ENERGY

STEP CODE

BUILDING BEYOND THE STANDARD

2017 Metrics Research
Summary Report

September 2017

A report prepared for BC Housing and the Energy Step Code Council.
With the support of Natural Resources Canada and Remi Charron.

BC HOUSING

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INTEGRAL GROUP

KEY FINDINGS

This Summary Report presents the findings of a comprehensive exploration of the energy, emissions and economic impacts of the British Columbia (BC) Energy Step Code ("Step Code"). The research represents one of the most extensive energy analyses of buildings in Canada.

The study was commissioned by BC Housing, in partnership with BC Hydro, the BC Building and Safety Standards Branch at the Province of British Columbia, the City of Vancouver, and Natural Resources Canada. An interdisciplinary team led by Integral Group conducted all analysis. This team consisted of Morrison Hershfield and E3 Eco Group, with input from Remi Charron—an energy modeller with specific expertise in applications relevant to the project—as well as expert stakeholders representing local governments, utilities, and construction-related community and industry associations.

The scope of this project was to examine a series of research questions that were developed by the study partners. Questions covered a wide range of topics related to the implementation of the BC Energy Step Code. However, the core of the investigation was to determine the costs associated with achieving the proposed metrics and performance requirements for both Part 3 and Part 9 buildings, and baselining these against the state of building construction in the province. A comprehensive data set of both energy modelling and associated costing data was developed to answer these questions.

Optimized costing results were obtained for three primary metrics: incremental capital costs, net present value (NPV), and carbon abatement costs. It should be noted that the costs presented in this and the Full Report are estimates only, and do not reflect the costs of individual builders or buildings. There are many different ways a builder can achieve a given step, and an underlying assumption of this study is that cost savings are a priority for builders and building owners. As such, cost-saving measures have been adopted in calculating the cost premiums or savings associated with meeting higher performance requirements.

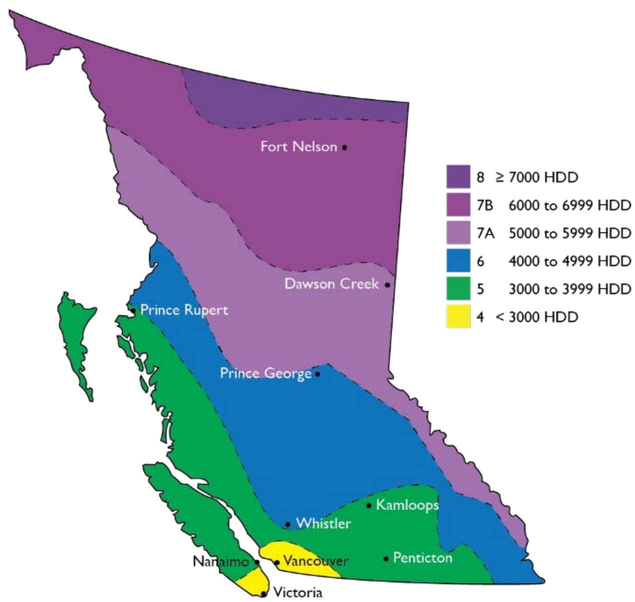

Figure 1: British Columbia Climate Zones, based on heating degree days

The research shows that meeting the requirements of the Lower Steps of the BC Energy Step Code involve only very modest construction premiums. In most situations, builders can achieve the Lower Steps for less than a 2% construction cost premium above that of a home built to the requirements of the *BC Building Code*. The construction cost premiums associated with Step 1 compliance is even smaller—just a small fraction of a percent.

This finding suggests to us that improved energy efficiency and affordability can go hand in hand.

Other high-level findings include the following:

- It is generally easier and more cost-effective to meet BC Energy Step Code requirements in simple buildings that share common walls—such as townhomes and apartments.
- When it comes to energy efficiency, building shape and orientation impact cost. A south-facing home with modest window areas and compact building form will be more cost effective in achieving higher performance than a complicated building with many windows looking north.
- As industry gains experience with energy efficient construction practices—and energy-efficient products become more readily available—cost premiums will decrease. A clear timeline with extra time allowed for implementation of higher steps will help industry to get ready.
- The most cost-effective time to invest in a building's energy efficiency is at its conceptual design stage.

Part 3 Buildings

Part 3 buildings are defined in the BC Building Code as those buildings classified as Group A, B or F-1 that exceed 600m^2 in building area or three storeys in building height and that have major occupancies. We selected the initial Part 3 archetypes for this study using the BC Energy Step Code framework. This framework defines Total Energy Use Intensity (TEUI) and Thermal Energy Demand Intensity (TEDI) performance requirements for Multi-Unit Residential buildings (MURB), Commercial Office, and Big Box Retail buildings. We modelled all archetypes using EnergyPlus v8.6 and Morrison Hershfield's Building PathFinder program. We sourced costing data from current projects in both Morrison Hershfield's and Integral Group's portfolio, and supplemented it, where appropriate, with information from the Altus Construction Guide and BC Housing project data.

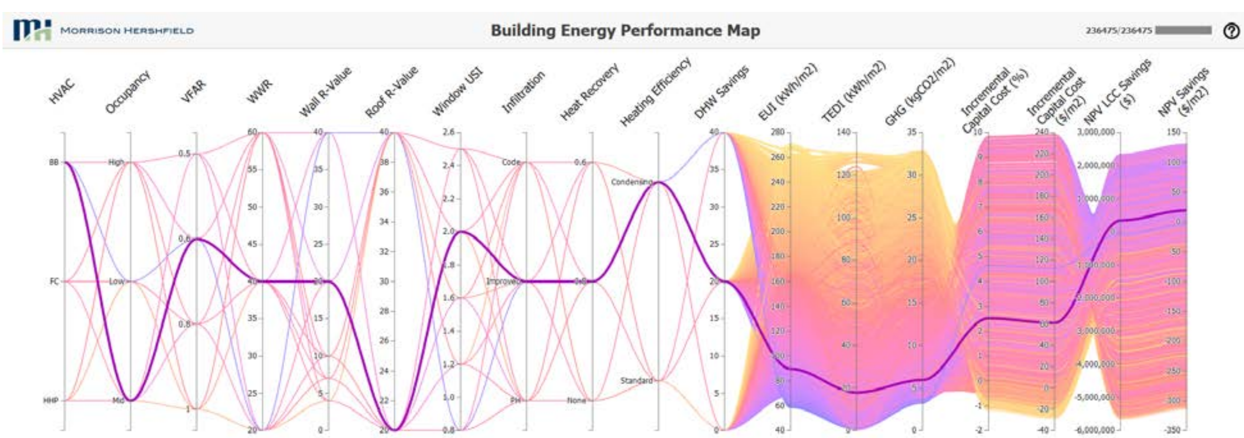

Figure 2: The Building PathFinder tool was used to identify results for Part 3 buildings. Visit http://www.buildingpathfinder.com/ to view the results for Part 3 MURB.

