California Academy of Sciences Green Roof

Methods

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This investigation was conducted as part of the Landscape Architecture Foundation's 2024 *Case Study Investigation* (CSI) program. CSI matches faculty-student research teams with design practitioners to document the benefits of exemplary high-performing landscape projects. Teams develop methods to quantify environmental, social, and economic benefits and produce Case Study Briefs for LAF's *Landscape Performance Series*.

The full case study can be found at: https://landscapeperformance.org/case-study-briefs/CA-academy-green-roof

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Environmental Benefits

- **Attracts at least 36 species of pollinators and insects. Over 70% of the living roof's plant species are native to California.**

Background:

The 2.5-acre living roof atop the California Academy of Sciences was planted with an estimated 1.7 million individual plants native to the San Francisco Bay Area. The project's initial plant palette was selected based on several key factors including tolerance to harsh conditions such as low nutrient soil depth, low water requirements, and attractiveness to key pollinators. Initial plant species included herbaceous perennials: *Achillea millefolium*, *Heuchera micrantha*, *Satureja douglasii*, *Solidago californica*, *Stachys bullata*, *Trifolium wormskioldii*; Grasses: *Festuca rubra*, *Festuca idahoensis*, *Koeleria macrantha*; Emergent wetland species: *Juncus patens*, *Juncus xiphioides*, *Carex tumulicola*, *Sisyrinchium bellum*, *Carex pansa*; Succulents: *Dudleya farinosa*; and Wildflowers: *Dichelostemma capitatum*, *Plantago erect*a. [1] Since the project opened in 2005, museum staff and local volunteers have introduced additional species. These additional plantings include species that bloom at various times of year, providing nectar, pollen, and food sources for an array of regional pollinators and other wildlife. Museum staff have observed regular rooftop visits from species including: Lesser goldfinches, Black phoebes, Dark-eyed juncos, Annas hummingbirds, Killdeer, Red-tailed hawks, California bumble bees, and Green hairstreak butterflies. [2]

[1] Greenroofs.com. "California Academy of Sciences (CAS) Living Roof." Accessed August 2, 2024. http://www.greenroofs.com/projects/california-academy-of-sciences-cas-living-roof/.

[2] Green Grid Roofs. "Northern California Suggested Plants from the Living Roof Manual." Accessed August 1, 2024. https://www.greengridroofs.com/wp-content/uploads/2018/01/Northern-CA-Suggested-Plants-from-Living-Roof-Manual.pdf.

