BUILDING ENERGY CODES
WORKING GROUP

EBC

Energy in Buildings and
Communities Programme

Best practices for building energy codes compliance

November 2021

Technology Collaboration Programme
by iea

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Participating countries in the EBC TCP: Australia, Austria, Belgium, Brazil, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, 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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International Energy Agency

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Building Energy Codes Working Group

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Authors

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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 Tool-kit 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 (*)
Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles (*)
Annex 65: Long-Term Performance of Super-Insulating Materials in Building Components and Systems (*)
Annex 66: Definition and Simulation of Occupant Behavior in Buildings (*)
Annex 67: Energy Flexible Buildings (*)
Annex 68: Indoor Air Quality Design and Control in Low Energy Residential Buildings (*)
Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings
Annex 70: Energy Epidemiology: Analysis of Real Building Energy Use at Scale
Annex 71: Building Energy Performance Assessment Based on In-situ Measurements
Annex 72: Assessing Life Cycle Related Environmental Impacts Caused by Buildings
Annex 73: Towards Net Zero Energy Resilient Public Communities
Annex 74: Competition and Living Lab Platform
Annex 75: Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables
Annex 76: ☼ Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO_2 Emissions
Annex 77: ☼ Integrated Solutions for Daylight and Electric Lighting
Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications
Annex 79: Occupant-Centric Building Design and Operation
Annex 80: Resilient Cooling
Annex 81: Data-Driven Smart Buildings
Annex 82: Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems
Annex 83: Positive Energy Districts
Annex 84: Demand Management of Buildings in Thermal Networks
Annex 85: Indirect Evaporative Cooling
Annex 86: Energy Efficient Indoor Air Quality Management in Residential Buildings

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

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– **Michael Donn, New Zealand, BECWG Co-Chair, Victoria University of Wellington**
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Executive Summary

Building energy codes are recognized worldwide as a proven policy for achieving economy-wide savings in buildings. However, achieving the desired energy savings from codes depends in large part on code compliance which determines whether code requirements are being met. Approaches to code compliance can vary widely across jurisdictions in terms of institutional set up and criteria for demonstrating code compliance. This paper reviews those differences and explores the need for stronger institutional approaches to enforce building energy codes that will lead to code compliance. Specifically, it sets out to address the question of what practices result in effective building energy code compliance.

The report findings draw from responses to a web-based survey (Appendix A) and interviews which captured the experiences of eleven member countries of the Energy in Buildings and Communities Programme (EBC) Building Energy Codes Working Group (BECWG): Australia, Brazil, Canada, India, Italy, Japan, New Zealand, Portugal, Turkey, the United Kingdom, and the United States. A total of 38 representatives from various jurisdictions in these countries responded to the survey. The survey was followed by selected interviews to clarify certain points about the codes and compliance practices in place in the participating countries.

The report is divided in two main sections: (1) a review of current practices and (2) a section highlighting "notable" practices. We distinguish notable practices as those practices which are unique to one or more of the surveyed jurisdictions, practices that resulted in easier or faster implementation of the code, and/or practices which led to demonstrated energy efficiency improvements.

Current Practices: The report development team surveyed current practices around four major topics: (1) enforcement set-up to verify code compliance, (2) capacity building and education on the code and code enforcement, (3) penalties and other mechanisms for improving compliance and (4) code compliance assessments. The following table summarizes the current practices and issues countries are facing under each category.

Summary Table: Current approaches and compliance issues reported by the surveyed countries

Practice category	**Current practice**	**Reported issues**
Enforcement set-up	While there is variation within countries, almost all countries reported having plan or design reviews prior to construction, about half implement compliance checks during construction, and only four countries have some form of check prior to occupancy (e.g., airtightness tests).	- Uneven enforcement from a lack of compliance checks - Lack of understanding of the code - Inspections timed for health and safety reviews may not occur when key energy efficiency measures need to be checked
Capacity building and education	Nearly all countries have some form of training and capacity building program to support code implementation, ranging from industry seminars to courses. This can include accreditation for code officials, and licenses and continuing education for builders, designers, and contractors.	- Lack of exposure by building officials to more complex aspects of the codes - Lack of mechanisms to ensure quality of trainings - Low investment in trainings
Penalties and other mechanisms for improving compliance	Common penalties to achieve code compliance include withholding construction and occupancy permits, publication of building owners' names who fail to comply, fines, and loss of licenses. Examples of incentives to achieve higher building performance include tax credits and low-interest loans, relaxed zoning requirements, and use of energy rating systems as an alternative path to demonstrate code compliance.	- Limited penalties or incentives in some jurisdictions
Code compliance assessments	Code compliance assessments vary in methods (e.g., using statistical methods and surveys), in frequency (e.g., reoccurring or a one-time analysis), and in coverage (national or local).	- Code compliance assessments are not widely or regularly conducted across the surveyed countries

Notable practices: This section of the report highlights certain notable practices that can be beneficial or interesting to other jurisdictions. The section covers three major themes:

- ***Pooling together resources across jurisdictions with the same energy efficiency goals:*** Initiatives such as the European Union's Concerted Action framework and the Northwest Energy Efficiency Alliance in the United States help countries in several ways. For example, they provide a forum to share challenges and practical options for improving implementation, they help to minimize redundant efforts, and maximize resources to verify code compliance and provide stronger training programs and analysis.
- ***Requiring accreditation and trainings of inspectors and official government endorsement of third parties:*** Several jurisdictions identified the lack of staff to perform inspections as an issue. The use of third parties in inspections has helped to address this challenge in countries such as Japan and Canada. However, the success stories reveal that third-party inspection systems must be accompanied by trainings as well as checks and balances to ensure the rigor and consistency of the inspections. Government endorsement of third-party trainings and accreditation programs is also important. In addition, certification programs which are tied to energy rating systems have also been successful in building capacity for checking codes compliance in a few countries such as the United States and Australia.
- ***Utilizing a data driven approach to improve code implementation:*** Incorporating data-driven approaches such as data-driven methodologies to conduct field studies and statistical analysis on the impacts of codes are helping jurisdictions in the United States to assess and target their efforts to improve code compliance. Digitalization efforts such as web tools that use data are also helping to automate compliance checks and improve consistency.

