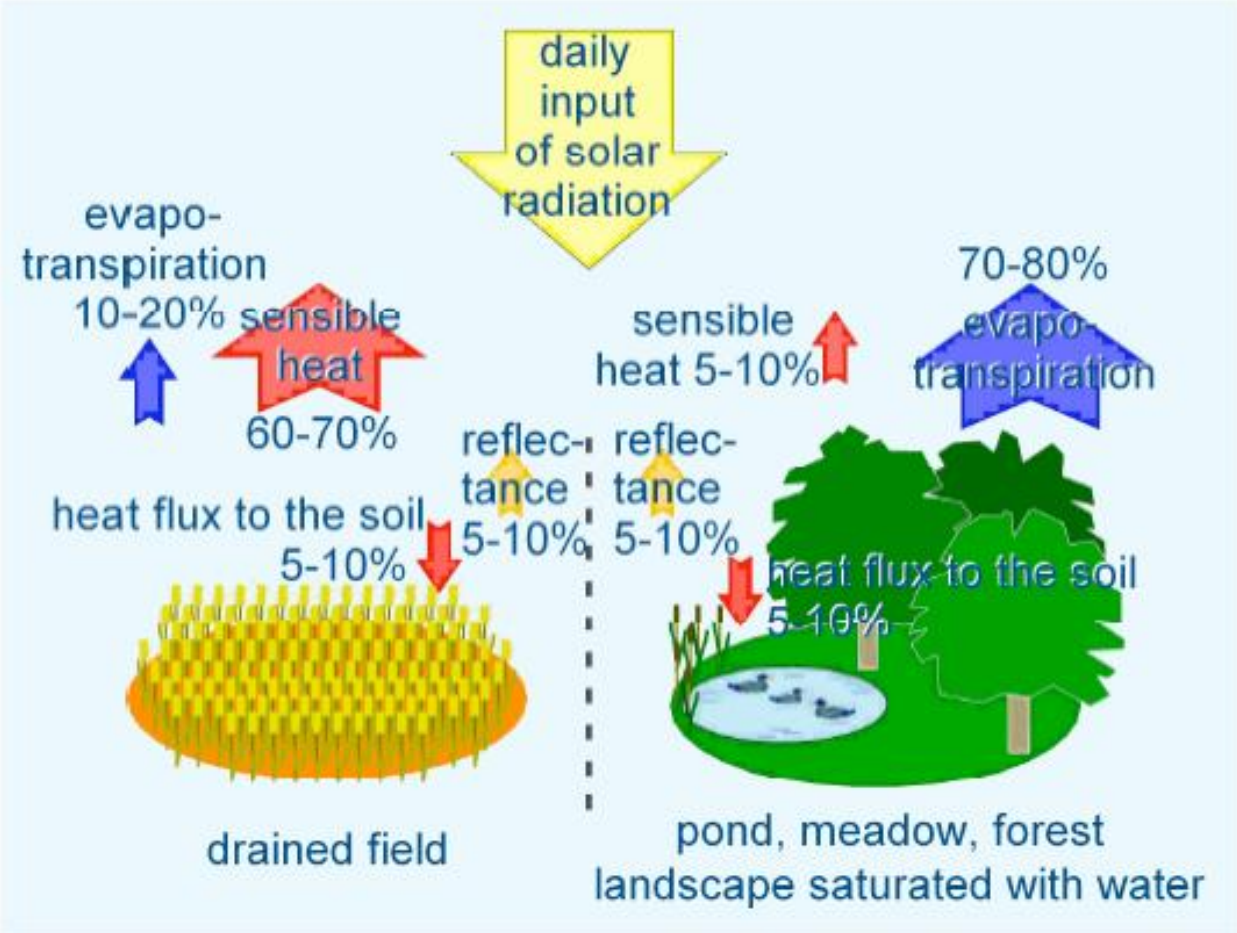
Planning of a diverse substrate distribution on the green roofs.



Improving habitat quality by varying the substrate thickness.

