Complex Mechanical Retrofit Environmental Scan Summary

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This report was commissioned by the Engineers and Geoscientists BC with support from BC Hydro. The content is authored by RDH Building Science in collaboration with SES Consulting.

Contents

1 Introduction

Under the CleanBC Roadmap to 2030, the Government of BC is accelerating the adoption of the highest-efficiency standards for existing buildings for new space and water heating equipment by 2030, or earlier, where feasible. After 2030, all new space and water heating equipment sold and installed in B.C. is expected to be at least 100% efficient, significantly reducing emissions compared to current combustion technology. A policy approach that is under consideration is the development and administration of a "Point of Installation Standard" to be enforced through regulation that ensures that large complex mechanical system retrofits meet CleanBC policy objectives. The Province (via the Ministry of Energy, Mines and Low Carbon Innovation or EMLI) has done some initial work toward defining point of sale versus the point of installation regulatory pathways.

Engineers and Geoscientists BC secured funding from BC Hydro to support both registrants and the Province as we take the first steps toward operationalizing CleanBC's space and water heating equipment performance standards, and engaged RDH and SES (the Project Team) to this end. The scope of this work was to complete an environmental scan focused on more complex equipment retrofits in existing Part 3 buildings (i.e. point of installation standards). Dual fuel systems that use electric heat pumps as primary and gas or other combustion fuel as backup or top-up were a particular area of focus.

The Project Team completed an environmental scan of existing literature and resources to address the following specific topics:

- → Assessment of existing standards/policies that are relevant to mechanical system retrofits and the identification of potential gaps in these standards in meeting CleanBC policy objectives.
- → Compilation of best practices to ensure best outcomes for energy use and emissions in gas-electric hybrid systems, including controls/measures to maximize greenhouse gas reductions in dual fuel systems.
- → Compilation of tools and approaches to compare a building's energy to similar buildings (specific to space conditioning and water heating), to its past consumption, or to a reference performance level.
- → Established thresholds for mechanical system complexity that require the engagement of engineers for retrofitting (as opposed to those that can be installed with a permit from Technical Safety BC/municipality).
- → Existing best practices and/or approaches to assessing the Coefficient of Performance (COP) of mechanical systems.
- → Compilation of potential templates and/or content to inform the future creation of compliance documents.

This report summarizes the current best practices, standards, and policies related to complex HVAC system retrofits and lays the foundation for future phases of this work, which will include an Engineers and Geoscientists BC Practice Advisory and then Professional Practice Guidelines.

2 Environmental Scan Summary

This section summarizes the results of the environmental scan, beginning with the broadest policies and narrowing into the specifics of how mechanical system retrofits are currently designed and verified.

2.1 Existing Precedents for Regulation of Existing Buildings

Several jurisdictions in North America have enacted policies and regulations specific to existing buildings. Many have adopted total building performance targets for existing buildings, meaning that their compliance requirements align with overall building reporting (including Energy Use Intensity and Greenhouse Gas Intensity) tools, most typically Energy Star Portfolio Manager. Several have also developed specific requirements around mechanical system retrofits, either to ensure the use of efficient equipment during retrofits, to limit emissions, or both. Several relevant examples are described below, and a summary table of all the jurisdictions that were scanned is included in Appendix A.

City of Denver, CO:

The City of Denver has committed to eliminating greenhouse gas emissions by 2040, with the corollary that all existing buildings and homes are to be "net zero energy" by 2040, and that all existing commercial and multifamily buildings reduce their greenhouse gas emissions by 80% by 2040.

The Energize Denver ordinance[1], passed by Denver City Council in November 2021, establishes Energy Use Intensity (EUI) targets for larger existing buildings (i.e. 25,000 ft^2 and greater), based on use type. They must meet a final target by 2030, with interim targets in 2024 and 2027. The EUI targets are generated specifically for each building, with interim targets based on its 2019 actual EUI baseline and linear reductions toward the final target. Credits are offered for electrification and renewables.

The ordinance also codifies electrification requirements beginning in 2025 (with incentives prior to that date to encourage early adoption), requiring partial electrification when replacing gas-fired space and water heating and cooling equipment. This applies to all commercial and multifamily buildings regardless of size (but excludes single family dwellings, duplexes, and townhomes).

The staged electrification requirements are as follows:

- Beginning March 1, 2023, the permit process for replacing a unitary air conditioner or condensing unit, natural gas heating system, or natural gas water heater in commercial and multifamily buildings became the same as the permit process for heat pumps, effectively eliminating the 'quick permit' process that previously favoured the former types of equipment over heat pumps.
- Effective 2025, the electrification requirements are expanded to require an electric primary heating system for any exterior furnace equipment replacement;

[1] https://www.denvergov.org/Government/Agencies-Departments-Offices/Agencies-Departments-Offices-Directory/Climate-Action-Sustainability-Resiliency/High-Performance-Buildings-and-Homes/Energize-Denver-Hub

to require that unitary air conditioners be replaced by electric equipment that can also provide space heating, and to require that replacement water heaters be electric.