General Part 3 Findings

- Absolute EUI and TEDI targets shift the focus towards the optimization of a building's form factor to improve its energy performance. We found floor plate size and level of articulation to be the principal factors affecting a building's ability to meet the TEDI performance requirements.
- Consistent with the current National Building Code, builders must decrease window to wall ratio in higher climate zones to meet the targets.
- As larger numbers of occupants lead to higher plug loads, higher occupancy and unit density (i.e. many smaller units) can challenge the achievement of TEUI performance requirements, particularly without the use of highly energy efficient appliances.
- Builders and designers can achieve higher R-values at lower costs by using wood frame construction (when possible) instead of steel and/or concrete structures.
- Builders and designers of office and retail projects will find that choice of mechanical systems most significantly impacts EUI and TEDI. In general, higher efficiency variable refrigerant flow (VRF) or heat pump-based systems offer the largest cost advantages.
- Meeting the TEDI requirements generally leads to complying with EUI performance requirements with conventional gas-based or electric heating sources unless the buildings have significant internal loads, at which point heat pump systems may be required. That is, buildings with non-typical occupancy use or process loads can still comply with the Step Code via higher efficiency mechanical systems.

Key Terms

Thermal Energy Demand Intensity (TEDI) provides a measure of the amount of energy a building requires to maintain an indoor temperature that is be thermally comfortable for occupants, per meter of conditioned floor area per year.

Total Energy Use Intensity (TEUI) provides a measure of a building's total energy use, including both "process" and "regulated" loads, per meter of building area per year.

Mechanical Energy Use Intensity (MEUI) provides a measure of the modelled amount of energy used by space heating and cooling, ventilation, and domestic hot water systems, per square meter of conditioned floor space, per year.

We used parametric analysis to investigate the potential increase in capital costs. Our research team reviewed thousands of modelling results to identify a package of energy-conservation measures that achieved the lowest incremental capital cost results. The costs were then compared to those associated with meeting the existing prescriptive requirements of the *BC Building Code*. Costs included all materials and labour, as well as costs associated with the mandatory requirement for airtightness testing in commercial buildings.

- Our analysis finds that builders and designers can achieve the requirements of all steps of the BC Energy Step Code for almost all building types, and in almost all climate zones, for less than a 4% cost premium above conventional construction. There were only two exceptions: Low-Rise MURB in Climate Zones 7a and 7b for Step 4, and Retail buildings in Climate Zone 7a for Steps 2 and 3. High-rise MURB could not meet Step 4 in Climate Zone 7a or 7b within the set parameters. However, this was considered acceptable because there are currently no examples of this building form in these zones, and this is not expected to change in the foreseeable future.

- Modelling suggests that builders and designers can achieve Step 4 (the highest step for Part 3) for less than a 3% capital cost premium, and achieve Step 3 for less than 2.4%. To provide context for this number, it is not uncommon for construction costs to vary by 2% a year due to market forces.
- In general, incremental capital costs do not increase significantly in colder climate zones due to higher baseline code requirements.
- At higher step levels, especially in higher climate zones, the use of high-performance windows typically drives any increases in incremental capital costs. As the climate gets colder and the TEDI requirement becomes more challenging to achieve, builders must use higher performance windows. This can involve a significant cost premium.

Table 1: Lowest Incremental Capital Costs for Part 3 Buildings (% change over BCBC)

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b
High-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	0.0%	0.0%	0.0%	0.0%	N/A
	2	0.4%	1.0%	1.3%	2.0%	N/A
	3	0.8%	2.3%	1.8%	2.3%	N/A
	4	2.4%	3.2%	2.7%	N/A	N/A
Low-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.5%	0.5%	0.4%	1.4%	3.3%
	3	0.6%	2.2%	1.0%	1.6%	3.2%
	4	2.6%	3.3%	2.2%	4.1%	N/A
Commercial Office *No IT Load Default Occupancy with ASHP*	1	0.0%	0.0%	0.0%	0.0%	N/A
	2	-0.2%	-0.1%	0.4%	1.6%	N/A
	3	0.0%	0.2%	1.4%	1.8%	N/A
Retail *Big Box with FC*	1	0.0%	0.0%	0.0%	0.0%	N/A
	2	0.8%	1.3%	2.8%	4.6%	N/A
	3	2.0%	3.7%	5.5%	6.6%	N/A

NPV and Carbon Abatement Costs

In addition to increased capital costs, the study assessed the long-term value of adopting the BC Energy Step Code to consumers and local governments interested in using the regulation as a climate action tool. This analysis was completed through a net present value (NPV) calculation that examined potential savings compared to additional costs over a 20-year period.

- NPV and carbon abatement costs numbers were mixed and should be interpreted carefully. The lead takeaway from these metrics is that costs were generally positive below Step 4 – in other words, buildings can be designed to lower overall costs to consumers. Where the NPV numbers are negative, they are small relative to the overall cost of constructing and operating a building, and do not exceed 2% of the total cost of ownership.
- Two notable exceptions to NPV results are an increase of up to 5% in total costs over a 20-year period for Low-Rise MURB in Climate Zone 7B, and a 3% increase in total costs for Retail buildings to meet Step 3 in Climate Zones 6 and 7A. In terms of carbon abatement costs, carbon savings are often associated with NPV savings, especially in Climate Zone 4. In colder climate zones, the cost of abated carbon can be up to 10 to 15 times the current carbon tax in BC, currently at $30/tonne but expected to rise to $35/tonne in April 2018.

- It is important to also note that optimizing buildings for NPV and for first costs resulted in different building outcomes and configurations. One of the major drivers of NPV and GHG outcomes is fuel source, on which the code provides no explicit direction. However, the starting point for base costs (i.e. gas-based heating vs. electric-based heating) will be highly influential on final NPV and GHG outcomes, as a result of the disparity in costs and GHG emissions between fuel sources in BC.

Table 2: Highest Net Present Value for Part 3 Buildings ($/m2)

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b
High-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	--	--	--	--	--
	2	15.1	-0.1	18.6	-44.6	--
	3	21.0	-14.0	24.0	-30.2	--
	4	-2.7	-16.1	15.5	N/A	--
Low-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	--	--	--	--	--
	2	27.5	20.8	51.9	0.1	
	3	33.5	1.3	57.3	14.6	-16.1
	4	10.8	-1.8	47.0	-47.5	--
Commercial Office *No IT Load Default Occupancy with ASHP*	1	--	--	--	--	--
	2	25.8	16.2	6.0	-26.7	--
	3	22.3	10.7	-22.7	-33.7	--
Retail *Big Box with ASHP*	1	--	--	--	--	--
	2	20.6	13.7	-18.3	-26.9	--
	3	16.1	2.2	-36.3	-36.6	--

Table 3: Lowest Carbon Abatement Costs for Part 3 Buildings ($tonneCO2e)