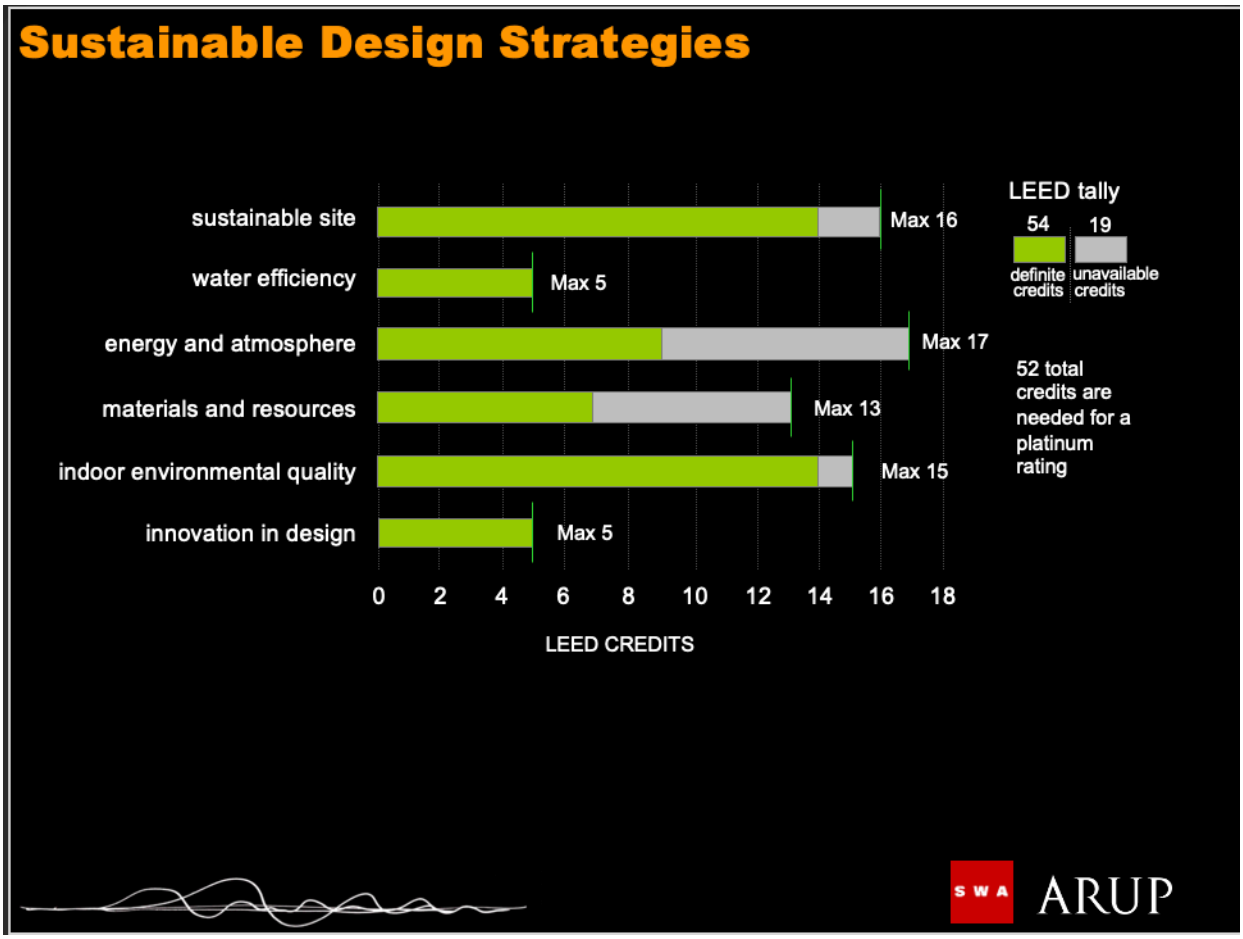


Figure 1: Presentation slide by SWA, 2006

The California Academy of Sciences building received an overall LEED Platinum rating, which at the time, required at least 52 out of 71 total credits across multiple performance categories. At the time this rating was awarded, projects were evaluated based on myriad criteria including “on-site protection or restoration of open habitat.” The living roof’s provision of native habitat helped the Academy earn credits in this category.

Figure 2: Paul Kephart from RANA Creek created a mock up to measure plant success

The design team constructed 1:1-scale mock-ups of the living roof's steep topography before installing plants on the site itself. The test plots were constructed adjacent to the Academy in order to ensure that select plant material would be able to thrive under the extreme microclimate conditions of San Francisco's Golden Gate Park.

Figure 3: RANA and other project team members gather near the mock up green roof.

Method:

Information related to the project's use of native plants for supporting regional pollinators was gathered from web-based archives, and materials provided by the landscape architects. All data was published and cross-referenced with California Academy of Sciences staff. RANA conducted the mock-up studies and monitored the success rate of plant longevity along with which general pollinators were attracted. Over time, the California Academy of Sciences has updated their information on which species of pollinators have occupied the green roof.

Calculations:

Species	Common Name	Survival	70% cover (3 months)	Plant Height	Utilization
Herbaceous perennials					
Achillea millefolium	yarrow	yes	yes	12"	flys/bees/lady bugs
Armeria maritima ssp. californica	sea thrift	yes	yes	6"	bees
Fragaria chiloensis	beach strawberry	yes	yes	3"	bees
Heuchera micrantha	alum root	yes	no	5"	hummers
Prunella vulgaris var. lanceolata	self heal	yes	yes	6"	bees/ladybugs
Satureja douglasii	yerba buena	yes	no	3"	unobserved
Solidago californica	goldenrod	yes	yes	16"	bees/ladybugs
Stachys bullata	hedge nettle	yes	yes	14"	hummers
Trifolium wormskioldii	cow clover	no	no		n/a
Grasses					
Festuca rubra	red fescue	yes	yes	14"	butterflies
Festuca idahoensis	Idahoe fescue	yes	yes	8"	unobserved
Koeleria macrantha	June grass	yes	no	8"	unobserved
Emergent Wetland Species					
Junus patens	spreading rush	yes	yes	12"	unobserved
Juncus xiphioides	iris leaved rush	yes	yes	12"	unobserved
Carex tumulicola	foothill sedge	yes	yes	8"	unobserved
Sisyrinchium bellum	blue eyed grass	yes	yes	6"	native bees
Carex pansa	sand sedge	yes	yes	6"	unobserved
Succulents					
Sedum spathulifolium	sedum	yes	no	3"	butterflies
Dudleya farinosa	dudleya	yes	yes	8"	unobserved
Wildflowers					
Eschscholzia maritima	poppy	yes	n/a	6"	bees/butterflies
Lupinus bicolor	lupine	yes	n/a	6"	unobserved
Lasthenia californica	gold fields	yes	n/a	4"	butterflies
Layia platyglossa	tidy tips	yes	n/a	4"	unobserved
Dichelostemma capitatum	blue dicks	no	no		n/a
Plantago Erecta	California Plantain	yes	yes	2"	butterflies

Figure 4: Table created by RANA. Observing plant success and pollinators.

Based on the table above, certain plants, such as *Trifolium wormskioldii* and *Dichelostemma capitatum,* did not have a high success rate. However, a majority of plants tested did flourish and also were able to provide resources for pollinators.