The survey of practices across the different countries reveals that the jurisdictions that have experienced the greatest success in code enforcement have utilized a combination of approaches. A combination of strategies prevents unintended consequences. Regardless of the approach, the experiences discussed in this report underscore the importance of implementing a holistic strategy whenever a new or updated code is introduced.

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Acknowledgements

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Abbreviations

Table 1. List of frequently used abbreviations

Abbreviations	Meaning
ADENE	Energy Agency (Agência para Energia)
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECWG	Building Energy Codes Working Group
BR	Brazil
CA	Canada
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
DGEG	Directorate-General for Energy and Geology (Portugal)
DOE	U.S. Department of Energy
EBC	Energy in Buildings and Communities
EED	Energy Efficiency Directive
ENEA	National Agency for New Technology, Energy and Sustainable Economic Development
EPBD	Energy Performance Building Directive
EPC	Energy Performance Certificate
EU	European Union
HERS	Home Energy Rating System
HVAC	Heating, ventilation, and air conditioning
ICC	International Code Council
IEA	International Energy Agency
IN	India
IT	Italy
JP	Japan
NABERS	National Australian Built Environment Rating System
NEEA	Northwest Energy Efficiency Alliance
NZ	New Zealand
PNNL	Pacific Northwest National Laboratory
PT	Portugal
TR	Turkey
UK	United Kingdom
US	United States

1. Introduction

Building energy codes are a proven policy mechanism to achieve economy-wide energy savings in buildings. According to the International Energy Agency (IEA), energy use reductions from building energy codes range from 22% (e.g., in the Netherlands and Germany) to 6% (e.g., Southern European countries) of average annual energy consumption per residential buildings (IEA 2013). In the United States, it is estimated that today's energy codes provide more than 30% savings compared to those of less than a decade ago, translating to more than $60 billion saved by residences and businesses (DOE 2016; Athalye et al. 2016). However, achieving energy savings depends in large part on code compliance. In a nutshell, code compliance signifies that code requirements are met. As would be expected, current approaches to code compliance can vary greatly across jurisdictions in institutional set up and criteria for demonstrating compliance.

In 2021, the International Energy Agency Energy's Buildings and Communities Programme (IEA EBC) Building Energy Codes Working Group (BECWG) conducted a survey on the code compliance practices across BECWG member countries. While codes vary in format and approach, attaining the energy reduction potential of any building energy code requires effective implementation and compliance. This is a large undertaking for several countries, as effective compliance checking requires adequate resources, technical knowledge, capacity, and strong institutions (Evans et al. 2018; IPEEC 2015). Many nations face the same compliance issues, such as requiring faster and easier methods to verify codes and coordinating among numerous stakeholders and levels of government. These challenges are compounded by a need to meet ambitious policy objectives such as zero net energy construction standards. This paper explores the need for stronger institutional approaches to enforce building energy codes that will lead to code compliance. Specifically, this report sets out to address the question of what practices result in effective building energy code compliance in selected BECWG member countries. Following this introduction, the report describes the analytical methodology. The report then covers current practices found in the participating countries across dimensions such as enforcement and training. It also describes notable practices that are unique and impactful before the conclusions.

2. Method

This report draws information from eleven countries that are part of the BECWG: Australia, Brazil, Canada, India, Italy, Japan, New Zealand, Portugal, Turkey, the United Kingdom, and the United States. The report development team initiated this effort by reviewing country-specific information on the implementation of building energy codes from past Working Group activities and from the Global Buildings Performance Network's Building Energy Codes Portal (https://tools.gbpn.org/laboratory/building-energy-codes-portal). The participating country delegates also held a series of group calls to discuss the goals and scope of this report. Building on this information, the team designed a simple online survey (Appendix A) around code implementation institutional arrangements and enforcement mechanisms to help achieve code compliance. The survey questions covered the following four major topics, which are covered in the section "Current practices":

1. Enforcement set-up (to verify code compliance)
2. Capacity building and education on the code and code enforcement
3. Penalties and other mechanisms for improving compliance, and
4. Code compliance assessments

Countries participating in the survey were selected, first, based on the expressed interest from the BECWG country delegates, and second, to cover a wide geographical area. A total of 38 representatives from these countries provided information on their jurisdiction's building energy codes via the online survey. A representative from the International Code Council (ICC) also participated in the survey. Based on the survey responses, the report team followed up with phone interviews as needed to clarify certain points about the codes and compliance practices in place in those countries.

