Appendix 7. Financial Cost Catalog

Resilient Efficient Buildings Project

Financial Assumptions

(October 05, 2022)

The tables below detail the financial assumptions and projections for the State of Oregon Resilient Efficient Buildings Project Project, which were applied to the actions/scenarios detailed in the Actions and Assumptions Table. Total costs/investments/savings were then calculated for each of the scenarios. These assumptions have been reviewed and approved by the State. Wherever possible, local data was used. For the most part, when costs are held steady over the projection period (2019-2050), this is because only data for 2019 was available.

Prepared for: State of Oregon
Prepared by: Sustainability Solutions Group

Specific Financial Analysis to be Undertaken

Financial modelling in the BAP and Policy Scenarios offers several points of analysis, including:
- The total incremental capital investment required in the Policy Scenarios, relative to the BAP Scenario;
- Total energy cost savings and operation and maintenance savings over a period of years in the Low-Carbon Scenarios, relative to the BAP Scenario;
- Average household energy savings per year;
- The average cost to reduce each tonne of GHG (abatement cost); and,
- The most cost-effective GHG reduction actions.

Financial Assumptions in this Workbook

This workbook contains draft financial assumptions to be incorporated into modelling the BAP Scenario and the Low-Carbon Scenarios. All financial variables are presented in the *Cost Intensity Data tab* within thematic tables. Unless otherwise indicated, the finacial assumption **DO NOT include inflation**.

Disclaimer

Reasonable skill, care and diligence has been exercised to prepare the financial assumptions in this workbook, but no guarantees or warranties are made regarding the accuracy or completeness of this information. This workbook, the information it contains, the information and basis on which it relies, and the associated factors are subject to changes that are beyond the control of the author. The information provided by others is believed to be accurate but has not been verified.

This workbook includes strategic-level estimates of capital investments and related revenues, energy savings, and avoided costs of carbon associated with emissions reduction actions to be modelled under the Resilient, Efficient Buildings Project. The intent of this analysis is to help inform project stakeholders about the potential costs and savings of actions prior to modelling the Policy Scenarios. It should not be relied upon for other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above, and do not accept responsibility to any third party for the use, in whole or in part, of the contents of this document.

This analysis applies to the State of Oregon and cannot be applied to other jurisdictions without further analysis. Any use by the State of Oregon, its sub-consultants or any third party, or any reliance on or decisions based on this document, are the responsibility of the user or third party.

OREGON FINANCIAL DATA DICTIONARY

October, 2022

The tables below detail the financial assumptions and projections for the State of Oregon Resilient Efficient Buildings Project Project, which were applied to the actions/scenarios detailed in the Actions and Assumptions Table. Total costs/investments/savings were then calculated for each of the scenarios.

These assumptions have been reviewed and approved by the State. Wherever possible, local data was used. For the most part, when costs are held steady over the projection period (2019-2050), this is because only data for 2019 was available.

Buildings

New Buildings

New Building Construction

Average of values for Portland [USD/sqft]	
Single	270
Double/Row	270
Apartment 1-4 storey	343
Apartment 5-14 storey	394
Apartment > 15 storeys	445
University	587
School	302
Retirement home	412
Hospital	743
Penal institution	672
Military	255
Transit station	511
Airport	894
Hotel	429
Greenhouse	148
Recreation	416
Community centre	416
Golf course	371
Museum	970
Retail	426
Vehicle and heavy equipment services	267
Restaurant	268
Commercial/Retail	426
Commercial	412
Warehouse	254
Religious institution	268
Energy utility	148
Fire station	605
Police station	605
Municipal	640
Surface infrastructure	240
Industrial	267
Agriculture	148

source: Cummings Insights, Construction Market Analysis 2021 downloaded Feb 2022
https://ccorpinsights.com/costs-per-square-foot/
the cost data for categories not included in the report cited above have been estimated by using the ratios of costs from other projects

Dwelling Operations & Maintenance Costs

Household spending intensity	
USD / sqft*year	3.47

source: Siniavskaia, N. (2021). Operating Costs of Owning a Home. National Association of Home Builders - Economics and Housing Policy.
https://www.nahb.org/-/media/04F57989FBC74C82BEF51C382C654E54.ashx

