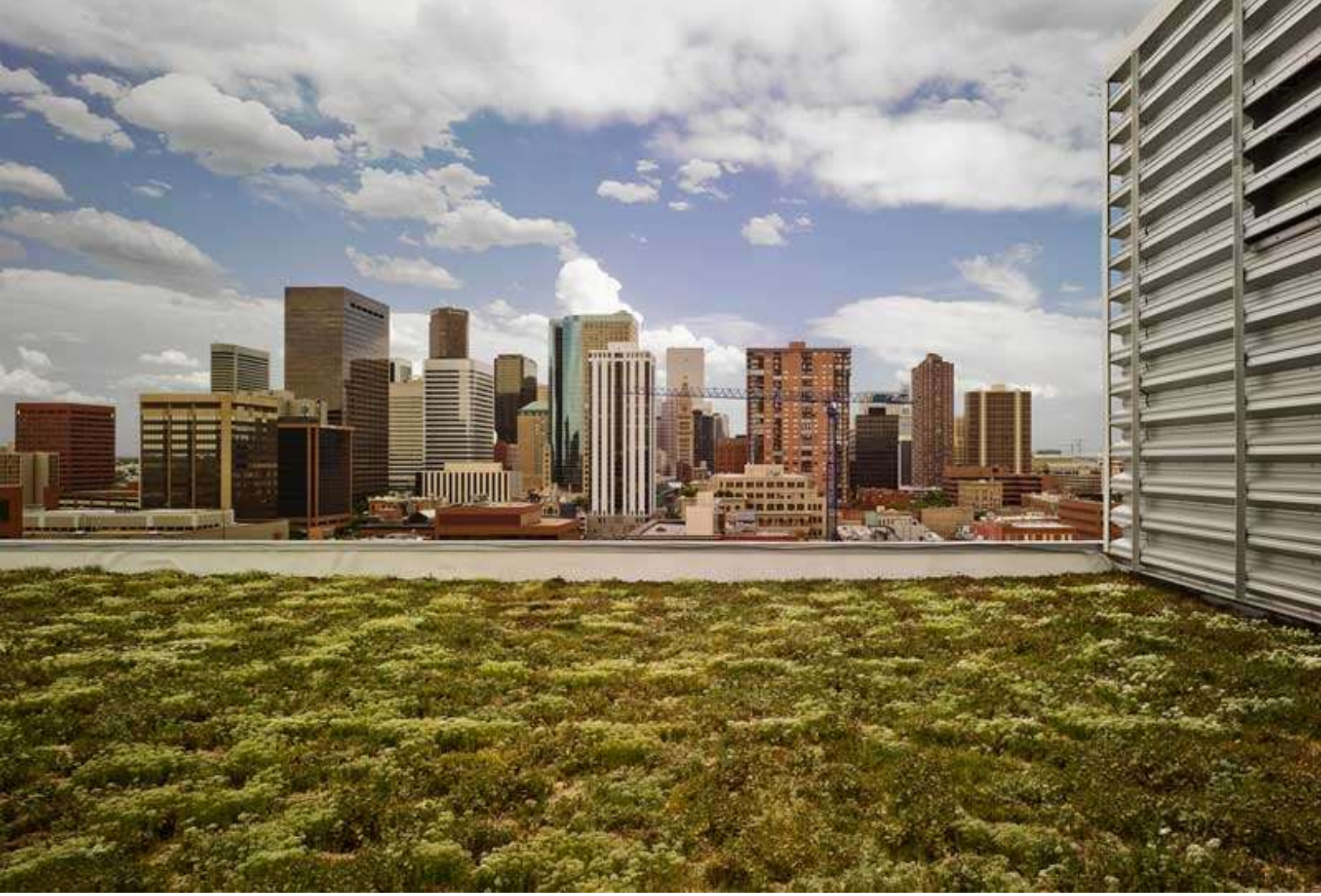

Making Informed Decisions: A Green Roof Cost and Benefit Study for Denver

October 13, 2017

GREEN ROOFS FOR HEALTHY CITIES
www.greenroofs.org

GREEN INFRASTRUCTURE FOUNDATION

Contents

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Cover Photo: The EPA Region 8 Headquarters, Denver. This building features a green roof and solar PV panels, and research on the two technologies has been conducted here.

Executive Summary

Key Findings

- A cost-benefit study on a typical building and for widespread implementation resulting from a positive outcome of ballot initiative I-330 in Denver was conducted.
- On a typical office building, benefits from energy and stormwater savings, increased employee productivity and improved real estate values ***more than offset*** the installation and maintenance cost premium of an extensive green roof for the building owner. This is ***in addition to significant community benefits***.
- If I-300 passes, an estimated 57.5 million square feet of green roofs would be built by 2033. The Net Present Value of these green roofs would be ***$50 million*** and generate almost 25,000 job-years, reduce the urban heat island and help manage stormwater.
- By 2058, the 57.5 million square feet of green roofs would have a Net Present Value of ***$1.85 billion***, as benefits continue to accrue and only maintenance costs are present.
- There are many public and private benefits from green roofs; a number of them, including health benefits, reduced flooding, and reduced damage from hail storms are not included in the study.

This report is designed to provide information for Denver citizens and building industry stakeholders regarding the costs and benefits of implementing the citizen-led I-300 green roof ballot initiative. A group of citizens has collected the requisite number of signatures to require a vote on a measure to implement a mandatory, but flexible requirement for green roof and or solar installations on new and existing buildings over 25,000 square feet of floor space. This study does not incorporate solar installations and is focused on green roof costs and benefits at the building and aggregate scale.

Many cities have studied the costs and benefits of green roofs, and now either require through regulations or incentives, significant green roof development on public and privately owned new and existing buildings. In many cases a combination of incentives and regulations are used in cities such as San Francisco, Portland, Seattle, Chicago, Toronto, Milwaukee, New York City, Washington, D.C., Toronto, Paris, London, and Tokyo. Private financing for green roofs has recently been introduced into the U.S. market under the PACE program (Property Assessed Clean Energy), allowing building owners and developers to obtain off-balance sheet long-term financing for installation and maintenance costs applied to a building's tax assessment.[1]

This report is the result of a combined effort to analyze both the individual project costs and benefits of a standard office green roof compared a conventional roof, as well as the aggregate costs and benefits associated with implementing the I-300 citizen-led ballot initiative to

[1] See counterpointesre.com for more about PACE financing.

mandate green roofs in Denver. Green roof technology delivers many different public and private benefits which can be economically quantified, as well as many benefits that cannot.

Data for this economic analysis was collected based a variety of previous studies, as well as market cost and benefit data for Denver specifically and averages for the United States. The assumptions for this study are conservative in nature for two reasons: conservative cost and benefit values have been used and secondly, benefits such as health improvement, property value increases, protection from hail storm damage and flooding risk, and aesthetic values because they are very difficult to quantify.

A project-specific cost-benefit analysis of an *extensive* green roof was conducted over 25 years for a new, 3 storey office building compared to a conventional roof. It found that benefits in the areas of stormwater management (NPV of $15.1/sq. ft.), energy ($5.7/sq. ft.), biophilia ($8.5/sq. ft.), and real estate/economics ($21.9/sq. ft.) more than offset the installation and maintenance cost premium for building owners and/or tenants ($21.1/sq. ft.). Affordability is not an issue for many types of buildings because the life-cycle economic benefits outweigh the additional costs. In affordable housing projects specifically, there is evidence of reduced vandalism and greater community cohesion, particularly when residents can access the roof to use it as amenity space. Moreover, the application of the proposed green roof mandate applies to larger buildings - over 25,000 square feet of floor space - reducing the initial cost premium to a small percentage of total project costs.

An aggregate cost-benefit analysis was also conducted, to capture the cumulative, quantifiable costs and benefits of widespread green roof implementation by 2033. A 15-year time frame is used because it coincides with the average roof replacement in Denver. The study team estimated the number of new and existing buildings that the new law would capture, and what type of green roofs would likely be applied. We estimate that only 15% of existing buildings with more than 25,000 feet of floor space will have green roofs due to structural limitations and other factors in the new law proposal which allow for flexibility. We estimate that 10% will be light weight, low cost, and low maintenance *extensive* green roofs, and that 5% will be heavier, higher maintenance, greater plant diversity, and greater cost *intensive* green roofs. Of the 5% *intensive* green roofs, we estimated half will be used to produce food, which increases maintenance costs but also delivers a host of additional benefits for the community that are not fully captured in this study, such as improved food security.

For new buildings, we estimate a 2% increase in building stock per year based on projected and historical growth rates, and that all will have green roofs, with 66.7% being *extensive*, 16.7% *intensive* food producing and 16.7 % *intensive* non-food producing. We also assume that the green roofs will implemented in equal measure every year, for the next fifteen years. A discount rate of 6.5% and average inflation rate of 2.5% are used to determine the net present value of cumulative costs and benefits. This analysis found that a capital investment of $1.06 billion and maintenance investment of $336 million over fifteen years would support

57.5 million square feet of green roofs, and generate the following cumulative public and private benefits:

- Approximately 25,000 job-years in construction, maintenance, and food production
- $445 million worth of food produced locally
- $573 million in savings due to increased roof membrane durability
- $59 million in direct energy savings
- $171 million in savings due to a reduced urban heat island
- $23 million in reduced stormwater fees
- $37 million in biophilic benefits, including improved productivity and reduced absenteeism associated with exposure to green roofs
- $95 million in real estate benefits, from improved tenant retention and reduced vacancy
- $38 million in community economic benefits associated with a larger employment tax base

Looking at costs and benefits further into the future strengthens the business case for widespread green roof implementation. In 2034, if no further green roofs were built, the Net Present Value (NPV) of maintenance costs would be $34 million, while total public and private benefits would be $145 million. By 2058, the 57.5 million square feet of green roofs built between 2018 and 2033 would have a NPV of $1.85 billion, as benefits continue to accrue but costs are limited to maintenance.

Background

This report is designed to provide information for Denver citizens regarding the costs and benefits of implementing the citizen-led I-300 green roof ballot initiative. It is the result of a combined effort to analyze a cost-benefit scenario over 25 years for a typical project, as well as an aggregate cost and benefit analysis associated with implementing the I-300 ballot initiative to mandate green roofs in Denver over 15 years to the year 2033.

The study was prepared by Green Roofs for Healthy Cities (the industry association for green roofs and walls across North America), and the Green Infrastructure Foundation (a 501(c)(3) charitable organization that partners with communities across North America to use green infrastructure). Additional input was provided by policy makers at the City and County of San Francisco and the City of Toronto and Kirstin Weeks of Arup, a large engineering consulting firm.

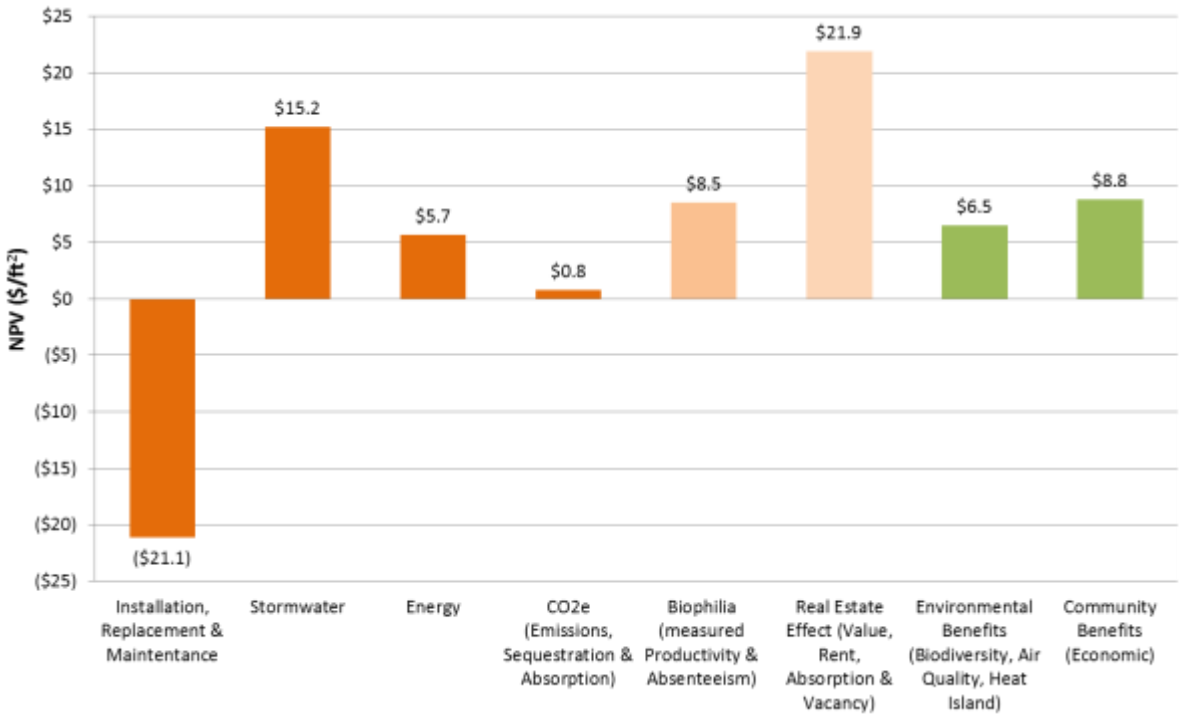
Data for this analysis was collected based on various government and industry sources for Denver, as well as national averages from previous studies conducted for the US General Services Administration and the City and County of San Francisco by Arup, and the City of Toronto by Ryerson University.

Project Specific Cost-Benefit Analysis

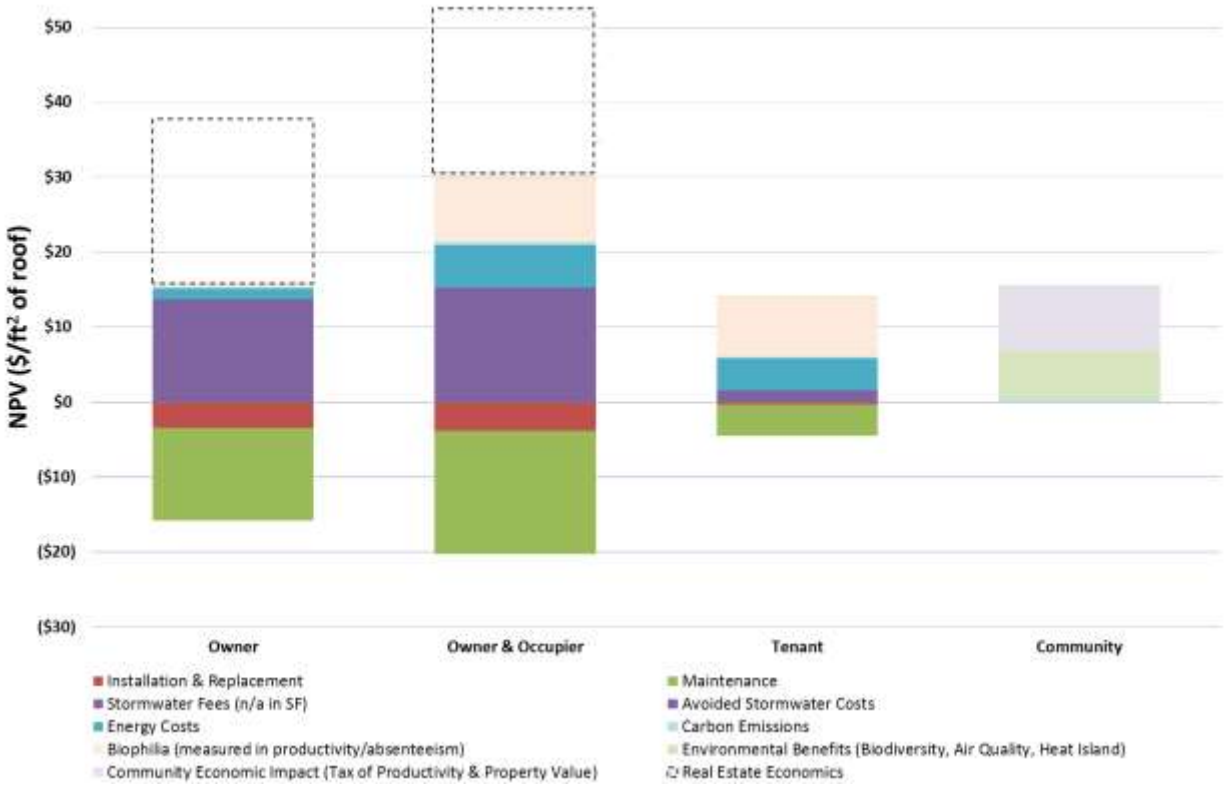
A case study of a new 20,000 sq. ft., 3 storey office building was used to demonstrate the costs and benefits of an extensive green roof versus a conventional roof over 25 years. Using a number of assumptions (found in Appendix A), the analysis looked at costs and benefits to building owners, operators, and the community.

Findings

It determined that over 25 years, the net present value (NPV) of installation, maintenance, and replacement cost of a green roof was $21.1 more than the conventional roof per square foot. However, over the same period of time, the NPV of significant benefits in the areas of stormwater management ($15.1/sq. ft.), energy ($5.7/sq. ft.), biophilia ($8.5/sq. ft.), and real estate/economics ($21.9/sq. ft.) more than offset the initial cost premium for building owners and/or tenants. Additionally, a number of environmental benefits ($6.5/sq. ft.) in the form of reduced heat island, improved biodiversity, and improved air quality are generated. Economic benefits to the community in the form of increased tax revenue from job creation and other community benefits are estimated at $8.8/sq. ft). Assumptions and detailed results can be found in Appendix A. See Figures 1 and 2 below.



Net present value over 25 years, per square foot of green roof on an example new office building in Denver by benefit category (Figure 1, above), and by building ownership/tenure (Figure 2, below).



Aggregate Cost-Benefit Analysis

The aggregate costs and are for the year 2033 and based on a number of reasonable, but conservative assumptions. A scenario of the aggregate costs and benefits was created for 15 years into the implementation of the I-300 ballot initiative, the average length of time for reroofing waterproof membranes on existing buildings.

Conservative assumptions are used – see the Limitations section for more of this. See Appendix B for detailed assumptions, sources, and methods.

The City of Toronto City Hall Green Roof. Toronto has implemented 3.9 million square feet of green roofs under its mandatory green roof bylaw between 2010 and Dec. 2016. Costs have fallen 30% since the inception of the bylaw. Photo: Padraic on Flickr.

Findings

Over 15 years, the analysis found that 57.5 million square feet of green roof would be implemented on existing and new buildings. This includes 38.1 million square feet of lightweight extensive green roofs, and 19.4 million square feet of intensive, higher-maintenance green roofs. Of these intensive roofs, half would produce food. The NPV of capital costs of these roofs would be $1.06 billion over 15 years, and the NPV of maintenance costs would be $336 million.

This level of investment would create 18,790 job-years in construction, and 5,930 job-years in maintenance and food production over 15 years. Many of these jobs could be filled by people from underserved communities with educational and workforce development programs. There are examples of programs like this in Philadelphia, Chicago, and New York City.

Private benefits include reduced stormwater fees (NPV of $23 million over 15 years), reduced energy consumption ($58 million), food produced ($445 million), increased roof lifespan ($573 million), improved productivity and reduced absenteeism ($37 million), and improved real estate factors, such as better tenant retention and reduced vacancy ($94 million).

Annual public and indirect benefits include improved air quality ($11 million), a reduction in the urban heat island ($171 million), which includes indirect energy use reductions, reduced peak power demand, and an additional effect on air quality. Community economic benefits from increased taxation due to increased employment and other factors are estimated at $94 million. More information about assumptions and detailed results can be found in Appendix B.

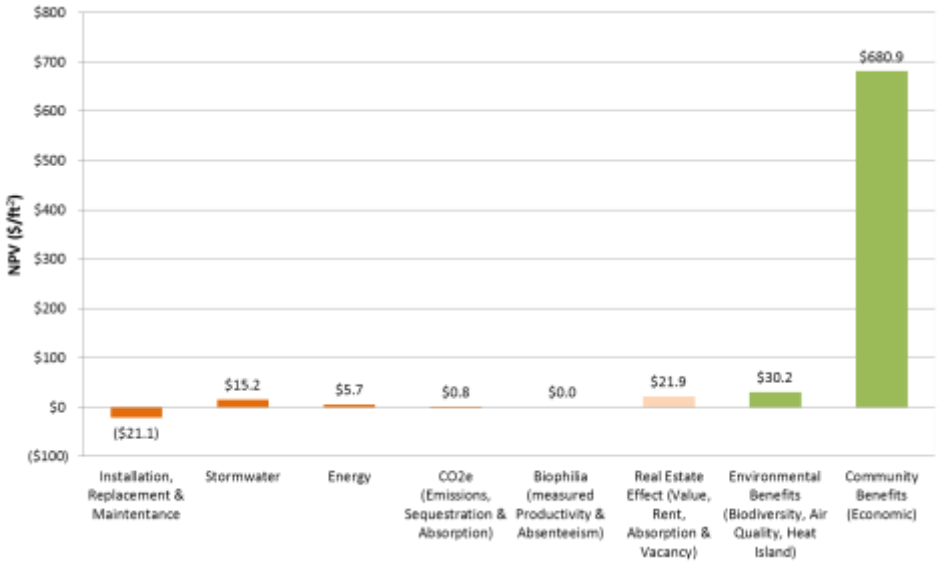
It is important to note that all energy and heat island savings have significant greenhouse gas reduction potential, considering Colorado's energy mix is currently 82% fossil-fuel based, and will still be 70% fossil-fuel based in 2020 if the state's Renewable Energy Standard is met.[2]

Overall, $1.4 billion of investment over 15 years yields public and private benefits of $1.45 billion for a NPV of $50 million. However, looking at costs and benefits further into the future continues to improve the argument for green roofs. In 2034, if no further green roofs were built, NPV of maintenance costs would be $34 million, while total public and private benefits would be $145 million. By 2058, the 57.5 million square feet of green roofs built between 2018 and 2033 would have a NPV of $1.85 billion, as benefits continue to accrue but costs are limited to maintenance.

Limitations

This report is intentionally conservative, using a number of assumptions that understate the overall benefits of green roofs:

- For example, Denver's green roof costs are estimated to be significantly higher than the national average, and we only project a 20% cost decrease after 7.5 years. In comparison, jurisdictions like Toronto have seen decreases of over 30% in as little as 5 years as local design, installation, and maintenance professionals gain expertise and firms achieve economies of scale.
- We have not included a monetary value for a number of benefits, many of which are likely to be significant, including health impacts, reduced flooding, reduced damage from hail storms, increased lifespan of existing stormwater infrastructure, increased biodiversity and habitat, improved aesthetics, increased property values, increased community cohesion, etc. These benefits could be incorporated into future studies.
- The community economic benefits captured in this analysis only reflect additional tax revenue from the economic impacts of green roofs. If we count the full value of green roof economic impacts, the economic impact of green roofs is immense. ***See Figure 3 (right).***



[2] Colorado: State Profile and Energy Estimates. US Energy Information Administration. Retrieved from https://www.eia.gov/state/?sid=CO

Conclusion

This report describes many of the well-established costs and benefits associated with an extensive green roof implementation compared to a conventional roof on a typical office building over 25 years, and the net present value of widespread green roof implementation on new and existing buildings over a 15 year period and beyond.

Although the study doesn't include a monetary valuation of all of the benefits, it makes a strong business case to building industry stakeholders and citizens in Denver to support the I-300 ballot initiative. Green roofs are not to be feared as something that will spin costs out of control or that aren't applicable to the Denver climate. Many jurisdictions have policies and programs designed to rapidly increase the number of green roofs due to their widespread public and private benefits.

Green roofs are being implemented in the tens of millions of square feet worldwide, from Alaska to Dubai. Denver's extreme urban heat island challenges, combined with its sustainability and climate goals, make it the ideal environment to take advantage of the benefits of green roofs. Many markets have seen significant cost reductions - more than 30% as the green roof market develops. This will undoubtedly be the case in Denver, allowing for these public and private benefits to be achieved at a lower cost than apparent today.

Communities want to capitalize on their wasted roof spaces for both public and private benefits. Hence, in many jurisdictions, green roofs are now a requirement of all new buildings, and or there are either regulatory or financial incentives provided to developers and building owners that support green roofs and recognize the value of the many public benefits these spaces can provide.

The tangible building owner benefits associated with energy and roof membrane durability significantly offset life-cycle implementation and maintenance costs of green roofs and may even generate a profit in many cases. Widespread implementation will generate significant employment opportunities for the citizens of Denver – approximately 25,000 job-years over a 15 year period - while helping to address climate change mitigation and adaptation challenges and support food security. Looking at costs and benefits further into the future continues to improve the argument for green roofs. By 2058, the 57.5 million square feet of green roofs built between 2018 and 2033 would have a NPV of $1.85 billion, as benefits continue to accrue but costs are limited to maintenance.

Appendix A: Assumptions and Results for Project-Specific Cost-Benefit Analysis

Summary, Assumptions & Variables

General Assumptions:

Discount Rate, %	6.5%
Investment Outlook, years	25
Living Roof Medium Depth	6"

Assumptions

	Living	Standard		Living	Standard
Climate Zone	5		Electricity Price, $/kWh	$0.09	
Installation Cost, $/sf of roof	$35.00	$10.00	Natural Gas Price, $/therm	$0.12	
Replacement Premium, %	33.51%	20.0%	Avg Rent, $/sf/yr	$25.36	$25.36
Maintenance Costs, $/sf of roof	$1.00	$0.18	Avg Value, $/sf	$351.9	$350.0
Roof Life (yrs)	40	15	Average Vacancy, %	9.11%	9.20%
Disposal Costs, $/sf of roof	$0.12	$0.37	Cap Rate, %	7.46%	7.50%
Stormwater Surcharges, $/sf of roof	$0.00	$0.0729	Absorption, months	5.9	6.0
Income Growth Rate	3.70%		Tenant Retention, months	52.8	52.6
Expenses Growth Rate	0.00%				

Variables - /sf of roof/yr unless noted

	Living	Standard
Energy Equipment Cost, $/sf of roof (not counted)	$0.00	$0.00
Stormwater Equipment Cost, $/sf of roof	$1.00	$11.00
BMP Maintenance Cost	$0.07	$0.24
Heating/Cooling Cost Premium	($0.16)	$0.00
Embodied Carbon, tonnes of CO_2e/sf of roof	0.0006	0.00001
Reflectance + sequestration, metric tonnes of CO_2e	0.0002	0.0000
Carbon savings from heating/cooling savings	0.0004	0.0000

Nominal Growth Rates

Labor & Materials	5.0%
Stormwater Costs	10.0%
Energy Prices	0.5%
Carbon (included in price)	0.0%
Community Benefits (Inflation)	2.5%
Rent, Absorb & Retention	3.0%
Living Roof Risk Contingency	2.0%

Soft Variables - $/sf of roof/yr

	Living	Standard			
Internal Real Estate Impact (Living Roof on Green Building rent contribution)	$0.3	n/a	Biodiversity & Habitat	$0.03	n/a
			Air Quality	$0.11	n/a
External Real Estate Impact (Biophilia/Productivity)	$0.2	n/a	Heat Island Energy Savings	$0.00	n/a
			Heat Island Peak Shaving Savings	$0.23	n/a
Employment (Community Benefit)	$0.024	n/a	Noise Abatement	$0.04	n/a

Cost/Benefit Analysis Results of Living Roof vs White Roof:

	NPV/sf of roof
Installation, Replacement & Maintentance	($21.1)
Stormwater	$15.2
Energy	$5.7
CO_2e (Emissions, Sequestration & Absorption)	$0.8
Biophilia (measured Productivity & Absenteeism)	$8.5
Real Estate Effect (Value, Rent, Absorption & Vacancy)	$21.9
Real Estate Effect, Year 1 Value (capitalized)	$5.5
Environmental Benefits (Biodiversity, Air Quality, Heat Island)	$6.5
Community Benefits (Economic)	$8.8

For methods, sources for assumptions, and further information, see the San Francisco Living Roof Cost-Benefit Study (http://default.sfplanning.org/Citywide/livingroof/SFLivingRoofCost-BenefitStudyReport_060816.pdf)

Appendix B: Assumptions and Results for Aggregate Cost-Benefit Analysis

Assumptions

- A GIS based analysis indicates that Denver has an estimated total of 5000 acres of rooftops on buildings over 25,000 square feet in floor area.
- Of that total existing rooftops, we are conservatively estimating that only 10% (500 ac.res) can support extensive, light weight, low cost and maintenance green roofs and that they will be required to achieve 40% coverage on average (I-300 mandates between 20%-60% coverage based on building size).
- We are assuming that only 5% (250 acres) can support heavier, intensive green roofs with 40% coverage. Due to political support for local food production in Denver, we are assuming that half these intensive roofs will produce food.
- We are assuming that these green roofs will be implemented over a period of 15 years as buildings require new roofs – averaged equally each year. This is how we arrived at the 15 year time frame for the analysis.
- Denver's population growth rate is conservatively assumed to be 2% from 2018-2033 (1.9% in 2015-2016, well over 2% for over a decade prior)[3]
- We will estimate the growth rate of 2% applied to existing building stock (we have not been able to find a growth rate for buildings over 25,000 sf.)
- All new buildings will feature green roofs (67% extensive 40% coverage; 33% intensive, 40% coverage, food producing)
- Cost of extensive green roofs are conservatively estimated at $25/square foot; intensive green roofs are $30/square foot. These numbers are higher than national averages. Communication with stakeholders in Toronto has verified a reduction of costs of up to 30% in the five years after the passage of a similar law. This has also been the case in other cities in the U.S. and Europe where mandatory or incentive programs have supported the local green roof market.
- We have conservatively estimated a 20% reduction in costs halfway through the 15 year study period. These cost reductions are typically accompanied by, and resulting from, a

[3]Murray, J. (2017). Denver's growth spurt slows down — a little — as the city's population nears 700,000. The Denver Post. Retrieved from http://www.denverpost.com/2017/03/28/denvers-growth-spurt-slows-down/

robust emergence and presence of increasingly experienced design, installation, and maintenance professionals.

Discount Rate	6.5%
Inflation Rate	2.5%
Investment Outlook	15 years
Extensive green roof installation premium[4]	$25/sq ft
Intensive green roof installation premium[5]	$30/sq ft
Cost premium reduction after 7.5 years[6]	20%
Extensive green roof maintenance premium[7]	$0.19/sq ft/yr
Intensive green roof maintenance premium[8]	$2.79/sq ft/yr
Energy savings[9]	$0.166/sq ft/yr
Urban heat island reduction benefits (indirect energy use reductions, reduced peak power demand, and air quality effect)[10]	$0.53/sq ft/yr
Air quality improvement	$0.035/sq ft/yr
Stormwater fee reduction[11]	$0.0729/sq ft/yr
Increase in roof lifespan (annualized, benefit realized at roof replacement)	$1.67/sq ft
Food production[12]	$8.18/sq ft/yr (on intensive, food-producing green roofs only)
Biophilic Impact (productivity and absenteeism)[13]	$0.34/sq ft (on intensive green roofs only)
Real Estate Impacts[14]	$0.876/sq ft (on intensive green roofs only)

[4] Based on personal communication with a Denver green roof installer
[5] Based on personal communication with a Denver green roof installer
[6] Initial cost figures are higher than national averages. Communication with stakeholders in Toronto has verified a reduction of costs of up to 30% in the five years after the passage of a similar law. This has also been the case in other cities in the U.S. and Europe where mandatory or incentive programs have incited the local green roof market. We have conservatively estimated a 20% reduction in costs halfway through the 15 year study period. These cost reductions are typically accompanied by, and resulting from, a robust emergence and presence of increasingly experienced design, installation, and maintenance professionals.
[7] Based on personal communication with a Denver green roof installer
[8] Based on personal communication with a Denver green roof installer; includes food production
[9] General Services Administration (2011). The Benefits and Challenges of Green Roofs on Public and Commercial Buildings.
[10] General Services Administration (2011). It is important to note that this is likely an extremely conservative assumption. Denver had the 3rd worst urban heat island (the urban area is on average 4.9 degrees hotter than the surrounding rural areas)(Source: Climate Central, 2014).
[11] City and County of Denver Wastewater Management (2017). Storm Drainage Rates. Retrieved from https://www.denvergov.org/content/denvergov/en/wastewater-management/billing-and-rates/wastewater-rates.html Note: This number is lower than national average values for stormwater; these rates may not reflect the full cost of managing runoff from impervious surfaces.
[12] Tomalty, R., Komorowski, B., & Doiron, D., (2010). Monetary Value of the Soft Benefits of Green Roofs. Prepared for Canada Mortgage and Housing Corporation (CMHC).
[13] San Francisco Living Roof Cost-Benefit Study. Retrieved fromhttp://default.sfplanning.org/Citywide/livingroof/SFLivingRoofCost-BenefitStudyReport_060816.pdf
[14] San Francisco Living Roof Cost-Benefit Study. Retrieved fromhttp://default.sfplanning.org/Citywide/livingroof/SFLivingRoofCost-BenefitStudyReport_060816.pdf

Results (Cumulative Totals for 2033)

Extensive, light weight, low cost and maintenance green roofs implemented	38.8 million sq. ft. (8.7 million on existing buildings, 30.1 million on new buildings)
Intensive, food producing green roofs implemented	9.7 million sq. ft. (4.4 million on existing buildings, 15 million on new buildings)
NPV of capital cost	$1.06 billion
NPV of maintenance and food production costs	$336 million
Total employment based on capital expenditures	18,790 FTE jobs created in construction
Total employment based on maintenance expenditures	5,930 FTE jobs created in maintenance and food production
NPV of food produced	$445 million
NPV of stormwater fee savings	$23 million
NPV of savings due to a reduction in the urban heat island (reduced energy use and improved air quality through lower city-wide temperatures, reduced peak power use)	$171 million
NPV of energy use reductions	$59 million
NPV of air quality improvement	$11 million
NPV of increase in roof lifespan/avoided roof replacement	$573 million
NPV of biophilic benefits	$37 million
NPV of real estate benefits	$94 million