International Energy Agency

EBC Working Group Final Report: Scan of Code Requirements to Address Greenhouse Gas Emissions

Energy in Buildings and Communities Technology Collaboration Programme

June 2023

Technology Collaboration Programme
by iea

Published by the Pacific Northwest National Laboratory, operated by the Battelle Memorial Institute for the U.S. Department of Energy, P.O. Box 999, Richland, WA 99352.

Participating countries in the EBC TCP: Australia, Austria, Belgium, Brazil, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States of America.

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The present document is based on the report "Scan of Code Requirements to address Greenhouse Gas Emissions" authored by the Posterity Group on behalf of the Office of Energy Efficiency at Natural Resources Canada

Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 30 IEA participating countries and to increase energy security through energy research, development, and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes (TCPs). The mission of the IEA Energy in Buildings and Communities (IEA EBC) TCP is to support the acceleration of the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge, technologies and processes and other solutions through international collaborative research and open innovation. (Until 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)

The high priority research themes in the EBC Strategic Plan 2019-2024 are based on research drivers, national programmes within the EBC participating countries, the Future Buildings Forum (FBF) Think Tank Workshop held in Singapore in October 2017 and a Strategy Planning Workshop held at the EBC Executive Committee Meeting in November 2017. The research themes represent a collective input of the Executive Committee members and Operating Agents to exploit technological and other opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy technologies, systems and processes. Future EBC collaborative research and innovation work should have its focus on these themes.

At the Strategy Planning Workshop in 2017, some 40 research themes were developed. From those 40 themes, 10 themes of special high priority have been extracted, taking into consideration a score that was given to each theme at the workshop. The 10 high priority themes can be separated in two types namely 'Objectives' and 'Means'. These two groups are distinguished for a better understanding of the different themes.

Objectives - The strategic objectives of the EBC TCP are as follows:

– reinforcing the technical and economic basis for refurbishment of existing buildings, including financing, engagement of stakeholders and promotion of co-benefits;
– improvement of planning, construction and management processes to reduce the performance gap between design stage assessments and real-world operation;
– the creation of 'low tech', robust and affordable technologies;
– the further development of energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible;
– the creation of holistic solution sets for district level systems taking into account energy grids, overall performance, business models, engagement of stakeholders, and transport energy system implications.

Means - The strategic objectives of the EBC TCP will be achieved by the means listed below:

– the creation of tools for supporting design and construction through to operations and maintenance, including building energy standards and life cycle analysis (LCA);
– benefitting from 'living labs' to provide experience of and overcome barriers to adoption of energy efficiency measures;
– improving smart control of building services technical installations, including occupant and operator interfaces;
– addressing data issues in buildings, including non-intrusive and secure data collection;
– the development of building information modelling (BIM) as a game changer, from design and construction through to operations and maintenance.

The themes in both groups can be the subject for new Annexes, but what distinguishes them is that the 'objectives' themes are final goals or solutions (or part of) for an energy efficient built environment, while the 'means' themes are instruments or enablers to reach such a goal. These themes are explained in more detail in the EBC Strategic Plan 2019-2024.

The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (*) and joint projects with the IEA Solar Heating and Cooling Technology Collaboration Programme by (☼):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: ☼ Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: ☼ Solar Sustainable Housing (*)
Annex 39: High Performance Insulation Systems (*)
Annex 40: Building Commissioning to Improve Energy Performance (*)
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43: ☼ Testing and Validation of Building Energy Simulation Tools (*)
Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45: Energy Efficient Electric Lighting for Buildings (*)
Annex 46: Holistic Assessment Toolkit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48: Heat Pumping and Reversible Air Conditioning (*)
Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51: Energy Efficient Communities (*)
Annex 52: ☼ Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis and Evaluation Methods (*)
Annex 54: Integration of Micro-Generation and Related Energy Technologies in Buildings (*)

Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (*)
Annex 56: Cost Effective Energy and CO2 Emissions Optimization in Building Renovation (*)
Annex 57: Evaluation of Embodied Energy and CO2 Equivalent Emissions for Building Construction (*)
Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
Annex 59: High Temperature Cooling and Low Temperature Heating in Buildings (*)
Annex 60: New Generation Computational Tools for Building and Community Energy Systems (*)
Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings (*)
Annex 62: Ventilative Cooling (*)
Annex 63: Implementation of Energy Strategies in Communities (*)
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Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)
Working Group - HVAC Energy Calculation Methodologies for Non-residential Buildings (*)
Working Group - Cities and Communities
Working Group - Building Energy Codes

Acknowledgements

This report is based on work carried out by the Posterity Group on contract from Natural Resources Canada's Office of Energy Efficiency and enhanced with input from the Building Energy Codes Working Group (BECWG) members.

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Acronyms

BC: British Columbia

BR18: Bygningsreglementet-Technical provisions (Denmark)

CAGBC: Canada Green Building Council

CALGreen: California Green Building Standards Code

CHBA: Canadian Home Builders' Association

EPBD: Energy Performance of Buildings Directive (European Union)

EPD: Environmental product declaration

EU: European Union

EV: Electric vehicle

GHG: Greenhouse gas

GWP: Global warming potential

LCA: Life cycle analysis

MURB: Multi-unit residential building

NCC: National Construction Code (Australia)

PV: Photovoltaic

RE2020: Réglementation Environnementale (France)

RNG: Renewable natural gas

TGS: Toronto Green Standard

VBBL: Vancouver Building Bylaw

UK: United Kingdom

1. Executive Summary

Introduction

Buildings account for 27% of total energy sector emissions. Many countries have committed to reduce greenhouse gas (GHG) emissions for achieving net zero emissions by 2050. It is well understood that building energy codes are effective tools to reduce GHG emissions from the building sectors. However, building energy codes mainly focus on improving energy efficiency in buildings by regulating energy use while there is also an opportunity to limit carbon emissions through building codes as well. Limiting carbon emissions can encompass reduction in both operational emissions as well as embodied carbon in the building's construction materials.

This report therefore provides a scan of building codes to explore how different jurisdictions dealt with limiting carbon emissions in codes and provides a comprehensive perspective of code requirements in support of GHG reduction targets.

Key Findings: Code Requirement Themes

Methods to Reduce Fossil Fuel Use

Two approaches to the treatment of fossil fuels in new buildings were identified through the jurisdictional review and interviews: an implicit ban on fossil fuels, and an explicit ban on fossil fuels. In jurisdictions with implicit bans on fossil fuels, compliance is difficult if natural gas is used.

Structure of Operational Emissions Limits

Three themes emerged related to the structure of operational emissions limits: performance limits versus prescriptive paths, methods to adjust limits (by region and by typology), and communication of future limits.

1) Performance Limits vs Prescriptive Paths

Three types of operational emissions performance limits were identified for **low-rise residential buildings**: limits normalized by floor area in kg CO_2e/m^2/year, absolute limits in kg CO_2e/yr and limits relative to a modelled reference building. Three prescriptive compliance paths for operational emissions were identified for low-rise residential buildings: an explicit ban on fossil fuel use, a points-based path, and a path to decarbonize one or more systems (e.g., space heating or water heating).

Two types of operational emissions performance limits were identified for **high-rise residential and commercial buildings**: limits normalized by floor area in kg CO_2e/m^2/year, and a limit relative to a modelled reference building. Two prescriptive compliance paths for operational emissions were identified for high-rise residential and commercial buildings: a points-based path, and a path that explicitly bans fossil fuel use.

2) Methods to Adjust Performance Limits

In addition to normalizing by floor area, two other methods to adjust performance limits were identified: by region and by building typology.

3) Communication of Future Limits

A common theme from the jurisdictional review and interviews was increasing stringency of operational emissions limits over time towards net zero emissions for buildings. These limits were communicated early so that industry would have time to prepare for the changes.

Complementary Requirements

Examples of complementary requirements were identified under the following headings:

- **EV-readiness:** EV-ready or EV-capable (i.e., requirement to have electric vehicle supply equipment installed or a raceway to accommodate a decided 208/240-volt branch circuit) spaces are required for new buildings in many jurisdictions.
- **Renewable Energy Generation**: renewable energy generation requirements were identified for new buildings in the United States and Denmark[1]. Renewable energy generation is listed as voluntary for new buildings in many jurisdictions. Australia's National Construction Code (NCC) also requires future-ready provisions in buildings for the installation of renewable energy.
- **Demand Response:** demand response requirements were identified in the NBI's Building Decarbonization Code for thermostatic controls, water heating and lighting; the US DOE and PNNL Stretch codes for water heating and thermostats; and in Seattle's upcoming energy code for electric storage water heaters that meet certain criteria[2].

Flexibility Mechanisms

The use of on-site renewables to meet operational emissions limits is allowed in several jurisdictions. Flexibility mechanisms for all-electric requirements were identified for cooking and backup heating.

Choice of Emissions Factors

Several interviewees explained that simplicity was prioritized in establishing emissions factors for their carbon codes, especially for the first iteration of the code.

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[1] One example of a renewable energy generation requirement for new low-rise residential buildings was identified in New York City.

[2] With some exceptions, will apply to electric storage water heaters with rated water storage volume between 40 and 120 gallons and a nameplate input rating equal to or less than 12kW.

Key Findings: Code Development Process Themes

Importance of Consultation in Carbon Code Development Process

Interviewees attributed lack of pushback on code requirements to industry's involvement in an open and transparent development process. Others viewed stakeholder consultation as an opportunity to educate and connect with the people who will be impacted by new regulations.

Evidence-Based Carbon Code Development

Pre-feasibility and affordability studies, and energy modelling were completed in several jurisdictions to ensure carbon code requirements were evidence-based, feasible and/or cost-effective prior to publication.