Residential Building Energy Improvement Incremental Cost

kBtu/ft2	5	6	8	10	11	13	14	16	17	19
single	4.97	3.90	2.90	1.90	1.00	0.90	0.70	0.50	0.40	0.00
single_large	4.30	3.40	2.40	1.50	1.00	0.80	0.60	0.50	0.30	0.00
semi	5.85	4.70	3.60	2.50	1.40	1.10	0.90	0.70	0.40	0.00
town	3.00	1.10	0.60	0.50	0.50	0.40	0.30	0.20	0.20	0.00

source: extrapolated from Internal building energy model analysis of envelope improvement measures using CanmetENERGY's HTAP platform

Non-residential Building Energy Improvement Incremental Cost

kBtu/ft2	5	6	8	10	11	13	14	16	17	19
office	4.0	3.4	2.8	2.2	1.6	1.0	0.0	0.0	0.0	0.0
primary_school	13.0	10.6	8.2	5.8	3.4	1.0	0.8	0.6	0.4	0.0
warehouse	10.0	8.2	6.4	4.6	2.8	1.0	0.8	0.6	0.4	0.0

retail	15.0	12.2	9.4	6.6	3.8	1.0	0.8	0.6	0.4	0.0
other	9.5	7.8	6.1	4.4	2.7	1.0	0.4	0.3	0.2	0.0

source: https://www.cagbc.org/news-resources/research-and-reports/making-the-case-for-zero-carbon-building/, p. 18
note: more detailed extrapolations by region could be made in future if deemed necessary
Other was determined as being the mid point between highest and lowest category

Building Retrofits

Residential Building Envelope Retrofits Incremental Cost

% energy reduction	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
dwellUnit (USD / unit)	0	960	1,920	2,880	3,850	5,770	7,690	13,460	19,230	26,920	34,620	44,230	53,850	65,380	76,920	96,150	115,380	144,230	173,080
apartmentUnit (USD / unit)	0	380	770	1,150	1,540	1,920	2,310	2,690	3,080	3,850	4,620	8,080	11,540	17,310	23,080	34,620	46,150	69,230	92,310

source: https://www.pembina.org/docs/event/netzeroforum-backgrounder-2016.pdf, Table 2
based on above source and extrapolated to specific ranges

Non-residential Building Envelope Retrofits Incremental Cost

% energy reduction	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
USD / sqft	0.0	0.5	1.0	1.5	2.0	3.0	7.5	12.5	20.0	23.8	27.5	31.3	35.0	38.8	42.5	46.3	50.0	65.0	80.0

source: https://www.pembina.org/docs/event/netzeroforum-backgrounder-2016.pdf, Table 2
based on above source and extrapolated to specific ranges

Building Equipment

Residential Heat Pump Capital Costs, Installed

USD / heat pump	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Air source	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100
Natural Gas	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700
Geothermal	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550	20,550

source: US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018. page 29, 'high' values used
https://www.eia.gov/analysis/studies/buildings/equipcosts/

Residential Heat Pump Maintenance Costs

USD / heat pump/year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Air source	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5
Natural Gas	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170
Geothermal	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75

source: US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018. page 29
https://www.eia.gov/analysis/studies/buildings/equipcosts/

Residential Water Heater Capital Costs, Installed

USD / unit	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
40 Gallon natural gas-fired	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925
50 Gallon Electric Resistance	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
50 Gallon Heat Pump	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075	2,075

source: US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018 pages 51-58
https://www.eia.gov/analysis/studies/buildings/equipcosts/

Residential Water Heater Maintenance Costs

USD / unit/year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
40 Gallon natural gas-fired	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50 Gallon Electric Resistance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50 Gallon Heat Pump	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

source: US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018 pages 51-58
https://www.eia.gov/analysis/studies/buildings/equipcosts/

Non Residential Heat Pump Capital Costs

USD / heat pump		
Air source (32 kbtu/hour)	5,100	Typical Capacity (32 kBtu/h)
Ground source (36 kbtu/hour)	16,150	Typical Capacity (36 kBtu/h)

source: US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018, page 29 and 33
https://www.eia.gov/analysis/studies/buildings/equipcosts/

