ENERGY

STEPCODE

BUILDING BEYOND THE STANDARD

2017 Metrics Research
Full 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.

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1 INTRODUCTION

1.1 The BC Energy Step Code

The BC Energy Step Code (the "Step Code") is an amendment to the BC Building Code (BCBC) that provides a performance-based path intended to support a market transformation from current energy efficiency requirements to net zero energy ready buildings by 2032. The Province has committed to taking these incremental steps as a part of its overarching commitments to improving energy efficiency in the built environment.

The path to net zero energy ready buildings is set out through a series of increasingly stringent requirements for energy use, thermal energy demand, and airtightness. The performance requirements that have been set were the result of a lengthy consensus-building process among a number of key stakeholders from across the province, and supported by energy modelling and analysis. The process of establishing the Step Code took a period of approximately two years through the efforts of the Energy Efficiency Working Group and the Energy Step Code Council, and is still ongoing.

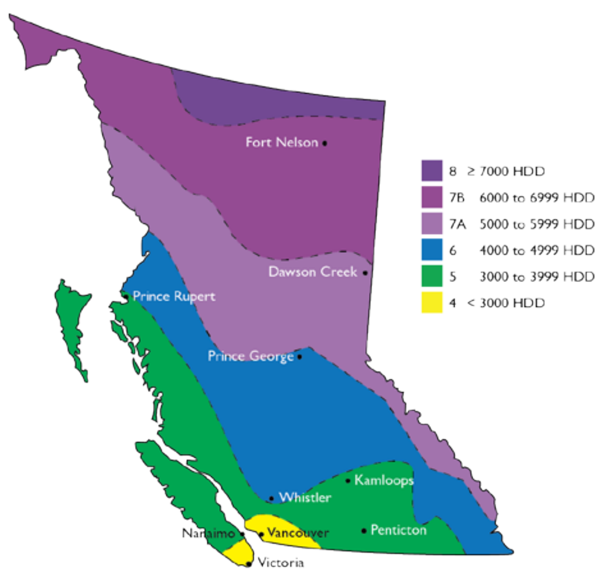


Figure 1: British Columbia Climate Zones, based on heating degree days (HDD).

One of the central purposes of the Step Code is to provide province-wide consistency and predictability in local government building energy and emissions policies and bylaws. As of December 15, 2017, local governments regulated by the BC Building Act and Community Charter (i.e. all but Vancouver) that wish to require higher energy efficiency standards may only reference the Step Code. The Step Code applies to any new construction of Part 9 residential buildings province-wide, with different performance requirements set for Climate Zones 4, 5, and 6/7a/7b/8 (see Figure 1). The Step Code also applies to Part 3 multi-unit residential and large commercial buildings (Group D & E) in Climate Zone 4. As a technical regulation, it is a voluntary compliance option for builders, owners, and local governments, who can elect to adopt higher or lower Steps. Builders can also comply with the Step Code in lieu of s9.36 or the National Energy Code for Buildings (NECB)/ASHRAE.

1.2 Study Purpose and Scope

The purpose of this study is to explore and anticipate the implications of the Step Code in terms of its impact on the design and construction sector. More specifically, the study was designed to:

- Identify potential design solutions and other technical responses to the Step Code (e.g. design and construction practices);
- Anticipate implementation impacts of the proposed metrics and targets, including both benefits and outcomes relative to building size, climate zone, greenhouse gas (GHG) emissions, peak electrical demand, first and operating costs, and lifecycle GHG abatement costs; and
- Identify any modifications to the Step Code necessary to ensure that it effectively and efficiently achieves the desired outcomes, while mitigating negative impacts.

In covering the above, the report identifies both areas in which effectiveness and efficiency may be improved using regulatory changes, as well as opportunities for local governments to better implement the Step Code in the absence of such regulatory changes. In scoping the project, a set of ten multi-part research questions was developed, to be answered by the consultant team via a combination of research, energy modelling, and cost and sensitivity analyses. The consultant team used these questions alongside the guiding objectives above to select specific methods, identify databases to be developed, guide the analysis of modelling results, and evaluate any anticipated implementation impacts and challenges.

1.3 Oversight Committee and Consultant Team Members

This project was led by BC Housing, in collaboration with and with funding and/or in-kind support from the following individuals and institutions:

- Wilma Leung, BC Housing (Project Lead)
- Gary Hamer, BC Hydro
- Zachary May, BC Building and Safety Standards Branch
- Patrick Enright, City of Vancouver, and
- Alex Ferguson, Natural Resources Canada

All analysis was conducted by the following consultant team members:

- Integral Group (Consultant Team Lead)
- Morrison Hershfield
- E3 Eco Group

All work received input from Oversight Committee members and Dr. Remi Charron, an energy modeller with specific expertise in applications relevant to the project. Results also received input from expert stakeholders representing local governments, utilities, and construction-related community and industry associations across British Columbia.

1.4 Building Energy Modelling

The Step Code is a performance-based framework, which by definition is a flexible approach to compliance. A key challenge in researching compliance with performance-based codes is that there is a vast number of potential solutions to compliance. Identifying one, two, or even a dozen paths to compliance does not adequately address market variations in construction that may be impacted by the proposed Step Code. As such, a much larger set of potential outcomes must be explored.

To overcome this challenge, a large-scale parametric analysis (or “options analysis”) was conducted, a process that allows for the analysis of hundreds of thousands of design possibilities for each building archetype to gain deeper insight into compliance with the Step Code. The large data can be analyzed using various techniques to identify opportunities with the lowest incremental capital costs, best life cycle opportunities, emission reduction potential, design constraints, market segment challenges, and impacts on other potential building outcomes not currently measured by the Step Code.This parametric analysis was key to answering many of the research questions posed by this study, including those related to potential building costs and the testing of different design strategies in particular. Specifics on the approach and software used to model the building archetypes explored in this study are provided in more detail in the sections below. Note that all GHG savings noted in the document are operational carbon emissions, and do not include any embodied carbon metrics.

Table 1: BC Step Code Metrics Research Questions & Methods

1	• What existing and proposed building archetypes will combine to establish a reasonable collection of building archetypes to be used in the modelling and analyses necessary to adequately explore and answer each of the research questions in this project? Why is this adequate?
	• How would builders achieve the performance targets established in the Step Code for each of the building types, climate zones, building and dwelling sizes, and common construction styles?
2	• How do the proposed intensity metrics impact small and large buildings, and dwelling units?
	• What is the typical window to wall ratio that is required to achieve the targets established in the Step Code? What impact may building and dwelling size make?
3	• What outcomes (GHG emissions, building energy use and peak demand, and envelope construction) are the proposed targets in the Step Code likely to achieve?
	• Are the outcomes equitable across climate zones, building types and dwelling sizes?
	• What options are there to address any undesirable outcomes and what difference would these options make?
4	• What are the anticipated first and operating costs, and life-cycle cost per abated tonne of carbon, from the implementation of these metrics and targets across climate zones, building types and dwelling sizes?
	• What conventional archetypes should or should not be used to evaluate the practical and financial impacts of the Step Code? Are unique archetypes required for different building sizes, levels of performance, or climate zones? Are certain archetypes subject to 'performance ceilings' whereby they cannot attain Step 4 or Step 5 performance levels? If so, why?
5	• Would the proposed Part 9 metrics and targets in Step 2 risk resulting, in some cases, in a building envelope less than the BCBC 2012 prescriptive requirements shown in the Illustrated Guide on Energy Efficiency Requirements for Houses in B.C.?
	• Would the proposed Part 9 metrics and targets in Step 3 and Step 4 risk resulting, in some cases, in a building envelope less than that shown in the Illustrated Guide for R22+ Effective Walls in Wood-Frame Construction in B.C.?
6	• How do the metrics used in the Step Code align with existing energy benchmarking and reporting programs, such as Energy Star Portfolio Manager and the EnerGuide Rating System (ERS)?
7	• What standards or requirements referenced in the Building Code, particularly ventilation standards, need to be reviewed and/or modified to ensure that they are serving the Step Code appropriately?
8	• What are the potential risks or unintended outcomes associated with the Step Code targets?
	• Is there a risk of overheating due to solar heat gain and does the Step Code provide adequate measures to avoid overheating? Under what conditions is overheating a risk?
9	• Are the Step Code metrics effective in gauging building energy use, peak demand and GHG impact, when renewables, waste energy, district energy and other energy sources are being used, or when there are electric vehicle charging requirements? If not, what options are there to improve effectiveness?
10	• Are the proposed metrics and targets for Part 9 residential buildings applicable and effective for Part 9 non-residential buildings? Are there occupancy types that will have particular difficulty with these metrics and targets?
	• Are the proposed metrics and targets for Part 3 buildings applicable and effective for Part 9 non-residential buildings? Are there occupancy types that will have particular difficulty with these metrics and targets?

1.5 Modelling Part 3 Buildings

1.5.1 Part 3 Archetypes

As above, the archetypes selected for this study were initially defined by the framework of the Step Code, which defined Total Energy Use Intensity (TEUI) and Thermal Energy Demand Intensity (TEDI) performance requirements for Multi-Family buildings, Commercial Office, and Big Box Retail buildings (see Table 2). One base building per category was modelled, with the exception of Multi-Unit Residential Buildings (MURB) where both a wood frame mid-rise and high-rise scenario were modelled. The base building attributes were developed in consultation with the Oversight Committee and based on project experience by both the Committee and the consultant team.

At present, the Step Code only addresses two classes of Part 3 buildings, each with a separate performance limit: Residential and Commercial/Mercantile. However, due to the significant diversity within each of these building types, it was determined that one archetype for each class would not be appropriate to answer all of the research questions. For Commercial/Mercantile, two separate archetypes were developed: Commercial Office and Retail. While the Step Code requires these two building types to meet the same targets, they can have very different characteristics. In total, four archetypes were modelled with the following characteristics (see Figures 2-5 for examples of each):

Archetype	Details
• Low-Rise MURB	Variable characteristics to represent the range of MURBs in the marketplace (see below for more detail), 90% suites, 10% common area
• High-Rise MURB	Variable characteristics to represent the range of MURBs in the marketplace (see below for more detail), 90% suites, 10% common area
• Office	Market, 18,200m^2, 10 storeys, 790 people, 155 parking spaces
• Retail (big box)	Market, 4,500m^2, 1 storey, 150 people

Table 2: Proposed Step Code Targets - Part 3 Buildings in Climate Zone 4
(Source: Energy Step Code Implementation Recommendations, August 2016)

	Energy Modelling & Airtightness Testing	Thermal Energy Demand Intensity Target (kWh/m^2/yr)	Total Energy Use Intensity Target (kWh/m^2/yr)	Estimated Annual Energy Savings (over BCBC Baseline)	Estimated Cost Impact (% Increase in Construction Costs)
Multifamily Residential (MURB)					
Step 1 Enhanced Compliance	Required	No target	No target	Up to 20%	0-2%
Step 2	Required	45	130	Up to 40%	2-5%
Step 3	Required	30	120	Up to 50%	5-10%
Step 4	Required	15	100	Up to 60%	Insufficient data
Commercial (Group D & E)					
Step 1 Enhanced Compliance	Required	No target	No target	N/A	N/A
Step 2	Required	30	150	N/A	N/A
Step 3	Required	20	120	N/A	N/A

For Residential Part 3 buildings, a number of different archetypes could be used that represent the current BC market. However, instead of defining many, discrete residential archetypes, one amorphous archetype was developed for this study. This single archetype was programmed with the ability to modify key characteristics and performance drivers to reflect the province's different residential market segments. The key program characteristics were selected based on their potential impact with the absolute metrics in the Step Code, and include design attributes not typically included within the list of energy efficiency measures. These include:

- Shape;
- Occupancy density (to mimic variations in suite size);
- Combustible (wood frame) vs. non-combustible (concrete) construction; and
- Process loads.

Details on each one are provided in the next section.

Figure 2: Example of a Low-Rise MURB
(Source: Cor)

Figure 3: Example of a High-Rise MURB
(Source: KPF)

Figure 4: Example of a Commercial Office Building
(Source: MGA)

Figure 5: Example of a Retail Building
(Source: REA)

1.5.2 Impact of Program Variations on Step Code Compliance

This section presents details on select program variations that were used in modelling Step Code compliance for Part 3 buildings. A full summary of variations is presented in Table 3.

Table 3: Summary of Program Variations for Part 3 Buildings

Program Variation	Options
Shape / Massing	VFAR (MURB only), values ranging from 0.4 to 1.2
Occupancy Density	o Three values were modelled in MURB as surrogates for suite size ▪ High – 25.2m^2/p (ex. 25m^2 SRO/studio, 50 m^2 1 bed, 75m^2 2 bed) ▪ Mid – 28.8m^2/p (ex. 29m^2 SRO/studio, 58m^2 1 bed, 87m^2 2 bed) ▪ Low – 40.4m^2/p (ex. 40m^2 SRO/studio, 80m^2 1 bed, 121m^2 2 bed) o Two values were modelled in Commercial Office to represent the typical value *and* double the typical value to represent denser offices, such as call centers); ▪ Default – 20m^2/p, 7.5 W/m^2 plug load ▪ Double – 10m^2/p, 15 W/m^2 plug load o Two values were modelled for Retail Buildings to represent and big box store, and a mall ▪ Big Box – 100% Retail ▪ Mall – 40% Retail, 30% Warehouse, 20% Concourse, 5% Dining, 5% Food Prep
Ventilation Standards	62-2001 or 62.1-2010 (MURB only)
Process Loads	In the form of IT/data loads at 1, 2.2 and 11 W/m^2 for Commercial Office only
Construction Type	Wood frame and Concrete

Building Shape and Massing

A building’s vertical surface area to floor area ratio (VFAR) is a significant influential factor on the heating energy use of a building, especially when the TEDI target is normalized for floor area. This metric is similar to a more common metric of surface area to volume ratio. However, in the BC context for MURB buildings, the majority of heat loss occurs in the vertical surface areas because walls and windows have significantly higher U-values than roofs, and floors are typically over below-grade parkades with lower temperature differences. As such, VFAR has a more direct relationship with TEDI than surface area to volume ratio and has been used as the primary shape metric.

The majority of building codes render the VFAR metric compliance-neutral, by using a reference building with the same geometry as the proposed building. However, absolute EUI and TEDI targets can shift the focus towards optimizing a building’s form factor to improve performance. The VFAR for a sample of high- and low-rise MURB projects in British Columbia and across Canada was calculated, and found that the majority of projects fall within the range of 0.5 to 0.65 VFAR. Floor plate size and level of articulation were found to be the principal factors affecting VFAR, assuming floor-to-floor heights are consistent.

Table 4 shows the VFAR for a selection of building shapes and floor plate sizes. Very small or narrow buildings will have elevated VFAR and will likely require improved envelope systems to compensate for high vertical surface area. A single family detached home typically has a VFAR between 1.2 and 1.5.

Table 4: VFAR for Example Building Shapes and Floor Plate Sizes

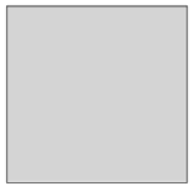
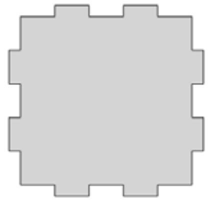
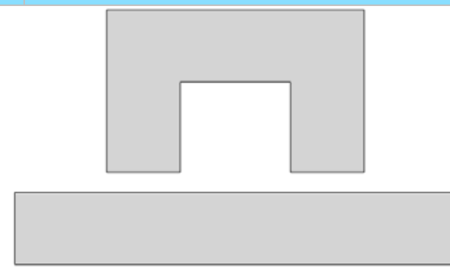
Floor Plate Size	Building Shapes		
	Square	Articulated	Narrow
			
600m²	0.49 VFAR	0.59 VFAR	0.7 VFAR
400m²	0.6 VFAR	0.72 VFAR	0.86 VFAR

Figure 6 demonstrates the impact of VFAR on a MURB's EUI and TEDI. Except for VFAR, the design parameters are identical and represent solutions that would comply with Step 2 for buildings with 0.6 VFAR. Doubling VFAR, from 0.5 to 1, more than doubles TEDI. The absolute change in TEDI is larger in Climate Zone 7 than 4, however the percentage increase in TEDI is largest for Climate Zone 4 because the wall and window heat loss is proportionally greater to other heating loads such as ventilation and infiltration. The impact on building energy use is similar for both Climate Zone 4 and 7, with a 40% increase in EUI with VFAR 1 vs. VFAR 0.5. Assuming a VFAR of 0.6 as typical, 20% TEDI savings and 7% EUI savings are possible by reducing VFAR to 0.5, which can be achieved by designing with less articulation, more compact or square shapes, or larger floorplates. All solutions presented elsewhere in this report for Part 3 MURB assumes a VFAR of 0.6.

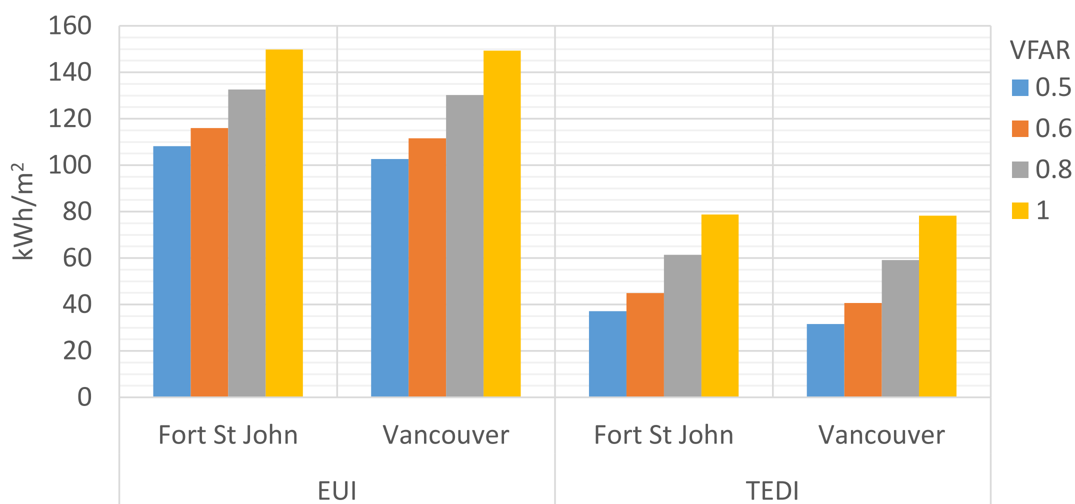


Figure 6: Impact of VFAR on MURB EUI and TEDI

Figure 7 shows the impact of window-to-wall ratio (WWR) on a MURB's EUI and TEDI. For other building parameters, the solutions used are those required to comply with Step 2 at 40% WWR in Climate Zone 4 and 20% WWR in Zone 7. The effect of WWR in Climate Zone 7 appears smaller than in Climate Zone 4 because the Climate Zone 7 solution includes higher performance glazing, which mitigates the impact of higher glazing ratios. For reference, the NECB prescriptive path requires a maximum WWR for a location based on local heating degree days, which varies from 40% in Climate Zones 4 and 5 down to 20% in Climate Zone 8.

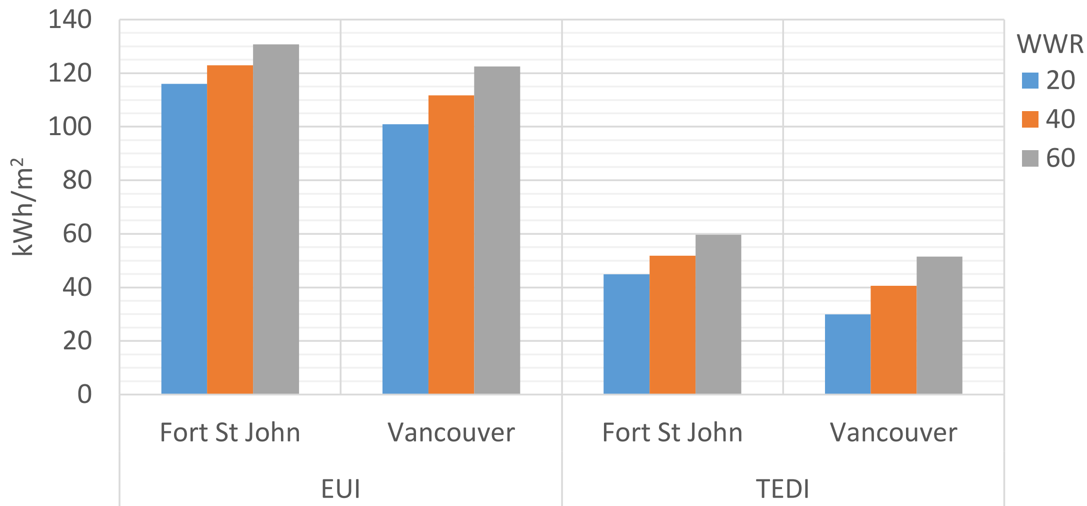


Figure 7: Impact of WWR on MURB EUI and TEDI

Occupancy Density and Process loads

MURB occupancy density typically falls within the range of 25 to 30m^2/person, with lower densities found in very large, normally luxury apartments. A value of 25m^2/person is a very high occupancy case representing an 800ft^2 two bedroom, a 540ft^2 one bedroom, or a 270ft^2 bachelor apartment. While some MURB may have a selection of suites at high density, typically buildings will also have some lower density suites available.

While higher occupancy densities do produce more internal heat gains, the ventilation air requirement also increases, which produces a small net effect on TEDI, as show in Figure 8. The principal impact of higher occupancy density is increased domestic hot water heating energy, on EUI, which can be mitigated by purchasing low flow fixtures and installing drain water heat recovery. Depending on the energy efficiency of other building components, DHW can make up 12% to 40% of total energy use, meaning a 50% increase in occupancy can produce a 6% to 20% increase in EUI. For buildings that are otherwise energy efficient, occupancy density will have a larger impact on energy use.

For Commercial Office buildings, the difference between the default and double occupancy case is primarily due to increased plug load affecting total energy use. TEDI is slightly decreased at double occupancy, as increase occupant heat gain and plug load counteracts increased ventilation requirements. The doubled plug loads in office spaces increases overall EUI by around 25%, shown in Figure 9. This increase typically has little effect on a buildings ability to meet Step 2 of the code, but Step 3 may requirement additional energy savings measures. Incorporating additional process loads, such as IT loads, has a similar effect. . It should be noted that modelled occupancy in commercial buildings is standardized by the BC Energy Step Code's referenced Energy Modelling Guidelines. The increased occupancy and plug load scenarios are intended to show the actual operating impact of atypical occupancies in commercial buildings. These buildings will not be impacted with respect to compliance, as modelled inputs will need to align with the Energy Modelling Guidelines.

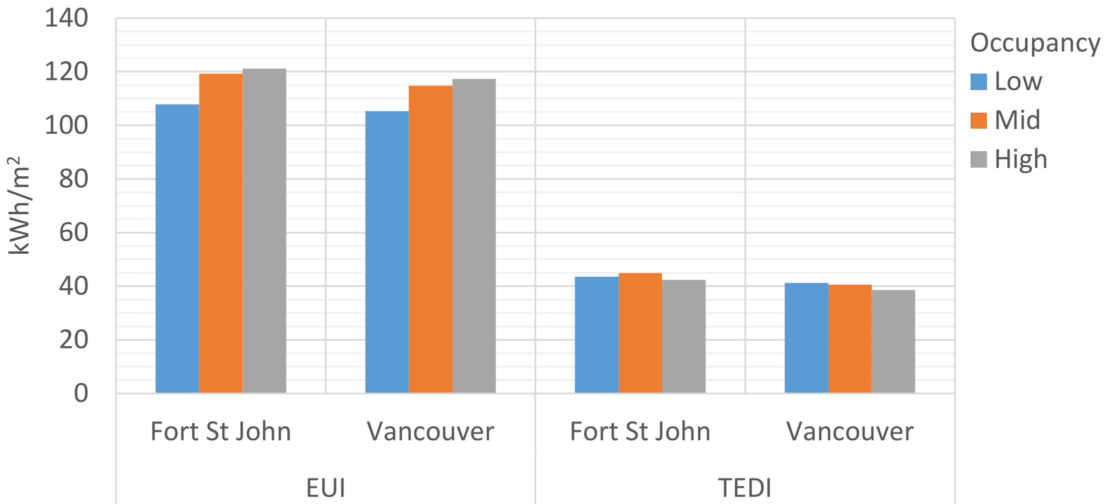


Figure 8: Impact of Occupancy Density on MURB EUI and TEDI

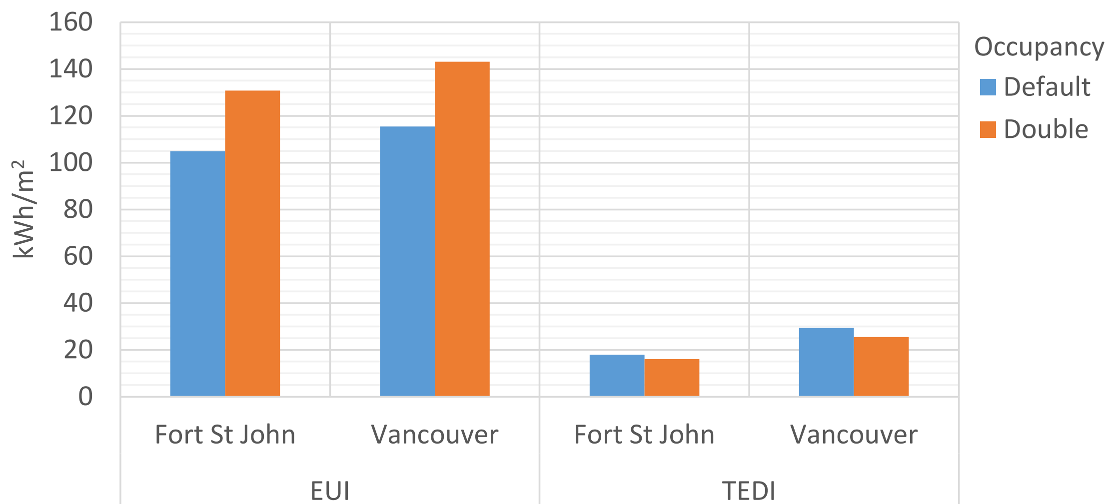


Figure 9: Impact of Occupancy Density on Commercial Office EUI and TEDI

For Retail buildings, a big box, ground floor or strip retail typically have higher plug and lighting power densities and ventilation requirements than a mall with mixed-space use. In warmer climates, the internal heat gains reduce TEDI for the big box store-type retail, but in colder climates, the cold ventilation air negates the internal heat gain benefit making it more in line with the mall occupancy scenario, show in Figure 10. The mall has a higher domestic hot water load, due to the presence of food services, however due to lighting and plug loads, big box stores have significantly higher EUI, which will have the most impact on achieving Step 3.

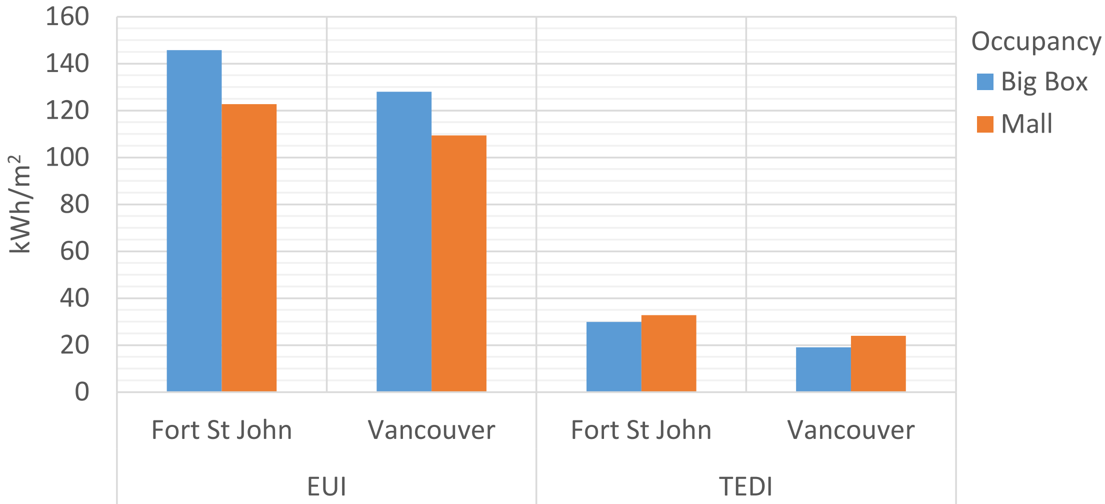


Figure 10: Impact of Occupancy Density on Retail EUI and TEDI

Construction Type
In general, method of construction does not significantly change the physics of building behaviour. For example, an effective R10 wood-framed wall will have a similar level of performance as an effective R10 concrete wall (except for impacts on thermal mass, which have been shown to be insignificant for residential building types in the BC climate[1]). However, the method of construction has two primary impacts within this analysis that have been taken into account: cost and performance.

With respect to *cost*, wood frame construction has a lower base construction cost, which impacts the % incremental capital cost numbers presented within the report. Wood frame construction also typically has less thermal bridging than concrete construction and therefore the premiums to achieve higher effective R-values are lower than concrete construction. With respect to *performance*, wood frame construction can achieve higher effective R-values within known methods of construction. A high of R40 effective wall performance was included for wood frame construction versus a high of an effective R20 wall for concrete construction.

All results presented in subsequent sections have held building shape, occupancy density and process loads constant. Costing results are provided for both types of construction (MURB only) throughout.

1.5.3 Modelling with EnergyPlus – Pathfinder

The analysis of Part 3 buildings was conducted using EnergyPlus v8.6, the primary simulation engine used for whole building energy modeling. EnergyPlus is a free, open-source, and cross-platform simulation program, whose development is funded by the U.S. Department of Energy's Building Technologies Office. EnergyPlus is compliant software for energy code compliance throughout North America and used extensively in both industry and research. All energy models were developed in compliance with the City of Vancouver's Energy Modelling Guidelines, which are directly referenced in the BCBC.

[1] See BC Hydro's Building Envelope Thermal Bridging Guide, 2016

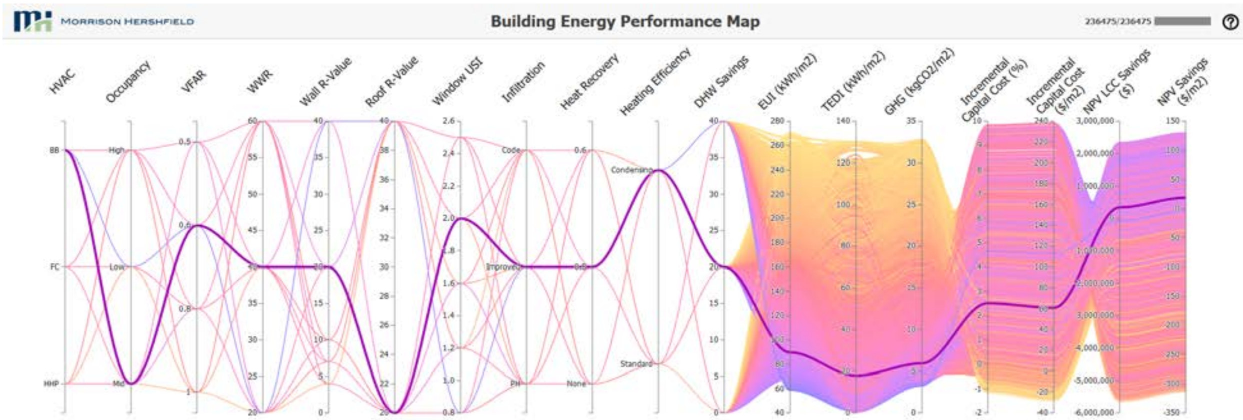


Figure 11: Screenshot of the Building PathFinder tool

The primary technique used to analyze the data was through an interactive data visualization tool developed at Morrison Hershfield called Building PathFinder ("PathFinder"). PathFinder allows the analysis of the large data sets generated by parametric analysis, with the purpose of identifying the relationships between different design parameters and their various outcomes (e.g. energy, economic and environmental). It also allows the optimization of design options based on preferred outcomes (e.g. lowest first cost) and the identification of design constraints under the imposition of fixed requirements (e.g. Step Code performance limits). The PathFinder tool was used in a workshop setting with the Step Code Working Group to better articulate the methodology and communicate some of the main findings of the project.

1.5.4 Part 3 Energy Conservation Measures

Modelled parameters were chosen carefully so as to feed the dataset the necessary information to adequately answer the research questions posed in this study. While the parameters assessed are dependent on building type, general ECMs used in Part 3 modelling are presented in Table 5 (and are defined in more detail in Appendix 7.1)

Table 5: ECM Options and Design Constraints used in Part 3 Modelling

Component	Options
Climate Zones	Vancouver (CZ4), Kamloops (CZ5), Prince George (CZ6), Fort St. John (CZ7A), Whitehorse (CZ7b)
Envelope performance	o Wall R values, R-4, 7, 10, 20, 40 o Roof R values, R-20, 30, 40 o Window U values, USI-2.5, 2, 1.6, 1.2, 0.8 o Air leakage (BCBC, "Improved" and Passive House)
Window to Wall Ratio (WWR)	o 20%,40%,60% MURB o 30%,50%,70% Office o 5%, 20%, 40% Retail
HVAC	o System: Baseboards, fan coils and DOAS, VAV, RTUs o Heating Efficiency, Standard or Condensing o Primary Fuel Source: electric baseboards, standard or condensing gas boilers and coils, air-source heat pump options
Lighting Efficiency	0, 25, 50% (Office and Retail only)

1.6 Modelling Part 9 Buildings

1.6.1 Part 9 Archetypes

The archetypes selected for this study were initially defined by the framework of the Step Code, which defined targets for Airtightness, Mechanical Energy Use Intensity (MEUI) and Thermal Energy Demand Intensity (TEDI) for Part 9 residential buildings (see Table 6 to Table 8).

A total of 6 archetypes were modelled for Part 9 buildings, which represented the widest possible range of potential performance outcomes. These archetypes were selected based on BC Housing research that sought to identify the most common types of Part 9 residential buildings found across the province, and refined in consultation and deliberation with the Oversight Committee. Archetypes were ultimately selected to assess the impact of Step Code targets on the size and complexity of different forms of housing, and included the following (See Figures 8 to 13 for examples of each archetype):

Archetype	Details
• MURB (10 units)	Market, 1,654m^2, 1,780ft^2/unit, 3 storey over underground parkade
• Row House (6 units)	Market, 957m^2, 1,720ft^2/unit, 3 storey over underground parkade
• Quadplex	Market, 513m^2, 1,382ft^2/unit, 3 storey over underground parkade
• Large SFD	Market, 511m^2, 2 storey with basement
• Medium SFD	Market, 237m^2, 2 storey with basement
• Small SFD*	Market, 102m^2, single storey on heated crawlspace

**single family dwelling*

It should be noted that while a Duplex archetype was not modelled, results pertaining to the Quadplex archetype are generally applicable to Duplex housing types as well.

Table 6: Step Structure and Requirements for Part 9 – Climate Zone 4

Step Level	Energy Modelling	Airtightness	Equipment and Systems	Envelope
Step 1 Enhanced Compliance (BC Building Code Performance)	Required	No target	Comply with BCBC 9.36.5 OR ERS v15 ref. house (MEUI of 80 kWh/m^2/yr is likely, but not required)	Report on TEDI and PTL (TEDI 50 kWh/ m^2/yr is likely, but not required)
Step 2 10% Beyond Code	Required	3.0 ACH_{50}	10% better than ERS v15 ref. house OR MEUI – 60 kWh/m^2/yr	TEDI – 45 kWhm^2/yr OR PTL – 35 W/m^2
Step 3 20% Beyond Code	Required	2.5 ACH_{50}	20% better than ERS v15 ref. house OR MEUI – 45 kWh/m^2/yr	TEDI – 40 kWh/m^2/yr OR PTL – 30 W/m^2
Step 4 40% Beyond Code	Required	1.5 ACH_{50}	40% better than ERS v15 ref. house OR MEUI – 35 kWh/ m^2/yr	TEDI – 25 kWh/m^2/yr OR PTL – 25 W/m^2
Step 5: 50%+ Beyond Code	Required	1.0 ACH_{50}	MEUI – 25 kWh/m^2/yr (no ERS option)	TEDI – 15 kWh/m^2/yr OR PTL – 10 W/m^2

Table 7: Step Structure and Requirements for Part 9 – Climate Zone 5

Step Level	Energy Modelling	Airtightness	Equipment and Systems	Envelope
Step 1 Enhanced Compliance (BC Building Code Performance)	Required	No target	Comply with BCBC 9.36.5 OR ERS v15 ref. house (MEUI of 100 kWh/ m^2/yr is likely, but not required)	Report on TEDI and PTL (TEDI 65 kWh/ m^2/yr is likely, but not required)
Step 2 10% Beyond Code	Required	3.0 ACH_{50}	10% better than ERS v15 ref. house OR MEUI – 90 kWh/ m^2/yr	TEDI – 60 kWh/ m^2/yr OR PTL – 55 W/m^2
Step 3 20% Beyond Code	Required	2.5 ACH_{50}	20% better than ERS v15 ref. house OR MEUI – 75 kWh/ m^2/yr	TEDI – 50 kWh/ m^2/yr OR PTL – 45 W/m^2
Step 4 40% Beyond Code	Required	1.5 ACH_{50}	40% better than ERS v15 ref. house OR MEUI – 45 kWh/ m^2/yr	TEDI – 40 kWh/ m^2/yr OR PTL – 40 W/m^2
Step 5: 50%+ Beyond Code	Required	1.0 ACH_{50}	MEUI – 25 kWh/ m^2/yr (no ERS option)	TEDI – 15 kWh/ m^2/yr OR PTL – 10 W/m^2

Table 8: Step Structure and Targets for Part 9 – Climate Zones 6, 7a, 7b, and 8

Step Level	Energy Modelling	Airtightness	Equipment and Systems	Envelope
Step 1 Enhanced Compliance (BC Building Code Performance)	Required	No target	Comply with BCBC 9.36.5 OR ERS v15 ref. house (MEUI of 115 kWh/m^2/yr is likely, but not required)	Report on TEDI and PTL (TEDI 75 kWh/m^2/yr is likely, but not required)
Step 2 10% Beyond Code	Required	3.0 ACH_{50}	10% better than ERS v15 ref. house OR MEUI – 100 kWh/m^2/yr	TEDI – 70 kWh/m^2/yr OR PTL – 55 W/m^2
Step 3 20% Beyond Code	Required	2.5 ACH_{50}	20% better than ERS v15 ref. house OR MEUI – 85 kWh/m^2/yr	TEDI – 60 kWh/m^2/yr OR PTL – 50 W/m^2
Step 4 40% Beyond Code	Required	1.5 ACH_{50}	40% better than ERS v15 ref. house OR MEUI – 55 kWh/m^2/yr	TEDI – 50 kWh/m^2/yr OR PTL – 45 W/m^2
Step 5: 50%+ Beyond Code	Required	1.0 ACH_{50}	MEUI – 25 kWh/m^2/yr (no ERS option)	TEDI – 15 kWh/m^2/yr OR PTL – 10 W/m^2

Figure 12: Example of a Medium SFD
(*Source: realspace*)

Figure 13: Example of a Large SFD
(*Source: bm2dev*)

Figure 17: Example of a Quadplex
(Source: Core Development)

Figure 16: Example of a Small SFD
(Source: Smallworks)

Figure 15: Example of a 10-Unit MURB
(Source: blue host)

Figure 14: Example of a 6-Unit Row House
(Source: House Plans)

1.6.2 Modelling in H2000/HTAP

The six base building archetypes were modelled using Version 11.3 of Natural Resources Canada (NRCan)'s HOT2000 program, an energy simulation and design tool used for low-rise residential buildings. Each archetype was designed with various combinations of the energy conservation measures (ECM), which resulted in nearly 54 million possible modelling combinations for each archetype. Each archetype was further modelled across BC's six climate zones using the HOT2000 weather file locations listed below:

- Climate Zone 4: Vancouver – 2,825 HDD
- Climate Zone 5: Summerland – 3,350 HDD
- Climate Zone 6: Cranbrook – 4,400 HDD
- Climate Zone 7a: Fort St John – 5,750 HDD
- Climate Zone 7b: Fort Nelson – 6,710 HDD
- Climate Zone 8: Uranium City, SK[2] – 7,500 HDD

Given the quantity of possible ECM combinations, as well as the significant number of climate zones, the need for a secondary form of analysis was identified. Developed by NRCan in 2010, the Housing Technology Assessment Platform (HTAP) was used to examine the costs and benefits of increasing energy efficiency in residential buildings, allowing for an estimate of the energy impact of implementing various ECMs. HTAP expanded the capabilities of HOT2000 by incorporating:

- Batch processing and optimization capabilities that automate the task of evaluating different combinations of ECMs, housing archetypes and locations; and
- High performance computing resources that shorten the time required to evaluate hundreds-of-thousands of different home designs.

For the purpose of this study, one of HTAP's most useful innovations is the ability to automate home design variations that apply different combinations of ECMs. HTAP automates configuring, dispatching, and collecting the results from HOT2000 energy simulation runs using an objective function that factors in capital and operating costs. Based on the value of the objective function for a set of ECMs evaluated, HTAP automatically selects more design variants with the aim to improve the objective function. HTAP can optimize for a range of criteria, including upgrade costs, utility bills, energy use, and home ownership affordability. Traditionally done manually by energy advisors, this HTAP process greatly increased the variety of Step Code-related design options that could be explored.[3]

1.6.3 Part 9 Energy Conservation Measures

For each archetype, between 10,000 and 20,000 combinations of ECM's were evaluated for each climate zone in order to identify those that could meet the Step Code's performance thresholds. For all archetypes, baseload values for *occupancy*, *appliance/lighting loads* and *hot water consumption* were assumed to be the same as those stipulated in Version 15 of the EnerGuide Rating System. Some archetypes were also modelled with different ventilation rates and dominant window orientations (discussed below). Altogether, 60,000 to 240,000 separate HOT2000 evaluations were modelled, representing different ECM combinations for each archetype.

[2] Uranium City, SK was selected because no climate files for Climate Zone 8 are available for BC in HOT2000.
[3] HTAP's automation capabilities are provided in part by third-party optimization tool GenOpt: https://simulationresearch.lbl.gov/GO/.

Table 9: ECM 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

Note: All values in the table are effective R-values.

It should be noted that under the direction of BC Housing, limitations were set for select types of ECMs when modelling different archetypes in different climate zones. In particular, limitations on airtightness levels, window USI, ventilation heat recovery, and drain water heat recovery were set in order to generate more realistic building outcomes. For example, it is unlikely that drain water heat recovery would be used in buildings of less than two storeys, and as such these possibilities were excluded from the model. Limitations that were placed on the Part 9 ECMs that were modelled in this study are detailed in Appendix 7.1.

Although not treated as ECMs, it should be noted that the orientation of a building and the proportion of glazing on each façade affects the quantity of solar gains available to offset a portion of heating loads. These differences will in turn affect the ability of an archetype to meet specific Step Code requirements, in terms of both the MEUI and TEDI values. To provide clarity on the distribution of windows assumed in this study, Table 10 presents a summary of the distribution of the windows on each façade for each of the six Part 9 archetypes. In the case of the Quadplex archetype, different orientations were modelled by rotating each window defined in the model in a specific direction (e.g. 90 degrees south) from the primary compass-based solar alignment (due north/east/south/west). For the Medium SFD archetype, windows from other orientations were moved to the south façade to examine the impact of a more passive solar design approach. The impact of window orientation on the three key Step Code metrics (MEUI, TEDI, and PTL) was evaluated and is summarized in the results (see Section 3.2).

Table 10: Distribution of Windows in Modelled Archetypes

Archetype	Percent of Window Area Facing Each Direction			
	South	North	East	West
Small SFD	22.5%	22.5%	22.5%	32.5%
Medium SFD	45.3%	13.8%	18.0%	22.8%
	22.8%	22.8%	22.5%	31.8%
Large SFD	24.4%	26.9%	24.4%	24.4%
Quadplex	18.1%	14.1%	39.7%	28.2%
	28.2%	39.7%	18.1%	14.1%
	39.7%	28.2%	14.1%	18.1%
6-Unit Row House	38.0%	48.3%	6.9%	6.9%
10-Unit MURB	49.5%	10.4%	10.4%	29.7%

1.6.4 Identifying Solutions that Meet the Performance Requirements

It should be noted that the modelling process described above was unable to identify solutions (i.e. ECM combinations) that met the performance requirements for all steps in all climate zones. This was particularly the case for higher levels of the Step Code in colder climates. As such, a second process was undertaken. This involved adapting and simplifying the geometry of the base archetypes to reflect a higher attention to thermal bridging and envelope-to-volume ratios necessary in colder climates. These included the following conditions:

- Exterior wall areas were reduced to the minimum perimeter to enclose the floor area, plus 10%;
- The corners and intersections in exterior walls were reduced by 50%;
- The heel height of attic trusses increased to 1.0ft or 1.5ft;
- Window areas were reduced by 33%;
- Envelopes R-values were increased to provide added insulation.

1.6.5 Limitations

A few limitations of the Part 9 analysis should be noted. First, the analysis presented here is limited to the archetypes that were studied. As such, it may be easier or harder for other archetypes (e.g. sixplex, larger MURB) to reach different levels of the Step Code. For example, a house that has an area spread out over two storeys and a basement will have less difficulty achieving higher levels of performance compared to a single storey, slab-on grade house with a larger area of exposed envelope per unit area of living space.

Second, the modelling approach involves the application of different combinations of ECM to a single base building design for each archetype. More specifically, results are derived by taking a code compliant home and increasing its performance by adding different combinations of ECMs. While this is a traditional, rational and effective method to equitably compare between interventions, it is also limited in its ability to achieve higher performance levels. This is because the approach normalizes any efficiency gains derived from the use of passive design measures, which can provide a major source of savings in EUI-based frameworks

It should also be noted that this methodology may approximate how a builder and designer go about optimizing a building at Steps 2, 3 and 4 in milder climates, and where the services of an Energy Advisor are engaged to provide guidance on energy saving strategies. However, it may not be the most cost-effective approach for colder climates or for reaching higher tiers of the Step Code. Designers targeting higher levels of performance will likely pursue a more thoughtful and site-specific design strategy that maximizes passive design strategies before pursuing more costly or complicated ECMs.

Finally, time and computing power limited the total number of ECM combinations that could be evaluated. Recall that the set of ECMs in Table 9 can be combined into 54 million different variations. Even with the HTAP evaluation running for 12 to 24 hours, only 10,000 to 20,000 HOT2000 evaluations could be run, representing only 0.00025% to 0.0005% of the possible combinations for each archetype in each climate location. As such, there could be some combinations of ECMs that would have achieved higher performance than those found in the simulation, although this is mitigated to some degree through HTAP optimizing for an objective function (as described above). The different combinations of ECMs that were ultimately evaluated were determined by optimizing for an objective function. To ensure that the most energy efficient design combination was modelled for each case, one simulation was carried out for each archetype and climate that included the most energy efficient options of each ECM category

1.7 Costing

1.7.1 Context

One of the research questions and a major overarching goal of this report is to explore the costing impacts of applying various steps of the Step Code to different steps archetypes across multiple climate zones in BC. The goals of these investigations are to understand if the costs of implementing the Step Code vary across archetypes and climate and if these costs are significant enough to impact affordability. It should be noted that BCBC is currently structured such that the code becomes more stringent in colder climate zones, which has cost implications even in the absence of more stringent levels of the Step Code. However, although past studies commissioned by the City of Vancouver[4] projected modest increases in construction costs resulting from the adoption of higher requirements for building energy performance, the higher requirements have proven to have no demonstrable impact on cost.

Figure 18 shows changes in construction costs for MURB, SFD and Commercial Office buildings between 2007 and 2017, and notes where in 2009 and 2014 new energy codes were adopted. The graph shows that the cost impact of increasing energy requirements may in fact be lower than other factors that affect construction cost. In two cases, construction costs actually decreased substantially within a year of adopting new requirements that were expected to add costs.

