Moving new construction to net zero: progress and lessons from Europe and North America

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Abstract

In order to meet the Paris Agreement and other decarbonization targets, new homes and buildings will need to be net zero emissions. It is much easier to build efficiently at the time of new construction than having to retrofit these buildings later. Getting new construction to net zero energy and/or net zero greenhouse gas emissions will likely require a mix of building code upgrades and voluntary programs. In Europe, the Energy Performance of Buildings Directive (EPBD), obligates EU member states to steadily improve the energy performance of their buildings, both new and existing, and sets out how the EU can achieve a zero-emission and fully decarbonised building stock by 2050. But implementation of the EPBD varies widely between countries, even regarding new construction which is the subject of this paper. Activities are also underway in non-EU member states including Norway, Switzerland and the UK. Likewise, in North America, Canada (driven in part by the province of British Columbia) has made great strides in establishing a code pathway to zero energy ready new construction. In the U.S., ASHRAE, the organization that develops the model building code for commercial buildings has established a goal to require net zero energy and emissions by 2030. Some states have made great strides in their codes (e.g. California and Massachusetts). There are also new federal tax incentives that reward zero energy ready new construction and more than a dozen utilities offer technical assistance and incentive programs targeting net zero energy. In this paper, jointly written by European and American experts, we report on and contrast net zero new construction efforts in Europe and North America, identify lessons learned, and discuss some needed next steps.

Introduction

To meet Paris and other decarbonization targets, new homes and buildings will need to be net zero emissions. Making new buildings efficient at time of new construction is much easier than having to retrofit these buildings later. For example, according to the International Energy Agency (IEA), there are presently about 90 billion square meters of building floor area in advanced economies throughout the world, and another 15 billion square meters will be built over the 2023–2050 period. To achieve net zero emissions by 2050, they find that all new buildings need to be net zero emissions by 2030 (IEA 2023). A mix of building code upgrades and voluntary programs and efforts will be needed to move new construction to net zero energy and emissions. In the sections below we discuss the status of efforts to advance net zero new construction in Europe and North America. We then discuss trends across these two continents and discuss next steps for both continents on ways to enhance current efforts.

In some jurisdictions, new construction efforts focus on net zero energy, in other jurisdictions the focus is on net zero emissions or both. Some jurisdictions emphasize near zero (a term used in Europe) or zero ready (a term used in North America). Both terms typically mean high efficiency and with sufficient electric service for electric space and water heating and other appliances so a building can be easily electrified later. A few

jurisdictions emphasize buildings that achieve net zero as built. In our discussions we note which jurisdictions do what.

Europe

Since the 1993 SAVE Directive (EU 1993), the European Union has linked improvements in energy efficiency with reducing carbon emissions. The linkages have evolved over the years as the need to reduce carbon emissions became ever more necessary to address climate change. The link between energy efficiency improvements and reducing carbon emissions has become stronger since 1993. With buildings accounting for about 36 % of CO_2 emissions and 40 % of energy demand (EC 2021), the need to significantly improve the energy performance of new buildings is essential. This work essentially started with the first Energy Performance of Buildings Directive (EPBD) in 2002. Most of Europe is dominated by the policy framework of the European Union but other approaches are happening in non-EU countries. That said, Norway by and large follows the EU-EPBD and the UK did until recently. Switzerland has followed a separate approach. All of the countries see the need to reach net zero energy and/or emissions in order to meet their long-term climate and energy obligations.

EUROPEAN UNION

The European Union has established a framework directive, EPBD, that sets the policy foundation for improving the energy performance of EU's new buildings. It is also linked with the EU's Energy Efficiency Directive and the Renewable Energy Directive, that affect the energy performance of buildings. Being framework directives, they need to be transposed into national law before implementation. Originally approved in 2002, the EPBD has been revised in 2010, 2018 and the directive is currently under revision with adoption expected in April 2024. The recast in 2010 created a new obligation for nearly zero-energy new buildings. It set a date of December 31, 2020 when all new buildings had to be nearly zero-energy. Member states had some latitude in how they defined nearly zero-energy buildings. To help, in 2016, the European Commission published "guidelines for the promotion of nearly zero-energy buildings and best practices to ensure that, by 2020, all new buildings are nearly zero-energy buildings" (EC 2016). The long-term aim is to achieve a highly efficient and decarbonised building stock by 2050. The directive currently under revision is expected make zero-emission buildings the new standard for new buildings and not just zero-energy. Member states will also have to ensure that new buildings are solar-ready, meaning that they have to be fit to host solar rooftop photovoltaic or solar thermal installations. The 2023 agreement was formally adopted by the European Parliament and awaits the formal adoption by the European Council in 2024.

