STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

Washington State Energy Code Development

Standard Energy Code Proposal Form

May 2018

Log No. ______________

Code being amended: ☒ Commercial Provisions ☐ Residential Provisions

Code Section # __C404.2.1, C404.2.2, C406.1, C406.8, C406.9_____

Brief Description: Provide heat pump water heating, rather than fossil fuel or electric resistance water heating, for all commercial buildings. Exceptions are provided to allow electric resistance heating for hand washing facilities.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

[Note: New definitions to add]

TEMPERATURE MAINTENANCE: The system used to maintain the temperature of the building domestic hot water delivery system, typically by circulation and reheating or by a heat trace system.

SINGLE-PASS: A heat pump water heater control strategy using variable flow or variable capacity to deliver water from the heat pump at the final target storage water temperature in a single pass through the heat exchanger with variable incoming water temperatures.

MULTI-PASS: A heat pump water heater control strategy requiring multiple passes of water through the heat pump to reach the final target storage water temperature.

[Note: Strike all of Section C404.2.1 and C404.2.2 and replace with the new language below.]

C404.2.1 Buildings with central service water heating systems. In buildings with central service water heating systems, the primary water heating equipment shall not use fossil fuel combustion or electric resistance. Service hot water shall be provided by an air-source heat pump water heating (HPWH) system meeting the requirements of this section. Supplemental service water heating equipment is permitted to use electric resistance in compliance with Section C404.2.1.4.

Exceptions:

1. Permits applied for prior to January 1, 2022.
2. Buildings with combined water heating capacity of less than 21 kW and no greater than 120 gallons of total hot water storage capacity are permitted to utilize electric resistance water heating.

3. Point of use instantaneous electric water heaters serving fixtures no more than 8 feet of developed pipe length from the water heater, are permitted and do not contribute to the building combined water heating capacity calculation for Exception 2.

4. Solar thermal, wastewater heat recovery, other *approved* waste heat recovery, ground source heat pump, water-source heat pump system utilizing waste heat, and combinations thereof, are permitted to offset all or any portion of the required HPWH capacity where such systems comply with this code and the Seattle Plumbing Code.

5. Systems meeting the requirements of the Northwest Energy Efficiency Alliance (NEEA) Advanced Water Heater Specifications for central service water heating systems.

C404.2.1.1 Primary heat pump system sizing. The system shall include a primary service minimum output at 40°F out-door air temperature that provides sufficient hot water for R-1 and/or R-2 occupancy uses as calculated using the equipment manufacturer's selection criteria or another *approved* methodology. Air source heat pumps shall be sized to deliver no less than 50 percent of the calculated demand for hot water production during the peak demand period when entering air temperature is 24°F.

Exception: 50 percent sizing at 24°F is not required for heat pumps located in a below-grade enclosed parking structure or other ventilated and unconditioned space that is not anticipated to fall below 40°F at any time.

WSEC Informative Note: Estimates of the appropriate heat pump system sizing and hot water storage volume for HPHW systems, calculated per bedroom or per occupant, vary widely, depending on type of use, output capacity of the heat pumps, and other factors.

C404.2.1.2 Primary hot water storage sizing. The system shall provide sufficient hot water, as calculated using an *approved* methodology, to satisfy peak demand period requirements.

C404.2.1.3 System design. The service water heating system shall be configured to conform to one of the following provisions:

1. For *single-pass* HPWHs, *temperature maintenance* heating provided for reheating return water from the building's heated water circulation system shall be physically decoupled from the primary service water heating system storage tank(s) in a manner that prevents destratification of the primary system storage tanks. *Temperature maintenance* heating is permitted to be provided by electric resistance or a separate dedicated heat pump system.

2. For multi-pass HPWHs, *recirculated temperature* maintenance water is permitted to be returned to the primary water storage tanks for reheating.

C404.2.1.3.1 Mixing valve. A thermostatic mixing valve capable of supplying hot water to the building at the user temperature set point shall be provided, in compliance with requirements of the Seattle Plumbing Code and the HPWH manufacturer's installation guidelines. The mixing valve shall be sized and rated to deliver tempered water in a range from the minimum flow of the *temperature maintenance* recirculation system up to the maximum demand for the fixtures served.

C404.2.1.4 Supplemental water heaters. Total supplemental electric resistance water heating equipment shall not have an output capacity greater than the primary water heating equipment at 40°F entering air temperature. Supplemental electric resistance heating is permitted for the following uses:

1. *Temperature maintenance* of heated-water circulation systems, physically separate from the primary service water heating system. *Temperature maintenance* heating capacity shall be no greater than the primary water heating capacity at 40°F.

2. Defrost of compressor coils.

3. Heat tracing of piping for freeze protection or for *temperature maintenance* in lieu of recirculation of hot water.

4. Backup or low ambient temperature conditions, where all of the following are true:

a. The supplemental heating capacity is no greater than the primary service water heating capacity at 40°F.

b. During normal operations the supplemental heating is controlled to operate only when the entering air temperature at the air-source HPWH is below 40°F, and the primary HPWH compressor continues to operate together with the supplemental heating when the entering air temperature is between 17°F and 40°F.

c. The primary water heating equipment cannot satisfy the system load due to equipment failure or entering air temperature below 40°F.

5. Supplemental heating downstream from a *multi-pass* HPWH system.

6. Stand-alone electric water heaters serving single zones not served by the central water heating system.

C404.2.1.5 Alarms. The control system shall be capable of and configured to send automatic error alarms to building or maintenance personnel upon detection of equipment faults, low leaving water temperature from primary storage tanks, or low hot water supply delivery temperature to building distribution system.

TABLE C406.1

EFFICIENCY PACKAGE CREDITS

Code Section	Commercial Building Occupancy					
	Group R-1	Group R-2	Group B	Group E	Group M	All Other
	Additional Efficiency Credits					
~~8. High-efficiency service water heating in accordance with Sections C406.8.1 and C406.8.2~~	~~4.0~~	~~5.0~~	~~NA~~	~~NA~~	~~NA~~	~~8.0~~

9. High performance service water heating in ((~~multi-family~~)) buildings in accordance with Section C406.9	~~7.0~~ 2.0	~~8.0~~ 2.0	~~NA~~ 2.0	~~NA~~ 2.0	~~NA~~ 2.0	~~NA~~ 2.0

[Note: Strike all of Section C406.8.]

C406.9 High performance service water heating ~~in multifamily buildings~~. For a whole building, building addition, or tenant space ~~with not less than 90 percent of the conditioned floor area being Group R-2 occupancy~~, not less than 90 percent of the annual building service hot water energy use shall be provided by a heat pump system ~~with a minimum COP of 3.0. This efficiency package is allowed be taken in addition to Section C406.8.2.~~ meeting the requirements of Section C404.2.1 plus the following:

1. The refrigerant used in the heat pump system shall have a global warming potential (GWP) no greater than 675.
2. No electric resistance heating capacity shall be provided.

Exceptions to item 2.

1. Electric resistance heating is permitted for circulating system *temperature maintenance* and heat tracing of service hot water supply and return piping.

2. On-demand electric resistance water heaters for hand washing facilities are permitted in public toilet rooms.

Purpose of code change:

Heat pump water heating eliminates a significant source of fossil fuel combustion in buildings, and is generally 2-4x more energy efficient than either fossil fuel or electric resistance heating. This proposal aligns with State policy to increase energy efficiency by 70% by 2031. Additionally, this proposal will significantly reduce emissions, aligned with State policy to achieve the broader goal of building zero fossil-fuel greenhouse gas emission homes and buildings by the year 2031. According to analysis done on data from the 2021 Washington State Energy Strategy, we would need to reduce the commercial buildings sector emissions by 38% to keep on track to meet our 2050 climate goals. To achieve this, the State will need to dramatically increase the proportion of annual sales of heat pump water heaters from 2% of all commercial water heating equipment in 2020 to 50% by 2030. To get to this increase in market penetration of heat pump water heaters, the Washington State Energy Code should require heat pump water heating in the 2021 code cycle.

Your amendment must meet one of the following criteria. Select at least one:

☐ Addresses a critical life/safety need.

☐ The amendment clarifies the intent or application of the code.

☒ Addresses a specific state policy or statute.

(Note that energy conservation is a state policy)

☐ Consistency with state or federal regulations.

☐ Addresses a unique character of the state.

☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

☐ Single family/duplex/townhome	☒ Multi-family 4 + stories	☒ Institutional
☐ Multi-family 1 – 3 stories	☒ Commercial / Retail	☒ Industrial

Your name Jonny Kocher Email address jkocher@rmi.org

Your organization RMI Phone number 619-459-4267

Other contact name Denise Grab; dgrab@rmi.org

Instructions: Send this form as an email attachment, along with any other documentation available, to: sbcc@des.wa.gov. For further information, call the State Building Code Council at 360-407-9278.

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

Construction costs for heat pump water heating are often, but not always, higher than for conventional gas or electric resistance water heating. Annual energy costs for heat pump water heaters are much lower than for electric resistance water heating, but the same or slightly higher when compared with gas water heating, at current rates (World Bank long term forecasts indicate an increase of over 80% in gas prices over the coming decade.) When including an updated Social Cost of Carbon, heat pump water heaters are more cost effective than both gas water heaters and electric resistance water heaters.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal? (See OFM Life Cycle Cost **Analysis tool** and **Instructions;** use these **Inputs. Webinars on the tool can be found Here and Here**)

The average net present value capital cost increase for this proposal will be around $2.47/square foot. The proposal will have a life cycle cost increase of $2.43/square foot when not accounting for the social cost of carbon. When accounting for the adjusted social cost of carbon, the heat pump water heater proposal will have a $0.38/sq ft savings. See "Heat Pump Water Heating Proposal - Energy & Cost Data Supplemental" for more details.

Show calculations here, and list sources for costs/savings, or attach backup data pages

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

The average energy savings for this proposal will be around 5.5 KBTU/ square foot. See "Heat Pump Water Heating Proposal - Energy & Cost Data Supplemental" for more details on the data.

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

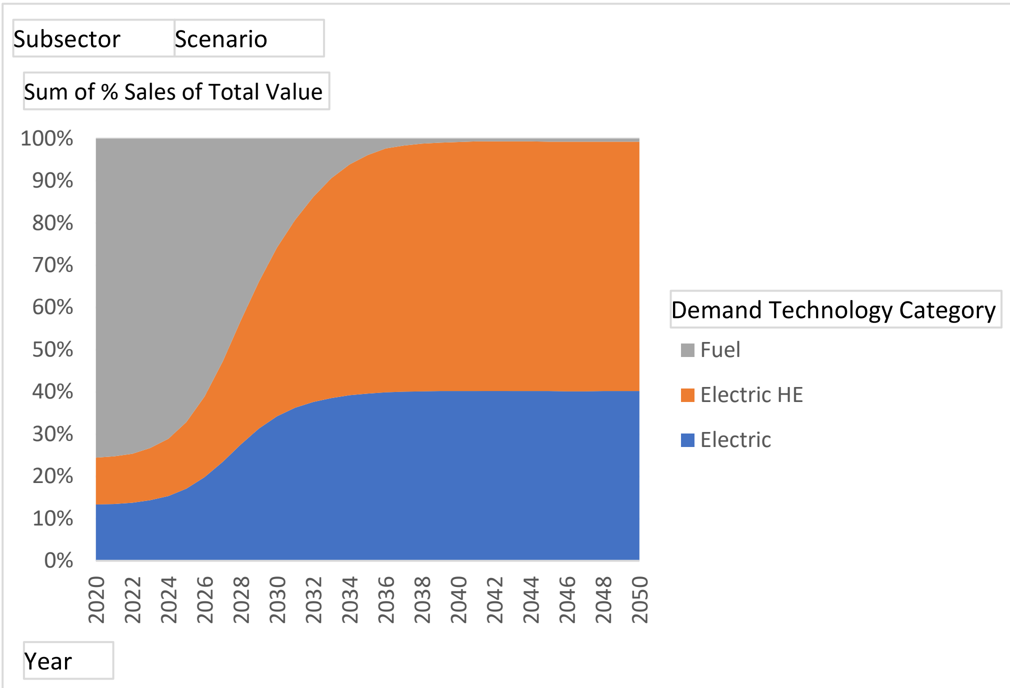
List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

No increase in plan review or inspection time.

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

Subsector	commercial space heating
Scenario	Electrification

Sum of % Sales of Total Value	**Column Labels**			
Row Labels	**Electric**	**Electric HE**	**Fuel**	**Grand Total**
2020	13.3%	11.1%	75.6%	1
2021	13.5%	11.3%	75.2%	1
2022	13.8%	11.6%	74.6%	1
2023	14.3%	12.4%	73.3%	1
2024	15.3%	13.6%	71.1%	1
2025	17.1%	15.7%	67.2%	1
2026	19.8%	19.1%	61.1%	1
2027	23.5%	23.8%	52.7%	1
2028	27.6%	29.3%	43.1%	1
2029	31.3%	34.8%	33.9%	1
2030	34.2%	39.9%	25.9%	1
2031	36.2%	44.5%	19.2%	1
2032	37.6%	48.6%	13.8%	1
2033	38.6%	52.1%	9.4%	1
2034	39.2%	54.7%	6.1%	1
2035	39.6%	56.5%	3.9%	1
2036	39.9%	57.7%	2.3%	1
2037	40.1%	58.3%	1.6%	1
2038	40.1%	58.7%	1.2%	1
2039	40.2%	58.9%	1.0%	1
2040	40.2%	59.0%	0.8%	1
2041	40.2%	59.1%	0.7%	1
2042	40.2%	59.1%	0.7%	1
2043	40.2%	59.1%	0.7%	1
2044	40.2%	59.1%	0.7%	1
2045	40.2%	59.1%	0.7%	1
2046	40.2%	59.1%	0.7%	1
2047	40.2%	59.1%	0.7%	1
2048	40.2%	59.1%	0.7%	1
2049	40.2%	59.1%	0.7%	1
2050	40.2%	59.1%	0.7%	1
Grand Total	**10.17417324**	**13.62728959**	**7.198537176**	**31**



Subsector
Scenario
Sum of % Sales of Total Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
Year
Demand Technology Category
Fuel
Electric HE
Electric

