


Photo 1 (left): Green roof on April 28, 2005. Photo 2 (right): Green roof on Aug. 18, 2005.

Evaluating Green Roof Energy Performance

Summertime data indicate significantly lower peak roof surface temperatures and higher nighttime surface temperatures for the green roof. The maximum average day temperature seen for the conventional roof surface was 130°F (54°C) while the maximum average day green roof surface temperature was 91°F (33°C), or 39°F (22°C) lower than the conventional roof.

By Jeff Sonne

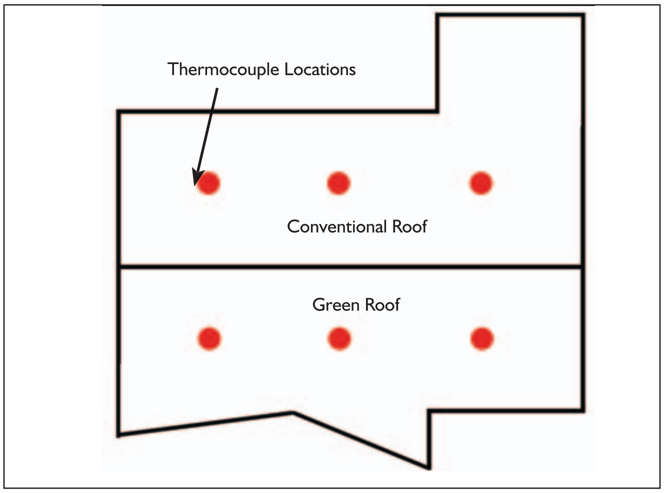
Green or vegetated roofs are becoming more popular in the United States. High profile examples of U.S. green roofs include the Chicago City Hall and Ford Motor Company Dearborn truck plant that has a total green roof area of more than 10 acres (4 ha). Chicago has begun issuing grants to help residential and small commercial building owners install green roofs.

Green roofs have been in use in Europe for centuries and are a more recent phenomenon in the U.S. Germany has emerged as a leader in modern green roof technology and usage where it's estimated that there are more than 800 green roofs that comprise 10% of all flat roofs.[1,2]

In addition to rainwater runoff reduction and aesthetic benefits, studies have found that green roofs significantly reduce roof surface temperatures and heat flux rates. A study in Toronto found that two green roofs with minimal vegetation reduced peak summertime roof membrane temperatures of a gymnasium by more than 35°F (1.6°C) and summertime heat flow through the roof by 70% to 90% compared with a conventional roof on the same building[3]. Simulations also indicate cooling load reductions from green roofs ranging from 1% to 25% depending on building specifics and characteristics of the green roof.[4,5]

This column evaluates a study of a green roof installed on a two-story building addition completed in June at the University of Central Florida. This project is led by the University of Central Florida's Stormwater Management Academy through a grant from the Florida Department of Environmental Protection. The department, through a U.S. Department of Energy State Energy Program grant, also is funding the author to compare the energy performance of the green and conventional roofs.

One half of this project's 3,300 ft² (307 m²) roof is a conventional, light colored membrane roof (*Photos 1* and *2*). The project half has the same membrane with a green roof of grasses and small plants covering the project surface. It consists of 6 in. to 8 in. (0.15 m to 0.2 m) of plant media and a variety of primarily native Florida vegetation up to approximately 2



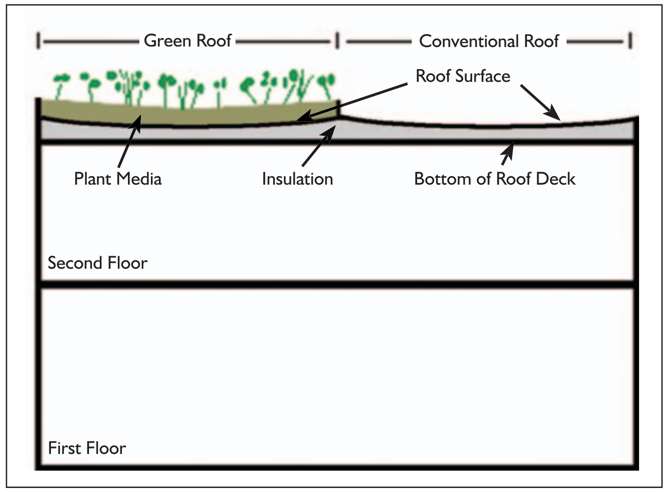


Figure 1 (left): Roof diagram with sensor locations. Figure 2 (right): Building section diagram.

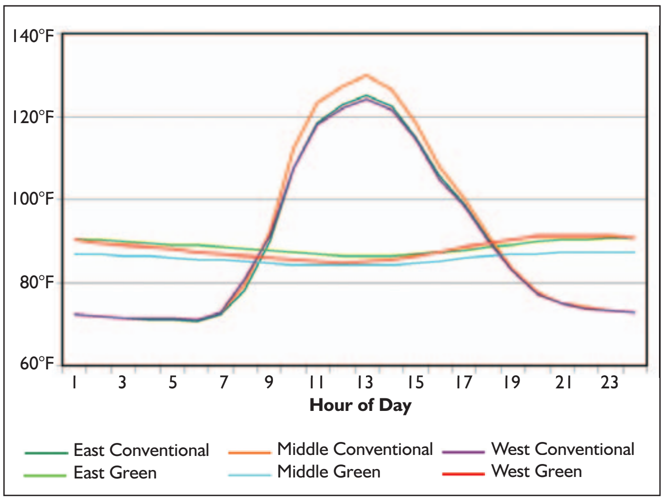


Figure 3: Comparison of average roof surface temperatures.

