

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/ft² 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
	Cost Range (\$)	\$1,800-\$40,000	\$4,000-\$6,000	\$4,000-\$40,000	\$4,000-\$40,000

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 ²)	50,000	150,000	150,000	300,000
Cost per ft ² (\$)	\$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 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

New Construction Buildings

Solar & Green Roof

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 (\$)	\$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 ² (\$)	\$1.86	\$2.05	\$8.97	\$0.31
Additional Solar & Green Roof Cost (\$)	\$93,032	\$307,681	\$1,345,529	\$94,449
Cost Increase for Solar & Green Roof (%)	1.3	1.6	9.0	0.2

New Construction Buildings

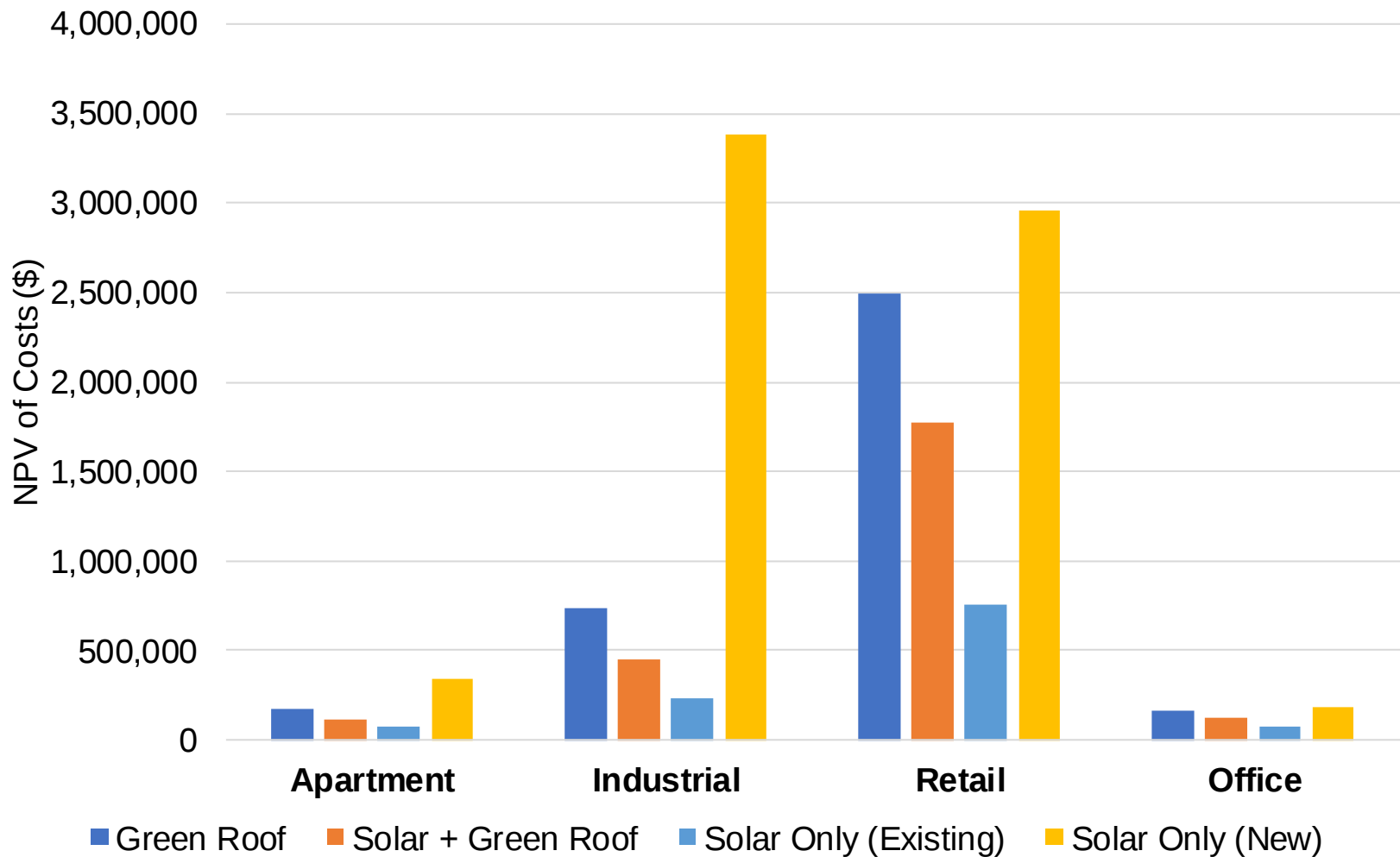
PV Only (100% of Roof)