An initiative funded by the European Commission entitled "Concerted Action EPBD (CA EPBD)" brings together experts from all the member states to help implement the provisions of the directive. Norway also participates in the initiative and, until recently, so did the UK. Because of Brexit, the UK no longer does. There are a number of themes CA EPBD works on including building codes and technical requirements, smart buildings and system integration, and zero-emission buildings. Current work streams will now focus on the soon-to-be-approved directive.

In the sections below we review three EU member states in terms of their pathway to net zero new buildings. These are illustrative examples, chosen to provide regional balance.

Ireland

Building Regulations in Ireland apply to the construction of new buildings, to major renovations, and to extensions or material alterations to existing buildings. The 2019 Building Regulations for residential buildings set minimum energy performance requirements for dwellings and their application to new dwellings to achieve the Nearly Zero Energy Buildings (NZEB) standard, which is equivalent to a 25 % improvement in energy performance when compared to the 2011 regulations. Maximum permissible energy performance and greenhouse gas emissions requirements were first introduced for residential buildings in 2005 and for non-residential and public buildings in 2008. While energy from renewable energy sources has been mandatory for new residential buildings since 2008, as of 1 January 2019, building regulations require that renewable energy systems are installed in all new buildings. The renewable energy ratio must be at least 20 %, or 10 % where the primary energy and emissions are 10 % lower than minimum requirements (CA EPBD.2022-6).

Of the 50,706 homes built in the 2015–2020 period, 97 % are considered NZEB (CA EPBD.2022-1). There is an effective enforcement system in place through 31 local authorities designated as Building Control Authorities who monitor compliance with the Building Regulations in their area.

Poland

The framework directive was transposed through the Act on the Energy Performance of Buildings (published in September 2014) entered into force in Polish law in March 2015. Minimum requirements for new buildings were made obligatory in January 2017. The energy performance requirements for new buildings apply to the fabric of the building as well as to its heating, ventilation, air conditioning and domestic hot water systems (CA EPBD.2022-2).

The national plan for increasing the number of buildings with low energy consumption was adopted in 2015. The plan continues to pay particular attention to the definition of NZEB and their specific characteristics. The national plan also provides important information for investors, designers and contractors. It also describes the main and intermediate objectives related to improving the energy efficiency of buildings, together with a timetable for achieving them (CA EPBD-2022-2).

Control of the construction process is carried out by both the architectural and building administration and building supervision (CA EPBD.2022-2). The Polish government confirms that all new buildings are now NZEB (PMCE 2024).

Spain

The Technical Building Code (CTE), approved by Royal Decree 314/2006, is the regulatory framework that establishes the basic quality requirements that buildings and facilities must meet. It was modified in December 2019 to comply with the 2018 revision of the EPBD. The CTE has regulated the energy performance requirements for new buildings since 2007. As required by legislation, updates were carried out in 2013 and 2019 and are required to take place every five years (CA EPBD.2022-3).

In 2013 three changes were made: stricter energy performance requirements, the indicator system was made to incorporate a new indicator for non-renewable primary energy consumption, and requirements for the contribution of renewable energy were increased. In 2019, there were increased regulatory requirements promoting energy efficiency and renewable energy and new indicators such as total primary energy consumption (CA EPBD.2022-3). Also there was a clearer definition of NZEB. The new definition sets a more ambitious limit of a 40–60 % reduction in energy consumption, improvements in thermal envelope requirements, tighter conditions for controlling energy demand, conditions for thermal installations, conditions for lighting installations, a minimum contribution of renewable energy to cover the demand for hot water, and a minimum generation of electricity from renewable sources (IEA.2021)

To support the implementation of NZEB construction, the Spanish administration published two additional documents: the Housing Plan of the Ministry of Development, and the Renovation Strategy of the Spanish Building Stock (CA EPBD.2022-3).