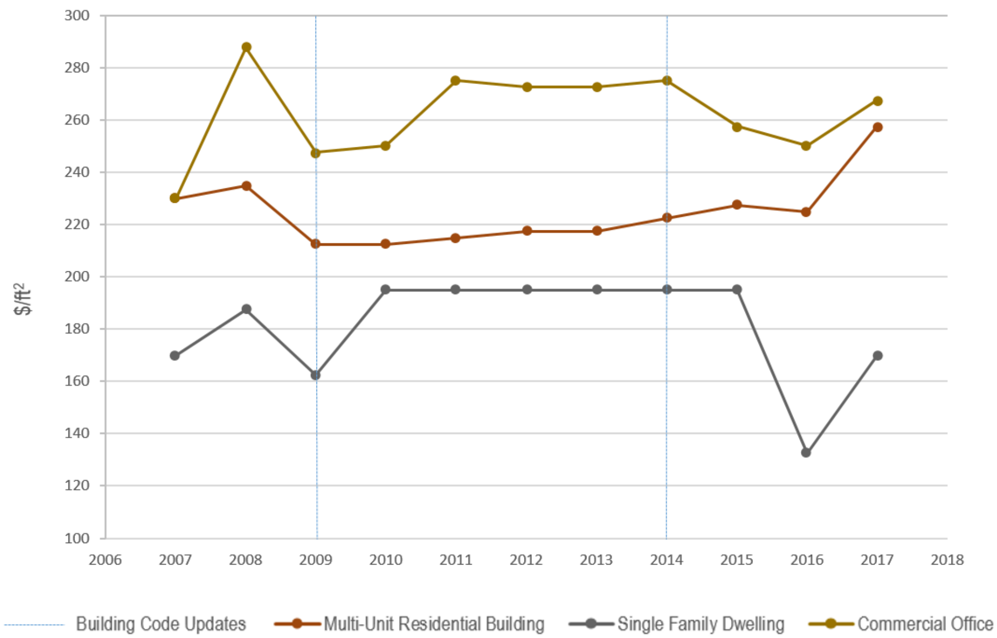


Figure 18: Changes in Construction Costs in Vancouver, 2009-2017

Finally, it should be noted that while the analysis produced comprehensive results for both Part 3 and Part 9 buildings across Climate Zones 4 to 7a, models were run for Part 3 Low-Rise MURB only in Climate Zone 7b, and no models were run in Climate Zone 8 for Part 3 buildings. This is because there are currently no weather files in the national data base for cities in BC in these climate zones, as there are very few municipalities in these regions, and they are extremely small in terms of both population and scale of development. For example, there are three municipalities in Zone 7b and one municipality in Zone 8. The combined population of both Climate Zone 7b and 8 is approximately 4,000 people, 3,900 of which live in Fort Nelson in Zone 7b. As such, the economic, energy saving and greenhouse gas implications of applying the Step Code for Part 3 buildings in these regions are fairly limited. However, for the sake of comprehensiveness our team undertook analysis of examining MURB archetypes in 7b using climate data from a comparable location in Saskatchewan or the Yukon as a proxy for Fort Nelson in order to capture this population center.

[4] Building Energy Code Update Study - City of Vancouver (2012). Prepared by BTY Group and Stantec Consulting Ltd

1.7.2 Part 3 Costing Information Sources

Costing sources for Part 3 buildings were derived from two major sources. *Base construction costs* were developed by the consultant team by sourcing multiple projects across the different archetypes (see Table 11). These costs were vetted extensively by industry members during the City of Vancouver's Zero Emissions buildings consultation process and over the course of 2016-2017. *Base construction costs* were sourced from the 2016 Altus Canadian Construction Guide.

Table 11: Base Construction Costs for Part 3 Buildings

Part 3 Archetype	Cost per square meter ($/m²)	Cost per square foot ($/ft²)	Description
High Rise MURB	3,035	282	See Section 1.5.1
Low Rise MURB	3,422	225	See Section 1.5.1
Office	2,874	267	18,200m², 10 storeys, 155 parking spaces
Retail	1,722	160	4,500m², 1 storey, 150 people

1.7.3 Part 9 Costing Information Sources

Base construction costs for Part 9 archetypes were sourced from the 2017 Altus Construction Guide, with input from the Province, and are outlined in Table 12.

Table 12: Base Construction Costs for Part 9 Buildings

Part 9 Archetype	Cost per square meter ($/m²)	Cost per square foot ($/ft²)	Description
10-Unit MURB	2,422	225	Three storey apartment building on underground parking garage
6-Unit Row House	1,749	163	Three storeys on slab on grade; garage on ground floor
Quadplex	1,857	173	3 storeys, on underground parkade
Large House	1,948	180	2 storeys on basement
Medium House	2,002	190	2 storeys on basement
Small House	1,938	215	1 storey on 4ft crawlspace

Costing sources for the ECMs modelled for Part 9 buildings were derived by leveraging the work that NRCan put into its costing calculator tool used for the Local Energy Efficiency Partnership (LEEP) program. NRCan has collected costing data for many upgrades, based on dollar figures provided by quantity surveyors. Those figures have been used and evaluated by LEEP Builder participants in the Lower Mainland, Okanagan and Northern BC.

Material costs and labour costs of Part 9 ECMs were provided on a per square foot of assembly basis, allowing the overall costs to be calculated by entering the area of building assemblies specific to the archetype under evaluation. Using a spreadsheet tool, the total cost of different upgrade scenarios for each of the particular building archetypes could then be calculated. Those costs were in turn entered into the HTAP software, which produced variations of the HOT2000 energy models, along with their associated cost increments. These costs went through an additional vetting process by comparing them with project experiences from within the E3 - EcoGroup. Where costs were deemed out of date, they were compared against input from local suppliers and builders in order to assess if any changes or adjustments were necessary to more accurately represent present day (2017) costs. Examples where this occurred included certain efficiency levels of HRVs and the cost of different types of rigid foam insulation.

1.7.4 Regional Costs

The costs of building construction vary across the province according to a range of factors, including the availability of labour and materials and local economies of scale. To reflect this range, *ECM and base costs* were adjusted by climate zone.

For Part 9 buildings, costs were adjusted using factors obtained from BC Housing, which were in turn created to reflect their own project and budgeting experience. For Part 3 buildings, base and incremental capital costs were multiplied by location factors according to the Altus Construction Guide. Table 13 presents the location factors used for both Part 3 and Part 9 buildings.

Table 13: Regional Cost Multipliers for Part 3 and Part 9 Buildings

Climate Zone	Multiplier over CZ4		
	Part 9 – All	Part 3 – MURB	Part 3 – Office/Retail
4	1	1	1
5	1.073	1.073	0.95
6	1.126	1.126	1.15
7a	1.502	1.502	1.15
7b	1.502	1.502	1.502
8	1.502	N/A	N/A

1.7.5 Costing Assumptions

All of the steps within the Step Code were optimized for both lowest cost and for the lowest Net Present Value (NPV) in order to assess both capital costs and long-term cost effectiveness. Cost calculations were all base-lined against the minimum code requirements for a given climate zone.

NPV calculations apply a real discount rate of 3% and assume a time horizon of 20 years to represent a consistent lifespan of major component units associated with the analysis. This means that all ECMs are assumed to last a minimum of 20 years, and any residual or remaining value that any ECM may have beyond a 20 year lifespan is not accounted for. For example, while wall systems are expected to last far beyond 20 years, this analysis only accounts for overall costs through the initial impact on the overall capital costs of the building. The implications of this assumption are twofold:

1) If an ECM lasts less than 20 years, the additional investment required to replace it is not captured. In the event that an ECM fails before the 20 year period is over, it would have a downward effect on NPV.
2) Conversely, ECMs that last beyond the 20 year time horizon continue to provide value to the building owner; for example, by decreasing annual energy costs that are not fully reflected in the 20 year NPV. Adjusting the NPV to account for the ongoing value of these ECMS would create a more positive result.

Effectively, the 20 year time horizon functions like a weighted average for building components. This approach, while not detailed in its methodology, does provide a level playing field by which to assess the relative cost effectiveness of the thousands of buildings within this study. For example, while exterior cladding may have a projected lifespan of up to 50 years[5], HVAC system components may have to be replaced after as little as 10 to 15 years[6].
As some utility and other government programs typically use a more conservative rate of 6% to 7%, a sensitivity analysis was conducted on Medium SFD NPV results and associated carbon abatement costs, to determine the impact of a range of discount rates between 3% and 7%. The results are presented in Section 2.2.2. It's important to note that the base case 3% discount rate partially offsets the fact that all costs in the report are presented in today's (2017) costs. For example, the costing results presented in this report do not reflect the inevitable declines in the costs of

[5] http://www.rdh.com/long-buildings-last/
[6] As outlined by ASHRAE, see http://www.culluminc.com/wp-content/uploads/2013/02/ASHRAE_Chart_HVAC_Life_Expectancy%201.pdf

certain technologies (e.g. HRVs) that are achieved through economies of scale and market maturity. As such, while the low discount rate has an upward effect on NPV results, the overestimation of future ECM costs has a downward effect.

Other assumptions are noted below:

- **Projected energy price estimates** were based on a review of BC Hydro and Fortis BC rate projections and include the **carbon tax**, which is assumed to increase to $50/t$CO_2$e in 2022; see Appendix 7.2 for details.
- The **GHG intensity of electricity** was assumed to be 0.0000107 tonnes/kWh, as per the 2016/2017 BC Best Practices Methodology for Quantifying GHG Emissions.
- The **GHG intensity of natural gas** was assumed to be 0.049870 tonnes/kWh, as per the 2016/2017 BC Best Practices Methodology for Quantifying GHG Emissions.[7]

Finally, Part 9 costs calculated for all Steps include estimates for the Energy Advisor services and blower door tests that are required to comply with the Step Code. Cost estimates were sourced from local practitioners who provided estimates for Climate Zone 4, which were adjusted for colder climate zones using the regional cost multipliers noted above. These cost assumptions for Part 9 services are presented in Table 14 and Table 15. Part 3 costs also include costs for airtightness testing, based on a baseline cost of $25,000 for testing at Step 1. Part 3 airtightness testing costs assume one test and some additional consulting based on industry experience in the province's Lower Mainland. The actual costs of air-tightness testing will vary depending on location, size and complexity of building, as well as how well-planned and coordinated the testing is undertaken.

Table 14: Cost Estimates for Part 9 Energy Advisor Services (CZ4)

Part 9 Archetype	Energy Advisor Costs				
	Step 1	Step 2	Step 3	Step 4	Step 5
10-Unit MURB	$1,200	$ 1,360	$1,920	$3,200	$4,800
6-Unit Row House	$1,200	$ 1,360	$1,920	$3,200	$4,800
Quadplex	$1,000	$ 1,133	$1,600	$2,667	$4,000
Large House	$750	$ 850	$1,200	$2,000	$3,000
Medium House	$500	$ 850	$1,200	$2,000	$3,000
Small House	$400	$ 680	$960	$1,600	$2,400

Table 15: Cost Estimates for Part 9 Blower Door Tests (CZ4)

Part 9 Archetype	Blower Door Costs (All Steps)	Assumptions
10-Unit MURB	$3,050	Mid Construction, Thermal Bypass, Check and Blower, Fan Test
6-Unit Row House	$1,450	Mid Construction, Thermal Bypass, Check and Blower, Fan Test
Quadplex	$1,250	Mid Construction, Thermal Bypass, Check and Blower, Fan Test
Large House	$800	Mid Construction, Thermal Bypass, Check and Blower, Fan Test, 450, Final Blower Fan Test, 350
Medium House	$600	Mid Construction, Thermal Bypass, Check and Blower, Fan Test, 350, Final Blower Fan Test
Small House	$600	Mid Construction, Thermal Bypass, Check and Blower, Fan Test, 350

[7] http://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/methodology/2016-17-pso-methodology.pdf

2 RESULTS

This section presents the results of the costing analysis, as well as additional analysis required to answer some of the key research questions posed by the study.

The study sought to optimize results for each of the three metrics – capital costs, net present value (NPV), and costs per tonne of carbon abated. However, it should be noted that optimizing these three metrics separately will yield in results that are sub-optimal for the other two. For example, when ECMs are optimized for NPV, an increase in GHG emissions tends to be a common outcome. Of course, it should be borne in mind that, as with any performance-based framework, there are multiple possible outcomes that can be used to meet the targets, and that these represent only one possibility. The full set of results have been made available to BC Housing for any additional analysis.

2.1 Part 3 Buildings

As outlined in Section 2 above, all costs for this analysis were baselined off the Part 3 prescriptive code requirements for each climate zone. Optimized costs for incremental capital costs, cost per tonne of carbon abated, and NPV are shown in Table 16, Table 17 and Table 18, respectively. The full results of the Part 3 costing analysis are summarized in Appendices 8.3 to 8.5.

2.1.1 Incremental Capital Cost

Incremental Capital Cost refers to the cost premium associated with going to a higher step within the Step Code framework, and includes both materials and labour. It does not include any savings that might be realized from lower operating costs, or the likely reductions in the capital costs of mechanical equipment due to the use of better building envelopes. It also does not include potential for increases in design costs – while these may be initially higher, changes to the market will see these increases disappear over time. Incremental capital costs are typically used by the building industry as they are seen to have the biggest impact on consumer choice and affordability.

Table 16 shows the results of the incremental capital cost analysis. All building types across all climate zones studied could achieve all levels of the Step Code for less than 4%, with 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 due to the limited presence of this building form in the north.

In general, incremental capital costs do not increase significantly in higher climate zones due to the increase in baseline code requirements. Higher climate zones already require higher performance envelope characteristics, as well as the use of heat recovery on ventilation air as per NECB 2011 (referenced by BCBC). As such, base costs in higher climate zones already included many of the energy efficiency measures required to meet the different step levels.

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 difficult to achieve, the use of higher performance windows is necessary, which can come at a significant cost premium. It is also important to note that in these colder climates, window-to-wall ratio is significantly lower than in other climates, but consistent with the NECB's prescriptive pathway. The cost optimized results for Climate Zones 6 and 7A, for example, have a window-to-wall ratio of 20%.

It should also be noted that Retail buildings appear to have the highest incremental capital costs, though it is comparable to other building types on the basis of absolute $\$/m^2$. Lower base construction costs for Retail buildings inflate the premium substantially.

In summary, in Climate Zones 4-6 (where 95% of BC's population resides), all buildings modelled were able to achieve Step 4 for less than a 3% incremental capital cost, and achieve Step 3 for less than 2.4%. In comparison, incremental capital costs for Commercial Office buildings were correlated to their choice of mechanical system, and not to the achievement of the different levels of the Step Code. In all cases, these costs were less than 3%. It is important to note that in Climate Zones 4 and 5, the achievement of Step 3 (the highest step for Commercial Office) could be achieved for less than a 1% cost premium for the majority of cases. For MURB, these costs are substantially lower than what was originally anticipated (see Table 2).

2.1.2 Net Present Value & Carbon Abatement Costs

Net Present Value (NPV) is a measurement commonly used in the financial industry as a method of calculating potential profit or loss over time. It is calculated by subtracting the present value of the initial costs from the present value of any savings or revenues over time. It is often used as a method of comparing capital investments over time. In the case of this analysis, the total costs of the upgraded ECM package and the total savings from utility bills over time were assessed in comparison to the code baseline. A positive NPV indicates that savings outweigh any incurred costs over time, whereas a negative NPV indicates that any incremental costs could not be recovered in operational savings. The cost of abated carbon was calculated using the NPV analysis to ascertain the total cost of abated carbon once all of the costs and savings were applied over a 20 year time horizon. As noted in Section 1.7.5, a 3% real discount rate was assumed.

Table 17 shows the results for costs per tonne of carbon abated, while Table 18 shows the results of the NPV analysis. While overall cost premiums were low, NPV and costs per tonne of carbon abated results were mixed and range from positive to negative values. It is important to remember that these cost metrics are based on a comparison to a BCBC compliant building with one set of fixed characteristics that do not necessarily reflect typical market practice. For example, the code allows for different compliance mechanisms that can lead to very different solutions and resulting energy, energy cost and GHG use for equally code compliant buildings. Therefore, a fixed energy use intensity, energy cost, and GHG emissions for a "code compliant" building does not really exist. It is a key limitation to the code and a major impetus for moving to the target-based approach presented in the Step Code. Further, it is very difficult to achieve positive NPV results in British Columbia. This is because the province has some of the lowest energy costs in North America, so any savings achieved are also small, making the recovery of any incremental costs very challenging.

One of the major indicators 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 sensitive to the final NPV and GHG outcomes, as a result of the disparity in costs and GHG emissions between fuel sources in BC.

Overall, NPV and costs per tonne of carbon abated numbers should be interpreted carefully. The main takeaway from these metrics is that even the most unfavourable NPV numbers are small relative to the overall cost of building and operating a building, and do not exceed 2%. Two notable exceptions 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 cost per tonne of carbon abated, carbon savings are often also associated with NPV savings, especially in Climate Zone 4. As such, the majority of optimized carbon abatement costs indicate that Part 3 building can reduce GHG emissions while also reducing the total cost of building ownership. In colder climate zones, the cost of abated carbon can be up to 10 to 15 times the current carbon tax in BC, at $30/tonne.

While overall cost premiums were low, NPV results were mixed. In most cases, MURB NPV's were positive, Retail NPV's were negative, and Commercial Office numbers were dependent on heating fuel type.

Table 16: Lowest Incremental Capital Costs (% change) – Part 3 Buildings

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%	2.7	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

Table 17: Lowest Carbon Abatement Costs ($/tonneCO2e) – Part 3 Buildings

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	--

Table 18: Highest Net Present Value ($/m^2) – Part 3 Buildings

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	-28.9	--
Low-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	--	--	--	--	--
	2	27.5	20.8	51.9	0.1	-16.1
	3	33.5	1.3	57.3	14.6	-19.0
	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 FC*	1	--	--	--	--	--
	2	20.6	13.7	-18.3	-26.9	--
	3	16.1	2.2	-36.3	-36.6	--

Table 19: Highest Net Present Value ($/unit*) – Part 3 MURB

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b
High-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	--	--	--	--	--
	2	1027	-7	1265	-3033	--
	3	1428	-952	1632	-2054	--
	4	-184	-1095	1054	-1965	--
Low-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	--	--	--	--	--
	2	1870	1414	3529	7	-1095
	3	2278	88	3896	993	-1292
	4	734	-122	3196	-3230	--

**Assumes 68m^2 units*

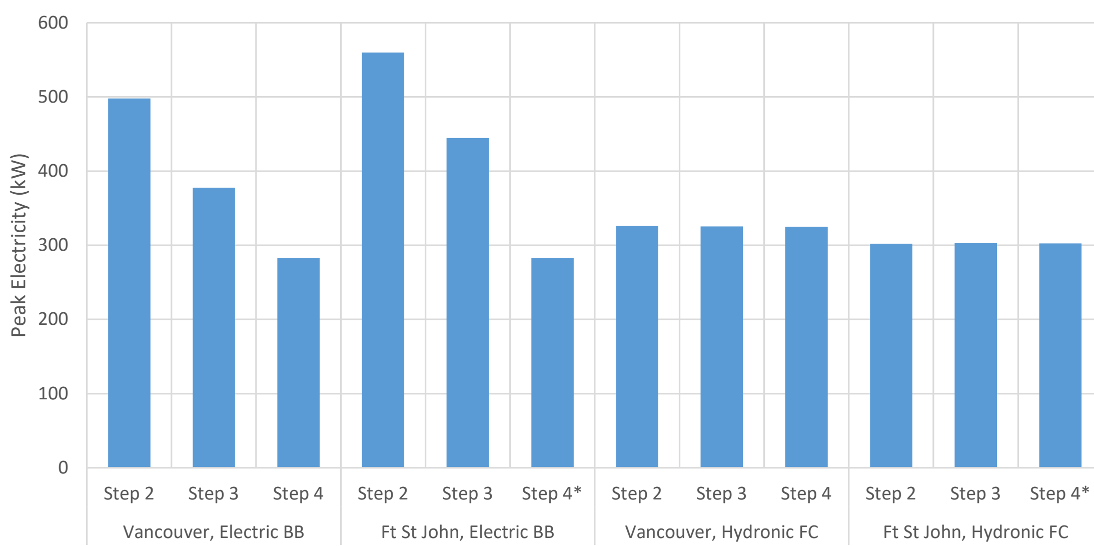
2.1.3 Appropriateness of Metrics and Targets

Peak Load and GHGs

In this section, the effectiveness of current Step Code metrics and performance requirements are explored with regard to their ability to gauge reductions in energy use, peak demand, and GHG emissions. From the results of the analysis, some interesting findings can be discerned.

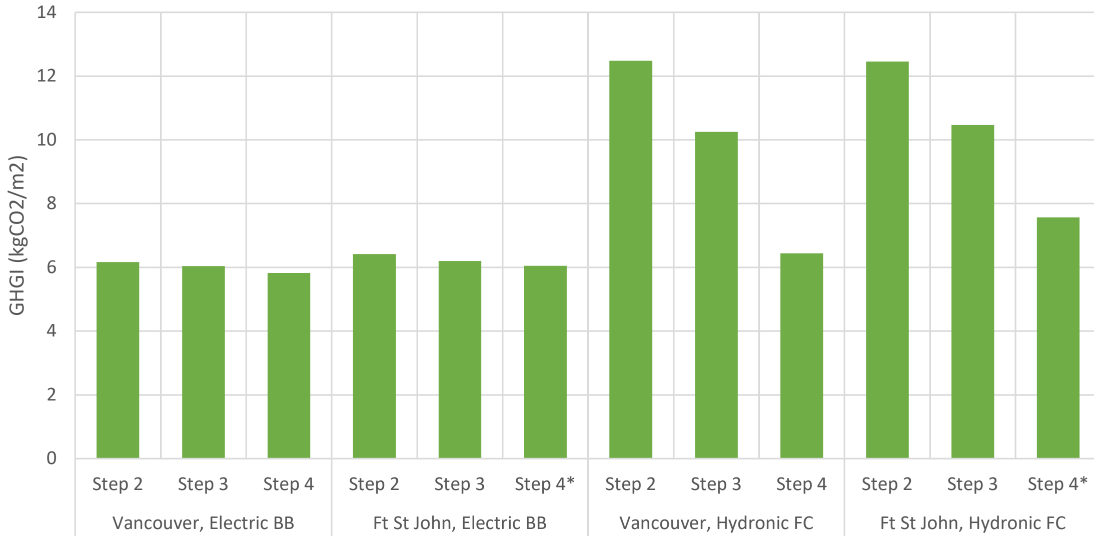
First, designing a Part 3 MURB to meet the EUI and TEDI performance requirements for higher steps of the Step Code does result in lower peak electricity and GHG intensity (GHGI) outcomes, as shown in Figure 19. Large reductions are seen for peak electricity when heating is provided by electric baseboards, and for GHGI when heating is provided by natural gas (i.e. the hydronic fan coil case). This is expected since the Step Code primarily drives down heating energy use; electrically heated buildings will have reductions in electrical peak demand, while gas-heated buildings will have reductions in GHGs since gas is more carbon intensive than electricity. When heat is provided by electric baseboards, peak electricity use can be reduced by 40% in Vancouver and by 60% in Fort St. John by reaching Step 4 instead of Step 2. For buildings with hydronic fan coils where heating is provided by a gas-fired hot water boiler, GHGI can be reduced by approximately 50% in both climates. Only slight reductions in peak electricity and GHGI are achieved for buildings heated by natural gas and electricity, respectively, assuming there is no fuel switching for any other building systems.

At Steps 2 and 3, gas-heated scenarios naturally have lower peak electricity demand and higher GHGI than the electric baseboards scenarios. At Step 4, however, the more stringent TEDI performance requirement reduces heating demand sufficiently that the peak electricity demand of the electric baseboard scenarios is lower than the hydronic fan coil scenarios. This is due to the peak in the hydronic fan coil scenario changing from a winter peak to a summer peak as the TEDI performance requirement gets lower (the hydronic fan coil scenarios include cooling, while the electric baseboard scenarios do not). The Step 4 GHGI result for both HVAC systems and across all climates zones is similar, as the bulk of the GHGI is attributed to domestic hot water heating with additional use by the corridor make-up air unit gas-fired coil for both electric baseboards and hydronic fan coil scenarios.



**Represents the most feasible scenario which approaches, but does not meet the performance requirements*

Figure 19: Step Code Peak Electricity Outcomes for MURB in Climate Zones 4 & 7



**Represents the most feasible scenario which approaches, but does not meet the performance requirements*

Figure 20: Step Code GHGI Outcomes for MURB in Climate Zones 4 and 7

Variations in Mechanical Systems

The measures taken for MURB using electric baseboards (BB) and hydronic fan coils served by a gas boiler (FC) to meet the Step Code in Climate Zones 4 and 7 are summarized in Table 20. The base building is a High Rise MURB with 0.6 VFAR and the mid-density occupancy scenario. Switching from electric baseboards to fan coils reduces pressure on the TEDI performance requirement in exchange for higher energy use. This is attributed to the higher electricity use and corresponding internal heat gains from additional fans and pumps – as fans run continuously, waste heat is dumped into the space, lowering heating coil demand and thus the building's TEDI. In general, this means that capital may be required to be spent on other energy saving measures such as domestic hot water use reduction, rather than further envelope improvements.

For Commercial Office and Retail buildings, EUI and TEDI are largely impacted by mechanical system choice. Notably, moving away from conventional air-based systems that combine heating, cooling and ventilation to hydronic systems that separate ventilation functions from heating and cooling can improve both metrics. The current Step Code performance limits will not generally push projects to a specific fuel source. 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 through the use of higher efficiency mechanical systems.

For each of the steps, solutions are given for the progression of mechanical system interventions, beginning with conventional air-based systems (VAV), hydronic systems with dedicated outdoor air delivery with gas-based heating, and hydronic systems with dedicated outdoor air delivery with heat pump based heating. Results show that moving to hydronic systems takes pressure off the building envelope to meet the TEDI, primarily due to elimination of reheat energy for VAV systems. The heat pump solution takes pressure off of electrical load reductions such as lighting and plug loads. A selection of recommended high NPV solutions is shown in Table 21, with full tables of solutions available in Appendix 7.4.

Variations in Window to Wall Ratio

Table 22 to Table 24 below show the recommended solutions for warm and cold climates at a range of glazing ratios, optimized for NPV. The typical MURB WWR is 40% in Climate Zones 4 and 5, and 20% in Zones 6 and 7. The typical Office WWR is 50% (unless a lower value is required to meet performance requirements), and the retail typical WWR is 20%.

Recommended measures are typically similar for different glazing ratios, with some improvements in window performance and heat recovery efficiency required for some scenarios. If high performance glazing is required, the incremental capital cost for glazing increases with WWR due to the larger glazing area, which can significantly impact ICC and NPV, even when overall energy use remains relatively constant. High glazing ratios do not prevent higher steps from being achieved in any climate, but choosing to design with low glazing ratios can be beneficial in terms of economic outcomes. While lower WWR may be undesirable for select building types in select markets, there are other opportunities to meet performance requirements using a different combination of ECMs that permit a higher WWR (e.g. 50%).

2.1.4 Applying Part 3 Targets to Part 9 Non-Residential Buildings

Part 9 Non-residential buildings differ from Part 3 Non-residential buildings primarily due to building size leading to higher vertical surface to floor area ratios. Since the proposed solutions for Part 3 Commercial/Retail buildings are typically selected to meet the TEDI restriction, and are less limited by EUI restrictions, the elevated VFAR of small buildings will directly impact the building envelope performance and ventilation heat recovery efficiency required to meet the Part 3 performance requirements. The impact may be reduced by design measures such as lower window-to-wall ratios, and the use of combustible construction, which reduces thermal bridging and allows for higher opaque wall performance at lower cost than the equivalent non-combustible construction. Buildings with high process loads and associated internal heat gain will be less impacted by VFAR. Based on the analysis for increased WWR (which also causes increased envelope heat loss) in Commercial/Retail buildings, Step 2 and Step 3 performance requirements are achievable in all climate zones for Part 9 Non-Residential Buildings.

2.1.5 District Energy and Waste Heat

It is also important to clarify the implications of the Step Code performance requirements for the use of district energy and waste heat systems. Due to the ‘envelope first’ and fuel-neutral approach taken in the Step Code, the focus is on reducing the amount of heating required by the building by building an energy efficient envelope. Consequently, the source of heating systems supplying buildings that are targeting the Step Code would not significantly impact a project’s ability to meet the requirements. That is, regardless of whether the source of heat is from district heating or a conventional gas-fired boiler, it would still be possible for the project to demonstrate energy performance of the building in a step-wise manner by addressing the envelope and equipment efficiencies. As it is defined in the Code, Thermal Energy Demand Intensity (TEDI) is a measure of the annual heating energy required by the building and is not influenced by the source of heat. Therefore, connecting to a district energy system will have no impact on this metric

However, as explained below, there is an impact to the Energy Use Intensity (EUI) due to a connection to a district energy system because EUI is influenced by, among other things, the difference in heating system efficiencies. According to the Version 1.0 of City of Vancouver’s Energy Modelling Guidelines (which is referenced in the Step Code as the guidelines to show compliance with the Code), district heating is to be measured at the site and any upstream efficiencies from the source are ignored, whereas the energy use of a gas-fired boiler would be higher for the same heating load, due to the efficiency loss. The EUI for a building using district energy would be the same for a building with electric heating, provided all other things are identical. Alternatively, the use of high efficiency site equipment, such as heat pumps, would be a significant advantage to EUI over district heating.

Table 20: Step Code Solutions for MURB with Alternate HVAC Systems

Scenario			Measures								Outcome						
Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Savings	EUI (kWh/m²)	TEDI (kWh/m²)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m²)	NPV LCC Savings ($)	NPV LLC Savings ($/m²)	COC ($/tonCO₂e)
CZ4	2	BB	40%	10	20	2.5	Code	60%	Condensing	20%	111.7	40.6	0.4%	11.8	$266,000	14.8	-222.9
		FC									128.4	33.8	0.4%	12.4	-$669,000	-37.2	204.6
	3	BB	40%	10	20	2.5	Improved	80%	Condensing	20%	100.8	29.7	0.8%	24.9	$371,000	20.6	-299.5
		FC						60%		40%	116.7	28.8	0.6%	18.5	-$673,000	-37.4	165.1
	4	BB	40%	10	20	1.6	PH	80%	Condensing	20%	85.8	14.8	2.4%	74.3	-$55,000	-3.0	41.6
		FC								40%	98.8	9.8	2.6%	78.0	-$1,664,000	-92.4	305.8
CZ7	2	BB	20%	20	40	1.2	Code	60%	Condensing	20%	116.0	44.9	2.0%	92.5	-$817,000	-45.4	638.2
		FC			20	1.6		80%		40%	130.0	39.8	2.3%	104.3	-$669,000	-109.6	481.4
	3	BB	20%	20	20	0.8	Improved	60%	Condensing	20%	100.3	29.2	2.3%	104.6	-$544,000	-30.2	401.5
		FC			40	1.2				40%	119.8	29.8	2.3%	102.7	-$1,864,000	-103.5	386.8
	4*	BB	20%	20	40	0.8	PH	80%	Condensing	20%	88.7	17.6	2.7%	123.3	-$520,000	-28.9	368.4
		FC								40%	106.5	15.3	2.8%	128.9	-$2,289,000	-127.2	390.6

**Measures and outcomes represent the most feasible scenario that approaches, but does not meet the performance requirements*

Table 21: Step Code Solutions for Retail Buildings with Alternate HVAC Systems

Scenario			Measures						Outcome						
Climate	Step	HVAC	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	EUI (kWh/m²)	TEDI (kWh/m²)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m²)	NPV LCC Savings ($)	NPV LLC Savings ($/m²)	COC ($/tonCO₂e)
CZ4 Retail *Big Box Cond. Boiler 20% WWR*	2	RTU	10	20	2.5	Code	60%	0	139.9	15.4	0.9	13.2	-$40,085	-8.9	105.3
		FC	10	20	2.5	Code	60%	0	128.1	19.1	0.8	12.1	$17,461	3.9	-39.9
		ASHP	7	20	2.5	Code	60%	0	114.7	22.4	0.8	12.1	$18,885	4.2	-24.8
	3	RTU	10	20	2.5	Improved	60%	25	118.0	15.6	2.1	31.3	-$5,105	-1.1	12.8
		FC	10	20	2.5	Improved	60%	25	106.3	18.6	2.0	30.1	$49,472	11.0	-106.0
		ASHP	10	20	2.5	Improved	60%	0	114.1	13.9	1.2	17.6	-$2,812	-0.6	3.7
CZ6 Retail *Big Box Cond. Boiler 20% WWR*	2	RTU	20	20	2.5	Code	80%	0	158.5	27.1	2.6	43.7	-$154,696	-34.4	173.9
		FC	10	20	0.8	Code	80%	0	142.5	29.8	2.8	47.8	-$109,493	-24.3	109.6
		ASHP	10	20	0.8	Code	80%	0	120.0	29.8	2.8	47.8	-$82,608	-18.3	57.5
	3	RTU	20	40	2	Improved	80%	25	118.3	16.8	6.0	102.3	-$260,657	-57.9	221.8
		FC	10	40	0.8	Improved	80%	25	111.9	19.0	5.5	93.9	-$193,981	-43.1	161.0
		ASHP	20	20	1.2	Improved	80%	0	118.6	19.8	3.9	67.5	-$163,200	-36.3	113.5

Table 22: Step Code Solutions for High Rise MURB with Varying WWR

Scenario			Measures							Outcome						
Archetype	Step	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Savings	EUI (kWh/m²)	TEDI (kWh/m²)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m²)	NPV LCC Savings ($)	NPV LLC Savings ($/m²)	COC ($/tonCO₂e)
CZ4 High-Rise MURB *Mid Occupancy 0.6 VFAR Electric BB*	2	20	10	20	2.5	Code	60%	Condensing	40%	94.2	29.9	0.7	21.2	$499,236	27.7	-295.5
		40	10	20	2.5	Code	60%	Condensing	40%	104.9	40.6	0.5	15.2	$272,282	15.1	-166.0
		60	20	20	2.5	Code	80%	Condensing	40%	105.0	40.7	1.1	32.6	-$42,676	-2.4	26.0
	3	20	10	20	2.5	Improved	60%	Condensing	40%	89.1	24.8	0.8	24.0	$610,212	33.9	-356.6
		40	10	20	2.5	Improved	80%	Condensing	40%	94.0	29.7	0.9	28.4	$377,269	21.0	-223.8
		60	10	40	2	Improved	80%	Condensing	40%	94.2	29.9	2.5	77.1	-$505,055	-28.1	299.0
	4	20	20	20	2.5	PH	60%	Condensing	40%	77.4	13.1	1.7	51.4	$477,326	26.5	-268.4
		40	10	20	1.6	PH	80%	Condensing	40%	79.1	14.8	2.6	77.8	-$48,294	-2.7	27.4
		60	10	20	1.2	PH	80%	Condensing	40%	76.3	12.0	3.7	113.8	-$611,882	-34.0	342.7
CZ7 High-Rise MURB *Mid Occupancy 0.6 VFAR Electric BB*	2	20	20	40	0.8	Code	60%	Condensing	20%	110.3	39.2	2.2	101.5	-$802,763	-44.6	612.0
		40	20	40	0.8	Code	60%	Condensing	20%	112.4	41.3	3.1	141.7	-$1,590,596	-88.4	1216.8
		60	20	40	0.8	Code	60%	Condensing	20%	115.5	44.4	4.0	181.9	-$2,411,886	-134.0	1862.6
	3	20	20	40	0.8	Improved	60%	Condensing	20%	99.7	28.6	2.3	105.7	-$543,752	-30.2	400.5
		40	20	20	0.8	Improved	80%	Condensing	20%	97.2	26.1	3.5	160.3	-$1,452,773	-80.7	1057.9
		60	20	20	0.8	Improved	80%	Condensing	20%	100.5	29.4	4.4	200.5	-$2,276,701	-126.5	1675.1
	4*	20	20	40	0.8	PH	80%	Condensing	20%	88.7	17.6	2.7	123.3	-$519,845	-28.9	368.4
		40	20	40	0.8	PH	80%	Condensing	20%	91.4	20.3	3.6	163.5	-$1,328,322	-73.8	949.3
		60	20	40	0.8	PH	80%	Condensing	20%	94.6	23.5	4.5	203.7	-$2,151,292	-119.5	1553.8

Table 23: Step Code Solutions for Commercial Offices with Varying WWR

Scenario		Measures							Outcome						
Climate	Step	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	EUI (kWh/m^2)	TEDI (kWh/m^2)	Incremental Capital Cost (%)	Incremental Capital Cost ($\$/m^2$)	NPV LCC Savings ($)	NPV LLC Savings ($\$/m^2$)	COC ($\$/tonCO_2e$)
CZ4 Office *Default Occupancy No IT Load Hydronic FC*	2	30	10	20	2.5	Code	None	0	110.8	26.0	-0.1	-2.4	$445,671	24.5	-367.1
		50	10	20	2.5	Code	None	0	115.4	29.4	-0.2	-5.8	$458,761	25.2	-471.9
		70	10	20	2.5	Code	60%	0	112.9	21.1	-0.2	-5.1	$378,593	20.8	-247.1
	3	30	10	20	2.5	Improved	60%	0	99.9	11.2	0.1	3.1	$362,084	19.9	-162.1
		50	10	20	2.5	Improved	60%	0	104.8	14.7	0.0	-0.3	$370,345	20.3	-186.8
		70	10	20	2.5	Improved	60%	0	110.0	18.1	-0.1	-3.7	$371,792	20.4	-214.1
CZ7 Office *Default Occupancy No IT Load Hydronic FC*	2	30	20	20	1.2	Code	60%	0	112.2	29.3	1.0	34.4	-$165,172	-9.1	57.5
		50	20	40	1.2	Code	60%	0	115.0	29.7	1.6	51.9	-$539,435	-29.6	190.5
		70	10	20	0.8	Code	60%	0	118.5	28.5	2.3	77.0	-$1,086,924	-59.7	375.0
	3	30	20	20	0.8	Improved	60%	0	102.7	19.0	1.3	41.9	-$249,129	-13.7	69.4
		50	20	20	0.8	Improved	60%	0	106.4	19.4	1.8	60.8	-$668,208	-36.7	188.3
		70	20	40	0.8	Improved	60%	0	109.5	18.6	2.5	82.3	-$1,137,770	-62.5	317.0

Table 24: Step Code Solutions for Retail Buildings with Varying WWR

Scenario			Measures						Outcome						
Climate	Step	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	EUI (kWh/m²)	TEDI (kWh/m²)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m²)	NPV LCC Savings ($)	NPV LLC Savings ($/m²)	COC ($/tonCO$_2$e)
CZ4 Retail *Big Box Condensing Boiler Hydronic FC*	2	5	10	20	2	Code	60%	50	93.8	29.9	2.9	42.5	$100,281	22.3	-339.3
		20	10	20	2.5	Code	80%	50	93.7	25.8	3.0	44.8	$75,900	16.9	-210.0
		40	10	20	2.5	Code	80%	50	100.6	29.6	2.8	41.2	$69,207	15.4	-235.6
	3	5	10	20	2.5	Improved	80%	50	82.7	16.2	3.6	53.1	$61,948	13.8	-117.1
		20	10	20	2.5	Improved	80%	50	88.0	19.1	3.4	50.3	$56,832	12.6	-119.2
		40	20	20	2.5	Improved	80%	50	91.7	19.9	4.0	59.7	-$2,132	-0.5	4.6
CZ7 Retail *Big Box Condensing Boiler Hydronic FC*	2	5	20	40	2	Improved	80%	25	117.9	29.6	5.2	89.5	-$69,561	-15.5	43.0
		20	20	40	1.2	Improved	80%	25	121.9	29.9	6.0	101.9	-$145,545	-32.3	90.5
		40	20	40	0.8	Improved	60%	0	144.8	29.2	5.9	100.7	-$263,790	-58.6	165.2
	3	5	20	40	0.8	PH	80%	25	110.0	19.5	5.8	99.0	-$107,373	-23.9	60.0
		20	20	40	0.8	PH	80%	25	114.8	19.7	6.6	112.4	-$192,084	-42.7	107.8
		40*	20	40	0.8	PH	80%	25	122.3	20.6	7.6	130.3	-$309,149	-68.7	175.7

**Measures and outcomes represent the most feasible scenario that approaches, but does not meet the performance requirements*

As noted above, while the use of district heat has no bearing on the TEDI performance requirement, the EUI for a district energy system could be higher or lower depending on the specifics. To allow flexibility for district energy systems within the Zero Emissions Building Plan, the City of Vancouver has allowed for a relaxation in the EUI performance requirement for buildings connected to district energy systems. However, the City of Vancouver's GHGI performance requirement ensures that only low-carbon district energy could be used, despite the relaxation of other metrics. The Energy Step Code Council is in the midst of preparing a clarification that states that relaxations of up to 20% of the EUI required to be achieved at a particular level of the Step Code may be granted where a building is connected to a district energy system. Though it should be noted that EUI is not directly correlated to GHGI, and therefore a relaxation of the EUI for district energy connected buildings, while providing more flexibility in meeting the performance requirements, will not ensure Greenhouse Gas benefits without a GHGI performance requirement. Given this, and the relative affordability of achieving a broad spectrum of Step Code performance requirements we would not recommend supporting this relaxation. An alternative could be to leave it to local governments to require different steps in district energy zones. For example outside of a district energy zone buildings could be required to hit Step 4 while within a district energy zone buildings could be required to only achieve Step 2.

Peak Thermal Load is a metric which is indicative of the heating energy demand required on the day of the year with the highest heat use. Similar to TEDI, this metric is also blind to the source of heat, and therefore will not be impacted due to connection to a district energy system. Greenhouse Gas Emissions Intensity (GHGI) is the metric that will show a reduction due to the connection to low carbon district energy. Because of the way GHGI has been defined, if the emission factor for a district energy system is lower than on-site natural gas, then a district energy connected building would have an advantage over a building heated by natural gas. Although not required to be reported under the BC Step Code, Local Governments could require compliance with an additional GHGI metric under the climate action charter to encourage the use of low-carbon district energy. District energy emissions factors are something that modellers can easily obtain at little to no extra effort.

Low carbon district energy utilities are a significant shared infrastructure investment by the local government which provide measurable GHG benefits. In addition to the relaxation of the EUI metric, a relaxation of the TEDI metric may also be warranted to improve the economics of district energy connections (i.e. a building with very little heating load does not make a good district energy customer). The City of Vancouver uses this approach, recognizing that low carbon district energy systems can also lower GHG emissions for existing buildings and therefore incentivizing their use through relaxed requirements for new buildings can lead to an overall net reduction in GHG emissions community wide.

Future revisions to the energy modeling guidelines could address how district energy is treated to capture some of the benefits discussed above. It is expected that the upstream efficiencies (e.g. losses from gas-fired systems or improvements from heat pump systems) would be captured in the modelled EUI, potentially rewarding efficient district energy systems over in-efficient on-site solutions.

Similar to district energy, waste heat sources do not impact TEDI, as TEDI is measured as the heating requirement of the building, regardless of its source. However, waste heat sources that reduce energy consumption at the utility meters can reduce EUI. This balanced approach means that passive design strategies cannot be compromised regardless of heat source, but if waste heat sources are available and leveraged, a reduction in EUI can be achieved. Examples of waste heat sources include heat recovered from space conditioning (e.g. heat pump systems that can take the heat from cooling parts of the building and using it to heat other parts of the building) and waste heat generated from processes (e.g. cogeneration, industrial, etc.).

2.1.6 Adapting to the Warming Climate

Determination of building envelope heat loss through the consideration of building orientation, and daylighting for example, presents opportunities to address the overheating aspect in buildings. Neither TEDI nor PTL will be impacted due to addition of space cooling equipment. All else being equal and unless offset by on-site renewable energy, the addition of a space cooling equipment or the increase in the electricity use due to its upsizing could result in most cases a modest increase of the building EUI. Warming temperatures in the future could increase EUI's in buildings with a cooling-dominant energy use (e.g. buildings with large computer servers). When daylighting and building orientation aspects are considered from an overheating standpoint, the sizing of the space cooling equipment can be optimized, especially since the cooling losses are mitigated through the building of an airtight building.

Analysis undertaken that applied aggressive TEDI performance requirements to MURB's found that meeting these higher performance requirements made the buildings more habitable during power failures that could be brought on by increased storm activity resulting from climate change. This was because the building was able to stay at a comfortable temperature for longer without mechanical systems. This improved resilience was a primary benefit in the winter months in Climate Zone 6 and above.

2.2 Part 9 Buildings

Table 25, Table 26 and Table 27 present the findings from the costing analysis of Part 9 buildings. These results reveal a number of high-level trends. Recall from Section 2 presented a limitation of the traditional approach to modelling taken in this study (i.e. adding combinations of ECM to a base, code-compliant building), in that it would not necessarily produce the best or more cost effective solutions at higher levels of the Step Code and/or in colder climates. This limitation can be seen in the results of the analysis, in that the cost premiums associated with achieving the Step Code performance requirements in Part 9 buildings varied widely. Recall also that certain ECMs have been excluded from the Part 9 analysis for select archetypes and climate zones (see Appendix 7.1).

As outlined in Section 2 above, all costs for this analysis were baselined off the Part 9 prescriptive code requirements for each climate zone. Base building and ECM costs were also factored up for each climate zone based on regional cost multipliers provided by BC Housing (as summarized in Section 1.7.4). The following pages provide a summary of results that have been optimized to minimize incremental capital costs (Table 25), maximize NPV (Table 26), and minimize carbon abatement costs (Table 27). Most of these results were generated through the H2000/HTAP process outlined in Section 1.6, while some required a subsequent process to identify ECM combinations that achieved all steps for each archetype in each climate zone. Due to the larger impact that absolute performance metrics have on smaller buildings (especially smaller homes), a wider variety of archetypes was run for this building category than for Part 3. The full results of the Part 9 costing analysis are summarized in Appendices 7.6 to 7.10. For definitions and discussion of lowest incremental cost, net present value, and cost of carbon abatement, please see Section 1.7.

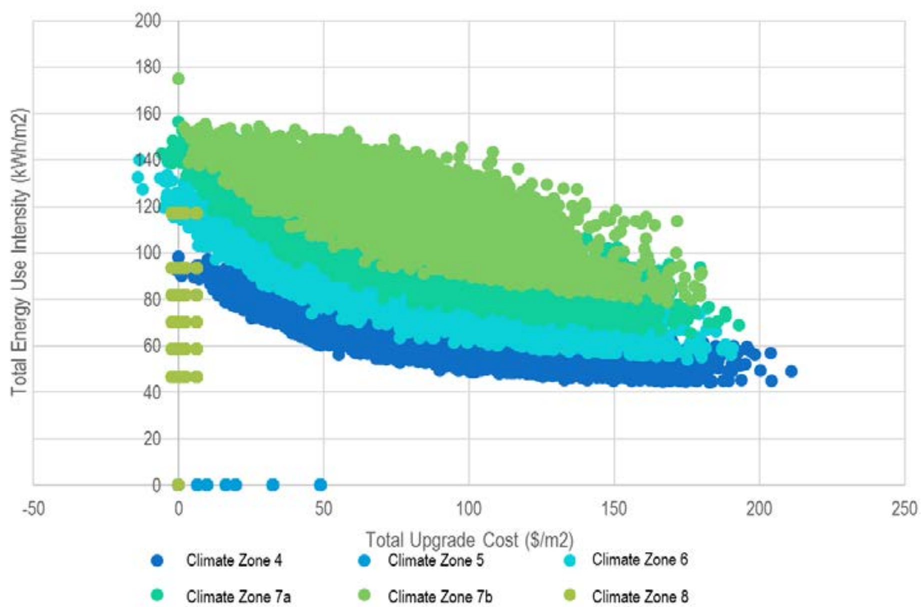


Figure 21: Sample Scatterplot Output Optimized Capital Costs for TEDI in Medium SFD Archetypes

2.2.1 Incremental Capital Costs

Looking at Table 25, the incremental capital cost results are generally modest, as the majority of steps can be achieved for less than a 2% incremental capital cost. This is particularly true for the MURB, Row House, and Large SFD archetypes, each of which can reach Step 4 for under 2% in Climate Zones 4 through 6. The MURB is able to reach Step 4 in Climate Zones 7a and 7b for under 1% and 1.5%, respectively, and Step 5 in Climate Zones 4 and 5 for under 2%. The full results, including ECM combinations, are summarized in Appendix Section 7.6.