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b
High-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	--	--	--	--	--
	2	-332.1	0.7	-370.6	470.3	--
	3	-499.5	144.6	-509.4	314.8	--
	4	27.4	158.8	-240.5	368.4	--
Low-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	--	--	--	--	--
	2	-731.6	-528.3	-1374.3	-1.7	151.5
	3	-897.5	-17.0	-1441.3	-250.3	181.6
	4	-144.9	18.0	-1005.6	464.0	--
Commercial Office *No IT Load Default Occupancy with ASHP*	1	--	--	--	--	--
	2	-471.9	-251.5	-3.6	190.5	--
	3	-204.8	-94.9	180.0	188.3	--
Retail *Big Box with FC*	1	--	--	--	--	--
	2	-115.4	-57.7	57.5	62.4	--
	3	-90.2	-9.2	113.5	84.9	--

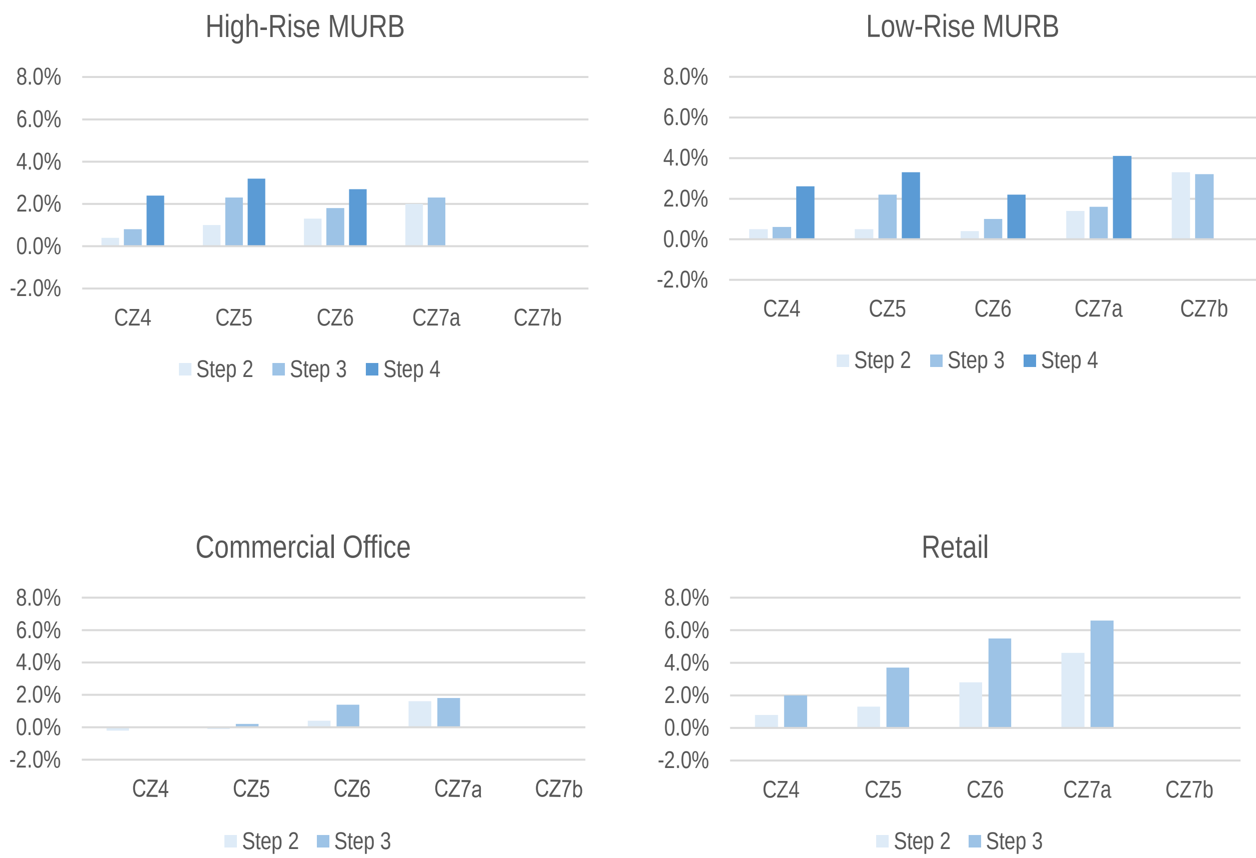

Figure 3: Lowest Incremental Capital Costs for Part 3 Buildings (% change over BCBC)

Part 9 Buildings

Part 9 buildings are defined in the BC Building Code as those buildings classified as Group C, D, E and F with a building height of three storeys or less, that do not exceed 600m^2 in building area and that have major occupancies. We selected Part 9 archetypes for this study according to the BC Energy Step Code framework, which for Part 9 residential buildings defines targets for Airtightness, Mechanical Energy Use Intensity (MEUI) and Thermal Energy Demand Intensity (TEDI). A total of 6 archetypes were modelled for Part 9 buildings, including: 10-Unit MURB, 6-Unit Row House, Quadplex, and Small, Medium and Large single family dwellings (SFD). The six base building archetypes were modelled using Version 11.3 of Natural Resources Canada (NRCan)'s HOT2000 program and analyzed using NRCan's Housing Technology Assessment Platform (HTAP). Out of 54 million Energy Conservation Measures (ECM) combinations for each archetype, 60,000 to 240,000 separate HOT2000 evaluations were modelled for each archetype.

Table 4: Options used in Part 9 Energy Modelling

Component	Options	# of choices
Airtightness ACH	3.5 ACH, 2.5 ACH, 1.5 ACH, 1.0 ACH, 0.6 ACH	5
Wall R-Value	R16, R18, R22, R24, R30, R40, R50, R60	8
Under-slab R-Value	R11, R15, R20, R40	4
Foundation Wall R-Value	R11, R17, R20, R25	4
Exposed Floor R-Value	R27, R29, R35, R40	4
Ceiling/Roof R-Value	R40, R50, R60, R70, R80, R100	6
Window Option & U-Value	Double (1.8), double (1.6), double (1.4), high gain triple (1.2), low gain triple (1.2), triple (1.0), high performance triple (0.8)	7
Domestic Hot Water (DHW) System	Electric & gas tank, 2 x gas tankless, heat pump (electric)	5
Drain Water Heat Recovery	None, 30%, 42%, 55% (recovery efficiencies)	4
Space Heating	Gas 92% & 95% AFUE, gas combo, Cold Climate ASHP (electric), Baseboard (electric)	5
Ventilation Heat Recovery	None, 60%, 70%, 75% & 84% SRE	5
Total Number of Possible Combinations	53,760,000	