The energy performance requirements for heating, cooling and domestic hot water generation systems are regulated through the Regulation of Thermal Installations of Buildings (RITE). The energy performance requirements for lighting in non-residential buildings is through the CTE (CA EPBD.2022-3). There is no information on enforcement.

UNITED KINGDOM

Buildings are a devolved responsibility and there are different approaches taken in England, Scotland, Wales and Northern Ireland. The comments in this paper pertain to England. Energy efficiency requirements for new homes and non-domestic buildings are set by Part L (Conservation of Fuel and Power) and Part 6 of the Building Regulations 2010 ("the Building Regulations"). There is now a consultation underway that sets out the government's plans for achieving the Future Homes Standard and Future Buildings Standard (GOV.UK 2023). The consultation ends in March 2024. The Government is aiming to publish the finalised regulations and guidance in 2024 and for them to come into force (with transitional arrangements) in 2025. A key objective for the government of the 2025 standard is ensure homes and buildings are "net zero carbon" ready, meaning they will be fully electric and need no retrofitting to produce zero carbon emissions as the electricity grid decarbonises. The consultation explicitly states that gas boilers, hybrids and hydrogen-ready boilers will not meet the 2025 standards and that biomass is unlikely to. (Fogarty 2024).

Since 2010, energy standards for new buildings have been strengthened by over 30 % (CA EPBD.5). In 2019, the Government passed legislation to commit the UK to a legally binding target of net zero emissions by 2050.

Local authorities have a general duty to enforce the Building Regulations in their area.

NORWAY

The EU EPBD provides the main policy framework for Norway. Norway has fully implemented the EPBD since 2010. The main energy efficiency measure in the buildings sector is the adoption of building codes. Norway's building codes were revised in 2010 and last updated in 2015 (and enforced since 2017), to the passive house level, which are 20–25 % stricter than previous energy efficiency requirements. The regulation requires that new buildings or buildings undergoing major renovation have either a total net energy need lower than specified in the regulation or meet a set of energy requirements for individual building components (such as windows, doors, roof and walls) (IEA.2022-2). A ban on the installation of fossil fuel heating systems in new buildings came into force in 2017. According to a Concerted Action EPBD report, the requirements of 2015 do not fully meet the Norwegian passive house standards but are set at a more cost-optimal level (CA EPBD.2022-4). The 2010 recast of the EPBD defines cost-optimal level as: "the energy performance level which leads to the lowest cost during the estimated economic lifecycle." (EU 2010).

Norway included the 2010 EPBD in the European Economic Area Agreement with the EU. However, the 2018 revision of the EPBD is not included in the EEA Agreement (CA-EPBD.2022-4).

SWITZERLAND

Buildings also account for about one third of Switzerland's CO_2 emissions. Energy Strategy 2050 (Switzerland's new energy policy) aims to reduce the energy consumption of the Swiss buildings stock to 65 TWh by 2050. The federal government – and thus the Swiss Federal Office of Energy – only plays a subsidiary role in the regulation of energy use in buildings. This means there is no national building code or regulations. Each of the 26 cantons sets its own requirements. The Conference of Canton Directors of Energy (EnDK) plays a key role in coordinating the cantons. The EnDK prepared cantonal model prescriptions to facilitate the adoption of more unified building regulations. The latest version of the "Model regulations of the cantons in the energy sector" (MuKEn 2024) dates back to 2014 and sets the standard for new buildings in line with EU recommendations for near zero energy buildings; prescribing a maximum consumption of 3.5 litres of oil equivalent per square metre per year for new residential buildings (MuKEn 2024). The consumption targets have been reduced by over 75 % since 1975. The EnDK recommends that the cantons incorporate the MuKEn as unchanged and completely as possible into their cantonal decrees. This system has proven successful and the cantons have largely followed this recommendation. The basic module of MuKEn 2008 was implemented in most cantons. The cantons are currently implementing MuKEn 2014 (IEA,2023-2). Note that Cantonal energy laws differ in some respect, for example as far as the replacement of fossil heating systems, the need to install PV on new buildings or a prescription to remove direct electrical heating systems within a certain deadline (MukEn2024). Looking to the future, EnDK recently started to renew MuKEn and plans to make it more ambitious in the future.