Native Plant Species on the Living Roof

SEPTEMBER 2014

SCIENTIFIC NAME	COMMON NAME
Achillea millefolium	Common Yarrow
Acmispon glaber (syn. *Lotus scoparius*)	Deerweed
Ambrosia chamissonis	Beach Bur
Anaphalis margaritacea	Pearly Everlasting
Anthoxanthum occidentale (syn. *Hierochloe occidentalis*)	California Sweet Grass
Aquilegia formosa	Western Colombine
Arctostaphylos edmundsii 'Big Sur'	Big Sur Manzanita
Arctostaphylos uva-ursi	Kinnikinick
Armeria maritima ssp. californica	Sea Pink
Artemisia californica	California Sagebrush
Artemisia douglasiana	Mugwort
Artemisia pycnocephala	Beach Sagewort
Asarum caudatum	Wild Ginger
Astragalus nuttallii	Nuttall's Milkvetch
Baccharis pilularis	Coyote Bush
Baccharis pilularis 'Twin Peaks'	Coyote Bush
Carex pansa	Sand Dune Sedge
Carex praegracilis	Clustered Field Sedge
Ceanothus maritimus	Maritime Ceanothus
Ceanothus thyrsiflorus var. griseus (syn. *Ceanothus griseus var. horizontalis*)	Yankee Point Lilac
Clinopodium douglasii (syn. *Satureja douglasii*)	Yerba Buena
Corethrogyne filaginifolia (syn. *Lessingia filaginifolia var. filaginifolia*)	Common Sandaster
Dudleya caespitosa	Coast Dudleya
Dudleya cymosa	Canyon Liveforever
Dudleya farinosa	Powdery Liveforever

SCIENTIFIC NAME	COMMON NAME
Dudleya lanceolata	Lanceleaf Liveforever
Dudleya pulverulenta	Chalk Dudleya
Epilobium canum ssp. canum	California Fuchsia
Dudleya lanceolata	Lanceleaf Liveforever
Dudleya pulverulenta	Chalk Dudleya
Epilobium canum ssp. canum	California Fuchsia
Epilobium canum ssp. canum 'Everetts Choice'	California Fuchsia
Equisetum hyemale	Scouringrush Horsetail
Erigeron glaucus	Seaside Daisy
Eriogonum grande var. rubescens	Redflower Buckwheat
Eriogonum latifolium	Coast Buckwheat
Eriogonum parvifolium	Seacliff Buckwheat
Eriogonum umbellatum	Sulphur Flower Buckwheat
Eriophyllum staechadifolium	Lizard Tail
Eschscholzia californica	California Poppy
Eschscholzia californica 'Maritima'	California Poppy
Festuca brachyphylla ssp. breviculmis 'Pt. Joe'	Point Joe Fescue
Festuca californica	California Fescue
Festuca rubra 'Patricks Point'	Red Fescue
Fragaria chiloensis	Beach Strawberry
Frangula californica 'Eve Case' (syn. *Rhamnus californica 'Eve Case'*)	California Coffeeberry
Grindelia hirsutula	Hairy Gumweed
Grindelia stricta	Gumweed
Heuchera maxima	Island Alumroot
Heuchera micrantha	Alumroot

SCIENTIFIC NAME	COMMON NAME
Iris douglasiana	Douglas Iris
Juncus balticus	Baltic Rush
Juncus patens	Spreading Rush
Juncus xiphioides	Irisleaf Rush
Lasthenia californica	Goldfields
Layia platyglossa	Tidy Tips
Leymus mollis	American Dune Grass
Lonicera hispidula	Pink Honeysuckle
Lupinus arboreus	Yellow Bush Lupine
Lupinus bicolor	Miniature Lupine
Lupinus nanus	Sky Lupine
Lupinus variicolor	Manycolored Lupine
Mimulus aurantiacus	Sticky Monkeyflower
Mimulus cardinalis	Scarlet Monkeyflower
Mimulus guttatus	Seep Monkeyflower
Monardella villosa	Coyote Mint
Morella californica (syn. Myrica californica)	California Wax Myrtle
Muhlenbergia rigens	Deer Grass
Nemophila menziesii	Baby Blue Eyes
Oenothera elata ssp.hookeri	Yellow Evening Primrose
Penstemon heterophyllus	Foothill Penstemon
Phacelia californica	California Phacelia
Plantago erecta	California Plaintain
Polystichum munitum	Western Sword Fern
Prunella vulgaris ssp. lanceolata	Selfheal

SCIENTIFIC NAME	COMMON NAME
Pteridium aquilinum var. pubescens	Bracken Fern
Ranunculus californicus	California Buttercup
Ribes speciosum	Fuchsia-Flowered Gooseberry
Rosa californica	California Wild Rose
Rubus ursinus	California Blackberry
Salvia mellifera	Black Sage
Salvia sonomensis	Sonoma Sage
Salvia spathacea	Hummingbird Sage
Scrophularia californica	Bee Plant
Sedum spathulifolium	Stonecrop
Sidalcea malvaeflora	Checker Mallow
Sisyrinchium bellum	Blue-Eyed Grass
Sisyrinchium bellum 'Rocky Point'	Blue-Eyed Grass
Sisyrinchium californicum	Golden-Eyed Grass
Solidago velutina ssp. californica	California Goldenrod
Stachys bullata	California Hedge Nettle
Stipa pulchra (syn. Nassella pulchra)	Purple Needle Grass
Symphoricarpos albus 'Tilden Park'	Common Snowberry
Symphyotrichum chilense (syn. Aster chilensis)	Pacific Aster
Woodwardia fimbriata	Giant Chain Fern

Figure 5: Updated plant palette with native plants highlighted

95 total on plant palette in Figure 5; 70 of which are native = 73% of species native to California

Interview with Kendra Hauser
California Academy of Sciences

How does your living roof provide habitat?