Enforcement and Unintended Consequences

Interviewees explained that carbon codes are enforced similarly to building codes, and that the same staff will be tasked with ensuring both types of compliance. Unintended consequences of carbon code requirements that surfaced through the interviews included exposing knowledge gaps, and a potential conflict between requirements in the energy code and carbon code.

Challenges Faced to Establish Embodied Carbon Policy

Identified challenges associated with the development and introduction of embodied carbon policy included defining the scope and boundary of the life cycle analysis, managing complexity so that the calculation methodology would be accessible and understandable for the intended audience, lack of EPDs in some jurisdictions, and lack of tools and training to support industry.

Options Assessment

Options assessments were completed for buildings, informed by findings from the jurisdictional review and interviews. The options assessments focus on requirements related to operational carbon, fuels, grid emissions factors, and electrification, and will inform the development of requirements in building codes.

Structure of Operational Emissions Limits

Operational emissions limits normalized by floor area or expressed relative to the performance of a reference building are well-suited to buildings with energy models. A tiered (stepped) approach to presenting operational emissions limits for buildings lays out a performance trajectory so that industry can plan accordingly.

Prescriptive requirements for low-rise residential buildings to decarbonize space and/or water heating systems, or a prescriptive points-based system that translates to operational emissions savings are simple for stakeholders to understand. These approaches are well-suited to low-rise residential buildings without energy models and may be advantageous to new low-rise residential buildings in remote communities where the number and availability of energy advisors may be lower compared to urban centers.

Limits normalized by floor area for buildings accounts for variations in size. Only one example of a prescriptive points-based system for buildings was identified for buildings, in the Ithaca Energy Code Supplement.

Common practice that emerged for the structure of operational emissions limits was to mirror the approach for the presentation of energy use limits.

Variation of Limits by Low-Rise Residential Building Size

Normalizing operational emissions limits by floor area or setting absolute limits by low-rise residential building size (e.g., separate limits for small low-rise residential buildings versus large low-rise residential buildings[3]) creates a more level playing field for low-rise residential buildings of different sizes but adds complexity for stakeholders. Common limits are a disadvantage to small low-rise residential buildings with less conditioned floor area compared to larger low-rise residential buildings. Common practice that emerged from the jurisdictional review and interviews was not to vary operational emissions limits by low-rise residential building size.

Variation of Limits by Typology

Variation of operational emissions limits by typology for buildings adds complexity for stakeholders. This added complexity may yield diminishing returns for low-rise residential buildings, since the variation in occupancy patterns and end use loads is relatively homogenous across low-rise residential building types as compared to high-rise residential and commercial buildings. In addition, attached low-rise residential buildings don't have as many exposed walls as detached ones. No examples of variation by typology for low-rise residential buildings were noted in the jurisdictional review or interviews.

In contrast, examples of variation of limits by high-rise residential and commercial building typology were observed in the jurisdictional review. This approach accounts for occupancy pattern variations across different building types and recognizes that end-use intensities vary by building type. For example, more hot water is used in hotels, motels and multi-unit residential buildings (MURBs) than in offices. Limits that benchmark by building typology would account for this, while common limits would not. Common practice that emerged from the jurisdictional review and interviews was variation of operational emissions limits by building typology.

Grid Emissions Factors

Regional grid emissions factors add complexity for energy modellers, builders and designers who may operate in more than one climate zone within a province or territory but account for regional differences in

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[3] In the VBBL, a large low-rise residential building has a floor area greater than 325 m^2.

the electricity supply mix. National emissions factors are a ‘free pass’ for regions with a carbon intensive grid. Future emissions factors can be used to account for planned grid decarbonization but are uncertain. Monthly factors reflect realistic annual variation in the electricity supply mix.

Common practice was to use current, annual, national (or jurisdiction-wide) grid emissions factors.

Fuels

Carbon codes that permit fossil fuels provide flexibility for builders and designers and may reduce pushback from stakeholders during consultation processes, even if compliance is difficult when fossil fuels are used. Further, codes that permit fossil fuels rely on the stringency of performance limits to limit fossil fuel use. Codes that explicitly ban fossil fuels provide clarity for builders and designers, and more certainty regarding GHG emissions impact than codes that permit fossil fuels. No common practice emerged from the jurisdictional reviews and interviews, as several examples of codes that permit and ban fossil fuels were identified.

Electrification

The inclusion of electric-ready provisions in a carbon code provides flexibility for the future if all-electric requirements are introduced. For example, if gas cooking is permitted for low-rise residential buildings or restaurants, an electric-ready provision for cooking ensures possible conversion later. Similarly, EV-ready provisions facilitate the future installation of EV chargers. EV requirements take things one step further to ensure chargers are in place once new building construction is complete. Electrification-ready and EV-ready provisions emerged as common practice for buildings in jurisdictions with codes that permit fossil fuels.

2. Introduction

Buildings account for 27% of global energy sector emissions. Many countries have committed to reduce greenhouse gas (GHG) emissions for achieving net zero emissions by 2050. It is well understood that building energy codes are effective tools to reduce GHG emissions from the building sectors. However, most building codes mainly focus on improving energy efficiency of buildings through regulating only energy use while it is important to establish carbon emissions limits in building codes as well.

To address this need for information on carbon emissions limits in building codes, Natural Resources Canada contracted with the Posterity Group to conduct a jurisdictional review via desktop research of building and carbon codes and supplementary material (e.g., PowerPoint presentations, white papers, etc.) to identify requirements for buildings under the following categories[4]:

- Operational emissions limits
- Electrification
- Renewable Energy Generation
- Demand Response
- Embodied Carbon Limits or Measurements

The jurisdictions and codes examined in the study are presented in Exhibit 1.

Exhibit 1. Jurisdictions and Codes Examined

Jurisdiction	Code or Standard
Australia	National Construction Code (NCC)
Canada	Canada Green Building Council Zero Carbon Building Design Standard Version 3
- British Columbia	Carbon Pollution Standard
- Toronto	Toronto Green Standard
- Vancouver	Vancouver Building Bylaw
Denmark	Bygningsreglementet-Technical Provisions
Finland	Decree of the Ministry of the Environment on Energy Performance of New Buildings
France	Réglementation Environnementale (RE) 2020
New Zealand[5]	Transforming Operational Efficiency Framework

[4] Requirements under the categories listed were not identified in every jurisdiction and code examined.

[5] The operational efficiency framework and embodied carbon technical methodology are not yet in force.

Jurisdiction	Code or Standard
	Whole-of-Life Embodied Carbon Assessment: Technical Methodology
Norway	Regulations on Technical Requirements for Building Works
The Netherlands	Energy Performance of Buildings Directive (EPBD) of the European Union (EU) Environmental Performance Assessment Method for Construction Works
Sweden	Boverket´s building regulations – mandatory provisions and general recommendations
United Kingdom	The Building Regulations, Part L
United States	International Energy Conservation Code
United States	International Residential Code
United States	ASHRAE 90.1-2019
United States	New Buildings Institute "Building Decarbonization Code"
United States	US Department of Energy (DOE) and Pacific Northwest National Laboratory (PNNL) Stretch Codes
- California	California Green Building Standards Code (CALGreen)
- Massachusetts	Massachusetts State Building Code 780
- New York	Energy Conservation Code of New York State
- New York City	Local Law 154
- Santa Monica	2020 Energy Reach Code
Marin County, USA	Title 19 Marin County Building Code
- Seattle	Seattle Building Code
- Town of Ithaca	Ithaca Energy Code Supplement
- Washington	Washington State Energy Code

Following the jurisdictional review, Posterity Group conducted structured interviews with code officials from select jurisdictions to confirm the carbon code requirements, and to examine their experiences with code development, adoption, implementation, and enforcement.

The results of the research are intended to provide options to building code development groups determining the direction of potential requirements.

The remainder of this report is structured as follows:

- Section 3 summarizes the method
- Section 4 presents key findings
- Section 5 presents the options assessments
- Appendix A points to the companion MS Excel file entitled "Appendix A – Overview Table"
- Appendix B lists the interviewees for the study

Sections 3 and 4 present the study method and key findings applicable to low-rise and high-rise residential and commercial buildings. Dedicated chapters for the buildings options assessments are presented in sections 5.1 and 5.2, respectively. Appendices A and B apply to low-rise and high-rise residential and commercial buildings.

3. Methodology

This section presents the study method for the jurisdictional review and interviews.

3.1 Jurisdictional Review

Posterity Group conducted a jurisdictional review via desktop research to identify international jurisdictions with carbon codes in development or in force, and to collect requirements under the categories shown in Exhibit 2. In addition, Posterity Group identified the following data for each jurisdiction under study:

- Climate zone (s) impacted
- Applicability (e.g., new and/or existing buildings)
- Year of adoption
- Relationship to local energy code
- Code basis (i.e., ASHRAE 90.1, IECC, unique code, etc.)
- Scope of operational emissions and/or embodied carbon limits calculations

Results of the jurisdictional review are provided under separate cover, in a companion MS Excel spreadsheet entitled "Appendix A – Overview Table."