North America

In this section we discuss zero energy building efforts in Canada and the U.S. As of mid-2022, nearly 700 net zero (energy or emissions) commercial and multifamily buildings have been catalogued in the U.S. and Canada (NBI 2022). For the residential sector, there were 38,646 net zero single-family homes (including net-zero ready) as of mid-2022, up 440 % from 2020 (EEBA 2022).

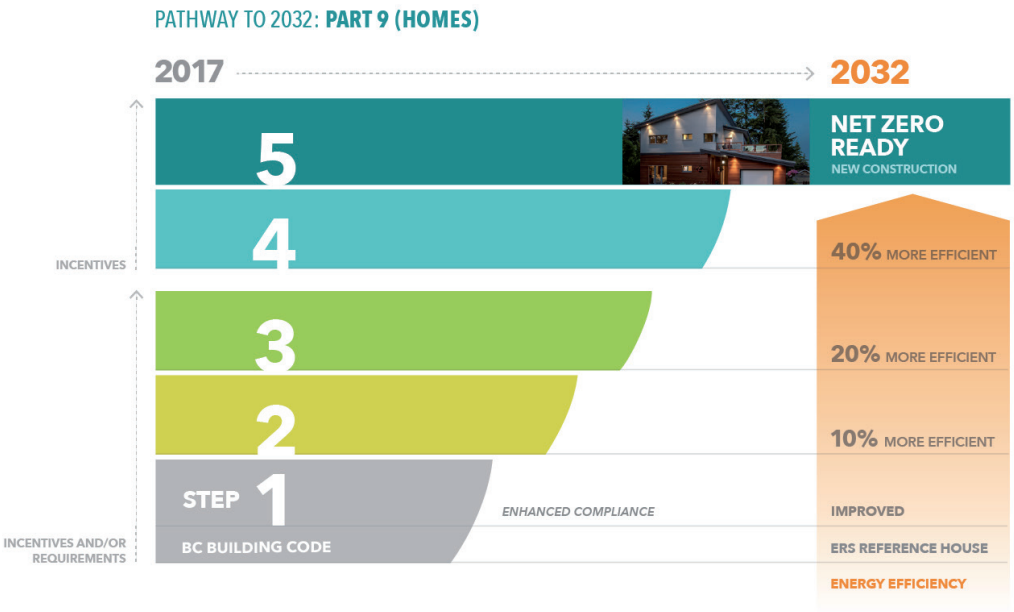


Figure 1. Illustration of British Columbia step code for homes. Source: BSSB 2018.

CANADA

We begin by discussing the province of British Columbia, which is a leader on building codes, and then discuss Canada-wide policies.

British Columbia

The Canadian province of British Columbia has developed a "step code" that contains five increasingly stringent "steps." Step five is zero-energy ready, which in this case means approximately North America Passive House levels (PHIUS [2024], similar to the European program of the same name). The plan is to adopt the step five code across the province by 2032, but in addition the province is promoting the steps through local building codes and voluntary programs. Figure 1 illustrates the step code for many homes. Initially only step one was required, but as of May 1, 2023, step three is required for new homes (BSSB 2023). A few local jurisdictions are requiring step four for homes (BSSB 2022). There are also four steps for commercial buildings and wood frame homes (not shown in the figure) and as of 2023, step 2 is required for these other buildings, with 20–40 % better energy efficiency (varying by building type) than the 2017 baseline new building (BSSB 2023).

Canada Wide

In Canada, development of the National Building Code (NBC) for most residences and the National Energy Code for Buildings (NECB) for commercial and multifamily buildings is led by the National Research Council. This code is typically adopted by individual provinces and territories, sometimes with modifications to suit specific local needs. The code is revised approximately every five years. The 2015 version is now in use, with provinces and territories due to make decisions by March 2024 on adoption of the 2020 code (publication was delayed until early 2022 due to COVID). Under a 2019 agreement between the federal, provincial and territory governments, all provinces and territories have agreed to adopt the NBC and NECB starting with the 2020 versions (RCT 2019). The plan is to move to zero energy ready standards by 2030, as spelled out in a 2016 *Pan-Canadian Framework on Clean Growth and Climate Change* (GOC 2016).