Results for the Quadplex and Medium SFD were more costly, but still fell under 3.0% for most results up to and including Step 4. For the Quadplex, capital costs increase more significantly starting at Step 5 for Climate Zones 4 (6.1%), Step 4 for 7a (5.8%), and Step 3 for 7b (4.2%).[8] The story is similar for the Medium SFD archetype, with more prohibitive costs emerging for Step 5 in Climate Zone 7a (12.1%), Step 4 in 7b (5.1%), and Step 4 in 8 (9.5%).

Table 25: Lowest First Costs (% change) – Part 9 Buildings

Note: Highlighted areas indicate results that were derived from the secondary analysis performed for colder climates

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8
10 Unit MURB	1	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
	2	0.4%	0.3%	0.2%	0.2%	0.4%	0.8%
	3	0.3%	0.3%	0.0%	0.1%	0.1%	0.6%
	4	0.7%	0.5%	0.2%	0.7%	1.4%	2.1%
	5	1.7%	2.0%	2.5%	- -	7.7%	8.7%
6 Unit Row House	1	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	2	0.4%	0.5%	-0.1%	0.4%	1.2%	2.0%
	3	1.1%	0.5%	-0.1%	0.6%	1.3%	1.7%
	4	2.0%	1.7%	1.4%	2.3%	3.6%	5.7%
	5	3.4%	4.4%	5.3%	- -	- -	13.0%
Quadplex	1	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%
	2	1.2%	0.7%	0.3%	1.4%	2.1%	- -
	3	2.1%	0.7%	0.9%	2.4%	4.2%	- -
	4	3.3%	2.9%	2.7%	5.8%	- -	- -
	5	6.1%	- -	- -	- -	- -	- -
Large SFD	1	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	2	0.1%	-0.3%	-0.5%	-0.2%	0.3%	1.5%
	3	0.5%	-0.3%	-0.9%	-0.1%	1.6%	2.8%
	4	1.5%	0.7%	0.6%	2.4%	4.4%	10.3%
	5	4.2%	6.9%	- -	15.4%	17.4%	- -
Medium SFD	1	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%
	2	0.2%	0.0%	-0.4%	-0.2%	0.4%	2.6%
	3	0.8%	0.0%	-0.3%	0.9%	2.1%	3.3%
	4	1.8%	1.5%	1.3%	2.7%	5.1%	9.5%
	5	3.6%	4.9%	9.3%	12.1%	20.5%	20.5%
Small SFD	1	0.4%	0.4%	0.5%	0.6%	0.6%	0.6%
	2	2.4%	0.8%	1.9%	6.7%	11.7%	12.1%
	3	4.7%	2.4%	3.4%	12.5%	12.5%	32.7%
	4	7.5%	7.1%	7.7%	16.2%	33.2%	33.1%
	5	13.5%	16.2%	18.1%	- -	- -	- -

The Small SFD has the greatest difficulty achieving the steps at lower costs. Based on the dataset and assumptions, costs to reach Step 2 ranged from 0.8% to 12.1% (in Climate Zones 5 and 8, respectively). Moving to Step 3 and above

[8] Note that limited time and resources prevented the identification of solutions for all steps in all climate zones for all archetypes. Single family dwellings and higher steps in larger multifamily buildings were prioritized, so several Quadplex solutions are missing from the table (as indicated by "- -").

involves premiums of 3.4% or greater, except for Step 3 in Climate Zone 5 at 2.4%. Shaded cells indicate where solutions were identified through the process outlined in Section 1.6.4. Higher step requirements were more difficult to meet in colder Climate Zones across all archetypes, but particularly for the Small SFD. This is partly due to the smaller building footprint over which to spread the energy consumption, and partly due to the assumption in HTAP that SFDs consume the same amount of non-thermal and process energy (e.g. plug loads from occupant behaviour) regardless of building area. The resulting incremental capital costs are significantly higher than their counterparts in other archetypes, ranging from 11.7% to 33.2% (for Climate Zone 7b Steps 2 and 4, respectively).

As indicated in the Appendix, results of the Part 9 investigation show that when optimizing for capital costs, envelope values in Climate Zones 7a and below generally fall into the range of R16 to R18 (with the exception of the Small SFD archetype and Step 5 in all archetypes). These envelope values are roughly equivalent to current building code values. The explanation for this trend is that the requirements for air tightness improve envelope performance sufficiently enough to meet the thermal demand requirements without extra insulation. The importance of airtightness was also found in the process of identifying ECM combinations that met higher steps and steps in colder climates described in Section 1.6.4. These solutions typically required greater airtightness performance; further, investing in airtightness was found to be one of the more cost-effective ways to achieve these steps.

2.2.2 Net Present Value & Carbon Abatement Costs

With regards to NPV, results are mixed. In general, larger buildings are found to have higher and often positive NPVs, decreasing as building area decreases and becoming primarily negative for SFDs. For example, achieving Step 3 for 10-Unit MURBs 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. Note that positive values indicate a net financial gain over 20 years (i.e. energy cost savings outweigh incremental capital costs over 20 years). Given that carbon abatement costs are based on the NPVs, the same pattern follows for the NPVs. The reason for this pattern is that smaller buildings use and spend less on energy, and the reduction in annual energy spending is not enough to offset the increase in capital costs. Even a small increase in capital costs may outweigh the small decreases in energy costs. The results are summarized in Table 26 and Table 27, with associated ECM solutions and other data found in Appendices 7.7 and 7.8.

The full set of optimized NPV outcomes indicates 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 or instead of electric systems, due to their lower operating costs. As such, it is important to note that in some cases (particularly for Steps 1 to 3), optimizing for NPV can lead to higher GHG outcomes than what would occur in a code-compliant building using the prescriptive methodology, or if buildings had been optimized for another objective, such as GHG reductions.

In assessing the NPV and carbon abatement cost, the same cautions expressed in Section 2.1.2 apply here. Outcomes and their relative performance are partly dependent on fuel choice and in many cases, particularly for smaller buildings, initial investments cannot be recovered via lower energy costs. As noted previously, all ECM costs are based on current prices that will likely decrease as market maturity forces further drive down equipment and installation costs. Furthermore, an analysis of the *optimized* carbon abatement cost unfortunately does not yield actionable results for all archetypes. This occurs because low cost interventions that have only minor impacts on GHGs can nevertheless yield attractive carbon abatement costs, and become the optimized results found through this process, despite achieving a very small GHG reduction. As a result, optimized carbon abatement costs do not correlate well to overall greenhouse gas reductions, and the resulting solutions can obscure other ECM combinations that may achieve deeper GHG reductions at still modest costs. An approach that should be considered for future studies is to compare the carbon abatement potential for different suites of ECMs, and explore the relative differences between them in terms of cost-effectiveness and impacts on GHG reductions. Alternatively, new and likely valuable optimized results could be generated by requiring solutions to achieve a certain level of GHG reductions.

A similar comment can be made about the NPV results. The summary tables in this section present results that have been optimized for each of the three primary financial outcomes: lowest incremental capital costs, highest NPV, and lowest carbon abatement costs. When optimizing for one, the others may be higher or lower than desired. As such, the lowest incremental capital costs solutions may appear to have poor NPV results, and vice versa for the optimized NPV results.

Table 26: Highest Net Present Value ($/m²) – Part 9 Buildings

Note: Highlighted areas indicate results that were derived from the secondary analysis performed for colder climates

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	-	-	-

While the optimized cost of carbon abatement data presented in this report may not be useful on its own, this report does provide recommendations and guidance to local governments and the Province on how to optimize the Step Code for both GHG outcomes and limited impacts on affordability (see Section 6). The inclusion of a Greenhouse Gas Intensity (GHGI) metric similar to the Vancouver Zero Emissions Buildings Policy (see Section 5.4.3) is one approach that could be taken. Such a GHGI metric could be optimized to ensure that as steps increase, a predictable reduction in GHG outcomes could follow. This is not the case under the existing Step Code, as some cost-optimized outcomes had higher GHG emissions than the baseline code archetypes. Furthermore, additional analysis can be run on the Part 9 modelling outcomes, offering the Province the opportunity to explore and pose additional research questions that can provide new and valuable insights (see Section 6.2 for some examples).

Table 27: Lowest Carbon Abatement Costs ($/m²) – Part 9 Buildings

Notes: (1) Negative values indicate a decrease in GHG reductions with a positive NPV. (2) Highlighted areas indicate results that were derived from the secondary analysis performed for colder climates.

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	-	-	-

It should also be noted that unit size and unit density are variables that are critical to affordability solutions in meeting the Step Code in residential construction. The size of units and how many units are constructed in a given building have a significant impact on a building's achievement of the MEUI performance requirements. This is because energy use from domestic hot water, lighting and appliances is assumed to remain constant regardless of size, and when sizes of units are small, energy use intensity is spread over a smaller floor area and thus result in higher values. This can be seen most prominently in the Small SFD and Quadplex archetypes. On the other hand, spreading heat loss from occupants and appliances across a smaller unit can have a beneficial impact to TEDI, though this is somewhat counterbalanced by the higher building envelope to floor area ratio.

2.2.3 Sensitivity Analysis on NPV Discount Rate

A sensitivity analysis was performed to determine the impact of assuming different discount rates for the NPV analysis. The base case assumes 3%, but some utility and government program analyses can use higher rates such as 6% to 7%, which reduces the value of future cost relative to upfront costs. Using the Medium SFD, optimum NPVs were calculated for discount rates from 3% to 7%. A comparison of NPV results and associated carbon abatement costs is provided in Table 28.

Table 28: Comparison of Optimized NPVs and Associated Carbon Abatement Costs for Discount Rate Sensitivity Analysis on Medium SFD

CZ	Step	NPV per m² (20-year) Discount Rate					Range	Associated Carbon Abatement Cost ($/tCO2e) Discount Rate					Range
		3%	4%	5%	6%	7%		3%	4%	5%	6%	7%	
4	1	-$5	-$5	-$5	-$5	-$5	-	No change in GHGs					
	2	-$6	-$7	-$7	-$8	-$8	$2	$198	$213	$225	$237	$246	$48
	3	-$23	-$25	-$26	-$27	-$28	$4	$271	$286	$299	$310	$320	$49
	4	-$45	-$46	-$47	-$47	-$48	$3	$365	$309	$313	$316	$319	$45
	5	-$71	-$72	-$73	-$74	-$75	$4	$391	$398	$403	$408	$413	$22
5	1	-$5	-$5	-$5	-$5	-$5	-	No change in GHGs					-
	2	-$8	-$8	-$8	-$8	-$8	-	$200	$200	$200	$200	$200	-
	3	-$8	-$8	-$9	-$9	-$10	$2	$200	$214	$227	$238	$248	$48
	4	-$39	-$39	-$40	-$40	-$41	$2	$319	$269	$273	$276	$278	$41
	5	-$87	-$89	-$90	-$92	-$93	$5	$403	$411	$418	$424	$429	$25
6	1	-$6	-$6	-$6	-$6	-$6	-	No change in GHGs					-
	2	-$3	-$3	-$3	-$3	-$3	$0	No change in GHGs					-
	3	-$4	-$4	-$5	-$5	-$6	$2	$100	$114	$127	$138	$148	$48
	4	-$32	-$34	-$36	-$38	-$39	$7	$223	$239	$252	$264	$275	$51
	5	-$184	-$187	-$189	-$191	-$193	$9	$667	$677	$685	$693	$699	$32
7a	1	-$9	-$9	-$9	-$9	-$9	-	No change in GHGs					-
	2	-$7	-$9	-$10	-$11	-$12	$5	$76	$91	$104	$115	$125	$50
	3	-$34	-$37	-$39	-$41	-$42	$8	$213	$229	$243	$255	$266	$52
	4	-$88	-$92	-$95	-$98	-$101	$13	$347	$362	$375	$387	$397	$50
	5	-	-	-	-	-	-	-	-	-	-	-	-
7b	1	-$9	-$9	-$9	-$9	-$9	-	No change in GHGs					-
	2	-$27	-$29	-$32	-$34	-$36	$9	$153	$168	$181	$192	$202	$50
	3	-$70	-$73	-$76	-$78	-$80	$11	$314	$328	$340	$351	$361	$48
	4	-$183	-$185	-$184	-$182	-$181	$2	$518	$416	$412	$409	$406	$112
	5	-	-	-	-	-	-	-	-	-	-	-	-
8	1	-$9	-$9	-$9	-$9	-$9	-	No change in GHGs					-
	2	-$58	-$62	-$66	-$69	-$72	$13	$216	$231	$244	$256	$266	$50
	3	-$108	-$112	-$116	-$119	-$122	$14	$372	$387	$400	$411	$422	$50
	4	-$330	-$326	-$323	-$320	-$318	$12	$577	$570	$564	$559	$555	$22
	5	-	-	-	-	-	-	-	-	-	-	-	-

The results indicate a wider spread in resulting NPVs at higher steps and colder climate zones. The largest spread is for Step 3 in Climate Zone 8 at $14/m², equal to $3318 total, or approximately 0.5% of base case Medium SFD capital costs in Climate Zone 8. This is relatively small compared to total capital costs, however even this change could outweigh energy cost savings for smaller buildings. Although the net effect is small, this change in discount rate may change a positive NPV to a negative for some cases.

2.2.4 Achieving Higher Building Performance in Colder Climates

As noted above, the HTAP process was not successful in generating results in all cases. To address this, additional iterations were generated for Part 9 buildings, in which the architecture, massing and fenestration was altered to achieve Step Code performance requirements. These additional optimizations reveal a number of key takeaways that should be noted, particularly for the achievement of the Step Code in colder climates.

First, it is challenging to achieve higher levels of the Step Code (i.e. Steps 4 and 5) in the coldest climate zones. In these areas of the province, R-values of 40 and above both above- and below-grade walls will likely be necessary. The thermal performance of certain building envelope components become something of a limiting factor. For example, window U-values of 0.80 or lower would considerably help to achieve TEDI thresholds. Doors also present a limitation – particularly in multi-unit buildings such as Row Houses, which can have 2-3 doors per unit. As doors have lower overall thermal performance, the higher the number of doors, the more difficulty designers may encounter in achieving TEDI thresholds.

Second, airtightness becomes increasingly important for larger buildings in colder climates – indeed, even small improvements in airtightness in these archetypes and situations yield significant improvements in TEDI and PTL for lower costs than other upgrades. Airtightness values of less than 1.0ACH_{50} for smaller buildings, and 05ACH_{50} in larger buildings will help to cost-effectively reach the TEDI targets. Finally, cold-climate air source heat pumps become a viable choice in mechanical systems.

2.2.5 Window to Wall Ratios

An analysis of the impact of window-to-wall ratios (WWR) on the achievement of Step Code performance requirements was not conducted using the results of this study, as the tool used (i.e. HOT2000) does not allow for a sensitivity analysis on this particular building feature. However, other recent studies point to a number of conclusions that can be drawn on this issue. Work conducted by Alex Ferguson on window selection[9] found that adding window area only reduces energy use in gas-heated and electric baseboard homes when the primary façade faces south. Increased EUI was found in homes equipped with heat pumps, as well as homes with added glass in cases where the rear façade faced north, east or west. Where wall R-values are increased beyond R-18 (the base case used in this particular study), energy savings associated with added glass diminished further. The author concludes that increasing WWR may provide some modest benefits in homes that are optimally oriented, but that in instances where orientation cannot be controlled (e.g. in subdivisions), net energy savings may be negative more often than positive. This impact changes when exploring for TEDI, where an increased WWR would instead have positive results. However, the overall impact on EUI, utility bills, and occupant comfort would likely be negative. These findings are supported by an analysis by Gary Proskiw on Identifying Affordable Net Zero Energy Housing Solutions[10].

2.2.6 Equity and Affordability

One of the central research questions of this project centred on determining how equitable the Step Code performance requirements were for various steps and archetypes. In other words, do the Step Code performance requirements adversely impact certain build types in certain climate zones, and do these impacts make affordability potentially worse for home buyers with limited budgets in northern communities?

The results show that the 10-Unit MURB and the Row House had some of the most “equitable” (e.g. affordable regardless of climate zone and archetype) results of any of the building analyzed. All results for Steps 3 and under were less than 1.7% across all climate zones. For Steps 4 and 5, results for Climate Zones 4 to 6 were under 5.3%. For the colder climate zones (7a, 7b and 8), incremental capital costs for Steps 4 and 5 are more significant, with lower costs for the MURB (maximum of 8.7% for Step 5 in Climate Zone 8) than the Row House (maximum of 13.0% for Step

[9] Ferguson A (n.d). Window Selection Guide. CanmetENERGY, NRCan.

[10] Proskiw G (2010). Identifying Affordable Net Zero Energy Housing Solutions. Prepared for Alex Ferguson, Sustainable Building and Communities, CanmetENERGY, NRCan.

5 in Climate Zone 8). Still, up to Step 4 in Climate Zone 7b can be achieved for a 1.4% premium for the MURB and a 3.6% premium for the Row House.

Results were more mixed for detached housing types, while again displaying a trend towards less attractive financial outcomes for smaller buildings. The results for larger and medium sized single family showed that although slightly higher capital costs did correlate with colder climate zones, the cost impacts of achieving Steps 1 to 3 were generally equitable, with most results having incremental capital costs under 3.5%, and many under 1%, including some with incremental savings where an archetype could achieve the Step Code with lower cost ECMs than the BCBC. Overall, given these results Steps 4 and 5 will likely require some incentives to remain equitable if targeted in any climate zone

Small SFDs results are more problematic in terms of equity. This archetype has a harder time achieving the Step Code in colder climate zones and results indicate some very high costs in Climate Zones 7a to 8. For Climate Zones 4 to 6, Step 3 can be achieved for under 4.7%. However, achieving Step 3 for Climate Zones 7a, 7b, and 8 yields incremental capital costs of 12.5%, 12.5%, and 32.7%, respectively. Steps 4 and 5 had higher costs across all climate zones, while still displaying the pattern discussed above. These results are extremely high and, for this reason and others, this report discusses this issue and possible approaches to dealing with small homes in Sections 3.2 and 6.1. Suggestions range from relaxing the steps to excluding smaller homes from the Step Code altogether in northern climates.

2.2.7 Unintentionally Increasing GHG Emissions

One of the goals of this project was to identify potential unintended outcomes associated with the current Step Code metrics. Findings indicate that buildings can achieve Steps 3, 4, and 5 while increasing GHG emissions, rather than decreasing them and contributing to the Province's GHG reduction targets. Table 29 below summarizes select examples of such instances in achieving Step 3 or above across all climate zones. In all cases, the increase in GHGs is attributable to a fuel switch from electricity to natural gas for space heating and/or domestic hot water. Though the table includes only the MURB and Quadplex archetypes, results indicate that GHGs would also increase for other archetypes in making the same fuel switch from electricity to natural gas. As such, the Step Code risks increasing GHG emissions in some buildings, even if those buildings achieve the stringent energy efficiency requirements of higher steps. One way this issue could be mitigated is through a GHG intensity (GHGI) metric, as discussed above and in Section 5.5.

Table 29: Examples of Results in which Achieving Higher Steps Increases GHG Emissions

Archetype	Climate Zone	Step	DHW System	Space Heating System	Change in GHGs from BCBC (%)
Quadplex	4	3	Instantaneous Gas	Gas furnace	+14%
10 unit MURB	5	3	Base DHW	Gas furnace	+158%
Quadplex	5	4	Combination	Combination	+11%
Quadplex	6	4	Instantaneous Gas	Gas furnace	+25%
10 unit MURB	7a	4	Combination	Combination	+9%
10 unit MURB	7b	4	Combination	Combination	+31%

2.2.8 Appropriateness of Part 9 Targets for MURB

One of the goals of this report was to explore whether there was any inherent advantage or disadvantage to modelling MURB's in HOT2000 versus an ASHRAE compliant model. Low-rise MURB's were modelled both using Energy Plus and HOT2000 to attempt to discern the difference between modelling programs, and how the Part 9 and Part 3 performance requirements impacted similar buildings. It is important to note that this comparison is imperfect, as the archetypes are not exactly the same, and because steps and performance metrics also vary between the Part 9 and Part 3 frameworks. With those qualifiers noted, the results for the costing derived from the use of HOT2000 (Part 9) were lower. For example, achieving Steps 3 and 4 for the 10-Unit MURB in Climate Zone 4 using HOT2000 yielded an incremental cost of 0.3% to 0.7%. The range for achieving Steps 3 and 4 in Climate Zone 4 varied between 0.6% and 2.6%. It is important to note, however, that in both cases the results for this archetype were some of the most affordable and cost-effective, regardless of the energy modelling tool or the framework applied. The majority of the results in both cases had an incremental capital cost less than 1%.

3 THE IMPACT OF CLIMATE AND SIZE ON PART 9 REQUIREMENTS

3.1 Climate Zone

A key objective of this study was to investigate the impacts of the Step Code performance requirements on the affordability and constructability of key Part 9 building types across climate zones. This concern around affordability was already built into the original Part 9 performance requirements developed for the Step Code. Targets were normalized for climate zone using a sample of HOT2000 files based on completed projects, and then adapted to represent 10%, 20%, and 40% improvements over the base code's compliance path for whole building energy use for each climate zone. For Step 5, an option was given to achieve Passive House levels of performance (using Passive House modelling software), which were not normalized for climate, but were instead held constant across climate zones. The results of this exercise were used by the Province of BC to determine a climate-adjusted set of Mechanical Energy Use Intensity (MEUI), Peak Thermal Load (PTL), and Thermal Energy Use Intensity (TEDI) metrics.

However, costing analysis results for Part 9 buildings demonstrate that costs to achieve the Step Code in colder climate zones are higher. 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. In an attempt to address concerns of higher cost, current methodologies for the normalization of energy use intensity performance requirements by climate were explored to determine if they could be used to improve the Step Code normalization process. Methodologies were assessed as to whether they could produce results that minimized affordability impacts of the Step Code in northern climates, but that were still effective in reducing energy and carbon emissions. Two primary methodologies were evaluated:

- The Passive House Institute of the United States' (PHIUS) methodology for adjusting Heating Demand and EUI targets, which adjusts heating demand and total EUI targets based on climate zone and utility costs; and
- The National Research Council (NRC) – Canadian Codes Centre's linear regression analysis for Part 3 buildings based on heating degree days (HDD)[11].

All Part 9 archetypes were run through both normalization methods to investigate whether they would improve the equity or effectiveness of the performance requirements. The PHIUS method was applied to TEDI only, while the NRCan method was applied to all three metrics. Overall, the results of the PHIUS analysis did not yield improved results for affordability in colder climates. A ratio was derived using values generated by climate zones in the United States and comparing them to the static Passive House standard. For example, to derive a ratio for Climate Zone 6, a comparison between the normalized target developed for the US and the static Passive House standard was made:

- International Passive house target = 15 kWh/m^2/yr
- PHIUS-adjusted target for Climate Zone 6 = 24.5 kWh/m^2/yr
- Resulting Ratio = 1.41

This was applied across climate zones to explore the impact of the adjustment across the province, the results of which are shown in Table 30. For example, applying the ratio to the Step 4 performance requirement in Climate Zone 8 resulted in an increase from the original TEDI performance requirement of 25 kWh/m^2/year to a TEDI of 45 kWh/m^2/year.

[11] Energy Modelling Report. Modelling of Archetype Building to the NECB 2015 using Various Simulations Programs. Prepared for NRC, May 2014.

A similar result occurred in the application of NRC's heating degree day normalization methodology, though with much more exaggerated results. This approach uses a formula through which targets can be adjusted based on the specific HDD of a given city, or *y=mx+b,* where:

- *y* is the resulting MEUI or TEDI target to be adjusted;
- *m* is 0.0115, the "best fit slope", developed as a result of modelling residential buildings that comply with the National Energy Code for Buildings in different climate zones;
- *x* is HDD; and,
- *b* is a constant or baseline value – in this case, the Climate Zone 4 performance requirement for each step.

When applied to Step Code TEDI performance requirements, the formula resulted in values from 89% to 573% higher than the energy requirements currently proposed in the regulation (see Table 30), making the thresholds far too relaxed to achieve the Province's climate and energy goals. The same result occurred with MEUI and PTL performance requirements (see Table 31).

The results of these adjustments demonstrate that the approach to normalization that was taken to the original set of Part 9 targets in fact reflects both a reasonable and equitable result for northern climates of the approaches explored here. As such, the recommended approach to ensuring the affordability for Step Code performance requirements for Part 9 buildings in northern regions of the province is to retain the original set of targets and adjust the approach to implementation.

While additional efforts could be made to derive an ideal normalization methodology, it should be noted that Climate Zones 7b and 8 represent small fraction of the provincial population. As noted above, there are three municipalities in Zone 7b and one municipality in Zone 8. It should also be repeated that these climate zones have a combined population of approximately 4,000 people, 3,900 of which live in Fort Nelson in Zone 7b. As such, the economic implications and environmental benefits of applying the Step Code for Part 9 buildings in these regions is somewhat limited. Where northern local governments elect to adopt the Step Code, the recommended approach is therefore to adopt lower steps (i.e. Steps 1 through 3) until such time that costs decline.

In the instance that a more specific methodology is still desired, a partnership with NRC's Canadian Codes Centre could be sought to develop an alternate "best fit slope" that designed specifically for Part 9 buildings.

Table 30: Two Methods of Adjusting Requirements based on Climate Zone

	PHIUS			NRCan		
Step	Original TEDI	Adjusted TEDI	% Change from Original	Original TEDI	Adjusted TEDI	% Change from Original
Climate Zone 4						
Step 1	Report only			Report only		
Step 2	45	45		45	45	
Step 3	40	40	0%	40	40	0%
Step 4	25	25		25	25	
Step 5	15	15		15	15	
Climate Zone 5						
Step 1	Report only			Report only		
Step 2	45	54		45	85	89%
Step 3	40	48	20%	40	80	100%
Step 4	25	30		25	65	164%
Step 5	15	18		15	55	267%
Climate Zone 6						
Step 1	Report only			Report only		
Step 2	45	63		45	97	115%
Step 3	40	56	40%	40	92	130%
Step 4	25	35		25	77	208%
Step 5	15	21		15	67	346%
Climate Zone 7 A						
Step 1	Report only			Report only		
Step 2	45	72		45	108	140%
Step 3	40	64	60%	40	103	157%
Step 4	25	40		25	88	252%
Step 5	15	24		15	78	420%
Climate Zone 7 B						
Step 1	Report only			Report only		
Step 2	45	72		45	120	167%
Step 3	40	64	60%	40	115	188%
Step 4	25	40		25	100	300%
Step 5	15	24		15	90	500%
Climate Zone 8						
Step 1	Report only			Report only		
Step 2	45	81		45	131	191%
Step 3	40	72	80%	40	126	215%
Step 4	25	45		25	111	344%
Step 5	15	27		15	101	573%

Table 31: Impact of NRCan Climate Adjustment on MEUI and PTL

Step	Original MEUI	Adjusted MEUI	% Change from Original	Original PTL	Adjusted PTL	% Change from Original
Climate Zone 4						
Step 1	Report Only		0%	Report Only		0%
Step 2	60	60		35	35	
Step 3	45	45		30	30	
Step 4	35	35		25	25	
Step 5	25	25		10	10	
Climate Zone 5						
Step 1	Report Only			Report Only		
Step 2	90	100	11%	55	75	36%
Step 3	75	85	13%	45	70	55%
Step 4	45	75	67%	40	65	63%
Step 5	25	65	160%	10	50	400%
Climate Zone 6						
Step 1	Report Only			Report Only		
Step 2	100	112	12%	55	87	58%
Step 3	85	97	14%	50	82	64%
Step 4	55	87	58%	45	77	71%
Step 5	25	77	200%	10	62	500%
Climate Zone 7 A						
Step 1	Report Only			Report Only		
Step 2	100	123	23%	55	98	78%
Step 3	85	108	27%	50	93	86%
Step 4	55	98	78%	45	88	96%
Step 5	25	88	252%	10	73	630%
Climate Zone 7 B						
Step 1	Report Only			Report Only		
Step 2	100	135	35%	55	110	100%
Step 3	85	120	41%	50	105	110%
Step 4	55	110	100%	45	100	122%
Step 5	25	100	300%	10	85	750%
Climate Zone 8						
Step 1	Report Only			Report Only		
Step 2	100	146	46%	55	121	120%
Step 3	85	131	54%	50	116	132%
Step 4	55	121	120%	45	111	147%
Step 5	25	111	344%	10	96	860%

3.2 Building Size

A second key component of this research was to determine whether Step Code performance requirements should be adjusted according to the size of a dwelling. Interest in this aspect of the research is partially founded in findings from other markets that have used performance-based frameworks with energy intensity metrics, which have demonstrated that these frameworks can be more difficult for smaller buildings to achieve. This can especially be the case in residential buildings, where major energy consumers in the home are not dependent on size. For example, housing units almost always have a kitchen and laundry facility, regardless of the home's size.

The analysis of Part 9 buildings presented in Section 3 also indicates a much greater challenge for smaller homes to achieve Step Code values than larger homes, in that cost premiums were higher in smaller dwellings when compared to larger homes. Moreover, it should also be noted that there were select cases in which the results of parametric analysis were not able to yield any solutions that met the Step Code performance requirements using the ECMs provided in smaller homes.

This consideration has been addressed in other performance-based standards in Europe. Building codes subject to the European Building Directive require buildings to divide heated floor areas by 1650 kWh/m^2/yr and add the result to the MEUI requirement, which has the function of relaxing the threshold for smaller homes. As above, this approach to adjusting targets was applied to the original set of targets developed for Part 9 building to determine if it would yield a more equitable result.

However, it has been noted that adjustments for size may be more appropriate in the reverse direction; in other words, an adjustment that would see targets Step Code become more stringent for larger homes. The rationale behind this direction of adjustment is with the use of an intensity-based metric, larger homes are permitted larger energy budgets, whereas smaller homes will have a much more difficult time reducing their energy footprint. The fact that larger homes tend to have much larger energy footprints than smaller households also indicate that they can have a much more significant impact on the energy use reductions targeted by the Step Code.

Using the formulas above, performance requirements for Small and Medium SFD were made less stringent, while requirements for Large SFD were made more stringent. For example, applying the calculation noted above to the Small SFD (102m^2) at Step 5 in Climate Zone 7 results in the following:

- Original TEDI target for SFD: 1 kWh/m^2/yr
- Adjustment for Size: 1650kWh/yr/m^2 /102m^2) = 16kWh
- Adjusted TEDI = 15kWh/m^2/yr + 16kWh/m^2/yr = 31kWh/m^2/yr

Conversely, an example of this adjustment for the Large SFD (511m^2) at Step 5 in Climate Zone 7 has the following result:

- Original TEDI target for SFD: 15 kWh/m^2/yr
- Adjustment for Size: 1650 kWh/yr/m^2 / 511m^2 = 3kWh
- Adjusted TEDI = 15 kWh/m^2/yr - 3 kWh/m^2/yr = 12 kWh/m^2/yr

Table 32, Table 33, and Table 34 show the effect of this combined set of adjustments on incremental capital costs, NPV, and carbon abatement costs, respectively. The result of the application of this size adjustment methodology show an increase in the number of solutions that are possible for smaller homes, as well as lower cost premiums for this archetype. Incremental capital costs for Small SFD declined by up to 4.1% for Step 4 in Climate Zones 4 to 6, and up to 4.4% for Step 2 in Climate Zone 7a, with higher savings in colder climate zones and at higher steps. Medium SFD results show a similar pattern, with decline in incremental capital costs by 4.0% for Step 5 in Climate Zone 6. Finally, the loosening of the Large SFD requirements led to incremental capital cost increases with a maximum of 2.1% (Step 5 in Climate Zone 4), indicating that the target adjustment could result in a net improvement in the costs of the Step

Code. Confirming the overall impact of adjusting targets would require additional analysis to account for the relative total square footage of these housing types in different climate zones and across the province.

NPVs and carbon abatement costs also improved for Small and Medium SFDs, with NPV increasing by as much as $135/m^2 for Medium SFDs achieving Step 4 in Climate Zone 8, and $269/m^2 for Small SFDs achieving Step 4 in Climate Zone 7a. Carbon abatement cost increases for Large SFD ranged considerably, with a majority of increases ranging from $1 to $6 in several climate zones, and a single outlier of $227 for Step 4 in Climate Zone 7b. Similar to the change in incremental capital costs, the tighter targets mean NPVs for Large SFD decreased, but at a smaller rate. NPVs tended to decline by less than $10/m^2, with significantly worse declines for Step 5 in Climate Zone 4 (-$37/m^2) and Step 4 for Climate Zone 7b (-$49/m^2). Carbon abatement costs are directly linked to NPV, and the results follow a similar pattern.

Based on the results below, there is significant enough difference in costs to warrant a further examination of adjusting the Step Code performance requirements by size, particularly in higher Climate Zones (7a to 8). While modest, the reductions in performance proposed under this formula do help to lower costs for smaller homes which are more impacted by intensity-based targets. It is also recommended that the implementation of the Step Code for smaller homes be adjusted, or moderated. Given that smaller homes consume less in absolute terms than larger homes, local governments that exclude small homes from compliance with the Step Code should not create a significant impact on emissions reductions, which will be significantly more affected by fuel choice. As average detached home sizes are growing in BC, there is no significant development pressure to build smaller homes, outside of municipalities that are starting to allow laneway homes.

Table 32: Comparison of Incremental Capital Costs under Original vs. Adjusted Targets

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8
Large SFD	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.7%	0.1%	0.0%	0.5%	0.0%	0.2%
	4	0.3%	0.2%	0.4%	0.0%	0.8%	-
	5	2.1%	-	-	-	-	-
Medium SFD	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.1%	0.0%	0.0%	-2.1%
	3	-0.2%	0.0%	0.0%	-0.3%	-1.1%	-1.0%
	4	-0.6%	-0.7%	-0.3%	-0.6%	-1.0%	-3.7%
	5	-1.2%	-1.8%	-4.0%	-	-	-
Small SFD	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	-1.2%	-0.3%	-1.1%	-4.4%	-2.4%	-
	3	-2.2%	-1.5%	-1.4%	-5.6%	-	-
	4	-4.0%	-3.3%	-4.1%	-8.6%	-	-
	5	-6.8%	-7.9%	-3.9%	-	-	-

Note: Results that were found using the secondary process of analysis described in Section 1.6.4 were not included in the adjusted target analysis.

Table 33: Comparison of NPVs under Original vs. Adjusted Targets

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8
Large SFD	1	$0	$0	$0	$0	$0	$0
	2	$0	+$1	+$0	$0	-$12	-$5
	3	-$7	-$0	-$2	$0	$0	$0
	4	-$8	-$2	-$7	-$7	-$49	-
	5	-$37	-	-	-	-	-
Medium SFD	1	$0	$0	$0	$0	$0	$0
	2	$0	$0	$0	+$2	+$0	+$12
	3	+$7	$0	$0	+$10	+$14	+$47
	4	+$16	+$14	+$11	+$22	+$73	+$135
	5	+$18	+$19	+$85	-	-	-
Small SFD	1	$0	$0	$0	$0	$0	$0
	2	+$46	+$11	+$26	+$75	+$123	-
	3	+$66	+$40	+$54	+$203	-	-
	4	+$75	+$82	+$85	+$269	-	-
	5	+$174	+$230	+$133	-	-	-

Note: Results that were found using the secondary process of analysis described in Section 1.6.4 were not included in the adjusted target analysis.

Table 34: Comparison of Carbon Abatement Costs under Original vs. Adjusted Targets

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8
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	$0	-$114	$0	$0	+$43	+$16
	3	+$39	+$431	+$87	$0	$0	$0
	4	+$44	$0	+$42	+$26	+$34	-
	5	+$156	-	-	-	-	-
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	$0	$0	+$383	-$17	$0	-$22
	3	-$16	$0	$0	-$35	-$41	-$125
	4	-$28	-$13	-$45	-$38	-$79	-$168
	5	-$34	-$59	-$274	-	-	-
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	-$21	+$16	-$48	-$147	-$223	-
	3	-$70	-$16	-$65	-$505	-	-
	4	-$144	-$141	-$112	-$493	-	-
	5	-$559	-$583	-$295	-	-	-

Notes: Results that were found using the secondary process of analysis described in Section 1.6.4 were not included in the adjusted target analysis.

4 THE STEP CODE—BUILDING POLICY INTERFACE

This section explores the interface between the Step Code and BC Building Code (BCBC). This intersection is important to explore in order to identify any potential conflicts or contradictions between the two codes, as well as to identify opportunities to provide further guidance or changes to ensure their harmony. Issues covered in this section include an exploration of ventilations requirements for both Part 3 and Part 9 buildings, as well as minimum R-value requirements under the BCBC.

4.1 Part 9 R-Values

Two research questions outlined by this study pertain to the intersection of the Step Code with BCBC requirements. First, it is necessary to explore the potential for the Step Code to allow the use of wall assemblies in the construction of Part 9 buildings with lower R-values than the prescriptive requirements identified in BC Building Code. Secondly, it is important to determine whether performance steps can be achieved using R-values less than R-22 effective (i.e. the minimum value set out by the Vancouver Building By-law). Such questions are of interest principally due to a stated principle raised during the Step Code development process to encourage the use of passive design over mechanical solutions. It was deemed important to ensure that wherever possible, savings should be derived primarily from building envelopes. As lower R-values place greater reliance on buildings' mechanical systems to provide indoor heating and cooling, it is important to identify where lower R-values might be permitted.

With respect to the first question, the results of the analysis show that it is in fact possible to achieve Step 2 of the Step Code in Part 9 buildings with R-values that are lower than those identified in BC Building Code in Climate Zones 5, 6, 7a and 7b. Climate zones in which an envelope value lower than those prescribed as a part of the BCBC formed a part of potential solutions to achieve Step 2 performance requirements are presented in Table 35. These numbers are based on a review of optimized solutions for capital costs using original targets only. Wall solutions varied according to the inclusion or exclusion of an HRV as a part of the total ECMs used to achieve performance requirements, as per Section 9.36 of the BCBC. It should be noted that while these findings are based on a small set of optimized results, but yielded several instances where the BCBC can be met with envelope values that do not meet prescribed BCBC requirements. As such, these results likely indicate that many more instances exist in which the Step Code can be achieved using wall and window assemblies that fall below what is prescribed by the BCBC.

Based on a review of optimized solutions for incremental capital costs, it was also determined that buildings across several climate zones may be constructed using walls that fall below an R22 effective level of performance to achieve Steps 2, 3 and 4. Overall, buildings can achieve both Steps 2 and 3 across all climate zones with effective wall R-values below R22, including CZ6, where the 10-Unit MURB achieves Step 4 with walls with an effective R-value of 16. In single family homes, the size of the home has an inverse relationship with its ability to achieve Steps 3 and 4 using walls with effective R-values below R-22. In other words, the Large SFD has the greatest possibility of meeting Steps 3 and 4 with walls less than R-22 effective across all Part 9 archetypes, while the Small SFD has the lowest possibility across all archetypes. However, all archetypes were able to meet various levels of the Step Code using R-values below 22 effective. While this is an important finding, it is also important to bear in mind that such results can also be achieved under the current Building Code's performance pathway, as the purpose of the performance pathway itself is to allow for a multitude of solutions that allow builders to optimize to their needs.

Table 35: Part 9 R-Values that fall below BCBC Precriptions when Optmizing for Incremental Captial Costs

Archetype	Climate Zone	Step 2 (Windows)	Step 2 (Walls)	Step 3 (Walls)	Step 4 (Walls)
10-Unit MURB	4				
	5				
	6	1.8	R-16		R-16
	7a	1.8			
	7b	1.6	R-18		
	8	1.8			
6-Unit Row House	4				
	5				
	6	1.8	R-16	R-16	
	7a	1.8	R-16	R-18	
	7b		R-18	R-16	
	8				
Quadplex	4				
	5		R-16	R-16	
	6	1.8	R-16		
	7a		R-16		
	7b				
	8				
Large SFD	4				
	5		R-16	R-16	R-16
	6	1.8	R-16		R-16
	7a				
	7b	1.6	R-16		
	8				
Medium SFD	4				
	5		R-16	R-16	
	6	1.8	R-16	R-16	R-16
	7a	1.8			
	7b		R-18		
	8				
Small SFD	4				
	5				
	6		R-16		
	7a				
	7b				
	8				

A potential means for local governments interested in addressing this issue is to explicitly specify that walls cannot fall below the minimum prescribed requirements of the BCBC. While they do not explicitly address this issue, local governments may also wish to consider the development of zoning policies that allow for wall thickness exclusions or floor area ratio relaxations for better performing walls. This practice has already been implemented in the Cities of Vancouver and New Westminster to effectively remove the incentive for builders to construct thinner walls as a way of increasing total saleable floor area.

4.2 Ventilation Requirements

Two issues related to the implementation of the Step Code that were evaluated in this report are relevant to ventilation. The first relates to how Part 9 buildings are modelled within the EnerGuide Rating System, while the second considers the design of ventilation systems in Part 3 buildings. Both are presented in the sections below.

4.2.1 The Impact of Different Ventilation Standards on Part 3 Step Code Targets

For Part 3 buildings, the BCBC requires compliance with ASHRAE 62-2001, excluding Addendum n. Addendum n of ASHRAE 62-2001 introduced a substantially different methodology to calculating outdoor air requirements in buildings, recognizing that ventilation rates could be lowered in buildings if the air was delivered efficiently. ASHRAE 62-2004 Addendum h, however, changed the outdoor air requirements for residential dwelling units, primarily from having exhaust driven requirements to being treated like any other commercial type space with both a ventilation rate for people and for floor area. This change led to higher ventilation rates in larger suites, where the overall outdoor air requirements are driven by the floor area. The National Building Code (NBC), and the provinces that predominantly base their code on the NBC, have maintained their reference to ASHRAE 62-2001, excluding Addendum n, avoiding the major changes implemented by ASHRAE 62 over subsequent years.

A comparison was done to a more recent version of ASHRAE 62.1-2010, which is referenced by other jurisdictions (e.g. Ontario), as well as LEED v4. Figure 22 shows the design ventilation rate for different sizes of two bedroom suites with three occupants according to ASHRAE 62-2001 and 62.1-2010. For very small suites, the two codes produce similar ventilation rates. At more typical floor areas for two bedroom suites, the 2010 version of the code requires up to 46% more outdoor air than the 2001 version. The ASHRAE 62-2001 results are used for all other sections of this report.

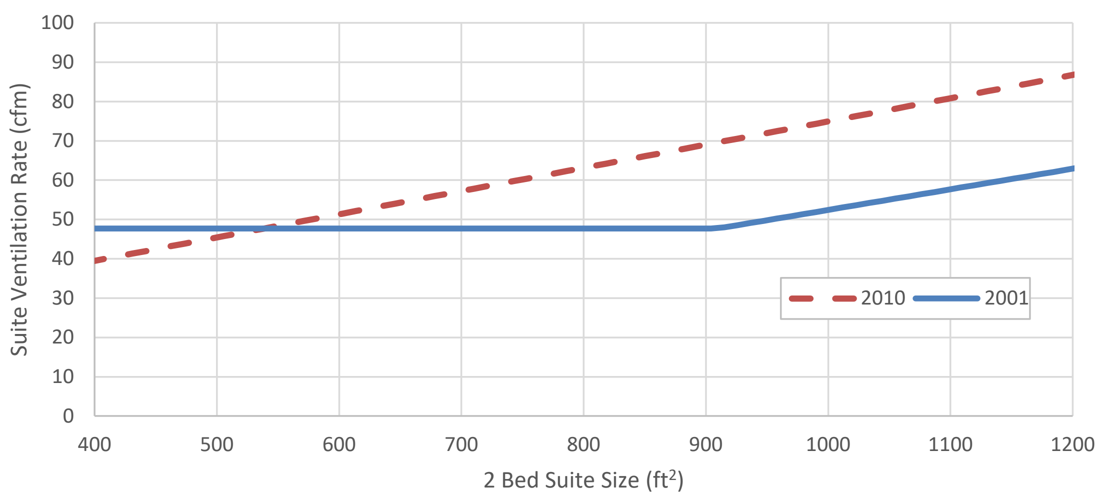


Figure 22: Two Bedroom Suite Ventilation Rates for ASHRAE 62.1-2001 and 2010

The energy implications of higher ventilation rates are affected by several factors, including climate zone, the use of heat recovery ventilation, and the magnitude of other building loads.

Figure 23 shows the impacts of different ventilation code versions on EUI and TEDI for the recommended solutions for meeting Step 2 of the Step Code for each climate zone. All solutions include 60% efficient heat recovery ventilation and pertain to low occupancy densities. The results show an increase of over 40% in ventilation rates between 2001 and 2010 versions of ASHRAE 62. This change is most pronounced in Fort St. John (Climate Zone 7A), resulting in a 9 kWh/m^2 increase in EUI, and an 8 kWh/m^2 increase in TEDI – an increase similar in magnitude to one step of the Step Code. In Vancouver (Climate Zone 4), the milder climate reduces the influence of ventilation rates and shifting from 2001 to 2010 versions of the code increases EUI by 5 kWh/m^2, and TEDI by 4 kWh/m^2.

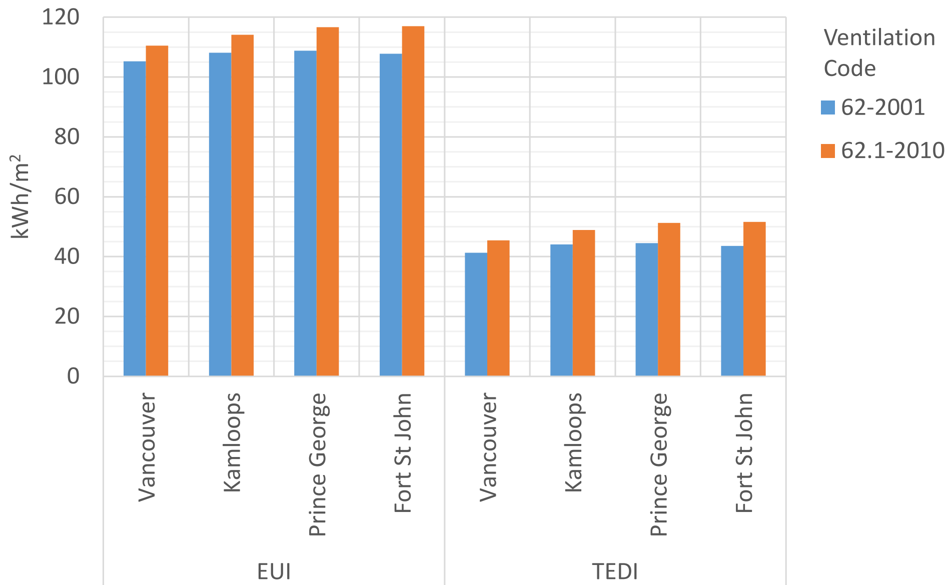


Figure 23: Impact of Ventilation Code on MURB EUI and TEDI

Another important ventilation implication for MURB is the practice of corridor pressurization. This involves supplying corridors with substantially more air than what is required by code to pressurize the corridor to overcome stack effect forces and to minimize odour transmission between suites and the corridors. As it is difficult to design a corridor pressurization system that utilizes heat recovered air, this approach can significantly impact the TEDI and subsequently, the EUI. The expectation is that over time, as buildings get more air tight and designers use new ways to manage stack effect and odours, the practice of corridor pressurization will be eliminated. All of the targets presented in this report are in line with the City of Vancouver's Energy Modelling Guidelines, which give an allowance of up to 9.4 L/s/suite (20 cfm/suite) of corridor pressurization at no penalty to the TEDI or EUI.