Exhibit 2: Requirements Under Study

Requirement	Examples
Operational emissions limits	• Absolute GHG emissions limit • GHG intensity limits
Electrification	• All-electric or electric ready requirements • EV or EV-ready infrastructure • Heat pump or cold climate heat pump requirement (or ban of fossil fuel or electric resistance heating) • Trade or easing of other compliance requirements when selecting an all-electric vs mixed-fuel pathway
Renewable Energy Generation	• Solar PV, solar thermal or solar readiness • On-site renewable requirements • Expansion of solar and battery standards • Offset allowances
Demand Response	• Infrastructure (energy storage ready infrastructure) • Controls (thermostats, DHW storage, lighting level reduction)
Embodied Carbon Limits or Measurements	• Disclosure and tracking of carbon in materials • Requirement to use LCA

	• GHG intensity limits by building area or by material unit basis • GWP limits on refrigerants in mechanical equipment • Exceptions for recycling or re-use of existing material • Requirement to consider wood use
Other	• Requirements to meet other certification programs (e.g., Canada's CHBA net zero home certification program and Passive House, Australia's NABERS and Green Star) • NetZero Energy Ready Code or Tiered/Stretch/Step Code • Other key GHG reducing requirements and features tied to a net zero emissions pathway

3.2 Stakeholder Interviews

Interviews were completed with representatives from select jurisdictions to supplement findings from the jurisdictional review, and to conduct a deeper assessment of the options for code requirements that support GHG reduction targets. The goals of each interview were to:

- Confirm the inclusion and scope of GHG reduction requirements within the building code or standard,
- Gather information on the code development process (e.g., technical considerations and strategies),
- Understand the qualitative and quantitative impacts of GHG reduction targets in the building code/standard, and
- Gather insights on the successes and challenges associated with introducing and maintaining GHG reduction regulations within each jurisdiction.

The study team developed an interview guide template and provided a customized copy to each interviewee ahead of the scheduled meeting. Each interview lasted approximately one hour.

Exhibit 3: Summary of Interviews

Location	Interviews Completed
Canada	2
Denmark	1
France	1
The Netherlands	2
New Zealand	1
UK	1
United States	5

Exhibit 3 shows the number of interviews completed by country. All interviews were conducted by phone or video call, except for one Canadian and one international jurisdiction where written responses to interview questions were provided. One interview was completed with representatives from the United States to provide an over-arching view of carbon codes, and one interview was completed with a representative from the United States who provided an over-arching view on carbon codes in the Northeast United States. Some interviewees from Canada and the United States attended the same interview session. The scope of each interview covered low-rise and high-rise residential and commercial buildings.

Sections 4 that follows presents findings from the jurisdictional review and the stakeholder interviews, with subsections highlighting key themes that emerged from each interview.

4. Key Findings

This section presents key findings and themes that emerged from the jurisdictional review and interviews under the following topics:

Code Requirement Themes

- **Methods to reduce fossil fuel use**: Implicit and explicit bans on fossil fuels and electrification requirements.
- **Structure of operational emissions limits:** Level of specificity by size, region, type, and through time.
- **Complementary requirements**: Code requirements supporting EVs, demand response, and renewable energy generation.
- **Flexibility mechanisms**: Allowances for renewables to offset operational emissions, carbon offsets, and exceptions.
- **Choice of emissions factors:** Choosing simplicity over precision.

Code Development Process Themes

- **Importance of consultation in carbon code development process**: Engaging the public and industry during the carbon code development process.
- **Evidence-based carbon code development**: Building an evidence base for carbon codes through modelling, stress-testing using real building data, and assessing cost-effectiveness and affordability.
- **Enforcement and unintended consequences:** Enforcing carbon codes, penalties for non-compliance, and unintended consequences of requirements.
- **Challenges faced to establish embodied carbon policy:** Challenges in defining scope, balancing complexity with accessibility, how to ensure data quality and availability, and access to tools and training to support industry.

Findings apply to low-rise and high-rise residential and commercial buildings unless specified in the narrative.

4.1 Methods to Reduce Fossil Fuel Use

Two distinct approaches to the treatment of fossil fuels in new buildings were identified through the jurisdictional and the interviews: an implicit ban on fossil fuels, and an explicit ban on fossil fuels. This section explores these approaches and provides examples of each one.

Implicit Ban of Fossil Fuels

A common theme that emerged through the interviews was an implicit ban on fossil fuels in new buildings. An interviewee from Toronto explained that electrification cannot be mandated directly because it would be considered a prescriptive requirement that could conflict with the Ontario Building Code. Therefore, electrification would have to be mandated implicitly, and would be inevitable as operational emissions limits are reduced. Interviewees from the UK and France echoed this finding. They explained that although fossil fuels are not explicitly banned in the UK or France, compliance with Part L of the Building Regulations 2010 and RE2020, respectively, is difficult if natural gas is used in new buildings. In addition, in some jurisdictions, heat pumps may be implicitly required as well due to high efficiency requirements.

Interviewees from Toronto and the Town of Ithaca explained that the downside of implicit bans is that it is difficult to address unregulated fossil fuels without an explicit ban, for example fireplace use, cooking and other laboratory or factory loads. BC is investigating a modelling guideline update to address this.

In the Ithaca Energy Code Supplement, there is no explicit ban on fossil fuels for space heating, water heating, or cooking. However, up to six of the six prescriptive path points required for compliance can be earned by electrifying space heating, water heating and cooking in buildings. For low-rise residential buildings, up to nine points can be earned by electrifying space heating, water heating, cooking, and clothes drying, while only six points total are required for compliance.

Under Seattle's current Building Code, there is a requirement to select several above-code measures from a list of options for new low-rise residential buildings. According to an interviewee from Seattle, 90% of new low-rise residential buildings appear to be electing heat pump options. In the draft Seattle Building Code under consideration for 2023, heat pumps will be required for space heating and water heating in low-rise residential buildings, although as a compromise, gas backup heating would still be permitted.

New York City's Local Law 154 prohibits the combustion of substances that emit 25 kg or more of CO_2e per million BTU of energy in new buildings[6]. This means that natural gas, which emits approximately 50 kg of CO_2e per million BTU of energy, is not permitted. The language in Local Law 154 focuses on air emissions, which likely helped it pass according to an interviewee from New York City.

Explicit Ban of Fossil Fuels or Electrification Requirements

In other jurisdictions, there is an explicit ban on fossil fuel combustion in new buildings. In California for example, dozens of cities including Petaluma, Fairfax, Alameda, San Jose, Santa Cruz, and Morgan Hill have adopted gas bans that prohibit gas infrastructure in new buildings. Dozens of other cities in California have adopted electric-required or electric-preferred[7] reach codes that exceed minimum state energy standards[8].

[6] The nine exceptions to Local Law 154 set different compliance dates for various building types and systems. The first compliance date is January 1, 2024.

[7] An electric-preferred reach code requires buildings with gas systems to achieve higher energy standards.

[8] T. DiChristopher, "Gas ban monitor: Calif. count reaches 50 as West Coast Movement Grows," S&P Global, 23-Nov-2021. [Online]. Available: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/gas-ban-monitor-calif-count-reaches-50-as-west-coast-movement-grows-67732585. [Accessed: 03-Oct-2022].

With some exceptions (e.g., if the rooftop area is limited, if location for the evaporator part of the heat pump is an issue, etc.), new buildings in the Netherlands have not had natural gas connections since 2018. These new buildings have heat pumps and solar panels or are connected to district heating systems. The gas field in Groningen province, which at one time was connected to virtually all buildings in the Netherlands, is expected to be closed between 2025 and 2028.

As of June 2021 in Seattle, heating in new buildings cannot be provided by electric resistance or fossil fuel combustion appliances (including natural gas, heating, oil, propane, or other fossil fuels). However, there is a long list of exceptions, allowing limited electric resistance use for small loads (e.g., individual rooms in an apartment building) and supplementary heat for very cold weather. Service hot water must be provided by an Air Source Heat Pump (ASHP) water heating system for permits applied for after January 1, 2022[9]. The interviewee from Seattle explained that Washington State will enforce similar rules on July 1, 2023.

Other notable electrification requirements identified include:

- For new low-rise residential buildings under the prescriptive compliance path of the Vancouver Building Bylaw (VBBL), all systems must use electricity except for gas fireplaces. The maximum combined rated input for all gas fireplaces in a low-rise residential building must be less than 17.5kW (60,000 BTU/hr).
- In Marin County, new buildings must be all-electric.
- In New York City, new buildings of all sizes must be constructed fully electric by 2027.
- In Washington State, most new buildings and large MURBs will have to install heat pumps for space heating under a provision of the revised energy code to be effective July 1, 2023. An overall trend towards electric heat pumps was also observed in other jurisdictions.
- Massachusetts has a ten-city pilot program that bans fossil fuels from most new construction, except for labs and hospitals.
- Finland will phase out fossil fuel oil in heating in new buildings by the start of the 2030s[10]. In Norway, the installation of fossil fuel heating systems in new buildings is not permitted.

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[9] There are exceptions here to: Instantaneous water heaters, solar heaters, wastewater heat recovery, ground source, water source, meeting NEEA advanced water heater specifications, existing district systems, replacement equipment, process equipment (commercial food service).

[10] "Finland's Integrated Energy and Climate Plan," Valto, 20-Dec-2019. [Online]. Available: https://julkaisut.valtioneuvosto.fi/handle/10024/161977. [Accessed: 11-Nov-2022].

4.2 Structure of Operational Emissions Limits

Operational emissions limits were identified in several international jurisdictions. These operational emissions limits were expressed relative to direct and indirect GHG emissions associated with fuels used by the building during its operation.

This section explores themes related to the structure of the limits under three headings: performance limits versus prescriptive paths, methods to adjust performance limits, and communication of future limits.

1) Performance Limits vs Prescriptive Paths

Performance Limits: Low-Rise Residential Buildings

Performance limits for the operational emissions from low-rise residential buildings are typically normalized by floor area in kg CO_2e/m^2/year, although they are occasionally expressed on an absolute basis in kg CO_2e/building/year. In some jurisdictions (e.g., UK, Washington, Seattle), operational emissions limits are expressed relative to a modelled reference building.

As shown in Exhibit 4, BC's proposed Carbon Pollution Standard offers two performance options for low-rise residential buildings. Option one is an absolute limit in kg CO_2e/building/year, and option two has a limit normalized by floor area in kg CO_2e/m^2/year and an absolute limit. Option one is well suited to small low-rise residential buildings, while option two is more applicable to medium and large low-rise residential buildings.

