

# **APPENDIX: COST EVALUATION**

# Cost Evaluation Overview

In this section, we will:

- Show fees in lieu of compliance
- Show typical costs for adding a green roof and PV for four representative buildings: apartment, industrial, retail, and office.
- Compare these costs to conventional roof replacement costs for existing buildings
- Compare these costs to total construction costs of a new building
- Show a life cycle cost analysis of green roofs and PV



# Representative Buildings

## **Apartment**

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

Green Roof Coverage requirement: 30% or 3,300 sq ft.

## **Industrial or Retail**

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

Green Roof Coverage requirement:

- 10% for Industrial or 15,000 sq ft.
- 50% for Retail or 75,000 sq ft.

## **Office**

300,000 square feet, 15 floors, roof is 6,000 sq ft.

Green Roof Coverage requirement: 60% or 3,600 sq ft.

## Fee in Lieu of Compliance

\$25/ft<sup>2</sup> of green roof area

Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
\$82,500	\$375,000	\$1,875,000	\$90,000

# Structural Assessment Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Engineering Company #1	Engineering studies	\$5,000-\$8,000	\$15,000-\$20,000	\$15,000-\$20,000	\$5,000-\$8,000
Engineering Company #1	Fees are only for studies and do not include producing construction documents, permit sets and construction administration. No structural documents: fee includes investigation of existing framing conditions.	\$1,800-\$2,500 or \$3,600-\$5,000 (no structural documents)	\$4,000-\$6,000 or \$8,000-\$12,000 (no structural documents)	\$4,000-\$6,000 or \$8,000-\$12,000 (no structural documents)	\$4,000-\$5,000 or \$8,000-\$10,000 (no structural documents)
Roof Consultant #1	Structural engineering cost to prove the building will not support a green roof.	\$15,000-\$40,000	\$15,000-\$40,000	\$15,000-\$40,000	\$15,000-\$40,000
Engineering Company #3	Potential structural engineering costs of evaluating existing buildings for the incorporation of green roofs and/or solar systems.	\$20,000	\$25,000	\$40,000	\$20,000
	<b>Cost Range (\$)</b>	<b>\$1,800-\$40,000</b>	<b>\$4,000-\$6,000</b>	<b>\$4,000-\$40,000</b>	<b>\$4,000-\$40,000</b>

# Green Roof and Solar Scenarios

## **Baseline: Conventional Roof**

### **Scenario 1: Green Roof Only**

- Green roof is 100% of required green roof space

### **Scenario 2: Solar & Green Roof**

- Solar is covering 70% of required green roof space
- Green roof is covering 30% of required green roof space

### **Scenario 3: Solar Only**

- Existing Buildings: Solar is covering 70% of required green roof space
- New Buildings: Solar is covering 100% of the roof

# Existing Buildings

## Green Roof Only

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Conventional Roof Replacement Cost (\$)	\$137,700	\$1,539,900	\$1,539,900	\$101,250
Additional Green Roof Cost (\$)	\$140,636	\$490,089	\$2,224,759	\$132,300
Cost Increase for Green Roof (%)	102	32	144	131

## Solar & Green Roof

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Conventional Roof Replacement Cost (\$)	\$137,700	\$1,539,900	\$1,539,900	\$101,250
Additional Solar + Green Roof Cost (\$)	\$93,032	\$307,681	\$1,345,529	\$94,449
Cost Increase for Solar + Green Roof (%)	68	20	87	93

# Existing Buildings

## Solar Only

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Conventional Roof Replacement Cost (\$)	\$137,700	\$1,539,900	\$1,539,900	\$101,250
Additional Green Roof Cost (\$)	\$55,294	\$166,467	\$685,039	\$59,315
Cost Increase for Green Roof (%)	40	11	44	59



# New Construction Buildings

## Green Roof Only

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Total Building Floor Area (ft <sup>2</sup> )	50,000	150,000	150,000	300,000
Cost per ft <sup>2</sup> (\$)	\$139.81	\$130.95	\$100.00	\$186.69
New Building Construction Costs (\$)	\$6,990,500	\$19,642,500	\$15,000,000	\$56,007,000
Additional Green Roof Cost per ft <sup>2</sup> (\$)	\$2.81	\$3.27	\$14.83	\$0.44
Additional Green Roof Cost (\$)	\$140,636	\$490,089	\$2,224,759	\$132,300
<b>Cost Increase for Green Roof (%)</b>	<b>2.0</b>	<b>2.5</b>	<b>14.8</b>	<b>0.2</b>