Description	Building 1: Apartment	Building 2a: Industrial	Building 2b: Retail	Building 3: Office
Total Building Floor Area (ft ²)	50,000	150,000	150,000	300,000
Cost per ft ² (\$)	\$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 ² (\$)	\$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

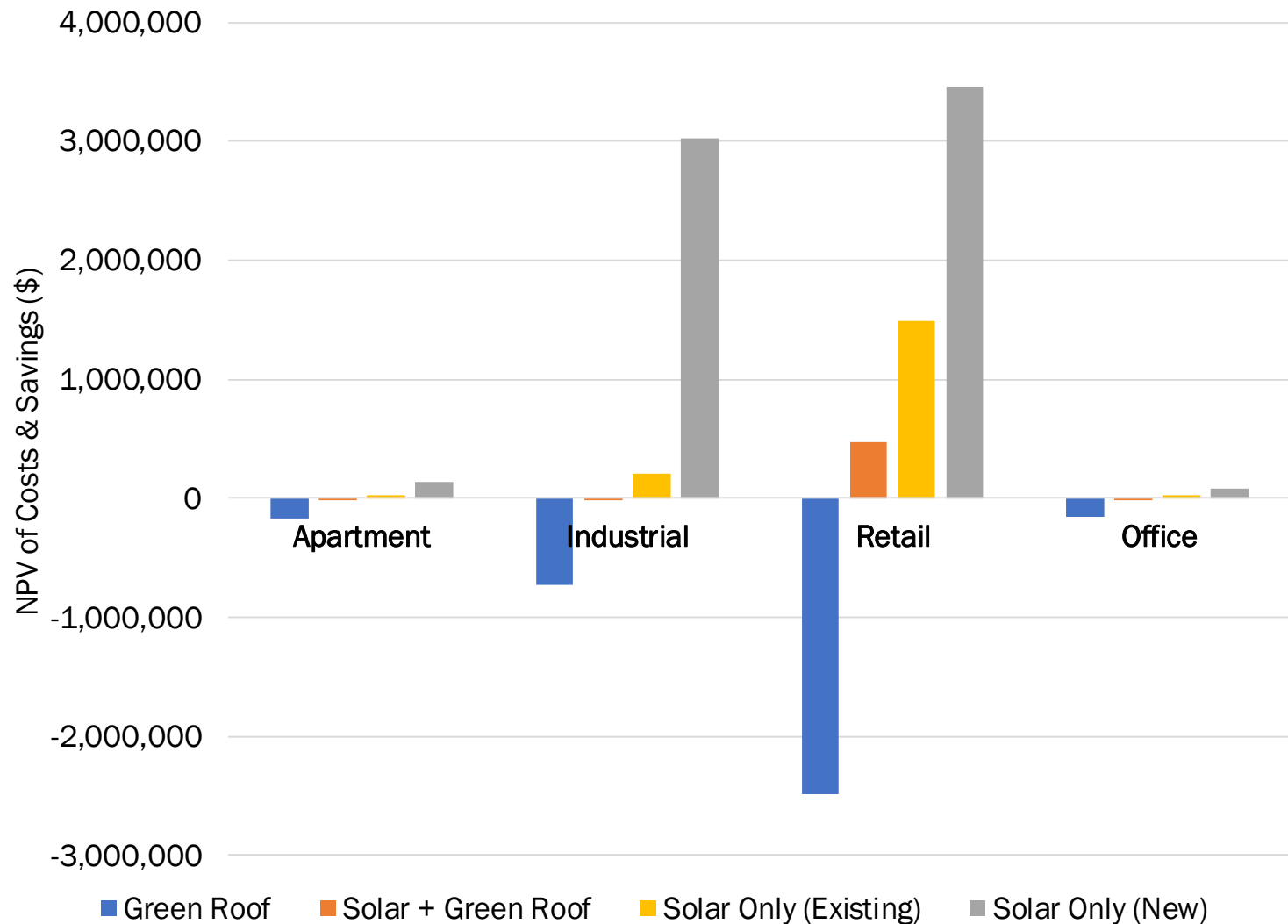
What is Net Present Value (NPV)?