The California Academy of Sciences' living roof is 2.5 acres and composed of over 90 species of California native plants. We take an active role in selecting local native plants, introduce plant species that are important nectar, pollen, and seed sources for wildlife, and develop our plantings to incorporate plant species that will bloom at varying times of the year to maximize food sources. Emphasis is not only placed on providing food sources for local species, but also ensuring that wildlife has shelter for nesting and hiding from predators. To achieve this we select plants of varying heights, grass species, and incorporate rocks and branches on the roof. To encourage California native bees to nest on the roof, we created earth mounds and a bee house composed of logs.

What types of species regularly visit the living roof?

We have had a variety of birds visit the roof, including the Lesser goldfinch, black phoebe, dark-eyed junco, and Anna's hummingbird. Two reoccurring bird visitors are the killdeer and red-tailed hawk. Red-tailed hawks have been nesting in a Monterey Cypress on our grounds for many years. Within two years of the roof being installed, the hawks began using the roof as a space for their fledglings to practice flight. Nearly every day in the summer we will see the hawks sunning on the domes or feeding on the roof! A variety of bees, butterflies, and moths also visit the roof. We are always excited and surprised to see new ground dwelling animals as inhabitants in our growing media and currently have spiders, beetles, grasshoppers, pill bugs, and earth worms on the roof!

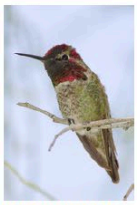
Figure 6: Interview with an employee of the California Academy of Sciences.

This interview provides a descriptive narrative on the kind of pollinators that have been observed on or within close proximity to the living roof, such as Red tailed hawks. It is notable to mention birds such as Lesser goldfinch, Black phoebe, Dark-eyed juncos and Anna's hummingbirds have been known to occupy the roof along with beetles, butterflies, bees, moths, pill bugs, grasshoppers, earthworms, and spiders. [3]

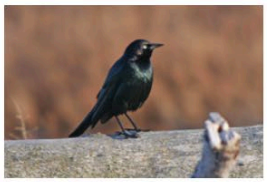
[3] Green Grid Roofs. "Northern California Suggested Plants from the Living Roof Manual." Accessed July 15, 2024. https://www.greengridroofs.com/wp-content/uploads/2018/Northern-CA-Suggested-Plants-from-Living-roof-manual.pdf

California Academy of Sciences Living Roof Fauna

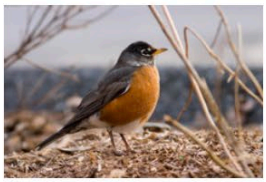
Red-tailed Hawk
Buteo jamaicensis [1]



Anna's Hummingbird
Calypte anna [2]



Brewer's Blackbird
Euphagus cyanocephalus [3]

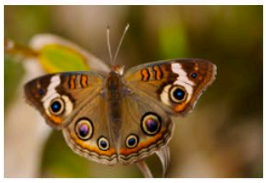


American Robin
Turdus migratorius [4]

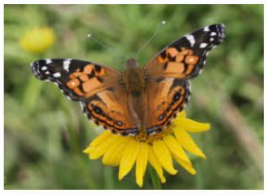
European Starling
Sturnus vulgaris [5]

California Slender Salamander
Batrachoseps attenuatus [6]

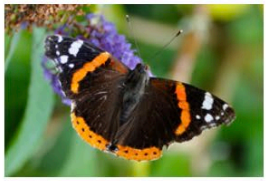
Honey Bee
Apis mellifera [7]



Common Buckeye
Junonia coenia [8]

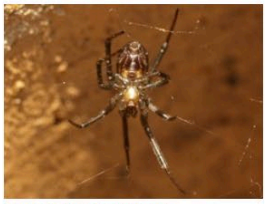


American Lady
Vanessa virginiensis [9]



Red Admiral
Vanessa atalanta [10]

Seven-spotted Ladybird
Coccinella septempunctata [11]



False Black Widow
Steatoda grossa [12]

Leopard Slug
Limax maximus [13]

Woodlouse Spider
Dysdera crocata [14]

Painted Ladybird
Mulsantina picta [15]

Chrysolina bankii
Chrysolina bankii [16]

Lawn Shrimp
Arcitalitrus sylvaticus [17]

California Pipevine Swallowtail
Battus philenor hirsuta [18]

Sugarcane soldier fly
Inopus rubriceps [19]

Porcellionides floria
Porcellionides floria [20]