Source: Green roof Competence Centre University of Applied Sciences Wädenswil

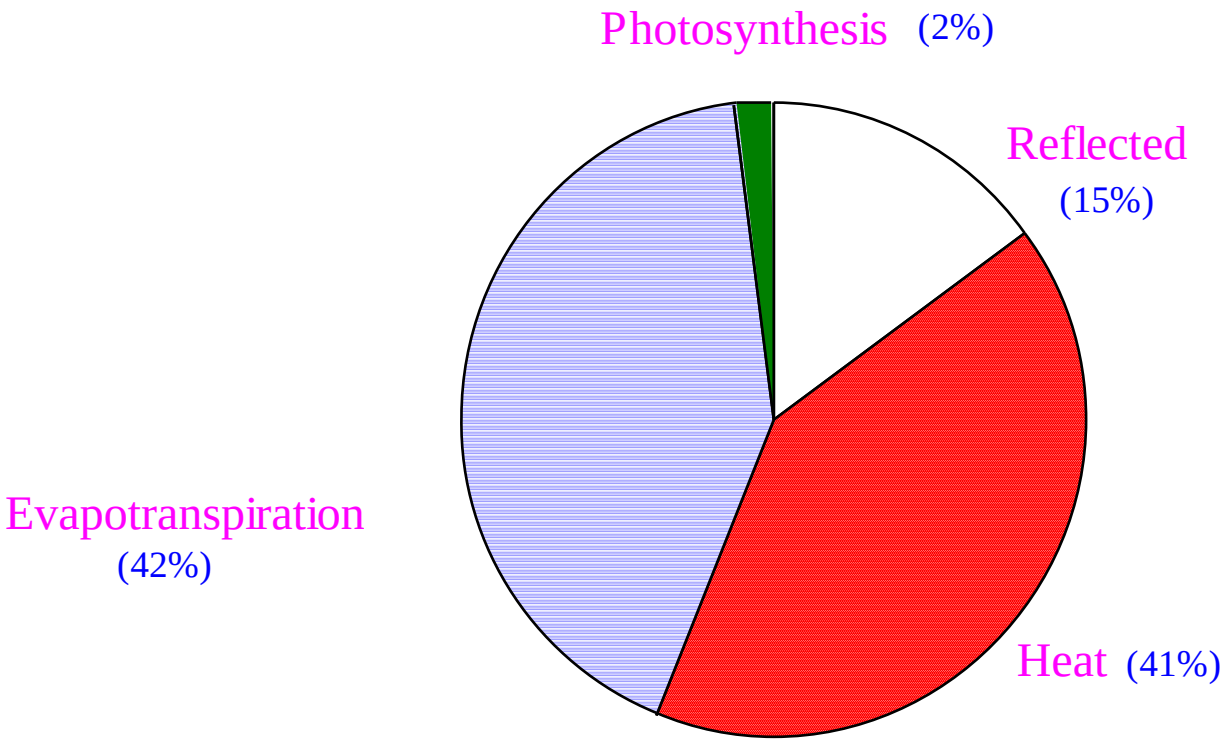
Distribution of Solar Energy on Two Different Landscapes