In addition, the interviews were used to seek further information regarding jurisdictions that were deemed models in their respective countries with regards to successful code implementation. Findings on this topic are highlighted in Section 4 of this report on "Notable practices." Feedback from the BECWG country delegates helped in identifying three main criteria to determine practices for inclusion in this section. These criteria center around practices that:

1. Are unique to one or more of the surveyed jurisdictions
2. Resulted in easier or faster implementation of the code
3. Led to demonstrated energy efficiency improvements

The novel practices highlighted fit into one or more of these criteria. In addition to the survey results, the report development team also conducted additional desk research to survey available literature on the evolution and scope of codes and institutional arrangements for implementation in the studied countries.

3. Current practices

Countries have a range of practices related to building energy code compliance. A brief examination of how different countries organize their building energy codes can help in providing context for these practices. Some countries such as Australia and England incorporate their building energy code into their main construction code, while others such as Canada and India, adopt a separate code for building energy efficiency measures.[1] There may also be regional variances.[2] It should be noted that currently, Brazil does not have mandatory building energy codes. It has a voluntary energy efficiency building labeling program which the government plans to make mandatory. The institutional set up for code development, code adoption, and code enforcement can also vary between countries (Table 2). In nearly all of the surveyed countries with mandatory energy codes, the national government is responsible for developing the code, except for the United States. While the U.S. Federal government participates in the building energy codes development process, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) develops a commercial code frequently used in the United States. The International Code Council (ICC) develops the most commonly used residential code, as well as a commercial code that includes the ASHRAE standard as a compliance path. Additionally, some U.S. states such as California, Washington, and Florida develop their own codes outside of the ASHRAE and ICC processes (although the residential codes are still largely based on the ICC at this point). There are exceptions in other countries as well. For example, some cities in Canada, such as Vancouver, have introduced their own energy codes which are stricter than the national and provincial codes (IPEEC 2015).

Local governments have a larger role with respect to code adoption and enforcement. In about half of the countries with mandatory codes, the national government has the authority to adopt the code. However, even in these countries, local governments support the national government in adopting the code. This is the case in the United Kingdom (England and Wales), New Zealand, Portugal, and Turkey. In other countries, particularly countries with federalist systems of government such as Australia, Canada, India, and the United States, only subnational jurisdictions can adopt the code.

In all of the countries with mandatory codes, local governments are responsible for code enforcement; although, in Japan, the national government also provides oversight. Many stakeholders may also be involved in the code enforcement process. In New Zealand, for

[1] Appendix B lists the building energy codes of each country and other overview information.

[2] For example, in Alberta, Canada, it is a mix of both. For small buildings (such as single family homes) the energy efficiency measures are part of the construction code (the National Building Code [Alberta Edition]), but for larger buildings (typically commercial buildings), it is a separate code (the National Energy Code for Buildings).

example, regional agencies called Building Consent Authorities are primarily responsible for code enforcement, but other stakeholders also provide support. For instance, a builder or installer may be required to certify that some parts of a building have been constructed in accordance with the approved building design plan. Additionally, in almost all of the countries, local governments use third parties to help with code enforcement.

Table 2. Implementation set-up in the surveyed countries[3]

	Code Development	Code Adoption	Code Enforcement
National government	AU, CA, UK[4], IN, IT[5], JP, NZ, PT, TR	JP, UK[6]	
Local governments		AU, CA, IN, IT, US	AU, CA, UK, IN, IT, JP[7], NZ, PT, TR, US
Combination of national and local governments		NZ, PT, TR	
Other	US[8]		

Table sources: Survey responses; International Partnership for Energy Efficiency Cooperation Building Code Implementation Country Summaries (Available at https://tools.gbpn.org); Fragoso and Baptista 2016; Vaquero 2020

3.1. Enforcement

Countries can enforce codes at the design and construction stages of a building. During the design stage, an enforcement agency typically verifies that the plans for the building meet the energy efficiency requirements in the codes. Almost all the surveyed jurisdictions reported having code officials review plans (Table 2). In some jurisdictions, building officials utilize software tools to help assess or automatically calculate if a building design meets the requirements of the code

[3] Apart from Federal buildings, Brazil does not currently have mandatory building energy codes (it has voluntary energy efficiency labeling schemes). Thus, Brazil was not included in this table. A new Brazilian initiative that begun in 2020 aims to establish a mandatory model in residential, non-residential and public sectors by 2022.

[4] This report only includes data on the the codes in England and Wales given the available survey responses for the UK. Thus, when referring to the UK, this report is referring to the data collected on England and Wales. Scotland and Northern Ireland also include energy effciency provisions in their building standards.

[5] The national government has the authority to develop the codes. However, a Conference of Regions and Autonomous Provinces (Conferenza Stato-Regioni) coordinates between the national and regional governments through committees and working groups made up of various stakeholders on code development. In addition, the National Agency for New Technology, Energy and Sustainable Economic Development (ENEA) supports the development of current financial instruments and upcoming new energy certification guidelines through a voluntary consultation mechanism called Tavoli di Lavoro 4E.

[6] For the England and Wales code, both the national and local governments are involved in adopting the code.

[7] State or provincial and local governments with support from third parties (called “designated confirmation bodies”) enforce the code in Japan; however, the national government also provides oversight and accreditation.

[8] ASHRAE and ICC develop the commercial and residential energy codes.