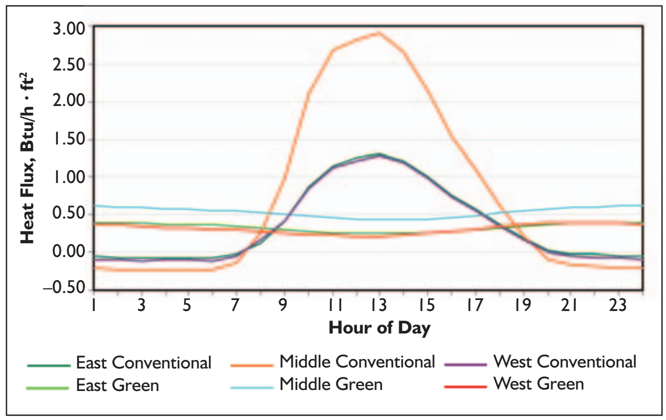


Figure 4: Comparison of average roof heat fluxes.

ft (0.6 m) in height. The green roof is irrigated twice a week for approximately 15 minutes each time, with collected rainwater when available. Roof surface solar reflectance tests were conducted Aug. 18 for the conventional and green roofs according to ASTM Standard E1918-97 methodology.[6] The conventional and green roof reflectances were found to be 58% and 12%, respectively.

The energy aspects of this study focus on roof temperature and heat flux comparisons between the conventional, light-colored membrane half of the roof and the green roof. Roof geometry and drainage were designed to allow both the conventional and green roofs to have similar "mirror image" insulation levels and corresponding temperature sensor locations as shown in the roof surface and building section diagrams (*Figures 1* and *2*).

Temperature measurements include the roof surface, bottom of roof deck, interior air and green roof plant media surface. Meteorological measurements include ambient air temperature, total horizontal solar radiation, rainfall, wind speed and wind direction. All sensors are sampled every 15 seconds and measurements are averaged or totaled every 15 minutes. Monitoring began in July 2005 and will continue through July 2006.

Summertime data indicate significantly lower peak roof surface temperatures and higher nighttime surface temperatures for the green roof. *Figure 3* compares the conventional and green roof surface temperatures for each of the six measurement locations (three conventional roof and three green roof) between July 4 and Sept. 1. The maximum average day temperature seen for the conventional roof surface was 130°F (54°C) while the maximum average day green roof surface temperature was 91°F (33°C), or 39°F (22°C) lower than the conventional roof. A significant shift occurs during peak temperature time periods. Peak surface temperatures for the conventional roof occur around 1 p.m. while the peak green roof surface temperatures occur around 10 p.m.

The minimum average roof surface temperature was 71°F (22°C) for the conventional roof and 84°F (29°C) for the green roof. The conventional roof's lower nighttime temperatures are due to its surface being directly exposed to the night sky while the green roof surface is covered with plants.

Initial heat flux estimates have also been made for each of the six roof measurement locations for the same period. Heat flux is

Location	Approx. R-Value	Avg. Green Roof Flux, Btu/h · ft²	Avg. Conventional Roof Flux, Btu/h · ft²
East	38	0.33	0.36
Middle	17	0.53	0.74
West	38	0.31	0.34

Table 1: Average heat flux estimates for July 4, 2005, through Sept. 1, 2005.

calculated from roof surface and bottom of roof deck temperature measurements and estimated insulation R-values, which because of drainage taper, range from approximately R-15 at the drains to R-60 at the east and west ends of each roof. *Figure 4* shows roof heat flux rates for the average day. Heat flux rates for the conventional roof peak in the early afternoon at approximately 2.9 Btu/h·ft² (9.15 W/m²) (at the middle sensor location) while the green roof peaks around midnight at approximately 0.6 Btu/h·ft² (1.89 W/m²) (also at the middle sensor location).

Table 1 shows average heat flux rates over the July 4 through September 1 monitored period. The weighted average heat flux rate over the period for the green roof is 0.39 Btu/h·ft² (1.23 W/m²) or 18.3% less than the conventional roof's average heat flux rate of 0.48 Btu/h·ft² (1.51 W/m²), with the most significant differences occurring near the middle of the roofs at the points of lowest insulation.

Estimating building energy use impacts from green roofs is somewhat involved and dependant on individual building characteristics such as size, use, number of stories and roof/attic design. Side-by-side monitoring studies often are further complicated by submetering issues, since it usually is difficult to separate out HVAC power use for sections of the building under the conventional roof vs. sections under the green roof.

As a rough estimate, assuming all heat gain through the roof must be removed by the AC system, an air-conditioning system efficiency of 10 Btu/h (3 W) per Watt (including fan power and distribution losses) and a total roof area of 3,300 ft² (307 m²), the average energy use to remove the additional heat gain from the conventional roof over the monitored summer period is approximately 700 Watt-hours per day.

Most commercial low slope roofs are darker than the conventional roof used in this study.[7] Thus, if the conventional roof color were more typical, benefits of the green roof would be greater than those seen here. Over time, the green roof's vegetative canopy will continue to spread and likely reduce heat gains while the conventional roof will darken somewhat and absorb more heat. Another solar reflectance test is planned for next summer to document reflectivity changes of both the conventional and green roofs. Additional temperature and heat flux comparisons will also be made at that time to look at corresponding roof performance changes.

References

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