Exhibit 4: Performance and Prescriptive Limits for New Low-Rise Residential Buildings in BC's Proposed Carbon Pollution Standard

GHG Emission Level	PROPOSAL: GHG Emission Compliance Options					
	Maximum GHG Emissions by House, Expressed in kg CO_{2e} per House	or	Maximum GHG Emissions by House[1]		or	Reduction of GHG Emissions by Energy Source of Building Systems
			Maximum GHGi of the House, Expressed in $kgCO_{2e}/m^2$/year	Maximum GHG Emissions by House, Expressed in $kgCO_{2e}$ per House		
1, medium	1050		6.0	2400		Decarbonize heating system energy source
2, low	440		2.5	800		Decarbonize heating and service water heating system energy source
3, zero carbon ready	265		1.5	500		Decarbonize all *building* systems energy sources

Prescriptive Pathways: Low-Rise Residential Buildings

Three prescriptive compliance paths for operational emissions were identified for low-rise residential buildings: an explicit ban on fossil fuel use (discussed in section 4.1), a points-based path, and a path to decarbonize one or more systems (e.g., space heating or water heating).

Ithaca Energy Code Supplement has a points-based compliance path for low-rise residential buildings. New low-rise residential buildings must earn a minimum of six points total, covering categories of efficient electrification, affordability improvements, renewable energy, and other (e.g., development density, walkability, EV parking spaces, etc.). For example, three points are awarded for ASHP for space heating, one point is awarded for installing heating systems in directly heated spaces, up to three points are awarded for on-site or off-site renewable electric systems or on-site renewable thermal systems, and one point is awarded for achieving sufficient development density.

In addition to the performance limits identified in BC's proposed Carbon Pollution Standard, there is a prescriptive compliance path for low-rise residential buildings to decarbonize one or more systems (Exhibit 5, right-most column). These low-rise residential buildings may not have had an energy model developed, perhaps because they are in regions with fewer energy advisors (e.g., Northern, and remote communities) compared to urban centres. The decision to include the prescriptive path was informed by feedback from these communities, who indicated that access to energy advisors and some high-performance building materials could be challenging.

Performance Limits: High-Rise Residential and Commercial Buildings

Exhibit 5: Performance Limits for New High-Rise Residential and Commercial Buildings in BC's Proposed Carbon Pollution Standard

GHG Emission Level	PROPOSAL: Maximum GHGi of the *Building*, $kgCO_{2e}/m^2/year$			
	Occupancy			
	Hotels and Motels	Other *Residential Occupancies*	Offices	Other Business and Personal Service or Mercantile Occupancies
Medium	9.0	7.0	5.0	6.0
Low	4.0	3.0	3.0	3.0
Zero-carbon ready	2.0	1.8	1.5	2.0

Performance limits for the operational emissions from high-rise residential and commercial buildings are typically normalized by floor area in kg $CO_2e/m^2/year$ (e.g., BC, Vancouver, Toronto, France, and New Zealand[11]). Exhibit 5 provides an example of tiered performance limits for new high-rise residential and commercial buildings in BC's proposed Carbon Pollution Standard.

11 New Zealand's "Transforming Operational Efficiency Framework" is not yet in force.

In some jurisdictions (e.g., UK, Washington, Seattle, Town of Ithaca[12]), operational emissions limits are expressed relative to a modelled reference building. In Denmark, both operational and embodied carbon are included in one life cycle carbon GHG intensity limit.

Prescriptive Pathways: High-Rise Residential and Commercial Buildings

Two prescriptive compliance paths for operational emissions were identified for high-rise residential and commercial buildings: a points-based path, and a path that explicitly bans fossil fuel use (discussed in Section 4.1).

In addition to a performance compliance path, the Ithaca Energy Code Supplement has a prescriptive operational emissions compliance path for new high-rise residential and commercial buildings, where six points are required for compliance. Points can be earned under the following categories: efficient electrification, affordability, renewable energy, and other (e.g., development density, walkability, EV parking spaces, etc.). For example, two points are awarded for air source heat pumps for space heating, one point is awarded for installing heating systems in directly heated spaces, up to three points are awarded for on-site or off-site renewable electric systems or on-site renewable thermal systems, and one point is awarded for achieving sufficient development density. Most points represent roughly 6-10% GHG savings relative to IECC 2016.

2) Methods to Adjust Performance Limits

Operational emissions from buildings are impacted by many factors in addition to design choices. In addition to normalizing by floor area, two other methods to adjust performance limits were identified: by region and by building typology.

Adjust by Region

In some regions (e.g., Seattle, Washington State, the UK) operational emissions limits for a new building are determined relative to a modelled reference building. This means that the building's specific location and climate data are accounted for in the calculation of its operational emissions.

Several jurisdictions including BC, Denmark, and New Zealand, list operational emissions limits and grid emissions factors for the entire province or country, and so do not account for regional variation of space conditioning loads due to climate. The province of BC completed archetype modelling of buildings to highlight potential technical implications of the proposed tiered carbon pollution standard. They found that the ability to meet operational emissions limits did not depend substantially on climate zone. Instead, ability

[12] Some jurisdictions, including the Town of Ithaca, have multiple compliance paths.

to meet limits was more dependent on the effective use of low-carbon fuels. For these reasons, the province has proposed one set of limits for all climate zones[13].

Adjust by Typology: High-Rise Residential and Commercial Buildings

Performance operational emissions targets are presented by high-rise residential and commercial building typology in BC, Vancouver, and Toronto. For example, the Toronto Green Standard lists separate normalized limits in kg CO_2e/m^2/year for commercial offices and commercial retail, and BC's proposed Carbon Pollution Standard lists separate limits normalized by floor area for hotels and motels, other residential occupancies, offices, and other business and personal service or mercantile occupations, as shown previously in Exhibit 5. In contrast, performance limits in New Zealand's *Transforming Operational Efficiency Framework* are presented for all buildings over 300 m^2.

Adjust by Typology: Low-Rise Residential Buildings

No examples of operational emissions limits that vary by low-rise residential building typology (e.g., detached, semi-detached, row/town house) were identified in the jurisdictional review. However, BC's proposed Carbon Pollution Standard lists two performance options for low-rise residential buildings, one ideal for small low-rise residential buildings (an absolute limit), and one ideal for large low-rise residential buildings (an absolute and a normalized limit).

3) Communication of Future Limits

A common theme from the jurisdictional review and interviews was increasing stringency of operational emissions limits over time towards net zero emissions for buildings. These limits were communicated early so that industry would have time to prepare for the changes.

4.3 Complementary Requirements

This section summarizes findings from the jurisdictional review and interviews for complementary requirements under the following headings: EV-readiness, demand response, and renewable energy generation. Detailed findings by jurisdiction for these research areas can be found in the companion MS Excel spreadsheet entitled "Appendix A - Overview Table."

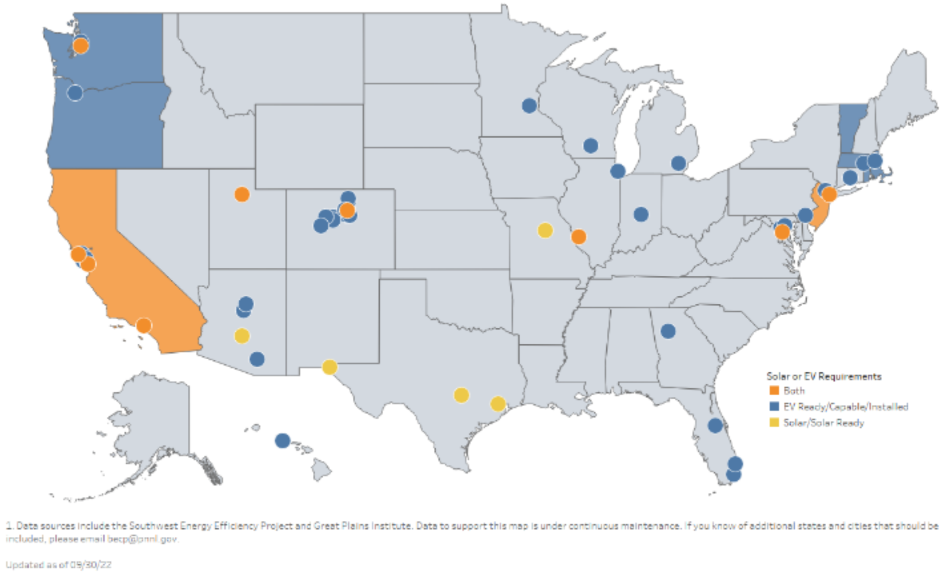
1) EV-readiness

A recurring requirement for new buildings in many jurisdictions was either EV-ready spaces or EV-capable spaces (i.e., requirement to have electric vehicle supply equipment installed or a raceway to accommodate a decided 208/240-volt branch circuit). For example, in California's Green Building

[13] Building and Safety Standards Branch, "Draft Building Carbon Pollution Standards for Part 3 buildings in British Columbia," *B.C. Public Review*, 21-Sep-2022. [Online]. Available: https://www2.gov.bc.ca/gov/content/industry/construction-industry/building-codes-standards/bc-codes/public-review. [Accessed: 12-Nov-2022]

Standards code for low-rise residential buildings, electric vehicle supply equipment must be installed in new low-rise residential buildings with private garages. Further, each new dwelling unit must have a raceway to accommodate a dedicated 208/240-volt branch circuit. Exhibit 6 summarizes where policies to support electric vehicle and solar infrastructure in buildings are adopted in the United States. Australia's NCC also requires EV-ready provisions in buildings.

