ARCH 241 | ARCHITECTURE HISTORY & THEORY II

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Part 07

What are some of the disadvantages and advantages of a green roof system?

WorkAC is building the North Boulder Library with a green roof on one half of the top, and the other will be solar power. The discussion will include the design concept presentation of the library as it pertains to the green rooftop. WorkAC has an extensive background in Green Roofs.

This paper covers the advantages and disadvantages of a green roof system on the North Boulder Library, as presented by WorkAC will be discussed. WORK Architecture Company (WorkAC) was founded in 2002. It was the creation of Amale Andraos and Dan Wood, who founded a company based in New York City, WorkAC. WorkAC is building the North Boulder Library with a green roof for one half of the rooftop, and the other will be solar power. This paper covers a brief history and definition of a Green Roof. The discussion will include the design concept presentation of the library as it pertains to the green roof.

The northern section of the building will have a planted green roof. It slopes down towards the residential development, minimizing the visual impact while providing a growing surface to view. WorkAC has an extensive background in Green Roofs. A green roof's retention capacity depends upon its physical configuration. Still, it is also strongly influenced by local climatic controls, including the rainfall characteristics and the restoration of retention capacity associated with evapotranspiration during dry weather. Studies suggest that green roofs with a reduced moisture-holding capacity and low

evapotranspiration rates will tend to offer reduced retention levels. In contrast, high moisture-holding degrees and low evapotranspiration rates provide the most robust drought resistance. Green roofs can and must be conceived of as ecosystems if they want to maintain their utility in providing ecosystem services and benefits while improving their effectiveness.

Figure 1 Marea Photo By Bruce Damonte 2019

WorkAC or WORK Architecture Company

WorkAC believes in the power of architecture and design to engage environmental and social concerns and to create new possibilities for the future. Their work throughout the US and worldwide deeply engages with local cultures, climates, and histories. Their focus is on public, cultural, and civic projects that re-invent how society lives, works, and experiences the world together. They aim to integrate architecture, landscape, and ecological systems and draw resolute realism with polemical optimism to move beyond the projected and towards the possible.[i]

Amale Andraos and Dan Wood founded WorkAC in 2003. The architectural firm based in New York City focuses on projects that re-invent the relationships between natural and urban environments. WorkAC rules were to:[ii]

- Act bigger
- Stay global
- The inside is different than the outside
- Plants are essential, animals too
- When in doubt, paint it blue

The company was named the number one design firm by Architect Magazine in the United States. It was also named Firm of the Year by AIA NYS. WorkAC has acclaimed projects such as:

- Diane von Furstenberg Studio in New York
- Blaffer Museum of Art in Houston,

Other projects they have made contributions to:

- Chicago Architecture Biennale
- Museum of Modern Art.

Current projects include:

- Two community centers in Mexico City
- North Boulder Public Library
- Making a new space for the Peoples Theater Project.

WorkAC has nine guiding principles that guide their development. These are what they use in all their building designs. They are

- to commit to the firm's engagement with reality

- to embrace this engagement as all-inclusive
- to design for an excess of life against its abstraction
- to mobilize this engagement to place architecture in the middle of the rural, the urban, and the natural.[iii]
- To intertwine form and performance in a narrative of systems and flows of water, air, light, energy, and food
- To obsess with history against authority
- To maintain a childlike delight in making
- To embrace design through disagreement as a process
- To hold together opposing ideas

Figure 2 Copyright 2019 WORK Architecture Company

North Boulder Branch Library

The new North Boulder Branch Library (NoBo) has been identified as a need for the community for nearly 30 years. The project is part of the primary goal Library Master Plan. On August 1, 2018, a contract was signed between The City of Boulder and Work Architecture Company (WorkAC). The agreement was for architecture consulting services associated with the first phase of work of a proposed new branch library in north Boulder. The City of Boulder extended the contract with WorkAC for phase two, including the new library's design and construction.

Preliminary planning began in 2018 for the new north Boulder branch library with outreach to the community and continued into the design phase in 2019. Construction plans to commence in the fourth quarter of 2022, with the new north Boulder branch library expected to open in late 2023 or early 2024.

One of the design's features is using a green roof as a thermal mass and solar panels for energy support. Large buildings are heat islands in large cities. Green roofs help to reduce heat islands. This paper provides a small overview of the role of green roofs in minimizing the heat island effect, green roof types, environmental and social benefits, and cost-benefit considerations. Below is a picture of a rooftop garden in Camelview. As you can see, there are other rooftop gardens in the neighborhood.

