



EPA's Region 8 Office was built as a demonstration project of the General Services Administration's (GSA's) Office of Federal High-Performance Green Buildings. This "build-to-suit" office and retail space was designed and constructed through a design-build public-private partnership to be as sustainable as technology and budget would allow, incorporating sustainability elements developed jointly by GSA and EPA. The building now stands as a hallmark of environmental sustainability in Denver's Lower Downtown Historic District. Since the Region 8 Office opened in 2007, one of its most successful sustainable features has been the vegetated or "green" roof, the first of its kind in Colorado.

Studying a Groundbreaking Green Roof

The green roof at the Region 8 Office, which is ENERGY STAR® certified, consists of plants growing in trays made of recycled plastic, which cover 20,000 square feet (nearly 60 percent) of the 35,000-square-foot total roof surface of the tiered 8th, 9th, and 10th floors. When first installed, the trays contained 40,000 individual plants rooted in 4 inches of soil. Four species of sedum were selected for visual appeal, survivability in harsh environments with temperature extremes, and for their capacity to withstand drought conditions.

A team of EPA researchers from Region 8 and EPA's Office of Research and Development's National Risk Management Research Laboratory led a series of research studies to address the numerous challenges faced by the green roof—limited natural precipitation, increased solar radiation, high wind velocities, predominately sunny days, and a thin layer of soil. The research team collaborated with partners from Colorado State University's (CSU's) Department of Horticulture and Landscape Architecture, the Denver Botanic Gardens, the Urban Drainage and Flood Control District (UDFCD), the Alliance for Sustainable Colorado, and the City of Denver. EPA dedicated 2,000 square feet of the green roof to conduct research on eight additional species, six of which are native to Colorado.

Vital Statistics

Facility Type: Office

Construction: Leased/New Construction

Location: Denver, Colorado

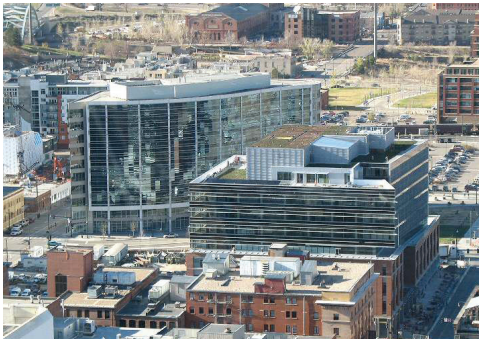
Size: 314,200 gross square feet (partially occupied by EPA)

Opened: January 2007

LEED® Status: Gold for New Construction (version 2.1)

LEED Points Earned: 40 of 69 possible





Overcoming Green Roof Growing Pains

An extensive green roof has a shallow growing medium with a modest roof load, limited plant diversity, minimal watering requirements, and is often not accessible. Due to the porous and well-drained nature of the typical soil used in extensive green roofs, the success or failure of the system depends on a species' ability to grow in the medium. This challenge is exacerbated for extensive green roofs in areas characterized by high elevation and a semi-arid climate. Over time, the original plantings of solely sedum species proved less than ideal for the local climate. Accordingly, the best approach for a green roof in the Denver area was to feature an array of plants that are adaptable to dry, porous soils. Furthermore, choosing diverse plant species can provide habitat for birds and insects in urban areas.

The green roof was originally equipped with a drip irrigation system. However, because the drip lines were placed on top of the trays instead of within the subsurface, the exposure to sunlight caused them to degrade. Researchers also suspected that the soil did not allow for water to spread laterally across the trays, which limited the growth of the plants. As a result, the drip system was replaced with a spray irrigation system in 2009.

The research team confirmed that watering practices should reflect seasonal conditions. Spring irrigation in March, April, and May might not be necessary, depending upon the amount of natural rainfall and the ambient temperature. In contrast, the summer months are the most crucial months for irrigation. Winter watering can be useful for maintaining healthy plants during warmer, dry periods. However, in seasons where regular snowfall is accumulating and melting on the green roof, winter watering is not necessary. In very dry years, watering can help prevent plant loss due to desiccation.

Notably, shading beneath or at the edge of the solar photovoltaic panels can produce a synergy with the green roof substrate, keeping the area cooler and requiring less irrigation.