Kravcik et al 2007, www.waterparadigm.org

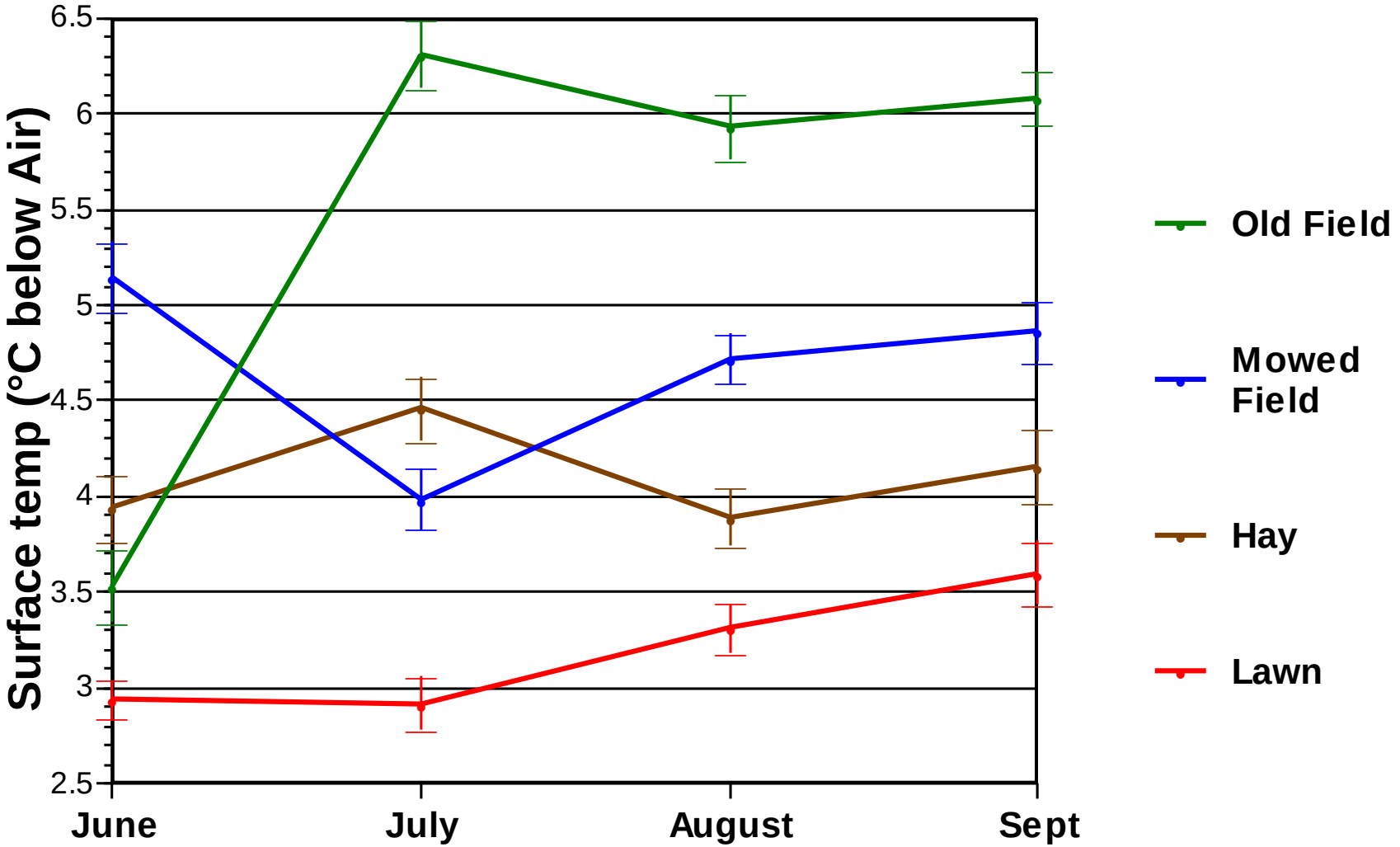
The distribution of solar energy during the growing season in the Hubbard Brook Forested Ecosystem