Exhibit 6: State and Local Electric Vehicle and Solar Building Requirements[14]



For new buildings, a common proposed requirement was that a percentage of parking spaces must be EV capable or EV ready, and in some jurisdictions, there is a requirement for level 2 EV charging readiness. The percentage of EV-ready or EV-capable spaces commonly varied based on building occupancy type. For example, the proposed 2021 Washington State Energy Code[15] will require that 10% of total parking spaces have EV charging stations for buildings for most occupancy groups, while 25% of total parking spaces will have to be EV-ready for MURBs, hotels and motels[16].

EV requirements are found in several different legislative structures. Some jurisdictions include them in the Building Code, (e.g., Massachusetts and California). Some jurisdictions include them in Zoning bylaws or Land Use Codes (e.g., Seattle). Some jurisdictions include them in separate EV specific legislation altogether (e.g., France, England).

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[14] "DOE Building Energy Codes Program Infographics," *Building Energy Codes Program*, 2022. [Online]. Available: https://www.energycodes.gov/infographics. [Accessed: 10-Nov-2022].

[15] Effective July 1, 2023

[16] Occupancy group R.

2) Demand Response

Examples of demand response requirements identified in the jurisdictional review and interviews include:

- In Seattle's upcoming energy code for buildings, electric storage water heaters meeting certain criteria must have demand responsive controls[17].
- The NY Energy Stretch Code states that new buildings must comply with at least one additional power distribution system package. The demand response option requires interoperable automated demand-response infrastructure that can receive demand-response requests from the utility, electrical system operator, or third-party DR program provider, and of automatically implementing load adjustments to the HVAC and lighting systems.
- The NBI's Building Decarbonization Code presents optional demand response amendments to the 2021 IECC (for low-rise and high-rise residential and commercial buildings) or ASHRAE 90.1 (for high-rise residential and commercial buildings) covering all-electric and mixed-fuel scenarios. Specific optional amendments covering thermostatic controls, electric storage water heaters and lighting can be found in the companion MS Excel spreadsheet.
- The US DOE and PNNL Stretch Code "Technical Brief on Demand Response in Residential Energy Code" proposes demand response controls for thermostats and electric storage water heaters with capacity greater than 76 L in new low-rise residential buildings.

Some interviewees expressed concerns about whether demand response "ready" control requirements would be obsolete when ready to be used. The issue of space availability when considering energy storage was raised by an interviewee from New York City who explained that requirements for energy storage-ready spaces were difficult to implement because the City's Fire Code has extensive requirements for fire suppression systems in energy storage spaces.

3) Renewable Energy Generation

Renewable energy generation requirements were identified in the United States (NBI's Building Decarbonization Code for high-rise residential and commercial buildings), California (CALGreen 2022 for high-rise residential and commercial buildings), Santa Monica (for high-rise residential and commercial buildings), New York City (Local Laws 92 and 94 for low-rise and high-rise residential and commercial buildings), Seattle (for high-rise residential and commercial buildings[18]), and Denmark (BR18 for high-rise residential and commercial buildings), and Australia (for high-rise residential and commercial buildings). These requirements were generally expressed as minimum energy production per area of conditioned floor space, although in New York City, Local Laws 92 and 94 of 2019 mandate that at least 4 kW of solar PV generating capacity must be installed. Additional state and local solar building requirements are identified on the map in Exhibit 6.

Interviewees from New York City and Seattle explained these laws have been difficult to implement because of space limitations on the roofs of new buildings in the city's dense urban environment. The interviewee from Seattle indicated a solution to this could be flexibility for offsite renewable energy, but

[17] With some exceptions, will apply to electric storage water heaters with rated water storage volume between 40 and 120 gallons and a nameplate input rating equal to or less than 12kW.

[18] On-site renewable energy generation systems are not required for affordable housing projects. Other buildings can transfer their obligation to an affordable housing project.

there are difficult questions in terms contractual attachments, an issue likely encountered in other jurisdictions. A renewable energy generation requirement was noted in Marin Country, where new restaurants larger than 8,000 ft. sq and with service water heaters rated 75,000 BTU/h or more must install a solar water heating system with a minimum solar savings fraction of 0.15.

A representative from the United States explained that the 10th edition[19] of the Massachusetts Energy Code contains solar-ready provisions. They further explained that in New Jersey, warehouses, and buildings with more than 10,000 ft^2 of floor space must be PV-ready, and that as of January 1, 2023, in New Castle Country Delaware, Ordinance 22-091 requires a solar ready zone on rooftops of new buildings with footprints of 50,000 ft^2 or more.

Renewable energy generation is listed as voluntary in many jurisdictions, including Toronto (Toronto Green Standard for low-rise and high-rise residential and commercial buildings), the United States (IECC for low-rise and high-rise residential and commercial buildings), the Town of Ithaca (Ithaca Energy Code Supplement for low-rise and high-rise residential and commercial buildings), Marin County (Title 19 Marin County Building Code for low-rise residential buildings), Washington (Washington State Energy Code for low-rise and high-rise residential and commercial buildings), New York (Stretch Energy Code for low-rise and high-rise residential and commercial buildings), the UK (Buildings Regulations 2010), France (RE2020 for low-rise and high-rise residential and commercial buildings), and the EU (EPBD).

4.4 Flexibility Mechanisms

This section explores flexibility mechanisms identified in the jurisdictional review and interviews as they pertain to on-site renewables, carbon offsets, and all-electric requirements.

1) On-Site Renewables to Meet Operational Emissions Limits

Several references to the use of on-site renewables to meet operational emissions limits were identified through the interviews:

- According to an interviewee from Denmark, on-site renewables can be included in the calculation of a building's operational emissions, but only up to 25% of the total energy demand to ensure efficiency is prioritized over renewables.
- The Toronto Green Standard states that incorporation of renewable energy production and/or connecting to an existing low carbon district energy system is strongly encouraged to

Use of Carbon Offsets

The Canada Green Building Council's (CAGBC) Zero Carbon Building Design Standard states that purchased carbon offsets can be used to offset direct or indirect emissions. In addition, renewable energy generated in excess of energy used and exported to the electricity grid is recognized as contributing to avoided emissions, if the associated renewable energy certificates are retained. The CAGBC's Zero Carbon Building Design Standard is an optional compliance path to meet operational emissions targets for buildings in the Toronto Green Standard.

No additional references to purchased carbon offsets were identified in the jurisdictional review.

19 Effective January 1, 2023

reduce or avoid carbon emissions and to meet the operational emissions limits for buildings.

- The US DOE and PNNL Stretch Code states that the installation of site-based renewable systems, typically PV panels that use site-available solar energy sources can offset imported metered energy into the building.
- The City of Vancouver's Energy Modelling Guidelines, which provide clarity on energy modelling inputs for compliance with the VBBL, state that on-site renewables can be used to positively impact the emissions factor for electricity for buildings. The more on-site renewables used (up to 7%), the greater the reduction in the emission factor. BC has followed this methodology in its proposed Carbon Pollution Standard.
- The Town of Ithaca's points-based prescriptive compliance path awards up to three points for on-site or off-site renewable electric systems, or on-site renewable thermal systems in buildings. An interviewee from the Town explained that off-site renewables were challenging to accommodate because they required contracting and financial expertise. They further explained that renewable energy systems were not a popular points path. Emerging codes such as the proposed IECC 2024 provide new methodologies to consider off-site renewables.

2) Exceptions to All-Electric Requirements

Several examples of flexibility mechanisms for all-electric requirements related to cooking and backup heating were identified during the interviews:

- In Seattle, there has been no attempt to regulate gas use for cooking in new commercial buildings, or for decorative fireplaces. In the Washington State Energy code, gas backup heating is permitted for buildings primarily heated by electric heat pumps. An interviewee from Seattle explained that this was a compromise to reassure stakeholders who expressed concerns about cold weather heat pump performance, and grid blackouts.
- In New York City, gas heating can be used for emergencies, and there is an exception for gas use for cooking in new commercial buildings, but not in new low-rise residential buildings.
- In the Town of Ithaca, gas cooking is permitted, but interviewees explained this will be revisited. They noted that stakeholders have a 'knee jerk reaction' to all-electric requirements for cooking in new buildings.

In addition, the proposed BC Carbon Pollution standard addresses renewable natural gas (RNG). The proposed standard accommodates RNG and other innovative fuel sources as they become available. As of August 2022, a proposal from FortisBC to introduce RNG at scale is before the BC Utilities Commission, an independent government agency responsible for regulating BC's energy utilities.

4.5 Choice of Emissions Factors

There are many ways to calculate emissions factors, and these factors fluctuate through time as electricity supply grids are decarbonized. No variation of operational emissions limits based on regional grid emissions factors was observed, except in Australia. Australia's NCC requires that the annual greenhouse gas emissions of the proposed and reference buildings be calculated using the same method and emissions factors.

Several interviewees explained that simplicity was prioritized in establishing emissions factors for their carbon codes, especially for the first iteration of the code. For example, BC has proposed to adopt emissions factors set by the City of Vancouver's Modelling Guidelines. This means one emissions factor for electricity for all of BC, regardless of whether a building is connected to the Integrated grid or the Fort Nelson grid, which has substantially higher emissions. Representatives from BC felt this was the simplest approach for the province and explained that it provided certainty and stability to industry.

Similarly, one emissions factor for electricity is used for all of Washington State. The representative from Seattle explained that the same carbon factor for electricity is used for the entire state of Washington, even though the fuel mix varies from one utility to the next. They further explained that localized factors could have been used, but this approach would have added complexity. Similarly, an interviewee from the UK explained that the same monthly carbon factors are used in England, Wales, and Scotland. These factors reflect realistic annual variation in the grid energy mix, which means that energy use in the winter is more carbon intensive than at other times of year.

It is worth noting that London (UK) government policy on whole lifecycle assessment requires the use of emissions factors from the 'Future Energy Scenario: Steady Progression.' This is the most conservative of several grid decarbonization scenarios published by National Grid.