Total Gross Emissions: Reference vs Electrification Scenario

WA SES EER DDP Modeling Final Report Page 26

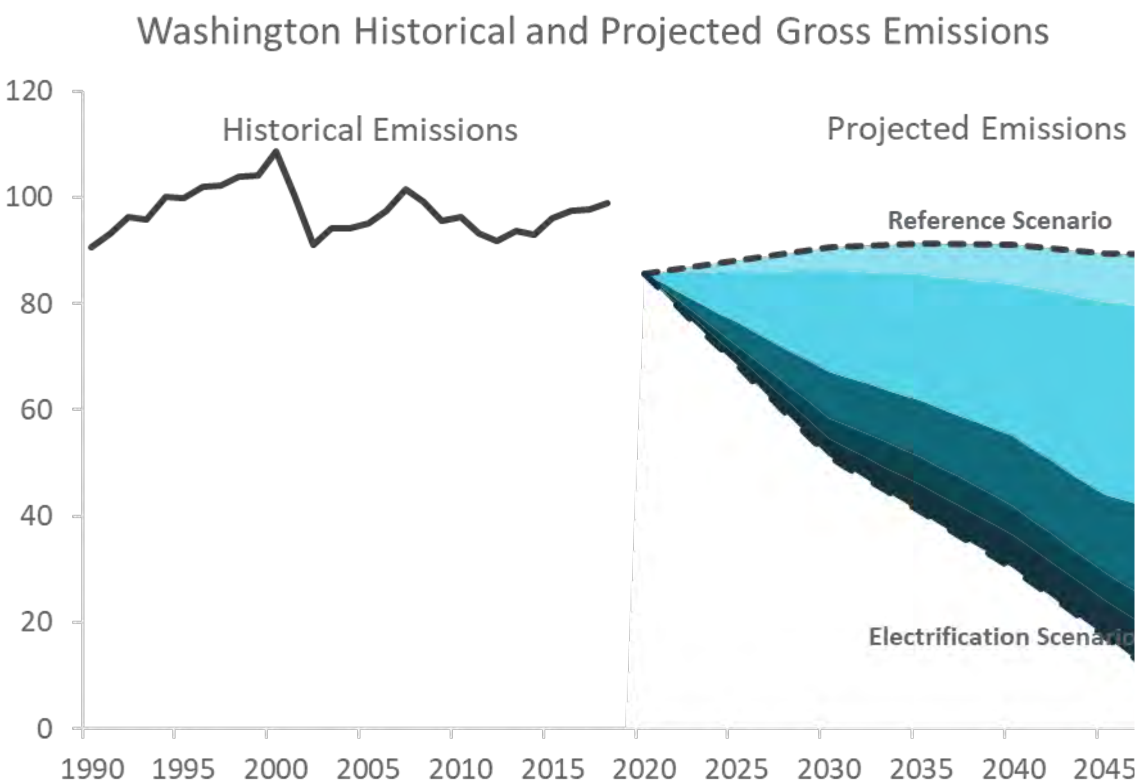
		Emissions (MMT CO2e)				
Year	Scenario	Total	Commercial	Residential	Industrial	Transport
1990	Historical	90.5				
1991	Historical	93.1				
1992	Historical	96.2				
1993	Historical	95.8				
1994	Historical	100.0				
1995	Historical	99.9				
1996	Historical	102.0				
1997	Historical	102.2				
1998	Historical	103.8				
1999	Historical	104.2				
2000	Historical	108.6				
2001	Historical	100.5				
2002	Historical	91.1				
2003	Historical	94.2				
2004	Historical	94.1				
2005	Historical	95.1				
2006	Historical	97.4				
2007	Historical	101.4				
2008	Historical	99.0				
2009	Historical	95.6				
2010	Historical	96.4				
2011	Historical	93.2				
2012	Historical	91.8				
2013	Historical	93.6				
2014	Historical	93.0				
2015	Historical	95.9				
2016	Historical	97.6				
2017	Historical	97.7				
2018	Historical	98.9				
2020	Reference	71.1	7.3	11.4	17.4	34.9
2030	Reference	75.1	7.4	9.0	19.7	39.1
2035	Reference	76.0	8.3	9.0	21.4	37.3
2040	Reference	75.8	8.6	8.1	22.7	36.5
2045	Reference	74.2	8.3	6.9	22.8	36.2
2050	Reference	74.0	8.6	6.5	23.8	35.0
2020	Electrification	70.0	6.6	10.2	19.0	34.2
2030	Electrification	40.1	4.1	5.0	11.0	20.0
2035	Electrification	31.2	3.2	3.7	10.8	13.4

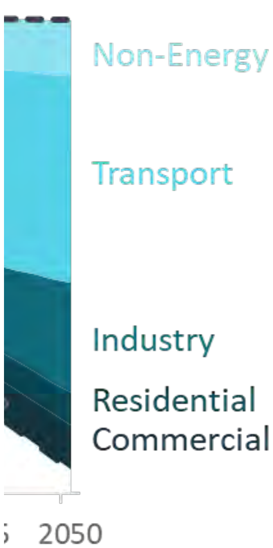
Emissions (MMT CO2e)

2040	Electrification	22.3	2.4	2.6	9.5	7.8
2045	Electrification	11.1	1.5	1.8	8.3	-0.3
2050	Electrification	0.0	0.2	0.5	3.1	-3.9

ɔs

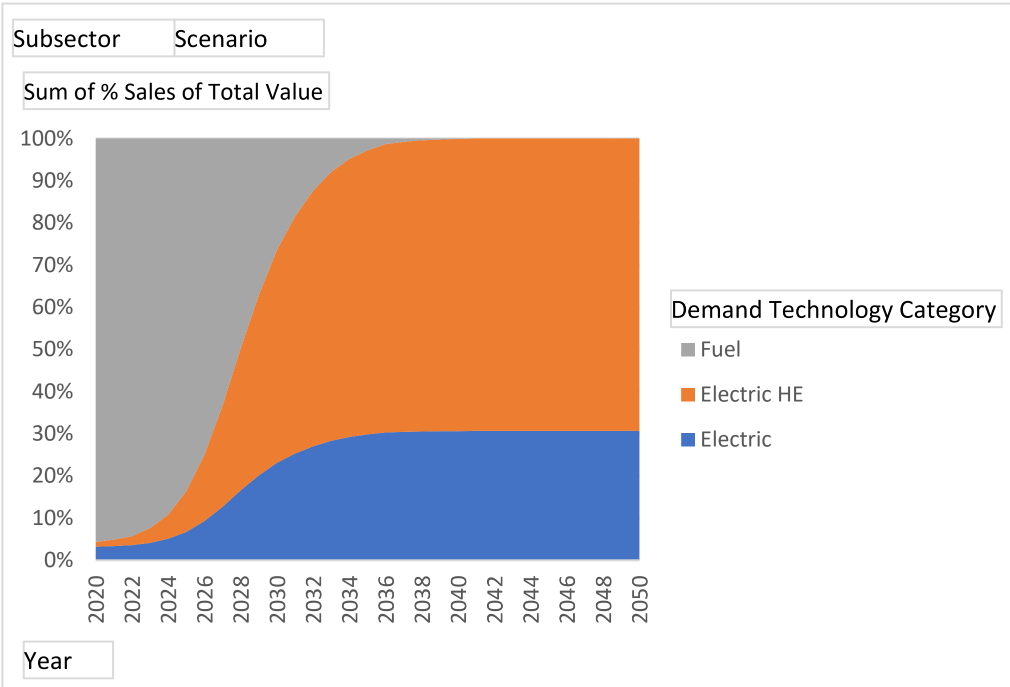
	% reduction in Commercial Building emissions required by target year in Electrification Scenario
2030	38%
2035	51%
2040	64%
2045	78%
2050	96%




Non-Energy
Transport
Industry
Residential
Commercial
2050

Subsector	commercial water heating
Scenario	Electrification

Sum of % Sales of Total Value	Column Labels			
Row Labels	**Electric**	**Electric HE**	**Fuel**	**Grand Total**
2020	3.2%	1.2%	95.6%	1
2021	3.4%	1.5%	95.1%	1
2022	3.6%	2.1%	94.2%	1
2023	4.2%	3.4%	92.4%	1
2024	5.1%	5.7%	89.2%	1
2025	6.7%	9.6%	83.7%	1
2026	9.3%	15.7%	75.0%	1
2027	12.7%	24.0%	63.2%	1
2028	16.6%	33.6%	49.8%	1
2029	20.2%	42.8%	37.1%	1
2030	23.1%	50.4%	26.6%	1
2031	25.3%	56.2%	18.5%	1
2032	27.1%	60.6%	12.4%	1
2033	28.4%	63.7%	7.9%	1
2034	29.3%	65.9%	4.8%	1
2035	29.8%	67.3%	2.8%	1
2036	30.3%	68.4%	1.4%	1
2037	30.4%	68.8%	0.8%	1
2038	30.5%	69.0%	0.4%	1
2039	30.6%	69.1%	0.2%	1
2040	30.6%	69.2%	0.1%	1
2041	30.7%	69.3%	0.0%	1
2042	30.7%	69.3%	0.0%	1
2043	30.7%	69.3%	0.0%	1
2044	30.7%	69.3%	0.0%	1
2045	30.7%	69.3%	0.0%	1
2046	30.7%	69.3%	0.0%	1
2047	30.7%	69.3%	0.0%	1
2048	30.7%	69.3%	0.0%	1
2049	30.7%	69.3%	0.0%	1
2050	30.7%	69.3%	0.0%	1
Grand Total	**7.071966526**	**15.41449096**	**8.513542512**	**31**


Subsector
Scenario
Sum of % Sales of Total Value
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
Year
Demand Technology Category
Fuel
Electric HE
Electric