(e.g. Canada, India, Japan, New Zealand and the United States).[9] This can simplify compliance for building officials, plan checkers, and inspectors by allowing them to quickly determine if a building project design meets the code. In six countries (Australia, Canada, New Zealand, Portugal, United Kingdom [England and Wales], and the United States), a code official visits the site during construction and oversees that the construction corresponds with the design. In Portugal, for example, energy experts who serve as inspectors and are trained by the national Energy Agency (ADENE), are responsible for verifying code compliance at the design and construction stages. After verifying that the plans are compliant with the code, an energy expert issues a certificate necessary for construction to begin. During the construction stage, the energy expert must take photos and gather documentation verifying that the building complies and is built as planned. The energy expert then submits the data to a national website. If there is a change during construction, the energy expert must review and submit a plan change order, only then can construction resume. There are also additional checks in place to prevent conflicts of interests. For example, ADENE reviews the documents the energy expert submits on the website. Additionally, both the municipality and the director of the construction company review the documents.

During the construction stage, the energy expert must take photos and gather documentation verifying that the building complies and is built as planned. The energy expert then submits the data to a national website. If there is a change during construction, the energy expert must review and submit a plan change order, only then can construction resume. There are also additional checks in place to prevent conflicts of interests. For example, ADENE reviews the documents the energy expert submits on the website. Additionally, both the municipality and the director of the construction company review the documents.

In addition to compliance checks at the design and construction stages, a few countries also conduct checks prior to occupancy, but this is rarer. Japan and the United States have commissioning requirements, although they are not universal in all building types and jurisdictions. Some jurisdictions in Canada, the United Kingdom, and the United States, for example, mandate airtightness testing which measures air leakage rates through a building envelope under controlled pressurization, as well as other issues identified during prior inspections. Elsewhere, this testing is not a mandatory test prescribed in the codes, but rather a performance-based option that some developers require. It should be noted that Italy, Portugal, and Turkey also have checks prior to occupancy for their Energy Performance Certificates (EPCs). Building energy regulations in these countries are based on the European Union's (EU) Energy Performance of Buildings Directive (EPBD). An EPC is a document that includes information on the estimated energy use and efficiency of a building, such as insulation properties

[9] In particular, jurisdictions that have a simulated performance compliance path rely on building energy simulation software to simulate energy use in a designed building, which is compared to a reference building or to a specified code requirement (Evans et al. 2017).

and heating and/or cooling systems of a building. The table below does not include EPCs because EPCs are mandatory ratings and labels, in effect, but by themselves, do not represent minimum performance standards in most countries.

Table 3. Overview of code enforcement mechanisms used by the surveyed countries

Enforcement Mechanism	EBC Member Country
Compliance check prior to construction	
Review plans	AU, BR, CA, IN, IT, JP, NZ, PT, UK, US
Compliance check during construction	
On-site inspections	AU*, CA, NZ, PT*, UK, US*
Compliance check prior to occupancy	
Comprehensive commissioning	JP, US*
Airtightness test	CA*, UK, US
*** varies by jurisdiction**	

The timing and frequency of on-site inspections are also important. For example, Australia mentioned that when inspections take place, they are often made at the foundation or structural stage and then at the completion stage (i.e., after cladding), making it impossible to perform quality assurance checks on insulation and building wraps, if wraps are used. In other words, inspections timed for health and safety reviews may not occur when key energy efficiency measures need to be checked. This can lead to issues down the road. In the case of limited uptake of waterproofing building wraps, for example, it can increase the likelihood of future condensation issues if the building envelope prevents water vapor from exiting the building.10 This has been found in other countries such as the United States as well.

In addition, several jurisdictions reported that the level of enforcement varied across regions. This was often due to a lack of compliance checks and builders not receiving feedback on whether they were achieving the required levels of compliance. In some cases, compliance checks are conducted but not in enough detail to be useful. In the case of Australia, this was often a result of staff shortages at the local level where approval and inspections generally reside, and of training not being a high priority. Other countries such as India, Canada, and the United States also mentioned the lack of understanding on the code and the lack of capacity to do building simulation and certification.

[10] Building wraps are used to protect sheathing from precipitation that infiltrates the exterior cladding, enabling water vapor to exit the building envelope, and regulating airflow between the outdoors and indoors.

3.2. Training and capacity building to support code implementation

Most countries have training and capacity building programs to support code implementation. These programs vary between and within countries. Jurisdictions from six countries (Australia, Canada, India, Japan, the United Kingdom, and the United States) mentioned that key stakeholders struggle to understand the complex technical components of the code, suggesting that more comprehensive training and capacity building is needed. For example, Canada remarked that energy efficiency by itself is a discipline and building officials need significant exposure to the energy code to become sufficiently knowledgeable on it. Codes typically only indicate what is required without explaining the reasoning, hindering those without a technical or professional background in the field.

Periodic training opportunities such as industry seminars are common in many jurisdictions, but it is rare that these will incorporate quality checks or employ effectiveness measures beyond capturing general feedback at the conclusion of the trainings or courses (e.g., whether the instructors ran the course well). For example, when changes occur in New Zealand's code, the Building Research Association, a research, and development body, typically runs industry seminars for designers, builders, and code officials in local Territorial Authorities (City Councils). However, one survey responder remarked that their measure of how well the seminar ran as a whole cannot measure the effectiveness of improving compliance. Others mentioned that training and accreditation programs were effective, but there might still be variation across regions which impacts implementation. In the United States, field studies on compliance rates revealed that training resulted in significantly higher rates of compliance.

A major challenge that countries noted was low investment in training on building energy codes. This is primarily because, for many departments responsible for building energy codes and other building codes, building energy codes fall behind health and safety building codes (e.g., fire codes) in terms of priority. Table 4 on the next page provides examples of some of the building energy code trainings in the countries surveyed, along with their self-assessed effectiveness.