Non Residential Heat Pump O&M Costs

USD / heat pump/year		
Air source	73	Typical Capacity (32 kBtu/h)
Ground source	75	Typical Capacity (36 kBtu/h)

source: US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018, page 29 and 33
https://www.eia.gov/analysis/studies/buildings/equipcosts/

Non Residential Water Heater Capital Costs

USD / water heater		
Electric	3,875	Commercial Electric Resistance Water Heaters, Input Capacity 18 kW
Natural gas	5,225	Commercial Gas Storage Water Heaters, Input Capacity 199 kBtu/h

source: US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018, page 120-135
https://www.eia.gov/analysis/studies/buildings/equipcosts/

Non Residential Water Heater O&M Costs

USD / water heater/year	
Electric	50
Natural gas	270

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018, page 120-135*
https://www.eia.gov/analysis/studies/buildings/equipcosts/

Commercial Equipment Upgrade Capital Costs (Effectively an incremental cost)

USD / MMBTU of energy saved	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Auxiliary equipment	22	22	23	24	24	25	26	27	28	30	31	32	34	35	36	38	39	40	42
Lighting	71	96	111	121	128	141	149	155	159	162	162	166	166	161	154	143	133	119	106

source: *auxiliary equipment and lighting. IESO 2019 Conservation Achievable Potential Study. Appendix 2 - Forecast Potential by Measure. Scenario B (Unconstrained Potenial). After Competition Groups - http://www.ieso.ca/2019-conservation-achievable-potential-study*
These represent the capital costs associated with 1 GJ of savings in year 1. There will be no further capital costs for that investment in the remaining years of the project

Residential Equipment Upgrade Capital Costs (Effectively an incremental cost)

USD / MMBTU of energy saved	2020	2025	2030	2035	2040	2045	2050
Lighting	31	28	27	26	24	23	22
Major Appliances	337	320	304	289	274	261	248
Plug Load	5	5	5	4	4	4	4

source: *IESO 2019 Conservation Achievable Potential Study. Appendix 2 - Forecast Potential by Measure. Scenario B (Unconstrained Potenial). After Competition Groups - http://www.ieso.ca/2019-conservation-achievable-potential-s*
Assumptions: Measure potential divided by total incentive ($) in 2019 as some incentive expenditures scheme may distort the cost per energy saved. 2018 dollars.
Following years costs are equal to 2019 cost multiplied by a learning factor of 0.95 every 5 years.
Caveat: Incentive cost includes the incremental capital cost of measures plus the administration costs for running an energy efficiency incentives program.

Industrial Upgrades

USD / MMBTU	2015	2020	2025	2030	2035	2040	2045	2050
Process Heat Improvements		11.08	4.22	2.27	1.15	1.15	1.15	1.15
Boiler upgrade		16.88	5.11	2.68	1.30	1.30	1.30	1.30
Process Heat Recovery (Gas)		14.28	5.11	2.43	0.89	0.89	0.89	0.89
Recommissioning		5.52	1.95	0.89	0.32	0.32	0.32	0.32
Improved Controls -Process Heating Gas		7.49	2.70	1.27	0.46	0.46	0.46	0.46

1.408011869

source: *Achievable Potential 2019. Scenario B (Unconstrained Potenial). After Competition Groups - http://www.ieso.ca/2019-conservation-achievable-potential-study*
http://www.ieso.ca/2019-conservation-achievable-potential-study
assumptions: *Measure potential for 2020, 2025, 2030, and 2035 divided by total incentive ($). For projected years, assume same as 2035.*
0.0373 GJ/m3 of NG
Top 5 measures for total potential selected

FUEL COST INTENSITIES

Electricity

USD / MMBTU	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Residential	42.15	42.15	46.80	45.17	44.75	44.49	45.40	46.93	47.27	47.62	47.87	48.61	49.51	49.74	50.02	50.30	50.42	50.50	50.52	50.44	50.37	50.44	50.51	50.69	50.71	50.79	50.95	51.12	51.12	51.15	51.11	51.03
Commercial	41.98	41.98	43.67	42.91	42.56	41.81	42.92	43.95	43.94	43.96	43.87	44.54	45.17	45.01	44.99	44.93	44.75	44.54	44.22	43.82	43.47	43.24	42.96	42.85	42.53	42.27	42.10	41.97	41.65	41.40	41.11	40.80
Industrial	29.32	29.32	29.29	27.60	26.96	26.41	27.58	27.92	27.90	27.87	27.80	28.38	28.70	28.59	28.55	28.49	28.34	28.17	27.93	27.66	27.44	27.32	27.19	27.11	26.94	26.83	26.77	26.68	26.51	26.42	26.33	26.24

source: *EIA. "Annual Energy Outlook 2021." (2021).*
https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2021&cases=ref2021&sou