For Commercial and Retail buildings, outdoor air requirements are typically lower in ASHRAE 62-1-2010 compared to ASHRAE 62-2001. As such, there is no risk to complying with the performance requirements for non-residential facilities due to ventilation.

4.2.2 The Impact of Ventilation Assumptions on Part 9 Modelling Results

With regard to Part 9 buildings, the Building and Safety Standards Branch Information Bulletin No. B14-05 issued in September 17, 2014, states that "*to satisfy the exhaust requirements of a principal ventilation system, every dwelling unit needs to have one fan that exhausts air continuously (24hr/day) at the minimum exhaust rates outlined in Table 9.32.3.5.*" [12] However, the Building and Safety Standards Branch allows the use of the EnerGuide Rating System to demonstrate compliance with energy performance requirements of the BCBC, which assumes that the principal ventilation system operates for only 8 hours a day. This presents a challenge, in that there can be significant implications for both the MEUI and TEDI in using an assumption for either 24-hour or 8-hour ventilation.

In order to investigate the impact of this discrepancy, the 10-Unit MURB and the Large SFD archetypes were modelled in HTAP twice: once with continuous (24-hour) ventilation and once with intermittent ventilation set at 8 hours per day.[13] Permutations with the same or very similar ECM combinations were modelled under both 8 hr and 24 hr ventilation

[12] http://www.housing.gov.bc.ca/building/B14-05_9%2032%20_Ventilation.pdf
[13] It should be noted that costing analyses assumed an 8-hour ventilation rate.

modes. Permutations from multiple climate zones (Zones 4, 5 and 8 for the SFD, and all zones except 7b for the MURB archetype) were included, as well as those that achieved multiple steps of the Step Code.

The outcomes of this exploration can be found in Appendix 7.12. The sample of results where all ECMs are identical, but ventilation rates are different, indicates that assuming 24-hour ventilation rather than 8-hour for the Large SFD increases MEUI and TEDI by an average of 8% and 7%, respectively. The difference in MEUIs ranges from 3% to 15% and difference in TEDIs from 0% to 16%, across all Climate Zones. The impact of different ventilation assumptions is greater and more varied for the MURB. Based on the selected samples, shifting from 8-hour to 24-hour ventilation increases the MURB's average MEUI and TEDI by 15% and 10%, respectively, with ranges of 9% to 21% and 0% to 20%, respectively.

Overall, these results demonstrate that the ventilation assumptions applied in modelling buildings can have a significant impact on energy performance, and thus what Step a building achieves. As such, there is a need for clarity in the regulation and guidelines for compliance to both the BCBC and the Step Code issued to Energy Advisors who model ventilation to ensure consistent results.

5 DESIGN AND INDUSTRY IMPACTS

A final component of this study is to identify the potential risks that may be posed as a result of the implementation of the Step Code, as well as any conflicts with existing tools or regulations. The sections below, implications for overheating and thermal comfort, fire safety, and building durability are explored first, followed by a summary of the alignment of the Step Code with two existing building energy performance tools (Energy Star® Portfolio Manager and EnerGuide) and the City of Vancouver's Zero Emissions Building Plan.

5.1 Risk of Overheating

5.1.1 Part 3

The City of Vancouver commissioned a study that assessed the impacts of the City's Zero Emissions Building Plan (ZEBP) on overheating in typical suites using passive cooling. The study uses energy modeling to assess the risk of overheating for MURB with no active cooling systems to compare the risk of overheating between conventional practice and buildings complying with the ZEBP. It was found that current typical practice could cause up to 1000 overheated hours per year for the modelled, worst-case suites (i.e. southwest facing). The updated ZEBP that encourages improved envelopes (roughly equivalent to Step 3 of the Step code) increases the number of overheated hours by an additional 100 and 1300 overheated hours per year, depending on suite type. It is reasonable to assume that implementing the Step Code could have similar impacts. For buildings that have no active cooling, overheating can be mitigated using typical approaches, such as properly sized windows for adequate natural ventilation, reduced solar heat gain coefficient on windows, and external overhangs in the form of balconies or sunshades. When these typical measures are applied, the maximum temperature experienced in a suite has been shown to be under 30C for Vancouver."

The Vancouver study went on to investigate a number of passive cooling strategies to mitigate this overheating, and compared the costs of those strategies with the cost premium of adding mechanical cooling. A number of design strategies were identified that allow the suites to reduce overheating to below 200 hours per year. Natural ventilation through larger operable windows, and shading provide savings without adding a cost premium to current typical practice. Other solutions, such as reducing solar heat gain through carefully selected window coatings, cost no more than installing a mechanical cooling system. Warmer climates in BC outside of Vancouver typically use mechanical cooling, though if not mechanically cooled, may require additional measures to limit overheating than what was studied for the City of Vancouver. This should be addressed on a project by project basis as indicated in the energy modelling guidelines.

5.1.2 Part 9

The same risks of designing homes that could have thermal comfort problems related to overheating that were outlined for Part 3 buildings apply to Part 9 buildings. Caution should be taken to ensure that buildings with highly heat-retentive envelopes and high solar gain glazing do not overheat, even in colder climates. This is particularly the case with the Small SFD, where overheating presented a potential problem at higher levels of the Step Code in Climate Zones 4, 5 and 6, and various levels in Climate Zones 7a, 7b and 8.

One key issue to note is that HOT2000 is not well suited to diagnosing overheating as a potential issue. An experienced energy modeller may realize from looking at the heating requirements of the home and derive that the home has the potential for over-heating. However, explorations into the development of a robust methodology to address this concern is necessary. One methodology that could be explored is the approach used in developing the CHBA Net-Zero label. Absent of this, designers should be encouraged to moderate solar gain and consider mechanical cooling where appropriate in buildings targeting Steps 4 and 5. This can be done through design with solar shading devices, window selection and placement and natural ventilation strategies, or through the selection of mechanical solutions such as heat pumps.

5.2 Fire Safety

Proposed design solutions that were generated by both the lowest cost premium investigations and the lowest NPV calculations were reviewed with Integral Group's Fire Protection Engineering Group, which concluded that the solutions proposed do not increase either the risk of fire or the ability of occupants to exit the building in an emergency.

5.3 Building Durability

All proposed solutions and wall assemblies likely to be employed as a result of pursuing Part 3 Step Code performance requirements were reviewed by Morrison Hershfield's Building Science Division. They found that while poor design or construction is always a risk, the proposed thresholds presented no more of a risk than current construction practices. It is also important to note that the building envelope professional review and sign off requirements for Part 3 will still be in effect to ensure that building durability will not be compromised.

While there are no requirements for professional review and sign off on building envelope performance for Part 9 buildings, an understanding of building science is increasingly critical with the implementation of the Step Code. As members of the construction industry are required to build increasingly thicker walls and more airtight homes, there is less margin for error with regards to possible moisture issues. This risk can be mitigated by placing insulation on the exterior of the envelope and outside the vapour barrier, but this is not a standard practice across the industry. As a result, more training and resources in correct design and installation for the achievement of airtight corners and windows will be required to support industry as higher steps are broadly implemented.

5.4 Industry Alignment

5.4.1 Energy Star® Portfolio Manager

Energy Star® Portfolio Manager is an interactive, web-based tool used to measure and track energy and water consumption in Part 3 buildings. It has become a widely used tool in energy benchmarking, reporting and disclosure policies across North America, and has been noted as the primary tool to calculate energy and emissions for compliance with the Canada Green Building Council's recently released Zero Carbon Building Standard.

In its current form, Energy Star® Portfolio Manager allows for a calculation of Total Energy Use Intensity (TEUI), but does not allow for the calculation of Thermal Energy Demand Intensity (TEDI). Further, it should be noted that the final calculation of TEUI within Portfolio Manager should not be expected to correlate with modelled results, as the energy modelling guidelines cited by the Step Code require the use of select normalized inputs. While this is important to ensure the comparability between energy models during Step Code compliance checks, it means that any TEUI values in these energy models will not be predictive of actual energy use, and therefore are unlikely to align with reported outcomes in Portfolio Manager. As such, it will be important to make this discrepancy clear in any guidance provided to assist buildings required to comply with the Step Code.

5.4.2 EnerGuide Rating System

EnerGuide is the Government of Canada's energy performance rating and labelling program for homes (as well as other energy-using products). The EnerGuide rating system does not explicitly collect or track any of the metrics currently used in the Step Code framework; however, its expanded reports do provide the necessary outputs needed to calculate Thermal Energy Demand Intensity (TEDI), Peak Thermal Load (PTL), and Mechanical Energy Use Intensity (MEUI). Efforts are currently underway to allow the software to automatically produce a performance path compliance report by pulling the metrics important to the Step Code directly out of a HOT2000 v11.3 XML file. Such an effort would assist in the harmonization between the Step Code and the use of the EnerGuide system, and support consistency within the industry.

5.4.3 The City of Vancouver's Zero Emission Building Plan

Released in 2016, the City of Vancouver's Zero Emissions Building Plan (ZEBP) is Vancouver's 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). In general, the GHGI requirement for ZEBP drives a fuel switch to various degrees depending on the building type and timeline. The discussion below focuses on the EUI and TEDI differences only.

Table 36 provides a comparison of the City of Vancouver's performance requirements with those outlined in the Step Code. It can be noted from this comparison that the City of Vancouver's requirements for High-Rise MURB are similar to those established in the Step Code, but start at a higher baseline equivalent to one step higher. The differentiation between the two sets of performance requirements for Low-Rise MURB accounts for the assumption that low-rise buildings will be of wood-frame construction, in which higher levels of envelope performance are possible with minimal incremental cost, and thermal bridging is typically less severe. Wood-frame, or combustible construction, also more easily allows for the installation of higher performance windows with vinyl or fibreglass frames. As such, there is an incentive to use wood-frame construction to meet the low-rise requirements. Low-Rise concrete/steel buildings will be somewhat challenged to meet the City of Vancouver's Low-Rise targets, requiring the use of better-performing materials over what is typical. The comparisons below only consider the EUI and TEDI requirements between the BC Step Code and the City of Vancouver Zero Emissions Building Plan targets. The GHG targets, which are only applicable to the City of Vancouver requirements are not considered in the comparison.

Table 36: Step Code vs. Vancouver Building Bylaw (VBBL) Performance Requirements

Building	BC Step Code			City of Vancouver (Without a Low-Carbon District Energy System)		
	Step	EUI (kWh/m²/yr)	TEDI (kWh/m²/yr)	EUI (kWh/m²/yr)	TEDI (kWh/m²/yr)	COV Rezoning Date
High-Rise MURB	1	Current Code		Current VBBL		VBBL
	2	130	45	120	32	2016 Rezoning
	3	120	30	100	18	2020 Rezoning*
	4	100	15	90	10	2025 Rezoning*
Low-Rise MURB	1	Current Code		110	25	VBBL
	2	130	45	100	15	2016 Rezoning
	3	120	30	Not Yet Defined		N/A
	4	100	15	Not Yet Defined		N/A
Office	1	Current Code		Current VBBL		VBBL
	2	170	30	100	27	2016 Rezoning
	3	120	20	100	21	2020 Rezoning*
Retail	1	Current Code		Current VBBL		VBBL
	2	170	30	170	21	2016 Rezoning
	3	120	20	Not Yet Defined		N/A

**Speculative*

High-Rise MURB

Table 37 summarizes the low cost solutions for typical High-Rise MURB to meet both the Step Code and City of Vancouver performance requirements. Incremental capital costs for the Step Code thresholds range between 0.4% and 3.2%, while the City of Vancouver's targets result in a range between 1.4% and 3.5%. Most steps require less than a 1% additional incremental capital cost to meet the more stringent City of Vancouver's thresholds over the Step Code performance requirements. The additional cost is usually attributed to improved window performance and heat recovery efficiency. Notably, in Climate Zone 7, the City of Vancouver's requirements cannot be met for Steps 2 and 3 without accelerating the timeline for air infiltration improvements, and Step 4 is not feasible within the parameters modelled. However, it should be noted that high-rise, non-combustible MURB are rare building forms in the north.

Alignment between the Step Code and City of Vancouver's requirements appears possible, where the City of Vancouver could align with Step 3 for the future 2020 VBBL requirements and Step 4 for the future 2020 rezoning requirements. Although the City of Vancouver has indicated a potentially more stringent target in 2025 than Step 4, the improvements are small and could likely be dealt with through the GHGI requirement.

Low-Rise MURB

Table 38 summarizes the lowest cost solutions for typical low-rise, wood-frame MURB that meet Step 2 of the Step Code and the City of Vancouver's 2016 rezoning target. For wood frame buildings, R-40 effective wall assemblies are feasible for relatively low absolute incremental capital costs. However, the lower base buildings costs for low-rise buildings can inflate the incremental capital cost as a percentage of the base building cost. Due to the feasibility of R-40 effective wall performance for wood stud assemblies vs. steel stud assemblies, the City of Vancouver 2016 Rezoning and Step Code Step 4 for Climate Zone 7A is attainable for low-rise buildings, as long as Passive House level air tightness standards are met. The more stringent performance requirement is not achievable in Climate Zone 7B due to TEDI limitations, although this may be addressed by designing for a low VFAR.

Step 2 performance requirements lead to the use of low-rise MURB measures that are similar to current practice, though with the addition of heat recovery ventilation. Aside from Climate Zones 7a and 7b, they also allow for a lower overall glazing performance than current prescriptive code requirements, which is not typical in the market. In general, the Step Code and City of Vancouver performance requirements for low-rise MURB can align in the future. The 2020 VBBL could align with Step 4 of the Step Code.

Commercial / Retail Buildings

Lowest costs solutions for Commercial Offices that meet Steps 2 and 3 are presented in Table 40, while solutions for big box Retail buildings that meet Step 2 are presented in Table 39. For Commercial Office buildings, the Step Code's and City of Vancouver's TEDI performance requirements are similar, while the City of Vancouver's EUI threshold is comparatively very low. Office buildings with default occupancy densities and no additional (i.e. Information Technology, or IT) loads can meet the City of Vancouver's requirements using lighting savings and some additional envelope improvements, or else a move to more efficient HVAC plants such as air-source heat pumps. However, buildings with very high IT loads will not meet the City of Vancouver's EUI performance requirement within the parameters modeled. As such, it is recommended that high process loads and their associated internal gains be allowed to be captured within the TEDI calculation, but that they can be excluded from TEUI calculations. To do so would further require separate metering to segregate any loads not included in the TEUI calculation.

It should also be noted that commercial office buildings with high occupancy will require higher efficiency HVAC plants. Buildings in Climate Zone 5 that have warmer summers and high occupancy also may be unable to meet the City of Vancouver's EUI performance requirement without additional interventions that were not within the parameters modeled (e.g. renewable energy).

Finally, the City of Vancouver's framework currently only defines performance requirements for Step 2 for Retail buildings. The Step 2 EUI threshold is the same for both codes, while the City of Vancouver's TEDI threshold is the same as BCBC's Step 3. Since Retail buildings solutions with typical internal loads are well below the EUI threshold at Step 2, City of Vancouver solutions need only focus on envelope improvements to reduce TEDI. HVAC system efficiency and lighting savings are not necessary.

Table 37: Step Code Low-cost Solutions for High-Rise MURB – Step Code vs. City of Vancouver (CoV) Targets

Scenario			Measures								Outcomes						
Climate	Step	Targets	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Loads Savings	EUI (kWh/m^2)	TEDI (kWh/m^2)	Inc. Cap. Cost	Inc. Cost $\$/m^2$	NPV	NPV $\$/m^2$	COC $\$/tCO_2e$
CZ4	2	BCBC	40	10	20	2.5	Code	0.6	Condensing	20	111.7	40.6	6.2	0.4	11.8	265815	14.8
		CoV	40	10	20	2	Code	0.8	Condensing	20	98.6	27.6	6.0	1.9	58.2	-162638	-9.0
	3	BCBC	40	10	20	2.5	Improved	0.8	Condensing	20	100.8	29.7	6.0	0.8	24.9	370803	20.6
		CoV	40	10	20	1.6	Improved	0.8	Condensing	20	88.4	17.4	5.9	2.4	72.9	-111005	-6.2
	4	BCBC	40	10	20	1.6	PH	0.8	Condensing	20	85.8	14.8	5.8	2.4	74.3	-54760	-3.0
		CoV	40	10	20	1.2	PH	0.8	Condensing	20	80.7	9.7	5.7	2.8	86.3	-116244	-6.5
CZ5	2	BCBC	40	20	20	2.5	Code	0.6	Condensing	20	114.9	43.8	6.3	1.0	33.6	-3094	-0.2
		CoV	40	10	20	1.6	Code	0.8	Condensing	20	102.6	31.6	6.1	2.3	75.3	-372192	-20.7
	3	BCBC	40	10	20	1.6	Improved	0.8	Condensing	20	97.2	26.1	6.0	2.4	78.3	-254325	-14.1
		CoV	40	20	20	1.2	Improved	0.6	Condensing	20	89.0	18.0	5.9	3.1	100.9	-413993	-23.0
	4	BCBC	40	10	20	0.8	PH	0.8	Condensing	20	82.5	11.5	5.8	3.2	105.5	-292175	-16.2
		CoV	40	20	20	0.8	PH	0.6	Condensing	20	80.8	9.8	5.8	3.5	115.3	-418544	-23.3
CZ6	2	BCBC	20	20	20	2.5	Code	0.6	Condensing	20	111.6	40.5	6.3	1.3	45.4	311748	17.3
		CoV	20	10	20	0.8	Code	0.8	Condensing	20	99.5	28.4	6.2	2.1	72.3	203258	11.3
	3	BCBC	20	20	20	2.5	Improved	0.8	Condensing	20	99.3	28.2	6.2	1.8	60.2	429605	23.9
		CoV	20	20	20	0.8	Improved	0.6	Condensing	20	88.7	17.6	6.0	2.6	89.1	230370	12.8
	4	BCBC	20	20	40	0.8	PH	0.6	Condensing	20	85.7	14.7	5.9	2.7	91.5	279667	15.5
		CoV	20	20	40	0.8	PH	0.8	Condensing	20	80.8	9.8	5.9	3.0	103.1	220799	12.3
CZ7A	2	BCBC	20	20	40	1.2	Code	0.6	Condensing	20	116.0	44.9	6.4	2.0	92.5	-816552	-45.4
		CoV*	20	20	40	0.8	Code	0.8	Condensing	20	104.0	32.8	6.2	2.6	117.1	-883310	-49.1
	3	BCBC	20	20	20	0.8	Improved	0.6	Condensing	20	100.3	29.2	6.2	2.3	104.6	-544081	-30.2
		CoV*	20	20	40	0.8	Improved	0.8	Condensing	20	94.0	22.9	6.1	2.7	121.3	-647440	-36.0
	4	BCBC*	20	20	40	0.8	PH	0.8	Condensing	20	88.7	17.6	6.0	2.7	123.3	-519845	-28.9
		CoV*	20	20	40	0.8	PH	0.8	Condensing	20	88.7	17.6	6.0	2.7	123.3	-519845	-28.9

* *Measures and outcomes represent the most feasible scenario which approaches, but does not meet the performance requirements*

Table 38: Step Code Lowest Cost Solutions for Part 3 Low-Rise MURB, BCBC vs. CoV Targets

Scenario			Measures								Outcomes						
Climate	Step	Targets	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Loads Savings	EUI (kWh/m^2)	TEDI (kWh/m^2)	Inc. Cap. Cost	Inc. Cost $/m^2	NPV	NPV $/m^2	COC $/tCO_2e$
CZ4	2	BCBC	40	20	20	2.5	Code	60%	Condensing	20%	104.4	33.4	0.5%	11.8	$489,000	27.2	-398.2
		CoV			40	1.2					85.7	14.7	3.1%	75.5	-$78,000	-4.3	58.5
CZ5	2	BCBC	40	20	20	2.5	Code	60%	Condensing	20%	114.9	43.8	0.5%	12.7	$373,000	20.7	-306.8
		CoV				0.8		80%			83.5	12.5	3.9%	101.0	-$248,000	-13.8	178.9
CZ6	2	BCBC	20	20	20	2.5	Code	60%	Condensing	20%	111.6	40.5	0.4%	12.0	$914,000	50.8	-704.0
		CoV		40		1.2		80%			85.3	14.2	4.1%	111.4	-$68,000	-3.8	46.6
CZ7A	2	BCBC	20	20	40	1.2	Code	60%	Condensing	20%	116.0	44.9	1.4%	52.1	-$89,000	-4.9	69.6
		CoV		40	20	0.8	PH	80%			84.2	13.1	4.1%	149.5	-$855,000	-47.5	590.4
CZ7B	2	BC Step	20	40	40	0.8	Code	60%	Condensing	40%	124.0	43.8	2.7	9.8	-79284	-22.0	217.1
		CoV*					PH	80%			101.3	21.1	3.5	12.9	-49700	-13.8	128.3

**Measures and outcomes represent the most feasible scenario which approaches, but does not meet the performance requirements*

Table 39: Step Code Lowest Cost Solutions for Big Box Retail, BCBC vs. CoV Targets

Scenario			Measures								Outcomes						
Climate	Step	Targets	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	EUI (kWh/m^2)	TEDI (kWh/m^2)	Inc. Cap. Cost	Inc. Cost $/m^2	NPV	NPV $/m^2	COC $/tCO_2e$
CZ4	2	BCBC	FC	20	10	20	2.5	Code	0.6	0	128.1	19.1	0.8	12.1	17461	3.9	-39.9
		CoV	ASHP	20	10	20	2.5	Code	0.6	0	113.3	19.1	0.8	12.1	6098	1.4	-7.0
CZ5	2	BCBC	FC	20	10	20	2.5	Code	0.8	0	147.0	26.7	1.3	18.8	2650	0.6	-4.5
		CoV	ASHP	20	10	20	0.8	Code	0.8	0	123.1	20.2	2.8	39.5	-75288	-16.7	66.1
CZ6	2	BCBC	FC	20	10	20	0.8	Code	0.8	0	142.5	29.8	2.8	47.8	-109493	-24.3	109.6
		CoV	ASHP	20	10	40	0.8	Code	0.8	0	119.5	20.3	4.3	73.1	-214167	-47.6	138.4
CZ7A	2	BCBC	FC	20	20	40	2	Improved	0.8	0	145.8	29.9	4.6	79.1	-168901	-37.5	106.7
		CoV*	ASHP	20	20	40	0.8	PH	0.6	0	124.7	20.9	5.2	89.2	-193198	-42.9	95.2

**Measures and outcomes represent the most feasible scenario which approaches, but does not meet the performance requirements*

Table 40: Step Code Lowest Cost Solutions for Commercial Office, BCBC vs. CoV Targets

Scenario			Measures								Outcomes						
Climate	Step	Targets	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	EUI (kWh/m²)	TEDI (kWh/m²)	Inc. Cap. Cost	Inc. Cost $/m²	NPV	NPV $/m²	COC $/tCO2e
CZ4	2	BCBC	FC	50	10	20	2.5	Code	None	0	115.4	29.4	-0.2	-5.8	458761	25.2	-471.9
		CoV	ASHP	50	10	20	2.5	Code	0.6	0	92.9	17.7	-0.1	-1.7	416036	22.8	-138.6
	3	BCBC	FC	50	10	20	2.5	Improved	0.6	0	104.8	14.7	0.0	-0.3	370345	20.3	-186.8
		CoV	ASHP	50	10	20	2.5	Improved	0.6	0	92.2	14.7	0.0	-0.3	405984	22.3	-135.1
CZ5	2	BCBC	FC	50	10	20	2.5	Code	0.6	0	117.8	24.9	-0.1	-1.6	254225	14.0	-195.0
		CoV	ASHP	50	10	20	2.5	Code	0.6	0	99.0	24.9	-0.1	-1.6	288523	15.8	-98.0
	3	BCBC	FC	50	20	20	2.5	Improved	0.6	0	111.1	18.5	0.2	5.9	166445	9.1	-94.9
		CoV	ASHP	50	10	40	2.5	Improved	0.6	0	97.7	20.3	0.1	1.8	254689	14.0	-86.3
CZ6	2	BCBC	FC	50	20	20	2.5	Code	0.8	0	116.2	28.7	0.4	12.0	6354	0.3	-3.6
		CoV	ASHP	50	20	20	2	Code	0.6	0	90.9	26.0	1.0	33.7	-239793	-13.2	67.3
	3	BCBC	FC	50	20	20	1.6	Improved	0.6	0	102.4	18.6	1.4	45.1	-450493	-24.7	180.0
		CoV	ASHP	50	10	40	1.6	Improved	0.6	0	90.0	20.9	1.3	41.6	-364254	-20.0	102.2
CZ7A	2	BCBC	FC	50	20	40	1.2	Code	0.6	0	115.0	29.7	1.6	51.9	-539435	-29.6	190.5
		CoV*	ASHP	50	20	20	0.8	Code	0.6	0	96.7	25.8	1.8	59.2	-614469	-33.7	142.3
	3	BCBC	FC	50	20	20	0.8	Improved	0.6	0	106.4	19.4	1.8	60.8	-668208	-36.7	188.3
		CoV*	ASHP	50	20	20	0.8	Improved	0.6	0	95.4	19.4	1.8	60.8	-613765	-33.7	141.9

**Measures and outcomes represent the most feasible scenario which approaches, but does not meet the performance requirements*

Overall, the performance requirements are very similar in terms of costs and outcomes. When the High-Rise MURB archetype (the most impacted by cost by the Step Code) was tested against the Vancouver performance requirements, the increase in capital costs was less than 1% in all cases but one. Energy and greenhouse gas savings were also greater when the COV framework was applied. Given these outcomes, the building industry may be willing to accept slightly higher costs for the sake of province-wide consistency. Given the relatively low costs, local governments may appreciate the ability to be more aggressive and aligned with a program that is already in operation.

5.5 Greenhouse Gas Emissions Reductions

One of the research questions posed by this report was to investigate if there are any possible unforeseen impacts to adopting the BC Energy Step Code that could be identified using the data generated by this project. One issue that local governments should examine is the level of GHG reductions being delivered by each step of the Step Code. In some cases, particularly at lower steps, achieving the Step Code does not yield GHG emissions reductions, or results in only small reductions. GHG emissions are not significantly reduced until Step 3. As discussed in Section 2.2.7, the parametric analysis revealed that it was even possible to have higher GHG emissions than a BCBC building by adopting Steps 3, 4, and even 5. This outcome is counter to the primary interests of the local governments who are interested in adopting the Step Code and also counter to the Province's own climate policy.

The primary issue driving GHG increases is fuel choice. Where buildings shift away from electricity and toward natural gas, GHG emissions will increase if overall energy use reductions are not significant enough. This is particularly true for BCBC base buildings assumed to rely primarily on electricity. In the present analysis, this is the case for the MURB and Quadplex base buildings. As can be seen in Table 41, where space heating and DHW systems shift to a natural gas dependence, even higher steps can result in significant GHG increases.
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Table 41: Examples of Increasing GHG Emissions while Achieving Higher Steps

Archetype	Climate Zone	Step Achieved	DHW System	Space Heating System	Change in GHGs from BCBC (%)
Quadplex	4	3	GasInstantaneous	gas-furnace-ecm	+14%
10 unit MURB	4	4	BaseDHW	gas-furnace-ecm	+43%
10 unit MURB	4	5	GasInstantaneous	gas-furnace-ecm	+0.4%
10 unit MURB	5	3	BaseDHW	gas-furnace-ecm	+158%
Quadplex	5	4	Combo	ComboHeatA	+11%
10 unit MURB	6	3	GasInstantaneous	gas-furnace-ecm	+73%
Quadplex	6	4	GasInstantaneous	gas-furnace-ecm	+25%
10 unit MURB	7a	3	GasInst_Low	gas-furnace-ecm	+76%
10 unit MURB	7a	4	Combo	ComboHeatA	+9%
10 unit MURB	7b	3	BaseDHW	gas-furnace-ecm	+62%
10 unit MURB	7b	4	Combo	ComboHeatA	+31%
10 unit MURB	8	3	BaseDHW	gas-furnace-ecm	+136%
10 unit MURB	8	4	HPHotWater	gas-furnace-ecm	+25%

Note: *Solutions found through the process outlined in Section 1.6.4 have been excluded as the process used to generate them precluded any increases in GHG emissions.*

To address this issue, the Province could look at requirements around fuel selection and/or explore the adoption of a GHG Intensity (GHGI) target for the Step Code that would result in predictable GHG emissions reductions. The authors of this report acknowledge that this may require an amendment to the BC Building Code to add GHG reductions as an objective, but that this would be consistent with the current draft of the Climate Action Plan. A GHGI metric may be able to be applied with little or no extra cost over what has been already contemplated. In the absence of clear direction on GHGI, there is also a risk that local governments may adopt differing GHG targets in order to ensure GHG savings. Such a trend would be counter to one of the central reasons for the Step Code's existence: to increase energy code alignment across the province.

6 SUMMARY AND RECOMMENDATIONS

6.1 Implementation Recommendations for Local Governments

Based on the analysis presented in this report, several recommendations have been made for the Province and local governments to consider for the implementation or ongoing development of the Step Code.

6.1.1 Targets for Part 3 Buildings

Given the affordability of the performance requirements developed for Climate Zone 4, it is recommended that the Step Code be applied to Climate Zones 4, 5, 6, and 7a. With some minor changes, the City of Vancouver could also adjust its requirements and better align with targets with the BC Energy Step Code, with limited impact. In future iterations or updates, the Province may wish to consider adding Low-Rise MURB (6 storeys) as a classification of building that would allow for m targets that better reflect the economics of this building type. It is acknowledged that this issue could also be dealt with at the local government level in implementation.

6.1.2 Greenhouse Gas Emissions Intensity Targets

Further to the above, it is also recommended that the Province explore the adoption of the City of Vancouver's GHGI targets into the Step Code. As noted above, this may require an amendment to the BC Building Code. However, this change would be consistent with the current draft of the Climate Action Plan and would mitigate one of the potential policy failures identified through this analysis: the unintended outcome whereby even higher steps of the Step Code can result in GHG increases.

6.1.3 Application of the Step Code on Different Building Types

Two archetypes of those that were tested were disproportionately *advantaged* in hitting the Step Code performance requirements: Low-Rise MURB and Large SFD. When applying the Step Code to these building types, local governments may want to consider applying Step 4 as the base code. In both cases, the cost premium is less than 1% of total construction costs in all climate zones when modelled with HOT2000. This is a similar or lower cost impact than what has been legislated in past building code updates. Note that this strategy of defining building types that do not exist in the BC Building code, such as Low-Rise MURB or "Large" SFD, may require alternate implementation policies that are executed through zoning and land-use regulations.

Two archetypes of those tested that were disproportionately *disadvantaged* by the Step Code performance requirements were Small SFD (including Laneway Homes) and the Quadplex. Duplexes will likely have similar results to the Quadplex typology. For these typologies, local governments are advised 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.

Overall, with the exception of the building types and locations noted above, most local governments in the province can target Step 3 for both Part 3 and Part 9 buildings as an aggressive but 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. Adopting Step 2 in Climate Zones 4, 5, and 6 may in fact prove disadvantageous, as the costs of going to Step 3 are marginal when compared to Step 2. There is furthermore lower risk of buildings with higher than building code levels of emissions at Step 3, which is a possible and even likely outcome at Step 2.

With regards to incentives, targeting incentives at Step 5 in Part 9 and Step 4 in Part 3 is likely where the greatest benefits will be realized. These are the steps most impacted by cost, and therefore potentially most likely to adversely impact affordability.

6.2 Future Research Directions

While this study has answered several questions as to the impact of the Step Code, several areas of further inquiry could still be pursued. In addition to the recommendation of using the existing dataset to test the application of the Vancouver ZEBP targets province-wide, some key possible directions for further research are outlined below.

Achieving Net Zero Ready Buildings

Further exploration into methods for lowering EUIs to ensure that net-zero ready levels of performance can actually be achieved should be conducted. Currently, the Step 4 TEUI performance requirement off 100 kWh/m^2/year is intended to achieve a 'net-zero ready' level of performance; however, lower performance requirements may be more effective in achieving the desired outcome without any additional impacts on cost.

Ventilation Rates

More detailed analysis is required to quantify the impact of modelling a house with 24-hour ventilation compared to 8 hr/day intermittent ventilation. The impact is more substantial in colder climates and with homes without heat recovery ventilation. When moving to Step 5, there is less of an impact in terms of energy use; however, it can make the difference in whether a building meets the MEUI and TEDI requirements.

Window WWR and Orientation

A number of archetypes were modelled by varying the distribution of windows on the different façade orientations. A short analysis quantifying the results of these cases would provide useful input.

Cost Impact and Incentive Analysis

More analysis on the monthly cost impact to a homeowner (financing + energy) for different utility rate increases, incentive programs, cost assumptions, etc., would be useful. Given that the same base house was modelled for all climate zones, it would be of interest to look at the net-monthly cost of the different steps from the same base building (Zone 4 code levels). This would provide a better comparison of the cost burden placed on homeowners in colder climate zones.

Analysis of 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. Considering the need to significantly reduce GHGs from buildings to achieve the Province's GHG reduction target, 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.

GHG Impact Assessments for Different Provinces

Given the low GHG emissions of the BC electrical grid, simple fuel switching can lead to a low upfront cost and $/tCO2e rate. It would be of interest to assess what the $/tCO2e of savings would be using the electricity GHG emissions intensities from different provinces.

Cooling Load Impact

Acknowledging that HOT2000 is not the best tool to model cooling, it would still be interesting to examine the cooling load implication of achieving the different steps. Hourly software could be used to model some archetype buildings to get a better understanding of the cooling load as well as the overheating potential of buildings if cooling is not included.

Software Tool Impact
The code allows the use of any ASHRAE 140 validated tool to be used for code compliance. It would be of interest to assess a few other tools to see how the results compare to HOT2000, or indeed if any other tools exist that can meet all modelling requirements outlined by 9.36.5.

Design Alternatives to Achieve Passive House in Upper Climate Zones
Additional modelling and analysis is needed to see how best to achieve Step 5 in the colder climates.

LEEP Type Plotting for Individual Measures
The analysis to date has looked at overall design and combinations of measures. Further analysis can be done to examine the effectiveness of individual measures. An example would be the type of graphs produced for the LEEP workshops that highlight individual measures in different plots.

7 APPENDICES

7.1 Part 9 ECM Limitations used in Costing Analysis

10 Unit MURB

ECM limitations for CZ4 to CZ8					
	Airtightness	Window USI	Space Heating	Ventilation Heat Recovery	Drain Water Heat Recovery
1	must be over 1.0	must be over 1.0	no furnace-based systems	must be under 75%	--
2	must be over 1.0	must be over 1.0	no furnace-based systems	must be under 75%	--
3	--	--	no furnace-based systems	--	--
4	--	--	no furnace-based systems	--	--
5	--	--	no furnace-based systems	--	--

6 Unit Row House

ECM limitations for CZ4 to CZ8				
	Airtightness	Window USI	Ventilation Heat Recovery	Drain Water Heat Recovery
1	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
2	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
3	--	must be over 1.0	must be under 75%	--
4	--	--	--	--
5	--	--	--	--

Quadplex

ECM limitations for CZ4 to CZ8				
	Airtightness	Window USI	Ventilation Heat Recovery	Drain Water Heat Recovery
1	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
2	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
3	must be over 1.0	must be over 1.0	must be under 75%	--
4	--	--	--	--
5	--	--	--	--

Large SFD

ECM limitations for CZ4 to CZ8				
	Airtightness	Window USI	Ventilation Heat Recovery	Drain Water Heat Recovery
1	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
2	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
3	must be over 1.0	must be over 1.0	must be under 75%	--
4	--	--	--	--
5	--	--	--	--

Medium SFD

ECM limitations for CZ4 to CZ8				
	Airtightness	Window USI	Ventilation Heat Recovery	Drain Water Heat Recovery
1	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
2	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
3	must be over 1.0	must be over 1.0	must be under 75%	--
4	--	--	--	--
5	--	--	--	--

Small SFD

ECM limitations for CZ4				
	Airtightness	Window USI	Ventilation Heat Recovery	Drain Water Heat Recovery
1	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
2	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
3	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
4	--	--	--	cannot have any
5	--	--	--	cannot have any
ECM limitations for CZ5 to CZ8				
	Airtightness	Window USI	Ventilation Heat Recovery	Drain Water Heat Recovery
1	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
2	must be over 1.0	must be over 1.0	must be under 75%	cannot have any
3	must be over 1.0	must be over 1.0	must be under 75%	--
4	--	--	--	--
5	--	--	--	--

7.2 Energy Price Escalation Estimates

Part 3 Buildings

Electricity	Rate	F2018	F2019	F2020	F2021	F2022	F2023	F2024	F2025	F2026	F2027	F2028	F2029	F2030	F2031	F2032	F2033	F2034	F2035	F2036	F2037	F2038
Consumption > 240,000 kWh/yr	Base Energy ($/kWh)	$ 0.055	$ 0.057	$ 0.058	$ 0.060	$ 0.061	$ 0.063	$ 0.064	$ 0.066	$ 0.067	$ 0.068	$ 0.070	$ 0.071	$ 0.073	$ 0.074	$ 0.075	$ 0.077	$ 0.079	$ 0.080	$ 0.082	$ 0.083	$ 0.085
	Rate Rider ($/kWh)	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004
	GST ($/kWh)	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004
	Total ($/kWh)	$ 0.061	$ 0.063	$ 0.064	$ 0.066	$ 0.067	$ 0.069	$ 0.071	$ 0.072	$ 0.074	$ 0.075	$ 0.077	$ 0.078	$ 0.080	$ 0.082	$ 0.083	$ 0.085	$ 0.087	$ 0.088	$ 0.090	$ 0.092	$ 0.094
Natural Gas	Rate	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Consumption > 2000 GJ/yr	Cost of NG delivery (commercial – 2017)	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997	$ 2.997
	Cost of NG Storage & Transport	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684	$ 0.684
	Cost of NG Midstream commodity (commercial – 2017)	$ 2.306	$ 2.306	$ 2.370	$ 2.370	$ 2.434	$ 2.434	$ 2.498	$ 2.498	$ 2.523	$ 2.549	$ 2.574	$ 2.600	$ 2.626	$ 2.652	$ 2.679	$ 2.705	$ 2.733	$ 2.760	$ 2.787	$ 2.815	$ 2.843
	Cost of NG carbon tax (commercial – 2017)	$ 1.493	$ 1.493	$ 1.493	$ 1.493	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488
	Muncipal Operating Charge (3.09% of amounts)	$ 0.185	$ 0.185	$ 0.187	$ 0.187	$ 0.189	$ 0.189	$ 0.191	$ 0.191	$ 0.192	$ 0.192	$ 0.193	$ 0.194	$ 0.195	$ 0.196	$ 0.197	$ 0.197	$ 0.198	$ 0.199	$ 0.200	$ 0.201	$ 0.202
	Clean Energy Levy	$ 0.024	$ 0.024	$ 0.024	$ 0.024	$ 0.024	$ 0.024	$ 0.025	$ 0.025	$ 0.025	$ 0.025	$ 0.025	$ 0.025	$ 0.025	$ 0.025	$ 0.025	$ 0.026	$ 0.026	$ 0.026	$ 0.026	$ 0.026	$ 0.026
	GST	$ 0.299	$ 0.299	$ 0.303	$ 0.303	$ 0.306	$ 0.306	$ 0.309	$ 0.309	$ 0.310	$ 0.311	$ 0.313	$ 0.314	$ 0.315	$ 0.317	$ 0.318	$ 0.319	$ 0.321	$ 0.322	$ 0.323	$ 0.325	$ 0.326
	PST	$ 0.419	$ 0.419	$ 0.424	$ 0.424	$ 0.428	$ 0.428	$ 0.433	$ 0.433	$ 0.434	$ 0.436	$ 0.438	$ 0.440	$ 0.441	$ 0.443	$ 0.445	$ 0.447	$ 0.449	$ 0.451	$ 0.453	$ 0.455	$ 0.457
	Total $/GJ	$ 8.407	$ 8.407	$ 8.481	$ 8.481	$ 9.550	$ 9.550	$ 9.624	$ 9.624	$ 9.653	$ 9.682	$ 9.712	$ 9.741	$ 9.771	$ 9.802	$ 9.832	$ 9.863	$ 9.894	$ 9.926	$ 9.958	$ 9.990	$ 10.022

Part 9 Buildings

Electricity	Rate	F2018	F2019	F2020	F2021	F2022	F2023	F2024	F2025	F2026	F2027	F2028	F2029	F2030	F2031	F2032	F2033	F2034	F2035	F2036	F2037	F2038
Residential TIER 1 (Energy Only) First 8,100 kWh/yr	Base Energy ($/kWh)	$ 0.086	$ 0.088	$ 0.091	$ 0.093	$ 0.095	$ 0.098	$ 0.101	$ 0.103	$ 0.105	$ 0.107	$ 0.109	$ 0.111	$ 0.113	$ 0.115	$ 0.118	$ 0.120	$ 0.123	$ 0.125	$ 0.127	$ 0.130	$ 0.132
	Rate Rider ($/kWh)	$ 0.004	$ 0.004	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.007
	GST ($/kWh)	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.005	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.006	$ 0.007	$ 0.007	$ 0.007	$ 0.007
	Total ($/kWh)	$ 0.095	$ 0.097	$ 0.100	$ 0.103	$ 0.105	$ 0.108	$ 0.111	$ 0.113	$ 0.115	$ 0.118	$ 0.120	$ 0.122	$ 0.125	$ 0.127	$ 0.130	$ 0.132	$ 0.135	$ 0.138	$ 0.141	$ 0.143	$ 0.146
Electricity	Rate	F2018	F2019	F2020	F2021	F2022	F2023	F2024	F2025	F2026	F2027	F2028	F2029	F2030	F2031	F2032	F2033	F2034	F2035	F2036	F2037	F2038
Residential TIER 2 (Energy Only) All energy above 8,100 kWh/yr	Base Energy ($/kWh)	$ 0.129	$ 0.133	$ 0.136	$ 0.140	$ 0.143	$ 0.147	$ 0.151	$ 0.154	$ 0.157	$ 0.160	$ 0.163	$ 0.166	$ 0.170	$ 0.173	$ 0.177	$ 0.180	$ 0.184	$ 0.187	$ 0.191	$ 0.195	$ 0.199
	Rate Rider ($/kWh)	$ 0.006	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.008	$ 0.008	$ 0.008	$ 0.008	$ 0.008	$ 0.008	$ 0.008	$ 0.009	$ 0.009	$ 0.009	$ 0.009	$ 0.009	$ 0.010	$ 0.010	$ 0.010
	GST ($/kWh)	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.008	$ 0.008	$ 0.008	$ 0.008	$ 0.008	$ 0.008	$ 0.009	$ 0.009	$ 0.009	$ 0.009	$ 0.009	$ 0.009	$ 0.010	$ 0.010	$ 0.010	$ 0.010	$ 0.010
	Total ($/kWh)	$ 0.142	$ 0.146	$ 0.150	$ 0.154	$ 0.158	$ 0.162	$ 0.166	$ 0.169	$ 0.173	$ 0.176	$ 0.180	$ 0.183	$ 0.187	$ 0.191	$ 0.195	$ 0.199	$ 0.203	$ 0.207	$ 0.211	$ 0.215	$ 0.219
Natural Gas	Rate	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Residential Rate (Rate 1) - Mainland	Cost of NG delivery (commercial – 2017)	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299	$ 4.299
	Cost of NG Storage & Transport	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811	$ 0.811
	Cost of NG Midstream commodity (commercial – 2017)	$ 2.306	$ 2.306	$ 2.370	$ 2.370	$ 2.434	$ 2.434	$ 2.498	$ 2.498	$ 2.523	$ 2.549	$ 2.574	$ 2.600	$ 2.626	$ 2.652	$ 2.679	$ 2.705	$ 2.733	$ 2.760	$ 2.787	$ 2.815	$ 2.843
	Cost of NG carbon tax (commercial – 2017)	$ 1.493	$ 1.493	$ 1.493	$ 1.493	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488	$ 2.488
	Clean Energy Levy	$ 0.030	$ 0.030	$ 0.030	$ 0.030	$ 0.030	$ 0.030	$ 0.030	$ 0.030	$ 0.031	$ 0.031	$ 0.031	$ 0.031	$ 0.031	$ 0.031	$ 0.031	$ 0.031	$ 0.031	$ 0.031	$ 0.032	$ 0.032	$ 0.032
	GST	$ 0.371	$ 0.371	$ 0.374	$ 0.374	$ 0.377	$ 0.377	$ 0.380	$ 0.380	$ 0.382	$ 0.383	$ 0.384	$ 0.385	$ 0.387	$ 0.388	$ 0.389	$ 0.391	$ 0.392	$ 0.393	$ 0.395	$ 0.396	$ 0.398
	PST	$ 0.519	$ 0.519	$ 0.524	$ 0.524	$ 0.528	$ 0.528	$ 0.533	$ 0.533	$ 0.534	$ 0.536	$ 0.538	$ 0.540	$ 0.542	$ 0.543	$ 0.545	$ 0.547	$ 0.549	$ 0.551	$ 0.553	$ 0.555	$ 0.557
	Total $/GJ	$ 9.828	$ 9.828	$ 9.900	$ 9.900	$ 10.967	$ 10.967	$ 11.039	$ 11.039	$ 11.067	$ 11.096	$ 11.124	$ 11.153	$ 11.183	$ 11.212	$ 11.242	$ 11.272	$ 11.302	$ 11.333	$ 11.364	$ 11.395	$ 11.426

7.3 Part 3 – Lowest Incremental Capital Costs

Scenario			Archetype Characteristics								Energy and Emissions Outcomes						Costing Outcomes									
Archetype	Climate	Step	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Loads Savings	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
High Rise MURB Electric BB Mid Occupancy 0.6 VFAR 62-2001	4	1									138.7	48.8	9.5	45.7	93.0											
		2	40	10	20	2.5	Code	60	Standard	20	114.7	40.6	6.7	31.4	83.3	498	0.4	11.6	239065	13.3	-242.0	9.5	17.3	12.4	29.0	8.6
		3	40	10	20	2.5	Improved	80	Standard	20	103.8	29.7	6.6	31.4	72.4	378	0.8	24.7	344091	19.1	-333.0	8.4	25.1	21.9	30.3	10.4
		4	40	10	20	1.6	PH	80	Standard	20	88.8	14.8	6.4	31.1	57.8	283	2.4	74.1	-81132	-4.5	72.8	7.0	35.9	34.9	32.7	19.7
	5	1									145.9	56.0	9.6	46.2	99.7											
		2	40	20	20	2.5	Code	60	Standard	20	118.0	43.8	6.8	31.8	86.2	678	1.0	33.3	-29600	-1.6	29.3	9.7	19.1	14.9	29.1	19.5
		3	40	20	40	2	Improved	60	Standard	20	104.0	29.9	6.7	31.7	72.4	476	2.3	75.7	-357709	-19.9	332.6	8.4	28.7	26.4	31.0	25.0
		4	40	20	40	1.2	PH	60	Standard	20	88.9	14.8	6.4	31.3	57.6	347	3.2	102.9	-379974	-21.1	327.6	7.0	39.1	38.7	33.4	23.2
	6	1									159.6	69.5	9.9	47.0	112.5											
		2	20	20	20	2.5	Code	60	Standard	20	114.8	40.5	6.9	32.5	82.2	501	1.3	45.1	284947	15.8	-262.2	9.4	28.1	26.0	30.4	13.7
		3	20	20	20	2.5	Improved	80	Standard	20	102.5	28.2	6.8	32.4	70.0	431	1.8	59.9	402894	22.4	-353.0	8.2	35.8	35.1	31.9	13.4
		4	20	20	40	0.8	PH	60	Standard	20	88.9	14.7	6.5	31.8	57.1	282	2.7	91.2	253598	14.1	-205.3	7.0	44.3	44.9	34.5	16.0
	7A	1									155.3	65.1	10.0	47.5	107.8											
		2	20	20	40	1.2	Code	60	Standard	20	119.2	44.9	7.0	32.7	86.5	560	2.0	92.1	-841637	-46.8	789.3	9.8	23.2	20.0	29.7	37.5
		3	20	20	20	0.8	Improved	60	Standard	20	103.5	29.2	6.8	32.5	71.0	445	2.3	104.2	-568932	-31.6	497.5	8.3	33.4	32.1	31.9	26.5
		4	20	20	40	0.8	PH	80	Standard	20	91.8	17.6	6.6	32.3	59.5	283	2.7	122.9	-544522	-30.3	453.5	7.2	40.9	41.0	33.5	24.5