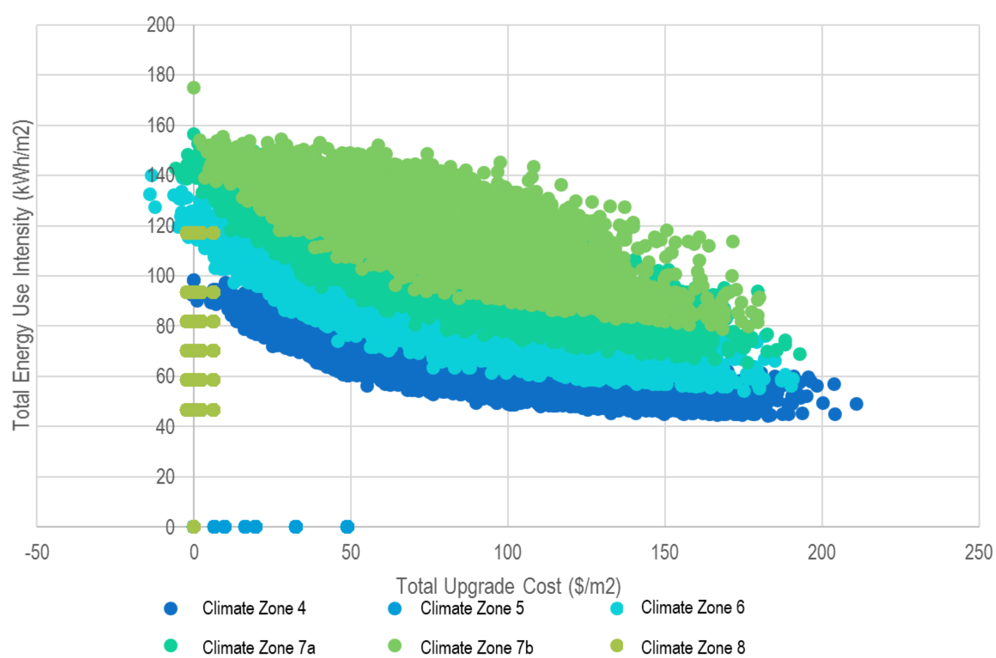

Figure 4: Sample HTAP scatterplot output for the optimization of capital costs for TEDI, Medium SFD

Incremental Capital Costs

Key findings for Part 9 capital building costs can be summarized as follows:

- We generally found modest incremental capital cost results overall—builders can achieve the majority of steps for less than a 2% capital cost premium above the cost of conventional construction. This is particularly true for the multi-unit residential building (MURB), Row House, and Large single family dwelling (SFD) archetypes, each of which can reach Step 4 for less than a 2% cost premium in Climate Zones 4 through 6. Those building MURBs can reach Step 4 in Climate Zones 7a and 7b for 0.7% and 1.4% premium respectively, and Step 5 in Climate Zones 4 and 5 for 2.1% or less.

- Builders of our modelled quadplexes and medium-sized SFDs will have a slightly bigger challenge meeting the BC Energy Step Code targets, but cost premiums still fell under 3% for most results up to and including Step 4. For the quadplexes, capital costs increase more significantly starting at Step 5 for Climate Zone 4 (6.1%). The story is similar for the Medium SFD archetype, with more prohibitive costs emerging for Step 5 in Climate Zones 6 (9.3%), 7a (12.1%), and higher.

- Builders of small SFDs will have the hardest time achieving the steps at lower costs. Based on the dataset and assumptions, cost premiums to reach Step 2 range from 0.4% to 0.6% in Climate Zones 4 and 8, respectively. Step 3 becomes costly to achieve in Climate Zone 7a at a 12.5% premium. Costs for achieving Step 4 start around 7% for Climate Zones 4 to 6, increasing in higher climate zones.

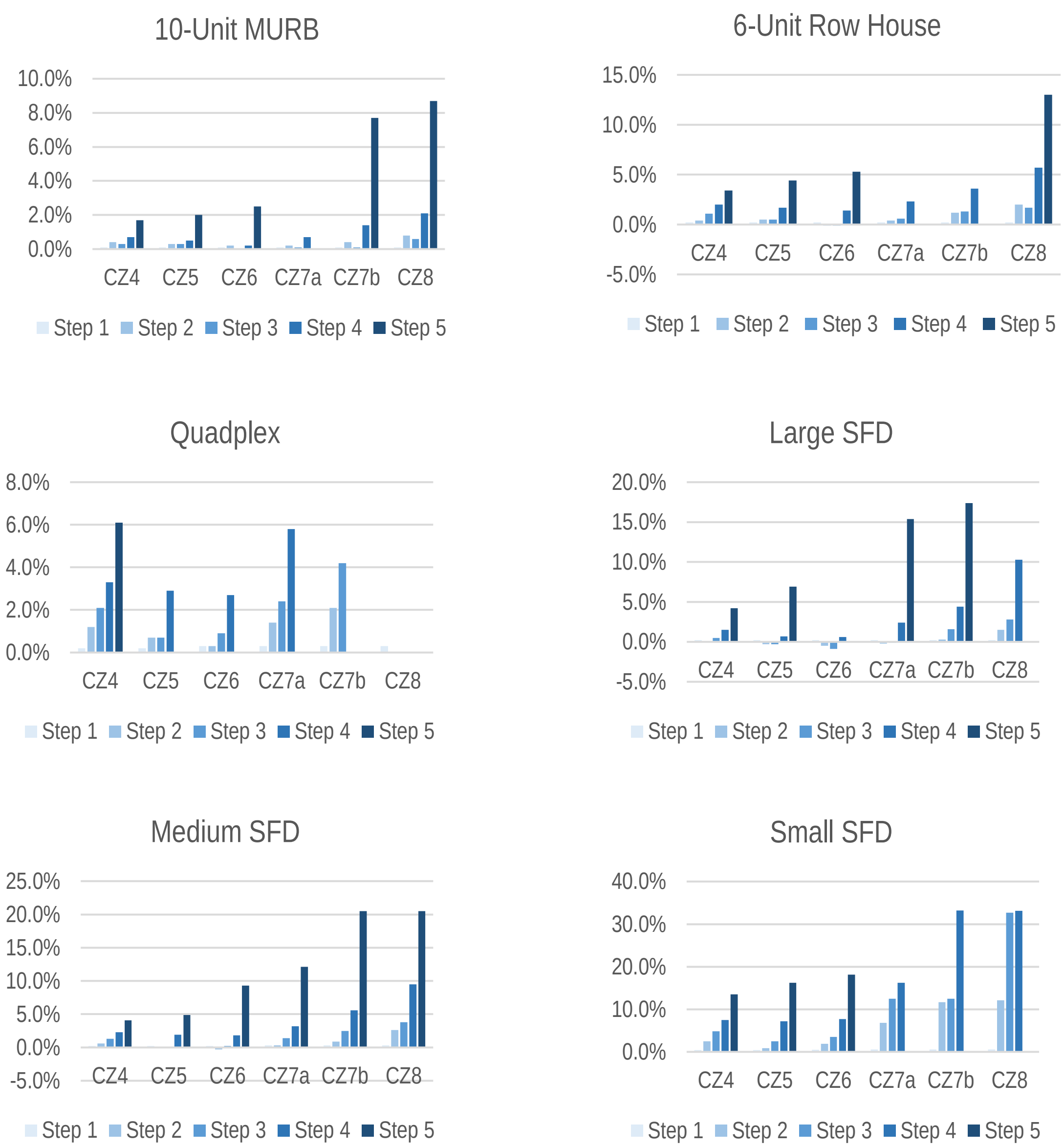

Figure 5: Lowest Incremental Capital Cost Premiums for all Part 9 Building Archetypes (% Change from BCBC)