- 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
	Average Capital Cost (\$)	\$137,700	\$1,539,900	\$1,539,900	\$101,250
Roof Consultant #1	Maintenance Costs (\$)	\$2,200	\$30,000	\$30,000	\$1,200

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
	Average Costs (\$)	\$125,792	\$470,714	\$2,201,634	\$117,112
	Cost per ft² of Green Roof (\$)	\$38	\$31	\$29	\$33

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
	Average Costs (\$)	\$2,383	\$19,372	\$21,210	\$2,221

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
	Total Capital Costs (\$)	\$93,032	\$307,681	\$1,345,529	\$94,449

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
	Total Maintenance (\$/year)	\$1,793	\$10,715	\$30,878	\$1,843

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
	Total Capital Costs (\$)	\$55,294	\$166,467	\$685,039	\$59,315

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
	Total Capital Costs (\$)	\$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
Total NPV of Costs Only	\$170,773	\$735,078	\$2,492,992	\$160,388
Energy Cost Savings (NPV)	\$432	\$2,063	\$10,313	\$416
Total NPV of Costs and Savings	-\$170,341	-\$733,015	-\$2,482,679	-\$159,972

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	Energy Escalation Rate Calculator (https://energy.gov/eere/femp/energy-escalation-rate-calculator-download): Colorado, 1.5% Inflation, Commercial
Electricity Blended Rate (\$/kWh)	0.098	U.S. Energy Information Administration (https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_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
Total NPV of Costs	\$117,483	\$451,260	\$1,776,382	\$119,694
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
Total NPV of Savings	\$99,182	\$450,817	\$2,254,070	\$108,187
Total NPV of Costs & Savings	-\$18,301	-\$443	\$477,688	-\$11,507

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	Energy Escalation Rate Calculator (https://energy.gov/eere/femp/energy-escalation-rate-calculator-download): Colorado, 1.5% Inflation, Commercial
Electricity Blended Rate (\$/kWh)	0.098	U.S. Energy Information Administration (https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_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
Total NPV of Costs	\$70,716	\$236,544	\$756,422	\$76,137
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
Total NPV of Savings	\$98,718	\$448,754	\$2,243,757	\$107,692
Total NPV of Costs & Savings	\$28,002	\$212,210	\$1,487,335	\$31,555