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Loads Savings	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Low Rise MURB Electric BB Mid Occupancy 0.6 VFAR 62-2001	4	1									138.7	48.8	9.5	45.7	93.0											
		2	40	20	20	2.5	Code	60	Standard	20	107.5	33.4	6.6	31.3	76.2	463	0.5	11.6	462783	25.7	-451.4	8.8	22.5	18.7	30.1	5.7
		3	40	20	20	2.5	Improved	60	Standard	20	102.5	28.4	6.6	31.3	71.2	369	0.6	14.3	569094	31.6	-544.1	8.3	26.1	23.0	30.7	5.8
		4	40	20	20	2	PH	80	Standard	20	87.9	13.9	6.4	31.0	56.9	272	2.6	62.1	162332	9.0	-144.9	6.9	36.6	35.7	32.8	16.1
	5	1									145.9	56.0	9.6	46.2	99.7											
		2	40	20	20	2.5	Code	60	Standard	20	118.0	43.8	6.8	31.8	86.2	678	0.5	12.4	346629	19.3	-343.6	9.7	19.1	14.9	29.1	7.2
		3	40	20	40	2	Improved	60	Standard	20	104.0	29.9	6.7	31.7	72.4	476	2.2	57.9	-38134	-2.1	35.5	8.4	28.7	26.4	31.0	19.2
		4	40	20	40	1.2	PH	60	Standard	20	88.9	14.8	6.4	31.3	57.6	347	3.3	85.2	-60399	-3.4	52.1	7.0	39.1	38.7	33.4	19.2
	6	1									159.6	69.5	9.9	47.0	112.5											
		2	20	20	20	2.5	Code	60	Standard	20	114.8	40.5	6.9	32.5	82.2	501	0.4	11.7	887538	49.3	-816.6	9.4	28.1	26.0	30.4	3.5
		3	20	20	20	2.5	Improved	80	Standard	20	102.5	28.2	6.8	32.4	70.0	431	1.0	26.4	1005486	55.9	-881.0	8.2	35.8	35.1	31.9	5.9
		4	20	20	40	0.8	PH	60	Standard	20	88.9	14.7	6.5	31.8	57.1	282	2.2	61.0	796737	44.3	-644.8	7.0	44.3	44.9	34.5	10.7
	7A	1									155.3	65.1	10.0	47.5	107.8											
		2	20	20	40	1.2	Code	60	Standard	20	119.2	44.9	7.0	32.7	86.5	560	1.4	51.7	-114145	-6.3	107.0	9.8	23.2	20.0	29.7	21.1
		3	20	20	20	0.8	Improved	60	Standard	20	103.5	29.2	6.8	32.5	71.0	445	1.6	59.4	237866	13.2	-208.0	8.3	33.4	32.1	31.9	15.1
		4	20	40	20	0.8	PH	80	Standard	20	87.3	13.1	6.5	32.0	55.3	222	4.1	149.1	-879749	-48.9	709.1	6.8	43.8	44.3	34.6	27.5
	7B	1									184.5	79.7	10.5	48.4	136.1											
		2	20	40	40	0.8	Improved	80	Condensing	20	113.3	26.4	6.4	29.6	83.7	81	3.3	11.8	-59151	-16.4	202.3	10.0	38.6	35.5	38.8	0.0
		3	20	40	40	0.8	PH	80	Condensing	20	105.7	18.8	6.2	29.2	76.5	57	3.2	11.5	-69769	-19.4	242.6	9.3	39.0	35.7	39.0	0.0

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Commercial Office No IT Load Default Occupancy	4	1									141.4	35.1	11.9	59.5	81.9											
		2	VAV	50	10	20	2.5	Code	60	0	120.5	18.7	7.2	33.8	86.7	420	0.1	1.6	57424	3.2	-33.5	6.6	14.8	6.8	39.5	3.3
			FC	50	10	20	2.5	Code	None	0	115.4	29.4	9.2	45.8	69.7	452	-0.2	-5.8	458761	25.2	-471.9	5.9	18.4	17.0	22.4	0.0
			ASHP	50	10	20	2.5	Code	None	0	93.9	29.4	3.7	15.2	78.8	460	-0.2	-5.8	469931	25.8	-156.7	5.5	33.6	22.0	69.2	0.0
		3	VAV	50	10	20	2.5	Improved	60	0	117.3	16.0	6.6	30.6	86.6	418	0.1	3.0	56881	3.1	-29.6	6.5	17.1	8.2	44.4	5.1
			FC	50	10	20	2.5	Improved	60	0	104.8	14.7	6.5	30.5	74.3	456	0.0	-0.3	370345	20.3	-186.8	5.7	25.9	19.4	45.7	0.0
			ASHP	50	10	20	2.5	Improved	60	0	92.2	14.7	3.7	15.2	77.0	465	0.0	-0.3	405984	22.3	-135.1	5.4	34.8	23.6	69.3	0.0
	5	1									141.3	36.0	11.8	59.0	82.3											
		2	VAV	50	10	20	2.5	Code	60	0	131.0	28.4	8.6	41.3	89.6	474	0.1	1.5	-54112	-3.0	46.7	7.0	7.3	1.0	26.9	22.5
			FC	50	10	20	2.5	Code	60	0	117.8	24.9	8.2	39.9	77.9	515	-0.1	-1.6	254225	14.0	-195.0	6.2	16.6	12.3	30.3	0.0
			ASHP	50	10	20	2.5	Code	60	0	99.0	24.9	3.7	15.2	83.9	590	-0.1	-1.6	288523	15.8	-98.0	5.8	29.9	17.5	68.5	0.0
		3	VAV	50	20	20	2.5	Improved	80	25	114.3	18.6	6.8	31.6	82.7	394	1.2	32.6	-399852	-22.0	217.0	6.3	19.1	11.5	42.8	42.1
			FC	50	20	20	2.5	Improved	60	0	111.1	18.5	7.0	33.2	77.9	511	0.2	5.9	166445	9.1	-94.9	6.0	21.4	15.1	40.8	5.8
			ASHP	50	20	20	2.5	Improved	60	0	97.0	18.5	3.7	15.2	81.9	582	0.2	5.9	194612	10.7	-65.9	5.7	31.3	19.3	68.6	4.5
	6	1									144.5	47.1	13.4	68.0	76.5											
		2	VAV	50	20	40	2.5	Code	80	0	127.6	30.0	8.2	39.0	88.7	417	0.7	24.6	-494660	-27.2	259.9	6.9	11.6	1.5	39.0	100.0
			FC	50	20	20	2.5	Code	80	0	116.2	28.7	8.5	41.6	74.5	438	0.4	12.0	6354	0.3	-3.6	6.0	19.6	13.3	36.5	11.3
			ASHP	50	20	20	2.5	Code	80	0	93.0	28.7	3.7	15.2	77.9	456	0.4	12.0	109418	6.0	-30.8	5.5	35.6	21.8	72.7	6.9
		3	VAV	50	20	40	1.2	Improved	60	0	113.1	19.8	6.3	28.9	84.2	423	1.9	61.3	-993617	-54.6	381.7	6.3	21.7	10.0	53.3	76.2
			FC	50	20	20	1.6	Improved	60	0	102.4	18.6	6.5	31.1	71.3	461	1.4	45.1	-450493	-24.7	180.0	5.5	29.1	20.9	51.2	26.9
			ASHP	50	20	20	1.6	Improved	60	0	89.3	18.6	3.6	15.2	74.2	472	1.4	45.1	-413784	-22.7	116.0	5.2	38.2	25.2	73.0	22.3
	7A	1									161.9	63.3	15.6	79.2	82.7						0.0					
		2	VAV	50	20	40	0.8	Improved	80	25	116.7	29.6	5.7	25.4	91.3	377	2.9	95.7	-1531638	-84.1	426.4	6.6	27.9	14.1	63.4	76.2
			FC	50	20	40	1.2	Code	60	0	115.0	29.7	7.8	37.5	77.6	514	1.6	51.9	-539435	-29.6	190.5	6.1	28.9	20.8	50.0	28.2
			ASHP	50	20	40	1.2	Code	60	0	97.0	29.7	3.7	15.2	81.8	515	1.6	51.9	-486397	-26.7	112.6	5.7	40.1	26.0	76.2	22.5
		3	VAV	30	20	40	0.8	PH	80	50	105.9	26.0	4.9	21.4	84.5	279	2.8	92.7	-1302735	-71.5	335.4	6.1	34.6	21.4	68.5	48.9
			FC	50	20	20	0.8	Improved	60	0	106.4	19.4	5.8	26.7	79.7	525	1.8	60.8	-668208	-36.7	188.3	5.9	34.3	23.3	62.6	29.5
			ASHP	50	20	20	0.8	Improved	60	0	95.4	19.4	3.7	15.2	80.2	540	1.8	60.8	-613765	-33.7	141.9	5.6	41.1	27.4	76.3	25.0

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Commercial Office 2.2 W/m2 IT Load Double Occupancy	4	1									154.3	20.8	10.3	49.3	105.0											
		2	FC	50	10	20	2.5	Code	None	0	156.1	25.4	10.1	48.1	108.0	598	-0.2	-5.8	40814	2.2	-591.3	8.4	-1.2	-1.9	1.8	100.0
		3	FC	50	20	20	2	Improved	60	50	120.0	8.7	6.7	30.7	89.3	477	2.0	57.4	-583106	-32.0	442.7	6.7	22.2	19.1	35.2	36.5
	5	1									170.6	26.7	11.6	56.1	114.4											
		2	FC	50	4	20	2.5	Code	60	0	168.4	28.6	10.6	50.0	118.4	675	0.0	-1.2	-28089	-1.5	71.4	9.1	1.2	-0.8	9.3	100.0
		3	FC	30	20	40	1.6	Improved	60	50	119.6	8.0	6.3	28.5	91.1	488	2.1	57.4	-355177	-19.5	181.9	6.7	29.8	25.8	46.1	25.9
	6	1									162.5	35.3	12.3	60.4	102.1											
		2	FC	50	10	40	2.5	Code	60	0	152.1	29.4	10.1	48.5	103.6	576	0.0	1.1	26000	1.4	-32.8	8.1	6.4	3.2	17.7	3.6
		3	FC	50	20	40	1.6	Improved	60	50	119.9	17.1	7.5	35.7	84.2	476	2.3	76.9	-846922	-46.5	487.8	6.5	26.2	22.7	38.8	35.2
	7A	1									181.7	52.2	14.7	72.9	108.8											
		2	FC	50	20	20	1.2	Code	60	0	153.8	28.4	8.9	41.5	112.2	657	1.5	49.9	-759744	-41.7	361.6	8.5	15.4	8.1	39.3	58.5
		3	FC	30	20	40	1.2	PH	60	50	119.2	17.5	6.6	30.2	89.0	476	2.1	69.3	-535497	-29.4	181.0	6.6	34.4	28.0	55.3	23.4

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Retail Big Box	4	1									159.8	30.4	11.0	52.9	107.0											
		2	RTU	20	10	20	2.5	Code	60	0	139.9	15.4	6.1	25.9	113.9	154	0.9	13.2	-40085	-8.9	105.3	8.1	12.1	5.3	41.1	29.1
			FC	20	10	20	2.5	Code	60	0	128.1	19.1	5.4	23.1	105.0	149	0.8	12.1	17461	3.9	-39.9	7.4	19.5	13.0	47.3	10.8
			ASHP	20	10	20	2.5	Code	60	0	113.4	19.1	1.8	3.2	110.2	159	0.8	12.1	25765	5.7	-33.7	7.2	28.7	16.2	82.5	8.7
		3	RTU	20	10	20	2.5	Improved	60	25	118.0	15.6	5.9	26.2	91.8	126	2.1	31.3	-5105	-1.1	12.8	6.7	25.8	21.8	43.0	16.8
			FC	20	10	20	2.5	Improved	60	25	106.3	18.6	5.1	22.6	83.7	123	2.0	30.1	49472	11.0	-106.0	6.1	33.2	29.2	50.4	12.1
			ASHP	20	10	20	2.5	Improved	60	0	114.1	13.9	1.8	3.2	110.9	161	1.2	17.6	-2812	-0.6	3.7	7.2	28.3	15.7	82.4	13.1
	5	1									188.0	39.1	14.0	68.5	119.4						0.0					
		2	RTU	20	10	20	2.5	Code	60	0	168.8	26.3	8.7	39.2	129.7	182	0.9	12.6	-50524	-11.2	120.6	9.5	9.8	3.3	34.9	39.3
			FC	20	10	20	2.5	Code	80	0	147.0	26.7	6.7	29.3	117.7	165	1.3	18.8	2650	0.6	-4.5	8.4	21.5	14.1	49.6	13.5
			ASHP	20	10	20	2.5	Code	80	0	124.5	26.7	1.9	3.2	121.3	193	1.3	18.8	30628	6.8	-29.8	7.9	33.5	19.9	85.6	9.6
		3	RTU	20	10	20	0.8	Improved	80	50	111.5	18.7	6.1	27.9	83.6	119	5.1	71.5	-51985	-11.5	79.7	6.2	40.5	36.8	54.4	19.8
			FC	20	20	20	2.5	Improved	80	25	116.0	19.5	5.1	21.7	94.2	132	3.7	52.4	-11170	-2.5	15.0	6.7	38.0	31.8	62.0	16.8
			ASHP	20	20	20	2.5	Improved	80	25	99.8	19.5	1.7	3.2	96.7	154	3.7	52.4	9719	2.2	-9.2	6.3	46.7	36.0	87.6	14.8
	6	1									203.3	54.9	18.5	93.4	109.9											
		2	RTU	20	10	20	1.6	Code	80	0	163.0	28.5	8.3	37.6	125.4	158	2.5	43.0	-168408	-37.4	197.3	9.2	19.5	7.9	53.2	54.5
			FC	20	10	20	0.8	Code	80	0	142.5	29.8	6.7	29.7	112.9	152	2.8	47.8	-109493	-24.3	109.6	8.1	29.6	18.4	62.2	26.1
			ASHP	20	10	20	0.8	Code	80	0	120.0	29.8	1.9	3.2	116.9	159	2.8	47.8	-82608	-18.3	57.5	7.6	40.7	23.9	89.5	20.0
		3	RTU	20	20	40	2	Improved	80	25	118.3	16.8	4.8	19.9	98.4	119	6.0	102.3	-260657	-57.9	221.8	6.9	41.6	30.7	73.2	33.4
			FC	20	10	40	0.8	Improved	80	25	111.9	19.0	4.4	18.5	93.4	119	5.5	93.9	-193981	-43.1	161.0	6.5	44.8	34.3	75.1	27.4
			ASHP	20	20	20	1.2	Improved	80	0	118.6	19.8	1.9	3.2	115.4	159	3.9	67.5	-163200	-36.3	113.5	7.5	41.5	24.9	89.6	27.2
	7A	1									245.1	69.1	23.9	121.9	123.2											
		2	RTU	20	20	40	2	Improved	80	0	157.7	30.0	6.3	26.1	131.6	158	4.8	82.7	-238093	-52.9	155.9	9.2	35.4	21.1	73.0	33.6
			FC	20	20	40	2	Improved	80	0	145.8	29.9	5.7	23.3	122.5	150	4.6	79.1	-168901	-37.5	106.7	8.6	40.3	26.8	75.7	25.3
			ASHP	20	20	40	2	Improved	80	0	126.9	29.9	2.0	3.2	123.7	158	4.6	79.1	-138878	-30.8	72.5	8.0	48.1	31.4	91.6	21.6
		3	RTU	20	20	40	0.8	PH	80	25	122.0	21.1	3.6	13.1	108.8	129	6.8	116.0	-244197	-54.2	138.3	7.4	50.1	36.9	84.4	26.8
			FC	20	20	40	0.8	PH	80	25	114.8	19.7	3.5	12.6	102.2	123	6.6	112.4	-192084	-42.7	107.8	6.9	53.0	40.7	85.1	23.6
			ASHP	20	20	40	0.8	PH	80	25	103.4	19.7	1.7	3.2	100.2	131	6.6	112.4	-164793	-36.6	84.9	6.5	57.7	44.3	92.7	21.7

7.4 Part 3 – Highest NPV

Scenario			Archetype Characteristics								Energy and Emissions Outcomes																
Archetype	Climate	Step	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Loads Savings	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
High Rise MURB Electric BB Mid Occupancy 0.6 VFAR 62-2001	4	1									138.7	48.8	9.5	45.7	93.0											
		2	40	10	20	2.5	Code	60	Condensing	40	104.9	40.6	4.9	21.6	83.3	498	0.5	15.2	272282	15.1	-166.0	9.2	24.3	15.2	48.1	9.3
		3	40	10	20	2.5	Improved	80	Condensing	40	94.0	29.7	4.8	21.6	72.4	378	0.9	28.4	377269	21.0	-223.8	8.1	32.2	24.7	49.4	10.6
		4	40	10	20	1.6	PH	80	Condensing	40	79.1	14.8	4.6	21.3	57.8	283	2.6	77.8	-48294	-2.7	27.4	6.7	43.0	37.6	51.7	19.1
	5	1									145.9	56.0	9.6	46.2	99.7											
		2	40	20	20	2.5	Code	60	Condensing	40	108.2	43.8	5.0	22.0	86.2	678	1.1	37.3	-1149	-0.1	0.7	9.4	25.9	17.5	47.9	18.6
		3	40	10	20	1.6	Improved	80	Condensing	40	90.4	26.1	4.8	21.8	68.6	462	2.5	82.0	-252380	-14.0	144.6	7.8	38.0	32.1	50.3	22.3
		4	40	10	20	0.8	PH	80	Condensing	40	75.8	11.5	4.6	21.4	54.3	337	3.4	109.2	-290230	-16.1	158.8	6.4	48.1	44.0	52.6	21.7
	6	1									159.6	69.5	9.9	47.0	112.5											
		2	20	20	40	2.5	Code	80	Condensing	20	103.7	32.6	6.2	29.3	74.4	474	1.7	57.9	334447	18.6	-250.8	8.5	35.0	32.6	37.3	14.0
		3	20	20	40	2.5	Improved	80	Condensing	20	98.7	27.6	6.2	29.3	69.5	425	1.8	61.0	432254	24.0	-319.0	8.1	38.1	36.3	37.9	13.3
		4	20	20	40	0.8	PH	60	Condensing	20	85.7	14.7	5.9	28.7	57.1	282	2.7	91.5	279667	15.5	-193.8	6.9	46.3	45.7	40.3	15.8
	7A	1									155.3	65.1	10.0	47.5	107.8											
		2	20	20	40	0.8	Code	60	Condensing	20	110.3	39.2	6.3	29.4	81.0	512	2.2	101.5	-802763	-44.6	612.0	9.2	28.9	25.1	36.6	33.0
		3	20	20	40	0.8	Improved	60	Condensing	20	99.7	28.6	6.2	29.3	70.4	439	2.3	105.7	-543752	-30.2	400.5	8.2	35.8	33.4	37.8	25.9
		4	20	20	40	0.8	PH	80	Condensing	20	88.7	17.6	6.0	29.1	59.5	283	2.7	123.3	-519845	-28.9	368.4	7.1	42.9	41.7	39.3	24.1

Scenario			Archetype Characteristics								Energy and Emissions Outcomes																
Archetype	Climate	Step	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Loads Savings	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Low Rise MURB Electric BB Mid Occupancy 0.6 VFAR 62-2001	4	1									138.7	48.8	9.5	45.7	93.0											
		2	40	20	20	2.5	Code	60	Condensing	40	97.7	33.4	4.8	21.5	76.2	463	0.6	15.2	495860	27.5	-295.7	8.5	29.5	21.4	49.2	6.6
		3	40	20	20	2.5	Improved	60	Condensing	40	92.7	28.4	4.8	21.5	71.2	369	0.7	18.0	602157	33.5	-354.8	8.0	33.1	25.8	49.8	6.5
		4	40	20	20	2	PH	80	Condensing	40	78.2	13.9	4.6	21.3	56.9	272	2.7	65.8	195132	10.8	-110.2	6.7	43.6	38.4	51.9	15.9
	5	1									145.9	56.0	9.6	46.2	99.7											
		2	40	20	20	2.5	Code	60	Condensing	40	108.2	43.8	5.0	22.0	86.2	678	0.6	16.4	375080	20.8	-225.4	9.4	25.9	17.5	47.9	8.2
		3	40	20	20	2	Improved	80	Condensing	40	89.0	24.7	4.8	21.8	67.2	446	2.7	69.1	24064	1.3	-13.7	7.6	39.0	33.3	50.5	18.1
		4	40	20	40	1.2	PH	60	Condensing	40	79.1	14.8	4.6	21.5	57.6	347	3.4	89.2	-32514	-1.8	18.0	6.7	45.8	41.3	52.2	18.9
	6	1									159.6	69.5	9.9	47.0	112.5											
		2	20	20	20	2.5	Code	80	Condensing	20	104.2	33.1	6.2	29.3	74.9	479	0.9	23.6	933748	51.9	-701.5	8.6	34.7	32.2	37.2	5.8
		3	20	20	20	2.5	Improved	80	Condensing	20	99.3	28.2	6.2	29.3	70.0	431	1.0	26.7	1032197	57.3	-763.1	8.1	37.8	35.9	37.8	5.9
		4	20	20	20	1.2	PH	80	Condensing	20	84.6	13.5	5.9	28.7	55.9	296	2.3	62.1	845870	47.0	-585.9	6.8	47.0	46.6	40.3	10.5
	7A	1									155.3	65.1	10.0	47.5	107.8											
		2	20	20	20	0.8	Code	60	Condensing	20	111.0	39.9	6.3	29.4	81.7	517	1.5	55.6	2205	0.1	-1.7	9.2	28.5	24.6	36.5	18.4
		3	20	20	20	0.8	Improved	60	Condensing	20	100.3	29.2	6.2	29.3	71.0	445	1.6	59.8	262717	14.6	-193.9	8.2	35.4	32.9	37.8	14.8
		4	20	40	20	0.8	PH	80	Condensing	20	84.2	13.1	5.9	28.8	55.3	222	4.1	149.5	-855422	-47.5	590.4	6.7	45.8	45.1	40.4	27.1
	7B	1									184.5	79.7	10.5	48.4	136.1											
		2	20	40	40	0.8	Improved	80	Condensing	40	106.6	26.4	5.2	22.9	83.7	81	3.3	12.2	-57858	-16.1	151.5	9.8	42.2	36.8	50.7	0.0
		3	20	40	40	0.8	PH	80	Condensing	40	99.0	18.8	5.0	22.5	76.5	57	3.3	11.9	-68476	-19.0	181.6	9.1	42.9	37.1	51.2	0.0

Scenario			Archetype Characteristics								Energy and Emissions Outcomes																
Archetype	Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Commercial Office No IT Load Default Occupancy	4	1									141.4	35.1	11.9	59.5	81.9											
		2	VAV	50	10	20	2.5	Code	60	25	111.1	21.2	7.5	36.1	74.9	357	0.5	14.1	63640	3.5	-39.8	5.9	21.4	16.4	36.9	12.1
			FC	50	10	20	2.5	Code	None	0	115.4	29.4	9.2	45.8	69.7	452	-0.2	-5.8	458761	25.2	-471.9	5.9	18.4	17.0	22.4	0.0
			ASHP	50	10	20	2.5	Code	None	0	93.9	29.4	3.7	15.2	78.8	460	-0.2	-5.8	469931	25.8	-156.7	5.5	33.6	22.0	69.2	0.0
		3	VAV	50	10	20	2.5	Improved	60	25	108.1	18.4	7.0	33.4	74.7	356	0.5	15.5	63190	3.5	-35.4	5.8	23.5	17.8	41.2	12.3
			FC	50	10	20	2.5	Improved	60	0	104.8	14.7	6.5	30.5	74.3	456	0.0	-0.3	370345	20.3	-186.8	5.7	25.9	19.4	45.7	0.0
			ASHP	50	10	20	2.5	Improved	60	0	92.2	14.7	3.7	15.2	77.0	465	0.0	-0.3	405984	22.3	-135.1	5.4	34.8	23.6	69.3	0.0
	5	1									141.3	36.0	11.8	59.0	82.3											
		2	VAV	50	10	20	2.5	Code	60	0	131.0	28.4	8.6	41.3	89.6	474	0.1	1.5	-54112	-3.0	46.7	7.0	7.3	1.0	26.9	22.5
			FC	50	10	20	2.5	Code	60	50	100.0	29.5	8.9	44.7	55.3	381	0.8	22.2	269461	14.8	-251.5	4.9	29.3	30.7	24.9	10.8
			ASHP	50	10	20	2.5	Code	60	50	78.5	29.5	3.5	15.2	63.3	445	0.8	22.2	294604	16.2	-97.3	4.5	44.5	36.1	70.4	9.1
		3	VAV	50	20	40	2.5	Improved	80	50	102.7	19.2	6.8	32.5	70.3	331	1.7	46.6	-396034	-21.7	216.0	5.5	27.3	22.4	42.6	31.0
			FC	50	20	20	2.5	Improved	60	0	111.1	18.5	7.0	33.2	77.9	511	0.2	5.9	166445	9.1	-94.9	6.0	21.4	15.1	40.8	5.8
			ASHP	50	20	20	2.5	Improved	60	0	97.0	18.5	3.7	15.2	81.9	582	0.2	5.9	194612	10.7	-65.9	5.7	31.3	19.3	68.6	4.5
	6	1									144.5	47.1	13.4	68.0	76.5											
		2	VAV	50	20	40	2.5	Code	80	0	127.6	30.0	8.2	39.0	88.7	417	0.7	24.6	-494660	-27.2	259.9	6.9	11.6	1.5	39.0	100.0
			FC	50	20	20	2.5	Code	80	0	116.2	28.7	8.5	41.6	74.5	438	0.4	12.0	6354	0.3	-3.6	6.0	19.6	13.3	36.5	11.3
			ASHP	50	20	20	2.5	Code	80	0	93.0	28.7	3.7	15.2	77.9	456	0.4	12.0	109418	6.0	-30.8	5.5	35.6	21.8	72.7	6.9
		3	VAV	50	20	40	1.2	Improved	60	0	113.1	19.8	6.3	28.9	84.2	423	1.9	61.3	-993617	-54.6	381.7	6.3	21.7	10.0	53.3	76.2
			FC	50	20	20	1.6	Improved	60	0	102.4	18.6	6.5	31.1	71.3	461	1.4	45.1	-450493	-24.7	180.0	5.5	29.1	20.9	51.2	26.9
			ASHP	50	20	20	1.6	Improved	60	0	89.3	18.6	3.6	15.2	74.2	472	1.4	45.1	-413784	-22.7	116.0	5.2	38.2	25.2	73.0	22.3
	7A	1									161.9	63.3	15.6	79.2	82.7											
		2	VAV	50	20	40	0.8	Improved	80	50	105.4	29.0	5.9	27.2	78.2	313	3.3	110.0	-1527410	-83.9	434.0	5.8	34.9	24.3	62.1	51.1
			FC	50	20	40	1.2	Code	60	0	115.0	29.7	7.8	37.5	77.6	514	1.6	51.9	-539435	-29.6	190.5	6.1	28.9	20.8	50.0	28.2
			ASHP	50	20	40	1.2	Code	60	0	97.0	29.7	3.7	15.2	81.8	515	1.6	51.9	-486397	-26.7	112.6	5.7	40.1	26.0	76.2	22.5
		3	VAV	30	20	40	0.8	PH	80	50	105.9	26.0	4.9	21.4	84.5	279	2.8	92.7	-1302735	-71.5	335.4	6.1	34.6	21.4	68.5	48.9
			FC	50	20	20	0.8	Improved	60	0	106.4	19.4	5.8	26.7	79.7	525	1.8	60.8	-668208	-36.7	188.3	5.9	34.3	23.3	62.6	29.5
			ASHP	50	20	20	0.8	Improved	60	0	95.4	19.4	3.7	15.2	80.2	540	1.8	60.8	-613765	-33.7	141.9	5.6	41.1	27.4	76.3	25.0

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Commercial Office 2.2 W/m2 IT Load Double Occupancy	4	1									154.3	20.8	10.3	49.3	105.0											
		2	FC	50	10	20	2.5	Code	None	25	146.1	27.6	10.4	50.3	95.7	532	0.2	6.7	58344	3.2	1768.0	7.7	5.3	6.8	-0.9	11.9
		3	FC	50	20	20	2	Improved	60	50	120.0	8.7	6.7	30.7	89.3	477	2.0	57.4	-583106	-32.0	442.7	6.7	22.2	19.1	35.2	36.5
	5	1									170.6	26.7	11.6	56.1	114.4											
		2	FC	50	10	20	2.5	Code	60	50	138.5	24.5	9.5	45.7	92.8	531	0.8	22.6	118279	6.5	-150.2	7.3	18.8	18.9	18.6	13.9
		3	FC	30	20	40	1.6	Improved	60	50	119.6	8.0	6.3	28.5	91.1	488	2.1	57.4	-355177	-19.5	181.9	6.7	29.8	25.8	46.1	25.9
	6	1									162.5	35.3	12.3	60.4	102.1											
		2	FC	50	10	40	2.5	Code	60	0	152.1	29.4	10.1	48.5	103.6	576	0.0	1.1	26000	1.4	-32.8	8.1	6.4	3.2	17.7	3.6
		3	FC	50	20	40	1.6	Improved	60	50	119.9	17.1	7.5	35.7	84.2	476	2.3	76.9	-846922	-46.5	487.8	6.5	26.2	22.7	38.8	35.2
	7A	1									181.7	52.2	14.7	72.9	108.8											
		2	FC	50	20	20	1.2	Code	60	0	153.8	28.4	8.9	41.5	112.2	657	1.5	49.9	-759744	-41.7	361.6	8.5	15.4	8.1	39.3	58.5
		3	FC	30	20	40	1.2	PH	60	50	119.2	17.5	6.6	30.2	89.0	476	2.1	69.3	-535497	-29.4	181.0	6.6	34.4	28.0	55.3	23.4

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Retail Big Box	4	1									159.8	30.4	11.0	52.9	107.0											
		2	RTU	20	10	20	2.5	Code	80	50	105.7	22.1	7.4	35.9	69.8	97	3.2	47.9	18932	4.2	-73.3	5.6	33.5	34.8	27.9	16.1
			FC	20	10	20	2.5	Code	80	50	93.7	25.8	6.3	30.1	63.6	96	3.0	44.8	75900	16.9	-210.0	5.0	41.1	41.6	39.0	12.6
			ASHP	20	10	20	2.5	Code	80	50	72.8	25.8	1.4	3.2	69.7	100	3.0	44.8	92791	20.6	-115.4	4.6	54.2	46.6	86.8	11.2
		3	RTU	20	10	20	2.5	Improved	80	50	96.8	15.6	5.7	26.4	70.5	98	3.6	53.4	7519	1.7	-18.0	5.3	39.1	37.7	45.0	16.6
			FC	20	10	20	2.5	Improved	80	50	88.0	19.1	5.0	23.1	64.9	96	3.4	50.3	56832	12.6	-119.2	4.9	44.7	43.1	51.5	13.7
			ASHP	20	10	20	2.5	Improved	80	50	71.9	19.1	1.3	3.2	68.7	101	3.4	50.3	72617	16.1	-90.2	4.5	54.8	47.3	86.9	12.4
	5	1									188.0	39.1	14.0	68.5	119.4						0.0					
		2	RTU	20	20	20	2.5	Code	80	50	124.3	28.8	8.8	42.9	81.4	117	4.4	61.9	-24667	-5.5	61.1	6.5	33.6	33.6	33.7	18.8
			FC	20	10	40	2.5	Code	80	50	103.3	29.6	6.8	32.3	71.0	104	4.5	63.4	42496	9.4	-71.8	5.5	44.8	43.6	49.3	14.8
			ASHP	20	10	40	2.5	Code	80	50	80.5	29.6	1.4	3.2	77.4	119	4.5	63.4	61759	13.7	-57.7	5.1	57.0	48.6	89.2	13.3
		3	RTU	20	10	40	2.5	Improved	80	50	106.3	17.5	5.7	26.1	80.2	110	5.1	71.6	-31815	-7.1	46.4	5.9	43.2	39.6	57.2	18.4
			FC	20	20	20	2.5	Improved	80	25	116.0	19.5	5.1	21.7	94.2	132	3.7	52.4	-11170	-2.5	15.0	6.7	38.0	31.8	62.0	16.8
			ASHP	20	20	20	2.5	Improved	80	25	99.8	19.5	1.7	3.2	96.7	154	3.7	52.4	9719	2.2	-9.2	6.3	46.7	36.0	87.6	14.8
	6	1									203.3	54.9	18.5	93.4	109.9											
		2	RTU	20	10	40	2.5	Code	80	25	138.7	29.2	8.3	38.7	99.9	123	3.9	66.0	-139281	-30.9	161.8	7.6	31.5	23.9	53.6	27.6
			FC	20	10	20	0.8	Code	80	0	142.5	29.8	6.7	29.7	112.9	152	2.8	47.8	-109493	-24.3	109.6	8.1	29.6	18.4	62.2	26.1
			ASHP	20	10	20	0.8	Code	80	0	120.0	29.8	1.9	3.2	116.9	159	2.8	47.8	-82608	-18.3	57.5	7.6	40.7	23.9	89.5	20.0
		3	RTU	20	20	40	1.2	Improved	80	50	97.8	18.5	5.0	22.8	75.1	92	7.3	125.1	-245073	-54.4	212.9	5.5	51.7	44.8	71.7	28.0
			FC	20	10	40	0.8	Improved	80	25	111.9	19.0	4.4	18.5	93.4	119	5.5	93.9	-193981	-43.1	161.0	6.5	44.8	34.3	75.1	27.4
			ASHP	20	20	20	1.2	Improved	80	0	118.6	19.8	1.9	3.2	115.4	159	3.9	67.5	-163200	-36.3	113.5	7.5	41.5	24.9	89.6	27.2
	7A	1									245.1	69.1	23.9	121.9	123.2											
		2	RTU	20	20	40	1.2	Improved	80	25	133.5	28.8	6.0	26.3	107.2	129	6.2	105.4	-211953	-47.1	136.9	7.7	45.4	34.4	74.0	26.2
			FC	20	20	40	1.2	Improved	80	25	121.9	29.9	5.4	23.2	98.7	123	6.0	101.9	-145545	-32.3	90.5	7.0	50.1	39.9	76.9	21.9
			ASHP	20	20	40	1.2	Improved	80	25	104.1	29.9	1.7	3.2	100.9	128	6.0	101.9	-120964	-26.9	62.4	6.6	57.4	43.9	92.7	19.9
		3	RTU	20	20	40	0.8	PH	80	25	122.0	21.1	3.6	13.1	108.8	129	6.8	116.0	-244197	-54.2	138.3	7.4	50.1	36.9	84.4	26.8
			FC	20	20	40	0.8	PH	80	25	114.8	19.7	3.5	12.6	102.2	123	6.6	112.4	-192084	-42.7	107.8	6.9	53.0	40.7	85.1	23.6
			ASHP	20	20	40	0.8	PH	80	25	103.4	19.7	1.7	3.2	100.2	131	6.6	112.4	-164793	-36.6	84.9	6.5	57.7	44.3	92.7	21.7

7.5 Part 3 – Lowest Carbon Abatement Costs

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Loads Savings	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
High Rise MURB Electric BB Mid Occupancy 0.6 VFAR 62-2001	4	1									138.7	48.8	9.5	45.7	93.0											
		2	40	10	20	2.5	Code	60	Standard	0	122.2	40.6	8.1	38.9	83.3	498	0.4	11.6	163253	9.1	-332.1	9.7	11.9	10.3	14.4	10.4
		3	40	10	20	2.5	Improved	80	Standard	0	111.3	29.7	8.0	38.9	72.4	378	0.8	24.7	268280	14.9	-499.5	8.7	19.7	19.9	15.7	11.5
		4	40	10	20	1.6	PH	80	Condensing	40	79.1	14.8	4.6	21.3	57.8	283	2.6	77.8	-48294	-2.7	27.4	6.7	43.0	37.6	51.7	19.1
	5	1									145.9	56.0	9.6	46.2	99.7											
		2	40	20	20	2.5	Code	60	Condensing	40	108.2	43.8	5.0	22.0	86.2	678	1.1	37.3	-1149	-0.1	0.7	9.4	25.9	17.5	47.9	18.6
		3	40	10	20	1.6	Improved	80	Condensing	40	90.4	26.1	4.8	21.8	68.6	462	2.5	82.0	-252380	-14.0	144.6	7.8	38.0	32.1	50.3	22.3
		4	40	10	20	0.8	PH	80	Condensing	40	75.8	11.5	4.6	21.4	54.3	337	3.4	109.2	-290230	-16.1	158.8	6.4	48.1	44.0	52.6	21.7
	6	1									159.6	69.5	9.9	47.0	112.5											
		2	20	20	40	2.5	Code	80	Standard	0	114.3	32.6	8.2	39.9	74.4	474	1.7	57.6	231892	12.9	-370.6	8.9	28.4	30.1	17.5	15.1
		3	20	20	40	2.5	Improved	80	Standard	0	109.4	27.6	8.1	39.9	69.5	425	1.8	60.7	329732	18.3	-509.4	8.4	31.5	33.8	18.1	14.2
		4	20	20	40	0.8	PH	60	Standard	0	96.3	14.7	7.9	39.2	57.1	282	2.7	91.2	177786	9.9	-240.5	7.2	39.7	43.2	20.7	16.6
	7A	1									155.3	65.1	10.0	47.5	107.8											
		2	20	20	40	0.8	Code	60	Condensing	40	103.6	39.2	5.1	22.6	81.0	512	2.3	106.7	-827385	-46.0	470.3	9.0	33.3	26.8	49.0	32.5
		3	20	20	40	0.8	Improved	60	Condensing	40	92.9	28.6	5.0	22.6	70.4	439	2.4	110.9	-568374	-31.6	314.8	8.0	40.2	35.0	50.3	25.8
		4	20	20	40	0.8	PH	80	Condensing	20	88.7	17.6	6.0	29.1	59.5	283	2.7	123.3	-519845	-28.9	368.4	7.1	42.9	41.7	39.3	24.1

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Loads Savings	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Low Rise MURB Electric BB Mid Occupancy 0.6 VFAR 62-2001	4	1									138.7	48.8	9.5	45.7	93.0											
		2	40	20	20	2.5	Code	60	Standard	0	115.0	33.4	8.0	38.7	76.2	463	0.5	11.6	386971	21.5	-731.6	9.0	17.1	16.6	15.5	6.5
		3	40	20	20	2.5	Improved	60	Standard	0	110.0	28.4	7.9	38.7	71.2	369	0.6	14.3	493283	27.4	-897.5	8.5	20.7	20.9	16.1	6.3
		4	40	20	20	2	PH	80	Standard	20	87.9	13.9	6.4	31.0	56.9	272	2.6	62.1	162332	9.0	-144.9	6.9	36.6	35.7	32.8	16.1
	5	1									145.9	56.0	9.6	46.2	99.7											
		2	40	20	20	2.5	Code	60	Standard	0	125.5	43.8	8.2	39.3	86.2	678	0.5	12.4	270818	15.0	-528.3	10.0	14.0	13.0	14.8	8.3
		3	40	20	20	2	Improved	80	Condensing	20	95.7	24.7	6.0	28.5	67.2	446	2.5	65.4	22119	1.2	-17.0	7.8	34.4	31.5	37.6	18.1
		4	40	20	40	1.2	PH	60	Condensing	40	79.1	14.8	4.6	21.5	57.6	347	3.4	89.2	-32514	-1.8	18.0	6.7	45.8	41.3	52.2	18.9
	6	1									159.6	69.5	9.9	47.0	112.5											
		2	20	20	20	2.5	Code	60	Standard	0	122.2	40.5	8.3	40.0	82.2	501	0.4	11.7	811727	45.1	-1374.3	9.6	23.4	24.2	16.5	3.8
		3	20	20	20	2.5	Improved	80	Standard	0	109.9	28.2	8.1	39.9	70.0	431	1.0	26.4	929674	51.6	-1441.3	8.5	31.1	33.4	18.0	6.2
		4	20	20	20	1.2	PH	80	Standard	0	95.2	13.5	7.9	39.3	55.9	296	2.3	61.8	743926	41.3	-1005.6	7.1	40.4	44.0	20.7	11.1
	7A	1									155.3	65.1	10.0	47.5	107.8											
		2	20	20	20	0.8	Code	60	Condensing	20	111.0	39.9	6.3	29.4	81.7	517	1.5	55.6	2205	0.1	-1.7	9.2	28.5	24.6	36.5	18.4
		3	20	20	20	0.8	Improved	60	Standard	0	110.9	29.2	8.2	39.9	71.0	445	1.6	59.4	162054	9.0	-250.3	8.5	28.6	30.2	18.0	16.0
		4	20	40	20	0.8	PH	80	Condensing	40	77.4	13.1	4.7	22.1	55.3	222	4.3	154.7	-880044	-48.9	464.0	6.5	50.1	46.7	52.9	27.0
	7B	1									184.5	79.7	10.5	48.4	136.1											
		2	20	40	40	0.8	Improved	80	Condensing	40	106.6	26.4	5.2	22.9	83.7	81	3.3	12.2	-57858	-16.1	151.5	9.8	42.2	36.8	50.7	0.0
		3	20	40	40	0.8	PH	80	Condensing	40	99.0	18.8	5.0	22.5	76.5	57	3.3	11.9	-68476	-19.0	181.6	9.1	42.9	37.1	51.2	0.0

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Commercial Office No IT Load Default Occupancy	4	1									141.4	35.1	11.9	59.5	81.9											
		2	VAV	50	7	20	2.5	Code	60	25	112.6	23.2	7.9	38.2	74.4	359	0.5	14.1	60334	3.3	-41.3	5.9	20.4	16.0	33.7	12.4
			FC	50	10	20	2.5	Code	None	0	115.4	29.4	9.2	45.8	69.7	452	-0.2	-5.8	458761	25.2	-471.9	5.9	18.4	17.0	22.4	0.0
			ASHP	50	10	20	2.5	Code	None	0	93.9	29.4	3.7	15.2	78.8	460	-0.2	-5.8	469931	25.8	-156.7	5.5	33.6	22.0	69.2	0.0
		3	VAV	50	10	20	2.5	Improved	60	25	108.1	18.4	7.0	33.4	74.7	356	0.5	15.5	63190	3.5	-35.4	5.8	23.5	17.8	41.2	12.3
			FC	50	10	20	2.5	Improved	60	50	86.4	18.7	7.0	34.6	51.7	327	0.9	24.7	367534	20.2	-204.8	4.4	38.9	38.1	41.4	9.2
			ASHP	50	10	20	2.5	Improved	60	0	92.2	14.7	3.7	15.2	77.0	465	0.0	-0.3	405984	22.3	-135.1	5.4	34.8	23.6	69.3	0.0
	5	1									141.3	36.0	11.8	59.0	82.3											
		2	VAV	50	10	20	2.5	Code	60	0	131.0	28.4	8.6	41.3	89.6	474	0.1	1.5	-54112	-3.0	46.7	7.0	7.3	1.0	26.9	22.5
			FC	50	10	20	2.5	Code	60	50	100.0	29.5	8.9	44.7	55.3	381	0.8	22.2	269461	14.8	-251.5	4.9	29.3	30.7	24.9	10.8
			ASHP	50	10	20	2.5	Code	60	25	88.7	27.1	3.6	15.2	73.5	517	0.4	10.3	293788	16.1	-98.4	5.2	37.3	26.9	69.4	5.7
		3	VAV	50	20	40	2.5	Improved	80	50	102.7	19.2	6.8	32.5	70.3	331	1.7	46.6	-396034	-21.7	216.0	5.5	27.3	22.4	42.6	31.0
			FC	50	20	20	2.5	Improved	60	0	111.1	18.5	7.0	33.2	77.9	511	0.2	5.9	166445	9.1	-94.9	6.0	21.4	15.1	40.8	5.8
			ASHP	50	20	20	2.5	Improved	60	0	97.0	18.5	3.7	15.2	81.9	582	0.2	5.9	194612	10.7	-65.9	5.7	31.3	19.3	68.6	4.5
	6	1									144.5	47.1	13.4	68.0	76.5											
		2	VAV	50	20	40	2.5	Code	80	0	127.6	30.0	8.2	39.0	88.7	417	0.7	24.6	-494660	-27.2	259.9	6.9	11.6	1.5	39.0	100.0
			FC	50	20	20	2.5	Code	80	0	116.2	28.7	8.5	41.6	74.5	438	0.4	12.0	6354	0.3	-3.6	6.0	19.6	13.3	36.5	11.3
			ASHP	50	20	20	2.5	Code	80	0	93.0	28.7	3.7	15.2	77.9	456	0.4	12.0	109418	6.0	-30.8	5.5	35.6	21.8	72.7	6.9
		3	VAV	50	20	40	1.2	Improved	60	0	113.1	19.8	6.3	28.9	84.2	423	1.9	61.3	-993617	-54.6	381.7	6.3	21.7	10.0	53.3	76.2
			FC	50	20	20	1.6	Improved	60	0	102.4	18.6	6.5	31.1	71.3	461	1.4	45.1	-450493	-24.7	180.0	5.5	29.1	20.9	51.2	26.9
			ASHP	50	20	20	1.6	Improved	60	0	89.3	18.6	3.6	15.2	74.2	472	1.4	45.1	-413784	-22.7	116.0	5.2	38.2	25.2	73.0	22.3
	7A	1									161.9	63.3	15.6	79.2	82.7											
		2	VAV	30	20	40	0.8	Improved	80	50	108.6	27.7	5.6	25.1	83.5	279	2.8	91.1	-1279722	-70.3	351.2	6.1	32.9	20.7	64.3	49.5
			FC	50	20	40	1.2	Code	60	0	115.0	29.7	7.8	37.5	77.6	514	1.6	51.9	-539435	-29.6	190.5	6.1	28.9	20.8	50.0	28.2
			ASHP	50	20	40	1.2	Code	60	0	97.0	29.7	3.7	15.2	81.8	515	1.6	51.9	-486397	-26.7	112.6	5.7	40.1	26.0	76.2	22.5
		3	VAV	30	20	40	0.8	PH	80	50	105.9	26.0	4.9	21.4	84.5	279	2.8	92.7	-1302735	-71.5	335.4	6.1	34.6	21.4	68.5	48.9
			FC	50	20	20	0.8	Improved	60	0	106.4	19.4	5.8	26.7	79.7	525	1.8	60.8	-668208	-36.7	188.3	5.9	34.3	23.3	62.6	29.5
			ASHP	50	20	20	0.8	Improved	60	0	95.4	19.4	3.7	15.2	80.2	540	1.8	60.8	-613765	-33.7	141.9	5.6	41.1	27.4	76.3	25.0

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Commercial Office 2.2 W/m2 IT Load Double Occupancy	4	1									154.3	20.8	10.3	49.3	105.0											
		2	FC	50	10	40	2.5	Code	None	25	145.2	26.8	10.2	49.5	95.7	532	0.3	8.9	25026	1.4	-1124.1	7.6	5.9	7.1	0.6	15.1
		3	FC	50	20	20	2	Improved	60	50	120.0	8.7	6.7	30.7	89.3	477	2.0	57.4	-583106	-32.0	442.7	6.7	22.2	19.1	35.2	36.5
	5	1									170.6	26.7	11.6	56.1	114.4											
		2	FC	50	7	20	2.5	Code	60	50	141.1	26.9	9.9	48.2	92.9	534	0.8	22.6	97740	5.4	-157.3	7.4	17.3	17.9	14.7	14.6
		3	FC	30	20	40	1.6	Improved	60	50	119.6	8.0	6.3	28.5	91.1	488	2.1	57.4	-355177	-19.5	181.9	6.7	29.8	25.8	46.1	25.9
	6	1									162.5	35.3	12.3	60.4	102.1											
		2	FC	50	10	40	2.5	Code	60	0	152.1	29.4	10.1	48.5	103.6	576	0.0	1.1	26000	1.4	-32.8	8.1	6.4	3.2	17.7	3.6
		3	FC	50	20	40	1.6	Improved	60	50	119.9	17.1	7.5	35.7	84.2	476	2.3	76.9	-846922	-46.5	487.8	6.5	26.2	22.7	38.8	35.2
	7A	1									181.7	52.2	14.7	72.9	108.8											
		2	FC	50	20	40	1.2	Code	60	0	152.1	26.8	8.6	39.9	112.2	658	1.6	52.4	-793413	-43.6	358.9	8.4	16.3	8.6	41.3	57.5
		3	FC	30	20	40	1.2	PH	60	50	119.2	17.5	6.6	30.2	89.0	476	2.1	69.3	-535497	-29.4	181.0	6.6	34.4	28.0	55.3	23.4

Scenario			Archetype Characteristics								Energy and Emissions Outcomes															
Archetype	Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Lighting Savings (%)	TEUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	Natural Gas Consumption (kWh/m2)	Electricity Consumption (kWh/m2)	Peak Electricity (kW)	Incremental Capital Cost (%)	Incremental Capital Cost ($/m2)	NPV LCC Savings ($)	NPV LLC Savings ($/m2)	COC ($/tonCO2e)	Energy Cost ($/m2)	Energy Savings (%)	Cost Savings (%)	GHG Savings (%)	Simple Payback (Years)
Retail Big Box	4	1									159.8	30.4	11.0	52.9	107.0											
		2	RTU	20	10	20	2.5	Code	80	50	105.7	22.1	7.4	35.9	69.8	97	3.2	47.9	18932	4.2	-73.3	5.6	33.5	34.8	27.9	16.1
			FC	20	7	20	2.5	Code	80	50	97.7	29.3	6.9	33.7	63.9	98	3.0	44.8	67714	15.0	-225.3	5.1	38.6	40.0	32.5	13.1
			ASHP	20	10	20	2.5	Code	80	50	72.8	25.8	1.4	3.2	69.7	100	3.0	44.8	92791	20.6	-115.4	4.6	54.2	46.6	86.8	11.2
		3	RTU	20	10	20	2.5	Improved	80	50	96.8	15.6	5.7	26.4	70.5	98	3.6	53.4	7519	1.7	-18.0	5.3	39.1	37.7	45.0	16.6
			FC	20	10	20	2.5	Improved	80	50	88.0	19.1	5.0	23.1	64.9	96	3.4	50.3	56832	12.6	-119.2	4.9	44.7	43.1	51.5	13.7
			ASHP	20	10	20	2.5	Improved	80	50	71.9	19.1	1.3	3.2	68.7	101	3.4	50.3	72617	16.1	-90.2	4.5	54.8	47.3	86.9	12.4
	5	1									188.0	39.1	14.0	68.5	119.4											
		2	RTU	20	10	20	2.5	Code	80	25	145.6	25.3	8.2	37.7	107.8	151	2.4	33.6	-27348	-6.1	58.9	8.1	22.2	17.9	38.7	19.1
			FC	20	10	40	2.5	Code	80	50	103.3	29.6	6.8	32.3	71.0	104	4.5	63.4	42496	9.4	-71.8	5.5	44.8	43.6	49.3	14.8
			ASHP	20	10	40	2.5	Code	80	50	80.5	29.6	1.4	3.2	77.4	119	4.5	63.4	61759	13.7	-57.7	5.1	57.0	48.6	89.2	13.3
		3	RTU	20	10	40	2.5	Improved	80	50	106.3	17.5	5.7	26.1	80.2	110	5.1	71.6	-31815	-7.1	46.4	5.9	43.2	39.6	57.2	18.4
			FC	20	20	20	2.5	Improved	80	25	116.0	19.5	5.1	21.7	94.2	132	3.7	52.4	-11170	-2.5	15.0	6.7	38.0	31.8	62.0	16.8
			ASHP	20	20	20	2.5	Improved	80	25	99.8	19.5	1.7	3.2	96.7	154	3.7	52.4	9719	2.2	-9.2	6.3	46.7	36.0	87.6	14.8
	6	1									203.3	54.9	18.5	93.4	109.9											
		2	RTU	20	10	40	2.5	Code	80	25	138.7	29.2	8.3	38.7	99.9	123	3.9	66.0	-139281	-30.9	161.8	7.6	31.5	23.9	53.6	27.6
			FC	20	10	20	0.8	Code	80	0	142.5	29.8	6.7	29.7	112.9	152	2.8	47.8	-109493	-24.3	109.6	8.1	29.6	18.4	62.2	26.1
			ASHP	20	10	20	0.8	Code	80	0	120.0	29.8	1.9	3.2	116.9	159	2.8	47.8	-82608	-18.3	57.5	7.6	40.7	23.9	89.5	20.0
		3	RTU	20	20	40	1.2	Improved	80	50	97.8	18.5	5.0	22.8	75.1	92	7.3	125.1	-245073	-54.4	212.9	5.5	51.7	44.8	71.7	28.0
			FC	20	10	40	0.8	Improved	80	25	111.9	19.0	4.4	18.5	93.4	119	5.5	93.9	-193981	-43.1	161.0	6.5	44.8	34.3	75.1	27.4
			ASHP	20	20	20	1.2	Improved	80	0	118.6	19.8	1.9	3.2	115.4	159	3.9	67.5	-163200	-36.3	113.5	7.5	41.5	24.9	89.6	27.2
	7A	1									245.1	69.1	23.9	121.9	123.2											
		2	RTU	20	20	40	1.2	Improved	80	25	133.5	28.8	6.0	26.3	107.2	129	6.2	105.4	-211953	-47.1	136.9	7.7	45.4	34.4	74.0	26.2
			FC	20	20	40	1.2	Improved	80	25	121.9	29.9	5.4	23.2	98.7	123	6.0	101.9	-145545	-32.3	90.5	7.0	50.1	39.9	76.9	21.9
			ASHP	20	20	40	1.2	Improved	80	25	104.1	29.9	1.7	3.2	100.9	128	6.0	101.9	-120964	-26.9	62.4	6.6	57.4	43.9	92.7	19.9
		3	RTU	20	20	40	0.8	PH	80	25	122.0	21.1	3.6	13.1	108.8	129	6.8	116.0	-244197	-54.2	138.3	7.4	50.1	36.9	84.4	26.8
			FC	20	20	40	0.8	PH	80	25	114.8	19.7	3.5	12.6	102.2	123	6.6	112.4	-192084	-42.7	107.8	6.9	53.0	40.7	85.1	23.6
			ASHP	20	20	40	0.8	PH	80	25	103.4	19.7	1.7	3.2	100.2	131	6.6	112.4	-164793	-36.6	84.9	6.5	57.7	44.3	92.7	21.7

7.6 Part 9 – Lowest Incremental Capital Costs – Original Targets

Note: Negative carbon abatement costs occur when a building has lower GHG emissions and a positive NPV, meaning investing in GHG reductions is profitable.