Table 5: Lowest Incremental Capital Costs for Part 9 Buildings

Scenario		Total ($)						Per Square Meter ($/m2)						Percent Premium vs. BCBC (%)					
Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8
10 unit MURB	1	$4,250	$4,799	$5,218	$8,683	$8,683	$8,683	$3	$3	$3	$5	$5	$5	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
	2	$16,030	$13,008	$9,418	$13,302	$26,317	$47,608	$10	$8	$6	$8	$16	$29	0.4%	0.3%	0.2%	0.2%	0.4%	0.8%
	3	$11,135	$13,008	-$2,101	$5,116	$8,030	$36,530	$7	$8	-$1	$3	$5	$22	0.3%	0.3%	0.0%	0.1%	0.1%	0.6%
	4	$26,450	$20,771	$9,553	$40,698	$86,720	$123,849	$16	$13	$6	$25	$52	$75	0.7%	0.5%	0.2%	0.7%	1.4%	2.1%
	5	$66,350	$84,818	$111,766	- -	$694,167	$783,623	$40	$51	$68	- -	$419	$473	1.7%	2.0%	2.5%	- -	7.7%	8.7%
6 unit Row House	1	$2,650	$2,957	$3,190	$5,074	$5,074	$5,074	$3	$3	$3	$5	$5	$5	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	2	$7,905	$10,393	-$2,317	$9,610	$31,471	$51,966	$8	$10	-$2	$10	$31	$52	0.4%	0.5%	-0.1%	0.4%	1.2%	2.0%
	3	$18,575	$10,393	-$2,317	$15,971	$34,070	$45,913	$18	$10	-$2	$16	$34	$46	1.1%	0.5%	-0.1%	0.6%	1.3%	1.7%
	4	$34,645	$31,338	$27,798	$61,586	$96,628	$150,602	$34	$31	$28	$61	$96	$149	2.0%	1.7%	1.4%	2.3%	3.6%	5.7%
	5	$59,400	$83,464	$104,969	- -	- -	$516,992	$59	$83	$104	- -	- -	$513	3.4%	4.4%	5.3%	- -	- -	13.0%
Quadplex	1	$2,250	$2,512	$2,711	$4,322	$4,322	$4,322	$4	$5	$5	$8	$8	$8	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%
	2	$11,758	$6,910	$3,385	$19,873	$29,591	- -	$23	$13	$7	$39	$58	- -	1.2%	0.7%	0.3%	1.4%	2.1%	- -
	3	$20,005	$6,858	$9,484	$35,000	$60,617	- -	$39	$13	$18	$68	$118	- -	2.1%	0.7%	0.9%	2.4%	4.2%	- -
	4	$31,607	$29,162	$29,191	$82,511	- -	- -	$62	$57	$57	$161	- -	- -	3.3%	2.9%	2.7%	5.8%	- -	- -
	5	$58,355	- -	- -	- -	- -	- -	$114	- -	- -	- -	- -	- -	6.1%	- -	- -	- -	- -	- -
Large SFD	1	$1,550	$1,726	$1,859	$2,931	$2,931	$2,931	$3	$3	$4	$6	$6	$6	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	2	$930	-$3,006	-$5,049	-$3,062	$4,869	$22,683	$2	-$6	-$10	-$6	$10	$44	0.1%	-0.3%	-0.5%	-0.2%	0.3%	1.5%
	3	$5,080	-$3,006	-$9,694	-$2,033	$23,171	$41,735	$10	-$6	-$19	-$4	$45	$82	0.5%	-0.3%	-0.9%	-0.1%	1.6%	2.8%
	4	$14,390	$7,600	$6,588	$35,990	$64,694	$149,519	$28	$15	$13	$70	$127	$293	1.5%	0.7%	0.6%	2.4%	4.4%	10.3%
	5	$42,015	$73,499	- -	$222,704	$253,043	- -	$82	$144	- -	$436	$495	- -	4.2%	6.9%	- -	15.4%	17.4%	- -
Medium SFD	1	$1,100	$1,227	$1,324	$2,105	$2,105	$2,105	$5	$5	$6	$9	$9	$9	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%
	2	$1,010	$101	-$1,981	-$1,515	$2,893	$19,227	$4	$0	-$8	-$6	$12	$81	0.2%	0.0%	-0.4%	-0.2%	0.4%	2.6%
	3	$3,945	$101	-$1,610	$6,303	$14,932	$23,936	$17	$0	-$7	$27	$63	$101	0.8%	0.0%	-0.3%	0.9%	2.1%	3.3%
	4	$8,710	$7,596	$7,213	$19,475	$37,191	$69,417	$37	$32	$30	$82	$157	$293	1.8%	1.5%	1.3%	2.7%	5.1%	9.5%
	5	$17,485	$25,279	$50,840	$82,847	$143,566	$143,566	$74	$107	$215	$350	$606	$606	3.6%	4.9%	9.3%	12.1%	20.5%	20.5%
Small SFD	1	$1,000	$1,120	$1,211	$1,954	$1,954	$1,954	$10	$11	$12	$19	$19	$19	0.4%	0.4%	0.5%	0.6%	0.6%	0.6%
	2	$5,690	$2,134	$4,966	$23,929	$39,653	$41,155	$56	$21	$49	$235	$389	$403	2.4%	0.8%	1.9%	6.7%	11.7%	12.1%
	3	$11,145	$6,147	$9,059	$41,906	$41,906	$113,432	$109	$60	$89	$411	$411	$1,112	4.7%	2.4%	3.4%	12.5%	12.5%	32.7%
	4	$17,635	$18,063	$20,443	$54,264	$114,559	$114,183	$173	$177	$200	$532	$1,123	$1,119	7.5%	7.1%	7.7%	16.2%	33.2%	33.1%
	5	$28,815	$37,877	$44,700	- -	- -	- -	$283	$371	$438	- -	- -	- -	13.5%	16.2%	18.1%	- -	- -	- -

Note: As discussed in the full report, a secondary process was used to develop solutions the primary modelling process did not identify, typically for smaller buildings achieving higher steps in colder climate zones. The manual process required to generate these results prevented this project from identifying such outcomes for all missing solutions, as indicated by "- -".

NPV and Carbon Abatement Costs

As with Part 3 buildings, the study assessed the long-term value of adopting the Step Code to consumers and local governments interested in using the regulation as a climate action tool. This analysis was completed through a net present value (NPV) calculation that examined potential savings compared to additional costs over a 20-year period. In general, the results of the analysis show that larger buildings have higher and often positive NPVs, and that NPVs decrease as building area decreases, becoming primarily negative for SFDs. For example:

- Achieving Step 3 for the 10-Unit MURB archetype in Climate Zones 4 to 6 yields NPVs between $70/m^2 and $148/m^2, whereas the same steps and climate zones for the medium SFD yields NPVs between -$23/m^2 and -$4/m^2.
- The full set of optimized NPV outcomes shows a significant shift to using high insulation values when optimizing the results for long term savings (i.e. via NPV).
- There is also a tendency for archetypes to shift to natural gas-based heating and domestic hot water appliances away from electric systems due to their lower operating costs.
- Optimized NPV results generally correlate with higher GHG emissions outcomes than results that were optimized for construction costs only.