# New Construction Buildings

## Solar & Green Roof

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Total Building Floor Area (ft <sup>2</sup> )	50,000	150,000	150,000	300,000
Cost per ft <sup>2</sup> (\$)	\$139.81	\$130.95	\$100.00	\$186.69
New Building Construction Costs (\$)	\$6,990,500	\$19,642,500	\$15,000,000	\$56,007,000
Additional Solar & Green Roof Cost per ft <sup>2</sup> (\$)	\$1.86	\$2.05	\$8.97	\$0.31
Additional Solar & Green Roof Cost (\$)	\$93,032	\$307,681	\$1,345,529	\$94,449
<b>Cost Increase for Solar &amp; Green Roof (%)</b>	<b>1.3</b>	<b>1.6</b>	<b>9.0</b>	<b>0.2</b>

# New Construction Buildings

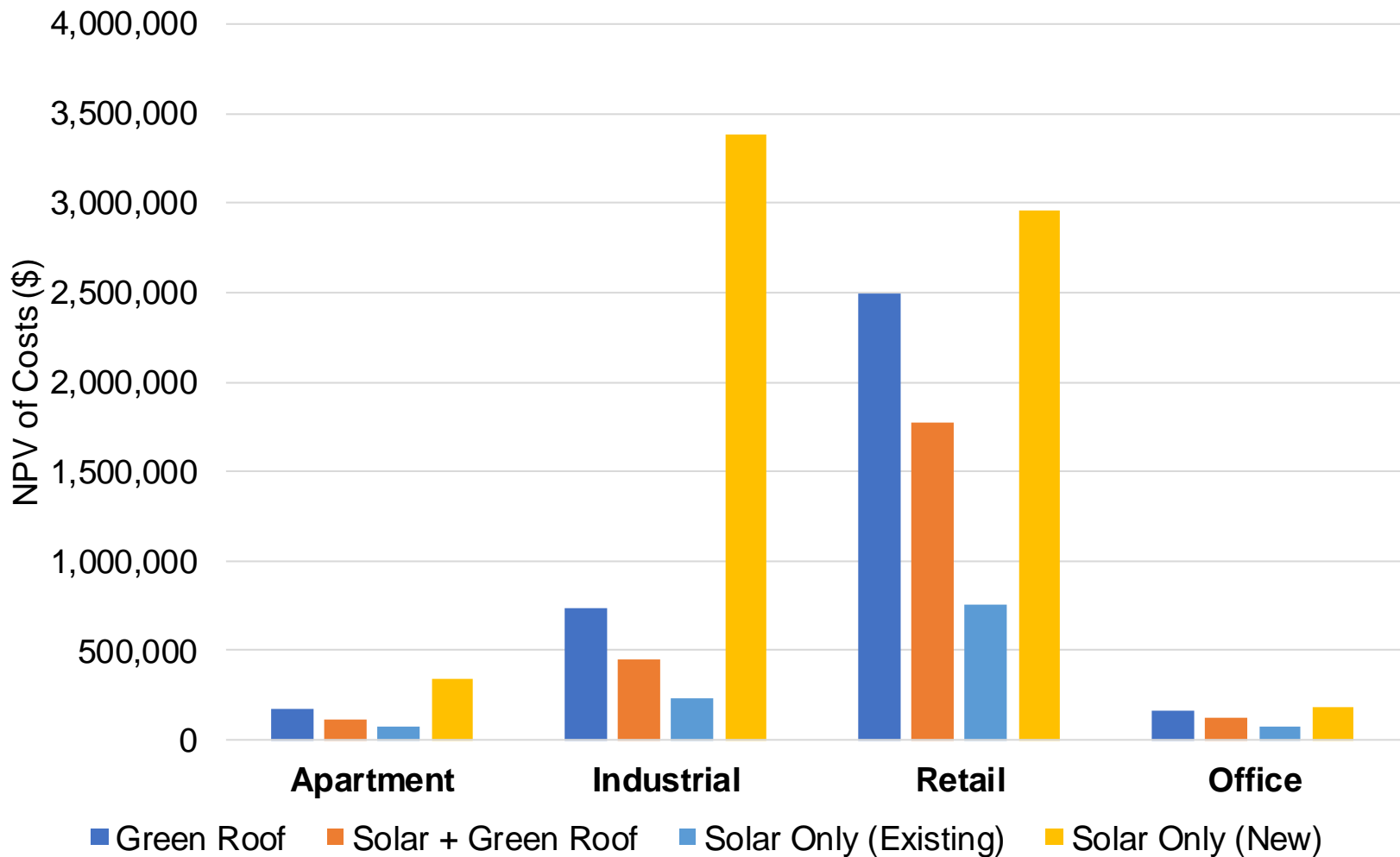
## PV Only (100% of Roof)