A few countries also mentioned that privatization of inspections can impact training efforts, positively or negatively. For example, England mentioned that privatization of inspections resulted in the trainings being inconsistently rigorous. However, Canada suggested that privatizing inspections can be very beneficial because private inspectors can be highly specialized and knowledgeable about energy efficiency, while code officials covering all aspects of a building cannot easily specialize in this manner.

Table 4. Examples of training and capacity building efforts in the surveyed countries*

Jurisdiction	Organizations	Capacity Building Content	Self-assessed Effectiveness
Australia	National Energy Efficient Building Project (NEEBP) on behalf of COAG Energy Council National Energy Productivity Plan, managed by the Government of South Australia[11]	Cross-industry Skills Training Project in 2017. Developing more training videos and short courses to improve capacity for energy compliance, such as a 10 module Commonwealth funded course to increase builder capacity to deliver Net Zero Energy Ready homes by 2030	Too early to tell, but enthusiastic uptake from many in industry
British Columbia, Canada	Building Officials' Association of British Columbia, Community Energy Association, Canadian Homebuilders' Association, British Columbia Housing	These programs help licensed builders with education and certification	Very effective in raising level of education. Quality of homes and level of energy efficiency have magnified
India	Bureau of Energy Efficiency (BEE)	Runs training programs for professionals sporadically, with no long-term program established yet	Training programs remain at a cursory level, more for awareness than in-depth
Japan	Ministry of Land, Infrastructure, Transport, and Tourism	Financially supports organizations to hold seminars and to publish websites containing trainings	To some extent
New Zealand	Building Research Association	When changes occur in the code, the R&D body typically runs industry seminars for designers, builders, and code officials in local Territorial Authorities (City Councils). Schools of architecture also mention code issues in construction courses and environmental design courses	Unsure of quality check or effectiveness
United States	International Code Council (ICC), ASHRAE, U.S. Department of Energy Building Energy Codes Program, regional nonprofits, state energy offices	Varies depending on training. U.S. Department of Energy trainings focus on train the trainer. ICC trainings target building code officials (plan reviewers, inspectors) at the jurisdictional level as well as third party agencies	Effective when used. Field studies by U.S. Department of Energy on compliance rates found that training resulted in significantly higher rates of compliance

* The information included in this table is based on self-reporting and is not meant to be a comprehensive assessment of trainings in the surveyed countries.

[11] In addition, several organizations such as the Australian Building Code Board, Green Building Institute of Australia, and Pointsbuild organize energy skill training activities. The Master Builders Association and Housing Industry Association also offer non-accredited member courses (Green Living and Green Smart, respectively).

3.3. Penalties for non-compliance

The consequences of non-compliance vary across jurisdictions, ranging from publication of the names of those who do not comply to withholding construction or occupancy certification. For most of the jurisdictions surveyed, building plans and construction must be compliant to receive construction and occupancy permits. In other cases, jurisdictions may issue fines for non-compliant buildings or components. At the same time, some jurisdictions also layer multiple types of consequences to address different aspects of code compliance, or to reinforce each other. Below we describe how each of these approaches works in practice, with examples.

Typically, the most rigorous enforcement mechanism is denying a construction or occupancy permit. This is effective for several reasons. First, it provides a clear market signal that compliance is in fact mandatory. Second, the delays that re-applying for a permit or adjusting buildings after construction begins can be expensive for developers. The cost and uncertainty of such delays are typically more expensive than simply investing in energy efficiency measures in the first place. New Zealand provides an example of how jurisdictions may inspect and withhold an occupancy permit if construction does not comply. Local officials in New Zealand may issue a "Notice to Fix" if non-compliant work is found, requiring the owner or contractor builder to rectify the building work. If a builder fails to achieve compliance, then the Council can fail the project and refuse to issue a certificate for the building work. This trend was common across jurisdictions.

Some jurisdictions will also issue fines for non-compliant buildings. This can either be in specific instances when rectifying an energy-related construction error is deemed not feasible, or, in some jurisdictions, it can serve as an alternative to denying permits. An example of this practice is found in a town in Alberta, Canada called Sherwood Park, where they double the permitting fees if construction is started without a permit issued. This is also common in most jurisdictions throughout British Columbia, Canada.

Another type of penalty is when the authority publicizes the building owner's name on a publicly available list. This is seen in Japan and Canada, where the authorities publish the names of property owners who fail to comply with the authority's guidance and instructions for improvement. The publishing of names aims to use public shame and professional recognition to add an additional layer to motivate compliance.

In some jurisdictions, compliance is encouraged or amplified through licensing requirements for designers, contractors, or builders. Failures to comply could put those individuals and companies at risk of maintaining their licenses and/or require substantially more oversight. This is frequently seen in the United States, such as in Wisconsin, where building designers who fail to comply can lose their license. Another example is in the Halifax Regional Municipality in Canada, among other jurisdictions in Canada, where continued non-compliance eventually results in the municipality taking legal action against the developer.

Some jurisdictions deploy multiple strategies at once. For example, Japan, at various times and depending on building type, will withhold construction and occupancy permits, publish the building owner's names, and/or present a fine. Almost all countries have more than one penalty deployed for specific scenarios. Table 5 provides examples of some penalties in place in some of the countries surveyed and how they're combined.

Table 5. Examples of penalties to achieve code compliance

Examples of penalties	Country
Construction and occupancy permit withheld	AU, CA, JP, IT, NZ, TR[12], UK, US
Publication of building owners' names who fail to comply	CA*, JP
Fines	CA*, JP, IT, NZ*, US*
Loss of license for contractors/builders or required increase in oversight	CA*, US*

* varies by jurisdiction

The information included in this table is based on self-reporting.