Table 6: Highest Net Present Value for Part 9 Buildings ($/m^2)

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8
10 Unit MURB	1	-$3	-$3	-$3	-$5	-$5	-$5
	2	$65	$100	$6	$208	$266	$301
	3	$70	$100	$148	$217	$271	$318
	4	$65	$101	$141	$193	$234	$229
	5	$45	$51	$69	--	$26	$53
6 Unit Row House	1	-$3	-$3	-$3	-$5	-$5	-$5
	2	-$5	-$7	$6	$3	-$20	-$31
	3	-$17	-$7	$6	-$6	-$3	-$5
	4	-$36	-$30	-$17	-$42	-$65	-$104
	5	-$54	-$75	-$85	--	--	-$135
Quadplex	1	-$4	-$5	-$5	-$8	-$8	-$8
	2	$47	$82	$124	$157	$26	--
	3	$21	$83	$111	$131	-$2	--
	4	-$7	$28	$59	$29	--	--
	5	-$42	--	--	--	--	--
Large SFD	1	-$3	-$3	-$4	-$6	-$6	-$6
	2	-$5	$4	$9	-$1	-$13	-$48
	3	-$16	$4	$8	-$12	-$45	-$194
	4	-$26	-$18	-$6	-$59	-$147	-$252
	5	-$67	-$131	--	-$407	-$457	--
Medium SFD	1	-$5	-$5	-$6	-$9	-$9	-$9
	2	-$6	-$8	-$3	-$7	-$27	-$58
	3	-$23	-$8	-$4	-$34	-$70	-$108
	4	-$45	-$39	-$32	-$88	-$183	-$330
	5	-$71	-$87	-$184	-$347	-$593	-$580
Small SFD	1	-$10	-$11	-$12	-$19	-$19	-$19
	2	-$77	-$29	-$57	-$222	-$392	-$384
	3	-$145	-$73	-$114	-$419	-$410	-$1,137
	4	-$184	-$195	-$228	-$597	-$1,162	-$1,152
	5	-$355	-$454	-$509	--	--	--

As NPV outcomes and their relative performance are often dependent on fuel choice, in many cases, initial investments cannot be recovered via lower energy costs, despite market maturity forces. Furthermore, an analysis of the *optimized* carbon abatement costs unfortunately does not yield actionable results, particularly in small archetypes. The reason for this is that small, low-cost interventions that achieve any measure of carbon emission reductions result in extremely high values that do not correlate well to overall greenhouse gas reductions. An approach that should be considered for future studies is to compare the relative carbon abatement potential for different suites or packages of ECMs, and explore the relative differences between them in terms of costs and impacts on GHG savings.

Table 7: Lowest Carbon Abatement Costs for Part 9 Buildings ($/tonneCO2e)

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8
10 Unit MURB	1	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs
	2	-$6,730	-$10,826	-$6,415	-$8,128	-$10,814	-$10,472
	3	-$8,979	-$10,826	-$12,108	-$11,774	-$12,527	-$11,374
	4	-$9,170	-$10,242	-$100,796	-$10,486	-$9,229	-$6,458
	5	-$324,591	-$134,319	-$916	--	-$243	-$468
6 Unit Row House	1	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs
	2	$250	$107	-$274	-$43	$100	$116
	3	$240	$107	-$274	$42	$13	$19
	4	$271	$247	$120	$150	$185	$246
	5	$313	$356	$319	--	--	$237
Quadplex	1	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs
	2	-$8,573	-$4,548	-$3,301	-$1,262	-$240	--
	3	-$892	-$7,579,449	-$7,351	-$1,580	$14	--
	4	$128	-$1,192	-$155,350	-$1,591	-	--
	5	$465	--	--	--	--	--
Large SFD	1	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs
	2	$86	-$563	-$15,414	$12	$94	$222
	3	$193	-$563	-$248	$80	$210	$355
	4	$206	$152	$46	$228	$375	$1,810
	5	$413	$594	--	$2,511	$2,819	--
Medium SFD	1	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs
	2	$198	$166	$122	$76	$153	$216
	3	$248	$166	$86	$213	$314	$349
	4	$304	$266	$212	$315	$416	$577
	5	$362	$403	$667	$830	$1,239	$1,070
Small SFD	1	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs	No change in GHGs
	2	$334	$280	$288	$550	$962	$789
	3	$416	$324	$366	$1,062	$876	$1,564
	4	$547	$520	$476	$1,005	$1,655	$1,574
	5	$1,091	$1,141	$1,053	--	--	--

Note: Negative carbon abatement costs indicate that GHG reductions are achieved alongside an economic benefit.

Adjusting for Climate

The costing analysis results for Part 9 buildings demonstrate that it is more costly to achieve the Step Code in colder climate zones. It is important to note that this is *also* the case for the building code, as the base building code is more stringent and expensive to meet, and has a higher cost multiplier.

To ensure the affordability of the Step Code performance requirements for Part 9 buildings in northern regions of the province, we recommend the province retain the original set of targets and adjust the approach to implementation. While additional efforts could be made to derive an ideal normalization methodology to correct for this issue, it should be noted that the economic implications and environmental benefits of applying the regulation for Part 9 buildings in these regions is somewhat limited. Where northern local governments elect to reference the Step Code in policy, we recommend they adopt lower steps (i.e. Steps 1 through 3) until costs decline.

Adjusting for Size

Performance-based frameworks with energy intensity metrics have often been shown to create challenges for smaller buildings to achieve performance targets. This can especially be the case in residential buildings, where major sources of energy consumption in the home are not dependent on its size.

We recommend that government adjust or moderate the implementation of the Step Code for smaller homes. Given that smaller homes consume less energy than larger homes in absolute terms, a local government that excluded small homes from compliance with the regulation would not significantly impact emissions reductions. As average home sizes are growing in British Columbia, there is no significant development pressure to build smaller homes, beyond municipalities that are actively encouraging laneway homes.

Illustrative Examples

To develop this costing study, over the better part of a year our team ran literally millions of calculations and developed hundreds of scenarios. As a result, the material in our report is dense, and we recognize that our findings can be challenging to visualize in “real-world” situations.

That’s why we have extracted data to produce these hypothetical scenarios. These examples aim to illustrate how the Step Code will impact construction costs for various building types in Surrey, Kamloops, and Prince George.

For the building types and climate zones used in these examples, all communities will find similar construction cost impacts—although building selling prices will differ due to land costs and other factors. In some cases, we have found situations where it is feasible for builders to see lower construction costs by building to higher levels of energy-efficiency than they would by building to code.

There are many different ways a builder can achieve a given step, and an underlying assumption of this study is that cost savings are a priority for builders and building owners. As such, cost-saving measures have been adopted in calculating the cost premiums or savings associated with meeting higher performance requirements.

We hope these examples are helpful to elected officials, local government staff, builders, and other decision makers reviewing this report.