- Effective 2027, further expansion of the regulation will require that gas-fired boiler replacements (for space heating or domestic hot water heating) must include equipment that can meet at least 50% of space heating needs with electric space heating. If a replacement gas-fired boiler is installed for supplementary heat, the applicant must:
  - Submit an electrification feasibility report, which is completed using an online tool and must be attached to the permit application (a rebate is also available to complete this report with the assistance of a qualified professional such as an engineer or energy consultant). The report is intended to assess the practicality and cost impacts of switching from gas to electric equipment and will specify:
    - the estimated energy consumption of the gas and electric replacement systems
    - the estimated energy and carbon savings for switching to an electric system
    - the estimated energy bills with the gas and electric replacement systems
    - the estimated costs for installing a replacement gas and electric system
  - Get an analysis of the building envelope, ventilation requirements, and energy load prepared by a registered professional. Right sizing the equipment following the Denver Building and Fire Code is also required.
  - Pressure test all the natural gas piping in the building

Exemptions to the above requirements are allowed for emergency replacement or 'economic hardship', and financial penalties apply for non-compliance. It was not clear how the 50% of space heating needs would be calculated or documented.

Washington State

As a state, Washington has committed to a 45% reduction in GHG emissions by 2030; 70% reduction by 2040 and 95% reduction by 2050 relative to 1990 levels.[2]

As it relates specifically to existing buildings, Washington State's 2019 Clean Buildings Act (implemented as WAC 194-50 in October 2020) establishes energy performance standards for the largest existing buildings (> 50,000 ft^2). The Clean Building Expansion Act, passed into law in March 2022, extends the Act to apply to buildings over 20,000 ft^2 and to multifamily buildings. Similar to other jurisdictions, it uses Energy Star Portfolio Manager for benchmarking and disclosure, and similar to Denver, it uses building type specific total EUI targets to regulate existing buildings.

Washington State's regulation explicitly references (and adapts) ASHRAE 100, which in addition to setting EUI targets by usage type, also specifies a process for making

[2] https://ecology.wa.gov/air-climate/climate-commitment-act

improvements, including developing and implementing Energy Management and O&M Plans.

At this time, there are no stated GHGI targets specific to existing buildings and the most visible regulation (i.e., the Clean Buildings Act) promotes and relies on fuel agnostic energy efficiency as its primary means of achieving emission reductions. Having said that, though, there are several provisions in the Washington State Energy Code (based on the International Energy Conservation Code 2021 (IECC) with amendments) that impact emissions in existing buildings by limiting the types of fuels that can be used when replacing heating equipment.[3]

The requirements of this code state that replacement mechanical equipment must follow the same design procedures as new construction, meaning that:

- → Climate parameters, enclosure performance and interior operating conditions must be accounted for in the sizing of replacement HVAC equipment (section C501.2.2).
- → Altered portions of mechanical equipment must be commissioned consistent with new building commissioning requirements (section C501.6).
- → There are also requirements to determine the Total System Performance Ratio (TSPR)[4] for new construction, although existing buildings are exempt except for when the entire HVAC system is replaced. In the case of new construction, the HVAC TSPR must be greater than or equal to that of a reference building.

A notable Washington specific amendment to the IECC is the following:

- → Replacement heating equipment cannot use electric resistance or fossil fuel combustion equipment (section C403.1.4), except in specific circumstances including back up and frost protection for heat pumps (electric resistance permitted in these cases). Notably, fossil fuel backup is *only* permitted in climate zone 5 (not 4) and *only* for air-to-water heat pumps (not air-to-air heat pumps).

City of Seattle, WA

The City of Seattle is building on the State's energy performance standard with a proposed Building Emissions Performance Standards policy that will apply to existing commercial and multifamily buildings larger than 20,000 ft^2[5]. The proposed policy will set incrementally more stringent hard emissions limits leading to zero emissions for all building types by 2045 (except multifamily housing, which must hit the target by 2050). The City already requires benchmarking and disclosure of all existing buildings >= 20,000 ft^2, using Energy Star Portfolio Manager, so presumably this tool will also be used to track and report progress on emissions targets.

[3] https://up.codes/viewer/washington/wa-energy-code-commercial-provisions-2021/chapter/CE_5/ce-existing-buildings#CE_5

[4] Defined as "The ratio of the sum of a building's annual heating and cooling load in thousands of Btus to the sum of annual carbon emissions in pounds from energy consumption of the building HVAC systems"

[5] https://www.seattle.gov/environment/climate-change/buildings-and-energy/building-performance-standards

New York City:

In 2009, New York City (NYC) released their Greener Greater Building Plan (GGBP) which set goals for both new construction and existing buildings, with a goal of achieving 30% emission reductions by 2030. Local Law 97 came into effect in 2019, which requires most buildings over 25,000 ft^2 to meet new energy efficiency *and emissions* limits by 2024, with stricter limits applying in 2030 (40% reduction in emissions for 'covered buildings' by 2030; 80% by 2050).[6]

Similar to other US jurisdictions, the regulation thus focuses on overall building performance, leaving the specific methods and system-related choices up to individual building owners and operators.

In terms of thresholds, the regulation applies to any building equal to or greater than 25,000 ft^2. The compliance tools used include benchmarking, public labeling, annual reporting via Energy Star Portfolio Manager and periodic building audit requirements (every 10 years), documented using a customized DOE Audit Template (similar to an ASHRAE Level 2 audit).