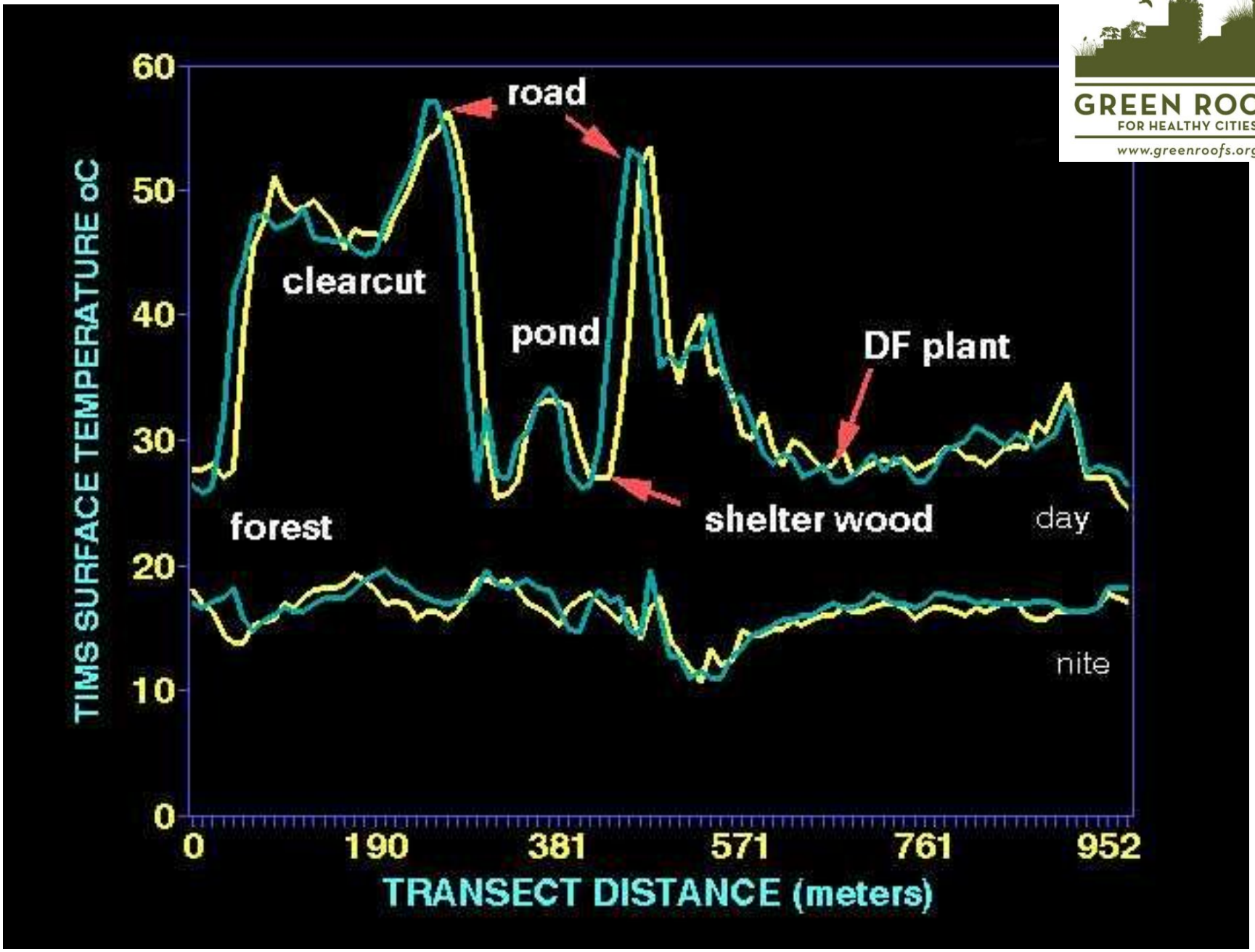
(From Bormann and Likens, 1978)



Courtesy of James Kay

Surface temperature and ecosystem development





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Luvall and Holbo (1989)

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	Quarry	Clearcut	Douglas Fir Plantation	Natural Regrowth	400 year old Douglas Fir Forest
K* (w/m^2)	**718**	**799**	**854**	**895**	**100 5**
L* (w/m^2)	**273**	**281**	**124**	**124**	**95**
R_n (w/m^2)	**445**	**517**	**730**	**771**	**830**
T (^oC)	**50. 7**	**51. 8**	**29. 9**	**29. 4**	**24. 7**
R_n/K^* (%)	**62**	**65**	**85**	**86**	**90**

where

$$R_n = K^* - L^* \qquad L^* = \varepsilon [\sigma (T)^4]$$

R_n/K^*: % of net incoming solar radiation used by the ecosystem.

Benefits of Biodiverse Roofs

- Summer
  - Increased evapotranspiration
  - Cooler surfaces
  - Increased insulation over some areas
- Winter
  - reduces wind speed and hence wind chill
  - Perhaps better at holding snow

Conclusions and Acknowledgments

- Reduce energy consumption in all four seasons
- Exact Savings depend on a range of factors
- Small summer savings may underestimate true value
- Biodiversity increases savings but exact amount requires further research

- Rob Berghage, Penn State U.
- Dusty Gedge, Living Roofs
- Green Roofs for Healthy Cities
- James Kay, U.Waterloo
- Jeff Luvall, NASA
- Ryan Martens
- Charlie Miller, Roofmeadow
- Ian Molloy, IES
- Don Mosley, Wal-Mart
- David Sailor, Portland State U.
- Kirstin Weeks, Arup