3.4. Incentives for higher building performance

Incentives can be used to achieve compliance above the minimum requirement, paving the way for more rigorous provisions as well as more comprehensive compliance. This is helpful to push the market to adapt, making compliance easier. Some jurisdictions utilize financial incentives, such as grants, tax credits, and low-interest loans. Others may provide expedited permitting, reduced fees, or relaxed zoning requirements. The following describes examples of incentives that encourage higher levels of building performance that create stronger codes in the future.

Tax exemptions and tax credits can be used as an incentive for high building performance. One example in the United States is the Home Energy Rating System (HERS) Index, developed by the U.S. Department of Energy. The HERS Index measures the overall energy efficiency of new construction as well as renovated properties. A minimum HERS rating can be used to demonstrate compliance with the building energy code in some jurisdictions. Jurisdictions, such as Baltimore County in the state of Maryland, also provide new, high-performance homes with tax credits based on the energy performance of a residential structure. For example, to qualify for the credit in Baltimore County, a newly constructed residence requires a HERS Rating of 70 or lower, and renovated structures must achieve an increase in energy efficiency of at least 30% (Baltimore County Government 2019). This is higher than the threshold for code compliance, but it involves

12 Turkey only withholds permits for occupancy, not construction.

the same process. Other U.S. jurisdictions may point to green building systems such as EnergyStar, Green Globes, Leadership in Energy and Environmental Design (LEED), International Green Construction Code, the National Green Building Standard, Enterprise Green Communities, or other local green building codes as the basis for incentives. In some cases, there are requirements that large, commercial buildings receive green building certification, but there are incentives for achieving recognition above the minimum level.

Other financial mechanisms can be used to incentivize energy efficient buildings above the codes. Japan offers subsidies and low-interest loans to residential and non-residential buildings for high-efficiency energy systems. In addition, they have a green investment tax rebate for non-residential buildings.

British Columbia, Canada utilizes step codes, which is further elaborated on in the Notable practices section; these help the market adjust to higher stringency codes by incentivizing the higher "steps" before they become mandatory for compliance. In addition, the City of Kimberley offers permit fee reductions and incentives to offset the cost of a third-party Energy Advisor and mid-construction tests. Italy recently enacted a temporary 110% Tax Deduction for certain energy efficiency improvements to existing buildings to boost the economy after the COVID-19 shutdowns. The tax deductions that are eligible for energy efficiency measures must be certified by a qualified expert. They also must improve the stated performance of a building by at least two energy classes. Jurisdictions also use non-financial incentives, such as offering public recognition for a high-performing building.

These various incentive mechanisms, such as tax exemptions, subsidies, low-interest loans, and grants, encourage jurisdictions to achieve higher building performance levels. Table 6 provides examples of incentives in a few of the surveyed countries. For example, in Japan, buildings that meet above-code "certification standards" can receive exceptions to floor-area ratio regulations (IBEC 2016). For instance, commercial buildings must be 20% better than code to be eligible for this valuable incentive. In addition, through local Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) programs, a rating tool used for evaluating environmental performance in Japan, many towns offer incentives for more efficient buildings (Evans et al. 2009).[13] For instance, the building owners may be eligible for certain construction subsidies and low-interest loans. Although CASBEE is not directly part of Japan's building energy codes, CASBEE incentivizes energy efficiency which helps codes to become more rigorous over time. Overall, countries can use multiple mechanisms to encourage enforcement at different phases of construction, for different specific compliance issues, and these can vary over time as they deepen their requirements and compliance.

[13] CASBEE is is required by 24 local governments in Japan.

Table 6. Examples of incentives to achieve higher building performance

EBC Member Country	Incentives for above minimum code construction and performance
Canada	Public recognition of high performing building. Tax credits and low-interest loans to improve energy efficiency in buildings. Step codes in British Columbia.
Italy	Enacted a temporary 110% Tax Deduction for certain energy efficiency improvements to existing buildings to boost the economy after the COVID-19 shutdowns. The tax deductions that are eligible for energy efficiency measures must be certified by a qualified expert and must improve the stated performance of a building by at least two energy classes.
Japan	Offers relaxed zoning requirements for certified, code-compliant buildings. Some jurisdictions mandate CASBEE and offer subsidies and low-interest loans for highly rated residential and non-residential buildings.
United States	Many local jurisdictions (for example, Baltimore County, Maryland) use the Home Energy Rating System (HERS) Index to measure overall energy efficiency of residential buildings and demonstrate compliance with the energy code. HERS-rated buildings can also apply a high-performance tax credit accordingly.

3.5. Assessment of effectiveness of compliance

Compliance assessments can help countries and local jurisdictions understand the effectiveness of their building code implementation programs. These assessments vary in methods, such as using statistical methods and surveys. Assessments also vary in frequency, such as a reoccurring assessment at a frequent interval or a one-time analysis. Assessments vary in coverage as well, such as national or local.

Several survey responses indicated that jurisdictions within their country conducted occasional one-off studies conducted either through the municipal level or from a research institution (e.g., in the United Kingdom, Australia, Canada, and the United States). One-time or periodic studies are useful to learn from the results and identify ways to improve the process. The U.S. Department of Energy has funded several state-level compliance studies and some states have used alternative mechanisms to conduct their own state-level assessment. There is a published, statistically based methodology with field analysis protocols to sample specific buildings during construction. Studies conducted surveys before and after a training intervention to determine the training's effectiveness, where the first survey determined how to better target trainings while the second verified its effectiveness. The studies concluded that training is an effective way to boost compliance and emphasize knowledge of codes, along with providing guidance on using compliance software/tools (Davis et al. 2020).