The city has also enacted its own NYC Energy Conservation Code to close loopholes in New York State's Energy Conservation Construction Code, which allowed like-for-like replacements of mechanical equipment. Similar to the Washington code, it is based on the International Energy Conservation Code (2018).

The NYC code references section 5 of the IECC for existing buildings and includes many of the same provisions as the State of Washington's Code, with a couple of modifications:

- → It allows the use of ASHRAE 90.1-2016 as an alternate compliance path for Alterations.
- → It does not include C403.1.4 which appears to be a Washington State specific provision to restrict the use of fossil fuels and electric resistance heating. Instead, it references minimum efficiency requirements for various types of equipment (C403.3.2).

Summary of Jurisdictions Outside Canada

The jurisdictions described above illustrate several paths that may prove useful to both the Province in developing its own compliance paths, and Engineering and Geoscientists BC in developing best practices and guidance for registrants. All jurisdictions profiled rely on total building performance and targets to improve efficiency of their existing buildings. Denver is very explicit with phased electrification requirements that will impact replacement equipment for heating, cooling, and domestic hot water heating. New York City sticks with the overall building targets and is silent on emissions or electrification as directly applied to equipment replacement. Washington State threads a middle ground, where its most public-facing policy focuses on energy efficiency, while its less visible but

[6] https://www.nyc.gov/site/sustainablebuildings/ll97/local-law-97.page and https://www.nyc.gov/site/buildings/codes/greenhouse-gas-emission-reporting.page

fundamental Energy Conservation Code limits when and how electric resistance and fossil fuel based heating and domestic hot water heating equipment can be used.

Denver appears to be the only jurisdiction scanned for which there is any kind of hybrid system performance requirement, with its 50% electrification requirement, but there is not yet any readily available guidance on how that is to be determined or documented. While it is not yet clear how Denver will verify compliance, it could choose to use its benchmarking program to demonstrate a 50% drop in building gas consumption following a retrofit, with some potential complications. Washington State is more prescriptive in allowing electric resistance or fossil fuel backup in only well-defined circumstances.

2.1.1 Federal Alterations Code for Existing Buildings (AEB)

The Pan-Canadian Framework on Clean Growth and Climate Change states a specific goal as it relates to existing buildings to "develop a model code for existing buildings to help guide energy efficiency improvements during renovations, with the goal that all provinces and territories adopt it."

The Province of BC has signaled a desire to harmonize with the federal Alterations to Existing Buildings (AEB) code, although the timing for release of this code is currently unknown. To date, the Joint Task Group has published a list of overarching principles that are intended to guide the development of technical requirements[7]:

1. Closing the performance gap between the current code and the existing building stock
2. Maintaining or increasing the life safety and overall building performance level (an alteration cannot make the building worse)
3. Avoiding negative unintended consequences or unrealistic expectations
4. Ensuring that when a repair, maintenance or alteration is in progress, the building cannot be left in an unsafe state.
5. All regulatory measures should be reasonable, pragmatic and effective (applying Smart Regulation principles).
6. Requiring flexibility so as to encourage alterations to existing buildings rather than placing an undue burden on owners, which could inspire them to avoid alterations altogether or turn to the "underground economy".
7. Requiring flexibility so as to preserve officially recognized (designated/registered) heritage elements.
8. Regulatory measures and voluntary programs should complement each other.

As far as the Project Team is aware, the current intention is to focus on energy efficiency and remain silent on fuel types, consistent with the national model codes for new construction. If this is the case, it is unlikely that the federal model code will provide guidance on whether a gas appliance can be used for primary heating and if it is used for backup or supplementary heating, how it must be controlled or commissioned.

[7] https://nrc.canada.ca/en/certifications-evaluations-standards/codes-canada/codes-canada-publications/final-report-alterations-existing-buildings

2.1.2 BC Context

CleanBC has stated that after 2030 all new and replacement space and water heating systems must be 100% efficient. This requirement could technically be met by electric resistance equipment, electric heat pump equipment, natural gas heat pumps, and hybrid solutions.

Vancouver

Vancouver has committed to implementing changes to the Vancouver Building Bylaw (VBBL) banning emission producing space and water heating equipment by 2025 for new or replacement equipment. For new low-rise residential buildings, this change to the VBBL was effective on January 1, 2022[8]. This change mandates the use of electric equipment for heating or domestic hot water, except where stringent limits to overall building GHGi are met (e.g. Passive House) or when used in conjunction with electric heat pumps. Compliance with these requirements is determined on the basis of building energy models submitted with the building permit application.

For existing buildings, starting in 2026, office and retail buildings larger than 100,000 ft^2 will be required to keep annual greenhouse gas emissions below a GHG intensity limit. This limit will be based on the amount of natural gas and district energy used per unit of floor area multiplied by the carbon pollution impacts of those energy sources. The limits are proposed to apply to remaining commercial buildings and strata buildings in 2030, and to purpose-built rental buildings in 2035[9]. The main objective of the GHGi limit is to reduce emissions from the largest sources (heating and hot water) while transitioning to low-carbon and renewable energy sources[10]. Buildings that exceed the GHG intensity limits will be subject to a fine equivalent to $350/tonne of CO_2 above the allowable limit. This fine is set high enough to encourage buildings to come into compliance by retrofitting inefficient gas fired systems or investing in energy efficiency. Owners may be able to leverage incentives from BC Hydro, CleanBC, and FortisBC to offset the costs of these upgrades.