Figure 3 The green roof at Camelview Village

A History of the Green Roof

Green roofs date back thousands of years. In ancient times, green roof structures began as sod roofs above caves, with "rooftop" earth and plant life used for dwelling, agricultural, and religious purposes. The disadvantage of these sod roofs was no protection against digging animals and a lack of waterproofing ability. The most famous (and most sophisticated) historical green roof, the Hanging Gardens of Babylon, was built around 500 BC. It gets waterproofing thru an inventive layering of reeds and thick tar made over arched stone beams.

Modern green roof technology exploded in the 1960s when Germany pioneered new, reliable technology that provided sophisticated irrigation and protection against roof ingress. With its invention, Germany could market and develop the new green roof technology on a large scale like never before.

There are two types of green roofs:

- Intensive green roofs have deep soil layers, widely varied plant life, and increased weight-bearing and stress load (requiring higher maintenance).
- Extensive green roofs have thin soil depth and fewer layers, a simplicity that allows for easier maintenance and makes them more accessible.

In the 1980s, the widespread introduction of extensive green roof technology further propelled the practice. The dynamic and customizable technology means that buildings can choose which green roof is right for them. Therefore, a larger population can participate in the sustainable practice of growing green roofs.

Green roofs have evolved since their inception, and the future will bring innovations to design, architecture, and sustainability in the coming years.