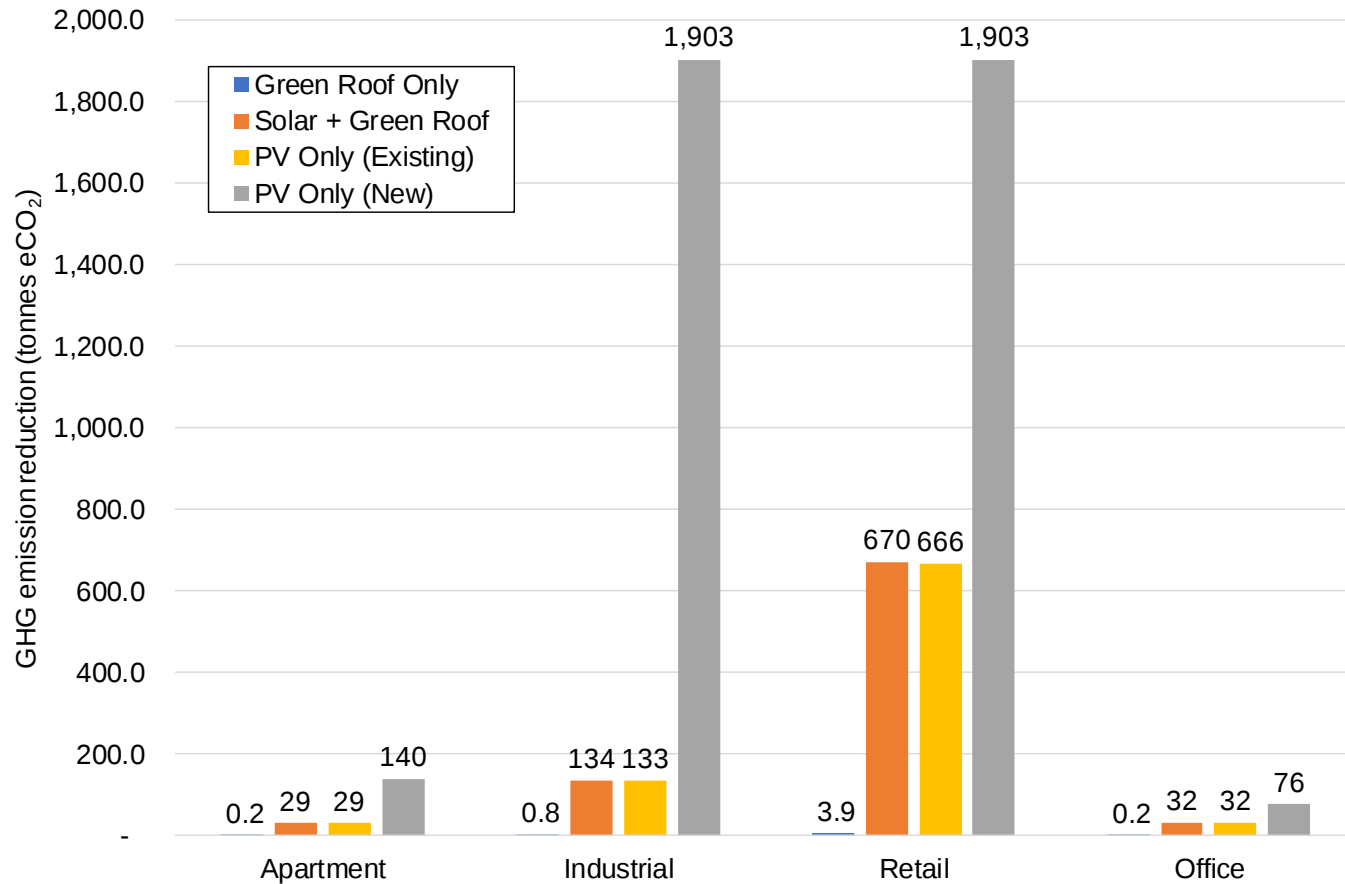
Parameter	Assumption	Source
Analysis Period (years)	32 (i.e. till year 2050)	
Discount Rate (%)	7	Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs (https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf)
Energy Escalation Rate (%)	2	Energy Escalation Rate Calculator (https://energy.gov/eere/femp/energy-escalation-rate-calculator-download): Colorado, 1.5% Inflation, Commercial
Electricity Blended Rate (\$/kWh)	0.098	U.S. Energy Information Administration (https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a): Colorado, Commercial

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
Total NPV of Costs	\$336,725	\$3,379,209	\$2,958,363	\$181,274
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
Total NPV of Savings	\$470,119	\$6,410,748	\$6,410,748	\$256,428
Total NPV of Costs & Savings	\$133,394	\$3,031,539	\$3,452,385	\$75,154