The City's plan calls for increasingly stringent emissions intensity limits over time, eventually reducing to 0 emissions before 2040. The scope of the City's regulations will include emissions related to on-site combustion of fossil fuels or district energy connections that use fossil fuels as a heat source. Gas uses that are not associated with building heating and hot water, such as commercial kitchens, will initially be excluded from the limit. The proposed regulation also sets limits for natural gas use (regardless of carbon intensity) to encourage efficiency. Emissions related to electricity are likely to be exempt from these regulations. The proposed limits for large commercial buildings and phase in dates are as follows:

- 2026 – GHG Intensity limit of 25 kg/m²/year
- 2040 – GHG Intensity limit of 0 kg/m²/year, Heat Energy Use Limit of 0.09 GJ/m²/year

[8] Zoning Amendments to support the Climate Emergency Response. 2023. Online [available] < https://vancouver.ca/green-vancouver/zoning-amendments-to-support-climate-emergency.aspx>
[9] https://council.vancouver.ca/20220517/documents/R1c.pdf
[10] Report, Annual Carbon Pollution Limits for Existing Large Commercial and Multifamily Buildings. 2022. Online [available] < https://council.vancouver.ca/20220517/documents/R1c.pdf>

Enforcement of these limits will be via mandatory benchmarking of building energy use information through Energy Star Portfolio Manager (ESPM). The city is currently in the process of determining requirements for validating the data entered into ESPM, and whether exemptions or alternate compliance pathways will be permitted. As currently envisioned, validation of building data by a qualified professional will be required as part of the certification process. Overlapping proposed regulation by other jurisdictions, the Province of BC and Metro Vancouver, may also affect how the proposed future limits are phased in as regulators seek to avoid duplication or conflicting requirements.

The City of Vancouver has also introduced a "mechanical permit", a new type of trade permit required for installation of heating and cooling systems where the fuel type is changed. This permit is intended primarily to regulate the installation of heat pumps systems and fill a gap on projects where building permits are not required. The permit requires installation of these systems to be overseen by a certified individual who may be a gas fitter, plumber, HVAC Refrigeration mechanic, or electrician. Performance verification of heat pump systems is not currently required under the permit, but it does provide a mechanism that could, in theory, be used by an AHJ in the future to enforce specific heat pump installation requirements.

Metro Vancouver

Metro Vancouver is currently considering Carbon Pollution limits through its delegated authority to regulate air pollution. The proposed approach aligns with regulatory best practices from jurisdictions across North America and with the City of Vancouver's Annual Greenhouse Gas and Energy Limits Bylaw. Applicable to existing large buildings (over 25,000 ft^2), the proposed requirements and intended supports include the following:

- → Annual GHG emission reporting requirements for building owners
- → Setting and phasing-in increasingly stringent GHG emission limits tailored to building types to achieve zero emissions by 2050
- → Developing compliance pathways for building owners to achieve compliance with emission limits
- → Providing exemptions and flexibility for certain building types or circumstances
- → Establishing program fees to encourage emission reductions and recover program costs fairly and efficiently
- → Providing technical support to building owners

Metro Vancouver is developing a regulatory intentions paper informed by engagement feedback collected in 2022 and will be seeking Board direction to conduct a second phase of engagement on the more detailed approach. As the City of Vancouver falls within Metro Vancouver's jurisdiction, a high degree of coordination between authorities will be required to ensure that there is no conflict between their respective bylaws.

2.2 Current Practice for Complex Mechanical System Retrofit Design and Verification

To understand how practices and policies may need to evolve within BC, it is useful to first outline how complex mechanical retrofits are currently designed, installed and verified. The approach taken, and whether or not an engineer is involved, typically aligns with the real or perceived level of complexity of the retrofit, as determined by the building owner, and/or explicit permitting requirements.

Design

For "Like-for-Like" retrofits, engineer involvement is less common. An engineer would typically only be engaged in these projects based on the following owner driven requirements:

- → Policy to have detailed design/drawings for every project
- → 3rd party verification of installation and operation
- → A strict procurement process that requires a detailed design for soliciting contractor bids or proposals.

In "Like-for-Similar" retrofits, engineer involvement is more common than "Like-for-Like" situations, but still not universal. Examples of like-for-similar retrofits would include replacing conventional boilers with high efficiency boilers, replacing packaged gas fired roof top units with heat pump roof top units, etc. Engineer involvement is more common in these retrofits where it involves major pieces of equipment such as boilers or chillers, and less common for packaged units (RTUs, split AC/Heat Pumps, furnaces, etc.). The owner considerations driving engineer involvement are similar to those for "Like-for-Like" replacements.