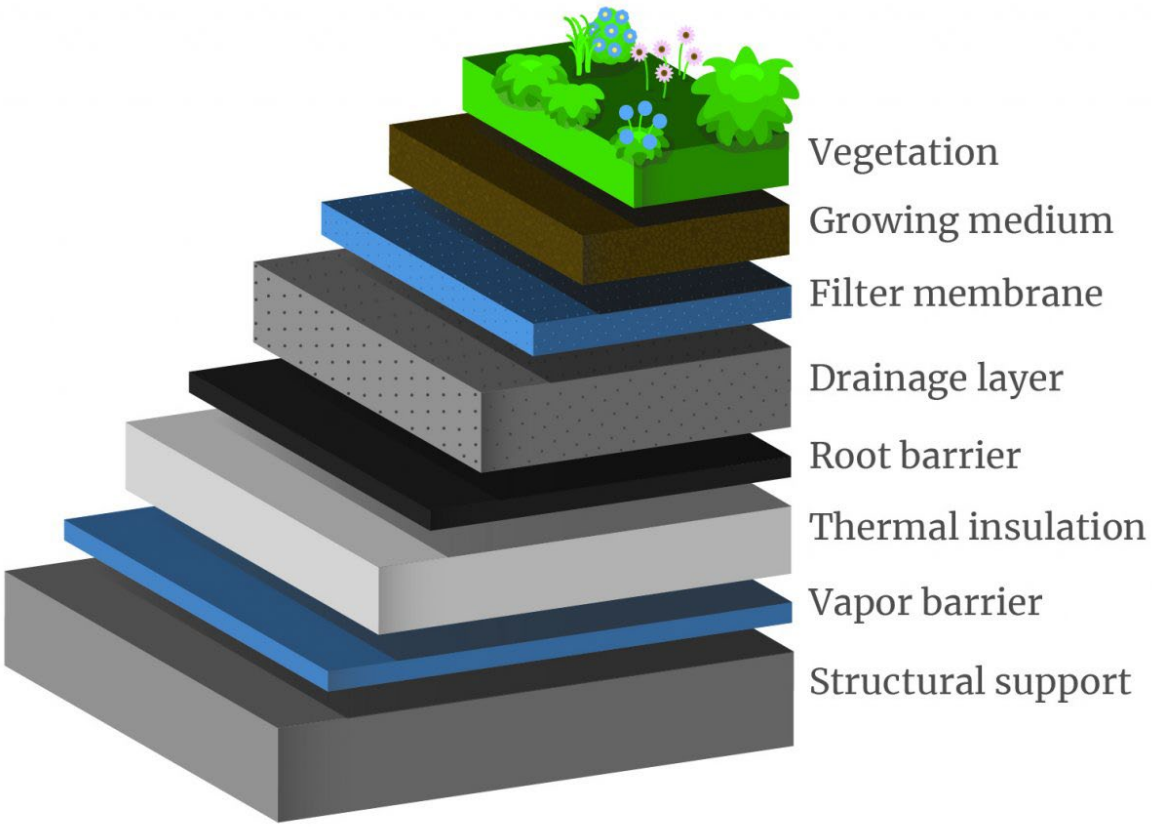

Figure 4 Using green roofs to reduce heat islands

A rooftop garden or green roof is layers of vegetation growing on a rooftop. Green roofs supply shade removes heat from the air, and reduces the roof surface and surrounding air temperatures. Green roofs provide environments with limited vegetation that can moderately affect the heat island effect, particularly during the day. Green roof temperatures can be thirty to forty degrees Fahrenheit lower than conventional roofs. Green rooftops can reduce city-wide ambient temperatures by up to five degrees. In addition, green roofs can reduce the energy used by the building by up to seven-tenths of one percent compared to traditional roofs. Green roofs reduce electricity demand during peak periods and lead to annual savings of up to twenty-three cents per square foot of the roof's surface. Temperature reductions and energy efficiency benefits are vital contributors to raising the popularity of the green roof in the

United States. The green roof industry in North America in 2016 grew by more than ten percent over 2015, continuing the industry's growth trend. In 2016, a sample of industry stakeholders reported nearly nine hundred green roof projects in forty US states and six Canadian provinces totaling more than four million square feet.[iv] An example of a current green roof is the rooftop of a Chicago skyscraper.

Figure 5 Chicago Green Roof. Photo credit: Mark Farina

Classic Green

Green roofs and rooftop gardens have existed for thousands of years. One of the most famous rooftop gardens is one of the original Seven Wonders of the World, the Hanging Gardens of Babylon, which used an elaborate irrigation system to create a terraced garden paradise outside modern-day Baghdad.

The Hanging Gardens have been described in detail by several Classical authors. Though some controversy with other authors disagreed on who built them, several descriptions agree that the gardens were located near the royal palace in Babylon and were set up upon vaulted terraces. They were also described as hydrated by a unique irrigation system and roofed with stone balconies layered with various materials, such as reeds, bitumen, and lead to limit the irrigation water from seeping through the terraces. No certain traces could be found of the Hanging Gardens. Robert Koldewey, a German archaeologist, uncovered a strange series of chambers and vaults in the northeastern corner foundations of the palace at Babylon. In one of the vaults, a well was used with a chain pump and thus was thought perhaps to be part of the once towering Hanging Gardens substructure.v

Figure 6 Hanging Gardens of Babylon

Northern Europeans, as a means of insulating houses, chose traditional sod roofs. Today, green roofs are prevalent or even required in some parts of Europe. Fourteen percent of all roof area is green in Germany.[vi]

Types of Green Roofs[vii]

Green roof installations are on many buildings. They can be found on building roofs, from industrial facilities to private residences. With the North Boulder Library branch, the part of the building not in direct sunlight, as that was reserved for the solar energy panels, is used as a green roof. Also, most of the grounds surrounding the building are part of a park that runs next to the building.

Extensive Green Roofs

- tend to be more straightforward. Planted with hardy plants. They had a growing medium depth of two to four inches
- since they are lighter in weight, they require the least amount of added structural support
- Need little maintenance once established

Figure 7 Green Roof Types

Intensive Green Roofs

- Tend to be more complex, such as a fully accessible park complete with trees
- They look like conventional gardens or parks
- Require a higher initial investment
- more structural support since they are heavier is required
- more intensive maintenance is required

Common Green Roof Layers in the figure below represent the most common design of a green roof. Both green roof types consist of essential layering components with several barriers to prevent water or root damage to the structure, such as a drainage layer from aiding in water drainage and a growing medium and vegetative layer. Not all these layers shown are found on every green rooftop.[viii]