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Total Building Floor Area (ft <sup>2</sup> )	50,000	150,000	150,000	300,000
Cost per ft <sup>2</sup> (\$)	\$139.81	\$130.95	\$100.00	\$186.69
New Building Construction Costs (\$)	\$6,990,500	\$19,642,500	\$15,000,000	\$56,007,000
Additional Solar & Green Roof Cost per ft <sup>2</sup> (\$)	\$23.94	\$15.85	\$13.05	\$23.54
Additional Solar & Green Roof Cost (\$)	\$263,305	\$2,378,099	\$1,957,253	\$141,226
Cost Increase for Solar & Green Roof (%)	3.8	12.1	13.0	0.3

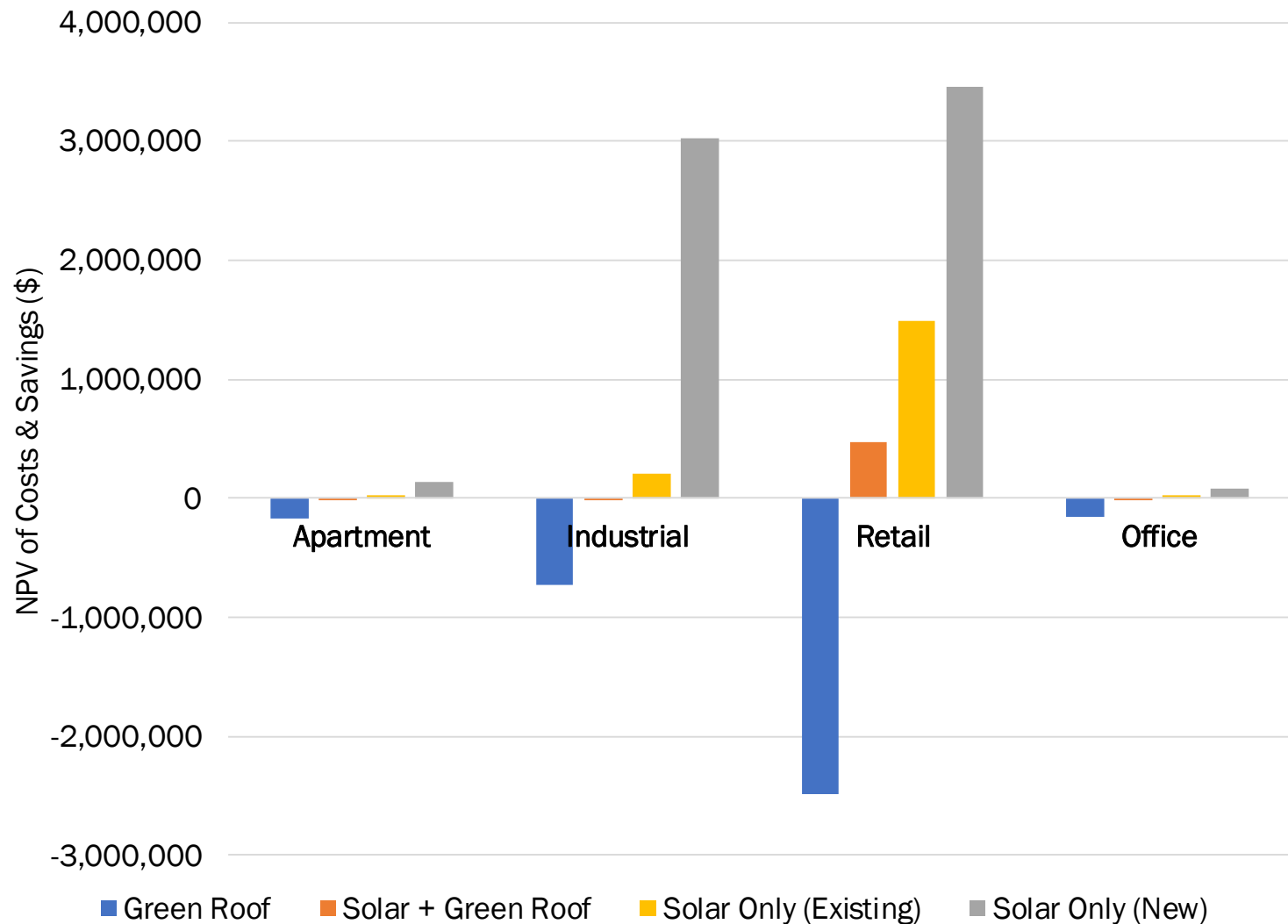
## What is Net Present Value (NPV)?