Engineer involvement is typical when the retrofit involves a significant change to the system type, or when there are changes required to piping or HVAC distribution. Examples of retrofits that would typically involve an engineer include changes to piping; the addition of an ASHP to central heating system; heat recovery chiller installation, etc. Projects of this nature are also being driven by a need to add cooling to buildings that previously had none, with owners taking the opportunity to install new heat pump equipment that can provide both cooling and low carbon heating. Aside from straightforward equipment swaps, nearly every project involving changes to hydronic heating or cooling systems would typically involve an engineer. Many of these projects would also involve multiple engineering disciplines including mechanical, electrical, and structural. Project value is also a consideration, with larger value projects somewhat more likely to have an engineer involved, even for relatively simple scopes.

These projects may also trigger building/development permits, which require submissions by an engineer and/or architect. Typical triggers for these permits include the addition of new rooftop equipment, alterations to life safety systems, or new penetrations in roof/exterior walls. The Architects Regulation lays out where the services of Architects are required to be engaged. Other trade permit types, such as plumbing or mechanical (City of Vancouver), may require submissions by an engineer as part of the permitting process.

The design process for retrofits follows standard practices that depend on factors such as the extent of the retrofit and the complexity of the systems. Retrofits that are mechanical only tend to be designed based on guidance provided by handbooks, industry provided sizing tools, and practitioner experience. More complicated "deep retrofits" that include system interactions (e.g., changes to building envelope affecting peak building loads) will usually involve the use of industry standard energy modelling tools.

Some practitioners are beginning to make use of real performance data, either gathered from data loggers, or from a facility's building automation system, to inform equipment selection and sizing. These data are particularly valuable for complex systems that may involve the use of heat recovery and multiple heating sources, or in cases where industry standard guidance on sizing is based on out of date or incorrect assumptions (e.g., domestic hot water consumption). At present, this practice is in limited use and mainly by engineers who have expertise in retrofits, operations, and building automation.

Verification

The verification phase of retrofits also follows mostly standard practices that include the following:

- Field reviews to verify that installation meets the design requirements. Where an engineer is involved in the design, they cannot provide final sign off/Letters of Assurance without field verification.
- Issuing of deficiency lists
- Review of contractor provided submittals which include items such as:
    - Commissioning reports, which are typically limited to functional testing of new equipment.
    - Air and water balancing reports
    - Shop drawings and equipment cut sheets
    - Contractor led training sessions for building operations staff
    - Warranty certificate
- Issuing Letters of Assurance if project involved building permits

The engineers' involvement typically ends with project completion when all outstanding deficiencies have been resolved and any building or trade permits have been closed.

A small number of projects will require performance commissioning, to ensure that new equipment achieves expected performance outcomes, and/or the use of 3rd party commissioning providers. These activities are typically undertaken only in cases where required by certain 3rd party green building certification programs (e.g., LEED). Engineer involvement in post project activities such as deferred seasonal testing and monitoring and verification is still rare, unless these activities are required by the project to meet 3rd party certification standards.

Gaps Specific to Heat Pump Retrofits

Heat pump retrofits typically do not adequately make use of available building performance data in their design approach, instead relying on more traditional

approaches to equipment sizing that use existing equipment sizing, handbook values, or load calculation software. All of these typical approaches to sizing are inherently conservative and do not take into account factors such as heating water temperatures. The consequences are that many low carbon heating systems are not sized properly or may not be compatible temperature-wise with the existing HVAC distribution system they are serving. Viable projects may also be dismissed as a result of overly conservative assumptions leading to high costs.

The lack of performance verification and ongoing commissioning in most projects also leads to underperforming equipment. In HVAC systems, especially more complex systems that may involve multiple heating sources working together, small changes to setpoints and settings can dramatically affect equipment performance. Ongoing engineer involvement, or the establishment of a robust ongoing commissioning process, is essential for ensuring continued performance of low carbon heating systems.

Enhanced Commissioning (Cx) requirements are present in some jurisdictions, though more commonly with new buildings. The City of Vancouver is currently exploring these requirements. These tend not to be specific to low carbon systems, but could be tweaked to add specific requirements.

2.3 Existing Precedents for Dual Fuel Systems

As mentioned previously, Denver's regulation implies a dual fuel approach but does not provide details for how to achieve or demonstrate compliance. The 2021 Washington State Energy Code – and specifically its amendments to the IECC upon which it is based – is the only precedent the environmental scan uncovered that provided explicit direction on fuel use. Relevant sections (for Part 3 dual fuel retrofits) are excerpted below.

The 2021 Washington State Energy Code – Commercial Provisions[11], section C403.1.4 (applicable to existing buildings when heating equipment is replaced, emphasis added), states:

"HVAC heating energy shall not be provided by electric resistance or fossil fuel combustion appliances. For the purposes of this section, electric resistance HVAC heating appliances include, but are not limited to, electric baseboard, electric resistance fan coil and VAV electric resistance terminal reheat units and electric resistance boilers. For the purposes of this section, fossil fuel combustion HVAC heating appliances include, but are not limited to, appliances burning natural gas, heating oil, propane, or other fossil fuels.

EXCEPTIONS:

1. **Defrost.** Heat pumps are permitted to utilize electric resistance heating when a heat pump defrost cycle is required and is in operation.
2. **Air-to-air heat pumps.** Buildings are permitted to utilize internal electric resistance heaters to supplement heat pump heating for air-to-air heat pumps that meet all of the following conditions:
    1. *Internal electric resistance heaters have controls that prevent supplemental heater operation when the heating load can be met by the*

[11] https://up.codes/viewer/washington/wa-energy-code-commercial-provisions-2021/chapter/CE_5/ce-existing-buildings#CE_5

heat pump alone during both steady-state operation and setback recovery.