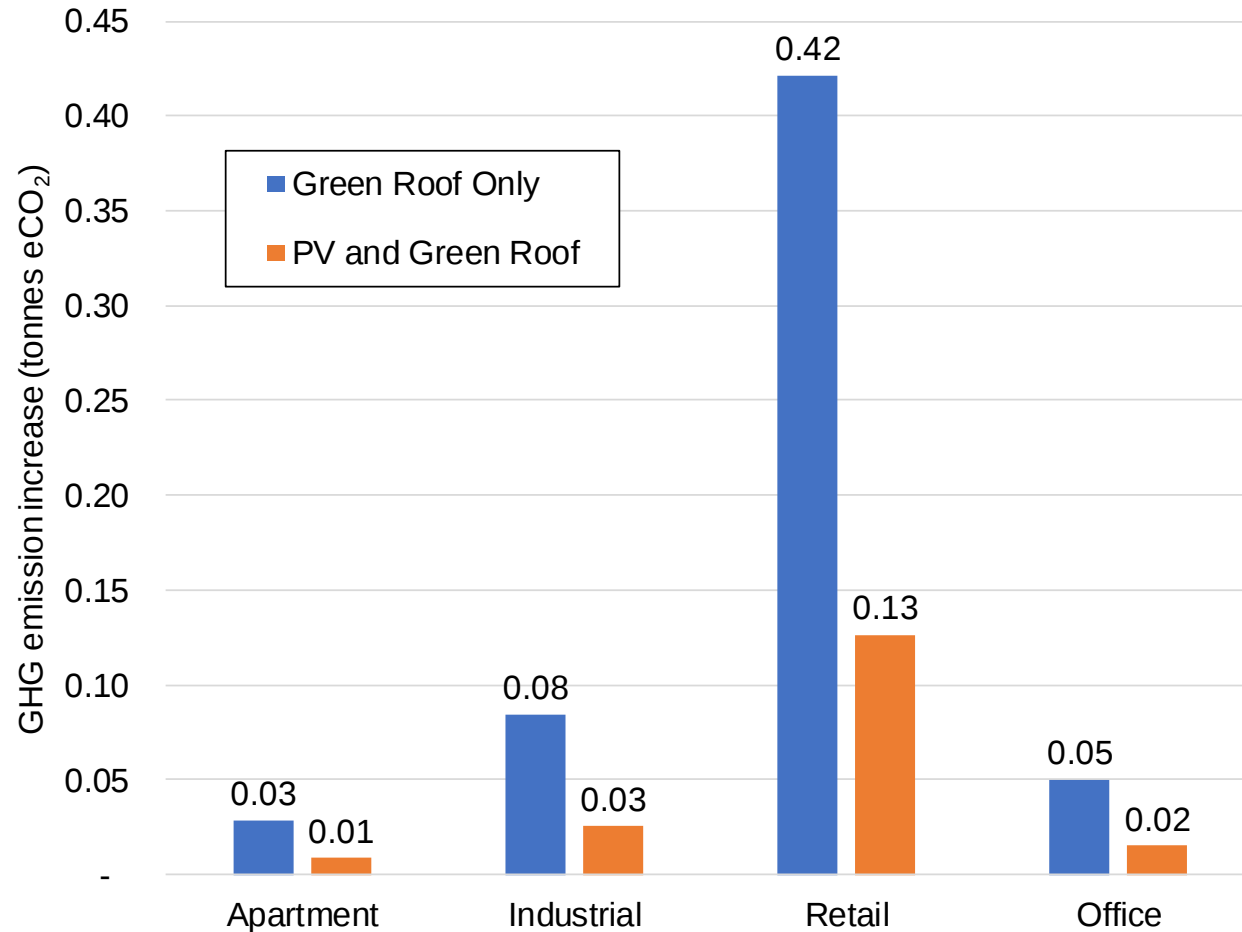
Parameter	Assumption	Source
Analysis Period (years)	32 (i.e. till year 2050)	
Discount Rate (%)	7	Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs (https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf)
Energy Escalation Rate (%)	2	Energy Escalation Rate Calculator (https://energy.gov/eere/femp/energy-escalation-rate-calculator-download): Colorado, 1.5% Inflation, Commercial
Electricity Blended Rate (\$/kWh)	0.098	U.S. Energy Information Administration (https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a): Colorado, Commercial