The 2020 codes are similar to and based in part on the BC Step Code, with five tiers provided in the NBC and four tiers provided in the NECB. Energy efficiency tiers are expressed as percent savings below the baseline (GOC 2022). Each province or territory (there are 13) will select the tier they will use. For example, BC is expected to adopt a step very similar to what they have recently adopted under their Step Code.

The 2025 version of the NBC and NECB are now in development with proposals going out for public review in February 2024 (CBHCC 2024) and final decisions due by the end of 2024. Two major changes in the 2025 codes will be the inclusion of building retrofits under the code (unless meeting the code is not feasible for a particular retrofit) and inclusion of greenhouse gas (GHG) emissions standards. Plans are to have six GHG tiers (A to F, with A being zero emissions). Provinces and territories will select both an energy tier and a GHG tier. For offices, schools and multifamily buildings, absolute energy limits per square meter are planned while for other sectors the provisions in the 2020 code can still be used. The expectation is that provinces with high contributions of hydroelectric generation will choose low GHG tiers while provinces that have extensive fossil fuel generation may choose less aggressive GHG tiers in 2025 while they work to clean up their power grids. As electrification increases, going to higher energy efficiency tiers will also be important to help slow the growth in peak power demand.

In addition to building codes, Natural Resources Canada has undertaken a variety of projects to demonstrate and support zero energy construction such as a net zero home pilot across seven provinces (NRCan 2021).

UNITED STATES

In the U.S., new construction energy performance is primarily driven by building codes, but federal tax incentives and utility incentive programs also have an influence. We discuss each of these in turn.

Building Codes

In the U.S., building codes are generally established at the state level. Most states adopt one of a few national model codes, perhaps with a few modifications, but some states develop their own codes. We begin with discussion of national model codes and then discuss recent efforts in four leading states.

National Model Codes

In the U.S., national model codes are developed by two consensus-based code bodies, with revisions every three years. For commercial and high-rise residential buildings, ASHRAE publishes Standard 90.1 which is written in building code language. Since 1980, this code has steadily gotten more stringent, with the 2023 edition reducing energy use of new buildings by an average of 60 % (USDOE 2024-1) relative to the 1980 edition. As of late-2023, 10 states were using the 2019 version of 90.1 or its equivalent, 24 states were using the 2010, 2013 or 2016 editions, nine states were using earlier editions, and seven states did not have a state-wide code, leaving code adoption to local jurisdictions (USDOE 2023). ASHRAE leadership has pledged that the 2031 edition of this code will be net zero energy and carbon emissions (ASHRAE 2023). If this happens, based on past experience, eventually the majority of states will adopt this code, but it might take a decade or longer for this to happen after the 2031 ASHRAE standard is finalized.

For low-rise residential, the national model code is the International Energy Conservation Code (IECC) which is developed by the International Code Council. The 2024 version was pending final approval as of March 2024. Since 1980, this code has steadily gotten more stringent, with the 2021 edition reducing energy use of new homes by an average of 45 % [(USDOE 2024-1) relative to the 1980 national model code. As of late-2023, 5 states were using the 2021 version of the IECC or its equivalent, 36 states were using the 2009, 2012, 2015, or 2018 editions, two states were using earlier editions, and seven states did not have a state-wide code, leaving code adoption to local jurisdictions (USDOE 2023). The IECC does not presently have a net zero goal but does contain optional net zero energy appendices with the same energy efficiency requirements as the main IECC but provisions to offset energy use with use of renewable energy, including on-site, off-site and by contracting for renewable energy certificates (ICC 2021). The IECC has been slow to adopt code changes as home builders have a large say in the IECC process, and they tend to oppose increases in code stringency. In addition to the IECC, ASHRAE publishes a low-rise residential standard 90.2 that has more stringent energy efficiency requirements than the IECC, targeting 50 % energy savings relative to the 2006 IECC (ASHRAE 2018). One option going forward may be for ASHRAE 90.2 to move towards net zero energy and emissions, and to encourage states to adopt 90.2 instead of the IECC.