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Arch.	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
10 unit MURB	4	BCBC	27.0%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	86	60	39	26	113,670	104	6.4	0.0%	n/a	$2,422	-
		1	27.0%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	86	60	39	26	113,670	104	6.4	0.1%	egative NPV but no GHG reducti	$2,424	-$3
		2	27.0%	2.5	16	11	20	27	50	LG-avg-Double	1.8	BaseDHW	30%	elec-baseboard	0%	80	54	33	22	104,034	103	6.2	0.4%	-$2,897	$2,432	$6
		3	27.0%	1.5	16	17	20	27	40	LG-avg-Double	1.8	ElectricStorage	0%	elec-baseboard	60%	66	40	21	19	108,996	0	1.2	0.3%	-$170	$2,429	$11
		4	27.0%	0.6	24	20	0	27	40	LG-avg-Double	1.8	ElectricStorage	0%	elec-baseboard	60%	59	33	14	15	97,750	0	1.0	0.7%	-$296	$2,438	$19
		5	27.0%	0.6	16	17	0	27	40	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	60%	47	22	11	14	78,371	0	0.8	1.7%	-$378	$2,462	$25
	5	BCBC	27.0%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	100	74	52	35	136,114	104	6.6	0.0%	n/a	$2,599	-
		1	27.0%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	100	74	52	35	136,114	104	6.6	0.1%	egative NPV but no GHG reducti	$2,602	-$3
		2	27.0%	1.0	18	17	15	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	82	56	35	22	106,820	104	6.3	0.3%	-$10,091	$2,607	$38
		3	27.0%	1.0	18	17	15	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	82	56	35	22	106,820	104	6.3	0.3%	-$10,091	$2,607	$38
		4	27.0%	0.6	18	11	0	27	40	LG-avg-Double	1.8	ElectricStorage	42%	elec-baseboard	60%	69	43	25	20	114,186	0	1.2	0.5%	-$489	$2,611	$32
		5	27.0%	0.6	18	11	0	27	40	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	84%	51	25	14	18	83,589	0	0.9	2.0%	-$595	$2,650	$41
	6	BCBC	27.0%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	118	92	70	49	164,518	108	7.2	0.0%	n/a	$2,727	-
		1	27.0%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	118	92	70	49	164,518	108	7.2	0.1%	egative NPV but no GHG reducti	$2,730	-$3
		2	27.0%	2.5	16	20	0	29	100	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	113	87	65	41	156,774	108	7.1	0.2%	-$6,415	$2,733	$6
		3	27.0%	1.0	18	17	11	27	40	LG-avg-Double	1.8	ElectricStorage	0%	elec-baseboard	0%	96	70	50	31	158,460	0	1.7	0.0%	-$323	$2,726	$21
		4	27.0%	0.6	16	25	0	29	50	LG-avg-Double	1.8	ElectricStorage	0%	elec-baseboard	60%	80	55	35	27	133,193	0	1.4	0.2%	-$778	$2,733	$54
		5	27.0%	0.6	50	11	0	27	60	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	84%	51	25	14	19	84,031	0	0.9	2.5%	-$916	$2,795	$69
	7a	BCBC	27.0%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	149	123	100	63	214,243	117	8.1	0.0%	n/a	$3,638	-
		1	27.0%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	149	123	100	63	214,243	117	8.1	0.1%	egative NPV but no GHG reducti	$3,643	-$5
		2	27.0%	2.5	22	11	15	27	80	LG-avg-Double	1.8	BaseDHW	55%	elec-baseboard	60%	124	99	75	51	174,205	115	7.6	0.2%	-$8,128	$3,646	$55
		3	27.0%	0.6	18	20	11	27	40	LG-avg-Double	1.8	ElectricStorage	55%	elec-baseboard	60%	97	72	51	33	161,247	0	1.7	0.1%	-$1,180	$3,641	$91
		4	27.0%	0.6	18	11	0	27	40	HG-avg-Triple	1.2	BaseDHW	0%	elec-baseboard	60%	81	55	31	29	101,210	117	6.9	0.7%	-$10,481	$3,662	$153
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	7b	BCBC	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	176	150	126	68	257,707	119	8.7	0.0%	n/a	$3,638	-
		1	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	176	150	126	68	257,707	119	8.7	0.1%	egative NPV but no GHG reducti	$3,643	-$5
		2	27.0%	1.5	18	20	15	27	70	MG-i89-Double	1.6	HPHotWater	30%	elec-baseboard	60%	118	93	81	44	195,877	0	2.1	0.4%	-$1,160	$3,654	$93
		3	27.0%	0.6	22	11	11	27	50	LG-avg-Double	1.8	ElectricStorage	30%	elec-baseboard	70%	109	83	62	34	180,051	0	1.9	0.1%	-$1,569	$3,643	$129
		4	27.0%	0.6	22	20	20	27	50	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	84%	79	54	42	29	131,261	0	1.4	1.4%	-$1,786	$3,690	$158
		5	17.1%	0.5	60	40	30	60	100	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	43	13	15	17	70,918	0	1.0	7.7%	-$243	$4,057	$26
	8	BCBC	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	200	174	150	73	297,846	121	9.2	0.0%	n/a	$3,638	-
		1	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	200	174	150	73	297,846	121	9.2	0.1%	egative NPV but no GHG reducti	$3,643	-$5
		2	27.0%	1.5	30	25	11	27	50	HG-avg-Triple	1.2	BaseDHW	0%	elec-baseboard	60%	121	96	71	43	167,184	121	7.8	0.8%	-$10,472	$3,666	$176
		3	27.0%	0.6	24	11	0	27	60	LG-avg-Double	1.8	HPHotWater	0%	elec-baseboard	84%	109	83	71	35	180,182	0	1.9	0.6%	-$1,976	$3,660	$174
		4	27.0%	0.6	50	11	0	27	70	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	84%	81	55	43	27	133,292	0	1.4	2.1%	-$2,070	$3,712	$195
		5	17.1%	0.5	80	40	30	80	150	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	43	15	15	15	70,679	0	1.0	8.7%	-$468	$4,111	$53

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Arch.	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
6 unit Row House	4	BCBC	22.2%	3.5	16	NA	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	63	30	26	44,913	219	11.4	0.0%	n/a	$1,749	-
		1	22.2%	3.5	16	NA	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	63	30	26	44,913	219	11.4	0.2%	egative NPV but no GHG reducti	$1,752	-$3
		2	22.2%	2.5	16	NA	0	27	50	LG-avg-Double	1.8	GasInst_Low	0%	basefurnace	0%	95	58	26	24	44,833	203	10.6	0.4%	$306	$1,757	-$5
		3	22.2%	1.5	16	NA	0	27	50	LG-avg-Double	1.8	HPHotWater	42%	basefurnace	0%	82	45	29	22	54,312	120	6.6	1.1%	$279	$1,768	-$27
		4	22.2%	0.6	16	NA	11	27	40	MG-HP-Double	1.4	HPHotWater	0%	basefurnace	0%	72	34	20	19	54,281	82	4.6	2.0%	$271	$1,784	-$36
		5	22.2%	0.6	16	NA	11	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	62	23	10	17	54,091	42	2.7	3.4%	$313	$1,808	-$54
	5	BCBC	22.2%	3.5	18	NA	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	111	75	42	34	45,131	264	13.7	0.0%	n/a	$1,877	-
		1	22.2%	3.5	18	NA	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	111	75	42	34	45,131	264	13.7	0.2%	egative NPV but no GHG reducti	$1,880	-$3
		2	22.2%	1.5	18	NA	0	40	40	LG-avg-Double	1.8	ElectricStorage	0%	basefurnace	0%	98	61	33	28	66,870	136	7.5	0.5%	$421	$1,887	-$52
		3	22.2%	1.5	18	NA	0	40	40	LG-avg-Double	1.8	ElectricStorage	0%	basefurnace	0%	98	61	33	28	66,870	136	7.5	0.5%	$421	$1,887	-$52
		4	22.2%	1.0	18	NA	0	27	40	MG-i89-Double	1.6	HPHotWater	0%	basefurnace	60%	82	44	29	25	54,455	118	6.5	1.7%	$247	$1,908	-$35
		5	22.2%	0.6	24	NA	11	35	70	HG-avg-Triple	1.2	HPHotWater	42%	basefurnace	60%	64	25	12	18	53,975	49	3.0	4.4%	$356	$1,960	-$75
	6	BCBC	22.2%	3.5	18	NA	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	90	53	45	45,351	317	16.3	0.0%	n/a	$1,970	-
		1	22.2%	3.5	18	NA	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	90	53	45	45,351	317	16.3	0.2%	egative NPV but no GHG reducti	$1,973	-$3
		2	22.2%	1.5	16	NA	0	27	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	120	84	51	38	45,311	296	15.2	-0.1%	-$274	$1,967	$6
		3	22.2%	1.5	16	NA	0	27	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	120	84	51	38	45,311	296	15.2	-0.1%	-$274	$1,967	$6
		4	22.2%	0.6	18	NA	0	27	40	MG-i89-Double	1.6	HPHotWater	0%	basefurnace	70%	92	55	37	31	55,040	155	8.3	1.4%	$167	$1,997	-$27
		5	22.2%	0.6	50	NA	11	40	100	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	64	25	11	20	54,539	48	3.0	5.3%	$319	$2,074	-$85
	7a	BCBC	22.2%	3.5	18	NA	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	122	79	56	45,848	431	22.0	0.0%	n/a	$2,627	-
		1	22.2%	3.5	18	NA	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	122	79	56	45,848	431	22.0	0.2%	egative NPV but no GHG reducti	$2,632	-$5
		2	22.2%	1.5	16	NA	11	27	50	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	70%	135	100	63	44	45,544	353	18.1	0.4%	-$43	$2,637	$3
		3	22.2%	0.6	16	NA	11	27	50	LG-avg-Double	1.8	HPHotWater	0%	basefurnace	60%	121	85	64	39	56,378	259	13.5	0.6%	$93	$2,643	-$16
		4	22.2%	0.6	22	NA	0	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	90	53	35	32	55,839	145	7.8	2.3%	$150	$2,688	-$42
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	7b	BCBC	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	143	98	59	46,207	506	25.7	0.0%	n/a	$2,627	-
		1	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	143	98	59	46,207	506	25.7	0.2%	egative NPV but no GHG reducti	$2,632	-$5
		2	22.2%	1.5	18	NA	0	27	40	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	0%	129	94	74	44	55,775	295	15.3	1.2%	$107	$2,658	-$22
		3	22.2%	0.6	16	NA	0	27	100	HG-avg-Triple	1.2	ElectricStorage	0%	basefurnace	70%	117	81	48	35	70,504	195	10.5	1.3%	$154	$2,661	-$47
		4	22.2%	0.6	50	NA	11	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	75%	92	55	37	29	56,081	151	8.1	3.6%	$185	$2,723	-$65
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	8	BCBC	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	164	117	63	46,566	582	29.5	0.0%	n/a	$2,627	-
		1	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	164	117	63	46,566	582	29.5	0.2%	egative NPV but no GHG reducti	$2,632	-$5
		2	22.2%	1.5	24	NA	0	27	70	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	0%	132	97	77	42	55,986	305	15.8	2.0%	$116	$2,679	-$31
		3	22.2%	0.6	22	NA	0	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	119	83	62	36	56,724	251	13.1	1.7%	$58	$2,673	-$19
		4	22.2%	0.6	60	NA	15	40	100	HG-avg-Triple	1.2	HPHotWater	30%	gas-furnace-ecm	75%	92	55	38	27	55,569	153	8.2	5.7%	$246	$2,777	-$104
		5	10.0%*	0.5	80	NA	40	50	120	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	68	15	13	17	68,291	0	1.0	13.0%	$237	$3,140	-$135

*Door area also reduced, by 33%.

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Arch.	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Quadplex	4	BCBC	17.3%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	126	70	35	32	46,726	64	3.7	0.0%	n/a	$1,857	-
		1	17.3%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	126	70	35	32	46,726	64	3.7	0.2%	egative NPV but no GHG reducti	$1,861	-$4
		2	17.3%	1.5	16	17	11	35	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	60%	114	58	23	26	40,629	64	3.6	1.2%	-$3,134	$1,880	$8
		3	17.3%	1.5	16	25	0	27	50	MG-i89-Double	1.6	HPHotWater	0%	gas-furnace-ecm	60%	99	43	26	25	35,528	55	3.1	2.1%	-$892	$1,896	$21
		4	17.3%	0.6	24	25	11	27	80	LG-avg-Double	1.8	HPHotWater	0%	elec-baseboard	60%	90	34	21	21	46,084	0	0.5	3.3%	$304	$1,918	-$38
		5	17.3%	0.6	40	11	0	27	70	HG-avg-Triple	1.2	HPHotWater	30%	gas-furnace-ecm	75%	80	25	10	18	35,380	21	1.4	6.1%	$472	$1,970	-$42
	5	BCBC	17.3%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	140	84	49	42	53,935	64	3.8	0.0%	n/a	$1,992	-
		1	17.3%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	140	84	49	42	53,935	64	3.8	0.2%	egative NPV but no GHG reducti	$1,997	-$5
		2	17.3%	2.5	16	11	0	35	100	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	60%	132	76	40	38	49,688	64	3.7	0.7%	-$4,548	$2,006	$8
		3	17.3%	1.5	16	11	0	35	50	LG-avg-Double	1.8	ElectricStorage	0%	gas-furnace-ecm	0%	129	74	39	35	43,882	81	4.5	0.7%	ositive NPV but no GHG reductio	$2,006	$32
		4	17.3%	0.6	24	11	0	27	80	LG-avg-Double	1.8	HPHotWater	42%	elec-baseboard	60%	100	45	32	28	51,543	0	0.5	2.9%	$194	$2,049	-$24
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	6	BCBC	17.3%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	157	102	65	55	62,125	67	4.0	0.0%	n/a	$2,091	-
		1	17.3%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	157	102	65	55	62,125	67	4.0	0.3%	egative NPV but no GHG reducti	$2,096	-$5
		2	17.3%	2.5	16	11	20	40	40	LG-avg-Double	1.8	ElectricStorage	0%	gas-furnace-ecm	60%	155	99	60	50	44,565	126	6.7	0.3%	ositive NPV but no GHG reductio	$2,097	$64
		3	17.3%	1.5	22	17	0	40	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	60%	139	84	47	42	52,905	67	3.9	0.9%	-$7,351	$2,109	$28
		4	17.3%	1.0	18	11	15	29	40	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	60%	109	53	39	38	55,905	0	0.6	2.7%	$33	$2,148	-$4
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	7a	BCBC	17.3%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	194	139	99	71	79,786	72	4.5	0.0%	n/a	$2,789	-
		1	17.3%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	194	139	99	71	79,786	72	4.5	0.3%	egative NPV but no GHG reducti	$2,797	-$8
		2	17.3%	1.5	16	17	0	35	50	MG-HP-Double	1.4	HPHotWater	0%	elec-baseboard	60%	150	95	80	54	77,083	0	0.8	1.4%	$16	$2,828	-$2
		3	17.3%	1.5	24	20	11	35	100	MG-i89-Double	1.6	HPHotWater	0%	elec-baseboard	60%	140	84	69	48	71,722	0	0.8	2.4%	$32	$2,857	-$5
		4	17.3%	0.6	40	17	15	35	60	HG-avg-Triple	1.2	HPHotWater	42%	elec-baseboard	84%	110	54	39	35	56,262	0	0.6	5.8%	$126	$2,950	-$19
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	7b	BCBC	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	214	158	118	73	89,399	74	4.6	0.0%	n/a	$2,789	-
		1	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	214	158	118	73	89,399	74	4.6	0.3%	egative NPV but no GHG reducti	$2,797	-$8
		2	17.3%	1.5	22	17	11	27	100	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	60%	151	95	80	50	77,374	0	0.8	2.1%	-$178	$2,846	$26
		3	17.3%	1.5	40	20	11	29	100	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	70%	138	83	68	45	71,059	0	0.8	4.2%	$14	$2,907	-$2
		4	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	8	BCBC	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	238	182	141	78	101,315	75	4.8	0.0%	n/a	$2,789	-
		1	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	238	182	141	78	101,315	75	4.8	0.3%	egative NPV but no GHG reducti	$2,797	-$8
		2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
		3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
		4	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Arch.	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Large SFD	4	BCBC	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.0%	n/a	$1,938	-
		1	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.2%	egative NPV but no GHG reducti	$1,941	-$3
		2	14.6%	2.5	16	11	0	NA	50	LG-avg-Double	1.8	GasInstantaneous	0%	baseboard	70%	66	52	44	24	29,864	14	1.0	0.1%	$391	$1,939	-$79
		3	14.6%	1.5	16	11	0	NA	60	MG-i89-Double	1.6	HPHotWater	0%	baseboard	0%	57	43	39	23	29,308	0	0.3	0.5%	$350	$1,947	-$80
		4	14.6%	1.5	16	11	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	CCASHP-ecm	84%	47	33	41	23	24,222	0	0.3	1.5%	$313	$1,966	-$72
		5	14.6%	0.6	40	17	20	NA	50	HG-avg-Triple	1.2	ElectricStorage	42%	baseboard	70%	37	23	15	14	18,835	0	0.2	4.2%	$425	$2,020	-$99
	5	BCBC	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.0%	n/a	$2,079	-
		1	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.2%	egative NPV but no GHG reducti	$2,082	-$3
		2	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	basefurnace	0%	88	74	57	33	12,109	118	6.0	-0.3%	$274	$2,073	-$9
		3	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	basefurnace	0%	88	74	57	33	12,109	118	6.0	-0.3%	$274	$2,073	-$9
		4	14.6%	1.0	22	11	0	NA	60	MG-HP-Double	1.4	GasInstantaneous	0%	baseboard	70%	57	43	35	24	25,530	14	1.0	0.7%	$280	$2,094	-$65
		5	14.6%	0.6	60	17	20	NA	70	HG-i89-Triple-B	0.8	ElectricStorage	42%	baseboard	84%	37	23	15	16	18,779	0	0.2	6.9%	$594	$2,223	-$155
	6	BCBC	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	105	91	69	44	8,122	165	8.3	0.0%	n/a	$2,182	-
		1	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	106	91	69	44	8,122	165	8.3	0.2%	egative NPV but no GHG reducti	$2,185	-$4
		2	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	70%	111	97	74	43	8,171	174	8.8	-0.5%	ositive NPV but no GHG reductio	$2,172	$7
		3	14.6%	1.5	18	11	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	baseboard	0%	93	79	70	39	47,309	0	0.5	-0.9%	$420	$2,163	-$128
		4	14.6%	0.6	16	11	0	NA	100	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	0%	69	55	46	32	35,086	0	0.4	0.6%	$315	$2,195	-$98
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	7a	BCBC	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.0%	n/a	$2,910	-
		1	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.2%	egative NPV but no GHG reducti	$2,916	-$6
		2	14.6%	1.5	22	11	15	NA	50	LG-avg-Double	1.8	BaseDHW	0%	baseboard	0%	111	97	84	44	50,282	23	1.7	-0.2%	$387	$2,904	-$144
		3	14.6%	1.5	22	11	0	NA	60	MG-i89-Double	1.6	GasInstantaneous	0%	baseboard	60%	97	83	73	41	44,892	16	1.3	-0.1%	$301	$2,906	-$117
		4	14.6%	0.6	22	11	0	NA	70	HG-avg-Triple	1.2	ElectricStorage	55%	CCASHP-ecm	70%	67	53	53	34	34,054	0	0.4	2.4%	$309	$2,981	-$131
		5	14.0%	0.6	80	60	25	NA	100	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	32	13	12	13	13,824	9	0.6	15.4%	$2,511	$3,346	-$407
	7b	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.2%	egative NPV but no GHG reducti	$2,916	-$6
		2	14.6%	1.5	22	17	0	NA	50	HG-avg-Triple	1.2	GasInst_Low	0%	baseboard	60%	102	88	77	41	46,698	19	1.4	0.3%	$298	$2,920	-$130
		3	14.6%	1.5	22	25	0	NA	100	HG-avg-Triple	1.2	GasInst_Low	55%	baseboard	70%	94	80	71	39	43,559	16	1.3	1.6%	$335	$2,955	-$149
		4	14.6%	0.6	40	20	20	NA	60	HG-avg-Triple	1.2	HPHotWater	42%	CCASHP-ecm	75%	68	54	55	31	34,852	0	0.4	4.4%	$378	$3,037	-$181
		5	9.3%	1.0	80	80	40	NA	150	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	34	16	15	12	13,698	13	0.8	17.4%	$2,819	$3,405	-$457
	8	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.2%	egative NPV but no GHG reducti	$2,916	-$6
		2	14.6%	1.5	22	17	0	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	CCASHP-ecm	60%	106	92	91	44	49,507	17	1.4	1.5%	$325	$2,955	-$166
		3	14.6%	1.5	50	17	0	NA	50	HG-avg-Triple	1.2	ElectricStorage	42%	baseboard	60%	96	82	73	38	49,059	0	0.5	2.8%	$360	$2,992	-$196
		4	14.0%	1.0	50	35	25	NA	100	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	45	27	27	16	15,111	29	1.7	10.3%	$1,810	$3,203	-$252
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Arch.	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Medium SFD	4	BCBC	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.0%	n/a	$2,045	-
		1	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.2%	egative NPV but no GHG reducti	$2,050	-$5
		2	14.7%	2.5	16	17	0	NA	40	LG-avg-Double	1.8	GasInst_Low	0%	baseboard	0%	85	55	35	27	15,640	16	1.0	0.2%	$378	$2,049	-$63
		3	14.7%	2.5	18	11	0	NA	40	LG-avg-Double	1.8	HPHotWater	0%	baseboard	70%	74	44	35	25	17,474	0	0.2	0.8%	$366	$2,062	-$85
		4	14.7%	0.6	22	17	0	NA	40	MG-i89-Double	1.6	HPHotWater	0%	baseboard	0%	63	33	24	21	14,918	0	0.2	1.8%	$329	$2,082	-$77
		5	14.7%	0.6	24	20	11	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	53	23	14	17	12,445	0	0.1	3.6%	$368	$2,119	-$87
	5	BCBC	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.0%	n/a	$2,194	-
		1	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.2%	egative NPV but no GHG reducti	$2,200	-$5
		2	14.7%	2.5	16	20	0	NA	40	LG-avg-Double	1.8	GasInst_Low	0%	baseboard	0%	95	65	46	34	18,224	16	1.0	0.0%	$408	$2,195	-$82
		3	14.7%	2.5	16	20	0	NA	40	LG-avg-Double	1.8	GasInst_Low	0%	baseboard	0%	95	65	46	34	18,224	16	1.0	0.0%	$408	$2,195	-$82
		4	14.7%	0.6	22	17	0	NA	40	MG-i89-Double	1.6	HPHotWater	0%	baseboard	0%	71	41	33	27	16,918	0	0.2	1.5%	$330	$2,226	-$88
		5	14.7%	0.6	40	25	0	NA	100	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	55	25	14	18	9,196	14	0.8	4.9%	$403	$2,301	-$87
	6	BCBC	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.0%	n/a	$2,303	-
		1	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.2%	egative NPV but no GHG reducti	$2,308	-$6
		2	14.7%	2.5	16	20	0	NA	40	LG-avg-Double	1.8	GasInst_Low	0%	baseboard	0%	116	86	65	46	22,780	17	1.1	-0.4%	$453	$2,294	-$113
		3	14.7%	2.5	16	25	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	baseboard	0%	113	83	64	45	26,724	0	0.3	-0.3%	$463	$2,296	-$147
		4	14.7%	1.0	16	25	0	NA	50	MG-HP-Double	1.4	HPHotWater	0%	baseboard	70%	84	54	45	36	20,002	0	0.2	1.3%	$341	$2,333	-$110
		5	14.7%	0.6	60	25	15	NA	100	HG-i89-Triple-B	0.8	HPHotWater	42%	gas-furnace-ecm	84%	54	24	14	21	9,069	14	0.8	9.3%	$667	$2,517	-$184
	7a	BCBC	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	126	86	59	7,738	106	5.4	0.0%	n/a	$3,072	-
		1	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	126	86	59	7,738	106	5.4	0.3%	egative NPV but no GHG reducti	$3,081	-$9
		2	14.7%	1.5	18	17	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	baseboard	60%	126	96	76	47	29,975	0	0.3	-0.2%	$385	$3,065	-$164
		3	14.7%	1.5	18	11	11	NA	60	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	0%	109	79	58	45	25,780	0	0.3	0.9%	$352	$3,098	-$151
		4	14.7%	0.6	24	20	11	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	85	55	45	35	20,029	0	0.2	2.7%	$330	$3,154	-$144
		5	8.0%	1.0	50	40	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	50%	CCASHP-ecm	75%	56	20	13	19	11,815	5	0.4	12.1%	$830	$3,421	-$347
	7b	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.3%	egative NPV but no GHG reducti	$3,081	-$9
		2	14.7%	1.5	18	11	11	NA	60	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	0%	129	99	78	49	30,669	0	0.3	0.4%	$365	$3,084	-$179
		3	14.7%	1.5	30	11	11	NA	50	HG-avg-Triple	1.2	HPHotWater	30%	baseboard	0%	115	85	75	47	27,197	0	0.3	2.1%	$388	$3,135	-$192
		4	14.7%	0.6	40	17	15	NA	70	HG-HP-Triple	1	HPHotWater	42%	baseboard	84%	85	55	46	31	20,113	0	0.2	5.1%	$416	$3,229	-$208
		5	8.0%	0.6	100	80	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	50%	CCASHP-ecm	84%	58	22	14	15	11,829	7	0.5	20.5%	$1,239	$3,678	-$593
	8	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	166	120	66	7,901	139	7.0	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	166	120	66	7,901	139	7.0	0.3%	egative NPV but no GHG reducti	$3,081	-$9
		2	14.7%	1.5	24	25	15	NA	100	HG-avg-Triple	1.2	ElectricStorage	0%	gas-furnace-ecm	60%	129	99	70	41	12,345	66	3.4	2.6%	$262	$3,153	-$80
		3	14.7%	1.5	40	17	11	NA	70	HG-avg-Triple	1.2	GasInst_Low	42%	baseboard	70%	114	84	63	39	22,196	17	1.1	3.3%	$349	$3,173	-$174
		4	14.7%	0.6	60	25	11	NA	70	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	70%	84	54	47	31	19,962	0	0.2	9.5%	$577	$3,365	-$330
		5	8.0%	0.6	100	80	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	50%	CCASHP-ecm	84%	59	23	15	14	11,563	9	0.6	20.5%	$1,070	$3,678	-$580

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Arch.	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Small SFD	4	BCBC	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.0%	n/a	$2,314	-
		1	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.4%	egative NPV but no GHG reducti	$2,324	-$10
		2	12.2%	2.5	24	11	11	NA	60	LG-avg-Double	1.8	HPHotWater	0%	baseboard	0%	129	59	40	48	13,140	0	0.1	2.4%	$401	$2,370	-$139
		3	12.2%	2.5	30	11	11	NA	100	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	60%	111	41	22	40	11,306	0	0.1	4.7%	$416	$2,424	-$145
		4	12.2%	0.6	24	11	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	70%	104	35	16	35	10,640	0	0.1	7.5%	$547	$2,487	-$192
		5	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	gas-furnace-ecm	75%	118	25	6	22	11,437	2	0.3	13.5%	$1,091	$2,597	-$355
	5	BCBC	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.0%	n/a	$2,483	-
		1	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.4%	egative NPV but no GHG reducti	$2,494	-$11
		2	12.2%	2.5	18	11	11	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	baseboard	0%	159	90	51	63	12,473	14	0.8	0.8%	$370	$2,504	-$99
		3	12.2%	2.5	18	11	11	NA	100	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	60%	143	73	31	53	14,557	0	0.2	2.4%	$428	$2,543	-$170
		4	12.2%	0.6	24	11	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	70%	114	44	25	45	11,612	0	0.1	7.1%	$525	$2,660	-$212
		5	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	75%	120	22	11	27	12,259	0	0.2	16.2%	$1,141	$2,855	-$454
	6	BCBC	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.0%	n/a	$2,606	-
		1	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.5%	egative NPV but no GHG reducti	$2,618	-$12
		2	12.2%	2.5	16	11	11	NA	100	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	60%	165	95	51	71	16,779	0	0.2	1.9%	$413	$2,655	-$200
		3	12.2%	2.5	24	11	11	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	baseboard	60%	153	83	42	65	11,556	14	0.8	3.4%	$366	$2,695	-$130
		4	12.2%	0.6	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	75%	120	50	30	53	12,195	0	0.1	7.7%	$476	$2,806	-$235
		5	6.9%	1.0	50	40	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	75%	122	27***	11	30	12,299	1	0.2	18.1%	$1,053	$3,044	-$509
	7a	BCBC	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	256	187	104	105	7,507	67	3.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	257	187	104	105	7,507	67	3.4	0.6%	egative NPV but no GHG reducti	$3,495	-$19
		2	12.2%	2.5	40	20	30	NA	50	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	60%	161	92	70	73	16,446	0	0.2	6.7%	$550	$3,711	-$351
		3	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	166	71	36	49	9,668	26	1.4	12.5%	$1,062	$3,887	-$419
		4	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	75%	139	46	34	46	12,864	5	0.4	16.2%	$1,005	$4,008	-$597
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	7b	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.6%	egative NPV but no GHG reducti	$3,495	-$19
		2	6.9%	3.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	190	94	58	56	9,748	35	1.9	11.7%	$962	$3,865	-$392
		3	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	174	77	42	45	9,792	29	1.6	12.5%	$876	$3,887	-$410
		4	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	gas-furnace-ecm	75%	133	39	20	28	12,558	4	0.4	33.2%	$1,655	$4,599	-$1,162
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	8	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.6%	egative NPV but no GHG reducti	$3,495	-$19
		2	6.9%	2.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	189	96	59	53	9,371	36	1.9	12.1%	$789	$3,879	-$384
		3	6.9%	2.5	100	100	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	84%	151	60	42	40	12,538	10	0.7	32.7%	$1,564	$4,588	-$1,137
		4	6.9%	0.6	100	100	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	84%	149	45	25	29	12,522	10	0.7	33.1%	$1,574	$4,595	-$1,152
		5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

*These CCASHPs have a -4F cutoff.

**Insulation added under footings and at slab edge in addition to underslab.

***Misses the MEUI requirement by <2kWh/m2.

7.7 Part 9 – Highest NPV – Original Targets

Note: Negative carbon abatement costs occur when a building has lower GHG emissions and a positive NPV, meaning investing in GHG reductions is profitable.

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
10 unit MURB	4	BCBC	27.0%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	86	60	39	26	113,670	104	6.4	0.0%	n/a	$2,422	-
		1	27.0%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	86	60	39	26	113,670	104	6.4	0.1%	egative NPV but no GHG reducti	$2,424	-$3
		2	27.0%	1.5	18	20	11	27	60	LG-avg-Double	1.8	Combo	0%	ComboHeatA	0%	73	47	26	18	50,284	255	13.3	0.8%	ositive NPV but no GHG reductio	$2,442	$65
		3	27.0%	0.6	18	25	20	27	40	LG-avg-Double	1.8	Combo	0%	ComboHeatA	60%	62	36	16	16	50,154	190	10.0	0.9%	ositive NPV but no GHG reductio	$2,443	$70
		4	27.0%	0.6	18	20	0	27	100	LG-avg-Double	1.8	Combo	0%	ComboHeatA	60%	60	35	14	15	50,131	180	9.5	1.1%	ositive NPV but no GHG reductio	$2,449	$65
		5	27.0%	0.6	22	17	20	40	40	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	60%	50	25	5	12	50,003	120	6.5	2.2%	ositive NPV but no GHG reductio	$2,475	$45
	5	BCBC	27.0%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	100	74	52	35	136,114	104	6.6	0.0%	n/a	$2,599	-
		1	27.0%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	100	74	52	35	136,114	104	6.6	0.1%	egative NPV but no GHG reducti	$2,602	-$3
		2	27.0%	1.0	22	25	20	27	40	LG-avg-Double	1.8	Combo	0%	ComboHeatA	60%	72	46	25	22	50,264	249	12.9	0.8%	ositive NPV but no GHG reductio	$2,619	$100
		3	27.0%	1.0	22	25	20	27	40	LG-avg-Double	1.8	Combo	0%	ComboHeatA	60%	72	46	25	22	50,264	249	12.9	0.8%	ositive NPV but no GHG reductio	$2,619	$100
		4	27.0%	0.6	18	20	11	27	60	LG-avg-Double	1.8	Combo	0%	ComboHeatA	60%	70	44	23	20	50,236	234	12.2	0.8%	ositive NPV but no GHG reductio	$2,620	$101
		5	27.0%	0.6	40	25	11	29	100	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	84%	51	25	5	14	50,005	122	6.6	3.2%	ositive NPV but no GHG reductio	$2,681	$51
	6	BCBC	27.0%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	118	92	70	49	164,518	108	7.2	0.0%	n/a	$2,727	-
		1	27.0%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	118	92	70	49	164,518	108	7.2	0.1%	egative NPV but no GHG reducti	$2,730	-$3
		2	27.0%	2.5	16	20	0	29	100	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	113	87	65	41	156,774	108	7.1	0.2%	-$6,415	$2,733	$6
		3	27.0%	0.6	16	20	0	27	50	LG-avg-Double	1.8	Combo	0%	ComboHeatA	60%	84	58	35	27	50,364	318	16.4	0.4%	ositive NPV but no GHG reductio	$2,738	$148
		4	27.0%	0.6	22	11	0	27	50	MG-i89-Double	1.6	Combo	0%	ComboHeatA	60%	74	48	26	25	50,262	261	13.5	0.8%	ositive NPV but no GHG reductio	$2,750	$141
		5	27.0%	0.6	50	11	0	27	60	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	84%	51	25	14	19	84,031	0	0.9	2.5%	-$916	$2,795	$69
	7a	BCBC	27.0%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	149	123	100	63	214,243	117	8.1	0.0%	n/a	$3,638	-
		1	27.0%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	149	123	100	63	214,243	117	8.1	0.1%	egative NPV but no GHG reducti	$3,643	-$5
		2	27.0%	1.5	16	17	11	27	40	LG-avg-Double	1.8	Combo	0%	ComboHeatA	70%	115	89	64	43	50,569	505	25.7	0.3%	ositive NPV but no GHG reductio	$3,649	$208
		3	27.0%	0.6	16	11	0	27	40	LG-avg-Double	1.8	Combo	30%	ComboHeatA	60%	103	77	53	34	50,481	431	22.0	0.3%	ositive NPV but no GHG reductio	$3,647	$217
		4	27.0%	0.6	16	11	20	27	40	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	70%	79	53	30	29	50,256	290	15.0	1.3%	ositive NPV but no GHG reductio	$3,685	$193
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	176	150	126	68	257,707	119	8.7	0.0%	n/a	$3,638	-
		1	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	176	150	126	68	257,707	119	8.7	0.1%	egative NPV but no GHG reducti	$3,643	-$5
		2	27.0%	1.5	22	25	0	27	50	MG-HP-Double	1.4	Combo	0%	ComboHeatA	60%	123	97	72	44	50,578	554	28.1	0.5%	ositive NPV but no GHG reductio	$3,655	$266
		3	27.0%	0.6	24	11	0	27	50	LG-avg-Double	1.8	Combo	0%	ComboHeatA	75%	111	85	60	34	50,508	478	24.4	0.5%	ositive NPV but no GHG reductio	$3,657	$271
		4	27.0%	0.6	40	17	11	27	60	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	84%	81	55	31	27	50,255	300	15.5	2.0%	ositive NPV but no GHG reductio	$3,712	$234
		5	17.1%	0.5	60	40	30	60	100	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	43	13	15	17	70,918	0	1.0	7.7%	-$243	$4,057	$26
	8	BCBC	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	200	174	150	73	297,846	121	9.2	0.0%	n/a	$3,638	-
		1	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	200	174	150	73	297,846	121	9.2	0.1%	egative NPV but no GHG reducti	$3,643	-$5
		2	27.0%	1.5	30	11	0	27	40	HG-avg-Triple	1.2	Combo	30%	ComboHeatA	60%	124	98	72	43	50,554	555	28.2	1.2%	ositive NPV but no GHG reductio	$3,683	$301
		3	27.0%	0.6	22	11	11	27	80	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	60%	101	75	50	30	50,396	419	21.4	1.1%	ositive NPV but no GHG reductio	$3,679	$318
		4	27.0%	0.6	50	11	15	40	80	HG-i89-Triple-B	0.8	Combo	0%	ComboHeatA	84%	80	55	31	25	50,225	299	15.4	3.9%	ositive NPV but no GHG reductio	$3,780	$229
		5	17.1%	0.5	80	40	30	80	150	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	43	15	15	15	70,679	0	1.0	8.7%	-$468	$4,111	$53

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
6 unit Row House	4	BCBC	22.2%	3.5	16	NA	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	63	30	26	44,913	219	11.4	0.0%	n/a	$1,749	-
		1	22.2%	3.5	16	NA	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	63	30	26	44,913	219	11.4	0.2%	egative NPV but no GHG reducti	$1,752	-$3
		2	22.2%	2.5	16	NA	0	27	50	LG-avg-Double	1.8	GasInst_Low	0%	basefurnace	0%	95	58	26	24	44,833	203	10.6	0.4%	$306	$1,757	-$5
		3	22.2%	1.0	16	NA	11	27	40	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	60%	82	44	14	20	44,605	154	8.2	1.6%	$268	$1,778	-$17
		4	22.2%	0.6	16	NA	11	27	40	MG-HP-Double	1.4	HPHotWater	0%	basefurnace	0%	72	34	20	19	54,281	82	4.6	2.0%	$271	$1,784	-$36
		5	22.2%	0.6	16	NA	11	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	62	23	10	17	54,091	42	2.7	3.4%	$313	$1,808	-$54
	5	BCBC	22.2%	3.5	18	NA	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	111	75	42	34	45,131	264	13.7	0.0%	n/a	$1,877	-
		1	22.2%	3.5	18	NA	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	111	75	42	34	45,131	264	13.7	0.2%	egative NPV but no GHG reducti	$1,880	-$3
		2	22.2%	0.6	18	NA	0	27	60	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	94	57	29	25	44,888	200	10.5	0.9%	$107	$1,894	-$7
		3	22.2%	0.6	18	NA	0	27	60	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	94	57	29	25	44,888	200	10.5	0.9%	$107	$1,894	-$7
		4	22.2%	0.6	22	NA	0	27	70	MG-HP-Double	1.4	GasInstantaneous	0%	basefurnace	70%	82	44	17	22	44,654	152	8.1	2.6%	$273	$1,925	-$30
		5	22.2%	0.6	24	NA	11	35	70	HG-avg-Triple	1.2	HPHotWater	42%	basefurnace	60%	64	25	12	18	53,975	49	3.0	4.4%	$356	$1,960	-$75
	6	BCBC	22.2%	3.5	18	NA	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	90	53	45	45,351	317	16.3	0.0%	n/a	$1,970	-
		1	22.2%	3.5	18	NA	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	90	53	45	45,351	317	16.3	0.2%	egative NPV but no GHG reducti	$1,973	-$3
		2	22.2%	1.5	16	NA	0	27	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	120	84	51	38	45,311	296	15.2	-0.1%	-$274	$1,967	$6
		3	22.2%	1.5	16	NA	0	27	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	120	84	51	38	45,311	296	15.2	-0.1%	-$274	$1,967	$6
		4	22.2%	0.6	22	NA	0	27	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	0%	88	51	22	27	44,751	177	9.3	2.1%	$120	$2,010	-$17
		5	22.2%	0.6	50	NA	11	40	100	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	64	25	11	20	54,539	48	3.0	5.3%	$319	$2,074	-$85
	7a	BCBC	22.2%	3.5	18	NA	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	122	79	56	45,848	431	22.0	0.0%	n/a	$2,627	-
		1	22.2%	3.5	18	NA	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	122	79	56	45,848	431	22.0	0.2%	egative NPV but no GHG reducti	$2,632	-$5
		2	22.2%	1.5	16	NA	11	27	50	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	70%	135	100	63	44	45,544	353	18.1	0.4%	-$43	$2,637	$3
		3	22.2%	0.6	18	NA	0	27	60	MG-HP-Double	1.4	GasInstantaneous	30%	basefurnace	0%	120	84	50	37	45,291	297	15.3	1.1%	$42	$2,655	-$6
		4	22.2%	0.6	22	NA	0	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	90	53	35	32	55,839	145	7.8	2.3%	$150	$2,688	-$42
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	143	98	59	46,207	506	25.7	0.0%	n/a	$2,627	-
		1	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	143	98	59	46,207	506	25.7	0.2%	egative NPV but no GHG reducti	$2,632	-$5
		2	22.2%	1.5	22	NA	20	27	100	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	60%	122	87	48	38	45,256	306	15.7	2.1%	$100	$2,681	-$20
		3	22.2%	0.6	16	NA	11	27	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	70%	120	84	50	37	45,289	297	15.3	1.5%	$13	$2,666	-$3
		4	22.2%	0.6	50	NA	11	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	75%	92	55	37	29	56,081	151	8.1	3.6%	$185	$2,723	-$65
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	164	117	63	46,566	582	29.5	0.0%	n/a	$2,627	-
		1	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	164	117	63	46,566	582	29.5	0.2%	egative NPV but no GHG reducti	$2,632	-$5
		2	22.2%	1.5	24	NA	0	27	70	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	0%	132	97	77	42	55,986	305	15.8	2.0%	$116	$2,679	-$31
		3	22.2%	0.6	22	NA	11	27	70	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	121	85	50	34	45,285	299	15.4	2.1%	$19	$2,681	-$5
		4	22.2%	0.6	60	NA	15	40	100	HG-avg-Triple	1.2	HPHotWater	30%	gas-furnace-ecm	75%	92	55	38	27	55,569	153	8.2	5.7%	$246	$2,777	-$104
		5	10.0%*	0.5	80	NA	40	50	120	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	68	15	13	17	68,291	0	1.0	13.0%	$237	$3,140	-$135