GHG Emission Reduction for Representative Buildings



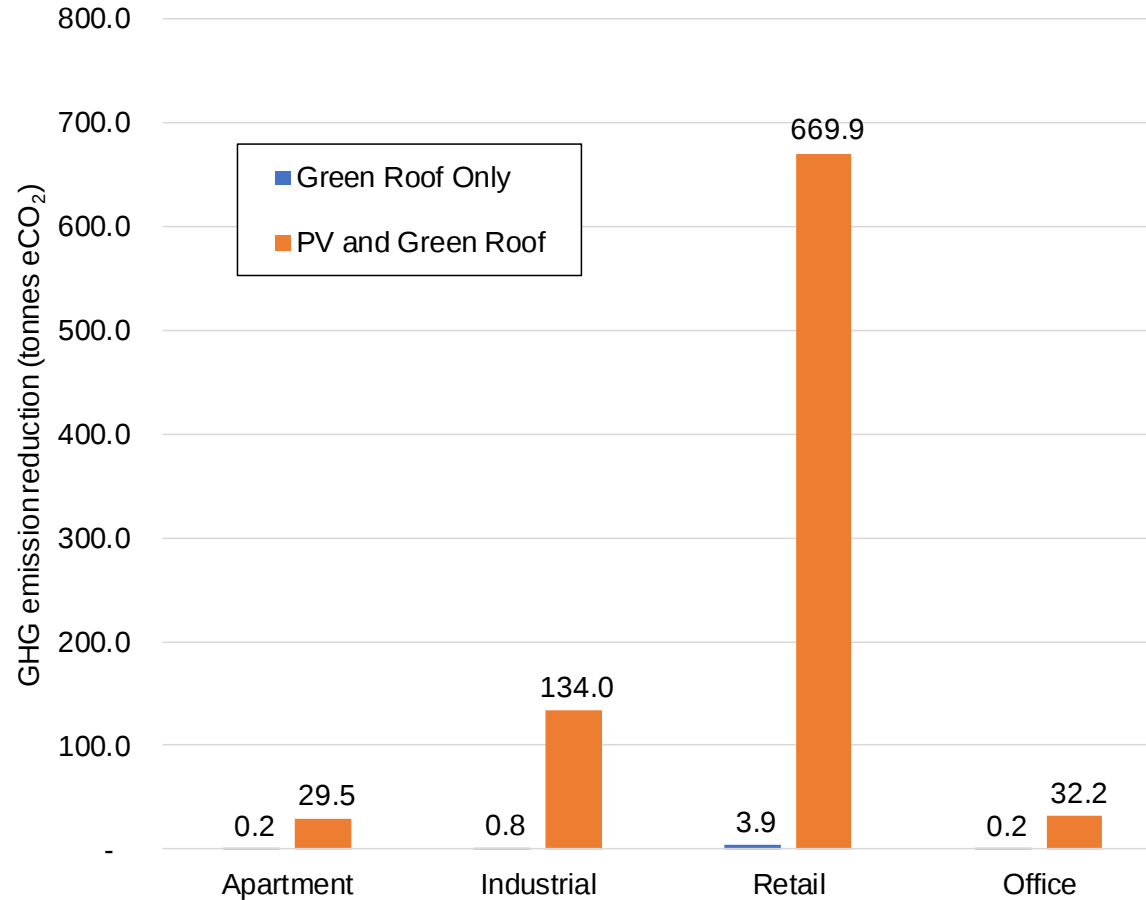
*2016 Xcel Energy GHG Emission Factor for Colorado: 1.32 lbs eCO₂/kwh (Electricity)

GHG Emissions for Water Usage for Representative Buildings



*2016 Xcel Energy GHG Emission Factor for Colorado: 1.32 lbs eCO₂/kwh (Electricity)

GHG Emission Reduction for Representative Buildings



*2016 Xcel Energy GHG Emission Factor for Colorado: 1.32 lbs eCO₂/kwh (Electricity)