Year	2.5% at 50th Pct; 2007 dollars (page 18; 2013 addition)	2.5% at 50th Pct Adjusted to 2015 dollars	3% at 95th Pct; 2007 dollars (page 25; 2016 addition)	3% at 90th Pct Adjusted to 2015 dollars	User Adjustment to final SCC (Inputted into Row 11 on LCCA spreadsheet)
2010	51	58.1	86	98.04	39.9
2011	52	59.3	90	102.6	43.3
2012	54	61.6	93	106.02	44.5
2013	55	62.7	97	110.58	47.9
2014	56	63.8	101	115.14	51.3
2015	57	65.0	105	119.7	54.7
2016	59	67.3	108	123.12	55.9
2017	60	68.4	112	127.68	59.3
2018	61	69.5	116	132.24	62.7
2019	62	70.7	120	136.8	66.1
2020	64	73.0	123	140.22	67.3
2021	65	74.1	126	143.64	69.5
2022	66	75.2	129	147.06	71.8
2023	67	76.4	132	150.48	74.1
2024	68	77.5	135	153.9	76.4
2025	69	78.7	138	157.32	78.7
2026	70	79.8	141	160.74	80.9
2027	71	80.9	143	163.02	82.1
2028	72	82.1	146	166.44	84.4
2029	73	83.2	149	169.86	86.6
2030	75	85.5	152	173.28	87.8
2031	76	86.6	155	176.7	90.1
2032	77	87.8	158	180.12	92.3
2033	78	88.9	161	183.54	94.6
2034	79	90.1	164	186.96	96.9
2035	80	91.2	168	191.52	100.3
2036	81	92.3	171	194.94	102.6
2037	83	94.6	174	198.36	103.7
2038	84	95.8	177	201.78	106.0
2039	85	96.9	180	205.2	108.3
2040	86	98.0	183	208.62	110.6
2041	87	99.2	183	208.62	109.4
2042	88	100.3	189	215.46	115.1
2043	89	101.5	192	218.88	117.4
2044	90	102.6	194	221.16	118.6
2045	92	104.9	197	224.58	119.7
2046	93	106.0	200	228.00	122.0
2047	94	107.2	203	231.42	124.3
2048	95	108.3	206	234.84	126.5
2049	96	109.4	209	238.26	128.8
2050	97	110.6	212	241.68	131.1
2051	98	111.7	215	245.1	133.4

2052	99	112.9	218	248.52	135.7
2053	100	114.0	221	251.94	137.9
2054	101	115.1	224	255.36	140.2
2055	102	116.3	227	258.78	142.5
2056	103	117.4	230	262.2	144.8
2057	104	118.6	233	265.62	147.1
2058	105	119.7	236	269.04	149.3
2059	106	120.8	239	272.46	151.6
2060	107	122.0	242	275.88	153.9
2061	108	123.1	245	279.3	156.2
2062	109	124.3	248	282.72	158.5
2063	110	125.4	251	286.14	160.7
2064	111	126.5	254	289.56	163.0
2065	112	127.7	257	292.98	165.3
2066	113	128.8	260	296.4	167.6
2067	114	130.0	263	299.82	169.9
2068	115	131.1	266	303.24	172.1
2069	116	132.2	269	306.66	174.4
2070	117	133.4	272	310.08	176.7

1.14 Adjustment from 2007 to 2015 costs (D10 on LCCA spreadsheet)

Cost Studies:

- Research done for the California Energy Commission (CEC) on the affordability of all-electric commercial buildings found substantial capital savings in all climate zones modeled for several different building types. The analysis found that a mixed-fuel medium size office building in California costs between $36,176 and $87,253 more than an all-electric version, with the cost-differential varying by climate zone. In that same study, the analysis found that a mixed-fuel medium size retail store cost between $21,762 and $32,504 more than an all-electric version and a mixed-fuel small hotel costs between $1,294,276 to $1,300,552 more than an all-electric version. In a separate study for the CEC, a mixed-fuel mid-rise residential building in California was found to cost about $14,400 more than an all-electric version.
    - 2019 Nonresidential New Construction Reach Code Cost Effectiveness Study at 29 (2020)
    - 2019 Nonresidential New Construction Reach Code Cost Effectiveness Study at 37 (2020)
    - 2019 Nonresidential New Construction Reach Code Cost Effectiveness Study at 46 (2020)
    - 2019 Mid-Rise New Construction Reach Code Cost Effectiveness Study at 8 (2020)
- Research done by Point Energy Innovation for the University of California in 2017 showed that the life cycle cost of an all-electric academic building was 0.7% lower than a mixed-fuel building, saving roughly $1.23/sq ft. That same study showed that the life cycle cost of an all-electric laboratory was about 0.8% less than a mixed fuel building, saving around $3.09/sq ft.
    - UC Carbon Neutral Buildings Cost Study at 15 (2017)
- Research done by Group 14 Engineering in 2020 found that a 28,000 square foot all-electric office building in Colorado costs about $18,100 less than its mixed-fuel counterpart.
    - Group 14 Electrification of Commercial and Residential Buildings at 13 (2020)
- According to a 2018 study conducted by Navigant for the California Building Industry Association (CBIA), electric space heating also has a lower first cost than natural gas space heating. Specifically, that report, which looked at total installed costs, states that "electric appliances for space heating, cooking, and clothes drying have lower costs than natural gas options" in new construction.
    - California Building Industry Association Comments – Impacts of Residential Appliance Electrification, Docketed 9/20/2018
- Data shows that on average a baseline code-compliant gas furnace/AC system unit is 14% more expensive than a baseline heat pump. Cost data for ultra-low NOx furnaces, which are required in key California markets including the South Coast and San Joaquin valley air districts show that the average cost of the furnace/AC unit is 29% higher (considering 0.80 AFUE ULN units only).
    - NRDC Comments - Price comparison of heat pumps vs gas furnace and AC systems, Docketed 11/12/2020
- NRDC's analysis found that heat pumps were generally offered at a similar or lower price than their gas furnace/AC equivalents.
    - NRDC Comments - Price comparison of heat pumps vs gas furnace and AC systems, Docketed 11/12/2020

Case Studies:

WA Climate Zone	All-Electric Building Name or Address	City	Building Type (check more than one if applicable)	Project Description - 1 or 2 sentences, highlight size, unique features, relevant certifications, etc	Please share any links to online information about this building.
4C	King County International Airport	Seattle	Airport	By replacing gas boilers with VRF heat pumps and a dedicated outdoor air system and adding energy recovery ventilators, the energy usage of this airport was decreased by 70%.	https://betterbuildingssolutioncenter.energy.gov/showcase-projects/king-county-airport-terminal
4C	Seattle Aquarium Ocean Pavilion	Seattle	Aquarium	The 50,000-square-foot new Ocean Pavilion will be sited adjacent to the existing Seattle Aquarium along the downtown Seattle Waterfront. Fulfilling the mission of the Aquarium, ocean health, the design uses low-carbon electric heat pumps instead of gas to prevent ocean acidification from combusting fossil fuels.	
4C	Hand's On Children's Museum	Olympia	Assembly		
4C	Taproot Theater	Seattle	Assembly		
4C	Climate Pledge Arena	Seattle	Assembly	No fossil fuel consumption in the arena for daily use. All facility mechanical systems, gas combustion engines, heating, dehumidification, and cooking have been converted to electric.	https://climatepledgearena.com/sustainability/
4C	Port Angeles Waterfront Center	Port Angeles	Assembly	The 40,000 sf Field Arts & Events Hall provides a new performing arts space and community gathering place on the city's waterfront, featuring a 500-seat multi-purpose performance hall. A high performance envelope with optimized glazing and shading, paired with a VRF HVAC system, provides an efficient, electrified building.	https://lmnarchitects.com/project/field-arts-and-events-hall
4C	Skokomish Tribal Community Center	Skokomish, WA	Assembly Space	This Zero Net Energy community center includes a photovoltaic array, air-source heat pumps, and energy recovery ventilators which allows the mechanical system to be designed for heating rather than peak cooling loads.	http://www.7directionsarchitects.com/project/skokomish-tribal-master-plan-community-center/
4C	King Street Station	Seattle	Assembly Space	The King Street Station is Seattle's railway hub for Amtrak and Sounder traffic, including regional light rail and buses. The building uses a geothermal well with ground-source heat pump (GSHP) for heating and cooling, and includes efficient features such as natural ventilation.	https://www.architectmagazine.com/project-gallery/king-street-station