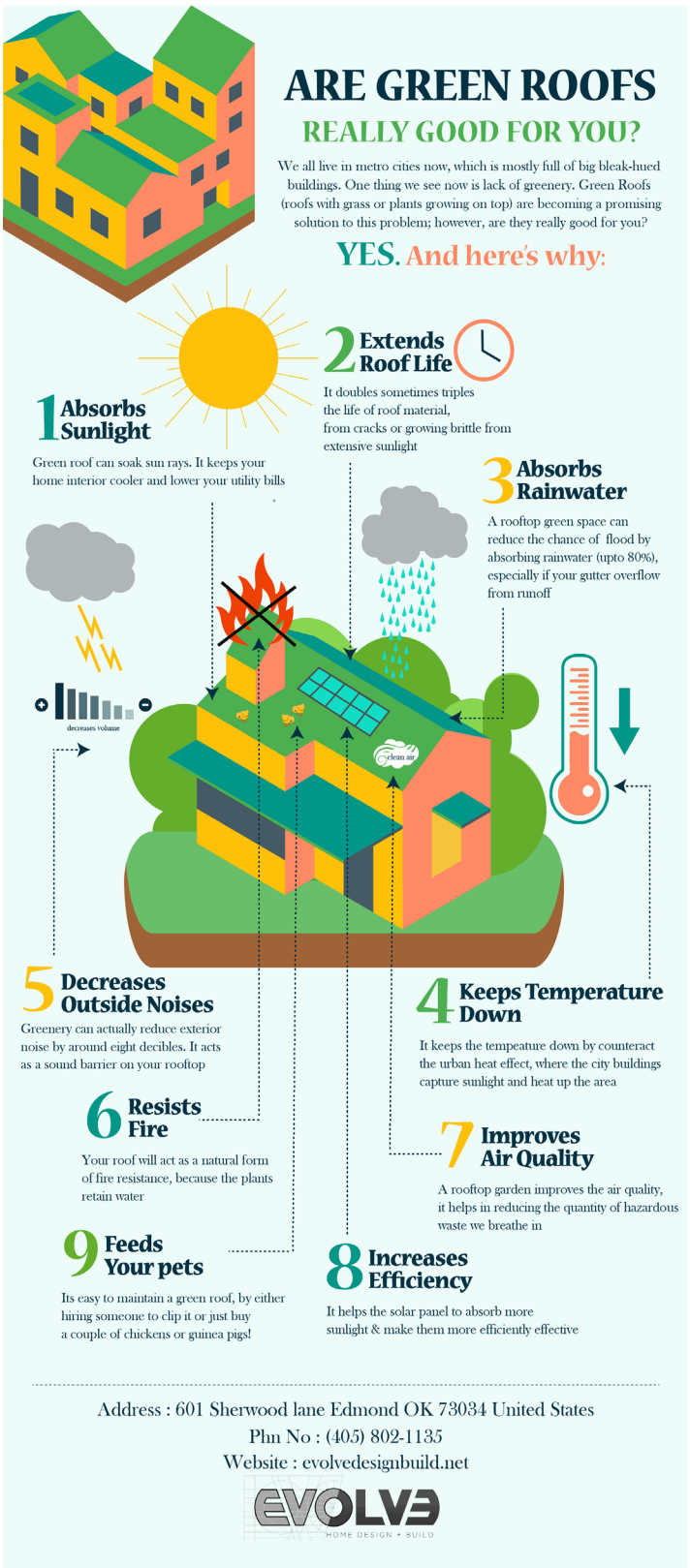

Figure 6 Are green roofs really good for you?

Co-Benefits of Green Roofs[ix]

Green roofs acting as a strategy to limit temperature absorption and other heat island mitigation strategies offer several co-benefits (see figure below). Benefits specific to green roofs include:

Co-Benefits of Heat Island Mitigation Strategies

Green roof co-benefits include air quality, energy use, greenhouse gas emissions, human health, quality of life, stormwater management, and water quality.

- Reduced air pollution and greenhouse gas emissions: Vegetation can remove pollutants and GHGs from the air through dry deposition[x], carbon sequestration, and storage. Green roofs can decrease the associated air pollution and greenhouse gas (GHG) emissions from conventional power sources by lowering air-conditioning demand.
- Reduced energy use: green roofs remove heat through evapotranspiration and act as building insulators, reducing the energy needed to provide cooling and heating.
- Improved human health and comfort: green roofs can reduce heat transfer through the rooftop, lower the incidence of heat stress associated with heat waves and enhance indoor comfort.[xi]
- Improved quality of life: green roofs provide aesthetic value and habitat for plant and animal species. They improve human interaction with nature by introducing green space into the built environment. Such connections to nature benefit human physical and mental health and productivity and reduce blood pressure and hospital stays.
- Enhanced stormwater management and water quality: green roofs can reduce and slow stormwater runoff in the urban environment and filter pollutants from rainfall. Green roofs' actual stormwater management potential depends on the season and rainfall patterns. Green roofs can retain nearly all storm-related precipitation during the summer, with lower retention during the winter months (less than twenty percent).