Urban Heat Island

A "heat island" is an urban area that experiences higher temperatures than nearby rural areas. The annual mean air temperature of a city with 1 million people or more can be 1.8 to 5.4 degrees Fahrenheit warmer than its rural surroundings. In the evening, the temperature differences can be as high as 22 degrees Fahrenheit. Heat islands affect communities by increasing summertime peak energy demand; air conditioning costs; air pollution and greenhouse gas emissions; heat-related illness and mortality; and water quality.

Stormwater Management

When the Region 8 Office was designed, mitigating stormwater runoff with green roofs was a non-standard practice.

Therefore, the building developer had to provide significant data up front without reasonable assurances that the project would be approved by the local drainage district, UDFCD, or prove effective in its designed purpose—detention and infiltration of stormwater.

Stormwater performance data collected from the green roof and compared to a conventional, gravel roof on a building across the street from the Region 8 Office supported the hypothesis that the green roof is effective at detaining and infiltrating stormwater runoff. This is especially true for snowmelt events and for smaller precipitation events (generally less than 1 inch of rainfall in a 24-hour period).

Data from the Region 8 Office project was used to establish the installation of green roofs as an approved best management practice for infiltrating and detaining runoff by UDFCD. Developers can now choose to install a green roof without additional analysis, using design specifications and performance criteria provided directly by UDFCD.

Green roofs can mitigate the heat island effect by providing shade and removing heat from the air through evapotranspiration. When compared to a conventional, gravel roof on a building across the street, the temperatures on the Region 8 Office's green roof were lower during hot weather and higher during cold weather. The cooling and warming properties of the green roof derive from the retention of moisture in the green roof's plants and growing medium.

Because temperatures on the green roof are less extreme than those of the conventional roof, the green roof waterproof membrane suffers less physical stress. This may explain why green roofs can last two to three times longer than a conventional roof. Not having to re-roof as frequently lowers the amount of construction debris generated and saves money on roof maintenance.

Lessons Learned

Research with CSU and an evaluation by a green roof expert revealed the following lessons from the green roof installation at the Region 8 Office. These lessons can educate others in the best approach for designing green roofs in the semi-arid and arid West.

- Plants are more vulnerable to temperature fluctuations when soil depth is 2 inches or less. Soil depth should be at least 4 inches to support evapotranspiration, which helps maintain a constant temperature across the green roof.
- Plants can die from intense ultraviolet (UV) and hot temperatures from the plastic tray edges. In addition, exposed irrigation lines are subject to degradation from UV rays.
- When the winter turns unseasonably warm, it can send a signal to plants to end their dormancy cycle. Should this signal occur during freezing temperatures, plants become more susceptible to die-back.
- In the fall, cut back dead flower heads and stems. During the following spring, seeds should be shaken out of their seed pods onto the green roof to encourage the germination of new plants.
- Reflective heat from windows and metal siding inhibits plant growth. Thus, cacti should be planted in areas with the highest reflective heat.
- Scouring from strong winds is the main cause of soil loss; parapet walls help prevent wind scour.
- Winter watering should be done during periods of low precipitation.

The Region 8 Office's green roof can help guide the design of future green roofs in semi-arid climates. The University of Colorado at Denver, working with EPA staff and UDFCD, developed a comprehensive resource called *Design Guidelines and Maintenance Manual for Green Roofs in the Semi-Arid and Arid West*. Using these guidelines and standard software for modeling stormwater runoff reductions, developers can design, construct, and access the many benefits of green roofs.

Under the Roof: Energy-Efficient Design

Beyond reducing the urban heat island effect with its green roof, the building's integrative energy-saving design features:

- **Forty-eight solar photovoltaic (PV) panels with peak output of 10 kilowatts.**
- **High-efficiency window glazing, external shading and interior light shelves, daylight and occupancy sensors, and reduced power use for lighting based on open workspace floor plans.**
- **Improved heating, ventilation, and air conditioning design parameters and equipment efficiency, variable frequency drive chillers, underfloor air distribution, and an air-side economizer.**
- **Increased insulation in walls (R19) and roofing (R31).**

The building's two "L" shaped wings with a central atrium maximize daylighting and allow building managers to take advantage of local environmental conditions in operating the building. The temperature and lighting can be adjusted to balance comfort levels in each "L" based on ambient daylighting and heat gain conditions. The central atrium helps reduce energy use because it is a partially conditioned space that acts as a thermal buffer for the building as a whole.