4C	Bellevue Youth Center	Bellevue	Assembly Space	This 12,000SF theater is built into the existing sloped hillside, which provides superinsulation of the ground concrete and is a very stable thermal environment. The focus on "right sizing" of heat pump capacity paired with low maintenance made a highly efficient mechanical system.	
4C	WSU Everett - Teaching/Research	Everett	Higher Ed	This 94,000sf higher education building houses mechanical, electrical, and software engineering programs for Washington State University. This all-electric building was completed in 2017 and uses variable refrigerant flow heat pumps for space heating and space cooling. Combined with a 78kW rooftop PV system, the verified energy performance of this building is ~25 kBtu/sf/yr.r	https://www.hoffmancorp.com/project/washington-state-university-everett/
4C	Seattle University Center for Science and Innovation	Seattle	Higher Ed	This new 5-story, 106,500 square-foot building in the heart of the Seattle University Campus will house the biology, chemistry, and physics departments, as well as provide a general science instructional lab space. Additionally, the building will house the Center for Environmental Justice and Sustainability, and the Innovation and Entrepreneurship Center. It has achieved LEED Gold and Electric Building Certification.	https://www.seattleu.edu/science-innovation/
4C	University of Washington, Foster School of Business Founders Hall	Seattle	Higher Ed	Founders Hall is all-electric building, drastically reducing operational carbon emissions by not connecting to the campus steam system. The design includes 91,000 square feet of instructional, academic, and administrative spaces within a mass timber structure.	https://foster.uw.edu/about-foster-school/campus/
4C	Peninsula College Allied Health and Early Childhood Development Center	Port Angeles, WA	Higher Ed	This 40,000 square foot building houses Peninsula Community College's healthcare and early childhood education programs, as well as childcare facilities for toddlers and preschoolers. It has achieved All Electric Building Status using: VRF heating and cooling, natural ventilation for passive cooling of classrooms and offices, low-temperature hot water heating via air-source heat pumps, low-flow plumbing fixtures, dedicated outdoor air systems for ventilation with heat recovery, a high performance building envelope, and fixed exterior shades.	https://pencol.edu/ECDC

5B	Samaritan Healthcare - Moses Lake	Moses Lake	Hospital	This new all-electric 175,000 square-foot hospital will house twelve ICU beds, twenty-five medical/surgical beds, a labor & delivery unit, diagnostic and treatment services, six operating rooms, two gastrointestinal labs, administrative support space, hospital support spaces, and a central utility plant. The HVAC systems includes a heat pump heat recovery chiller and decoupling heating and cooling from ventilation to minimize reheat mimicking active 4-pipe beams to heat and cool the patient rooms, emergency department, and B-occupancy areas	https://www.pae-engineers.com/projects/samaritan-healthcare-moses-lake
4C	Microsoft Campus Office Buildings and Commercial Kitchens	Redmond	Large Office, Commercial Kitchens	Microsoft is re-developing and expanding its East Campus in Redmond, WA, totaling 3 Million sf of office, retail, and restaurant space. The project will include fossil-fuel-free heating and hot water using a Central Plant with geo-wells. Cooking will also be fossil fuel free at the numerous restaurants as well as the large catering kitchen, often using induction technology.	https://news.microsoft.com/2021/03/16/microsoft-redmond-campus-modernization-construction-update-2/
4C	Harbor Square Condominiums	Bainbridge Island	Mid to High Rise Multifamily	180 units plus retail. 4 stories, 6 buildings. Built 2008 with heat pump heating and cooling. All-electric was the: lowest first cost.	
4C	Inspire	Seattle	Mid to High Rise Multi-Family	35 units in Fremont under the fossil-fuel free Living Building Pilot Program, has a solar array on the roof which provides enough energy for the building.	https://www.inspirefremont.com/
4C	Heron's Key Retirement Community	Gig Harbor	Mid to High Rise Multi-Family	Heron's Key Continuing Care Retirement Community uses heat pumps and energy recovery ventilators to achieve a highly energy efficient building for all 183 units and 24-hour nursing facility.	
4C	1916 Eastlake Ave E	Seattle	Mid to High Rise Multi-Family	6 story, 85,000 square foot All Electric Building assisted living facility. The building features ultra low-flow plumbing fixtures paired with a graywater reclamation system, aiming for reclaimed water only for non-potable water use. Additional sustainable building features include a rooftop photovoltaic array; a dedicated outdoor air system with heat recovery; triple pane windows; and optimized kitchen design and operations	https://www.pae-engineers.com/projects/aegis-living-lake-union
4C	Sunset Electric	Seattle	Mid to High Rise Multi-Family	This LEED Platinum apartment complex uses a central heat pump water heater system that harvests heat from the parking garage to create domestic hot water for the apartments.	https://www.architectmagazine.com/project-gallery/sunset-electric-6384

4C	Sitka Apartments	Seattle	Mid to High Rise Multi-Family	The innovative Sitka Apartments uses a waste water heat pump system which turns today's waste water into tomorrow's hot water. This LEED Platinum building also incorporates a greywater harvesting system to irrigate the surrounding landscaping.	https://www.metropolismag.com/architecture/residential-architecture/sitka-runberg-architecture-group/
4C	Cascade Apartments	Seattle	Mid to High Rise Multi-Family	This high-rise targeting LEED Platinum uses an ultra efficient HVAC and domestic hot water system with VRF heat pumps located in both the below grade parking garage and on the roof. By utilizing the thermal buffering effect of the ground as well as heat recovery from lights, cars, and garage exhaust air, this building is expected to be the most efficient high-rise in the region.	
4C	Batik Apartments	Seattle	Mid to High Rise Multi-Family	The Batik Apartments are part of the ambitious 30-acre Yesler Terrace redevelopment plan to replace an aging close-in affordable housing development with a mixture of low-income and market-rate housing and commercial buildings to create a more integrated, vibrant neighborhood. This LEED Platinum mid-rise multifamily uses a central heat pump water heating system.	https://www.zebx.org/batik-apartments-a-low-carbon-central-domestic-hot-water-system/
4C	Cypress Apartments	Seattle	Mid to High Rise Multi-Family	The Cypress Apartments are part of the ambitious 30-acre Yesler Terrace redevelopment plan to replace an aging close-in affordable housing development with a mixture of low-income and market-rate housing and commercial buildings to create a more integrated and vibrant neighborhood. This LEED Platinum mid-rise multifamily uses a central heat pump water heating system.	
4C	Clare's Place Supportive Housing	Everett	Affordable and Supportive Housing Housing	Ultra-High Efficiency Affordable Housing Demonstration Funding to create healthy, supportive housing. Uses heat pumps for domestic hot water and a heat pump VRF system for common spaces.	https://501eb6ac-6d64-4a8a-aa7d-e67cc8642e11.filesusr.com/ugd/8069ca_b12c791d8c8c4a6fbe5bf12cb956f563.pdf
4C	Hopeworks Station II	Everett	Affordable Housing	Design includes triple pane windows, energy recovery ventilators (ERVs) in all amenity spaces and residential units. Domestic hot water is supplied by a decentralized heat pump unit that each serves a vertical stack of six apartments. The low energy usage of the building is paired with a 200-kW photovoltaic array that will fully offset the energy use of the residential units. The project is on track for Net Zero Energy certification and Evergreen Sustainable Development Standard (ESDS)	

4C	Bill Hobson Place, Sawara, SCIDpda north Lot and Othello Buildings	Seattle	Affordable Housing	Othello: Amenity spaces use ductless split system heat pumps, while central hot water is provided with central CO2 heat pump water heaters paired with storage tanks.	https://exemplarybuilding.housingconsortium.org/
4C	Stackhouse Apartments	Seattle	Mid to High Rise Multi-Family, Office, Small Retail	This LEED Platinum apartment complex renovated the Supply Laundry Building into a multifamily complex as well as office and retail space. Design includes a heat pump water heater, rainwater catchment and reuse, and Design for Off™.	https://www.stinebaugh.com/wp-content/uploads/ASHRAE-Journal_April-2016_Stackhouse-Case-Study.pdf
4C	Bellevue 600	Bellevue	High Rise Office	This 1.2m sf all-electric new construction office tower uses heat recovery, air-to-water heat pumps, and electric boilers for space heating.	
5B	Catalyst Building	Spokane	Office	This newly completed 159,000sf cross-laminated timber office and higher ed building in Spokane houses computer and electrical engineering labs for Eastern Washington University. The Catalyst high performance envelope uses triple pane windows, an R-71 roof, and achieved a 0.035 cfm/sf (better than PHIUS) air infiltration standard. Hot water and chilled water is provided from the all-electric eco-district that features air-to-water heat pumps, thermal storage, and electric boiler back-up.	https://www.catalystspokane.com/
5B	840 Spokane	Spokane	Office / Higher Ed	When completed in Fall 2022, the Regional Health Partnership Building will offer 90,000 square feet of modern classroom, laboratory and office space for the University of Washington and Gonzaga University medical programs. The all-electric building features dedicated outdoor air systems and uses open loop ground source heat pumps for space heating and space cooling.	https://www.spokanehealthpeninsula.com/840building/
5B	Morris Center	Spokane	Office	The Scott Morris Center for Energy Innovation is a four-story 40,000 square foot facility that includes a restaurant and office space. The building uses hot water and chilled water from the all-electric central utility district it houses..	https://www.overcastinnovations.com/scott-morris-center-for-energy-innovation
4C	LOTT Clean Water Alliance	Olympia	Office	LOTT Clean Water Alliance is a regional wastewater treatment agency in the Pacific Northwest serving 85,000 customers across four jurisdictions. A 32,000 square foot, LEED Platinum, AIA COTE Top 10 Award Winner, makes the invisible visible through design and education	