From the survey, Japan was the only country that reported having a codes compliance study at the national level, although other countries do conduct regional codes compliance assessments.

Japan sends outs surveys yearly to monitor the rate of compliance to their Building Energy Efficiency Act for newly built residential and non-residential buildings. For buildings smaller than 300 m^2, the questionnaire survey is sent to builders. For buildings larger than 300 m^2, reports on energy efficiency are submitted by building owners to the Ministry of Land, Infrastructure, Transport and Tourism. The surveys found that the compliance rate of newly built residential buildings is increasing year by year. National assessment approaches can make it easier to learn across jurisdictions within that country.

The survey also indicated that many municipalities within jurisdictions conduct their own assessment of compliance effectiveness from collecting data of buildings and formal reporting. For example, the City of Kimberley in British Columbia analyzes the energy efficiency data of every building reported, which revealed that more and more buildings are constructed at above compliance levels since the step codes came into use. Intuitively, any study that analyzes the rate of compliance helps the jurisdictions adjust their code accordingly. An overview of these self-reported assessments is seen in Table 7.

Table 7. Examples of assessments analyzing code compliance

EBC Member Country	Assessment Description and Methodology	Coverage	Frequency	Assessment Conclusion
Canada	A compliance study was completed in 2015 where the province of British Columbia and British Columbia Hydro surveyed building officials and building professionals about their compliance rate.	Province-level	One-time	Found 60% compliance rate across British Columbia, 79% compliance rate among buildings the respondents were engaged with
Japan	Surveys sent to monitor the rate of compliance with the Building Energy Efficiency Act for newly built residential and non-residential buildings	National	Annually	Compliance rate is steadily improving year by year.
United States	Statistically based methodology with before and after field analysis to sample compliance in actual construction; assesses compliance rates, elements for improvement, and energy savings; informs training design	State-level	Periodically	Training is an effective way to increase compliance.

4. Notable practices

This section highlights certain notable practices that can be beneficial or interesting to other jurisdictions. We define “notable” practices as those practices that meet one or more of the following criteria: practices that are (1) unique to one or some of the surveyed jurisdictions, (2) led to easier or faster implementation of the code, and/or (3) led to demonstrated energy efficiency improvements.

4.1. Pooling resources to minimize redundant efforts and maximize resources

A unique practice seen is pooling together resources across jurisdictions with the same energy efficiency goals. For instance, in support of the European Union’s (EU) EPBD, the Concerted Action framework has been shown to contribute strongly to a greater transparency and availability of data on the EU’s Member States’ progress towards EPBD goals such as near-zero energy buildings (Garcia and Kranzl 2018). The Concerted Action on the EPBD, which receives funding from the EU’s Horizon 2020 research and innovation program, supports the implementation of the EPBD through the exchange of information and experience among Member States and other participating countries (Norway). In particular, regarding building energy codes, the Concerted Action has helped countries share challenges they have faced and practical options for improving implementation. Beyond the Concerted Action, connecting code regulations to larger transnational efforts in the EU has helped to minimize redundant efforts and maximize resources to help facilitate verification of code compliance. The EPBD and the EU’s Energy Efficiency Directive (EED) together have served as a transformative legislative framework for many EU Member States (see the case of Portugal in Box 1). While the implementation of the EPBD has been uneven across the EU, a public consultation on the EPBD in 2015 consisting of 308 stakeholders revealed that most stakeholders considered that the EPBD set a good framework to improve energy performance in buildings and raise awareness of energy consumption (Davies 2017).

Another example is the Northwest Energy Efficiency Alliance (NEEA) in the United States’ Pacific Northwest. NEEA was created and funded through local utilities across the Pacific Northwest states; these utilities decided to combine certain energy efficiency resources rather than having individual programs in each state and utility. This allows targeted resources to be pooled together to provide stronger training programs and analysis. Since each state’s code and compliance process is different, NEEA helped each state form their own code collaborative group to build open communication and channel collaboration among stakeholders, educators, and trainers. NEEA helps develop training resources, focused on having very specific, practical trainings. While

NEEA provides training resources, they do not perform the trainings directly, but rather serve as a reputable and cohesive resource.

Linking codes to transregional efforts and organizations allows each jurisdiction to learn from each other to speed deployment. Connecting code regulations to larger efforts can encourage compliance. For example, people who work for multiple jurisdictions in Alberta, Canada noticed that consistency across jurisdictions streamlines their processes overall. Also, jurisdictions that are required to follow mandates and regulations from a higher authority will take the necessary actions to comply at a localized level. However, it is also dependent on the higher authority having enough leverage (e.g., suitable “carrots and sticks” or incentives and penalties) to back up the requirements and therefore encourage code compliance.