One way to put the various U.S. residential efficiency standards in perspective is via the Home Energy Rating System (HERS). The is a 100-point scale where new homes meeting the 2006 IECC score 100 and a building that uses no outside energy scores zero. Older homes that do not meet the 2006 IECC score over 100. Under this scale, the average new home built in 2023 had a score of 57 (RESNET 2024), homes meeting the DOE Zero Energy Rated Homes specification have a score of 50 or less, and homes built to Passive House standards have a score in the high 30's or low 40's not counting any solar or other on-site energy systems that might be used.

California

California has developed its own building energy code since 1976. The code, which is called Title 24, is revised every three years. California has a moderate climate, with only limited heating and cooling needs along the Pacific Coast but large cooling needs inland and significant heating needs near the Sierra Mountains. Historically many California buildings use natural gas for space and water heating but in recent years a variety of programs as well as Title 24 have emphasized use of electric heat pumps for space and water heating to reduce greenhouse gas emissions. In 2022, renewable resources, including hydroelectric power and small-scale, customer-sited solar power, accounted for 49 % of California's in-state electricity generation. Natural gas fuelled another 42 % and nuclear power supplied most of the rest (EIA 2023a). Under state law, the renewable percentage is due to increase to 60 % by 2030 (CPUC 2023).

The 2022 Title 24 encourages use of efficient electric heat pumps for space and water heating, establishes electric-ready requirements for new homes, and expands solar photovoltaic and battery storage standards. The code generally establishes a performance baseline for use of heat pump water heaters in most homes and use of space heating heat pumps in some coastal and southern portions of the state (CEC 2022). The code also establishes a performance baseline for use of heat pumps instead of single-zone furnace/air conditioner systems for several commercial building types. The code requires photovoltaic systems for residential, with minimum size requirements that roughly mean that new homes will be net zero electricity not counting space and water heating loads (CEC 2019).

The 2025 Title 24 is still in development. An initial draft includes a variety of efficiency improvements and expands photovoltaic requirements for commercial buildings. For homes, the performance baseline includes both heat pump water and space heating systems. And for commercial buildings, the performance baseline all but requires the use of heat pumps instead of instead of chillers in offices and schools. Also proposed is a performance baseline for heat pumps when under 5-ton (5,000 Watts) single-zone furnace/air conditioners are replaced for several building types (CEC 2023).

In addition to Title 24, the California Air Resources Board (CARB) has announced that as part of efforts to meet federal ground-level ozone pollution standards, it proposes to set an emission standard for space and water heaters to require zero emissions, effective 2030 (CARB 2022). Detailed state-wide regulations have yet to be issued although a regional body that regulates air quality in the San Francisco area has already issued such regulations (Balaraman 2023).

Massachusetts

Massachusetts essentially has three energy codes – a base code (which applies in about 50 communities), a stretch code (which applies in over 250 communities), and a Specialized Net-Zero code (which as of this writing applies in 32 communities, including the City of Boston). The base code is presently the 2021 IECC and incorporates ASHRAE 90.1-2019. The stretch code applies in communities that have taken action to become "green communities", with specific criteria spelled out in state

legislation. The specialized code applies in communities that explicitly adopt this code (Commonwealth of Massachusetts 2023a and 2023b).

The current stretch code for low-rise residential requires either Passive House certification or performance modelling showing about 10 % energy savings relative to the basic code. In addition there are requirements for heat recovery ventilation and wiring for EV charging. Commercial and high-rise multifamily must have 10 % energy savings relative to the basic code, meet additional mandatory envelope requirements, must have electric heating for many building types. In addition, buildings over 20,000 sq. ft. (1,860 sq. meters) must meet Thermal Energy Demand Intensity (TEDI) targets that limit peak heating demand. Other commercial stretch code requirements reduce air leakage, thermal bridging, increase ventilation energy recovery and increase wiring requirements to accommodate EVs (DOER 2022).