4C	Rice Fergus Miller Office	Bremerton	Office	The office space for Rice Fergus Miller Architects renovated an abandoned 22,000 SF warehouse and achieved a LEED Platinum rating. The design includes VRF heat pumps and heat recovery ventilators which, in a passive mode of operation, uses no HVAC energy for 40% of the year.	https://www.hpbmagazine.org/rice-fergus-miller-office-and-studio-bremerton-wa/
4C	The Bullitt Center	Seattle	Office	The world's largest commercial Living Building, The 50,000 square foot Bullitt Center, a 6-story office building, features a 242 kW rooftop PV array; a closed-loop ground source heat pump HVAC system; radiant floors; rainwater harvesting; greywater treatment; and composting toilets	https://www.pae-engineers.com/projects/bullitt-center
4C	Pivotal Ventures	Kirkland	Office	Pivotal Ventures is a 20k square foot independent executive office, certified as an All Electric Building. Using a unique air source heat pump application allowed the AHU to be split while still meeting the heat recovery requirements of the Energy Code. An air source heat pump extracts heat not only from ambient air, but also from the building's exhaust air stream. The recovered heat is then used to heat the building. An underfloor supply air system and perimeter heating & cooling units provide an ultra-quiet HVAC system in open office spaces.	https://www.pivotalventures.org/
4C	King County Housing Authority Office	Tukwila	Office	This renovation of a 36,000 SF retail space into offices for the King County Housing Authority created a Net Zero Ready design, which includes ERV and VRF heat pump systems, lighting controls, and occupancy controls. The offices uses 70% less energy than the national average.	https://www.nxtbook.com/nxtbooks/ashrae/ashraejournal_201411/index.php?startid=64#/p/64
4C	Seattle Opera at the Center, Seattle	Seattle	Office	The Seattle Opera at the Center is a new 105,000 SF facility adjacent to McCaw Hall at the Seattle Center, completed in 2018. The facility includes offices, scene assembly rooms, shops, and rehearsal spaces. Building systems include variable refrigerant flow (VRF) and packaged heat pump HVAC and electric radiant floor.	
4C	The Northwest Maritime Center	Port Townsend	Office	A Port Townsend 26,000 LEED Gold facility with hands-on educational spaces, boat maintenance and storage spaces, administrative offices, and conference facilities. The project utilizes an ocean source heat pump system with titanium heat exchanger plates installed under the pier. A closed water loop circulated throughout the building uses the ocean as a heat source or sink. This variable speed heat pump loop provides all space conditioning needs including radiant floor as well as domestic hot water needs for the project.	

4C	King County Central Maintenance Facility	Renton	Office, Industrial	The Renton Shop is the headquarters for the Operations and Maintenance section of King County Park, including a crew/ administrative building, shop building, a storage building and (2) covered storage structures. The design is all-electric using heat pumps for space heating.	
4C	Seatown Restaurant	Seattle	Restaurant	At Pike Place Market, provide full-service, all electric kitchens that serve breakfast, lunch and dinner every day.	
4C	Rub with Love Restaurant	Seattle	Restaurant	At Pike Place Market, provide full-service, all electric kitchens that serve breakfast, lunch and dinner every day.	
4C	Sunnyland Elementary School (reconstruction)	Bellingham	School	Originally planned to be gas-heated, the design team helped Bellingham Public Schools change course to be all-electric and solar-ready. It will likely utilize multiple heating systems, including centralized heat pump HVAC.	https://bellinghamschools.org/about/committees-advisory-groups/sunnyland-educational-specifications-design-advisory-committee/
4C	Olympic High School	Bremerton	School	One of the most energy efficient high schools in the Pacific Northwest. The combined new floor area of 300,000SF uses half the energy prior to the remodel. It is an all-electric, Net Zero Ready school with new heat pumps and future upgrades with photovoltaic installation.	https://sklarchitects.com/portfolio_page/olympic-high-school-remodel/
4C	Blakely and Wilkes Elementary	Bainbridge Island	School	Both elementary schools use a hybrid deep-bore ground source heat pump (GSHP), with a backup electric boiler, for heating and cooling. Ventilation is provided using dedicated outside air unit(s) with heat recovery, and mixed-mode natural ventilation. Both schools also use daylighting features to reduce electricity use. Both schools have a cafeteria and kitchen with light food service (e.g. warming) but without extensive cooking on-site.	
4C	The Bush School - Gracemont	Seattle	School	New 20,175 square foot 3-story building includes classrooms, a faculty workroom, a study lounge and a 2500 square foot multi-purpose auditorium space. The building has achieved All Electric Building, Passive House, and Net Zero Energy.	https://www.bush.edu/experience-education/upper-school
4C	Westside School	Seattle	School	The renovated Westside School transformed an outdated 35,000 SF church structure into an extremely energy efficient 55,000 SF K-8 school in West Seattle. Dedicated outside air systems with energy recovery and zonal heat pumps help to make this the most efficient school in the region.	http://ecotope.com/westside-school-gets-an-a-for-energy-efficiency/

4C	Giddens School and Lake Washington Girls Middle Schools	Seattle	School	This 20,000SF joint venture elementary and middle school includes a highly efficient thermal envelope, LED lightening with daylighting controls, and future rooftop photovoltaic panels. The schools have a heat pump water heating system along with a rainwater harvesting used for toilet system.	https://www.architectmagazine.com/project-gallery/giddens-school-and-lake-washington-girls-middle-school-complex
4C	UW Intellectual House	Seattle	School, Assembly Space	This longhouse-style facility at the University of Washington is meant to increase Native American student's success at UW and includes a large community gathering space, commercial kitchen, meeting rooms, study spaces, and offices. The mechanical system includes a novel mixed-mode natural/mechanical ventilation design with an Energy Recovery Ventilator, and variable capacity heat pumps sized for space heating.	https://www.washington.edu/diversity/tribal-relations/intellectual-house/
4C	Mukilteo Ferry Terminal	Mukilteo	Transportation	The 20,000 sf building is entirely fossil fuel free for operations, including an all-electric hydronic radiant floor in the terminal. A heat pump with heat recovery serves a dedicated outside air unit to precondition fresh air and domestic hot water is provided by an electric boiler. The public areas use natural ventilation and ceiling fans for fresh air and cooling.	https://lmnarchitects.com/project/mukilteo-multimodal-ferry-terminal

Heat Pump Water Heating Proposal - Cost and Energy Analysis Supplemental

Model Inputs:
All of the model inputs for cost and energy can be found in "Heat Pump Water Heating Supplemental Cost & Energy Info." The cost data for heat pump water heaters, electric boilers and electric resistance water heaters was found through interviews of staff at various engineering firms. The gas boiler cost data was researched online and noted in the supplemental spreadsheet. The cost of electrical infrastructure upgrades was found in a California cost effectiveness study for nonresidential buildings.[1]

Energy data was modeled and calculated based on an assumption of a 173 unit, 182,000 square foot high-rise multifamily building. Assumptions for COP, recirculation losses, number of people per unit and amount of hot water indeed per person was assumed through interviews with various engineering firms. The life times of equipment were assumed using EIA values.[2]

Methodology:
Outside air temperature is unlikely to dramatically affect hot water consumption, so the model was not tested in various climate zones. A high-rise multifamily building was modeled because it would have the largest demand of any non-residential building. Overall, three sets of water heating scenarios were analyzed in the models. The three water heating scenarios evaluated were:

- Baseline: Central Heat Pump Water Heater System
- Alternative 1: Central Electric Boiler System
- Alternative 2: Central Gas Boiler System

Each electrification scenario assumes that there will be a required incremental increase in electrical capacity to be able to accommodate the additional electrical load. The electrification scenarios don't assume any cost advantage on reduced natural gas infrastructure because it's possible that both space heating and cooking appliances could use natural gas and thus need the gas infrastructure.