Part 3 Examples: Large and Complex Buildings

The following examples illustrate how the Step Code would apply in large and complex buildings, such as large multi-unit residential buildings, office towers, and retail stores. Provincial policy[1] states that in the initial years (2017-2020) of the implementation of the Step Code, local governments should only require lower steps, and adopt the upper steps only in specific circumstances and in conjunction with appropriate incentives.

Wood Frame Multi-Unit Residential Building (MURB)

Building a six-storey building to the requirements of Steps 1, 2 and 3 of the Step Code in Surrey will incur a construction cost premium of between $100 and $1,000 per unit. Construction costs for higher efficiency buildings are generally lower for MURB than for single-family detached homes, as apartment and condo units share common walls.

Location: Surrey
Climate Zone: 4
Unit Size: 730ft^2
Sample Sales Price per Unit: $270,000 - $730,000

Step 1: A construction cost premium of $100 per unit above the cost of building to the standard modelling requirements of the *BC Building Code*.
Step 2: A 0.5 percent construction cost premium – about $790.
Step 3: This level of energy efficiency performance may add about $970 to the per-unit build cost.
Upper Step: Building to the very high-performance levels of the Step 4 may entail a construction cost premium of $4,215.

High-Rise Condo Tower

Building a 30-storey concrete condo tower to the requirements of the Steps 1 and 2 in Surrey will incur a construction cost premium of between $100 and $790 per unit.

Location: Surrey
Climate Zone: 4
Unit Size: 730ft^2
Sample Sales Price per Unit: $270,000 - $730,000

Step 1: A construction cost premium of $100 per unit above the cost of building to the standard modelling requirements of the *BC Building Code*.
Step 2: A 0.4 percent construction cost premium, about $790.
Steps 3 & 4: Building to the high performance levels of upper steps may entail a construction cost premium of $1,675 (Step 3) to $5,025 (Step 4).

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[1] For more information on the BC Step Code, visit: http://www2.gov.bc.ca/gov/content/industry/construction-industry/building-codes-standards/energy-efficiency/energy-step-code

Office Building

A developer building an office block in Surrey to the performance requirements of Step 2 will save more than $100,000 over meeting the existing prescriptive approach of the BC Building Code. Building to the upper Step 3 is comparable with conventional building practices.

Location: Surrey
Climate Zone: 4
Total Heated Floor Area: 193,750ft²
Construction cost: $51.7 million


Source: MGA

Step 1: A construction cost premium of $25,000 above the cost of building to the standard modelling requirements of the *BC Building Code*.
Step 2: Building to Step 2 may save a developer $104,400, compared with the usual approach of meeting the *BC Building Code*.
Step 3: Building to the upper step level of Step 3 can be achieved with no cost premium above and beyond conventional construction.

Freestanding Retail Store

A developer building a freestanding retail store in Surrey to Steps 1 and 2 will incur a construction cost premium of between $25,000 and $54,500.

Location: Surrey
Climate Zone: 4
Total Heated Floor Area: 48,459ft²
Construction cost: $7.75 million


Source: REA

Step 1: Building to Step 1 may entail a construction cost premium of $25,000 above the cost of building to the standard modelling requirements of the *BC Building Code*.
Step 2: A cost premium of $54,500.
Step 3: Building to the upper step level of Step 3 may entail a cost premium of $140,000.

Part 9 Examples: Houses and Small Buildings

The following examples illustrate how the Step Code would apply in residences and small buildings. Provincial policy states that in the initial years (2017-2020) of the implementation of the Step Code, local governments should only require the lower steps (1-3), and adopt upper steps (4 & 5) only in specific circumstances and in conjunction with appropriate incentives. *All new home prices were sourced using Multiple Listing Service searches in September 2017, and are expressed in 2017 costs. Both are subject to change but offer a fair approximation for illustrative purposes.*

Row Houses (i.e. Townhomes)

Building a six-unit row house project to the lower steps of the Step Code in Surrey will increase the construction cost of each unit by between a few hundred and a few thousand dollars for lower steps, and $5,500 to $9,400 for higher steps. For most steps, cost premiums are actually lower in Prince George and Kamloops, as buildings are able to meet the Step Code with lower-cost building envelopes than those prescribed by the BC Building Code. For example, in Prince George, Steps 2 and 3 can be built for a lower construction cost than to the BC Building Code.

Source: House Plans

Location: Surrey **Climate Zone:** 4
Unit Size: 1,720ft^2 **Sample Sales Price per Unit**: $550,000 - $800,000

Step 1: A construction cost premium of $560 per unit above the cost of building to the BC Building Code.
Step 2: A 0.4% construction cost premium, about $1,250 per unit.
Step 3: This level of energy efficiency performance adds about $2,950 to the per-unit build cost.
Steps 4 & 5: Building to the very high-performance levels of upper steps may require non-conventional building practices, so our modelling revealed a construction cost premium of between $5,500 (Step 4) and $9,400 (Step 5) per unit.

Location: Kamloops **Climate Zone**: 5
Unit Size: 1,720ft^2 **Sample Sales Price per Unit**: $410,000 - $435,000

Step 1: A construction cost premium of $470 above the cost of building to the prescriptive requirements of the *BC Building Code*.
Step 2: Meeting this step may add about 0.5 percent, or about $1,650, to each unit's build cost.
Step 3: This level of energy-efficiency performance may add about $1,650 to the per-unit build cost.
Steps 4 & 5: Building to the very high-performance levels of the Upper Steps may require non-conventional building practices that may not be as familiar to builders in the Interior. Our modelling indicates a construction cost premium of between $4,975 (Step 4) and $13,200 (Step 5) per unit.

Location: Prince George **Climate Zone**: 6
Unit Size: 1,720ft^2 **Sample Sales Price per Unit**: $320,000 - $360,000

Step 1: A construction cost premium of $500 above the cost of building to the prescriptive requirements of the *BC Building Code*.
Step 2: Increasing performance to Step 2 may result in a construction **cost savings** of about $365 per unit due to the building being able to meet the Step Code requirements with equipment and building materials lower cost than the BCBC prescriptions.
Step 3: As with the next-lower-step, building to this level may **save** builders about $365 per unit compared with the costs of a conventionally constructed home.
Step 4 & 5: Building to the very high-performance levels of the Upper Steps may require new building practices and materials. Our modelling revealed a construction cost premium of between $4,400 (Step 4) and $16,650 (Step 5) per unit.

Medium-Size Single Family Dwelling


Source: realspace

Building a single-family home project in Surrey to the lower levels of the Step Code will increase the construction cost by between $1,000 and $3,950. Construction costs of the same-size building in Prince George and Kamloops will be significantly lower; in Prince George, using Step 2 will actually save builders money over not doing so. This is because the buildings can meet the Step Code with building envelopes that cost less than BCBC-prescribed envelopes.