- This metric is used to evaluate the total life cycle costs and financial viability of different upgrade scenarios.
- Life-cycle costs includes all costs, savings, and incentives incurred during the defined analysis period.
- The NPV calculation is a method used to 'shift' all the identified life-cycle costs to present value.
- NPV represents the sum of all annual net cash flows minus the total initial investment costs for the analysis period presented in terms of current dollar value.
- This equation considers opportunity cost (discount rate), energy rate escalation, and the time value of money.

# NPV of Costs for All Scenarios



# NPV of Costs & Savings All Both Scenarios



Cost Breakdown and Net Present Value Calculation

# Cost Evaluation Appendix

# Conventional Roof Replacement Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Roof Consultant #1	Black roofs are assumed to be 60 mil fully adhered EPDM Rubber or Built-up asphalt roof (BUR). Includes structural engineering costs. Life Expectancy: 25 years	\$154,400	\$1,729,800	\$1,729,800	\$94,500
Roof Consultant #2	Life Expectancy: 20 years	\$121,000	\$1,350,000	\$1,350,000	\$108,000
	<b>Average Capital Cost (\$)</b>	<b>\$137,700</b>	<b>\$1,539,900</b>	<b>\$1,539,900</b>	<b>\$101,250</b>
Roof Consultant #1	<b>Maintenance Costs (\$)</b>	<b>\$2,200</b>	<b>\$30,000</b>	<b>\$30,000</b>	<b>\$1,200</b>



# Green Roof Only Capital Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Green Roof Supplier #1	4.25in module with sedum, corners, Installation, crane, irrigation, irrigation installation.	\$130,885	\$565,341	\$2,800,001	\$140,550
Roof Consultant #1	Waterproofing, drain matt, root barrier, vegetative system, irrigation.	\$202,400	\$471,800	N/A	\$126,300
Roofing Consultant #2	Does not include irrigation system.	\$87,384	N/A	\$2,304,900	\$111,600
Green Roof Supplier #2		\$82,500	\$375,000	\$1,500,000	\$90,000
	<b>Average Costs (\$)</b>	<b>\$125,792</b>	<b>\$470,714</b>	<b>\$2,201,634</b>	<b>\$117,112</b>
	<b>Cost per ft<sup>2</sup> of Green Roof (\$)</b>	<b>\$38</b>	<b>\$31</b>	<b>\$29</b>	<b>\$33</b>

# Green Roof Only Maintenance Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Green Roof Supplier #1	Plants replacement annually, weeding	\$891	\$1,655	\$5,255	\$964
Roof Consultant #1	Green roof maintenance	\$3,300	\$45,000	\$45,000	\$1,800
Roof Consultant #2	Not including materials	\$3,690	\$23,333	\$23,333	\$4,320
Green Roof Supplier #2	Maintenance, irrigation/water pumping	\$1,650	\$7,500	\$11,250	\$1,800
	<b>Average Costs (\$)</b>	<b>\$2,383</b>	<b>\$19,372</b>	<b>\$21,210</b>	<b>\$2,221</b>

# Solar & Green Roof Capital Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Engineering Company #4	Solar Cost (\$)	\$89,889	\$326,871	\$1,470,919	\$98,061
Engineering Company #4	Solar Net Tax Benefits ITC	(\$26,967)	(\$98,061)	(\$441,276)	(\$29,418)
Engineering Company #4	Solar Net Tax Benefits / MACRS depreciation	(\$22,472)	(\$81,718)	(\$367,730)	(\$24,515)
Average Green Roof Capital Costs (prorated to a smaller area)	Green Roof Cost (\$)	\$37,738	\$141,214	\$660,490	\$35,134
Average Structural Costs	Structural Engineering Costs (\$)	\$14,844	\$19,375	\$23,125	\$15,188
	<b>Total Capital Costs (\$)</b>	<b>\$93,032</b>	<b>\$307,681</b>	<b>\$1,345,529</b>	<b>\$94,449</b>

# Solar & Green Roof Maintenance Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Engineering Company #4	Solar Maintenance Cost (\$/year)	\$1,079	\$4,903	\$24,515	\$1,177
Average Green Roof Maintenance Costs (prorated to a smaller area)	Green Roof Main. Cost (\$/year)	\$715	\$5,812	\$6,363	\$666
	<b>Total Maintenance (\$/year)</b>	<b>\$1,793</b>	<b>\$10,715</b>	<b>\$30,878</b>	<b>\$1,843</b>

# Solar & Green Roof Replacement Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Engineering Company #4	Inverter Replacement Life expectancy: 15 years	\$3,596	\$16,344	\$81,718	\$3,922
Engineering Company #4	Solar Replacement Live Expectancy: 40 years	\$89,889	\$326,871	\$1,470,919	\$98,061