In addition, a second model was evaluated with an increased social cost of carbon. The social cost of carbon assumed in the life cycle cost analysis tool is used to determine the cost effectiveness of the different scenarios, accounting for the carbon impacts of fossil fuels. The current model assumes a 2.5% discount rate at 50th percentile estimate set by the Interagency Working Group on

---

[1] https://localenergycodes.com/download/74/file_path/fieldList/2019%20NR%20NC%20Cost%20Effectiveness%20Report, page 21
[2] https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/full.pdf

Social Cost of Carbon.[3] The Biden Administration is currently evaluating these tables and will likely update it with more aggressive assumptions for the federal government starting next year.[4] Given this, the second model assumed a more aggressive social cost of carbon, 3% discount rate at 95% percentile, using the IWG SCC table. This reflects the likely increasing cost of carbon expected in the coming years as our governments further align policy with the reality of the climate crisis. See attached “Carbon Adjustment for Heat Pump Water Heating Scenario” document for details on how the social cost of carbon was adjusted in the second scenario.

Results:
The initial result indicates the central gas boiler system has the lowest life cycle cost with and without the current social cost of carbon assumptions. Notably, the heat pump water heater baseline has a substantially lower life cycle cost than the central electric boiler, with or without the social cost of carbon. For this reason, the electric resistance baseline was not studied further. See Table 1 below for results:

Table 1:

Life Cycle Cost Analysis			BEST
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intenstity (kBtu/sq.ft)	3.9	10.4	9.4
1st Construction Costs	$ 273,940	$ 196,040	$ 132,560
PV of Capital Costs	$ 664,331	$ 466,470	$ 214,758
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 575,184	$ 1,540,422	$ 581,597
Total Life Cycle Cost (LCC)	**$ 1,239,515**	**$ 2,006,892**	**$ 796,355**
Net Present Savings (NPS)	**N/A**	**$ (767,377)**	**$ 443,160**
Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption			
(GHG) Social Life Cycle Cost			BEST
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	768	2,056	4,567
% CO2e Reduction vs. Baseline	N/A	-168%	-185%
Present Social Cost of Carbon (SCC)	$ 54,846	$ 146,879	$ 289,891
Total LCC with SCC	**$ 1,294,361**	**$ 2,153,771**	**$ 1,086,246**
NPS with SCC	**N/A**	**$ (859,410)**	**$ 208,114**

[3]https://obamawhitehouse.archives.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf, page 18
[4]https://www.engage.hoganlovells.com/knowledgeservices/viewContent.action?key=Ec8teaJ9Var4U%2FM2JvDoRsxgHJMKLFEppVpbbVX%2B3OXcP3PYxlq7sZUjdbSm5FletvAtgf1eVU8%3D&nav=FRbANEucS95NMLRN47z%2BeeOgEFCt8EGQ0qFfoEM4UR4%3D&emailtofriendview=true&freeviewlink=true

When the social cost of carbon was re-evaluated at the 3%, 95th percentile rate, the central heat pump water heater baseline was shown to have the lowest life cycle costs when including the social cost of carbon. For more details, see Table 2 below.

Table 2:

Life Cycle Cost Analysis			BEST
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intenstity (kBtu/sq.ft)	3.9	10.4	9.4
1st Construction Costs	$ 273,940	$ 196,040	$ 132,560
PV of Capital Costs	$ 664,331	$ 466,470	$ 214,758
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 575,184	$ 1,540,422	$ 581,597
Total Life Cycle Cost (LCC)	**$ 1,239,515**	**$ 2,006,892**	**$ 796,355**
Net Present Savings (NPS)	**N/A**	**$ (767,377)**	**$ 443,160**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost	BEST		
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	768	2,056	4,567
% CO2e Reduction vs. Baseline	N/A	-168%	-185%
Present Social Cost of Carbon (SCC)	$ 109,340	$ 292,817	$ 621,138
Total LCC with SCC	**$ 1,348,854**	**$ 2,299,708**	**$ 1,417,493**
NPS with SCC	**N/A**	**$ (950,854)**	**$ (68,638)**

The data from the Executive Reports for each model was captured to determine the cost and energy impact per square foot. Energy impacts per square foot shows that a central heat pump system saves roughly 5.5 kBTU/sq ft annually compared to a central gas boiler. See Table 3 below. Cost results show that the increase in construction cost is roughly $2.47 per sq ft to install a central heat pump water heater over a central gas boiler system. When accounting for the increased social cost of carbon, the life cycle cost per square foot saves roughly $0.38/sq ft. See Table 4 below for cost savings per square foot.

Table 3:

Energy Savings per sq ft.	EUI of Heat Pump Baseline	EUI of Central Gas Boiler	EUI Savings
High Rise Residential	3.9	9.4	-5.5

Table 4:

Cost Savings per sq ft.	**Size of Building (sq ft)**	**Delta NPV of Capital Cost between Heat Pump and Gas Boiler**	**LCC of HPWH**	**LCC with SCC**	**NPV Capital Cost /sq ft**	**LCC /sq ft**	**LCC with SCC /sq ft**
High Rise Residential	182,000	$449,573	$443,160	$208,144	$2.47	$2.43	$1.14
High Rise Residential with Increased SCC	182,000	$449,573	$443,160	($68,638)	$2.47	$2.43	($0.38)

An Executive Report for each model is attached to this supplemental. Further cost and energy data can be found in "Heat Pump Space Heating Supplemental Cost & Energy Data." Additionally, the excel files for each model are included with the proposal.

Office of Financial Management
Olympia, Washington - Version: 2020-A
Life Cycle Cost Analysis Tool

Executive Report

Project Information	
Project:	
Address:	N/A, N/A, N/A
Company:	RMI
Contact:	Jonny Kocher
Contact Phone:	619-459-4267
Contact Email:	jkocher@rmi.org

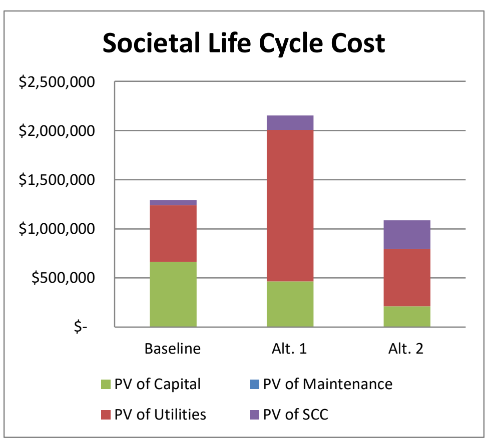
Key Analysis Variables		**Building Characteristics**	
Study Period (years)	50	Gross (Sq.Ft)	182,000
Nominal Discount Rate	5.00%	Useable (Sq.Ft)	182,000
Maintenance Escalation	1.00%	Space Efficiency	100.0%
Zero Year (Current Year)	2020	Project Phase	0
Construction Years	0	Building Type	0

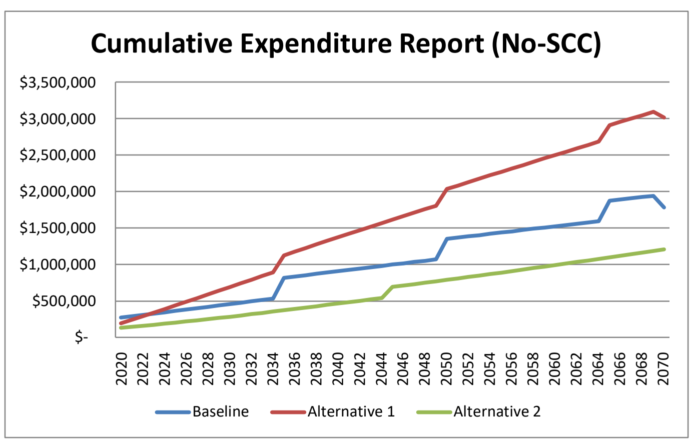
Life Cycle Cost Analysis			BEST
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intensity (kBtu/sq.ft)	3.9	10.4	9.4
1st Construction Costs	$ 273,940	$ 196,040	$ 132,560
PV of Capital Costs	$ 664,331	$ 466,470	$ 214,758
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 575,184	$ 1,540,422	$ 581,597
Total Life Cycle Cost (LCC)	**$ 1,239,515**	**$ 2,006,892**	**$ 796,355**
Net Present Savings (NPS)	**N/A**	**$ (767,377)**	**$ 443,160**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost			BEST
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	768	2,056	4,567
% CO2e Reduction vs. Baseline	N/A	-168%	-185%
Present Social Cost of Carbon (SCC)	$ 54,846	$ 146,879	$ 289,891
Total LCC with SCC	**$ 1,294,361**	**$ 2,153,771**	**$ 1,086,246**
NPS with SCC	**N/A**	**$ (859,410)**	**$ 208,114**