Urban areas are usually warmer than rural ones, a phenomenon known as the "heat island effect." As cities develop, vegetation is lost as more surfaces are paved or covered with buildings. The change in ground cover causes less shade and moisture to keep urban areas cool. Built-up areas also evaporate less water, increasing surface and air temperatures. Properties of urban materials, in particular thermal emissivity, solar reflectance, and heat capacity, influences the development of urban heat islands as they determine how the sun's energy is emitted, reflected, and absorbed.[xii]

Heat islands can affect communities by increasing air conditioning costs, summertime peak energy demand, greenhouse gas emissions, air pollution, heat-related illness and mortality, and water quality.

Price of a Green Roof by Type

Green Roof Type	*Price per Square Foot*	*Notes*
Extensive	*$10 – $20*	*Lighter weight, most common for houses. Work on sloped roofs.*
Intensive	*$20 – $40*	*Heavier, more common in more prominent buildings. Only work with flat roofs.*
Semi-intensive	*$15 – $30*	*Another word for a rooftop garden has the potential for an interactive design where people can walk around the plants.*
Blue	*$1 – $30*	*"Green" in terms of eco-friendly. They collect rainwater instead of growing plants.*

Figure 7 Price of a Green Roof by Type

Costs of Installing and Maintaining Green Roofs[xiii]

The initial costs of green roofs can be much higher than those of conventional materials. The estimated costs of installing and maintaining a green roof vary by the type of green roof. For example, a simple extensive rooftop without public access could be as little as one-tenth to one-third of the cost of constructing an intensive green roof for public access. Building owners can offset the differences in these costs through reduced energy costs and stormwater management fees, potentially by the longer lifespan of green roofs compared with conventional roofing materials. Intensive green roofs might require maintenance exceeding that needed for extensive roofs to maintain their aesthetic and public access. Typical maintenance includes irrigation, fertilization, weed control, and replanting when necessary.

Figure 8 Church of Jesus Christ Latter Day Saints intensive green roof – Salt Lake City, UT

Lawrence Berkeley National Laboratory researchers conducted a conventional and green roof lifecycle cost analysis. They found that green roofs are more expensive than cool or traditional roofs. Compared to conventional roofs, the benefits of extensive green roofs are fourteen dollars more per square foot. Cool roofs provide two dollars more per square-foot benefits than traditional roofs. Still, green roofs offer much higher relative benefits per square foot over a fifty-year lifecycle (for example, energy cost savings, reduced stormwater fees, and avoided emissions).

Improve the drainage system

Sustainable drainage is an essential component of any building to counter flooding from excess rainfall. Traditionally, a network of pipes connected to the sewage system has helped to control water. Due to increasing urban development, as much as seventy-five percent of water runs into urban areas. Global warming is not helping the cause either, nor is the risk of flooding from water rising throughout the United Kingdom. Green roofs are a terrific option to counter flooding. Plants and substrates store water before being released into the environment naturally.[xiv]

Increase the lifespan of the roof

A rooftop is constantly under attack from the elements. A roof must deal with wind and rain sufficiently, as well as ultraviolet light and fluctuating temperatures. They also have plenty to cope with throughout the year. The greenery barrier helps protect the waterproof membrane underneath and ensures your rooftop's life expectancy lasts for decades. Green roofs offer extended life expectancy and have been proven to double or even triple. As such, it is common for homeowners and businesses to re-consider an alternative option for the roof.

Boosting thermal performance

Undoubtedly, one of a green roof's beneficial advantages is thermal performance, and it is staggering how much of a difference this can make. A typical roof's biggest problem is poor insulation,

leading to heat loss in winter and sweltering conditions over the summer months.[xv] Plants absorb the sun's energy and reduce the roof's temperature in summer while aiding thermal efficiency in the colder winter by locking heat inside. This all changes with a green roof, which can also improve energy efficiency and limit air conditioning usage by implementing a green roof.

Helping out the environment

The release of carbon dioxide is the key contributing factor to global warming, and the government has to meet the stringent European Union targets by 2020. Green roofs are ideal for doing precisely this. Forty-four percent of total CO2 emissions are from buildings. Similarly, green roofs reduce the need for air conditioning while ensuring less heat is required for the winter. Both air conditioning and the generation of heat create CO2.