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Quadplex	4	BCBC	17.3%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	126	70	35	32	46,726	64	3.7	0.0%	n/a	$1,857	-
		1	17.3%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	126	70	35	32	46,726	64	3.7	0.2%	egative NPV but no GHG reducti	$1,861	-$4
		2	17.3%	1.5	16	20	0	27	50	LG-avg-Double	1.8	Combo	0%	ComboHeatA	60%	111	55	23	26	29,354	100	5.3	1.6%	ositive NPV but no GHG reductio	$1,887	$47
		3	17.3%	1.5	16	25	0	27	50	MG-i89-Double	1.6	HPHotWater	0%	gas-furnace-ecm	60%	99	43	26	25	35,528	55	3.1	2.1%	-$892	$1,896	$21
		4	17.3%	1.5	30	17	0	27	70	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	0%	89	34	18	22	35,511	38	2.3	3.9%	$128	$1,929	-$7
		5	17.3%	0.6	40	11	0	27	70	HG-avg-Triple	1.2	HPHotWater	30%	gas-furnace-ecm	75%	80	25	10	18	35,380	21	1.4	6.1%	$472	$1,970	-$42
	5	BCBC	17.3%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	140	84	49	42	53,935	64	3.8	0.0%	n/a	$1,992	-
		1	17.3%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	140	84	49	42	53,935	64	3.8	0.2%	egative NPV but no GHG reducti	$1,997	-$5
		2	17.3%	2.5	16	25	20	27	50	LG-avg-Double	1.8	BaseDHW	0%	gas-furnace-ecm	0%	141	85	44	39	29,120	156	8.1	0.8%	ositive NPV but no GHG reductio	$2,007	$82
		3	17.3%	1.5	18	20	0	29	60	LG-avg-Double	1.8	BaseDHW	0%	gas-furnace-ecm	60%	129	74	34	33	29,097	134	7.0	1.0%	ositive NPV but no GHG reductio	$2,013	$83
		4	17.3%	0.6	16	25	0	27	70	HG-avg-Triple	1.2	HPHotWater	30%	gas-furnace-ecm	60%	98	42	26	28	35,413	54	3.1	3.5%	-$980	$2,061	$28
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	BCBC	17.3%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	157	102	65	55	62,125	67	4.0	0.0%	n/a	$2,091	-
		1	17.3%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	157	102	65	55	62,125	67	4.0	0.3%	egative NPV but no GHG reducti	$2,096	-$5
		2	17.3%	1.5	18	20	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	gas-furnace-ecm	0%	155	99	55	45	29,145	181	9.3	0.3%	ositive NPV but no GHG reductio	$2,098	$124
		3	17.3%	1.5	16	11	11	27	50	MG-i89-Double	1.6	GasInstantaneous	30%	gas-furnace-ecm	60%	140	85	48	44	29,128	155	8.0	1.4%	ositive NPV but no GHG reductio	$2,119	$111
		4	17.3%	0.6	24	17	11	29	40	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	60%	106	50	32	33	35,823	67	3.7	3.5%	-$5,321	$2,164	$59
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7a	BCBC	17.3%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	194	139	99	71	79,786	72	4.5	0.0%	n/a	$2,789	-
		1	17.3%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	194	139	99	71	79,786	72	4.5	0.3%	egative NPV but no GHG reducti	$2,797	-$8
		2	17.3%	1.5	18	25	0	27	70	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	0%	155	99	61	51	29,639	180	9.3	2.3%	ositive NPV but no GHG reductio	$2,852	$157
		3	17.3%	1.5	22	11	0	27	70	HG-avg-Triple	1.2	HPHotWater	55%	gas-furnace-ecm	60%	139	83	61	48	36,184	127	6.7	2.6%	ositive NPV but no GHG reductio	$2,862	$131
		4	17.3%	0.6	60	11	15	35	80	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	84%	110	55	35	33	36,404	72	4.0	6.8%	-$1,591	$2,979	$29
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	214	158	118	73	89,399	74	4.6	0.0%	n/a	$2,789	-
		1	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	214	158	118	73	89,399	74	4.6	0.3%	egative NPV but no GHG reducti	$2,797	-$8
		2	17.3%	1.5	22	17	11	27	100	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	60%	151	95	80	50	77,374	0	0.8	2.1%	-$178	$2,846	$26
		3	17.3%	1.5	40	20	11	29	100	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	70%	138	83	68	45	71,059	0	0.8	4.2%	$14	$2,907	-$2
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	238	182	141	78	101,315	75	4.8	0.0%	n/a	$2,789	-
		1	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	238	182	141	78	101,315	75	4.8	0.3%	egative NPV but no GHG reducti	$2,797	-$8
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Large SFD	4	BCBC	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.0%	n/a	$1,938	-
		1	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.2%	egative NPV but no GHG reducti	$1,941	-$3
		2	14.6%	1.5	16	11	0	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	basefurnace	0%	66	52	39	23	7,826	94	4.8	0.7%	$86	$1,951	-$5
		3	14.6%	1.5	18	17	0	NA	60	MG-i89-Double	1.6	GasInstantaneous	0%	gas-furnace-ecm	60%	58	44	32	20	7,521	79	4.0	1.6%	$193	$1,968	-$16
		4	14.6%	0.6	18	11	0	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	49	35	27	19	9,503	56	2.9	2.0%	$206	$1,977	-$26
		5	14.6%	0.6	40	25	0	NA	70	HG-avg-Triple	1.2	GasInstantaneous	42%	basefurnace	60%	38	24	14	14	7,590	43	2.2	4.8%	$435	$2,031	-$67
	5	BCBC	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.0%	n/a	$2,079	-
		1	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.2%	egative NPV but no GHG reducti	$2,082	-$3
		2	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	60%	88	74	55	32	7,982	133	6.7	-0.1%	-$563	$2,076	$4
		3	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	60%	88	74	55	32	7,982	133	6.7	-0.1%	-$563	$2,076	$4
		4	14.6%	1.0	16	17	0	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	84%	59	45	33	25	7,523	81	4.1	1.8%	$163	$2,115	-$18
		5	14.6%	0.6	60	25	0	NA	100	HG-i89-Triple-B	0.8	Combo	55%	ComboHeatA	75%	36	23	14	15	7,671	40	2.1	7.8%	$690	$2,241	-$131
	6	BCBC	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	105	91	69	44	8,122	165	8.3	0.0%	n/a	$2,182	-
		1	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	106	91	69	44	8,122	165	8.3	0.2%	egative NPV but no GHG reducti	$2,185	-$4
		2	14.6%	1.5	16	11	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	60%	104	90	68	39	8,114	162	8.2	-0.4%	-$1,582	$2,174	$9
		3	14.6%	1.5	16	11	0	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	basefurnace	0%	96	82	64	39	8,077	148	7.5	-0.1%	-$248	$2,179	$8
		4	14.6%	1.0	22	11	0	NA	50	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	70%	69	55	40	30	7,840	98	5.0	1.3%	$46	$2,210	-$6
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7a	BCBC	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.0%	n/a	$2,910	-
		1	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.2%	egative NPV but no GHG reducti	$2,916	-$6
		2	14.6%	1.5	16	11	0	NA	100	HG-avg-Triple	1.2	BaseDHW	0%	basefurnace	0%	111	96	72	44	8,157	174	8.8	0.6%	$12	$2,928	-$1
		3	14.6%	1.5	22	11	0	NA	40	HG-avg-Triple	1.2	GasInst_Low	55%	gas-furnace-ecm	60%	94	80	63	40	7,608	146	7.4	1.3%	$80	$2,949	-$12
		4	14.6%	0.6	40	17	11	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	75%	67	53	39	27	7,550	96	4.9	3.5%	$238	$3,012	-$59
		5	14.0%	0.6	80	60	25	NA	100	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	32	13	12	13	13,824	9	0.6	15.4%	$2,511	$3,346	-$407
	7b	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.2%	egative NPV but no GHG reducti	$2,916	-$6
		2	14.6%	1.5	22	17	15	NA	50	HG-avg-Triple	1.2	GasInst_Low	0%	gas-furnace-ecm	0%	114	100	80	43	7,681	182	9.2	1.3%	$94	$2,948	-$13
		3	14.6%	1.5	40	17	0	NA	40	HG-avg-Triple	1.2	HPHotWater	55%	gas-furnace-ecm	60%	95	81	69	38	9,483	141	7.1	2.6%	$210	$2,985	-$45
		4	14.6%	0.6	60	25	0	NA	100	HG-i89-Triple-B	0.8	HPHotWater	30%	gas-furnace-ecm	84%	67	53	44	26	9,541	89	4.6	6.6%	$467	$3,104	-$147
		5	9.3%	1.0	80	80	40	NA	150	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	34	16	15	12	13,698	13	0.8	17.4%	$2,819	$3,405	-$457
	8	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.2%	egative NPV but no GHG reducti	$2,916	-$6
		2	14.6%	1.5	50	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	70%	112	98	76	38	8,211	176	8.9	3.0%	$222	$2,996	-$48
		3	14.6%	1.5	40	17	0	NA	50	HG-avg-Triple	1.2	ElectricStorage	42%	CCASHP-ecm	60%	93	79	76	39	47,283	0	0.5	3.0%	$355	$2,998	-$194
		4	14.0%	1.0	50	35	25	NA	100	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	45	27	27	16	15,111	29	1.7	10.3%	$1,810	$3,203	-$252
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Medium SFD	4	BCBC	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.0%	n/a	$2,045	-
		1	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.2%	egative NPV but no GHG reducti	$2,050	-$5
		2	14.7%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	90	60	37	27	7,512	50	2.6	0.6%	$198	$2,057	-$6
		3	14.7%	2.5	16	17	0	NA	60	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	0%	74	44	23	24	7,450	37	1.9	1.9%	$271	$2,083	-$23
		4	14.7%	0.6	18	11	15	NA	70	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	64	34	14	18	7,409	28	1.5	3.2%	$365	$2,111	-$45
		5	14.7%	0.6	22	25	0	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	84%	55	25	14	17	9,142	14	0.8	4.1%	$391	$2,130	-$71
	5	BCBC	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.0%	n/a	$2,194	-
		1	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.2%	egative NPV but no GHG reducti	$2,200	-$5
		2	14.7%	2.5	16	11	0	NA	60	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	60%	98	68	44	32	7,544	56	2.9	0.6%	$200	$2,209	-$8
		3	14.7%	2.5	16	11	0	NA	60	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	60%	98	68	44	32	7,544	56	2.9	0.6%	$200	$2,209	-$8
		4	14.7%	0.6	18	11	0	NA	40	HG-avg-Triple	1.2	GasInstantaneous	30%	basefurnace	60%	75	45	25	25	7,457	37	1.9	2.7%	$319	$2,253	-$39
		5	14.7%	0.6	40	25	0	NA	100	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	55	25	14	18	9,196	14	0.8	4.9%	$403	$2,301	-$87
	6	BCBC	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.0%	n/a	$2,303	-
		1	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.2%	egative NPV but no GHG reducti	$2,308	-$6
		2	14.7%	2.5	16	11	0	NA	40	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	46	7,618	80	4.1	0.1%	egative NPV but no GHG reducti	$2,306	-$3
		3	14.7%	1.5	18	17	0	NA	50	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	114	84	58	40	7,606	70	3.6	0.4%	$100	$2,313	-$4
		4	14.7%	0.6	16	25	0	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	70%	84	54	33	31	7,376	46	2.4	2.5%	$223	$2,360	-$32
		5	14.7%	0.6	60	25	15	NA	100	HG-i89-Triple-B	0.8	HPHotWater	42%	gas-furnace-ecm	84%	54	24	14	21	9,069	14	0.8	9.3%	$667	$2,517	-$184
	7a	BCBC	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	126	86	59	7,738	106	5.4	0.0%	n/a	$3,072	-
		1	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	126	86	59	7,738	106	5.4	0.3%	egative NPV but no GHG reducti	$3,081	-$9
		2	14.7%	1.5	18	11	0	NA	70	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	130	100	68	44	7,654	83	4.2	0.7%	$76	$3,095	-$7
		3	14.7%	1.5	16	20	0	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	60%	111	81	55	42	7,410	68	3.5	2.0%	$213	$3,134	-$34
		4	14.7%	0.6	40	20	20	NA	60	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	70%	85	55	30	29	7,488	46	2.4	4.3%	$347	$3,203	-$88
		5	8.0%	1.0	50	40	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	50%	CCASHP-ecm	75%	56	20	13	19	11,815	5	0.4	12.1%	$830	$3,421	-$347
	7b	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.3%	egative NPV but no GHG reducti	$3,081	-$9
		2	14.7%	1.5	22	25	11	NA	50	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	70%	126	96	63	41	7,640	80	4.1	1.8%	$153	$3,128	-$27
		3	14.7%	1.5	40	11	11	NA	40	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	70%	114	84	58	39	7,829	69	3.5	3.4%	$314	$3,177	-$70
		4	14.7%	0.6	60	25	11	NA	80	HG-i89-Triple-B	0.8	HPHotWater	0%	basefurnace	70%	84	54	39	29	9,647	37	2.0	7.2%	$518	$3,293	-$183
		5	8.0%	0.6	100	80	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	50%	CCASHP-ecm	84%	58	22	14	15	11,829	7	0.5	20.5%	$1,239	$3,678	-$593
	8	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	166	120	66	7,901	139	7.0	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	166	120	66	7,901	139	7.0	0.3%	egative NPV but no GHG reducti	$3,081	-$9
		2	14.7%	1.5	40	25	11	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	120	90	60	38	7,632	75	3.8	3.4%	$216	$3,175	-$58
		3	14.7%	1.5	60	25	11	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	114	84	55	36	7,608	70	3.6	5.1%	$372	$3,228	-$108
		4	14.7%	0.6	60	25	11	NA	70	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	70%	84	54	47	31	19,962	0	0.2	9.5%	$577	$3,365	-$330
		5	8.0%	0.6	100	80	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	50%	CCASHP-ecm	84%	59	23	15	14	11,563	9	0.6	20.5%	$1,070	$3,678	-$580

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Small SFD	4	BCBC	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.0%	n/a	$2,314	-
		1	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.4%	egative NPV but no GHG reducti	$2,324	-$10
		2	12.2%	2.5	18	11	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	124	54	29	43	9,120	13	0.7	3.3%	$334	$2,391	-$77
		3	12.2%	2.5	30	11	11	NA	100	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	60%	111	41	22	40	11,306	0	0.1	4.7%	$416	$2,424	-$145
		4	12.2%	0.6	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	basefurnace	70%	104	34	12	33	9,086	5	0.4	8.4%	$610	$2,510	-$184
		5	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	gas-furnace-ecm	75%	118	25	6	22	11,437	2	0.3	13.5%	$1,091	$2,597	-$355
	5	BCBC	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.0%	n/a	$2,483	-
		1	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.4%	egative NPV but no GHG reducti	$2,494	-$11
		2	12.2%	1.5	18	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	0%	158	88	41	59	7,380	31	1.6	1.9%	$280	$2,530	-$29
		3	12.2%	1.5	18	11	11	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	141	71	44	55	9,148	19	1.0	2.8%	$324	$2,554	-$73
		4	12.2%	0.6	40	17	11	NA	80	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	84%	115	45	22	41	9,068	10	0.6	8.4%	$617	$2,693	-$195
		5	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	75%	120	22	11	27	12,259	0	0.2	16.2%	$1,141	$2,855	-$454
	6	BCBC	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.0%	n/a	$2,606	-
		1	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.5%	egative NPV but no GHG reducti	$2,618	-$12
		2	12.2%	2.5	24	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	60%	168	99	49	69	7,315	36	1.8	3.2%	$365	$2,690	-$57
		3	12.2%	1.5	40	11	11	NA	40	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	60%	152	82	37	61	7,585	29	1.5	5.7%	$508	$2,753	-$114
		4	12.2%	0.6	40	11	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	gas-furnace-ecm	84%	123	53	28	50	9,160	12	0.7	9.7%	$598	$2,857	-$228
		5	6.9%	1.0	50	40	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	75%	122	27***	11	30	12,299	1	0.2	18.1%	$1,053	$3,044	-$509
	7a	BCBC	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	256	187	104	105	7,507	67	3.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	257	187	104	105	7,507	67	3.4	0.6%	egative NPV but no GHG reducti	$3,495	-$19
		2	12.2%	1.5	40	17	30	NA	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	168	99	64	69	9,458	28	1.5	6.9%	$582	$3,715	-$222
		3	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	166	71	36	49	9,668	26	1.4	12.5%	$1,062	$3,887	-$419
		4	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	75%	139	46	34	46	12,864	5	0.4	16.2%	$1,005	$4,008	-$597
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.6%	egative NPV but no GHG reducti	$3,495	-$19
		2	6.9%	3.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	190	94	58	56	9,748	35	1.9	11.7%	$962	$3,865	-$392
		3	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	174	77	42	45	9,792	29	1.6	12.5%	$876	$3,887	-$410
		4	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	gas-furnace-ecm	75%	133	39	20	28	12,558	4	0.4	33.2%	$1,655	$4,599	-$1,162
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.6%	egative NPV but no GHG reducti	$3,495	-$19
		2	6.9%	2.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	189	96	59	53	9,371	36	1.9	12.1%	$789	$3,879	-$384
		3	6.9%	2.5	100	100	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	84%	151	60	42	40	12,538	10	0.7	32.7%	$1,564	$4,588	-$1,137
		4	6.9%	0.6	100	100	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	84%	149	45	25	29	12,522	10	0.7	33.1%	$1,574	$4,595	-$1,152
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*These CCASHPs have a -4F cutoff.

**Insulation added under footings and at slab edge in addition to underslab.

***Misses the MEUI requirement by <2kWh/m2.

7.8 Part 9 – Lowest Carbon Abatement Costs – Original Targets

Note: Negative carbon abatement costs occur when a building has lower GHG emissions and a positive NPV, meaning investing in GHG reductions is profitable.

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
10 unit MURB	4	BCBC	27.0%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	86	60	39	26	113,670	104	6.4	0.0%	n/a	$2,422	-
		1	27.0%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	86	60	39	26	113,670	104	6.4	0.1%	egative NPV but no GHG reducti	$2,424	-$3
		2	27.0%	2.5	16	17	11	29	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	70%	71	46	24	22	89,483	104	6.1	0.7%	-$6,730	$2,439	$21
		3	27.0%	0.6	24	17	11	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	60%	61	35	14	15	72,536	104	6.0	0.7%	-$8,979	$2,439	$48
		4	27.0%	1.5	40	25	11	29	70	HG-avg-Triple	1.2	Combo	55%	ComboHeatA	84%	49	24	4	14	49,991	114	6.2	3.3%	-$9,170	$2,502	$19
		5	27.0%	0.6	18	17	0	40	50	HG-avg-Triple	1.2	Combo	55%	ComboHeatA	70%	50	24	5	12	49,999	117	6.4	2.6%	-$324,591	$2,486	$34
	5	BCBC	27.0%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	100	74	52	35	136,114	104	6.6	0.0%	n/a	$2,599	-
		1	27.0%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	100	74	52	35	136,114	104	6.6	0.1%	egative NPV but no GHG reducti	$2,602	-$3
		2	27.0%	0.6	16	17	0	27	60	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	60%	72	46	24	20	89,635	104	6.1	0.3%	-$10,826	$2,607	$65
		3	27.0%	0.6	16	17	0	27	60	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	60%	72	46	24	20	89,635	104	6.1	0.3%	-$10,826	$2,607	$65
		4	27.0%	0.6	18	11	11	27	40	MG-i89-Double	1.6	GasInst_Low	0%	elec-baseboard	60%	68	42	20	20	82,896	105	6.1	0.8%	-$10,242	$2,620	$63
		5	27.0%	0.6	22	20	0	40	100	HG-i89-Triple-B	0.8	Combo	30%	ComboHeatA	84%	51	25	5	14	50,004	122	6.6	4.2%	-$134,319	$2,708	$24
	6	BCBC	27.0%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	118	92	70	49	164,518	108	7.2	0.0%	n/a	$2,727	-
		1	27.0%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	118	92	70	49	164,518	108	7.2	0.1%	egative NPV but no GHG reducti	$2,730	-$3
		2	27.0%	2.5	16	20	0	29	100	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	113	87	65	41	156,774	108	7.1	0.2%	-$6,415	$2,733	$6
		3	27.0%	0.6	18	20	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	94	69	46	28	126,076	108	6.7	0.0%	-$12,108	$2,727	$60
		4	27.0%	0.6	60	25	0	40	60	HG-i89-Triple-B	0.8	Combo	30%	ComboHeatA	84%	52	27	6	17	50,010	132	7.1	4.5%	-$100,796	$2,849	$55
		5	27.0%	0.6	50	11	0	27	60	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	84%	51	25	14	19	84,031	0	0.9	2.5%	-$916	$2,795	$69
	7a	BCBC	27.0%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	149	123	100	63	214,243	117	8.1	0.0%	n/a	$3,638	-
		1	27.0%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	149	123	100	63	214,243	117	8.1	0.1%	egative NPV but no GHG reducti	$3,643	-$5
		2	27.0%	2.5	22	11	15	27	80	LG-avg-Double	1.8	BaseDHW	55%	elec-baseboard	60%	124	99	75	51	174,205	115	7.6	0.2%	-$8,128	$3,646	$55
		3	27.0%	0.6	16	25	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	70%	99	73	50	33	131,512	117	7.3	0.1%	-$11,774	$3,642	$126
		4	27.0%	0.6	22	20	11	27	40	HG-avg-Triple	1.2	GasInst_Low	0%	elec-baseboard	60%	78	52	28	28	95,950	119	7.0	1.1%	-$10,486	$3,676	$147
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	176	150	126	68	257,707	119	8.7	0.0%	n/a	$3,638	-
		1	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	176	150	126	68	257,707	119	8.7	0.1%	egative NPV but no GHG reducti	$3,643	-$5
		2	27.0%	1.5	30	17	20	27	100	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	60%	120	94	70	42	165,722	119	7.7	0.4%	-$10,814	$3,654	$128
		3	27.0%	0.6	24	17	11	27	50	LG-avg-Double	1.8	GasInst_Low	0%	elec-baseboard	70%	110	85	60	33	148,913	122	7.7	0.3%	-$12,527	$3,649	$159
		4	27.0%	0.6	50	11	11	27	60	HG-avg-Triple	1.2	BaseDHW	0%	elec-baseboard	84%	80	55	30	26	100,062	119	7.0	1.6%	-$9,229	$3,697	$188
		5	17.1%	0.5	60	40	30	60	100	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	43	13	15	17	70,918	0	1.0	7.7%	-$243	$4,057	$26
	8	BCBC	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	200	174	150	73	297,846	121	9.2	0.0%	n/a	$3,638	-
		1	27.0%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	200	174	150	73	297,846	121	9.2	0.1%	egative NPV but no GHG reducti	$3,643	-$5
		2	27.0%	1.5	30	25	11	27	50	HG-avg-Triple	1.2	BaseDHW	0%	elec-baseboard	60%	121	96	71	43	167,184	121	7.8	0.8%	-$10,472	$3,666	$176
		3	27.0%	0.6	40	17	0	27	40	MG-HP-Double	1.4	GasInst_Low	0%	elec-baseboard	60%	111	85	60	33	148,945	124	7.8	0.9%	-$11,374	$3,669	$202
		4	27.0%	0.6	60	25	11	35	100	HG-i89-Triple-B	0.8	BaseDHW	30%	elec-baseboard	84%	81	55	31	25	100,237	120	7.0	3.8%	-$6,458	$3,777	$171
		5	17.1%	0.5	80	40	30	80	150	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	43	15	15	15	70,679	0	1.0	8.7%	-$468	$4,111	$53

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
6 unit Row House	4	BCBC	22.2%	3.5	16	NA	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	63	30	26	44,913	219	11.4	0.0%	n/a	$1,749	-
		1	22.2%	3.5	16	NA	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	63	30	26	44,913	219	11.4	0.2%	egative NPV but no GHG reducti	$1,752	-$3
		2	22.2%	1.5	16	NA	11	27	60	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	70%	83	45	18	21	44,683	158	8.4	1.5%	$250	$1,775	-$15
		3	22.2%	1.0	18	NA	0	27	50	LG-avg-Double	1.8	HPHotWater	0%	basefurnace	0%	80	42	27	20	54,416	110	6.1	1.1%	$240	$1,768	-$26
		4	22.2%	0.6	16	NA	11	27	40	MG-HP-Double	1.4	HPHotWater	0%	basefurnace	0%	72	34	20	19	54,281	82	4.6	2.0%	$271	$1,784	-$36
		5	22.2%	0.6	16	NA	11	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	62	23	10	17	54,091	42	2.7	3.4%	$313	$1,808	-$54
	5	BCBC	22.2%	3.5	18	NA	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	111	75	42	34	45,131	264	13.7	0.0%	n/a	$1,877	-
		1	22.2%	3.5	18	NA	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	111	75	42	34	45,131	264	13.7	0.2%	egative NPV but no GHG reducti	$1,880	-$3
		2	22.2%	0.6	18	NA	0	27	60	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	94	57	29	25	44,888	200	10.5	0.9%	$107	$1,894	-$7
		3	22.2%	0.6	18	NA	0	27	60	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	94	57	29	25	44,888	200	10.5	0.9%	$107	$1,894	-$7
		4	22.2%	1.0	18	NA	0	27	40	MG-i89-Double	1.6	HPHotWater	0%	basefurnace	60%	82	44	29	25	54,455	118	6.5	1.7%	$247	$1,908	-$35
		5	22.2%	0.6	24	NA	11	35	70	HG-avg-Triple	1.2	HPHotWater	42%	basefurnace	60%	64	25	12	18	53,975	49	3.0	4.4%	$356	$1,960	-$75
	6	BCBC	22.2%	3.5	18	NA	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	90	53	45	45,351	317	16.3	0.0%	n/a	$1,970	-
		1	22.2%	3.5	18	NA	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	90	53	45	45,351	317	16.3	0.2%	egative NPV but no GHG reducti	$1,973	-$3
		2	22.2%	1.5	16	NA	0	27	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	120	84	51	38	45,311	296	15.2	-0.1%	-$274	$1,967	$6
		3	22.2%	1.5	16	NA	0	27	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	120	84	51	38	45,311	296	15.2	-0.1%	-$274	$1,967	$6
		4	22.2%	0.6	22	NA	0	27	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	0%	88	51	22	27	44,751	177	9.3	2.1%	$120	$2,010	-$17
		5	22.2%	0.6	50	NA	11	40	100	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	64	25	11	20	54,539	48	3.0	5.3%	$319	$2,074	-$85
	7a	BCBC	22.2%	3.5	18	NA	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	122	79	56	45,848	431	22.0	0.0%	n/a	$2,627	-
		1	22.2%	3.5	18	NA	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	122	79	56	45,848	431	22.0	0.2%	egative NPV but no GHG reducti	$2,632	-$5
		2	22.2%	1.5	16	NA	11	27	50	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	70%	135	100	63	44	45,544	353	18.1	0.4%	-$43	$2,637	$3
		3	22.2%	0.6	18	NA	0	27	60	MG-HP-Double	1.4	GasInstantaneous	30%	basefurnace	0%	120	84	50	37	45,291	297	15.3	1.1%	$42	$2,655	-$6
		4	22.2%	0.6	22	NA	0	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	90	53	35	32	55,839	145	7.8	2.3%	$150	$2,688	-$42
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	143	98	59	46,207	506	25.7	0.0%	n/a	$2,627	-
		1	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	143	98	59	46,207	506	25.7	0.2%	egative NPV but no GHG reducti	$2,632	-$5
		2	22.2%	1.5	22	NA	20	27	100	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	60%	122	87	48	38	45,256	306	15.7	2.1%	$100	$2,681	-$20
		3	22.2%	0.6	16	NA	11	27	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	70%	120	84	50	37	45,289	297	15.3	1.5%	$13	$2,666	-$3
		4	22.2%	0.6	50	NA	11	27	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	75%	92	55	37	29	56,081	151	8.1	3.6%	$185	$2,723	-$65
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	164	117	63	46,566	582	29.5	0.0%	n/a	$2,627	-
		1	22.2%	3.5	22	NA	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	164	117	63	46,566	582	29.5	0.2%	egative NPV but no GHG reducti	$2,632	-$5
		2	22.2%	1.5	24	NA	0	27	70	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	0%	132	97	77	42	55,986	305	15.8	2.0%	$116	$2,679	-$31
		3	22.2%	0.6	22	NA	11	27	70	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	121	85	50	34	45,285	299	15.4	2.1%	$19	$2,681	-$5
		4	22.2%	0.6	60	NA	15	40	100	HG-avg-Triple	1.2	HPHotWater	30%	gas-furnace-ecm	75%	92	55	38	27	55,569	153	8.2	5.7%	$246	$2,777	-$104
		5	10.0%*	0.5	80	NA	40	50	120	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	68	15	13	17	68,291	0	1.0	13.0%	$237	$3,140	-$135

*Door area also reduced, by 33%.

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Quadplex	4	BCBC	17.3%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	126	70	35	32	46,726	64	3.7	0.0%	n/a	$1,857	-
		1	17.3%	3.5	16	11	0	27	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	126	70	35	32	46,726	64	3.7	0.2%	egative NPV but no GHG reducti	$1,861	-$4
		2	17.3%	2.5	24	17	11	29	50	LG-avg-Double	1.8	HPHotWater	0%	gas-furnace-ecm	0%	105	49	32	27	35,540	66	3.7	2.3%	-$8,573	$1,900	$13
		3	17.3%	1.5	16	25	0	27	50	MG-i89-Double	1.6	HPHotWater	0%	gas-furnace-ecm	60%	99	43	26	25	35,528	55	3.1	2.1%	-$892	$1,896	$21
		4	17.3%	1.5	30	17	0	27	70	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	0%	89	34	18	22	35,511	38	2.3	3.9%	$128	$1,929	-$7
		5	17.3%	0.6	40	25	11	40	100	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	60%	79	24	9	17	35,494	19	1.3	6.2%	$465	$1,971	-$43
	5	BCBC	17.3%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	140	84	49	42	53,935	64	3.8	0.0%	n/a	$1,992	-
		1	17.3%	3.5	18	17	0	27	50	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	140	84	49	42	53,935	64	3.8	0.2%	egative NPV but no GHG reducti	$1,997	-$5
		2	17.3%	2.5	16	11	0	35	100	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	60%	132	76	40	38	49,688	64	3.7	0.7%	-$4,548	$2,006	$8
		3	17.3%	1.5	22	20	0	35	60	MG-i89-Double	1.6	HPHotWater	42%	gas-furnace-ecm	60%	106	50	33	31	35,391	68	3.8	2.7%	-$7,579,449	$2,046	$39
		4	17.3%	0.6	24	11	20	35	50	MG-i89-Double	1.6	HPHotWater	55%	gas-furnace-ecm	60%	100	45	28	27	35,330	58	3.3	3.6%	-$1,192	$2,065	$24
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	BCBC	17.3%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	157	102	65	55	62,125	67	4.0	0.0%	n/a	$2,091	-
		1	17.3%	3.5	18	17	0	27	50	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	157	102	65	55	62,125	67	4.0	0.3%	egative NPV but no GHG reducti	$2,096	-$5
		2	17.3%	1.5	30	17	11	29	60	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	0%	141	86	48	42	53,821	67	3.9	1.5%	-$3,301	$2,121	$11
		3	17.3%	1.5	22	17	0	40	40	LG-avg-Double	1.8	BaseDHW	0%	elec-baseboard	60%	139	84	47	42	52,905	67	3.9	0.9%	-$7,351	$2,109	$28
		4	17.3%	0.6	16	11	15	27	40	HG-i89-Triple-B	0.8	HPHotWater	0%	gas-furnace-ecm	84%	109	54	35	36	35,827	73	4.0	5.1%	-$155,350	$2,197	$25
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7a	BCBC	17.3%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	194	139	99	71	79,786	72	4.5	0.0%	n/a	$2,789	-
		1	17.3%	3.5	18	20	0	29	60	MG-i89-Double	1.6	BaseDHW	0%	elec-baseboard	0%	194	139	99	71	79,786	72	4.5	0.3%	egative NPV but no GHG reducti	$2,797	-$8
		2	17.3%	1.5	16	11	0	40	100	HG-avg-Triple	1.2	GasInstantaneous	0%	elec-baseboard	0%	154	99	64	52	61,883	62	3.8	2.1%	-$1,262	$2,848	$35
		3	17.3%	1.5	40	20	11	29	60	HG-avg-Triple	1.2	BaseDHW	42%	elec-baseboard	70%	139	83	44	44	51,744	70	4.1	4.2%	-$1,580	$2,907	$25
		4	17.3%	0.6	60	11	15	35	80	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	84%	110	55	35	33	36,404	72	4.0	6.8%	-$1,591	$2,979	$29
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	214	158	118	73	89,399	74	4.6	0.0%	n/a	$2,789	-
		1	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	214	158	118	73	89,399	74	4.6	0.3%	egative NPV but no GHG reducti	$2,797	-$8
		2	17.3%	1.5	50	17	0	35	50	HG-avg-Triple	1.2	BaseDHW	0%	CCASHP-ecm	60%	155	100	61	47	59,285	74	4.3	5.4%	-$240	$2,938	$3
		3	17.3%	1.5	40	20	11	29	100	HG-avg-Triple	1.2	HPHotWater	0%	elec-baseboard	70%	138	83	68	45	71,059	0	0.8	4.2%	$14	$2,907	-$2
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	238	182	141	78	101,315	75	4.8	0.0%	n/a	$2,789	-
		1	17.3%	3.5	22	20	0	29	60	MG-HP-Double	1.4	BaseDHW	0%	elec-baseboard	0%	238	182	141	78	101,315	75	4.8	0.3%	egative NPV but no GHG reducti	$2,797	-$8
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Large SFD	4	BCBC	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.0%	n/a	$1,938	-
		1	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.2%	egative NPV but no GHG reducti	$1,941	-$3
		2	14.6%	1.5	16	11	0	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	basefurnace	0%	66	52	39	23	7,826	94	4.8	0.7%	$86	$1,951	-$5
		3	14.6%	1.5	18	17	0	NA	60	MG-i89-Double	1.6	GasInstantaneous	0%	gas-furnace-ecm	60%	58	44	32	20	7,521	79	4.0	1.6%	$193	$1,968	-$16
		4	14.6%	0.6	18	11	0	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	49	35	27	19	9,503	56	2.9	2.0%	$206	$1,977	-$26
		5	14.6%	0.6	40	17	0	NA	70	HG-avg-Triple	1.2	ElectricStorage	42%	gas-furnace-ecm	70%	39	25	15	14	11,232	31	1.7	4.4%	$413	$2,022	-$73
	5	BCBC	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.0%	n/a	$2,079	-
		1	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.2%	egative NPV but no GHG reducti	$2,082	-$3
		2	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	60%	88	74	55	32	7,982	133	6.7	-0.1%	-$563	$2,076	$4
		3	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	60%	88	74	55	32	7,982	133	6.7	-0.1%	-$563	$2,076	$4
		4	14.6%	0.6	22	11	0	NA	40	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	70%	54	40	29	22	7,846	70	3.6	2.0%	$152	$2,120	-$20
		5	14.6%	0.6	60	17	20	NA	70	HG-i89-Triple-B	0.8	ElectricStorage	42%	baseboard	84%	37	23	15	16	18,779	0	0.2	6.9%	$594	$2,223	-$155
	6	BCBC	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	105	91	69	44	8,122	165	8.3	0.0%	n/a	$2,182	-
		1	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	106	91	69	44	8,122	165	8.3	0.2%	egative NPV but no GHG reducti	$2,185	-$4
		2	14.6%	2.5	16	11	0	NA	70	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	70%	106	91	72	41	8,157	165	8.3	-0.2%	-$15,414	$2,177	$4
		3	14.6%	1.5	16	11	0	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	basefurnace	0%	96	82	64	39	8,077	148	7.5	-0.1%	-$248	$2,179	$8
		4	14.6%	1.0	22	11	0	NA	50	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	70%	69	55	40	30	7,840	98	5.0	1.3%	$46	$2,210	-$6
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7a	BCBC	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.0%	n/a	$2,910	-
		1	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.2%	egative NPV but no GHG reducti	$2,916	-$6
		2	14.6%	1.5	16	11	0	NA	100	HG-avg-Triple	1.2	BaseDHW	0%	basefurnace	0%	111	96	72	44	8,157	174	8.8	0.6%	$12	$2,928	-$1
		3	14.6%	1.5	22	11	0	NA	40	HG-avg-Triple	1.2	GasInst_Low	55%	gas-furnace-ecm	60%	94	80	63	40	7,608	146	7.4	1.3%	$80	$2,949	-$12
		4	14.6%	0.6	40	17	0	NA	100	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	84%	67	53	42	28	9,951	88	4.5	3.2%	$228	$3,004	-$60
		5	14.0%	0.6	80	60	25	NA	100	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	32	13	12	13	13,824	9	0.6	15.4%	$2,511	$3,346	-$407
	7b	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.2%	egative NPV but no GHG reducti	$2,916	-$6
		2	14.6%	1.5	22	17	15	NA	50	HG-avg-Triple	1.2	GasInst_Low	0%	gas-furnace-ecm	0%	114	100	80	43	7,681	182	9.2	1.3%	$94	$2,948	-$13
		3	14.6%	1.5	40	17	0	NA	40	HG-avg-Triple	1.2	HPHotWater	55%	gas-furnace-ecm	60%	95	81	69	38	9,483	141	7.1	2.6%	$210	$2,985	-$45
		4	14.6%	0.6	50	11	15	NA	70	HG-avg-Triple	1.2	GasInstantaneous	0%	CCASHP-ecm	75%	69	55	50	29	30,713	16	1.1	4.5%	$375	$3,040	-$169
		5	9.3%	1.0	80	80	40	NA	150	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	34	16	15	12	13,698	13	0.8	17.4%	$2,819	$3,405	-$457
	8	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.2%	egative NPV but no GHG reducti	$2,916	-$6
		2	14.6%	1.5	50	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	70%	112	98	76	38	8,211	176	8.9	3.0%	$222	$2,996	-$48
		3	14.6%	1.5	40	17	0	NA	50	HG-avg-Triple	1.2	ElectricStorage	42%	CCASHP-ecm	60%	93	79	76	39	47,283	0	0.5	3.0%	$355	$2,998	-$194
		4	14.0%	1.0	50	35	25	NA	100	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	84%	45	27	27	16	15,111	29	1.7	10.3%	$1,810	$3,203	-$252
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Medium SFD	4	BCBC	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.0%	n/a	$2,045	-
		1	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.2%	egative NPV but no GHG reducti	$2,050	-$5
		2	14.7%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	90	60	37	27	7,512	50	2.6	0.6%	$198	$2,057	-$6
		3	14.7%	1.5	16	11	0	NA	60	MG-i89-Double	1.6	HPHotWater	0%	basefurnace	60%	72	42	29	23	9,267	28	1.5	1.6%	$248	$2,078	-$30
		4	14.7%	0.6	18	11	0	NA	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	61	31	19	20	9,222	19	1.0	2.9%	$304	$2,103	-$49
		5	14.7%	0.6	22	17	11	NA	100	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	75%	52	22	13	17	12,307	0	0.1	3.6%	$362	$2,119	-$86
	5	BCBC	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.0%	n/a	$2,194	-
		1	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.2%	egative NPV but no GHG reducti	$2,200	-$5
		2	14.7%	1.5	18	11	0	NA	60	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	88	58	33	28	7,494	48	2.5	1.1%	$166	$2,219	-$12
		3	14.7%	1.5	18	11	0	NA	60	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	88	58	33	28	7,494	48	2.5	1.1%	$166	$2,219	-$12
		4	14.7%	0.6	18	17	0	NA	70	MG-i89-Double	1.6	HPHotWater	0%	basefurnace	60%	75	45	32	25	9,276	30	1.6	2.1%	$266	$2,240	-$39
		5	14.7%	0.6	40	25	0	NA	100	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	55	25	14	18	9,196	14	0.8	4.9%	$403	$2,301	-$87
	6	BCBC	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.0%	n/a	$2,303	-
		1	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.2%	egative NPV but no GHG reducti	$2,308	-$6
		2	14.7%	1.5	16	11	0	NA	40	LG-avg-Double	1.8	GasInst_Low	0%	gas-furnace-ecm	60%	115	85	58	40	7,406	72	3.7	0.5%	$122	$2,314	-$4
		3	14.7%	1.5	16	11	0	NA	60	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	107	77	49	38	7,568	65	3.3	0.7%	$86	$2,319	-$5
		4	14.7%	1.0	22	11	0	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	75%	80	50	29	29	7,373	42	2.2	2.6%	$212	$2,364	-$33
		5	14.7%	0.6	60	25	15	NA	100	HG-i89-Triple-B	0.8	HPHotWater	42%	gas-furnace-ecm	84%	54	24	14	21	9,069	14	0.8	9.3%	$667	$2,517	-$184
	7a	BCBC	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	126	86	59	7,738	106	5.4	0.0%	n/a	$3,072	-
		1	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	126	86	59	7,738	106	5.4	0.3%	egative NPV but no GHG reducti	$3,081	-$9
		2	14.7%	1.5	18	11	0	NA	70	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	130	100	68	44	7,654	83	4.2	0.7%	$76	$3,095	-$7
		3	14.7%	1.5	16	20	0	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	60%	111	81	55	42	7,410	68	3.5	2.0%	$213	$3,134	-$34
		4	14.7%	0.6	40	17	0	NA	70	HG-avg-Triple	1.2	GasInst_Low	0%	baseboard	70%	84	54	31	29	14,668	18	1.1	3.2%	$315	$3,171	-$114
		5	8.0%	1.0	50	40	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	50%	CCASHP-ecm	75%	56	20	13	19	11,815	5	0.4	12.1%	$830	$3,421	-$347
	7b	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.3%	egative NPV but no GHG reducti	$3,081	-$9
		2	14.7%	1.5	22	25	11	NA	50	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	70%	126	96	63	41	7,640	80	4.1	1.8%	$153	$3,128	-$27
		3	14.7%	1.5	40	11	11	NA	40	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	70%	114	84	58	39	7,829	69	3.5	3.4%	$314	$3,177	-$70
		4	14.7%	0.6	40	17	15	NA	70	HG-HP-Triple	1	HPHotWater	42%	baseboard	84%	85	55	46	31	20,113	0	0.2	5.1%	$416	$3,229	-$208
		5	8.0%	0.6	100	80	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	50%	CCASHP-ecm	84%	58	22	14	15	11,829	7	0.5	20.5%	$1,239	$3,678	-$593
	8	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	166	120	66	7,901	139	7.0	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	166	120	66	7,901	139	7.0	0.3%	egative NPV but no GHG reducti	$3,081	-$9
		2	14.7%	1.5	40	25	11	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	120	90	60	38	7,632	75	3.8	3.4%	$216	$3,175	-$58
		3	14.7%	1.5	40	17	11	NA	70	HG-avg-Triple	1.2	GasInst_Low	42%	baseboard	70%	114	84	63	39	22,196	17	1.1	3.3%	$349	$3,173	-$174
		4	14.7%	0.6	60	25	11	NA	70	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm	70%	84	54	47	31	19,962	0	0.2	9.5%	$577	$3,365	-$330
		5	8.0%	0.6	100	80	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	50%	CCASHP-ecm	84%	59	23	15	14	11,563	9	0.6	20.5%	$1,070	$3,678	-$580

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Small SFD	4	BCBC	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.0%	n/a	$2,314	-
		1	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.4%	egative NPV but no GHG reducti	$2,324	-$10
		2	12.2%	2.5	18	11	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	124	54	29	43	9,120	13	0.7	3.3%	$334	$2,391	-$77
		3	12.2%	2.5	30	11	11	NA	100	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	60%	111	41	22	40	11,306	0	0.1	4.7%	$416	$2,424	-$145
		4	12.2%	0.6	24	11	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	70%	104	35	16	35	10,640	0	0.1	7.5%	$547	$2,487	-$192
		5	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	gas-furnace-ecm	75%	118	25	6	22	11,437	2	0.3	13.5%	$1,091	$2,597	-$355
	5	BCBC	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.0%	n/a	$2,483	-
		1	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.4%	egative NPV but no GHG reducti	$2,494	-$11
		2	12.2%	1.5	18	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	0%	158	88	41	59	7,380	31	1.6	1.9%	$280	$2,530	-$29
		3	12.2%	1.5	18	11	11	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	141	71	44	55	9,148	19	1.0	2.8%	$324	$2,554	-$73
		4	12.2%	1.5	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	70%	111	41	22	44	11,334	0	0.1	7.3%	$520	$2,666	-$210
		5	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	75%	120	22	11	27	12,259	0	0.2	16.2%	$1,141	$2,855	-$454
	6	BCBC	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.0%	n/a	$2,606	-
		1	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.5%	egative NPV but no GHG reducti	$2,618	-$12
		2	12.2%	1.5	18	11	11	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	165	96	63	71	9,276	27	1.5	2.5%	$288	$2,670	-$67
		3	12.2%	2.5	24	11	11	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	baseboard	60%	153	83	42	65	11,556	14	0.8	3.4%	$366	$2,695	-$130
		4	12.2%	0.6	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	75%	120	50	30	53	12,195	0	0.1	7.7%	$476	$2,806	-$235
		5	6.9%	1.0	50	40	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	75%	122	27***	11	30	12,299	1	0.2	18.1%	$1,053	$3,044	-$509
	7a	BCBC	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	256	187	104	105	7,507	67	3.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	257	187	104	105	7,507	67	3.4	0.6%	egative NPV but no GHG reducti	$3,495	-$19
		2	12.2%	2.5	40	20	30	NA	50	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	60%	161	92	70	73	16,446	0	0.2	6.7%	$550	$3,711	-$351
		3	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	166	71	36	49	9,668	26	1.4	12.5%	$1,062	$3,887	-$419
		4	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	75%	139	46	34	46	12,864	5	0.4	16.2%	$1,005	$4,008	-$597
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.6%	egative NPV but no GHG reducti	$3,495	-$19
		2	6.9%	3.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	190	94	58	56	9,748	35	1.9	11.7%	$962	$3,865	-$392
		3	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	174	77	42	45	9,792	29	1.6	12.5%	$876	$3,887	-$410
		4	6.9%	1.0	50	40	20	NA	80	HG-i89-Triple-B	0.8	HPHotWater	55%	gas-furnace-ecm	75%	133	39	20	28	12,558	4	0.4	33.2%	$1,655	$4,599	-$1,162
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.6%	egative NPV but no GHG reducti	$3,495	-$19
		2	6.9%	2.0	50	40	20	NA	80	HG-i89-Triple-B	1.2	GasInstantaneous	55%	gas-furnace-ecm	75%	189	96	59	53	9,371	36	1.9	12.1%	$789	$3,879	-$384
		3	6.9%	2.5	100	100	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	84%	151	60	42	40	12,538	10	0.7	32.7%	$1,564	$4,588	-$1,137
		4	6.9%	0.6	100	100	50	NA	120	PH_HG-i89-Triple-B	0.8	HPHotWater	55%	CCASHP-ecm*	84%	149	45	25	29	12,522	10	0.7	33.1%	$1,574	$4,595	-$1,152
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*These CCASHPs have a -4F cutoff.