Warning: OFM Assigned Variables Not Used





Baseline Short Description
Central Heat Pump Water Heater System
Alternative 1 Short Description
Central Electric Boiler System
Alternative 2 Short Description
Central Gas Boiler System

Office of Financial Management
Olympia, Washington - Version: 2020-A
Life Cycle Cost Analysis Tool

Executive Report

Project Information	
Project:	
Address:	N/A, N/A, N/A
Company:	RMI
Contact:	Jonny Kocher
Contact Phone:	619-459-4267
Contact Email:	jkocher@rmi.org

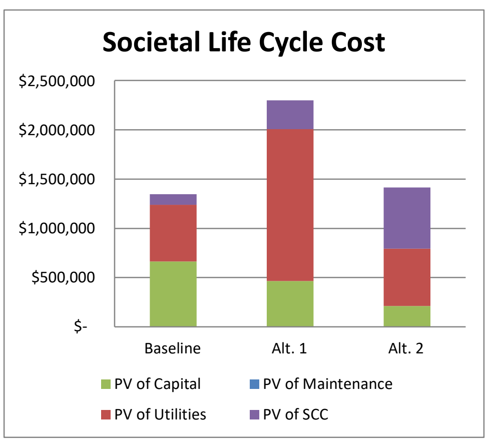
Key Analysis Variables		**Building Characteristics**	
Study Period (years)	50	Gross (Sq.Ft)	182,000
Nominal Discount Rate	5.00%	Useable (Sq.Ft)	182,000
Maintenance Escalation	1.00%	Space Efficiency	100.0%
Zero Year (Current Year)	2020	Project Phase	0
Construction Years	0	Building Type	0

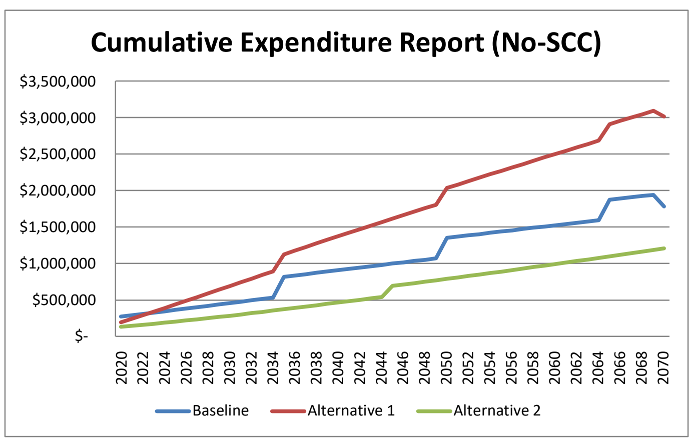
Life Cycle Cost Analysis			**BEST**
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intestity (kBtu/sq.ft)	3.9	10.4	9.4
1st Construction Costs	$ 273,940	$ 196,040	$ 132,560
PV of Capital Costs	$ 664,331	$ 466,470	$ 214,758
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 575,184	$ 1,540,422	$ 581,597
Total Life Cycle Cost (LCC)	**$ 1,239,515**	**$ 2,006,892**	**$ 796,355**
Net Present Savings (NPS)	**N/A**	**$ (767,377)**	**$ 443,160**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost	**BEST**		
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	768	2,056	4,567
% CO2e Reduction vs. Baseline	N/A	-168%	-185%
Present Social Cost of Carbon (SCC)	$ 109,340	$ 292,817	$ 621,138
Total LCC with SCC	**$ 1,348,854**	**$ 2,299,708**	**$ 1,417,493**
NPS with SCC	**N/A**	**$ (950,854)**	**$ (68,638)**

Warning: OFM Assigned Variables Not Used





Baseline Short Description
Central Heat Pump Water Heater System
Alternative 1 Short Description
Central Electric Boiler System
Alternative 2 Short Description
Central Gas Boiler System

Heat Pump Water Heater Code Proposal - Supplemental Cost Documentation

Proposed Hot Water Use	2,367,938	Gal/yr	RCC COP	2.8	
Electric Resistance Electrical Usage (100% EF Tanks)	403,097	kWh/yr	RECIRC COP	2.4	
Electric Resistance Recirc Loss	151,548	kWh/yr	Recirc Loss/Unit	100	Watts
Electric Resistance Total Electrical Usage	554,645	kWh/yr	Loss	17,300	Watts
			Loss	151,548	kWh/yr
HPWH Electric Usage(2.8 COP RCC)	143,963	kWh/yr			
HPWH Recirc Loss	63,145	kWh/yr	Apartments	173	
HPWH Total Electrical Usage	207,108	kWh/yr	People/Apt.	1.5	
			People	260	
Boiler Efficiency	80%		Gals DHW/Day/Person	25	
Total Gas Usage	17,196.99	therms			
			Mark Up Cost	80%	

Heat Pump Plant	QTY	Unit Price	Install and Markup	Total Costs
Heat Pumps (2) CXA-15 and (1) CXA-10	1	$79,000	$63,200	$142,200
Hot Water Storage (2000 Gallons)	4	$12,000	$9,600	$86,400
Controls	1	$15,000	$20,000	$35,000
		$106,000	$92,800	**$263,600**

Electric Tanks in Units	QTY	Unit Price	Install and Markup	Total Costs
Electric tanks in units	173	$800	$640	$249,120
				$249,120

Central Electric Boiler	QTY	Unit Price	Install and Markup	Total Costs
Electric Boiler 30 kw	2	$12,000	$9,600	$43,200
Electric Boiler 20 kw	1	$10,000	$8,000	$18,000
Hot Water Storage (2000 Gallons)	4	$12,000	$9,600	$86,400
Controls	1	$15,000	$20,000	$35,000
		$49,000	**$47,200**	**$182,600**

Central Gas Boiler	QTY	Unit Price	Install and Markup	Total Costs
Gas Boiler (275,000 BTU/hr)	1	$6,200	$4,960	$11,160
Hot Water Storage (2000 Gallons)	4	$12,000	$9,600	$86,400
Controls	1	$15,000	$20,000	$35,000
		$33,200	**$34,560**	**$132,560**

Incremental Cost for Electrical Upgrades	Cost per Unit
280 V, 400 A; Electrical Panel Cost	$3,100
Linear foot of electrical line	$4

Total Cost for Electrical Upgrades	QTY	Length of Electrical Line Needed	Total Incremental Cost
Total Incremental Cost for Heat Pump Water Heater	1	$2,000	$10,340
Total Cost Incremental for Electric Resistance Water Heater	2	$2,000	$13,440

Gas Cost	0.818	per kWH
Electric Cost	0.0856	per therm

Capital Cost	Total Cost
Central Electric HPWH	$273,940
Electric Resistance Heaters in Units	$262,560
Central Electric Boiler	$196,040
Central Gas Boiler	$132,560

Operational Cost	Total Costs
Central Electric HPWH	$17,728
Electric Resistance Heaters in Units	$47,478
Central Electric Boiler	$47,478
Central Gas Boiler	$14,067

Cost Savings per sq ft.	Size of Building (sq ft)	Delta NPV of Capital Cost between Heat Pump and Mixed Fuel	LCC Savings of HPWH	LCC with SCC	NPV Capital Cost/sq ft	LCC/sq ft	LCC with SCC/sq ft
High Rise Residential	182,000	$ 449,573	$ (443,160)	$ (208,144)	$ 2.47	$ (2.43)	$ (1.14)
High Rise Residential with Increased SCC	182,000	$ 449,573	$ (443,160)	$ 68,638	$ 2.47	$ (2.43)	$ 0.38

Energy Savings per sq ft.	EUI of Heat Pum	EUI of Central Gas Boiler	EUI Savings
High Rise Residential	3.9	9.4	-5.5