Supporting animals habitats

Green roofs help support animals and, in turn, can create a healthy habitat. While they will not directly replace ground environments, they are perfect for attracting birds and other animals to create a thriving eco-friendly habitat. Each green roof will support varying habitats, depending on the vegetation type. According to a Switzerland survey, the study of eleven green rooftops found an incredible one hundred seventy-two separate species.

Aiding air quality

Air pollution remains an essential issue in the United Kindom; staggeringly, some twenty-four thousand die yearly. As one might expect, air pollution is a more significant problem in urban areas, such as London and Birmingham. A green roof helps to improve the overall air quality. Green roofs help reduce up to thirty-seven percent sulfur dioxide, twenty-one percent nitrous acid, and two hundred grams of dust particles per square meter each year.

Disadvantages of Green Roofs[xvi]

Now, there are many superb advantages to considering a green roof. For those reasons, it is surprising there are not more green roofs around the United Kingdom, as you would find in the European countries of Switzerland and Germany. The British government tends to encourage the uptake of green roofs for all the benefits outlined above, especially for larger British cities, including London. But while the advantages speak for themselves, you should consider a few drawbacks before investing too.

A more significant expense than traditional roofs

Unfortunately, green roofs tend to be more expensive than the traditional option—one of the significant reasons for this is the extra support required to handle the increased dead load caused by the growing medium. Despite the more significant initial setback, these green roofs make up for the outlay over time. Considering the range of incredible benefits green rooftops offer, there should be no reason to allow cost to play a determining role in a decision since the benefits outweigh the cost.

An increase in weight load

There is no doubt that green roofs are heavier and require more structural support to implement. Typically, a green roof will add between fifty to two hundred kilograms/meter squared to an existing rooftop. Although some rooftops need to retrofit to cope with the load increase, most flat roofs can often handle this extra capacity.

Require extra maintenance

There is a lot of debate about the extent of maintenance required for a green roof. However, you will need to work to ensure a thriving atmosphere remains. Treat your green roof as a garden that requires watering, feeding, and weeding. You could undertake this or hire someone to take care of the space. Either way, keeping on top of this brilliant green area is excellent. With a green roof, you can see there are far more significant benefits to implementing one, and as such, you should consider the matter

seriously. There is a reason green roofs are a common sight around other European countries, so now is the time to take action and enjoy this beautiful environment.

What Does a Green Roof Do?[xvii]

Green roofs can last twice as long as conventional rooftops, like those on the Faroe Islands. Green roofs require professional design and careful structural analysis, and multiple layers and systems can be expensive. Even extensive green roofs usually start at eight dollars per square foot, significantly more costly than the one dollar and twenty-five cents per square foot for built-up roofs. But benefits and incentives, like those set up by the City of Chicago, have prompted a new green-rooftop project. The initial expense of green rooftops turns away prospective clients. As the American green-roof industry grows, the prices will drop.[xviii]

Long-term economic benefits already outweigh the start-up costs. Because green roofs protect the roof membrane from ultraviolet radiation and harsh weather, so they can last twice as long as traditional roofs. Green roofs also have a reasonably stable surface temperature, remaining in the air. At the same time, classic rooftops can soar up to ninety degrees Fahrenheit (thirty-two degrees celsius) above air temperature. The extra growing medium and vegetation insulate the building from intense temperatures and minimize heat gain. According to a Canadian study, even a six-inch extensive green roof can reduce summer energy demands by seventy-five percent.

These benefits encourage homeowners, businesses, and cities to build eco-minded green rooftops. Green roofs mitigate water runoff for rain and snow and prevent sewer overflows. Absorbing and filtering water, vegetation, and soil act as a sponge that typically plunges gutters and washes through streets, adding to the pollution already there and over-taxes sewer systems. A green roof's plants produce oxygen, remove air particulates, and provide shade. Green roofs, during evapotranspiration, use heat energy, a natural process that cools the air as the water evaporates from plant leaves.