## Solar Only (Existing) Capital Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Engineering Company #4	Solar Cost (\$)	\$89,889	\$326,871	\$1,470,919	\$98,061
Engineering Company #4	Solar Net Tax Benefits ITC	(\$26,967)	(\$98,061)	(\$441,276)	(\$29,418)
Engineering Company #4	Solar Net Tax Benefits / MACRS depreciation	(\$22,472)	(\$81,718)	(\$367,730)	(\$24,515)
Average Structural Costs	Structural Engineering Costs (\$)	\$14,844	\$19,375	\$23,125	\$15,188
	<b>Total Capital Costs (\$)</b>	<b>\$55,294</b>	<b>\$166,467</b>	<b>\$685,039</b>	<b>\$59,315</b>

# Solar Only (Existing) Maintenance Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Engineering Company #4	Solar Maintenance Cost (\$/year)	\$1,079	\$4,903	\$24,515	\$1,177

## Solar Only (Existing) Replacement Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Engineering Company #4	Inverter Replacement Life expectancy: 15 years	\$3,596	\$16,344	\$81,718	\$3,922
Engineering Company #4	Solar Replacement Live Expectancy: 40 years	\$89,889	\$326,871	\$1,470,919	\$98,061



# Solar Only (New) Capital Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Solar Costs per Area	Solar Cost (\$/ft²) Includes structural assessment	\$24	\$16	\$13	\$24
	<b>Total Capital Costs (\$)</b>	\$263,305	\$2,378,099	\$1,957,253	\$141,226

# Solar Only (New) Maintenance Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Engineering Company #4	Solar Maintenance Cost (\$/year)	\$5,137	\$70,044	\$70,044	\$2,802

# Solar Only (New) Replacement Costs

Source	Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Engineering Company #4	Inverter Replacement Life expectancy: 15 years	\$17,122	\$233,480	\$233,480	\$9,339
Engineering Company #4	Solar Replacement Live Expectancy: 40 years	\$428,045	\$4,669,584	\$4,202,626	\$233,479

# Green Roof Only NPV Calculation

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Total Capital Costs (Structural + Green Roof)	\$140,636	\$490,089	\$2,224,759	\$132,300
Green Roof Maintenance Costs (NPV)	\$30,137	\$244,989	\$268,233	\$28,088
<b>Total NPV of Costs Only</b>	<b>\$170,773</b>	<b>\$735,078</b>	<b>\$2,492,992</b>	<b>\$160,388</b>
Energy Cost Savings (NPV)	\$432	\$2,063	\$10,313	\$416
<b>Total NPV of Costs and Savings</b>	<b>-\$170,341</b>	<b>-\$733,015</b>	<b>-\$2,482,679</b>	<b>-\$159,972</b>

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 ( <a href="https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf">https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf</a> )
Energy Escalation Rate (%)	2	Energy Escalation Rate Calculator ( <a href="https://energy.gov/eere/femp/energy-escalation-rate-calculator-download">https://energy.gov/eere/femp/energy-escalation-rate-calculator-download</a> ): Colorado, 1.5% Inflation, Commercial
Electricity Blended Rate (\$/kWh)	0.098	U.S. Energy Information Administration ( <a href="https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a">https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a</a> ): Colorado, Commercial

# Solar & Green Roof NPV Calculation

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Total Capital Costs	\$93,032	\$307,681	\$1,345,529	\$94,449
Solar & Green Roof Maintenance Costs (NPV)	\$22,675	\$135,508	\$390,500	\$23,308
Inverter Replacements (NPV)	\$1,776	\$8,071	\$40,353	\$1,937
<b>Total NPV of Costs</b>	<b>\$117,483</b>	<b>\$451,260</b>	<b>\$1,776,382</b>	<b>\$119,694</b>
Energy Cost Saving (NPV)	\$77,146	\$350,651	\$1,753,238	\$84,149
REC Credit for 20 years (NPV)	\$22,036	\$100,166	\$500,832	\$24,038
<b>Total NPV of Savings</b>	<b>\$99,182</b>	<b>\$450,817</b>	<b>\$2,254,070</b>	<b>\$108,187</b>
<b>Total NPV of Costs &amp; Savings</b>	<b>-\$18,301</b>	<b>-\$443</b>	<b>\$477,688</b>	<b>-\$11,507</b>

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 ( <a href="https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf">https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf</a> )
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Electricity Blended Rate (\$/kWh)	0.098	U.S. Energy Information Administration ( <a href="https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a">https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a</a> ): Colorado, Commercial