The specialized net-zero code includes all of the stretch code requirements and in addition offers three pathways: net-zero emissions, all-electric, or mixed-fuel. In the all-electric pathway, roofs must be solar ready. In the mixed-fuel pathway, efficiency must be set to Passive House standards or can be a little less efficient but have some building integrated solar systems installed. And mixed-fuel buildings must have sufficient electrical service, space and wiring to allow for future conversion to all-electric (DOER 2022).

New York

New York primarily uses recent national model codes for its energy code. In addition, in 2023, a law was enacted requiring that the state building code be amended to require zero on-site greenhouse gas emissions in new construction. New buildings will not be able to install fossil fuel equipment starting in 2026 for small buildings and 2029 for larger ones. The prohibition starts in 2026 for new buildings up to 7 stories tall, except for commercial and industrial buildings larger than 100,000 square feet. In 2029, new buildings of all sizes – aside from the exemptions for certain uses listed in the bill – must be built without fossil fuel equipment. For example, the bill exempts manufacturing facilities, commercial food establishments, laundromats, hospitals, crematoriums, wastewater treatment facilities, and emergency backup power. The law also exempts new agricultural buildings, manufactured homes, car washes, other medical facilities beyond hospitals, and critical infrastructure including emergency management facilities. To address concerns about grid readiness, the law tasks the N.Y. Public Service Commission with determining whether the grid can reasonably support the additional load of new all-electric buildings. Details of the new code will be developed via a rulemaking (Manley 2023).

Washington

Washington is another state with a high proportion of zero emission electricity; in 2022 84 % of the state's power was hydroelectric, other renewables and nuclear (EIA 2023b). Washington is often one of the first states to adopt new versions of national model energy codes. In addition, the Washington code uses a point-based system requiring some improvements beyond the basic IECC. In the latest version of the code, which takes effect April 2024, points are earned for extra insulation and for installing heat pumps as a primary heating system instead of a fuel-based system (Cornfield 2023).

Complementary Initiatives

In addition to building codes, there are a variety of initiatives to promote more efficient new construction. The U.S. Department of Energy (DOE) runs a residential home certification program called Zero Energy Ready Homes (ZERH). The program includes roughly 20 % energy savings beyond base codes (sometimes a little more, sometimes a little less) and requires that conduit be installed and roofs designed to make it easy to install photovoltaic systems, heat pumps, heat pump water heaters, and electric vehicle charging equipment. As of 2023, builders are eligible for a federal tax incentive of $5,000 (approximately 4,550 Euros) for each ZERH they complete (US-DOE 2024-2). Additional federal tax incentives are available for installing air- and ground-source heat pumps, heat pump water heaters, and photovoltaic systems. Going a step farther on energy efficiency, the Phius program (Passive House US [PHIUS 2024], built on the European Passive House program) requires even higher levels of energy efficiency, making it easier to supply remaining energy use with renewable energy. More than a dozen utilities operate programs to provide technical assistance and incentives for building ZERH or Phius homes, sometimes with higher incentives for Phius levels of performance (Nadel 2020).

Similarly, for commercial buildings, a variety of organizations, such as the New Buildings Institute, promote zero-energy and zero-carbon design and construction. Some utilities operate technical assistance and incentive programs (Nadel 2020). And since 2023, a long-running federal tax incentive program was expanded to provide sliding scale incentives based on energy use reductions relative to the most recent ASHRAE 90.1 code, with a maximum incentive of $5 per square foot of building floor area (approximately (49 Euro/per square meter) (Ungar and Nadel 2023).

Trends in Europe and North America

Both Europe and North America are making substantial progress towards zero energy and emissions in new construction. In Europe, nearly zero energy is required under the Energy Performance of Buildings Directive. While many countries (e.g., Ireland and Norway) are making good progress, many other countries have been slower to adopt implementing details. Analysis from 2021 shows that 23 member states had a NZEB definition in place and four had a definition under review (D'Agostino 2021). Also, definitions of "nearly zero" vary substantially between countries, due in part to adapting to national conditions. In North America, Canada is making steady progress towards its goal of a net zero ready energy and emissions model code by 2030, with provinces and territories adopting this code a little later. In the U.S., progress is more uneven than in Europe and Canada. Some states, such as California, Massachusetts, New York and Washington are establishing goals and making good progress. Other states follow national model codes; if and when these codes move toward net zero, these states will eventually follow. But still other states are not interested in adopting new versions of these model codes.