Urban Heat Islands, also known as large buildings with flat tar roofs, increase temperatures in urban and suburban areas. Green roofs reduce the demand for air conditioning and prevent the launch of an energy consumption cycle leading to global warming. Evapotranspiration and the shading of plants counter the Urban Heat Island Effect brought on by an excess of reflective and impervious surfaces in cities and suburbs. If green roofs become a joint building initiative, cities may be able to reduce the uncomfortable effects of Urban Heat Islands.

Green roofs replace a complex infrastructure with one that is more efficient, beautiful, and useful. They offer office workers a rooftop retreat to eat lunch in a quiet, pleasant environment. Apartment residents have a place to plant gardens or relax. Even green roofs that are non-accessible create stunning views for surrounding citizens and provide animals with a secluded, safe space to live out their lives.

Conclusions

Throughout history, there have been green roofs. When the early pioneers crossed the prairies in their Conestoga wagons, they decided to settle there and built houses out of sod with green roofs. In Iceland, Norway, and other Scandinavian countries, the landscape has houses with green roofs. When modern Icelanders started moving to modern homes, they complained that their new ones appeared colder than their older ones with green roofs.

The advantages are Reduced air pollution and greenhouse gas emissions, Reduced energy use, Improved human health and comfort, and Improved quality of life. The disadvantage is the installation cost and the dead load added to the roof's weight by the soil. Other disadvantages were damage caused by digging animals and adequate waterproofing. But these can be offset by the advantages.

The North Boulder Library. It is an opportunity for new. Add green and energy-efficient roofs for new buildings and remove the typical lack of usefulness for tops. A roof covers a structure to protect it from rain and snow. And snow in the elements. A green roof allows it to be used for other things, such as

growing plants and adding beauty to the surroundings. Also, it provides for using solar energy so that buildings can be self-sufficient, which is a much better use for a roof.

Please appreciate that fluff was added to the paper due to the word count requirement.

These are called “green roofs” – they have been long popular in Europe and are quickly gaining a name in the United States. Essentially, they are a layer of vegetation atop a structure or building (according to the Environmental Protection Agency). The green roof is now a living and breathing organism in many homes and installations worldwide.

Beyond aesthetic beauty, there is an extensive list of environmental benefits: absorbing rainwater, providing insulation for the structure, and creating a habitat for animals. Even during the winter, it can better insulate your building by reducing heat loss and energy consumption.

The process is called “evapotranspiration,” which uses the air’s heat to evaporate the water from the plants. Instead of warming the building, this cools the structure in a process similar to human sweat. It does this through its layers: the uppermost is the vegetation – the grass or the plant. Directly underneath that is a layer of synthetic, woven fibers. Another layer of synthetic fibers follows that, with a lightweight, waterproof membrane as the bottom-most layer that keeps the structure from getting wet. Then come to the minerals, generally some composted organic matter.

Green roofs have been used in countries like Germany for over forty years. It’s a nifty piece of modern technology, given the advanced materials. However, the concept has been around since the Vikings. Buildings in the United States use two different types of green roofs. First is intensive, thicker (approximately five inches deep), and can facilitate irrigation and drainage, supporting vegetation like shrubs and trees (basically a park atop your building). The second type is extensive, which can range in depth (between one inch to five inches) and support a smaller variety of plants but requires less maintenance.

Costs run a bit high right now for green roof technology. As described in the design, it’s much more complicated than just laying some grass atop your roof; you need professional design, structural analysis, multiple systems, and layers in place. Prices per square foot are pretty high (about fifteen to twenty dollars per square foot), but incentives are forming which can help offset those costs.

Beyond the payoffs come the benefits for the community: they lessen water runoff, which can cause floods and water pollution; they produce oxygen; they even provide a nesting area for birds and other types of wildlife. The United States had previously been behind other countries, especially Germany, where about ten percent of the buildings incorporate green roofing technology.

Green roofs are part of a global effort to reduce warm temperatures in cities and implement more environmentally beneficial technologies. Even in other countries, Toronto has required green roofs in their new construction, like France, Germany, parts of Argentina, and many other cities. Hopefully, this trend only continues to grow.

End Notes

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[i] This article gives insight into the mind of Dan Woods as he thinks about his company. | Convention City | Rice Design Alliance. https://www.ricedesignalliance.org/antfarm-workac-conventioncity

[ii] From their book about WorkAC, as it concerns the rules that govern their working ethics. | Andraos, Amale, and Dan Wood. WORKac : We'll Get There When We Cross That Bridge. New York, NY: The Monacelli Press, 2017.

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