# Solar Only (Existing) NPV Calculation

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Total Capital Costs	\$55,294	\$166,467	\$685,039	\$59,315
Solar Maintenance Costs (NPV)	\$13,646	\$62,006	\$31,030	\$14,885
Inverter Replacements (NPV)	\$1,776	\$8,071	\$40,353	\$1,937
<b>Total NPV of Costs</b>	<b>\$70,716</b>	<b>\$236,544</b>	<b>\$756,422</b>	<b>\$76,137</b>
Energy Cost Saving (NPV)	\$76,682	\$348,588	\$1,742,925	\$83,654
REC Credit for 20 years (NPV)	\$22,036	\$100,166	\$500,832	\$24,038
<b>Total NPV of Savings</b>	<b>\$98,718</b>	<b>\$448,754</b>	<b>\$2,243,757</b>	<b>\$107,692</b>
<b>Total NPV of Costs &amp; Savings</b>	<b>\$28,002</b>	<b>\$212,210</b>	<b>\$1,487,335</b>	<b>\$31,555</b>

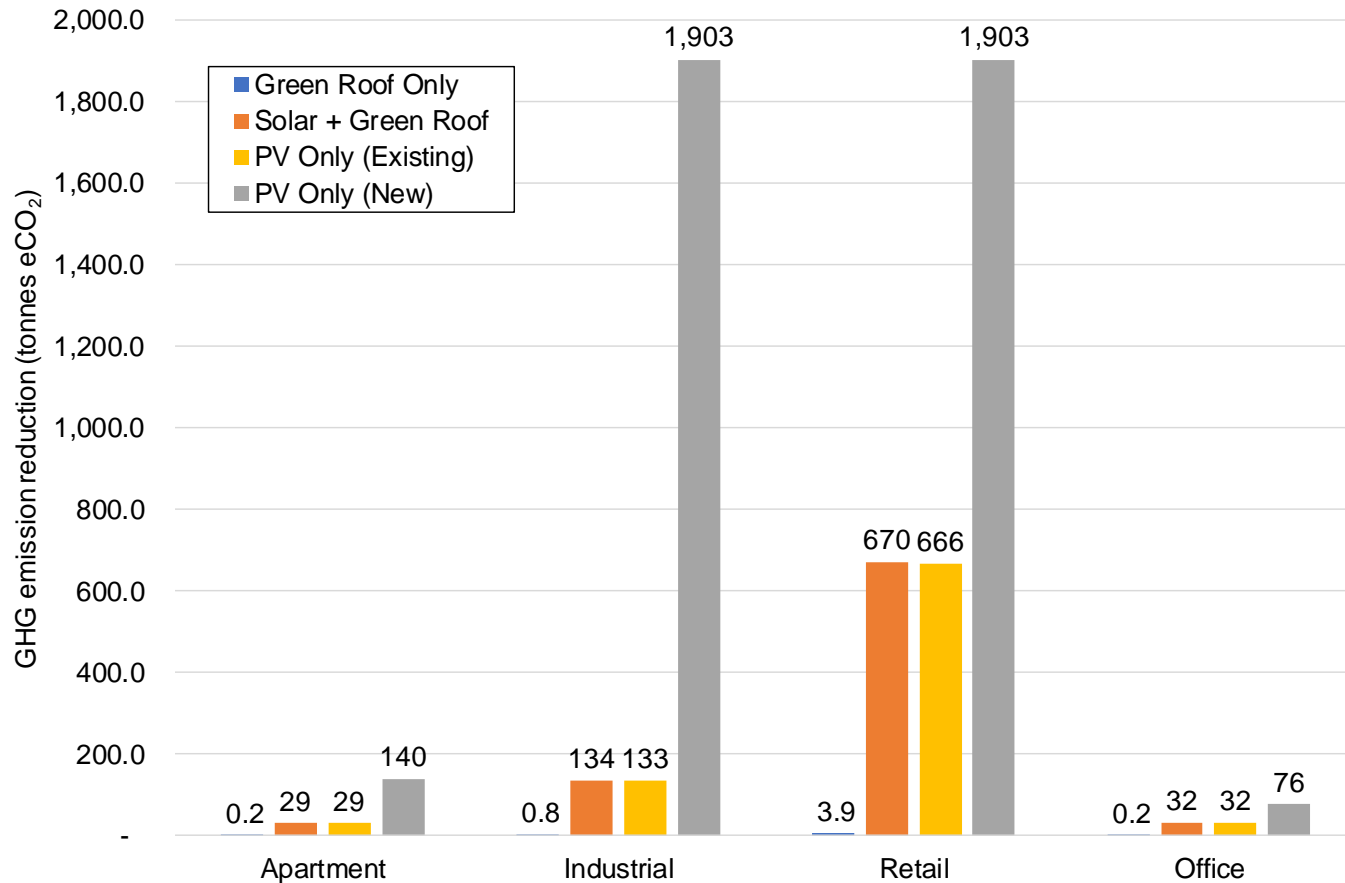
Parameter	Assumption	Source
Analysis Period (years)	32 (i.e. till year 2050)	
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# Solar Only (New) NPV Calculation