**Insulation added under footings and at slab edge in addition to underslab.

***Misses the MEUI requirement by <2kWh/m2.

7.9 Part 9 – Lowest Incremental Capital Costs – Adjusted Targets

Note: Negative carbon abatement costs occur when a building has lower GHG emissions and a positive NPV, meaning investing in GHG reductions is profitable.

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Large SFD	4	BCBC	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.0%	n/a	$1,938	-
		1	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.2%	Negative NPV but no GHG reduction	$1,941	-$3
		2	14.6%	2.5	16	11	0	NA	50	LG-avg-Double	1.8	GasInstantaneous	0%	baseboard	70%	66	52	44	24	29,864	14	1.0	0.1%	$391	$1,939	-$79
		3	14.6%	1.5	16	11	0	NA	50	HG-avg-Triple	1.2	ElectricStorage	30%	baseboard	0%	52	38	30	22	26,724	0	0.3	1.2%	$346	$1,960	-$80
		4	14.6%	0.6	16	11	0	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	CCASHP-ecm	0%	44	30	36	22	18,773	14	0.9	1.8%	$269	$1,972	-$55
		5	14.6%	0.6	50	25	0	NA	50	HG-i89-Triple-B	0.8	ElectricStorage	0%	baseboard	70%	34	20	11	13	17,418	0	0.2	6.4%	$569	$2,061	-$133
	5	BCBC	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.0%	n/a	$2,079	-
		1	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.2%	Negative NPV but no GHG reduction	$2,082	-$3
		2	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	basefurnace	0%	88	74	57	33	12,109	118	6.0	-0.3%	$252	$2,072	-$8
		3	14.6%	2.5	16	20	0	NA	40	LG-avg-Double	1.8	GasInst_Low	0%	baseboard	0%	78	64	55	32	35,531	16	1.2	-0.1%	$440	$2,076	-$99
		4	14.6%	0.6	16	11	0	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	54	40	36	25	27,474	0	0.3	0.9%	$291	$2,098	-$75
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	BCBC	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	105	91	69	44	8,122	165	8.3	0.0%	n/a	$2,182	-
		1	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	106	91	69	44	8,122	165	8.3	0.2%	Negative NPV but no GHG reduction	$2,185	-$4
		2	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	70%	111	97	74	43	8,171	174	8.8	-0.5%	Positive NPV but no GHG reduction	$2,172	$7
		3	14.6%	1.5	18	11	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	baseboard	0%	93	79	70	39	47,309	0	0.5	-0.9%	$420	$2,163	-$128
		4	14.6%	0.6	16	11	0	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	baseboard	84%	64	50	42	30	28,836	14	1.0	1.0%	$277	$2,203	-$79
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7a	BCBC	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.0%	n/a	$2,910	-
		1	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.2%	Negative NPV but no GHG reduction	$2,916	-$6
		2	14.6%	1.5	22	11	0	NA	60	MG-i89-Double	1.6	GasInstantaneous	0%	baseboard	60%	97	83	73	41	44,892	16	1.3	-0.2%	$298	$2,905	-$115
		3	14.6%	1.5	22	11	0	NA	40	HG-avg-Triple	1.2	BaseDHW	0%	baseboard	60%	90	76	63	41	39,587	23	1.6	0.4%	$282	$2,920	-$106
		4	14.6%	0.6	40	20	0	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	baseboard	75%	65	51	42	29	28,808	16	1.1	2.4%	$277	$2,981	-$109
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.2%	Negative NPV but no GHG reduction	$2,916	-$6
		2	14.6%	1.5	22	17	0	NA	50	HG-avg-Triple	1.2	GasInst_Low	0%	baseboard	60%	102	88	77	41	46,698	19	1.4	0.3%	$298	$2,920	-$130
		3	14.6%	1.5	22	25	0	NA	100	HG-avg-Triple	1.2	GasInst_Low	55%	baseboard	70%	94	80	71	39	43,559	16	1.3	1.6%	$335	$2,955	-$149
		4	14.6%	0.6	60	17	11	NA	70	HG-avg-Triple	1.2	HPHotWater	0%	CCASHP-ecm	75%	65	51	51	29	33,366	0	0.4	5.1%	$409	$3,059	-$196
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.2%	Negative NPV but no GHG reduction	$2,916	-$6
		2	14.6%	1.5	22	17	0	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	CCASHP-ecm	60%	106	92	91	44	49,507	17	1.4	1.5%	$325	$2,955	-$166
		3	14.6%	1.5	40	17	0	NA	50	HG-avg-Triple	1.2	ElectricStorage	42%	CCASHP-ecm	60%	93	79	76	39	47,283	0	0.5	3.0%	$355	$2,998	-$194
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Medium SFD	4	BCBC	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.0%	n/a	$2,045	-
		1	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.2%	Negative NPV but no GHG reduction	$2,050	-$5
		2	14.7%	2.5	16	17	0	NA	40	LG-avg-Double	1.8	GasInst_Low	0%	baseboard	0%	85	55	35	27	15,640	16	1.0	0.2%	$378	$2,049	-$63
		3	14.7%	2.5	16	11	0	NA	50	LG-avg-Double	1.8	GasInstantaneous	0%	baseboard	70%	80	50	33	25	15,140	14	0.8	0.6%	$359	$2,057	-$63
		4	14.7%	0.6	16	20	0	NA	40	LG-avg-Double	1.8	HPHotWater	0%	baseboard	0%	72	42	33	24	17,001	0	0.2	1.2%	$376	$2,069	-$87
		5	14.7%	0.6	16	11	0	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	59	29	21	21	14,084	0	0.2	2.4%	$343	$2,095	-$80
	5	BCBC	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.0%	n/a	$2,194	-
		1	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.2%	Negative NPV but no GHG reduction	$2,200	-$5
		2	14.7%	2.5	16	20	0	NA	40	LG-avg-Double	1.8	GasInst_Low	0%	baseboard	0%	95	65	46	34	18,224	16	1.0	0.0%	$408	$2,195	-$82
		3	14.7%	2.5	16	20	0	NA	40	LG-avg-Double	1.8	GasInst_Low	0%	baseboard	0%	95	65	46	34	18,224	16	1.0	0.0%	$408	$2,195	-$82
		4	14.7%	0.6	18	17	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	baseboard	70%	82	52	34	26	19,418	0	0.2	0.8%	$381	$2,212	-$101
		5	14.7%	1.0	22	25	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	60	30	21	23	14,196	0	0.2	3.0%	$344	$2,261	-$93
	6	BCBC	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.0%	n/a	$2,303	-
		1	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.2%	Negative NPV but no GHG reduction	$2,308	-$6
		2	14.7%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	basefurnace	0%	128	98	68	47	11,958	66	3.4	-0.3%	$558	$2,296	-$30
		3	14.7%	2.5	16	25	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	baseboard	0%	113	83	64	45	26,724	0	0.3	-0.3%	$463	$2,296	-$147
		4	14.7%	0.6	16	20	0	NA	70	MG-i89-Double	1.6	HPHotWater	0%	baseboard	0%	89	59	50	37	21,113	0	0.2	1.1%	$361	$2,327	-$116
		5	14.7%	0.6	40	11	11	NA	70	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	60%	59	29	20	25	13,946	0	0.1	5.3%	$410	$2,424	-$135
	7a	BCBC	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	126	86	59	7,738	106	5.4	0.0%	n/a	$3,072	-
		1	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	157	126	86	59	7,738	106	5.4	0.3%	Negative NPV but no GHG reduction	$3,081	-$9
		2	14.7%	1.5	18	17	0	NA	40	LG-avg-Double	1.8	ElectricStorage	0%	baseboard	60%	126	96	76	47	29,975	0	0.3	-0.2%	$385	$3,065	-$164
		3	14.7%	1.5	16	20	0	NA	100	LG-avg-Double	1.8	HPHotWater	0%	baseboard	70%	120	90	80	47	28,419	0	0.3	0.6%	$403	$3,091	-$172
		4	14.7%	0.6	18	17	0	NA	80	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	90	60	51	37	21,391	0	0.2	2.0%	$320	$3,134	-$139
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.3%	Negative NPV but no GHG reduction	$3,081	-$9
		2	14.7%	1.5	18	11	11	NA	60	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	0%	129	99	78	49	30,669	0	0.3	0.4%	$365	$3,084	-$179
		3	14.7%	1.5	18	20	11	NA	70	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	60%	122	92	70	44	28,863	0	0.3	1.0%	$360	$3,102	-$178
		4	14.7%	0.6	40	20	11	NA	40	HG-avg-Triple	1.2	HPHotWater	55%	baseboard	75%	89	59	51	34	21,196	0	0.2	4.1%	$379	$3,198	-$189
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	166	120	66	7,901	139	7.0	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	165	120	66	7,901	139	7.0	0.3%	Negative NPV but no GHG reduction	$3,081	-$9
		2	14.7%	1.5	18	17	0	NA	70	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	60%	136	106	84	47	32,253	0	0.3	0.5%	$336	$3,088	-$189
		3	14.7%	1.5	22	25	0	NA	100	HG-avg-Triple	1.2	GasInstantaneous	55%	baseboard	70%	120	90	73	42	24,585	14	1.0	2.3%	$329	$3,142	-$168
		4	14.7%	0.6	40	25	11	NA	70	HG-i89-Triple-B	0.8	HPHotWater	55%	baseboard	70%	91	61	52	33	21,557	0	0.2	5.8%	$409	$3,251	-$234
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Small SFD	4	BCBC	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.0%	n/a	$2,314	-
		1	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.4%	Negative NPV but no GHG reduction	$2,324	-$10
		2	12.2%	2.5	16	11	11	NA	50	MG-i89-Double	1.6	GasInstantaneous	0%	baseboard	0%	144	74	35	50	10,918	14	0.8	1.2%	$347	$2,342	-$75
		3	12.2%	2.5	24	11	11	NA	60	LG-avg-Double	1.8	HPHotWater	0%	baseboard	0%	129	59	40	48	13,140	0	0.1	2.5%	$409	$2,373	-$141
		4	12.2%	1.0	24	11	11	NA	60	MG-i89-Double	1.6	HPHotWater	0%	baseboard	0%	121	51	32	45	12,307	0	0.1	3.5%	$411	$2,395	-$143
		5	12.2%	0.6	40	11	20	NA	40	MG-HP-Double	1.4	HPHotWater	0%	baseboard	70%	109	40	21	37	11,168	0	0.1	6.6%	$532	$2,468	-$186
	5	BCBC	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.0%	n/a	$2,483	-
		1	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.4%	Negative NPV but no GHG reduction	$2,494	-$11
		2	12.2%	1.5	16	11	11	NA	50	LG-avg-Double	1.8	BaseDHW	0%	baseboard	0%	175	105	49	64	12,334	20	1.1	0.6%	$475	$2,497	-$98
		3	12.2%	2.5	18	11	11	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	baseboard	0%	159	90	51	63	12,473	14	0.8	1.0%	$381	$2,507	-$102
		4	12.2%	1.0	22	11	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	122	53	33	49	12,473	0	0.1	3.8%	$379	$2,579	-$152
		5	12.2%	0.6	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	75%	108	38	19	42	11,029	0	0.1	8.3%	$558	$2,689	-$226
	6	BCBC	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.0%	n/a	$2,606	-
		1	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.5%	Negative NPV but no GHG reduction	$2,618	-$12
		2	12.2%	2.5	18	11	11	NA	40	LG-avg-Double	1.8	GasInstantaneous	0%	baseboard	60%	185	115	74	77	14,890	14	0.9	0.8%	$420	$2,626	-$145
		3	12.2%	2.5	16	11	11	NA	100	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	60%	165	95	51	71	16,779	0	0.2	2.0%	$419	$2,658	-$203
		4	12.2%	1.0	22	11	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	139	69	49	64	14,168	0	0.2	3.6%	$363	$2,699	-$178
		5	12.2%	0.6	60	25	30	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	84%	109	39	19	42	11,140	0	0.1	14.1%	$758	$2,974	-$376
	7a	BCBC	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	256	187	104	105	7,507	67	3.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	257	187	104	105	7,507	67	3.4	0.6%	Negative NPV but no GHG reduction	$3,495	-$19
		2	12.2%	1.5	18	11	11	NA	100	HG-avg-Triple	1.2	ElectricStorage	0%	baseboard	70%	185	115	67	77	18,835	0	0.2	2.4%	$409	$3,558	-$259
		3	12.2%	2.5	40	20	30	NA	50	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	60%	161	92	70	73	16,446	0	0.2	6.9%	$557	$3,715	-$355
		4	12.2%	0.6	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	75%	141	71	49	63	14,334	0	0.2	7.7%	$512	$3,742	-$329
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.6%	Negative NPV but no GHG reduction	$3,495	-$19
		2	12.2%	1.5	60	11	20	NA	100	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	70%	184	114	61	67	7,732	40	2.1	9.3%	$739	$3,801	-$269
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.6%	Negative NPV but no GHG reduction	$3,495	-$19
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

7.10 Part 9 – Highest NPV – Adjusted Targets

Note: Negative carbon abatement costs occur when a building has lower GHG emissions and a positive NPV, meaning investing in GHG reductions is profitable.

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Large SFD	4	BCBC	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.0%	n/a	$1,938	-
		1	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.2%	Negative NPV but no GHG reduction	$1,941	-$3
		2	14.6%	1.5	16	11	0	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	basefurnace	0%	66	52	39	23	7,826	94	4.8	0.7%	$86	$1,951	-$5
		3	14.6%	1.5	18	17	0	NA	60	HG-avg-Triple	1.2	GasInst_Low	0%	gas-furnace-ecm	0%	53	39	27	20	7,506	71	3.6	2.1%	$236	$1,978	-$23
		4	14.6%	0.6	24	11	0	NA	70	HG-avg-Triple	1.2	GasInstantaneous	42%	basefurnace	60%	45	31	21	17	7,652	56	2.9	2.9%	$270	$1,994	-$35
		5	14.6%	0.6	60	11	15	NA	70	HG-HP-Triple	1	GasInstantaneous	30%	gas-furnace-ecm	84%	35	21	12	13	7,471	37	1.9	6.8%	$630	$2,070	-$104
	5	BCBC	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.0%	n/a	$2,079	-
		1	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.2%	Negative NPV but no GHG reduction	$2,082	-$3
		2	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	60%	88	74	55	32	7,982	133	6.7	-0.2%	-$677	$2,076	$4
		3	14.6%	1.5	16	11	0	NA	70	LG-avg-Double	1.8	GasInst_Low	0%	basefurnace	0%	83	69	52	30	7,960	124	6.3	0.0%	-$132	$2,080	$3
		4	14.6%	0.6	22	11	0	NA	40	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	70%	54	40	29	22	7,846	70	3.6	2.0%	$152	$2,120	-$20
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	BCBC	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	105	91	69	44	8,122	165	8.3	0.0%	n/a	$2,182	-
		1	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	106	91	69	44	8,122	165	8.3	0.2%	Negative NPV but no GHG reduction	$2,185	-$4
		2	14.6%	1.5	16	11	0	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	basefurnace	0%	96	82	64	39	8,077	148	7.5	-0.2%	-$272	$2,178	$9
		3	14.6%	1.5	22	11	0	NA	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	60%	94	80	62	36	8,057	143	7.2	0.0%	-$145	$2,183	$6
		4	14.6%	1.0	22	11	0	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	75%	65	51	38	29	7,533	93	4.7	1.7%	$88	$2,219	-$12
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7a	BCBC	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.0%	n/a	$2,910	-
		1	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.2%	Negative NPV but no GHG reduction	$2,916	-$6
		2	14.6%	1.5	16	11	0	NA	100	HG-avg-Triple	1.2	BaseDHW	0%	basefurnace	0%	111	96	72	44	8,157	174	8.8	0.6%	$12	$2,928	-$1
		3	14.6%	1.5	22	11	0	NA	40	HG-avg-Triple	1.2	GasInst_Low	55%	gas-furnace-ecm	60%	94	80	63	40	7,608	146	7.4	1.3%	$80	$2,949	-$12
		4	14.6%	0.6	40	20	0	NA	70	HG-avg-Triple	1.2	Combo	55%	ComboHeatA	70%	65	51	40	28	7,954	91	4.6	3.7%	$254	$3,019	-$65
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.2%	Negative NPV but no GHG reduction	$2,916	-$6
		2	14.6%	1.5	40	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	102	88	69	38	8,130	159	8.0	1.9%	$137	$2,966	-$25
		3	14.6%	1.5	40	17	0	NA	40	HG-avg-Triple	1.2	HPHotWater	55%	gas-furnace-ecm	60%	95	81	69	38	9,483	141	7.1	2.6%	$210	$2,985	-$45
		4	14.6%	0.6	60	17	11	NA	70	HG-avg-Triple	1.2	HPHotWater	0%	CCASHP-ecm	75%	65	51	51	29	33,366	0	0.4	5.1%	$409	$3,059	-$196
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.2%	Negative NPV but no GHG reduction	$2,916	-$6
		2	14.6%	1.5	40	25	15	NA	100	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	0%	110	96	74	38	8,192	174	8.8	3.1%	$238	$3,002	-$53
		3	14.6%	1.5	40	17	0	NA	50	HG-avg-Triple	1.2	ElectricStorage	42%	CCASHP-ecm	60%	93	79	76	39	47,283	0	0.5	3.0%	$355	$2,998	-$194
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Medium SFD	4	BCBC	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.0%	n/a	$2,045	-
		1	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.2%	Negative NPV but no GHG reduction	$2,050	-$5
		2	14.7%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	90	60	37	27	7,512	50	2.6	0.6%	$198	$2,057	-$6
		3	14.7%	1.5	18	11	0	NA	40	LG-avg-Double	1.8	GasInstantaneous	0%	gas-furnace-ecm	60%	80	50	30	23	7,372	42	2.2	1.4%	$265	$2,073	-$17
		4	14.7%	0.6	16	17	0	NA	40	MG-HP-Double	1.4	GasInstantaneous	0%	basefurnace	75%	72	42	21	20	7,442	35	1.8	2.2%	$303	$2,090	-$29
		5	14.7%	0.6	18	11	0	NA	50	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	61	31	19	20	9,222	19	1.0	3.1%	$330	$2,108	-$53
	5	BCBC	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.0%	n/a	$2,194	-
		1	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.2%	Negative NPV but no GHG reduction	$2,200	-$5
		2	14.7%	2.5	16	11	0	NA	60	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	60%	98	68	44	32	7,544	56	2.9	0.6%	$200	$2,209	-$8
		3	14.7%	2.5	16	11	0	NA	60	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	60%	98	68	44	32	7,544	56	2.9	0.6%	$200	$2,209	-$8
		4	14.7%	0.6	16	17	0	NA	40	MG-HP-Double	1.4	GasInstantaneous	0%	basefurnace	75%	81	51	30	26	7,480	43	2.2	1.8%	$253	$2,235	-$24
		5	14.7%	0.6	22	25	0	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	gas-furnace-ecm	84%	62	32	21	22	9,150	20	1.1	3.8%	$356	$2,278	-$68
	6	BCBC	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.0%	n/a	$2,303	-
		1	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.2%	Negative NPV but no GHG reduction	$2,308	-$6
		2	14.7%	2.5	16	11	0	NA	40	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	46	7,618	80	4.1	0.1%	Negative NPV but no GHG reduction	$2,306	-$3
		3	14.7%	1.5	18	17	0	NA	50	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	114	84	58	40	7,606	70	3.6	0.4%	$100	$2,313	-$4
		4	14.7%	1.0	18	11	0	NA	70	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	60%	90	60	34	32	7,501	50	2.6	1.8%	$167	$2,344	-$21
		5	14.7%	0.6	40	25	11	NA	100	HG-avg-Triple	1.2	HPHotWater	30%	basefurnace	75%	62	31	20	23	9,188	19	1.1	5.4%	$394	$2,427	-$99
	7a	BCBC	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	126	86	59	7,738	106	5.4	0.0%	n/a	$3,072	-
		1	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	157	126	86	59	7,738	106	5.4	0.3%	Negative NPV but no GHG reduction	$3,081	-$9
		2	14.7%	1.5	18	11	0	NA	60	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	131	101	68	44	7,657	84	4.3	0.7%	$58	$3,092	-$5
		3	14.7%	1.5	16	11	0	NA	100	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	70%	119	88	57	42	7,607	74	3.8	1.5%	$179	$3,119	-$24
		4	14.7%	0.6	30	20	0	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	84%	91	60	35	30	7,509	50	2.6	3.4%	$282	$3,177	-$66
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.3%	Negative NPV but no GHG reduction	$3,081	-$9
		2	14.7%	1.5	22	20	20	NA	50	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	0%	135	105	71	46	7,677	88	4.5	1.6%	$184	$3,122	-$26
		3	14.7%	1.5	40	25	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	0%	120	89	60	41	7,626	75	3.8	2.9%	$279	$3,160	-$55
		4	14.7%	0.6	40	25	11	NA	100	HG-avg-Triple	1.2	HPHotWater	30%	basefurnace	75%	92	61	46	31	9,512	44	2.3	4.7%	$337	$3,217	-$110
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	166	120	66	7,901	139	7.0	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	165	120	66	7,901	139	7.0	0.3%	Negative NPV but no GHG reduction	$3,081	-$9
		2	14.7%	1.5	40	17	0	NA	100	HG-avg-Triple	1.2	BaseDHW	0%	basefurnace	60%	133	103	65	41	7,650	86	4.4	2.7%	$207	$3,156	-$46
		3	14.7%	1.5	40	25	11	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	120	90	60	38	7,632	75	3.8	3.4%	$224	$3,178	-$60
		4	14.7%	0.6	60	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	30%	gas-furnace-ecm	84%	91	61	47	30	9,407	44	2.3	7.9%	$491	$3,315	-$195
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Small SFD	4	BCBC	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.0%	n/a	$2,314	-
		1	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.4%	Negative NPV but no GHG reduction	$2,324	-$10
		2	12.2%	2.5	18	11	11	NA	40	MG-HP-Double	1.4	GasInstantaneous	0%	basefurnace	60%	145	75	29	45	7,358	27	1.4	2.0%	$322	$2,362	-$31
		3	12.2%	2.5	18	11	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	124	54	29	43	9,120	13	0.7	3.4%	$346	$2,394	-$80
		4	12.2%	1.0	30	11	11	NA	70	MG-i89-Double	1.6	HPHotWater	0%	basefurnace	60%	121	51	26	39	9,114	11	0.7	4.8%	$447	$2,424	-$108
		5	12.2%	0.6	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	basefurnace	0%	109	39	16	38	9,095	7	0.5	8.2%	$642	$2,504	-$181
	5	BCBC	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.0%	n/a	$2,483	-
		1	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.4%	Negative NPV but no GHG reduction	$2,494	-$11
		2	12.2%	2.5	18	11	11	NA	40	MG-HP-Double	1.4	GasInst_Low	0%	basefurnace	0%	172	103	48	63	7,395	37	1.9	1.1%	$351	$2,511	-$19
		3	12.2%	1.5	18	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	0%	158	88	41	59	7,380	31	1.6	2.0%	$308	$2,533	-$32
		4	12.2%	0.6	30	11	11	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	130	60	34	49	9,129	15	0.8	4.8%	$429	$2,601	-$113
		5	12.2%	0.6	40	11	20	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	basefurnace	84%	111	41	18	39	9,098	8	0.5	9.7%	$676	$2,724	-$224
	6	BCBC	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.0%	n/a	$2,606	-
		1	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.5%	Negative NPV but no GHG reduction	$2,618	-$12
		2	12.2%	2.5	16	11	11	NA	50	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	70%	183	114	56	72	7,410	41	2.1	1.9%	$296	$2,655	-$31
		3	12.2%	2.5	24	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	60%	168	99	49	69	7,315	36	1.8	3.4%	$385	$2,693	-$60
		4	12.2%	0.6	40	11	11	NA	100	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	0%	140	70	41	62	9,234	18	1.0	6.0%	$442	$2,761	-$143
		5	12.2%	0.6	60	25	30	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	84%	109	39	19	42	11,140	0	0.1	14.1%	$758	$2,974	-$376
	7a	BCBC	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	256	187	104	105	7,507	67	3.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	257	187	104	105	7,507	67	3.4	0.6%	Negative NPV but no GHG reduction	$3,495	-$19
		2	12.2%	2.5	40	11	20	NA	100	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	60%	185	116	53	72	7,409	41	2.1	5.4%	$582	$3,665	-$147
		3	12.2%	1.5	40	25	20	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	70%	171	101	46	65	7,395	36	1.9	7.7%	$708	$3,743	-$216
		4	12.2%	0.6	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	75%	141	71	49	63	14,334	0	0.2	7.7%	$512	$3,742	-$329
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.6%	Negative NPV but no GHG reduction	$3,495	-$19
		2	12.2%	1.5	60	11	20	NA	100	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	70%	184	114	61	67	7,732	40	2.1	9.3%	$739	$3,801	-$269
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.6%	Negative NPV but no GHG reduction	$3,495	-$19
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

7.11 Part 9 – Lowest Carbon Abatement Costs – Adjusted Targets

Note: Negative carbon abatement costs occur when a building has lower GHG emissions and a positive NPV, meaning investing in GHG reductions is profitable.

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Large SFD	4	BCBC	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.0%	n/a	$1,938	-
		1	14.6%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	82	68	49	27	7,927	122	6.2	0.2%	Negative NPV but no GHG reduction	$1,941	-$3
		2	14.6%	1.5	16	11	0	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	basefurnace	0%	66	52	39	23	7,826	94	4.8	0.7%	$86	$1,951	-$5
		3	14.6%	1.5	18	17	0	NA	70	MG-i89-Double	1.6	HPHotWater	0%	gas-furnace-ecm	60%	55	41	33	21	9,314	69	3.5	1.8%	$233	$1,972	-$24
		4	14.6%	0.6	18	17	0	NA	70	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	46	32	24	18	9,475	50	2.6	2.6%	$250	$1,987	-$35
		5	14.6%	0.6	50	25	0	NA	50	HG-i89-Triple-B	0.8	ElectricStorage	0%	baseboard	70%	34	20	11	13	17,418	0	0.2	6.4%	$569	$2,061	-$133
	5	BCBC	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.0%	n/a	$2,079	-
		1	14.6%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	90	76	56	34	7,998	136	6.9	0.2%	Negative NPV but no GHG reduction	$2,082	-$3
		2	14.6%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	60%	88	74	55	32	7,982	133	6.7	-0.2%	-$677	$2,076	$4
		3	14.6%	1.5	16	11	0	NA	70	LG-avg-Double	1.8	GasInst_Low	0%	basefurnace	0%	83	69	52	30	7,960	124	6.3	0.0%	-$132	$2,080	$3
		4	14.6%	0.6	22	11	0	NA	40	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	70%	54	40	29	22	7,846	70	3.6	2.0%	$152	$2,120	-$20
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	BCBC	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	105	91	69	44	8,122	165	8.3	0.0%	n/a	$2,182	-
		1	14.6%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	106	91	69	44	8,122	165	8.3	0.2%	Negative NPV but no GHG reduction	$2,185	-$4
		2	14.6%	2.5	16	11	0	NA	70	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	70%	106	91	72	41	8,157	165	8.3	-0.2%	-$15,414	$2,177	$4
		3	14.6%	1.5	16	11	0	NA	40	MG-HP-Double	1.4	GasInst_Low	0%	basefurnace	0%	95	81	62	39	8,055	146	7.4	0.0%	-$161	$2,182	$6
		4	14.6%	1.0	22	11	0	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	gas-furnace-ecm	75%	65	51	38	29	7,533	93	4.7	1.7%	$88	$2,219	-$12
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7a	BCBC	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.0%	n/a	$2,910	-
		1	14.6%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	137	123	95	55	8,383	222	11.2	0.2%	Negative NPV but no GHG reduction	$2,916	-$6
		2	14.6%	1.5	16	11	0	NA	100	HG-avg-Triple	1.2	BaseDHW	0%	basefurnace	0%	111	96	72	44	8,157	174	8.8	0.6%	$12	$2,928	-$1
		3	14.6%	1.5	22	11	0	NA	40	HG-avg-Triple	1.2	GasInst_Low	55%	gas-furnace-ecm	60%	94	80	63	40	7,608	146	7.4	1.3%	$80	$2,949	-$12
		4	14.6%	0.6	40	20	0	NA	70	HG-avg-Triple	1.2	Combo	55%	ComboHeatA	70%	65	51	40	28	7,954	91	4.6	3.7%	$254	$3,019	-$65
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	153	139	110	58	8,535	251	12.6	0.2%	Negative NPV but no GHG reduction	$2,916	-$6
		2	14.6%	1.5	40	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	102	88	69	38	8,130	159	8.0	1.9%	$137	$2,966	-$25
		3	14.6%	1.5	40	17	0	NA	40	HG-avg-Triple	1.2	HPHotWater	55%	gas-furnace-ecm	60%	95	81	69	38	9,483	141	7.1	2.6%	$210	$2,985	-$45
		4	14.6%	0.6	60	17	11	NA	70	HG-avg-Triple	1.2	HPHotWater	0%	CCASHP-ecm	75%	65	51	51	29	33,366	0	0.4	5.1%	$409	$3,059	-$196
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.0%	n/a	$2,910	-
		1	14.6%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	173	159	128	61	8,711	288	14.4	0.2%	Negative NPV but no GHG reduction	$2,916	-$6
		2	14.6%	1.5	40	25	15	NA	100	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	0%	110	96	74	38	8,192	174	8.8	3.1%	$238	$3,002	-$53
		3	14.6%	1.5	40	17	0	NA	50	HG-avg-Triple	1.2	ElectricStorage	42%	CCASHP-ecm	60%	93	79	76	39	47,283	0	0.5	3.0%	$355	$2,998	-$194
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Medium SFD	4	BCBC	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.0%	n/a	$2,045	-
		1	14.7%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	99	69	38	29	7,517	57	2.9	0.2%	Negative NPV but no GHG reduction	$2,050	-$5
		2	14.7%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	GasInstantaneous	0%	basefurnace	0%	90	60	37	27	7,512	50	2.6	0.6%	$198	$2,057	-$6
		3	14.7%	1.5	18	11	0	NA	60	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	78	47	24	22	7,453	39	2.0	1.5%	$232	$2,075	-$17
		4	14.7%	1.5	16	11	0	NA	60	MG-i89-Double	1.6	HPHotWater	0%	basefurnace	60%	72	42	29	23	9,267	28	1.5	1.8%	$276	$2,081	-$33
		5	14.7%	1.0	22	25	0	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	56	26	15	18	9,200	15	0.8	3.4%	$328	$2,115	-$58
	5	BCBC	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.0%	n/a	$2,194	-
		1	14.7%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	109	78	47	37	7,556	66	3.3	0.2%	Negative NPV but no GHG reduction	$2,200	-$5
		2	14.7%	1.5	18	11	0	NA	60	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	88	58	33	28	7,494	48	2.5	1.1%	$166	$2,219	-$12
		3	14.7%	1.5	18	11	0	NA	60	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	88	58	33	28	7,494	48	2.5	1.1%	$166	$2,219	-$12
		4	14.7%	0.6	16	17	0	NA	40	MG-HP-Double	1.4	GasInstantaneous	0%	basefurnace	75%	81	51	30	26	7,480	43	2.2	1.8%	$253	$2,235	-$24
		5	14.7%	1.0	22	25	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	60	30	21	23	14,196	0	0.2	3.0%	$344	$2,261	-$93
	6	BCBC	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.0%	n/a	$2,303	-
		1	14.7%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	125	95	60	48	7,617	79	4.0	0.2%	Negative NPV but no GHG reduction	$2,308	-$6
		2	14.7%	2.5	16	11	0	NA	40	LG-avg-Double	1.8	HPHotWater	0%	basefurnace	0%	124	94	73	48	9,563	71	3.7	0.1%	$506	$2,305	-$17
		3	14.7%	1.5	16	11	0	NA	60	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	107	77	49	38	7,568	65	3.3	0.7%	$86	$2,319	-$5
		4	14.7%	1.0	18	11	0	NA	70	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	60%	90	60	34	32	7,501	50	2.6	1.8%	$167	$2,344	-$21
		5	14.7%	0.6	40	25	11	NA	100	HG-avg-Triple	1.2	HPHotWater	30%	basefurnace	75%	62	31	20	23	9,188	19	1.1	5.4%	$394	$2,427	-$99
	7a	BCBC	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	156	126	86	59	7,738	106	5.4	0.0%	n/a	$3,072	-
		1	14.7%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	157	126	86	59	7,738	106	5.4	0.3%	Negative NPV but no GHG reduction	$3,081	-$9
		2	14.7%	1.5	18	11	0	NA	60	MG-i89-Double	1.6	GasInst_Low	0%	basefurnace	60%	131	101	68	44	7,657	84	4.3	0.7%	$58	$3,092	-$5
		3	14.7%	1.5	16	11	0	NA	100	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	70%	119	88	57	42	7,607	74	3.8	1.5%	$179	$3,119	-$24
		4	14.7%	0.6	22	20	0	NA	70	HG-avg-Triple	1.2	GasInst_Low	0%	baseboard	75%	92	62	39	33	16,585	18	1.1	2.1%	$277	$3,135	-$100
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	175	145	103	62	7,817	122	6.1	0.3%	Negative NPV but no GHG reduction	$3,081	-$9
		2	14.7%	1.5	22	25	11	NA	50	HG-avg-Triple	1.2	GasInst_Low	0%	basefurnace	70%	126	96	63	41	7,640	80	4.1	1.8%	$153	$3,128	-$27
		3	14.7%	1.5	40	17	0	NA	70	MG-i89-Double	1.6	HPHotWater	0%	gas-furnace-ecm	70%	118	88	71	41	9,565	66	3.4	2.7%	$272	$3,154	-$63
		4	14.7%	0.6	40	25	11	NA	100	HG-avg-Triple	1.2	HPHotWater	30%	basefurnace	75%	92	61	46	31	9,512	44	2.3	4.7%	$337	$3,217	-$110
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	166	120	66	7,901	139	7.0	0.0%	n/a	$3,072	-
		1	14.7%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	196	165	120	66	7,901	139	7.0	0.3%	Negative NPV but no GHG reduction	$3,081	-$9
		2	14.7%	1.5	24	11	11	NA	60	HG-avg-Triple	1.2	ElectricStorage	0%	basefurnace	60%	137	107	75	43	12,596	71	3.7	1.6%	$194	$3,121	-$54
		3	14.7%	1.5	40	25	11	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	120	90	60	38	7,632	75	3.8	3.4%	$224	$3,178	-$60
		4	14.7%	0.6	40	25	11	NA	70	HG-i89-Triple-B	0.8	HPHotWater	55%	baseboard	70%	91	61	52	33	21,557	0	0.2	5.8%	$409	$3,251	-$234
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Scenario			Archetype Characteristics													Energy and Emissions Outcomes							Costing Outcomes			
Archetype	CZ	Step Achieved	WWR	Airtightness (ACH@50kPa)	Wall R-Value (effective)	Foundation Wall R-Value (effective)	Underslab R-Value (effective)	Exposed Floor R-Value (effective)	Ceiling / Roof R-Value (effective)	Window Option	Window U-Value	DHW System	Drainwater Heat Recovery (%)	Space Heating System	Vent. Heat Recovery (%)	TEUI (kWh/m2)	MEUI (kWh/m2)	TEDI (kWh/m2)	PTL (W/m2)	Electricity Consumption (kWh)	Natural Gas Consumption (GJ)	Annual GHG Emissions (tCO2e)	Incremental Capital Cost (%)	Carbon Abatement Cost ($/tCO2e)	Building with ECMs Cost per m2 ($/m2)	NPV per m2 (20-year)
Small SFD	4	BCBC	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.0%	n/a	$2,314	-
		1	12.2%	3.5	16	11	0	NA	40	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	172	102	37	57	7,373	37	1.9	0.4%	Negative NPV but no GHG reduction	$2,324	-$10
		2	12.2%	2.5	18	11	11	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	0%	133	63	37	49	9,135	16	0.9	2.4%	$313	$2,370	-$62
		3	12.2%	2.5	18	11	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	70%	124	54	29	43	9,120	13	0.7	3.4%	$346	$2,394	-$80
		4	12.2%	0.6	16	11	11	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	118	48	29	43	12,057	0	0.1	3.7%	$403	$2,399	-$140
		5	12.2%	0.6	40	11	20	NA	40	MG-HP-Double	1.4	HPHotWater	0%	baseboard	70%	109	40	21	37	11,168	0	0.1	6.6%	$532	$2,468	-$186
	5	BCBC	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.0%	n/a	$2,483	-
		1	12.2%	3.5	18	17	0	NA	50	LG-avg-Double	1.8	BaseDHW	0%	basefurnace	0%	187	118	51	70	7,400	42	2.2	0.4%	Negative NPV but no GHG reduction	$2,494	-$11
		2	12.2%	2.5	16	11	11	NA	40	MG-i89-Double	1.6	GasInstantaneous	0%	basefurnace	70%	164	94	47	58	7,391	34	1.8	1.5%	$295	$2,521	-$25
		3	12.2%	1.5	18	11	11	NA	40	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	0%	158	88	41	59	7,380	31	1.6	2.0%	$308	$2,533	-$32
		4	12.2%	1.0	22	11	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	122	53	33	49	12,473	0	0.1	3.8%	$379	$2,579	-$152
		5	12.2%	0.6	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	75%	108	38	19	42	11,029	0	0.1	8.3%	$558	$2,689	-$226
	6	BCBC	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.0%	n/a	$2,606	-
		1	12.2%	3.5	18	17	0	NA	50	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	213	143	71	89	7,439	51	2.6	0.5%	Negative NPV but no GHG reduction	$2,618	-$12
		2	12.2%	2.5	18	11	11	NA	50	HG-avg-Triple	1.2	GasInstantaneous	0%	basefurnace	60%	176	106	55	71	7,408	38	2.0	2.0%	$240	$2,659	-$32
		3	12.2%	1.5	18	11	11	NA	40	HG-avg-Triple	1.2	HPHotWater	0%	basefurnace	60%	165	96	63	71	9,276	27	1.5	2.6%	$301	$2,673	-$70
		4	12.2%	1.0	22	11	11	NA	60	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	70%	139	69	49	64	14,168	0	0.2	3.6%	$363	$2,699	-$178
		5	12.2%	0.6	60	25	30	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	84%	109	39	19	42	11,140	0	0.1	14.1%	$758	$2,974	-$376
	7a	BCBC	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	256	187	104	105	7,507	67	3.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	18	20	0	NA	60	MG-i89-Double	1.6	BaseDHW	0%	basefurnace	0%	257	187	104	105	7,507	67	3.4	0.6%	Negative NPV but no GHG reduction	$3,495	-$19
		2	12.2%	2.5	24	11	11	NA	100	HG-avg-Triple	1.2	GasInstantaneous	0%	baseboard	60%	182	112	67	78	14,140	16	0.9	3.3%	$403	$3,589	-$196
		3	12.2%	2.5	40	20	30	NA	50	HG-avg-Triple	1.2	HPHotWater	0%	baseboard	60%	161	92	70	73	16,446	0	0.2	6.9%	$557	$3,715	-$355
		4	12.2%	0.6	40	11	11	NA	100	HG-i89-Triple-B	0.8	HPHotWater	0%	baseboard	75%	141	71	49	63	14,334	0	0.2	7.7%	$512	$3,742	-$329
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7b	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	284	214	128	110	7,557	77	3.9	0.6%	Negative NPV but no GHG reduction	$3,495	-$19
		2	12.2%	1.5	60	11	20	NA	100	HG-avg-Triple	1.2	Combo	0%	ComboHeatA	70%	184	114	61	67	7,732	40	2.1	9.3%	$739	$3,801	-$269
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	BCBC	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.0%	n/a	$3,476	-
		1	12.2%	3.5	22	20	0	NA	60	MG-HP-Double	1.4	BaseDHW	0%	basefurnace	0%	309	239	150	115	7,602	86	4.4	0.6%	Negative NPV but no GHG reduction	$3,495	-$19
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

7.12 Impact of 8hr vs. 24hr Ventilations Rates on Part 9 Buildings

10 Unit MURB

CZ	Vent. Modelled	WWR	Airtightness ACH	Foundation R-Value	Underslab R-Value	Floor R-Value	Wall R-Value	Roof R-Value	Window USI	Space Heating	DHW System	Vent. Heat Recovery (%)	Drainwater Heat Recovery (%)	MEUI (kWh/m2)	TEDI (kWh/m2)	Annual Elec. (kWh)	Annual NG (m3)	Annual GHGs (t)	Step Achieved
4	24 hrs	0.2	3.5	11	0	27	16	40	1.8	Elec. BB	NG 67%	None	None	60	39	113,670	2,787	7.0	1
4	8 hrs	0.2	3.5	11	0	27	16	40	1.8	Elec. BB	NG 67%	None	None	51	32	98,190	2,787	6.8	1
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*18%*	*20%*	*16%*	*0%*	*3%*	
5	24 hrs	0.2	0.6	16	15	27	30	80	1.6	Elec. BB	HP COP2.3	84	55	26	16	85,281	-	1.3	4
5	8 hrs	0.2	0.6	16	15	27	30	80	1.6	Elec. BB	HP COP2.3	84	55	23	16	80,517	-	1.2	4
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*13%*	*0%*	*6%*	*0%*	*6%*	
5	24 hrs	0.2	1.5	25	11	27	30	80	0.8	Elec. BB	NG 80% Tankless	84	55	29	10	66,575	2,321	5.4	4
5	8 hrs	0.2	1.5	25	11	27	30	80	0.8	Elec. BB	NG 80% Tankless	84	55	26	10	61,713	2,321	5.3	4
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*11%*	*1%*	*8%*	*0%*	*1%*	
6	24 hrs	0.2	0.6	25	20	29	24	100	1	Elec. BB	NG 67%	70	55	31	12	70,056	2,381	5.6	4
6	8 hrs	0.2	0.6	25	20	29	24	100	1	Elec. BB	NG 67%	70	55	27	11	62,874	2,382	5.5	4
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*16%*	*14%*	*11%*	*0%*	*2%*	
7b	24 hrs	0.2	0.6	20	20	40	40	100	1.2	NG ECM Furnace 95%	NG 80% Tankless	84	55	50	30	49,996	7,346	14.8	4
7b	8 hrs	0.2	0.6	20	20	40	40	100	1.2	NG ECM Furnace 95%	NG 80% Tankless	84	55	46	29	45,249	7,116	14.2	4
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*9%*	*5%*	*10%*	*3%*	*4%*	
8	24 hrs	0.2	1	20	20	40	40	100	1.2	NG ECM Furnace 95%	HP COP2.3	84	55	65	55	59,895	8,744	17.6	3
8	8 hrs	0.2	1	20	20	40	40	100	1.2	NG ECM Furnace 95%	HP COP2.3	84	55	79	65	42,609	10,433	20.5	2
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*-17%*	*-16%*	*41%*	*-16%*	*-14%*	
8	24 hrs	0.2	1.5	16	11	29	30	70	1.8	Elec. BB	HP COP2.3	84	55	99	89	207,350	-	3.0	1
8	8 hrs	0.2	1.5	20	11	29	30	70	1.8	Elec. BB	HP COP2.3	84	55	114	101	209,618	-	3.1	1
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*-13%*	*-12%*	*-1%*	*0%*	*-1%*	
													average % difference of sample	14%	8%	10%	1%	3%	
													maximum	18%	20%	16%	3%	6%	
													minimum	9%	0%	6%	0%	1%	

Large SFD

CZ	Vent. Modelled	WWR	Airtightness ACH	Foundation R-Value	Underslab R-Value	Floor R-Value	Wall R-Value	Roof R-Value	Window USI	Space Heating	DHW System	Vent. Heat Recovery (%)	Drainwater Heat Recovery (%)	MEUI (kWh/m2)	TEDI (kWh/m2)	Annual Elec. (kWh)	Annual NG (m3)	Annual GHGs (t)	Step Achieved
4	24 hrs	0.2	1	11	20	n/a	30	60	1.8	NG PSC Furnace 92%	NG 80% Tankless	None	55	57	48	8,331	2,707	5.3	1
4	8 hrs	0.2	1	11	20	n/a	30	60	1.8	NG PSC Furnace 92%	NG 80% Tankless	None	55	50	42	7,739	2,388	4.7	2
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*15%*	*16%*	*8%*	*13%*	*13%*	
4	24 hrs	0.2	0.6	25	15	n/a	16	80	1.2	CCASHP COP2.0	NG 67%	60	42	27	15	16,010	497	1.2	4
4	8 hrs	0.2	0.6	25	15	n/a	16	80	1.2	CCASHP COP2.0	NG 67%	60	42	25	14	14,987	497	1.2	4
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*8%*	*6%*	*7%*	*0%*	*1%*	
5	24 hrs	0.2	2.5	16	11	n/a	24	60	1.6	CCASHP COP2.0	HP COP2.3	60	55	36	29	25,532	-	0.4	3
5	8 hrs	0.2	2.5	17	11	n/a	24	60	1.6	CCASHP COP2.0	HP COP2.3	60	55	35	29	24,928	-	0.4	3
	Modelled ECMs are very similar												*% diff. btw 24 and 8 hr ventilation*	*3%*	*0%*	*2%*	*0%*	*2%*	
5	24 hrs	0.2	1	25	20	n/a	24	50	1.4	CCASHP COP2.0	HP COP2.3	84	42	29	22	22,143	-	0.3	4
5	8 hrs	0.2	1	25	20	n/a	24	50	1.4	CCASHP COP2.0	HP COP2.3	84	42	28	22	21,387	-	0.3	4
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*5%*	*1%*	*4%*	*0%*	*4%*	
8	24 hrs	0.2	1.5	20	11	n/a	40	70	1.6	NG PSC Furnace 92%	HP COP2.3	None	None	127	121	11,144	5,865	11.4	1
8	8 hrs	0.2	1.5	20	11	n/a	40	70	1.6	NG PSC Furnace 92%	HP COP2.3	None	None	111	106	10,446	5,148	10.0	1
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*14%*	*14%*	*7%*	*14%*	*14%*	
8	24 hrs	0.2	1	25	20	n/a	40	100	0.8	NG PSC Furnace 92%	NG 80% Tankless	84	55	78	68	8,544	3,737	7.3	2
8	8 hrs	0.2	1	25	20	n/a	40	100	0.8	NG PSC Furnace 92%	NG 80% Tankless	84	55	75	66	7,959	3,641	7.1	2
	Modelled ECMs are identical												*% diff. btw 24 and 8 hr ventilation*	*4%*	*3%*	*7%*	*3%*	*3%*	
													average % difference of sample	8%	7%	6%	5%	6%	
													maximum	15%	16%	8%	14%	14%	
													minimum	3%	0%	2%	0%	1%	

7.13 Terms and Acronyms

AHJ - Authority Having Jurisdiction

COV - City of Vancouver

ECM - Energy Conservation Measures

GHGI - Greenhouse Gas Intensity

NBC - National Building Code

HDD - Heating degree days

HOT2000 - An energy simulation and design tool used for low-rise residential buildings

HTAP - Housing Technology Assessment Platform

LEEP - Local Energy Efficiency Partnership

MURB – Multi-Unit Residential Building

NECB - National Energy Code of Canada for Buildings

NPV - Net Present Value

NRC - The National Research Council

NRCan - Natural Resources Canada

PHIUS - Passive House Institute of the United States

PTL - Peak Thermal Load

SFD - Single Family Dwelling

TEDI - Thermal Energy Demand Intensity

TEUI - Total Energy Use Intensity

VFAR - Vertical surface area to floor area ratio

WWR - Window-to-wall ratio

ZEBP - City of Vancouver Zero Emissions Building Plan

More information:

energystepcode.ca
bchousing.org