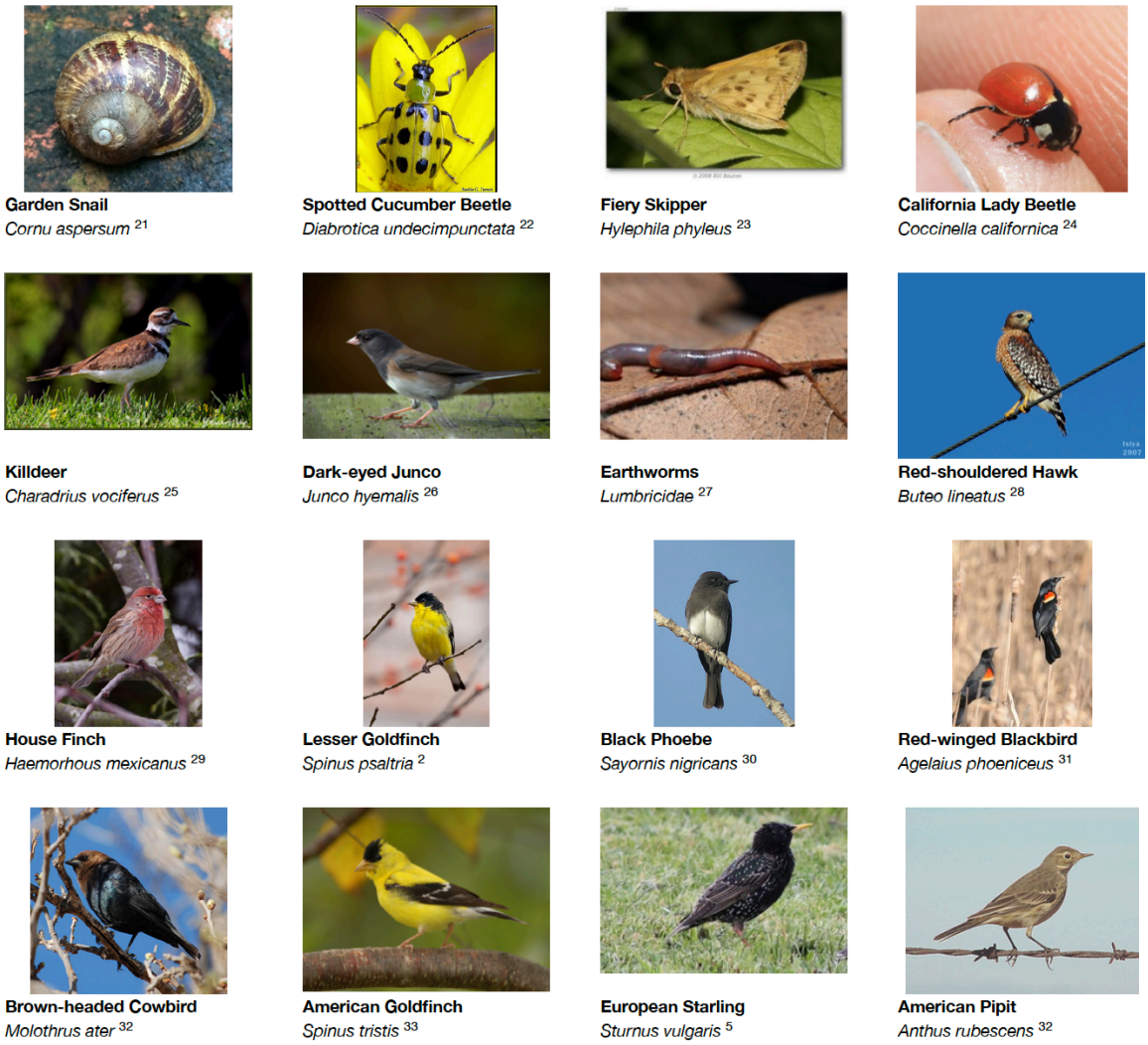


Figure 7: A Grid composed of fauna found on the living roof, built with iNaturalist Guides.

Sources:

https://www.greengridroofs.com/wp-content/uploads/2018/01/Northern-CA-Suggested-Plants-from-Living-Roof-Manual.pdf

https://www.inaturalist.org/guides/3755?view=grid

https://www.inaturalist.org/projects/fauna-of-the-cas-living-roof

Limitations:

Data has been updated since 2008 when the living roof was initially planted. Over time, plant species have been added to the roof both intentionally by Academy staff and inadvertently through naturally occurring seed dispersal. Today, many of the plants within the living roof include exotic species which were not part of the original plan, but were introduced by wind, birds, or other natural seed dispersal processes.

Pollinator data used for this calculation is published on the Academy's website. However, these data have not been regularly updated and may not represent the most current conditions.

iNaturalist is an open-source platform that can be updated with observations by any user. Not all observations are confirmed or corroborated by subject experts.

Environmental Benefits

- **Generates an average of 213,000 kWh per year of solar energy, which offsets museum electricity costs by 10% and prevents an estimated 405,00 lbs of greenhouse gas emissions annually.**

Background:

The planted portion of the California Academy of Science's living roof is ringed by a canopy structure that is home to 60,000 photovoltaic cells, which produce 213, 000 kilowatt-hours of renewable energy per year, representing 5 to 10% of the buildings operational electricity demand.[4] By producing this energy on-site with renewables instead of purchasing it from a local utility provider, the Academy is able to prevent as much as 405,00 annual pounds of greenhouse gas emissions.

Method:

The research team used resources provided by the California Academy of Sciences.