2. *The heat pump controls are configured to use the compressor as the first stage of heating down to an outdoor air temperature of 17˚F (-8˚C) or lower except when in defrost*.

3. The heat pump complies with one of the following:

    1. Controlled by a digital or electronic thermostat designed for heat pump use that energizes the supplemental heat only when the heat pump has insufficient capacity to maintain set point or to warm up the space at a sufficient rate.

    2. Controlled by a multistage space thermostat and an outdoor air thermostat wired to energize supplemental heat only on the last stage of the space thermostat and when outdoor air temperature is less than 32˚F (0˚C) except when in defrost.

    3. The minimum efficiency of the heat pump is regulated by NAECA, its rating meets the requirements shown in Table C403.3.2(2), and its rating includes all usage of internal electric resistance heating.

4. *The heat pump rated heating capacity is sized to meet the heating load at an outdoor air temperature of 32˚F (0˚C) or lower and has a rated heating capacity at 47˚F (8˚C) no less than 2 times greater than supplemental internal electric resistance heating capacity in Climate Zone 4 and no less than the supplemental internal electric resistance heating capacity in Climate Zone 5, or utilizes the smallest available factory-available internal electric resistance heater*.

3. **Air-to-water heat pumps.** Buildings are permitted to utilize electric resistance (for Climate Zone 4 or 5) or fossil fuel-fired (for Climate Zone 5) auxiliary heating to supplement heat pump heating for hydronic heating systems that meet all of the following conditions:

    1. Controls for the auxiliary electric resistance or fossil fuel-fired heating are configured to *lock out the supplemental heat when the outside air temperature is above 36˚F (2˚C), unless the hot water supply temperature setpoint to the building heat coils cannot be maintained for 20 minutes*.

    2. *The heat pump controls are configured to use the compressor as the first stage of heating down to the lowest exterior design temperature for which the equipment is rated except during startup or defrost operation*.

    3. *The heat pump rated heating capacity at 47˚F (8˚C) is no less than 75 percent of the design heating load at 29˚F (-2˚C).*

4. **DOAS ERV auxiliary heat.** *Dedicated outdoor air systems with energy recovery ventilation are permitted to utilize fossil fuel for Climate Zone 5 or electric resistance in Climate Zone 4 or 5 for auxiliary heating to preheat outdoor air for defrost or as auxiliary supplemental heat to temper supply air to 55˚F (13˚C) or*

lower for buildings or portions of buildings that do not have hydronic heating systems.

3 Recommendations

Based on the environmental scan, the Project Team has identified possible paths to achieve and document compliance with CleanBC, and specifically to ensure hybrid systems meet the 100% minimum efficiency policy intent in practice. Commentary on strengths, weaknesses, and limitations of each approach are also provided.

Achieving and Documenting Compliance

1. **Require involvement of an engineer** – This would be applicable to projects involving full or partial fuel switching of a space heating or domestic hot water system, except packaged units (e.g. RTUs, PTAC/HP, furnaces, split units, etc.) which would be covered by point of sale regulations. This requirement could potentially be included in the BC Building Code and enforced through existing permitting processes at the municipal level, through the creation of new permits applicable to fuel switching (such as the City of Vancouver's Mechanical Permit), or through changes to Technical Safety BC's mandate to include these kinds of systems.

2. **Model performance ahead of time** – A modeled approach likely makes sense for a comprehensive deep retrofit that includes enclosure and multiple system updates but would be a challenging approach to apply to system-specific mechanical retrofits without adding significant cost to a project. There is currently no standard approach to modelling equipment only.

   Because the ultimate performance of hybrid systems is so dependent on the way the system is commissioned and controlled, a modeled approach would ideally be paired with some form of post-install verification to ensure modeled outcomes were achieved.

3. **Document performance post-install** – One could measure energy in vs energy produced over some period of time post-install to document compliance. The difficulty with this approach is that AHJs usually have no jurisdiction once permits are closed off so a new reporting mechanism/procedure would need to be developed, as well as a follow up process if performance fails to meet the criteria. The equipment required to perform such measurements is also expensive and complex to install.

   Reporting overall building GHGi as a means of documenting performance could be a simpler option than regulating system performance. A building specific target could be established based on the current system efficiency and the 100% requirement when systems are replaced. ESPM, as used by all other jurisdictions that have pursued a total building performance path, is a well-established tool to facilitate this process.

   This could also be an alternate compliance path for jurisdictions (including Metro Vancouver and the City of Vancouver) that are already pursuing an overall

building performance path and for which GHGi targets effectively achieve the same outcome of decarbonization.

The challenge with this approach would be linking targets and reporting requirements to time of replacement rather than to overarching building performance timelines. There is also a time lag between design/installation and verification, and verification and reporting will require the new equipment to be fully commissioned and ideally operate for a full year to demonstrate savings.