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Total Capital Costs	\$263,305	\$2,378,099	\$1,957,253	\$141,226
Solar Maintenance Costs (NPV)	\$64,965	\$885,815	\$885,815	\$35,436
Inverter Replacements (NPV)	\$8,455	\$115,295	\$115,295	\$4,612
<b>Total NPV of Costs</b>	<b>\$336,725</b>	<b>\$3,379,209</b>	<b>\$2,958,363</b>	<b>\$181,274</b>
Energy Cost Saving (NPV)	\$365,185	\$4,979,814	\$4,979,814	\$199,189
REC Credit for 20 years (NPV)	\$104,934	\$1,430,934	\$1,430,934	\$57,239
<b>Total NPV of Savings</b>	<b>\$470,119</b>	<b>\$6,410,748</b>	<b>\$6,410,748</b>	<b>\$256,428</b>
<b>Total NPV of Costs &amp; Savings</b>	<b>\$133,394</b>	<b>\$3,031,539</b>	<b>\$3,452,385</b>	<b>\$75,154</b>

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 ( <a href="https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf">https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf</a> )
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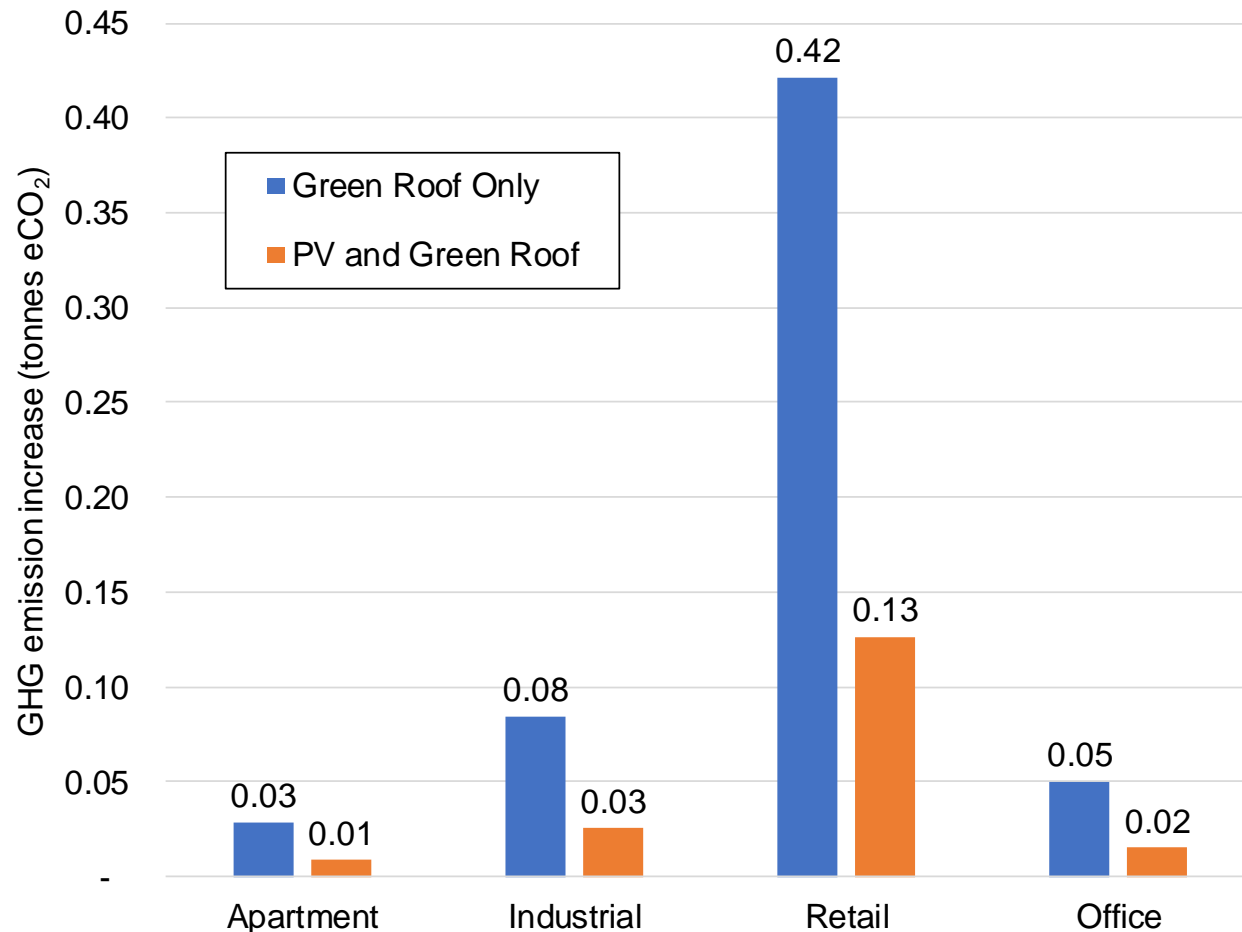
# GHG Emission Reduction for Representative Buildings