The emissions factor for electricity used in the Ithaca Energy Code Supplement came from the average baseload emission factor provided by the US EPA for upstate New York. They decided to use the same emissions factor from 2018 through to 2024, which was a point of contention during the industry consultation. One commenter wanted the marginal emission factor rather than average baseload emission factors to be used to consider peak emission. While another commenter had evidence that the EPA natural gas emission factors should be much higher due to fugitive leaks. However, interviewees explained that ultimately, they used their best judgment and chose what seemed fair.

4.6 Importance of Consultation in Carbon Code Development Process

Several interviewees highlighted the importance and benefits of public and industry consultation during their carbon code development processes. Representatives from the City of Toronto attributed lack of pushback from industry regarding the Toronto Green Standard requirements in part to industry's involvement in the open and transparent development of the energy and emissions requirements. Representatives from BC echoed this comment; they explained that a broad range of industry representatives were consulted during the development of the proposed Carbon Pollution Standard, with a goal to limit future re-work.

Other interviewees viewed stakeholder consultation as an opportunity to educate and connect with the people who will be impacted by new regulations. A representative from Seattle reported that stakeholder consultation was an opportunity to share information and to demonstrate a willingness to support industry through transition periods. An interviewee from New Zealand recommended being aware of the broader issues stakeholders may be facing in the development of regulations and prior to the consultation process.

For example, in New Zealand, some industry representatives resisted the proposed Operational Efficiency Framework, which could have been fuelled by COVID-related supply chain issues around timber and plaster board.

4.7 Evidence-Based Carbon Code Development

A theme that emerged from the interviews was the value of evidence-based, transparent carbon code development. Pre-feasibility studies or energy modelling was completed in several jurisdictions to ensure carbon code requirements were feasible and/or cost-effective prior to publication. This type of 'proof of concept' work was completed for individual building archetypes, and in some cases, a broader grid readiness study was completed. Several interviewees also explained that developers appreciated a stable and predictable building code so that they could clearly understand the implications for their project pipelines. In addition, several interviewees noted that affordability was deliberately considered during the development of carbon code requirements in their jurisdictions.

1) Technical Feasibility and Cost-Effectiveness

Examples of evidence-based carbon code development to demonstrate technical feasibility and cost-effectiveness include:

- As part of the development of the BC Carbon Pollution Standard, the province completed archetype modelling of Part 3 and Part 9 buildings across BC's climate zones to show whether decarbonizing a hypothetical building would be cost-effective. This modelling showed examples of how buildings could meet the proposed operational emissions limits. Additionally, the modelling informed the operational emissions limits by building type[20].
- The Toronto Green Standard operational emissions limits for part 3 building were established through an extensive two-part study completed between 2015 and 2017 of energy codes around the world, and a parametric and costing analysis of the most common part 3 building types expected to be built to 2040. Additionally, a study[21] was completed to benchmark embodied emissions in Part 3 buildings for Ontario as the basis for future policy development.
- New York City's Local Law 154 is based on a phased timeline that accounts for whether electrification requirements have been proven feasible depending on the building size. For example, as of January 2024, 1-2 family house and all other buildings less than seven stories are prohibited

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[20] Building and Safety Standards Branch, "Draft Building Carbon Pollution Standards for Part 3 buildings in British Columbia," *B.C. Public Review*, 21-Sep-2022. [Online]. Available: https://www2.gov.bc.ca/gov/content/industry/construction-industry/building-codes-standards/bc-codes/public-review. [Accessed: 12-Nov-2022].

[21] "Ontario's first benchmarking of embodied carbon for large buildings," *Mantle Developments*, 13-Sep-2022. [Online]. Available: https://mantledev.com/publications/ontarios-first-benchmarking-of-embodied-carbon-for-large-buildings/. [Accessed: 12-Nov-2022].

from combusting fossil fuels for space heating, but the compliance dates for buildings seven stories or more is not until July 2027. This is because feasibility has not been fully demonstrated for large buildings. NYC has commissioned heat pump and grid reliability studies to be published mid-2023 to inform feasibility. They have high confidence that low-rise residential buildings can be heated with heat pumps, but for taller buildings, there are concerns around space and where the evaporator part of the heat pump would go.

- The Town of Ithaca used real data from 10-20 new buildings to inform a baseline for their Prescriptive Compliance Path scoring. Then they stress tested the Prescriptive Compliance Path requirements using actual building data to ensure they were feasible. Then they made tweaks to ensure feasibility while also achieving an impact.
- Seattle City Light commissioned a grid readiness study that concluded the power generation system could handle full electrification, with the understanding that several local distribution facilities would likely need to be augmented. An interviewee from Seattle said that the grid readiness study arrived at this conclusion even without factoring in any demand flexibility or significant progress on codes or other regulations, which instilled confidence in stakeholders.
- The Netherlands used data collected during an embodied carbon reporting requirement phase to later inform limits for low-rise residential buildings and offices[22]. Before lowering the embodied carbon limit (referred to as the single-score indicator) from 1.0 to 0.8 for new low-rise residential buildings and office buildings, code officials analysed how many new buildings would comply. The limit was ultimately selected to ensure a high compliance rate that wouldn't push industry beyond 'reasonable levels' or building quality issues.
- In France, data from 1,215 buildings was collected between 2016 to 2020 to test the methodology and limits for the life cycle analysis. In 2019, a targeted consultation took place to refine the limits and calculations before limits were established. Lastly, modelling was completed using real building data to establish ambitious but attainable limits for embodied carbon and operational GHG emissions.
- In the UK, they use a large database of historical Energy Performance Certificates (EPCs) and Display Energy Certificates (DECs) to inform target emissions rates, and complete feasibility studies to confirm targets are realistic and cost-effective.
- An impact assessment was completed in the development of Finland's low-carbon construction roadmap to limit the carbon footprint of new buildings by the mid-2020s.

2) Affordability (Upfront and Operational Costs)

Studies were commissioned in several jurisdictions to ensure that carbon code requirements were affordable and available, with most having cost increases within an acceptable limit. Interviewees from the UK and the Netherlands indicated that their codes have impact on the cost of construction. The most progressive carbon codes, for example the London Future Standards and the French RE 2020 had an impact of about 10% and 3-15% respectively on costs of construction.

An interviewee from Seattle said they received vigorous but predictable arguments from certain industries related to the housing affordability crisis and clean electricity availability. However, studies commissioned found that these arguments were inaccurate and played a key role in alleviating industry

[22] Some jurisdictions introduce a reporting requirement as a steppingstone towards a future prescriptive or performance requirement.

concerns. Specifically, savings in gas infrastructure, energy efficiency savings of heat pumps over gas counterparts, and indicators that gas prices will increase were mentioned as alleviating upfront and operational costs. An interviewee from Toronto also mentioned business models from energy providers (i.e., third party utilities) were helping to mitigate upfront costs.

The Town of Ithaca addressed affordability through their prescriptive compliance path for buildings by awarding 'Affordability Improvements' points for specific design choices. Up to six of six compliance points can be awarded to buildings for smaller building or room size (for hotels and residential portions), installing heating systems in directly heated spaces, efficient building shape, reducing over lighting and implementing other lighting improvements, and for a modest window to wall ratio. For low-rise residential buildings, up to five of six compliance points can be earned for affordability improvements. These points can be earned for the same design choices as buildings, except that no points are awarded for lighting improvements. These affordability measures aren't traditionally accounted for in reference-based energy modelling but result in GHG savings.

Several interviewees also mentioned that cost and affordability concerns are largely driven by factors that have nothing to do with energy or carbon code requirements, such as inflation and supply chain issues brought on by the COVID-19 pandemic. Once carbon codes are in place, the interviewees found that industry quickly adapted and innovated, but only if required to.

Washington State law, for example, has been updated so that instead of traditional cost-effective studies which require demonstrating upfront costs and payback periods to validate the code change, the requirement for analysis was changed to demonstrate that 2050 Paris Climate agreement targets would be met the most cost effectively. In that sense, it costs much less to incorporate carbon requirements in new buildings rather than after the fact.

In Europe, where advancement on carbon life cycle analysis is much more pronounced, affordability conversations centre on lean building, material, and spatial efficiency, and promoting reuse and refurbishment over new builds to deliver affordable GHG mitigation or reductions.

4.8 Enforcement and Unintended Consequences

Interviewees were asked about carbon code enforcement and penalties for non-compliance. They explained that carbon codes are enforced similarly to building codes, and that the same staff will be tasked with ensuring both types of compliance. An interviewee from Toronto indicated there is no appreciable difference in the level of effort required to review applications since the introduction of operational emissions limits requirements. Development review costs are largely a function of application complexity and overall application volume. An interviewee from New York City indicated that given the local law's functional gas ban, enforcement will be straightforward since you cannot install gas infrastructure without a permit. Prescriptive gas ban reduces red tape as compared to modelled requirements. An interviewee from New Zealand expressed concerns in asking code enforcement officials to review and approve embodied carbon assessments. This task would beyond their current expertise and add to their heavy workloads.

Penalties for non-compliance with carbon code requirements include holdbacks on approvals, permits and/or occupancy certificates, or monetary fines.

A handful of interviewees also identified unintended consequences of carbon code requirements. These include:

- The operational emissions limits for buildings in the Toronto Green Standard, which imply fuel switching to electricity, have presented technical challenges for designers in Toronto's dense, high rise urban environment. The requirements have exposed knowledge gaps. However, the interviewee noted that City monitors how industry is affected by requirements, and that industry has responded to all cycles of the TGS.
- An interviewee from the Netherlands remarked that attention should be paid to ensure that carbon and energy codes don't work against each other. They explained that an unintended consequence of requiring additional insulation in the energy code led to a higher embodied carbon impact.