As noted in Metro Vancouver's proposed regulation, developing compliance pathways for building owners, and possibly providing tools to estimate the GHGi impact of the proposed retrofit, would be important to give building owners some assurance that their retrofit plan will comply with all applicable regulations. This path would ideally also be paired with requirements for system commissioning to ensure optimal performance is achieved.

4. **Prescriptively restrict the use of gas equipment, paired with requirements for system commissioning**. The requirement could reference an updated CSA Z5001:20 Existing Building Commissioning for energy using systems[12] with content around requirements for hybrid systems. Similar to the Washington approach, criteria for allowing use of backup boilers could be customized to suit the province's goals, and include requirements such as limits to the OAT in which it could operate; controls sequences to ensure the heat pumps always operated as first stage and were designed in a manner to be capable of satisfying 50%+ of the building's heating energy requirements; detailed Cx requirements; requirements to develop ongoing performance plans, etc, The commissioning could be required (and signed off by the engineer) before the final inspection by the AHJ.

   This approach would ensure the systems are initially set up optimally and would provide a means of verification through the normal permitting process, which in turn removes the added jurisdictional complication of validating performance after the fact.

Process/Framework

With respect to developing a practice advisory, practice guidelines or similar best practice documents to benefit registrants as they undertake compliant complex retrofit projects in the future, below is a possible process.

1. Assessment of existing system as well as how it integrates into the overall building, including consideration of other needed or planned upgrades such as enclosure that may impact the mechanical options, sizing, and installation details.
   a. Include verification/testing of any ductwork (for insulation where needed, leaks) or piping that will be re-used
2. Evaluation of equipment alternatives, including assessment of relative efficiencies
3. Proper equipment sizing, including heat loss/gain calculations
4. Verification and documentation that equipment meets minimum performance specifications, policies etc.

[12] https://www.csagroup.org/store/product/csa%20z5001:20/

5. Development of a performance specification and/or bid documents, including drawings and equipment schedules
6. Installation quality assurance and commissioning
7. Building operator training

4 Next Steps

This report summarizes the current best practices, standards, and policies related to complex HVAC system retrofits and lays the foundation for future phases of this work, which are proposed as follows:

1. Develop a proposal to incorporate a 'building commissioning for low carbon heating systems' section into Canadian Standards Association (CSA) Standard Z5000-18 – Building commissioning for energy using systems. The performance of hybrid systems is highly dependent on how the system is set up and controlled, and given this, a common thread to all the identified pathways is the recommendation to ensure new systems are properly commissioned. The CSA provides a well-defined framework for developing this guidance.
2. Develop an Engineers and Geoscientists BC Practice Advisory that focuses on engineering approaches to building retrofits that can meet existing regulations, specifically the City of Vancouver's Annual Carbon Pollution Limits for Existing Large Commercial and Multifamily Buildings. This practice advisory should also address the role and obligations of engineers in certifying the accuracy of data being submitted by building owners to the City of Vancouver as part of annual energy and carbon reporting requirements. This advisory can then serve as a template for aligning with additional regulations as these are rolled out in the future.
3. Continue to collaborate with the Province, Metro Vancouver and the City of Vancouver to ensure that any guidance developed for registrants of Engineers and Geoscientists BC is aligned with current and anticipated policy.

We look forward to contributing to the advancement of this work with Engineers and Geoscientists BC, other project partners, registrants and stakeholders.

Yours truly,

Christy Love | P.Eng., CPHC
Principal, Energy & Climate Specialist
clove@rdh.com
T 778-557-7042
RDH Building Science Inc.

Brad White | P.Eng., MASc
President
brad@sesconsulting.com
T 604-568-1802
SES Consulting

Riley Doyle
Building Science Engineer (EIT)
rdoyle@rdh.com
T 778-370-6972
RDH Building Science Inc.

encl.