Calculations:

Data Published by California Academy of Sciences

Sources:

https://www.un.org/en/chronicle/article/promise-solar-energy-low-carbon-energy-strategy-21st-century#:~:text=Solar%20power%20produces%20no%20emissions,%2Dgrave%22%20than%20fossil%20fuels

Limitations:

The research team could not obtain information for each individual month of electricity use by the museum.

[4] California Academy of Sciences. "Efficient Building Design." California Academy of Sciences. Accessed July 10, 2024. https://www.calacademy.org/efficient-building-design.

All data obtained for this calculation was published in LEED documentation or in public presentations.

Environmental Benefits

- **Reduces overall average surface temperatures by up to 18° F as compared to similar green spaces nearby.**

Background:

Plants in the living roof were selected to represent a native California landscape, The plants also provide a cooling effect. Of course, altitude has an impact on how the thermal comfort of people visiting or working on the green roof; however, it is likely that the types of plants and overall topography have an effect on temperatures. The mounds provide also shade and create small microclimates of their own.

Method:

The research team used a thermal imaging device (FLIR ONE® Edge Pro) connected to a smart phone to record a series of surface temperature measurements from various locations on the Academy's living roof. Measurements were taken during the warmest part the day across a variety of solar exposure conditions, slopes, and vegetation profiles. This same procedure was conducted at two nearby locations within Golden Gate Park – each less than 500 meters from the Academy building. The additional sites were selected for comparison with the Academy's living roof because of their similar plant palettes, solar exposure levels, irrigation schedules, and maintenance regimes. Measurements were taken at all three sites within a three-hour time period during the warmest part of the day. Measurements were collected twice to find the midrange surface temperature differential between each site.

Additionally, the research team referenced LEED Certification documents, which indicate that the California Academy roof temperature is approximately 40 degrees cooler than those recorded on the ground plane below.

Calculations:

1:00pm

Figure 8: San Francisco Botanical Garden lawn area with temperature measurement locations

Midrange Surface Temperature = 97 degrees Fahrenheit

2:00pm

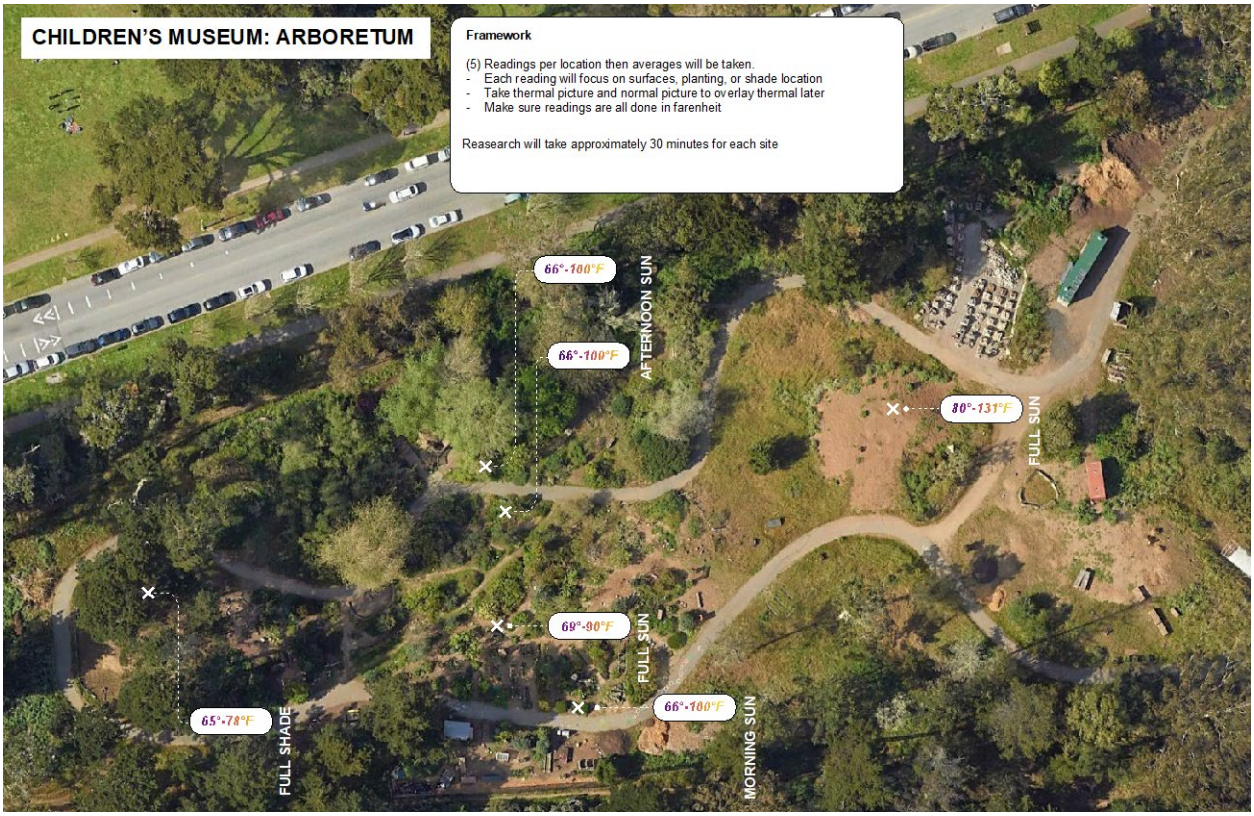


Figure 9: The Children's Garden at the San Francisco Botanical Garden with temperature measurement locations