4.9 Challenges Faced to Establish Embodied Carbon Policy

While some Canadian and many international jurisdictions have established operational GHG emissions limits, fewer have embodied carbon requirements in place. Jurisdictions surveyed as part of this study with embodied carbon requirement in force include France (for new low-rise residential buildings), the Netherlands (for new residential and office buildings over 100 m^2), and Marin County (for cement in new buildings). The jurisdictional review and interviews revealed that embodied carbon limits are planned additions to carbon codes in BC, the City of Vancouver (for Part 3 buildings), New York City, Finland, Denmark, New Zealand, the UK, and in the European Union's EPBD. More details on the status and scope of embodied carbon policy in Europe is available in One Click LCA's October 2022 report entitled "Construction Carbon Regulations in Europe - Review and Best Practices[23]."

Interviewees cited several challenges associated with the development and introduction of embodied carbon policy:

- **Scope and Method**:
  - **Module Inclusion:** Some regulations require a whole life cycle assessment, some require a simplified whole life cycle assessment, and others are limited to upfront carbon. An interviewee from New Zealand reported that it was challenging to establish the boundary for what life cycle stages to include in an embodied carbon policy. They considered only regulating up front embodied carbon and excluding use stage, end of life carbon and beyond initial life cycle to reduce complexity. However, they received feedback this would be a mistake as it could encourage the use of low embodied carbon products that require frequent replacement or maintenance.

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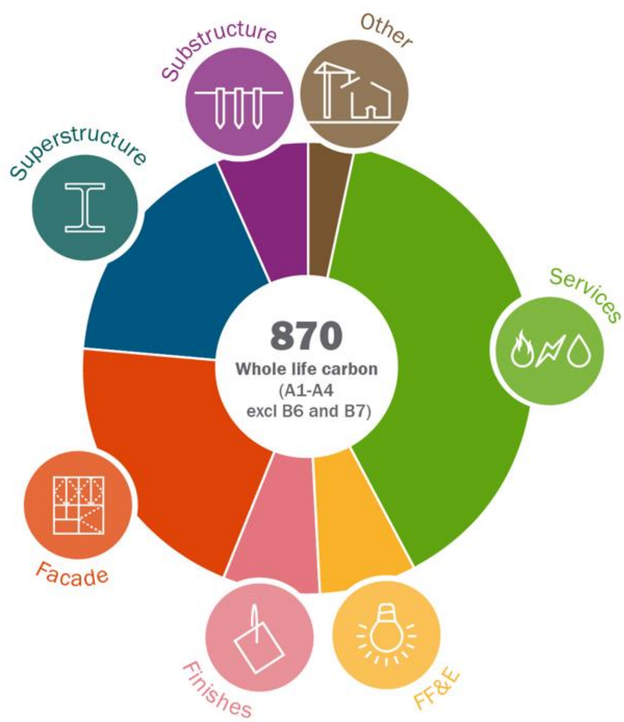
23 "Construction Carbon Regulations in Europe - Review and Best Practices, *One Click LCA*, October 2022. [Online]. Available: https://www.oneclicklca.com/wp-content/uploads/2022/10/EU-Regulations-Review-Ready-to-Publish.pdf?vgo_ee=MiYl9q70OFwiSV%2BWRRe3t76UuXqK4oj9zpWcE5%2FJs8s%3D. [Accessed: 10-Nov-2022].

An interviewee from the UK noted that several stakeholders insist that policies try to reuse existing buildings or materials before constructing new buildings or using new materials. A building scale approach using whole building life cycle will allow consideration for reuse, geometry, and material efficiency.

An interviewee from the Netherlands noted that inclusion of Stage D (reuse, recovery, and recycling) and the accounting of recycling before it takes place is advantageous to steel products. Biogenic material stakeholders in the Netherlands prefer to aim requirements at stage A, given their immediate impact. Currently in the Netherlands, the requirements do not limit material type, but require leaner material use.

- **Building Component Inclusion or Exemptions:** Regulations also differ when it comes to the inclusion of building components. Some regulations will focus on the elements that cause immediate major impacts while others will cover the entire building including all primary elements: envelope, mechanical, electrical, and plumbing equipment, superstructure, substructure, and finishes. In the UK's Part Z proposal for buildings, mechanical, electrical, and plumbing components are included (as denoted by "Services" in Exhibit 7), and the interviewee suggested that over a 60-year life, it can create similar carbon impacts as structural components since it must be replaced over several cycles.

Exhibit 7: Embodied Carbon Breakdown by Component



- **The Treatment of Sequestered Carbon:** There was recognition that there is a significant level of sensitivity surrounding the allowance of credit for sequestered carbon. Some countries have a requirement to report biogenic material separately, while France allows subtraction of biogenic carbon from A1-A3 to achieve their carbon limits. By 2031, France's carbon limits will generally encourage wood structures, or low carbon concrete structure or wood mixes with additional optimisation (refrigerant replacement, low-carbon materials, efficient geometry, etc.).

In France, they also have a “dynamic” methodology that considers earlier carbon release as more harmful, which further encourages bio sourced materials.

In the UK, proposed Part Z legislation would only require biogenic material to be reported. The interviewee explained that timber is mostly imported and there are concerns for monocultures and deforestation. The Netherlands’ EN15804 methodology version in use does not allow credit for biogenic material.

- **Complexity:** Several interviewees cited concerns around the complexity of embodied carbon requirements. An interviewee from New Zealand felt that embodied carbon methodology needed to be accessible and understandable for the intended audience. An interviewee from the Town of Ithaca felt that when the IECS was in development (2018), embodied carbon requirements represented a heavy lift to catalogue building material documentation. The focus was instead placed on an adaptive reuse option in the points-based prescriptive code which awards one point for substantial re-use of an existing building for a different use.
- **Data Availability:** Some countries have extensive environmental product databases to support embodied carbon calculations for new buildings. For example, France’s INIES database was created in 2004, around the same time that the Netherlands’ National Milieu Database was created. However, interviewees from the UK and New Zealand explained that there was a lack of EPDs to support an embodied carbon policy in their jurisdictions.
- **Tools and Training:** Lack of tools and training to support industry around an embodied carbon policy was cited as a challenge by several interviewees. In the UK, Part Z legislation on embodied carbon is in front of the government for approval, but tools and training have not yet been developed to support industry.

5. Options for Assessing Future Carbon Codes

This section presents the options assessments for buildings, informed by findings from the jurisdictional review and interviews. The options assessment focuses on requirements related to operational carbon, fuels, and electrification, and will serve to inform the development of future carbon code requirements.

In addition to the options presented for buildings in sections 5.1 and 5.2, overarching options that emerged from the jurisdictional review and interviews were for initial carbon codes to be simple and achievable, with increased complexity and stringency being introduced over time. For example, France's RE2020 introduces limits for low-rise and high-rise residential buildings, offices and education buildings, rather than for all building types as of January 1, 2022. Toronto's Green Building Standard is currently on version 4, with version 5 expected in 2025. As the standard has evolved, additional and more stringent requirements have been introduced. Tiered (stepped) operational emissions limits were also identified in more than one jurisdiction (e.g., BC, Toronto, New Zealand), which lay out a performance trajectory so that industry can plan accordingly.

5.1 Low-Rise Residential Buildings

The options assessment for low-rise residential buildings focuses on requirements related to operational carbon under the categories presented in Exhibit 8. The option identified as common practice for each category based on results of the jurisdictional review is identified in bold font. For example, the common practice under the variation of operational emissions limits by low-rise residential building size category was ‘none’.

Exhibit 8: Options Assessment for Low-Rise Residential Buildings

Category	Options	Examples	Considerations
Structure of operational emissions limits	• Absolute limit • Intensity limit normalized by floor area • Comparison to a modelled reference building • Prescriptive requirement to decarbonize space heating and/or water heating systems • Prescriptive points-based system	• BC: 1050 kg CO_2e/building for GHG emission level 1 (medium). • France: 160 kg CO_2e/m^2/building. • UK: ‘target emissions rate’ is calculated from energy performance and compared to a standardized building using the Standard Assessment Procedure. • VBBL: electric space space/water heating (prescriptive path). • BC: medium carbon, low carbon, and zero carbon ready compliance options. • Town of Ithaca: 3 points for air source heat pumps for space heating, 1 point for a water heating system that uses heat pumps.	• Prescriptive requirements are simple for stakeholders to understand. • Intensity limits and limits compared to a modelled reference building are well-suited to buildings with an energy model.
Variation of operational emissions limits by building size	• Compliance metric options • **None**	• BC: 1050 kg CO2e per building[24], or 6.0 kg CO_2e/m^2/year and 2400 kg CO_2e per building[24].	• Normalizing limits by floor area or setting separate absolute limits for small versus large low-rise residential buildings creates a more level playing field for low-rise

24 For GHG emissions level 1 (medium)

Category	Options	Examples	Considerations
			residential buildings of different sizes but adds complexity for stakeholders. • Common limits are a disadvantage to small low-rise residential buildings with less conditioned floor area compared to larger low-rise residential buildings.
Variation of operational emissions limits by typology	• Variation by typology (e.g., detached, semi-detached, row/town house) • **None**	• No example of variation by typology identified. • Town of Ithaca: 6 points required for low-rise residential buildings to comply with the prescriptive (easy) path.	• Adds complexity for stakeholders. • Disadvantageous to detached houses. • No examples found in the jurisdictional review.
Grid Emissions Factors	• **National (jurisdiction-wide)** • Regional • **Current** • Future • **Annual** • Monthly	• BC: one current emissions factor for electricity is used for the entire province, regardless of grid makeup. • UK: the same monthly emissions factors are used in England, Wales, and Scotland. These factors reflect realistic annual variation in the grid energy mix. • Washington: the same carbon factor for electricity is used throughout the state, even though the fuel mix varies by utility. • Australia: GHG emissions factors for various states published by the NCC.	• Regional emissions factors add complexity for energy modellers, builders and designers who may operate in more than one climate zone within a province or territory. • National emissions factors are a 'free pass' for regions with a carbon intensive grid. • Future emissions factors are uncertain. • Monthly factors reflect realistic annual variation in the grid energy mix.
Fuels[25]	• Fossil fuels permitted • Fossil fuels banned	• UK, France: fossil fuels permitted in new low-rise residential buildings, but compliance is difficult if they are used.	• Codes that allow fossil fuels provide flexibility for builders and designers.