Box 1. EPBD in Portugal

Countries such as Portugal have witnessed drastic improvements in their buildings’ energy performance in recent years. In Portugal, the Energy Agency (Agência para Energia or ADENE), a private, non-profit association which is recognized as a public interest institution, is responsible for developing and enforcing public policies that promote energy efficiency. ADENE is supervised by the Directorate-General for Energy and Geology (DGEG), a body of the Ministry of Environment and Climate Change. ADENE, in collaboration with DGEG, developed Portugal’s codes according to the EPBD. In 2002, the EPBD established that Member Countries had to implement an energy certification system to inform its citizens about the thermal quality of buildings when constructing, selling, or renting them. The EPBD has evolved over time and it is currently in the process of going through another major update. The transposition of the EPBD into Portugal’s national law transformed the energy efficiency industry in the country. In new buildings or buildings subject to major refurbishments, Portugal introduced new requirements following the introduction of the EPBD targeting opaque and glazed envelope; HVAC systems dimensioning, installation and maintenance; and Indoor Air Quality (Vaquero 2020). In 2009, the country made the Buildings Energy Certification System mandatory in all new or existing, residential, and service buildings. In just the first four years after Portugal transposed EBPD, Portugal saw an improvement of about 37% in its energy consumption (Vaquero 2020).

In Portugal, the local municipalities do not develop or adopt the codes, but they check the building plans for compliance and issues the construction and occupancy permits. An independent energy expert who is trained and certified by ADENE is tasked with verifying code compliance during the construction phase. During this phase, the energy expert takes photos and gathers documentation that the building complies and is built as designed. The energy expert then submits this data online. This data is then reviewed by multiple parties for completion and consistency: first by ADENE and the director of the construction company, and then by the municipality. If the energy expert does a poor job, this is noted on his/her record. At the end of the building construction, the energy expert issues an energy certificate that demonstrates that the building complies. Having a nationally endorsed institution such as ADENE, and a transnational legislative framework through the EPBD as a foundation and guide, has allowed Portugal to more quickly build capacity to implement energy efficiency reforms. However, it is not an end-all solution. For example, one of the challenges that Portugal is experiencing is a lack of energy experts to check plans.

4.2. Requiring accreditations and trainings of inspectors and official government endorsement of third parties

Several jurisdictions identified the lack of staff to perform inspections as an issue. A common strategy used by governments to address this challenge is involving private, third parties in inspections. This is the direction that some Indian states are taking to keep up with the rapid pace of construction in recent years (Yu et al. 2012). While employing third parties has several advantages, some of the survey responders mentioned that the privatization of inspections also introduced inconsistencies in the rigor of the inspections, reflecting the importance of incorporating checks and balances in a third-party system and providing training.

In Japan, for instance, third parties known as “designated confirmation bodies” validate building designs before they are submitted to the local government. The government agency officially accredits these bodies. Japan also has extensive training programs to complement its third-party system. For example, in a brief period of one year, the Japanese government funded over 100 training seminars regarding a single set of changes to the existing code (IPEEC 2015). Government endorsement of third-party trainings and accreditation programs is important.

Nova Scotia in Canada, for example, has large training and accreditation bodies which have become reputable because they are government-endorsed and work seamlessly with the code. For someone to qualify as a building official in Nova Scotia, the appointee must have a valid diploma from the Nova Scotia Building Code Training and Certification Board, an independent not-for-profit body that establishes the minimum requirements in Canada’s building code regulation (N.S. Reg. 148/2020). Nova Scotia’s code regulations also require building officials to be members in good standing of the Nova Scotia Building Officials Association which offers training courses as well. Additionally, Nova Scotia has multiple levels of qualifications and certification (Nova Scotia Municipal Affairs 2014). For example, under the first level, the building official is only allowed to inspect single- and two-unit dwelling buildings. The highest qualification allows building officials to inspect all buildings. By provincial law, building officials may only administer and enforce the provisions of the Building Code Act and regulations within the scope for which they hold a valid diploma from the Nova Scotia Building Code Training and Certification Board (N.S. Reg. 148/2020).

Government-endorsed accreditation programs which are tied to energy rating systems have also been successful in building capacity for checking codes compliance in a few countries. In the

United States, for example, HERS Assessors are accredited, and their residential building energy ratings can count towards demonstrating codes compliance, as long as the residential building receives a certain threshold score. Although voluntary, the National Australian Built Environment Rating System (NABERS) also highlights the impact of third-party certification and training. NABERS is a national rating system that can be used to measure a building's energy efficiency and carbon emissions. Although NABERS is not a codes program, it has been useful in building capacity for codes compliance. A key feature of this initiative is the use of independent accredited assessors to conduct ratings. To receive full accreditation, assessor candidates are required to attend training, pass an exam, and complete two supervised assessments. While building owners and tenants can use an online "self-assessment" tool, they cannot promote these results, and only ratings that have been certified by the NABERS National Administrator can be promoted using the NABERS trademark (Bannister 2012).

Beyond training, there is a big difference in the efficacy of third-party inspectors based on how they are regulated and monitored. In some jurisdictions, inspectors are required to report to the jurisdiction which maintains authority over the inspectors. In other jurisdictions, such as Australia, the third-party inspectors/assessors are licensed by a jurisdiction but operate independently without ongoing reporting to the jurisdiction.

Adjusting to new codes takes time, and to aid in building the capacity to verify code compliance, jurisdictions can line up resources to make the transition smoother. Building capacity and familiarity with the code before it becomes mandatory accelerates market acceptance, making it easier on builders and designers to be well-acquainted with future code changes. This can occur through capacity building prior to code changes or inherently through the design of the code (see Box 2 for an example of how jurisdictions, and in particular British Columbia in Canada, are building capacity for codes implementation using "step" or "stretch" codes in combination with other strategies).

Box 2: Building capacity before a code becomes mandatory

Step codes are creating a new approach to build capacity prior to requiring compliance on increasingly stringent measures. