



Green Roofs

Appendices
October 29th, 2018

Cool Roofs

1.3.2 Importance of Climate Projections for Denver

The Climate Adaptation Plan has identified the following three key potential impacts for Denver based on climate change projections for the Front Range:

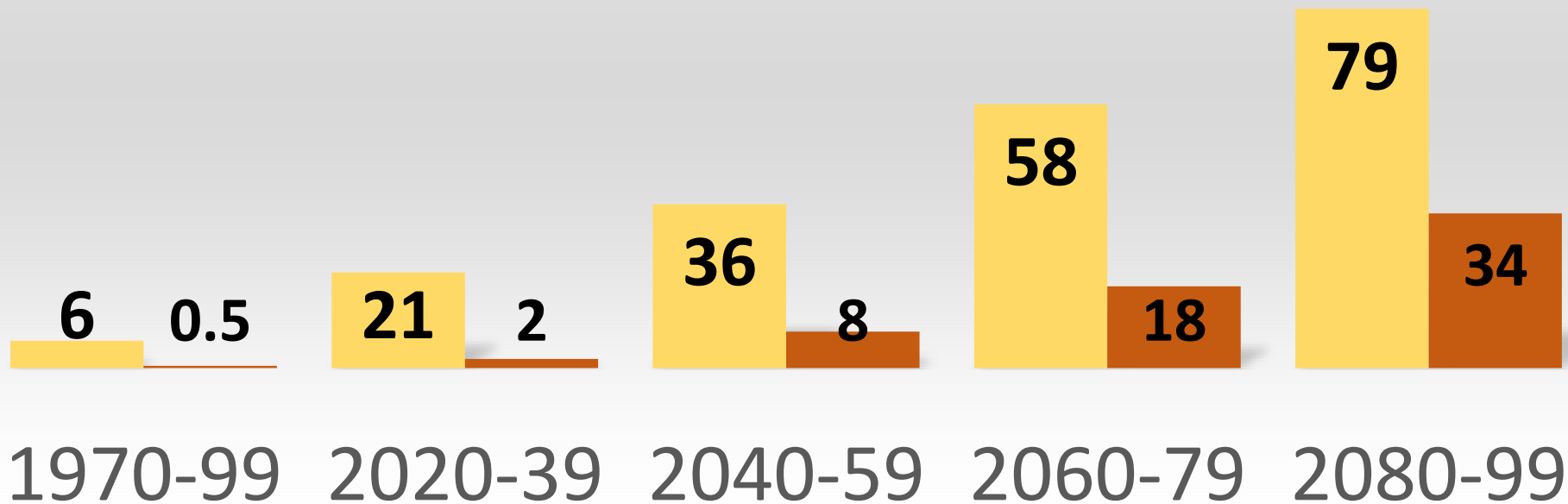
1. Increase in temperature and urban heat island effect
2. Increase in extreme weather events
3. Reduced snowpack and earlier snowmelt

Increase in Temperature and Urban Heat Island Effect^{1 12}

Urban heat islands refer to the elevated temperatures in developed areas compared to more rural surroundings. Urban heat islands are a result of surface properties of building materials, such as pavement and asphalt, combined with reduced vegetation. On a hot, sunny, summer day, surfaces exposed to the sun can reach 50 to 90°F hotter than the air temperature, while shaded or moist surfaces, often in more rural surroundings, remain close to air temperatures (figure 1.4). On average the difference in daytime surface temperatures between developed and rural areas is 18 to 27°F and the difference in nighttime temperatures is 9 to 18°F. Denver, being highly urbanized,

Projected Change in Denver's Climate

■ DAYS/YR $\geq 95^{\circ}$ F ■ DAYS/YR $\geq 100^{\circ}$ F




WHERE YOUR SUMMER IS HEADED

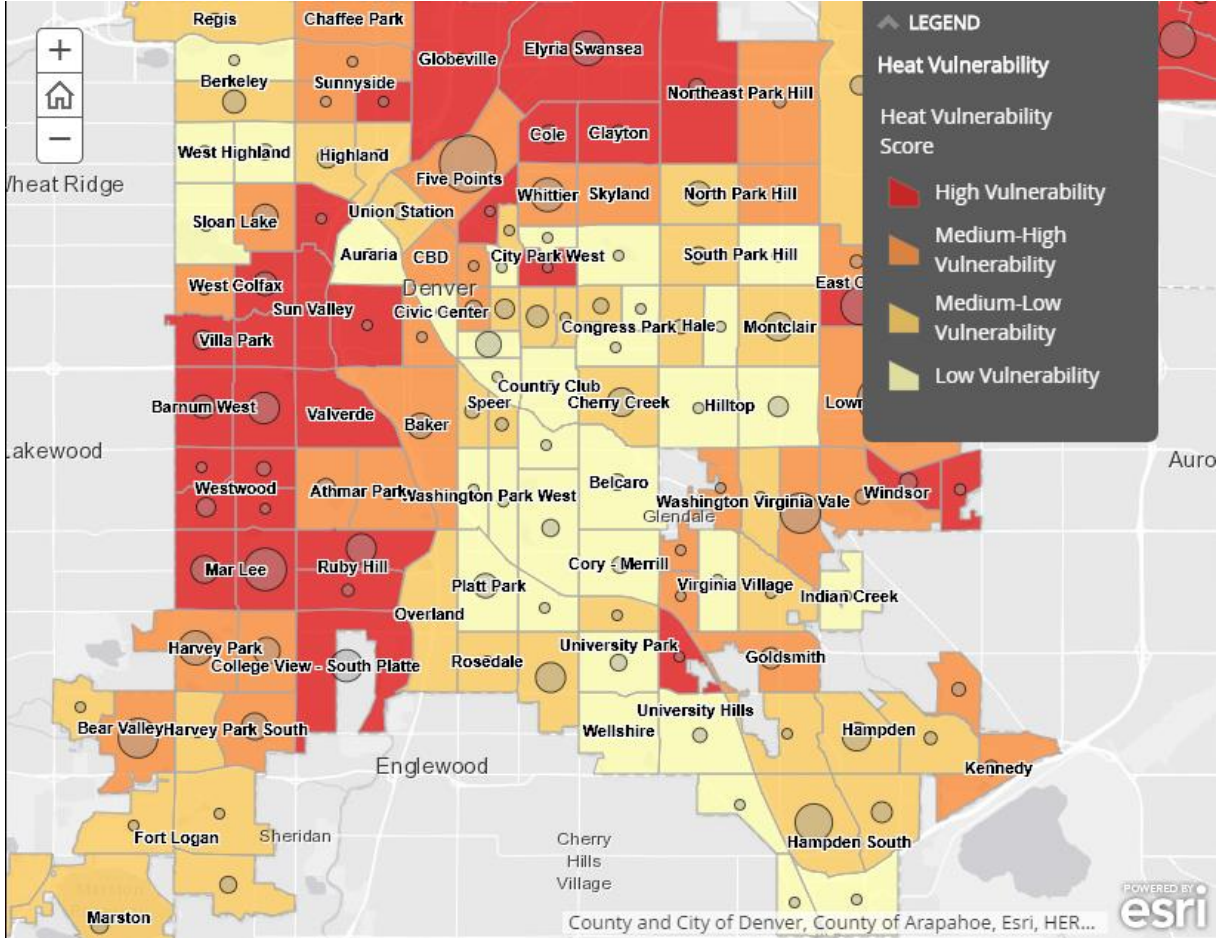


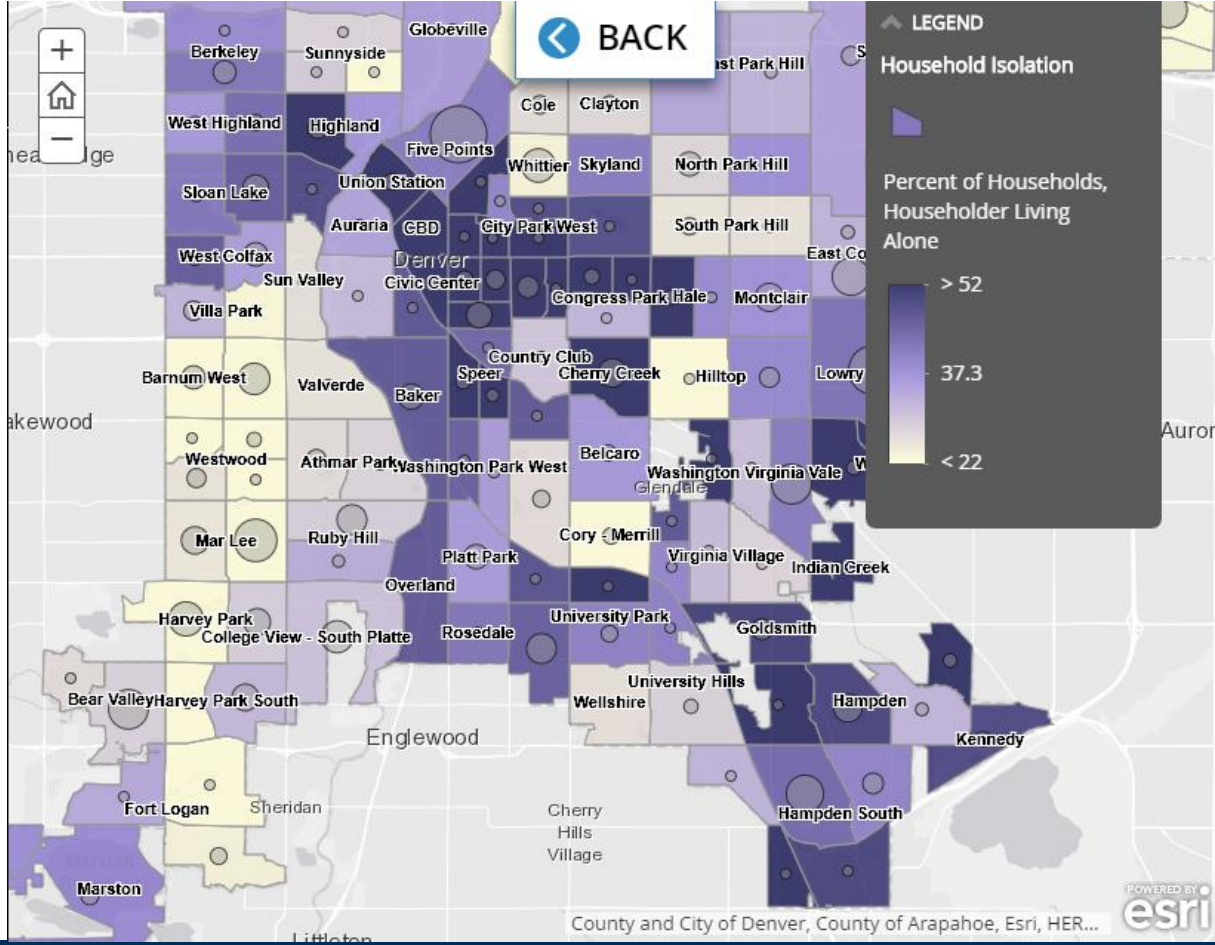
Current temperatures: PRISM Climate Group, Oregon State University, <http://prism.oregonstate.edu>, accessed July 1, 2014.
CMIP5 multi-model ensemble dataset based on current emission trends.

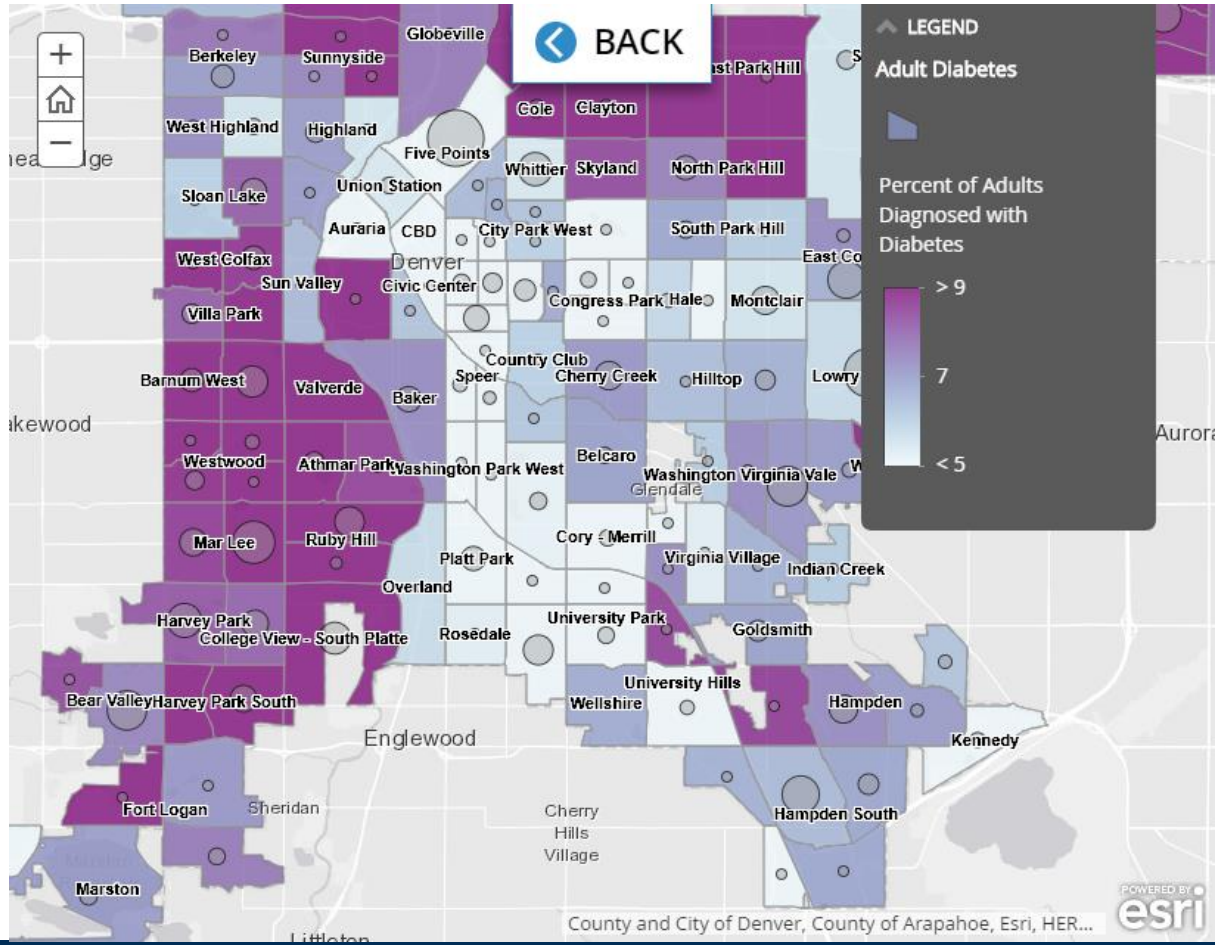
CLIMATE  CENTRAL



**50% of Denver
homes do not have
air conditioning**







Low Slope Black Roofs:



Built-up Roof (BUR)



EPDM

Low Slope Cool Roofs:



PVC/KEE




TPO



Modified Bitumen

**Cool roofs cost
0.3%-1.5% more
than black roofs**

An aerial photograph of a city, likely Denver, showing a dense urban area with various buildings, streets, and green spaces. A dark blue text box is overlaid on the right side of the image. The text inside the box reads: '~70% of buildings in Denver have a cool roof today'. The background shows a mix of modern and older buildings, with some featuring solar panels on their roofs. The overall scene is a high-angle view of a city grid.

**~70% of buildings in
Denver have a cool
roof today**

Insulation means roof color has little effect on heating and cooling costs for the building



Cool roofs are about outdoor comfort, keeping the outside temperatures a little lower in our City on the hottest summer days.

Cool Roof Working Group

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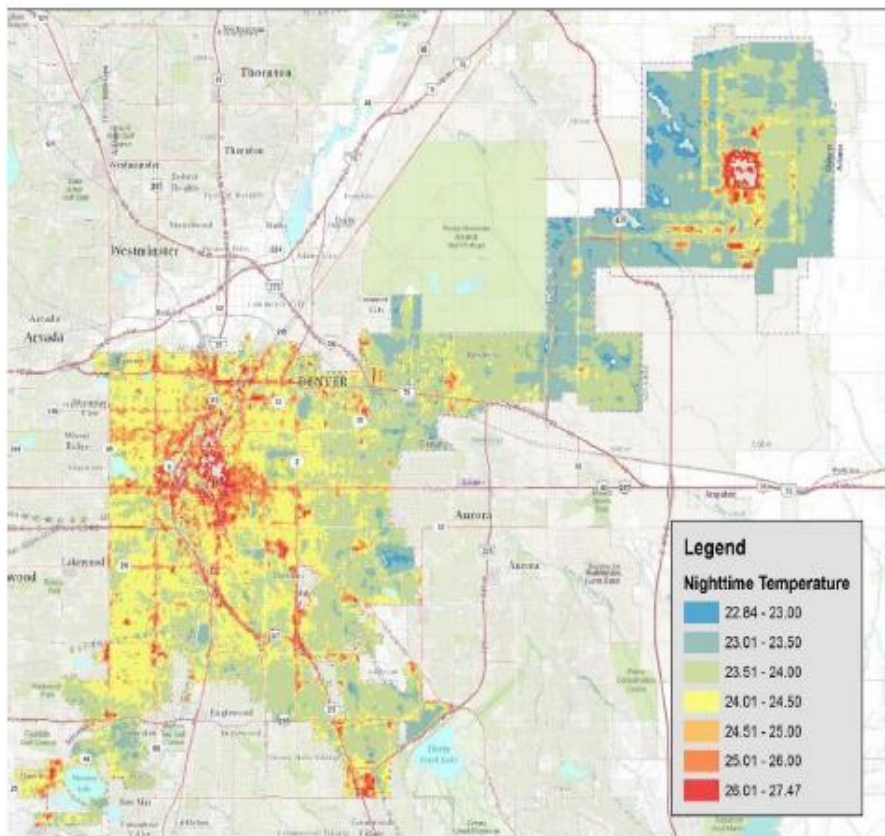
Rachel Bannon-Godfrey, Stantec

Tom Brangers, Prologis

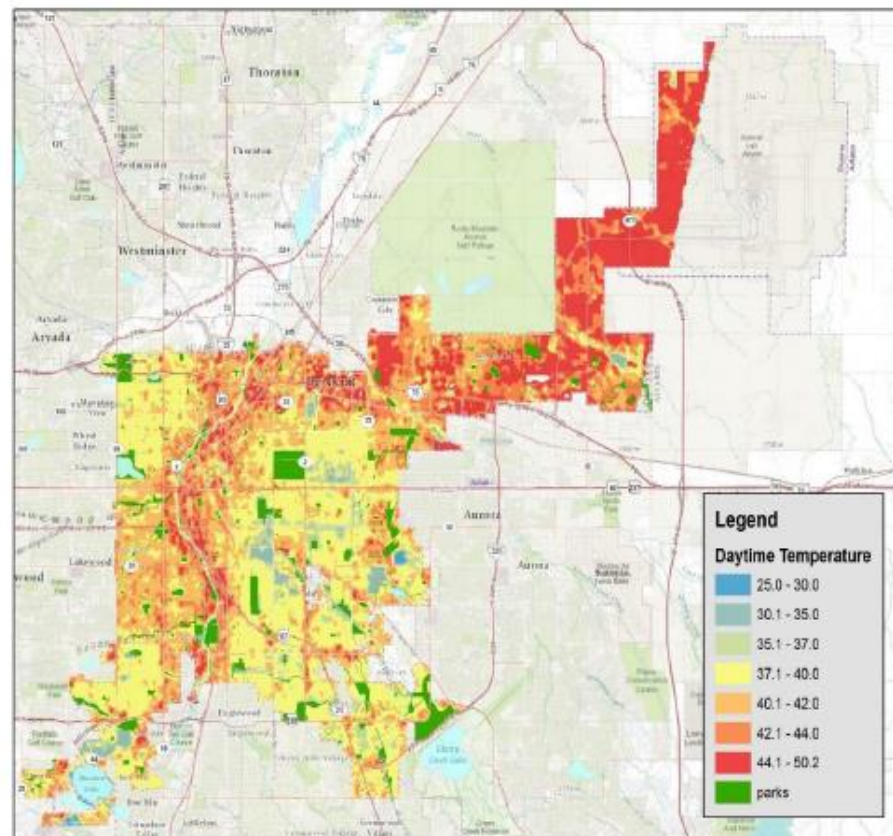
Cool Roof Drafting Timeline

- May 30th - Working Group Meeting
- July 9th - Working Group Meeting
- July 18th - Working Group Meeting
- July 23rd - Open Public Meeting and Discussion
- August 2nd - Working Group Meeting
- August 10th - Public Comment on Draft Closes
- August and September – Many emails and rounds of review between City staff and the Working Group

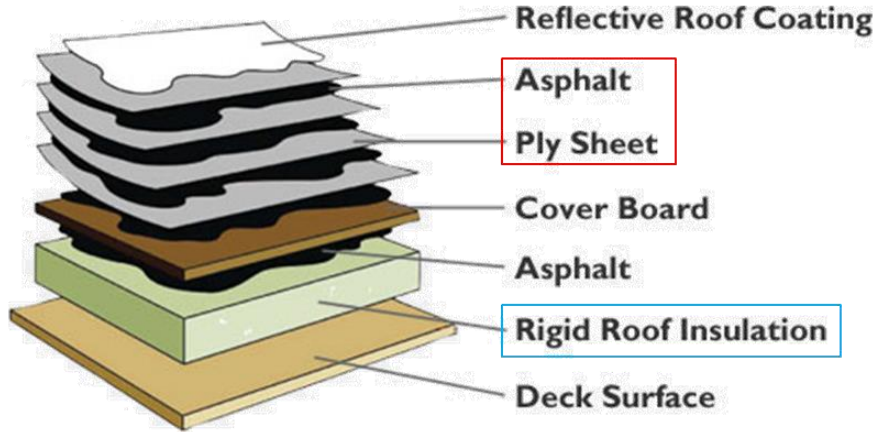
Nighttime August 2003



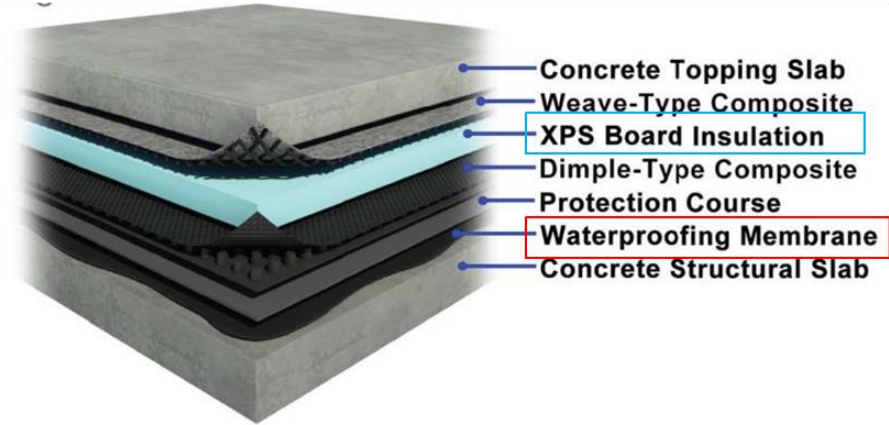
Daytime June 2012



Roof System Components

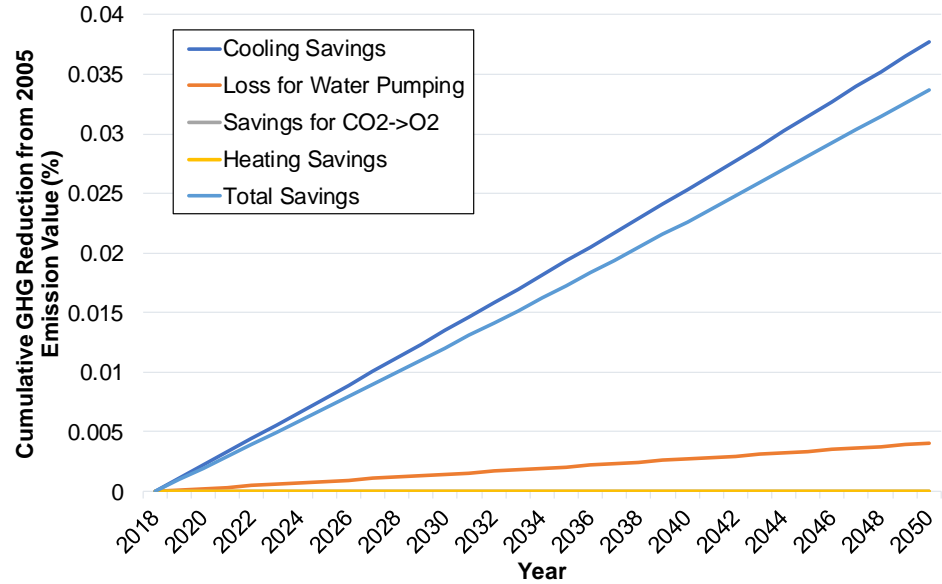


Typical Roofing – Membrane Above Insulation



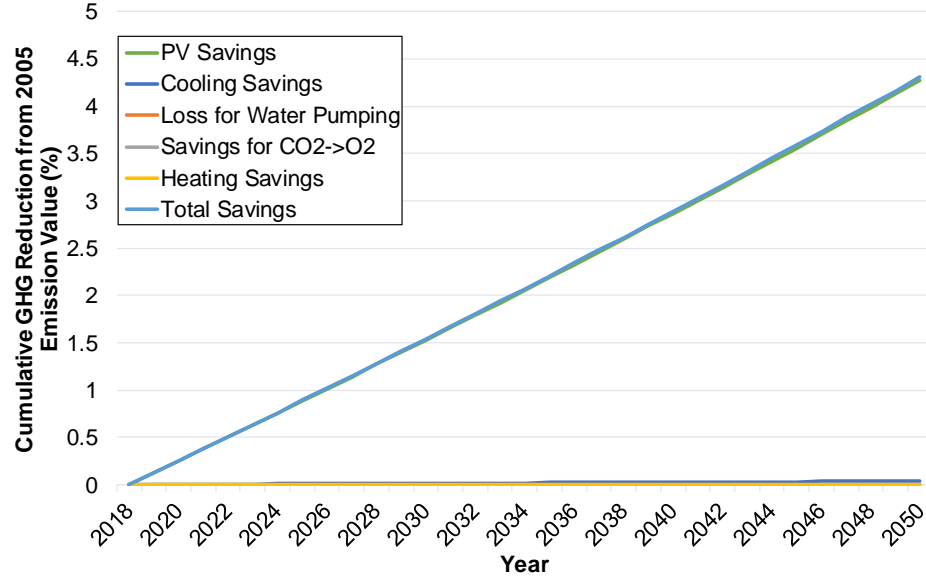
Typical Waterproofing – Membrane Below Insulation (No membrane UV Exposure)

Green Roof Only: GHG Emissions Reduction



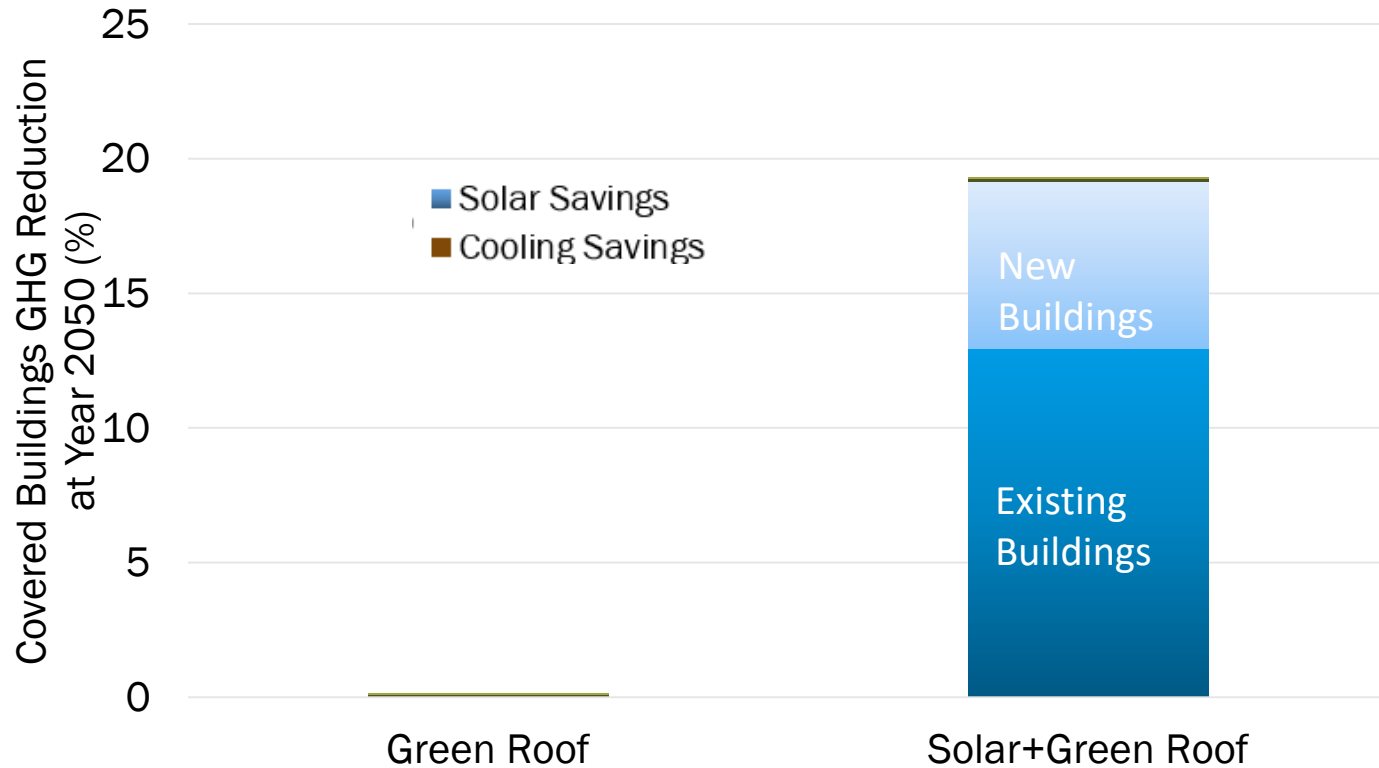
Parameter	Assumption
2005 GHG Emission Value	13.2 million mt-eCO ₂
New Construction Growth Rate	1.5% per year
Roof Replacement Rate	4% per year

PV & Green Roof: GHG Emissions Reduction



Parameter	Assumption
Max PV Area	70% of green roof space
2005 GHG Emission Value	13.2 million mt-eCO ₂
New Construction Growth Rate	1.5% per year
Roof Replacement Rate	4% per year

Stantec Analysis of the Original Ordinance Buildings GHG Reduction Comparison at Year 2050



~3.1 million mtCO₂e was emitted in 2017 from the energy used in buildings over 25,000 square feet.

Existing Building Cool Roof Costs & Premiums

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Black Roof Replacement Cost (\$)	\$137,700	\$1,539,900	\$1,539,900	\$101,250
Additional Green Roof Replacement Cost (\$)	\$140,636	\$490,089	\$2,224,759	\$132,300
Green Roof Cost Increase vs Black Roof (%)	102	32	144	131
<i>OR</i> Additional Green Roof + PV Replacement Cost (\$)	\$134,634	\$533,554	\$2,548,439	\$139,833
PV + Green Roof Cost Increase vs Black Roof (%)	98	35	165	138
<i>OR</i> Additional Cool Roof Replacement cost (\$)	\$550	\$4,750	\$4,750	\$1,500
Cool Roof Cost Increase vs Black Roof (%)	0.4	0.3	0.3	1.5

New Construction Cool Roof Costs & Premiums

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Total Building Floor Area (ft ²)	50,000	150,000	150,000	300,000
Cost per ft ² (\$/ft ²)	\$139.81	\$130.95	\$100.00	\$186.69
New Building Total Construction Costs (\$)	\$6,990,500	\$19,642,500	\$15,000,000	\$56,007,000
Additional Green Roof Cost per ft ² (\$)	\$2.81	\$3.27	\$14.83	\$0.44
Additional Green Roof Cost (\$)	\$140,636	\$490,089	\$2,224,759	\$132,300
Cost Increase for Green Roof (%)	2.0	2.5	14.8	0.2
Additional Green Roof + PV Cost per ft ² (\$)	\$2.69	\$3.56	\$16.99	\$0.47
Additional Green Roof + PV Cost (\$)	\$134,634	\$533,554	\$2,548,439	\$139,833
Cost Increase for Green Roof + PV (%)	1.9	2.7	17.0	0.2
Additional Cool Roof Cost per ft ² (\$)	\$0.01	\$0.03	\$0.03	\$0.01
Additional Cool Roof Cost (\$)	\$550	\$4,750	\$4,750	\$1,500
Cost Increase for Cool Roof (%)	0.008	0.024	0.032	0.003

Costs

New Building Cost Analysis

Cost Evaluation

Building	Cost Reduction from New Proposal
Office, 55,000 sq ft	~45%
Office, 300,000 sq ft	~20%
Industrial, 150,000 sq ft	~80%
Retail, 70,000 sq ft	~90%

New Building: Office

55,000 square feet, 5 floors, roof is 11,000 sq ft.

Coverage requirement on the ballot: 30% or 3,300 sq ft.

New proposed coverage requirement: 50% or 5,500 sq ft

Description	Current Law	New Proposal
Cost (\$) to construct the building	-\$6,990,500	-\$6,990,500
Additional Cost (\$)	-\$91,911 to -\$193,475	-\$63,003 to -\$93,500
Percent Cost Increase	1.3%-2.8%	0.9%-1.3%
Cost description	Lowest: green roof + solar Highest: solar only	Lowest: green area Highest: green covering an area equal to 15% of roof and 5% above code energy efficiency

~45% reduction in average costs for the new proposal

New Building: Office

300,000 square feet, 15 floors, roof is 20,000 sq ft.

Coverage requirement on the ballot: 60% or 12,000 sq ft.

New Proposed Coverage Requirement: 60% or 12,000 sq ft.

Description	Current Law	New Proposal
Cost (\$) to construct the building	-\$56,007,000	-\$56,007,000
Additional Cost (\$)	-\$275,315 to -\$405,562	-\$204,000 to -\$341,235
Percent Cost Increase	0.49%-0.72%	0.4%-0.6%
Cost description	Lowest: green roof + solar Highest: green roof only	Lowest: green area Highest: green covering an area equal to 18% of roof above code energy efficiency

~20% reduction in average costs for the new proposal

New Building: Industrial

150,000 square feet, 1 floor, roof is 150,000 sq ft.

Coverage requirement on the ballot: 10% or 15,000 sq ft.

New proposed coverage requirement: 10% or 15,000 sq ft.

Description	Current Law	New Proposal
Cost (\$) to construct the building	-\$19,642,500	-\$19,642,500
Additional Cost (\$)	-\$303,604 to -\$1,739,897	-\$174,713 to -\$255,000
Percent Cost Increase	1.5%-8.9%	0.9%-1.3%
Cost description	Lowest: green roof + solar Highest: solar only	Lowest: green area Highest: green covering an area equal to 3% of roof and 5% above code energy efficiency

~80% reduction in average costs for the new proposal

New Building: Retail

70,000 square feet, 1 floor, roof is 70,000 sq ft.

Coverage requirement on the ballot: 30%, or 21,000 sq ft.

New Proposed Coverage Requirement: 10% or 7,000

Description	Current Law	New Proposal
Cost (\$) to construct the building	-\$7,000,000	-\$7,000,000
Additional Cost (\$)	-\$648,702 to -\$1,107,275	-\$70,700 to -\$119,000
Percent Cost Increase	9.3%-15.8%	1.0%-1.7%
Cost description	Lowest: green roof + solar Highest: green roof only	Lowest: green area Highest: green covering an area equal to 3% of roof and 5% above code energy efficiency

~90% reduction in average costs for the new proposal

Existing Building: Office

55,000 square feet, 5 floors, roof is 11,000 sq ft.

Current Law Coverage: 30% or 3,300 sq ft.

New Proposal Options: 10% Green –or- 25% solar –or- Energy Program

Description	Current Law	New Proposal
Conventional Roof Replacement Cost (\$)	-\$137,700	-\$137,700
Additional Cost (\$)	-\$52,581	-\$3,750* to -\$19,250**
Cost Increase (%)	38%	3%-14%
Most Positive NPV (\$)	-	\$117,900*

*Energy Program: retro-commissioning

**10% Green

Note: Net Present Value (NPV) considers energy cost savings, costs (capital, maintenance, replacements), discount rates, and energy escalations rates for a time period of 32 years (i.e. up to year 2050).

Existing Building: Office

300,000 square feet, 15 floors, roof is 20,000 sq ft.

Current Law Coverage: 60% or 12,000 sq ft.

New Proposal Options: 18% Green –or- 42% solar –or- Energy Program

Cost Evaluation

Description	Current Law	New Proposal
Conventional Roof Replacement Cost (\$)	-\$337,500	-\$337,500
Additional Cost (\$)	-\$132,300	-\$62,117* to -\$65,000**
Cost Increase (%)	39%	18%-19%
Most Positive NPV (\$)	-	\$664,906**

*18% Green

**Energy Program: retro-commissioning

Note: Net Present Value (NPV) considers energy cost savings, costs (capital, maintenance, replacements), discount rates, and energy escalations rates for a time period of 32 years (i.e. up to year 2050).

Existing Building: Industrial Roof

150,000 square feet, 1 floor, roof is 150,000 sq ft.

Current Law Coverage: 50% or 75,000 sq ft.

New Proposal Options: 2% Green –or- 5% solar –or- Energy Program

Cost Evaluation

Description	Current Law	New Proposal
Conventional Roof Replacement Cost (\$)	-\$1,539,900	-\$1,539,900
Additional Cost (\$)	-\$725,445	-\$55,750* to -\$255,000**
Cost Increase (%)	47%	4%-17%
Most Positive NPV (\$)	-	\$247,579**

*2% Green

**Energy Program: LED lighting

Note: Net Present Value (NPV) considers energy cost savings, costs (capital, maintenance, replacements), discount rates, and energy escalations rates for a time period of 32 years (i.e. up to year 2050).

Existing Building: Retail

70,000 square feet, 1 floor, roof is 70,000 sq ft.

Current Law Coverage: 30% or 21,000 sq ft.

New Proposal Options: 2% Green –or- 5% solar –or- Energy Program

Cost Evaluation

Description	Current Law	New Proposal
Conventional Roof Replacement Cost (\$)	-\$769,950	-\$769,950
Additional Cost (\$)	-\$348,370	-\$27,050* to -\$119,000**
Cost Increase (%)	45%	4%-15%
Most Positive NPV (\$)	-	\$125,645**

*2% Green

**Energy Program: LED lighting

Note: Net Present Value (NPV) considers energy cost savings, costs (capital, maintenance, replacements), discount rates, and energy escalations rates for a time period of 32 years (i.e. up to year 2050).

NPV Parameters

Parameter	Assumption	Source
Analysis Period (years)	32 (i.e. till year 2050)	
Discount Rate (%)	7	Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs (https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf)
Energy Escalation Rate (%)	2	Colorado, 1.5% Inflation, Commercial Energy Escalation Rate Calculator (https://energy.gov/eere/femp/energy-escalation-rate-calculator-download):
Electricity Blended Rate (\$/kWh)	0.098	Colorado, Commercial U.S. Energy Information Administration (https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a)
Energy Savings	12% for LED 16% for Retro-Commissioning	Calculated based on site energy use intensity (EUI) of DOE Commercial Reference Buildings in Denver, Post-1980 Construction. Building types used were Mid-rise Apartment, Warehouse, Stand-alone Retail, and Medium Office.

Fee in Lieu

Task Force Recommendation

“That new buildings pay a fee-in-lieu of \$25 per square foot, and existing buildings pay a fee-in-lieu of \$17 per square foot, while recognizing that adopted rates will need to be informed by a rate study. The task force’s goal is to set the dollar amount so that this is a viable compliance option that achieves the benefits of the original ordinance. ”



Green Space Rate Study

Presentation to Denver City Council Green Roofs Committee

October 11, 2018



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720.228.2211 f

Scope

- Scope:
 - Estimate cost the City would incur to install *equivalent required* green space on the roof or ground
 - Include land values, capital costs, operation and maintenance (O&M) as well as City administrative costs
 - Based on City pricing not private pricing
 - Suggest fee index to track future cost changes
- Data Gathering:
 - Green roof specialists, private commercial landscape projects, City Parks & Recreation and Public Works

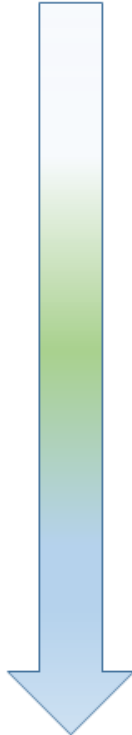
What is Equivalent Required Green Space?

- Urban green space – in transit areas, pocket parks, plazas, etc. (likely)
- Water quality and storm drainage (green infrastructure projects) (likely)
- Large new park (unlikely)
- Green roofs on City buildings
 - New City buildings meet the requirement on their own. Existing buildings would need to be assessed and potentially structurally reinforced



Projects providing Equivalent Benefit

Equivalent Benefit	\$ PSF	Example Projects
	\$ 15	Suburban park in Area 1
	\$ 30	Extensive green roof on City property (\$0 land value)
	\$ 30	Landscaping (no soil mitigation / hardscape) on \$0 land value property
	\$ 30	Suburban park in Area 2; land availability challenge
	\$ 35	Landscaping (only) in Area 1
	\$ 45	Intensive green roof on City property (\$0 land value)
	\$ 50	Urban green space on \$0 land value property
	\$ 60	Green infrastructure additions (low) on \$0 land value property
	\$ 70	Urban green space in Area 2 ; land availability challenge
	\$ 90	Green infrastructure additions (high) on \$0 land value property
	\$ 90	Urban green space in Area 3; land availability challenge
	\$ 100	Green infrastructure additions (low) in Area 3
	\$ 125	Urban green space in Area 4; land availability challenge
	\$ 135	Green infrastructure additions (low) in Area 4
	\$ 165	Green infrastructure additions (high) in Area 4
	\$ 210	Urban green space in Area 5; land availability challenge
	\$ 220	Green infrastructure additions (low) in Area 5
	\$ 255	Green infrastructure additions (high) in Area 5
	\$ 370	Urban green space in Area 6; land availability challenge
	\$ 385	Green infrastructure additions (low) in Area 6
	\$ 535	Mature landscaping, soil mitigation and hardscape in Area 6



Projects providing Equivalent Benefit: \$50-\$90 psf

\$ PSF	Example Projects
\$ 50	Urban green space on \$0 land value property
\$ 60	Green infrastructure additions (low) on \$0 land value property
\$ 70	Urban green space in Area 2 ; land availability challenge
\$ 90	Green infrastructure additions (high) on \$0 land value property
\$ 90	Urban green space in Area 3; land availability challenge

Menu of Equivalent Benefits

Land

- City owned property - \$0
- Area 1 - \$5
- Area 2 - \$20
- Area 3 - \$40
- Area 4 - \$75
- Area 5 - \$163
- Area 6 - \$323

Capital Costs

- Construction
 - Suburban park including significant natural areas - \$5
 - Extensive basic green roof - \$25
 - Landscaping (no hardscape, soil, etc.) - \$25
 - Urban green space - \$35
 - Green infrastructure - \$50 to \$80
 - Water quality - \$95
 - Extensive landscaping, soil mitigation and hardscape in downtown - \$200 to \$350
- Admin
 - Park PM - \$0.30
 - Green Infrastructure PM - \$4.15

Operations & Maintenance

- Admin
 - Interdepartmental staff oversight - \$2.48
- O&M
 - Basic landscaping to intensively used urban park - \$4.67 to \$11.00

Land Values