[25] No common practice emerged from the jurisdictional and interviews, as several examples of codes that permit and ban fossil fu els were identified.

Category	Options	Examples	Considerations
		• Toronto: electrification not mandated but may be required by proxy in the Toronto Green Standard as operational emissions limits are lowered. • Town of Ithaca: fossil fuels are permitted, but 6 of 6 prescriptive path compliance points can be earned by electrifying space heating, water heating and cooking. • Petaluma, Fairfax, Alameda, San Jose, Santa Cruz, and Morgan Hill California: gas ban prohibits gas infrastructure in new low-rise residential buildings. • New York City: combustion of substances that emit 25 kg or more of CO_2e per million BTU of energy is not permitted. Therefore, natural gas, which emits approximately 50 kg CO_2e per million BTU of energy is not permitted.	• Codes that ban fossil fuels provide clarity for builders and designers, and more certainty regarding GHG emissions impact than codes that permit fossil fuels.
Electrification	• Electrification requirements • **Electric-ready provisions** • EV requirements • **EV-ready provisions**	• Vancouver: electric space heating and hot water heating for most new low-rise residential buildings. • US DOE and PNNL Stretch Codes: household ranges, cooking appliances, clothes dryers, and water heaters must be electric-ready[26]. Electric-ready circuits and water heater space is required.	• Electric and EV-ready provisions provide flexibility for the future if all-electric or EV requirements are introduced. • EV requirements ensure charging infrastructure is in place when construction is complete.

[26] Electric-ready means that there is a sufficiently rated electrical receptable installed near permanently installed cooking equipment, appliances, clothes dryers, and water heaters. This assures a low-rise residential building built with gas or propane can easily accommodate future electric cooking equipment, appliances, clothes dryers, and water heaters.

Category	Options	Examples	Considerations
		• California: electric vehicle supply equipment must be installed in new low-rise residential buildings, and each dwelling unit must have a raceway to accommodate a dedicated 208/240-volt branch circuit. • No examples of EV requirements for low-rise residential buildings were noted.	

5.2 High-Rise Residential and Commercial Buildings

The options assessment for buildings focuses on options related to operational carbon under the categories presented in Exhibit 9. The option identified as common practice for each category based on results of the jurisdictional review is identified in bold font. For example, the common practice under the variation of operational emissions limits by typology category was 'variation by typology.'

Exhibit 9: Options Assessment for High-Rise Residential and Commercial Buildings

Category	Options	Examples	Considerations
Structure of operational emissions limits[27]	• Intensity limit normalized by floor area • Comparison to a modelled reference building • Prescriptive points-based system	• BC: 9.0 CO_2e/m^2/year for hotels and motels under medium GHG emission level. • UK: 'target emissions rate' is calculated from energy performance and compared to a standardized building using the Simplified Build Energy Model or other approved software tools. • Town of Ithaca: two points for using an air source heat pump; three points for using a ground source heat pump. • Toronto: Tier 1, Tier 2 (high performance), Tier 3 (near zero emissions), Net Zero Emissions.	• Intensity limits and comparison to a modelled reference building is well-suited to buildings with an energy model. • Prescriptive requirements are simple for stakeholders to understand.
Variation of operational emissions limits by typology	• **Variation by typology (e.g., office, retail, restaurant, etc.)** • None	• Toronto: 15 kg CO_2e/m^2/yr for offices; 10 kg CO_2e/m^2/yr for retail. • Denmark: From 2023 onward, whole-building CO_2 emissions must be less than 12 kg/CO_2e/heated square metre[28].	• Variation adds complexity for stakeholders. • Variation recognizes occupancy pattern and end-use intensity differences across building types.

[27] Common practice was to mirror the structure for the presentation of energy use targets.

[28] Includes building production and operation

Category	Options	Examples	Considerations
Grid Emissions Factors	• **National (jurisdiction-wide)** • Regional • **Current** • Future • **Annual** • Monthly	• BC: one current emissions factor for electricity is used for the entire province, regardless of grid makeup. • UK: the same monthly emissions factors are used in England, Wales, and Scotland. These factors reflect realistic annual variation in the grid energy mix. • Washington: the same carbon factor for electricity is used throughout the state, even though the fuel mix varies by utility. • Australia: GHG emissions factors for various states published by the NCC.	• Regional emissions factors add complexity for energy modellers, builders and designers who may operate in more than one climate zone within a province or territory. • National emissions factors are a ‘free pass’ for regions with a carbon intensive grid. • Future emissions factors are uncertain. • Monthly factors reflect realistic annual variation in the grid energy mix.
Fuels[29]	• Fossil fuels permitted • Fossil fuels banned	• Petaluma, Fairfax, Alameda, San Jose, Santa Cruz, and Morgan Hill California: natural gas ban prohibits gas infrastructure in new buildings. • New York City: combustion of substances that emit 25 kg or more of CO_2e per million BTU of energy is not permitted. Therefore, natural gas, which emits approximately 50 kg CO_2e per million BTU of energy is not permitted.	• Codes that allow fossil fuels provide flexibility for builders and designers. • Codes that ban fossil fuels provide clarity for builders and designers, and more certainty regarding GHG emissions impact than codes that permit fossil fuels. • A code that prohibits gas use in buildings fosters innovation and promotes complementary requirements like renewable energy generation.
Electrification	• Electrification requirements • **Electric-ready provisions** • EV requirements • **EV-ready provisions**	• Seattle: As of June 2021, heating in new buildings cannot be provided by electric resistance or fossil fuel combustion	• Electric and EV-ready provisions provide flexibility for the future if all-electric or EV requirements are introduced.

29 No common practice emerged from the jurisdictional and interviews, as several examples of codes that permit and ban fossil fuels were identified.

Category	Options	Examples	Considerations
		appliances (including natural gas, heating, oil, propane, or other fossil fuels). • Marin County: electric readiness or future proofing required if gas is permitted based on allowable exceptions. Buildings must have electric capacity for future electrification. • California: 10% of total parking spaces for MURBs, hotels, and motels must be EV charging spaces capable of supporting future Level 2 electric vehicle supply equipment. • Australia: Requirement for EV-ready provisions.	• EV requirements ensure charging infrastructure is in place when construction is complete.

6. Conclusions

The scan examined several jurisdictions' building codes spanning North America, Europe and Australia and provided a comprehensive perspective of code requirements addressing GHG emissions.

The report explored and described key findings on:

- Code requirements
- Code development process and on
- Options Assessments

It is worth underlining that while operational carbon implications are relatively thoroughly examined in codes, including considerations for embodied carbon face challenges related to:

1. Defining the scope and boundary of the life cycle analysis
2. Managing complexity so as to facilitate calculation methodology
3. The lack of EDPa in some jurisdictions and
4. The lack of tools and training to support the industry.

It is therefore imperative that the above challenges be tackled to account for the entire carbon footprint in building codes.

Appendix A Overview Table

Results of the jurisdictional review are provided under separate cover, in a companion MS Excel spreadsheet entitled "Appendix A – Overview Table."

Appendix B Interviewee List

Exhibit 10 shows the full list of interviewees, including their title, jurisdiction, organization, and email address.

Exhibit 10: Interviewee List

Contact Name & Title	Jurisdiction	Organization	Email
Scott Williams: Senior Codes Engineer	British Columbia, Canada	Building and Safety Standards Branch BC Government	Scott.B.Williams@gov.bc.ca
Tiffany Warkentin: Director, Building Policy & Legislation	British Columbia, Canada	Building and Safety Standards Branch BC Government	Tiffany.Warkentin@gov.bc.ca
Lisa King: Senior Policy Planner	Toronto, Canada	City of Toronto	Lisa.M.King@toronto.ca
David MacMillan: Program Manager	Toronto, Canada	City of Toronto	David.MacMillan2@toronto.ca
Duane Jonlin: Energy Code and Energy Conservation Advisor	Seattle, USA	City of Seattle Department of Construction and Inspections	duane.jonlin@seattle.gov
Emily Hoffman: Director of Energy Code Compliance	New York City, USA	New York City Department of Buildings Office of Sustainability	emhoffman@buildings.nyc.gov
Nick Goldsmith: Sustainability Planner	Town of Ithaca, New York, USA	Town of Ithaca	NGoldsmith@town.ithaca.ny.us
Ian Shapiro: Special Consultant	Town of Ithaca, New York, USA	Taitem Engineering	imshapiro@taitem.com
Darren Port, Codes and Standards Manager	Northeastern United States	Northeast Energy Efficiency Partnerships	dport@neep.org
Meredydd Evans: Senior Staff Scientist	United States	Pacific Northwest National Laboratory	m.evans@pnnl.gov

Erik Mets: Building Scientist	United States	Pacific Northwest National Laboratory	erik.mets@pnnl.gov
Anne Svendson: Special Advisor	Denmark	Danish Energy Agency	ansv@ens.dk
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Louis Bourru: Director of Low Carbon Buildings Projects	France	Cerema	louis.bourru@cerema.fr
Katie Symons: Principal Advisor, Engineering	New Zealand	Building Performance and Engineering Building System Performance Ministry of Business, Innovation & Employment	Katie.symons@mbie.govt.nz

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