Midrange Surface Temperature = 98 degrees Fahrenheit

3:00pm

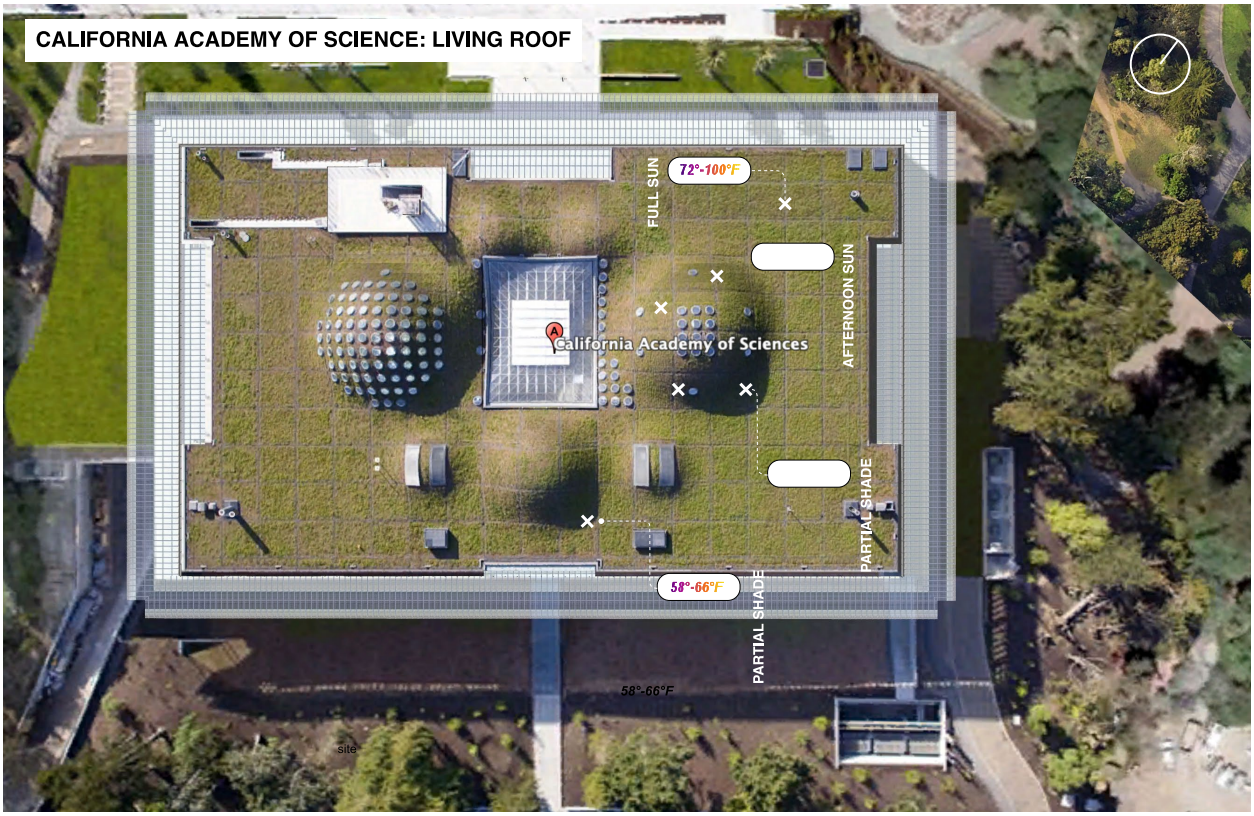


Figure 10: California Academy of Sciences living roof with temperature measurement locations

Midrange Temperature = 79 degrees Fahrenheit

Midrange = Lowest Temperature + Highest Temperature / 2

Based on these calculations, the average difference between the living roof and the other two sites is 18 degrees Fahrenheit. It is also important to note that the lowest temperature recorded across all three sites (58 degrees Fahrenheit) was the shadiest area of the green roof.

Sources:

https://gispoint.de/fileadmin/user_upload/paper_gis_open/DLA_2024/537752057.pdf

Limitations:

Neither ambient air temperature nor windspeed were included as a variables in this research.

Surface temperature data was only collected during June and July. The data was only collected during two site visits. Also it is important to note we did not record information about relative moisture, dew point, or plant turgidity. During observation, we noticed some areas had recently been watered. This may have impacted surface temperature.

Social Benefits

Attracted approximately 540,700 visitors in 2023, which made up almost half of the approximately 1.1 million total visitors to the museum.

Background:

Data from the California Academy of Sciences about visitor numbers shows that a total of 49% of guests who come to visit the museum access the rooftop. Additionally, 13% of guests purchase a ticket for the sole purpose of seeing the architecture. A total of 1,103, 499 guests visited the museum in 2023. 540,715 guests have visited the living roof deck or taken private tours of the roof. There were 21 events that were held on the rooftop that involved tours and educational programs.

Method:

The research team used averages taken from daily visitorship counts. Metrics were collected by California Academy of Sciences and shared with the research team.