\*2016 Xcel Energy GHG Emission Factor for Colorado: 1.32 lbs eCO<sub>2</sub>/kwh (Electricity)

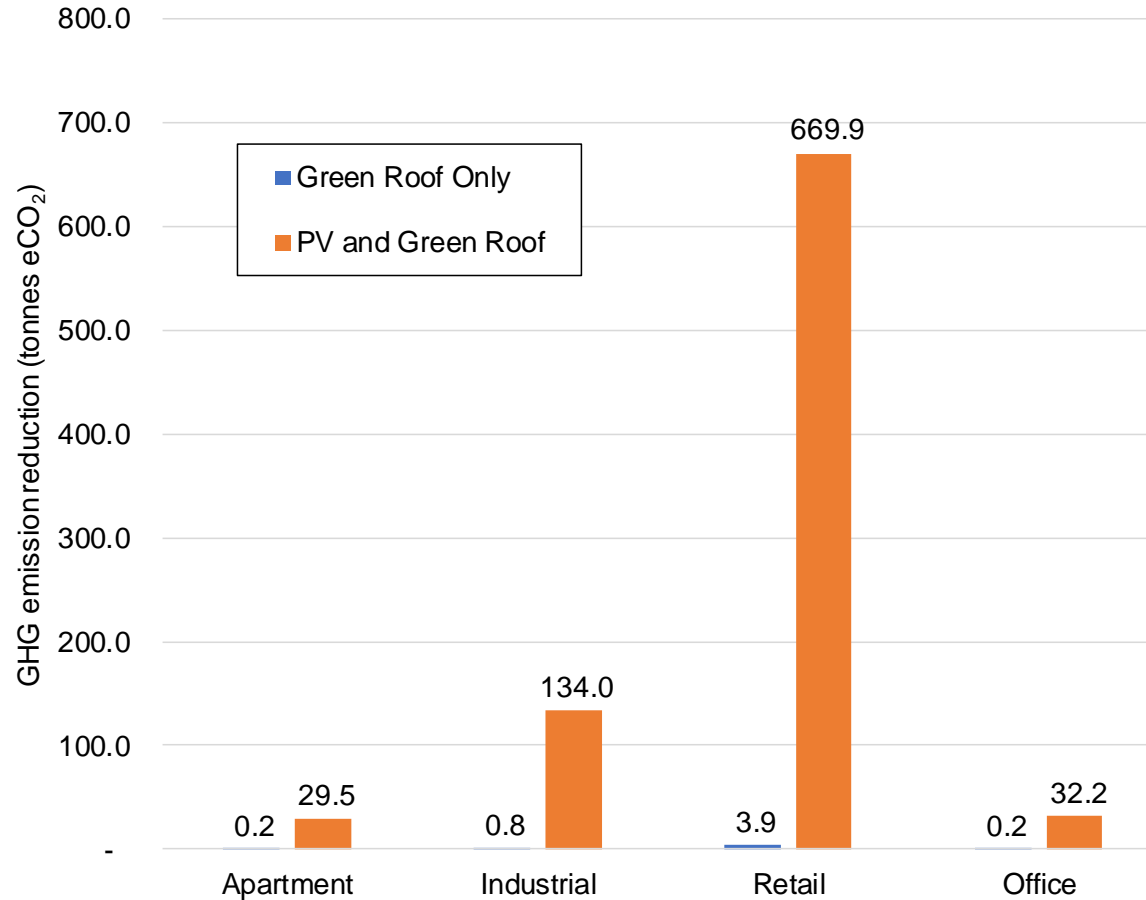


# GHG Emissions for Water Usage for Representative Buildings



\*2016 Xcel Energy GHG Emission Factor for Colorado: 1.32 lbs eCO<sub>2</sub>/kwh (Electricity)

# GHG Emission Reduction for Representative Buildings



\*2016 Xcel Energy GHG Emission Factor for Colorado: 1.32 lbs eCO<sub>2</sub>/kwh (Electricity)