Table 1. Key characteristics of the codes discussed in this paper.

Jurisdiction	Energy, Carbon, or Both	Generally require electric?	Near zero or Zero	Renewable energy requirements?
Ireland	Both	Encourage	Near zero	Yes
Poland	Both	Encourage	Near zero	Encourage
Spain	Both	Encourage	Near zero	Yes (hot water)
United Kingdom	Both	Encourage	Near zero	Encourage
Norway	Both	Yes	Near zero	Encourage
Switzerland	Both	Encourage	Near zero	Yes
BC	Both	Encourage	Near zero	No
Canada	Both	Encourage	Near zero	No
California	Both	Yes	Moving to zero	Yes
Massachusetts	Both	Encourage	Near zero	Encourage
New York	Both	Yes	Near zero	No
Washington	Both	Encourage	Near zero	Encourage

A summary on some of the key characteristics of the codes discussed in this paper is provided in Table 1. This shows that most of the jurisdictions we examined are looking at both energy and carbon.

A few other observations are worth noting across the two continents based on this table and the previous discussion:

- Most of the efforts to date focus on near zero, with high energy efficiency and other requirements, but generally not yet including requirements for on-site renewable energy generation. But California and Ireland are generally requiring solar installation, and Massachusetts includes solar in some of its zero code pathways. In Switzerland, the expectation is that the revised regulations will include targets for on-site electricity production, 100 % renewable energy for heating (and cooling) in all new buildings (IEA 2023). Spain generally requires solar hot water.
- Three jurisdictions are requiring electrification of space and water heat – Norway, California and New York. Other jurisdictions are encouraging electrification.
- In both continents, leaders are starting to close in on near zero goals for energy and/or GHG emissions. This includes Ireland, Norway, British Columbia, California and Massachusetts.
- In Europe, NZEB requirements average about 70 % lower than national minimum performance requirements in 2006 (D'Agostino 2021). In the U.S., the average new home reduces energy about 43 % relative to the 2006 code (RESNET 2024). Thus, Europe on average has made more progress than the U.S, both relative to their 2006 bases. We have not tried to compare the 2006 bases.
- Establishing long-term goals for zero ready or zero can help to motivate action. This is the case with the European EPBD, British Columbia and Canada's 2030 goals, ASHRAE's 2031 goal, and seems to be driving steady progress in places like California, Massachusetts and New York.
- In some jurisdictions, electrification of space and water heating is playing a substantial role in efforts to ultimately require near zero performance. Norway, Finland, Sweden, California, New York and Washington stand out as examples.
- In some areas, allowing local flexibility has been important for achieving policy consensus and allowing jurisdictions to move at their own pace. For example, the EPBD allows member states to set their own definitions of nearly zero-energy buildings and on other details. The British Columbia and Canada codes include various steps that local jurisdictions, provinces and territories can adopt. And Massachusetts has three codes, with each local jurisdiction picking one.

Conclusions

Substantial progress towards near zero construction is being made in both Europe and North America. But progress varies between jurisdictions, particularly in the U.S. In Europe, recent analysis has shown that Europe is not on track for carbon neutrality (BPIE 2023) and progress could be accelerated by banning fossil fuel heating systems in new buildings and ensuring that all buildings should be constructed as zero-emissions buildings from now on. This is being addressed in the soon-to-be approved revision of the EU EPBD. Canada appears to be on track to require zero ready new construction by the early 2030s and is also gradually adding building renovations. In the U.S., leading states are likely to be near zero emissions by the early 2030s, other states will eventually get there for commercial and multifamily buildings after the ASHRAE standard requires zero energy and emissions, but codes for homes will likely lag. A national zero energy and emissions model residential code is needed in the U.S. for middle-tier states to adopt. Under the U.S. system, code adoption is led by states, but with some federal assistance. While the U.S. federal government is unlikely to adopt a national code, the federal government could do more to encourage state progress by reducing building code funding for states that do not act and increasing funding for states that are moving codes towards zero energy and emissions.

If these steps are taken, hopefully at an ECEEE Summer Study in the early 2030s, we will be able to celebrate widespread success.

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