Appendix A: Jurisdiction Scan Summary

Jurisdiction	Policy	Summary of requirement	Means of compliance	Requirements specific to mech systems retrofits?	Description	Compliance path	Enablers
Denver	Energize Denver Ordinance (2021)	All existing buildings and homes "net zero energy" by 2040 All existing commercial and multifamily buildings reduce their GHG emissions by 80% by 2040 Phased EUI targets - 2024, 2027, final targets by 2030 (includes electrification credits and renewables credits)	Energy star portfolio manager annual disclosure (total EUI, GHGI)	Y	Phased electrification requirements: 2023: removal of 'quick permit' process for unitary AC and gas based heating and DHW equipment 2025: exterior furnace equipment retrofits must be electric primary; no more unitary AC equipment; water heaters must be electric 2027: all retrofits will require 50% of space heating and DHW needs to be met by electric	Every building >25,000 SF is sent a letter with their unique target (based on usage type) - can apply for adjustments as needed - or use Performance Requirements Look Up Tool Consitent permit path required for all HVAC equipment replacements Electrification feasibility report required if replacement equip for heating and DHW will include gas-fired backup, completed by a qualified professional Third party verification (by a qualified "data verifier" - PE, Registered Architect, CEM etc) required	Incentives for desired eqquipment and early adopters Rebates for electrification feasiblity report EUI 'credit' for early electrifiers (80% by 2030) Financial penalties for non-compliance
State of Washington	Climate Commitment Act, Jan 2023, to achieve 95% emissions reduction by 2050 (https://ecology.wa.gov/air-climate/climate-commitment-act) 2019 Clean Buildings Act (implemented as WAC 194-50 in Oct 2020) - commercial blgs > 50,000 SF (Tier 1) Clean Building Expansion bill passed into law March 2022 - applies to buildings 20,000 SF + and multifamily bldgs (Tier 2)	Energy performance standards for commercial buildings larger than 50,000 SF, mandatory as of 2026, using ASHRAE 100 as a base to establish EUI targets by building type	Benchmarking, energy management plans, O&M plans for Tier 2 required starting 2027; targets to be met by 2030 (pending confirming legislation) Tier 1 buildings phased in by size between 2026 and 2028 Emissions related rules not evident yet (although Cap-and-Invest program is in development)	Indirectly (see energy code item below)	Energy management plans, audits and O&M plans are part of the submission requirements, alhtough these requirements retain flexibility in solutions	Submit plans + audit documentation in addition to ESPM reporting	Incentives in years prior to mandatory compliance
	2021 Washington State Energy Code, based on IECC 2021 with amendments, includes Chapter 5: Existing Buildings https://up.codes/viewer/washington/wa-energy-code-commercial-provisions-2021/chapter/CE_5/ce-existing-buildings#CE_5			Y	Load calculation requirements; limitations on use of electric resistance or fossil fuels for replacement heating and DHW equipment; commissioning requirements		
City of Seattle	Building Emissions Performance Standards policy (proposed)	Existing building total emissions limits, ratcheting down to net zero by 2045 or 2050 Bnechmarking and reporting (via Energy Benchmarking Law) requires tracking and reporting of all buildings >=20,000 SF, using Energy Star Portfolio Manager		N			Seattle Clean Buildings Accelerator - no cost technical support (for the State Clean Buildings Act)
New York City	Greener Greater Building Plan (2009)	Annual benchmarking and disclosure required annually, using Energy Star Portfolio Manager (bldgs >50,000 SF) Large bldgs must complete energy audit every 10 yrs + do retro-commissioning, or undertake pre-approved energy eff measures in lieu of audit (for bldgs w simple systems)	Benchmarking and labeling Energy Star Portfolio Manager annual disclosure (total EUI, water consumption) ASHRAE Leve 2-type Audit every 10 years	Y	Local New York City Energy Code to eliminate state code's loophole that allows like-for-like replacements (applies to all renovations)		Design and fund Green workforce training Established pilot revolving loan fund
San Francisco	Climate Change Action Plan 2021 Existing Building Energy Performance Ordinance (2011) https://sfenvironment.org/existing-buildings-energy-performance-ordinance Renewable Electricity for Large Commercial Buildings	By 2035, zero onsite fossil fuel emissions from all large existing commercial buildings	Not clear how zero emissions piece will be rolled out Benchmarking using Energy Star Portfolio Manager Professional audits for non-res bldgs > 10,000 SF every 5 years; benchmarking for res bldgs > 50,000 SF (DOE Audit Template or a "Strategic Decarbonization Assessment")	N	Largest commercial buildings must obtain 100% renewable electricity - comply by subscribing to clean power suppliers No real specifics for existing buildings	Energy Audit (every 5 yrs) must be completed by a Qualified Professional (Licensed Engineer + 2 yrs audit experience or commissioning OR BEAP, CPMP, CEM, EBCP, CBCP, EMP (all existing building energy credentials) + at least 2 yrs auditing or commissioning experience OR qualified Building Operator (certification + experience) Also a list of firms that are credentialed	
San Francisco	2022 San Francisco Existing Building Code (adopts CEBC 2022 with amendment)			N			
State of California	California AB802 California Existing Building Code (CEBC 2022), based on International Building Code	commercial and multifamily bldgs >=50,000 SF must benchmark energy use and report annually CEBC doesn't seem to touch on anything we're talking about here					
International	International Energy Conservation Code (chapter 5 - existing buildings)		Code only applies when you choose to do something to your building - repair, alteration, change of occupancy, addition to and relocation of existing buildings Prescriptive or performance path (more of a scoring method) options focus on minimum public health, safety and wellfare	Y	See Washington State and NYC examples for local adoption/amendment		
Federal	Alterations Code for Existing Buildings	Not released yet so unknown	Triggered by voluntary upgrades				
Metro Vancouver	Metro Vancouver Clean Air Plan 2021	Regulatory intentions document to regulate emissions in buildings - will create a cap; mandatory reporting + target TBD					
City of Vancouver	2022 VBBL Updates	Part 3: 2026: GHGi limits come into effect for commercial office and retail buildings ≥ 9,290 m2 (100,000 ft2): Office = 25 kg CO2e/m2/year Retail = 14 kg CO2e/m2/year 2040: GHGi limits come into effect for commercial office and retail buildings ≥ 9,290 m2 (100,000 ft2): Office and retail = 0 kg CO2e/m2/year 2040: Heat energy limit for commercial buildings ≥ 9,290 m2 (100,000 ft2): 2040: Office and retail = 1.09 GJ/m2/year		Y	Indirectly through heat energy and GHGi limits		Climate Emergency Response.