Calculations: Averages and events calculated by California Academy of Sciences.

Sources:

Data received from California Academy of Sciences

Limitations:

Daily visitorship data is limited to raw numbers of individual ticket-holders. Other potentially useful information, such as visitor demographics, where they are visiting from, or student status were not provided.

Inconclusive Benefits

Stores an estimated 0.0452 kilograms of carbon dioxide equivalent (kgCO2e) per square meter in the living roof's plant material.

Method:

An inventory of plant types was used to estimate how much carbon may be sequestered by the living roof. Individual plant types included grasses, herbaceous plants, and small woody shrubs. We used direct observation along with input from California Academy of Sciences staff to identify the relative percent cover associated with each plant type and compared against original plant palettes. The living roof was found to include 60% grasses, 30% herbaceous plants, and 10% small woody shrubs. Based on the total biomass of each plant type, we estimated the plants' total carbon sequestration capacity.

We used published data sourced from peer-reviewed journal publications to estimate the carbon sequestration potential for the green roof. The calculations for carbon capture are not specific for the plants used in the green roof. Extensive research and time would be required to conduct site specific measuring and monitoring of the soil carbon sequestration for the site.

Calculations:

Steps to determine carbon content in biomass present on roof (C_{roof})

$$C_{roof} = C_{biomass,soil} + C_{biomass,plants} \quad (1)$$

Where,

$$C_{biomass,soil} = C_{soil\ carbon\ pool} * area_{roof} \quad (2)$$

$C_{soil\ carbon\ pool}$ is sourced from Table 2 in (Silver, Ryals, and Eviner 2010). For the purposes of this calculation, it is assumed that the soil carbon pool within the green roof is equivalent to the soil carbon pool in the grazed rangeland soil with a depth of 0-10cm. $C_{soil\ carbon\ pool}$ is measured in Mg C/ha [Megagrams of carbon per hectare of land].

And

$C_{biomass,plants}$ is total carbon content within the plants present on the green roof. This is calculated as a sum of the carbon content of each plant species present on the green roof as shown in equation 3.

$$C_{biomasss,plants} = \sum_{i=1}^{k} C_{plant\ species,i} * M_{plant\ species,i} \quad (3)$$

$C_{plant\ species,\ i}$ is the carbon content for species *i* (this value is taken from Table 1 (Ma et al. 2018)). [5] This is measured as a mass percentage (i.e. kg of carbon / kg of plant).

[5] Ma,Suhi, Feng He, Di Tian. 2018. "Variations and Determined of Carbon Content in Plants: A Global Synthesis." Biogeosciences 15(3): 693-702. https://doi.org/10.5194/ bg-15-693-2018

$M_{plant\ species,\ i}$ is the total mass of plant species *i* on the green roof as calculated per equation 4. This is measured in kg of plant.

$$M_{plant\ species,i} = M_i * PD_i * area_{roof,i} \quad (4)$$

M_i is the total biomass per plant for species *i* measured in kg per plant (from Table 1 (Körner and Renhardt 1987)) [6]

PD_i is the plant density for species *i* measured in # of plants per area

$Area_{roof,\ I}$ is the roof area covered by plant species *i*

Grass: 0.00208 kg per plant x 20 plant per area x 1.5 total area x 4047 (acre to square meters) =

252 kg CO2e

Poa laxa (grass)

Herbaceous: .00393 kg per plant x 15 plant per area x .75 total area x 4047 = 179 kg CO2e

Achiellum millefollium (herbaceous)

Woody: 0.00868 kg per plant x 3 plant per area x .25 total area x 4047 = 26 kg CO2e

Chrysanthemum leucanthemum (woody)

Total carbon content = 457 kg CO2e / 2.5 area of living roof / 4047 = .0452 KgCO2e

Sources:

https://zemdirbyste-agriculture.lt/99(1)tomas/99_1_tomas_str3.pdf

https://www.carboncycle.org/wp-content/uploads/2014/10/Silver-et-al.-2010-REM.pdf

https://bg.copernicus.org/articles/15/693/2018/bg-15-693-2018.pdf

https://zemdirbyste-agriculture.lt/99(1)tomas/99_1_tomas_str3.pdf

https://www.researchgate.net/publication/326134431_CO2_Payoff_of_Extensive_Green_Roofs_with_Different_Vegetation_Species

Limitations:

This calculation is limited by not accounting the soils variable depth, which can alter its total carbon uptake potential. The soil is also a component that should be considered since it is largely composed of local compost, and may represent a larger carbon sink than this calculation suggests.

[6] Korner,Ch and U. Renhardt. 1987. "Dry Matter Partitioning and Root Length/Leaf Area Ratios in Herbaceous Perennial Plants with Diverse Altitudinal Distribution." Oecologia 74 (3): 411-18. https://doi.org/10.1007/BF00378938

Also, this calculation does consider at ‘embodied carbon’ as a research element. Embodied carbon analysis can also provide an insight on overall carbon emissions since most the materials used were eco-conscious, locally sourced, and/or recycled materials.

The calculation was not site specific when it comes to the measurement of biomass, it used peer-reviewed science journals to make these generalizations of biomass.

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