Location: Surrey **Climate Zone:** 4
Unit Size: 2,551 ft²
Sample Sales Price: $800,000 - $2,200,000
Step 1: A construction cost premium of $1,100 above the cost of building to the prescriptive requirements of the *BC Building Code*.
Step 2: A 0.2 percent construction cost premium, about $1,010.
Step 3: This level of energy efficiency performance may add about $3,945 to the build cost.
Step 4 & 5: Building to the very high-performance levels of the Upper Steps may require non-conventional building practices. Our modelling revealed a construction cost premium of between $8,700 (Step 4) and $17,485 (Step 5).

Location: Kamloops **Climate Zone:** 5
Unit Size: 2,551ft²
Sample Sales Price: $410,000 - $700,000
Step 1: A construction cost premium of $1,225 above the cost of building to the prescriptive requirements of the *BC Building Code*.
Step 2: A construction cost premium of <0.1%, about $100.
Step 3: This level of energy efficiency performance may add about $100.
Steps 4 & 5: Building to the Upper Steps may call for non-conventional construction practices, so our modelling revealed a construction cost premium of between $7,600 (Step 4) and $25,275 (Step 5).

Location: Prince George **Climate Zone**: 6
Unit Size: 2,551ft²
Sample Sales Price: $400,000 - $500,000
Step 1: A construction cost premium of $1,325 above the cost of building to the prescriptive requirements of the *BC Building Code*.
Step 2: A 0.4 percent construction **cost savings**, about $1,980.
Step 3: This level of energy efficiency performance may result in a cost saving of about $1,610.
Steps 4 & 5: Building to the very high-performance levels of the Upper Steps may require non-conventional building practices, so our modelling revealed a construction cost premium of between $7,210 (Step 4) and $50,840 (Step 5).

Risks and Challenges

The results of the analysis suggests that in Climate Zones 5, 6, 7a and 7b, builders can actually achieve Part 9, Step 2 of the Step Code with R-values that are lower than those identified in *BC Building Code*. We also found scenarios that buildings may be constructed using walls that fall below an R22 effective level of performance to achieve Steps 3 and 4. These instances are counter to one of the central principles adopted in the development of the Step Code: that cost-effective and durable high performance envelopes and passive design solutions should be emphasized over comparatively less durable mechanical strategies to improve energy efficiency.

Local governments interested in addressing this issue might do so by explicitly specifying that walls cannot fall below the minimum prescribed requirements of the *BC Building Code*. Local governments may also wish to consider zoning policies that allow for wall thickness exclusions or floor area ratio relaxations, to allow for better performing walls. The cities of Vancouver and New Westminster have already implemented this practice to effectively remove the incentive for builders to construct thinner walls as a way of increasing total saleable floor area.

Ventilation

Results demonstrate that the ventilation assumptions applied in modelling buildings can significantly impact energy performance. To ensure consistent results, we recommend the province develop guidelines for compliance with both the BC Building Code and the Step Code, and distribute those guidelines to energy advisors who model ventilation.

Overheating & Fire Safety, and Building Durability

- Designers can mitigate risks of overheating through passive-ventilation strategies and through design strategies that limit solar gains, or by specifying mechanical cooling solutions, such as heat pumps.
- We found Step Code implementation did not increase risk of fire.
- While poor design or construction is always a risk that can only be mitigated with proper training and management, the proposed energy performance thresholds present no more of a risk than current construction practices.

The City of Vancouver's Zero Emissions Building Plan

Released in 2016, the City of Vancouver's Zero Emissions Building Plan (ZEBP) uses a very similar set of metrics and methodology as those used in the Step Code for Part 3 buildings. The ZEBP differentiates between high and low-rise MURB and provides separate sets of Step Code performance requirements for each building type. In addition to energy use and thermal energy demand intensity performance requirements, the ZEBP also includes thresholds for Greenhouse Gas Intensity (GHGI).

With respect to the costs and outcomes of TEDI and TEUI thresholds, performance requirements between the two codes are very similar. When we tested the High-Rise MURB archetype (the form with the largest Step Code cost impacts among Part 3 buildings) against the City of Vancouver's performance requirements, we noted a capital cost increase of less than 1% in all cases but one. Energy and greenhouse gas savings were also greater when the City of Vancouver's framework was applied.

Conclusion and Recommendations

The conclusions and recommendations summarized at the end of the report focus on high-level insights based on a detailed review of the data generated for the report. Recommendations for local governments and the Province include the following:

- *Apply Part 3 Climate Zone 4 targets across the province*
  Given the relatively low cost of achieving the Step Code for Part 3 buildings, and the comparable costs across regions, the performance requirements for Step 4 of the Step Code should be applicable to Climate Zones 4, 5, 6 and 7a.

- *Begin at Step 3 of the Step Code*
  We recommend British Columbia local governments adopt Step 3 for both Part 3 and Part 9 buildings as a progressive and affordable base code. The projected impacts on cost are lower than typical variations in construction rates from year to year over the past ten years, and are unlikely to impact housing affordability based on the data available. As the costs of going to Step 3 are marginal when compared to Step 2, adopting Step 2 in Climate Zones 4, 5, and 6 may in fact miss an opportunity to avoid built-in obsolescence and create a larger need for future energy retrofit.

- *Adjust implementation for disadvantaged building types and colder Climate Zones*
  Two archetypes of those tested that were disproportionately disadvantaged by the Step Code performance requirements were Small SFD (including Laneway Homes) and the relatively small Quadplex. Modestly sized Duplexes will likely have similar results to the Quadplex typology. For these typologies, we advise local governments to consider targeting lower levels of the Step Code (Steps 2 and 3) in Climate Zones 6 and lower. In colder Climate Zones (7 and above), the application of the Step Code should be limited to Steps 1 and 2, and re-evaluated in 5 years.

- *Harmonize performance requirements with the City of Vancouver's Zero Emissions Building Plan*
  The Province and the City of Vancouver should make efforts to harmonize their performance thresholds within the Step Code. The metrics are very similar and have similar costs.

- *Add a Greenhouse Gas Intensity (GHGI) Target*
  The analysis conducted in this report demonstrated that higher GHG emission outcomes would result from advancing to a higher step of the BC Energy Step Code wherever buildings shift from electricity to natural gas for space heating and/or domestic hot water. As a result, we recommend government consider exploring the development of a GHGI metric in the Step Code, or provide some official guidance on the topic to ensure consistency. It may be possible to apply a GHGI metric with little or no extra cost.

- *Further analyze costs of fuel switching to electricity and achieving deep GHG reductions*
  The findings indicate that fuel choice has a significant impact on GHG emissions reductions, where shifts to natural gas limit GHG reductions and can even increases GHGs, including at Steps 3, 4, and 5. Considering the need to significantly reduce GHGs from buildings to achieve the Province's GHG reduction target set out in the Climate Action Plan, an important follow-up analysis would involve focusing more specifically on the relationship between fuel switching and GHG reductions, and its implications for upfront capital costs, annual fuel costs, and the Step Code's MEUI and TEDI requirements. The existing dataset should be very valuable in this regard, and allow the Province to investigate items of interest, such as the energy efficiency improvements required to offset increased costs from switching to electricity.

More information:

energystepcode.ca

bchousing.org