Natural Gas

USD / MMBTU	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Residential	13.61	13.61	13.67	13.48	12.82	12.15	11.64	11.16	11.24	11.36	11.48	13.74	13.80	14.22	14.32	14.38	14.44	14.48	14.50	14.56	14.58	14.61	14.65	14.68	14.71	14.74	14.79	14.83	14.89	14.96	15.06	15.14
Commercial	9.48	9.48	9.46	9.24	9.17	9.02	9.01	8.96	9.03	9.13	9.22	11.21	11.16	11.49	11.56	11.60	11.65	11.67	11.68	11.73	11.74	11.76	11.78	11.80	11.83	11.85	11.89	11.91	11.96	12.02	12.10	12.17
Industrial	4.22	4.22	4.91	4.92	4.74	4.54	4.64	4.77	4.86	4.99	5.11	5.05	5.04	5.12	5.21	5.25	5.27	5.29	5.27	5.32	5.31	5.31	5.31	5.31	5.32	5.33	5.36	5.37	5.41	5.48	5.57	5.65

source: *EIA. "Annual Energy Outlook 2021." (2021).*
https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2021&cases=ref2021&sou

Fuel Oil

USD / MMBTU	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Residential	17.69	17.79	19.01	20.48	21.60	22.47	23.24	23.57	24.06	24.28	24.82	25.08	25.42	25.61	25.78	25.88	26.01	26.35	26.58	26.59	27.04	27.28	27.49	27.86	27.92	27.94	28.27	28.42	28.44	28.53	28.55	55.94
Commercial	19.09	19.21	19.47	20.34	20.50	20.42	20.25	20.55	21.01	21.23	23.74	23.97	24.55	24.69	24.82	24.93	25.01	25.29	25.51	25.51	25.92	26.15	26.31	26.59	26.62	26.65	26.97	27.12	27.15	27.28	27.26	47.55
Industrial	18.78	18.92	19.23	20.21	20.41	20.38	20.27	20.57	21.02	21.24	21.64	21.87	22.15	22.28	22.41	22.52	22.59	22.86	23.08	23.07	23.47	23.70	23.86	24.12	24.15	24.18	24.50	24.65	24.68	24.81	24.79	47.11

source: *EIA. "Annual Energy Outlook 2021." (2021).*
https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2021&cases=ref2021&sourcekey=0

Renewable Natural Gas

USD / MMBTU	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

source: *EPA. An overview of renewable natural gas from biogas. 2020. p.28. Average of mass scale and small scale production costs.*
https://www.epa.gov/sites/production/files/2020-07/documents/lmop_rng_document.pdf

Hydrogen

USD / kgH2	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Industrial	4.5	4.5	4.28	4.05	3.83	3.60	3.38	3.15	2.93	2.70	2.48	2.25	2.19	2.13	2.06	2.00	1.94	1.88	1.81	1.75	1.69	1.63	1.56	1.50	1.44	1.38	1.31	1.25	1.19	1.13	1.06	1

source: *Bartlett, J. and Krupnick, A. Decarbonized Hydrogen in the US Power and Industrial Sectors: Identifying and Incentivizing Opportunities to Lower Emissions. 2020. Figure 9. Averages of renewable H2 production.*
https://www.rff.org/publications/reports/decarbonizing-hydrogen-us-power-and-industrial-sectors/
IEA, "Hydrogen production costs by production source, 2018", IEA, Paris https://www.iea.org/data-and-statistics/charts/hydrogen-production-costs-by-production-source-2018
High end of production costs for renewables, assume energy density of H2 is 130 MJ / kg
IEA analysis finds that the cost of producing hydrogen from renewable electricity could fall 30% by 2030 as a result of declining costs of renewables and the scaling up of hydrogen production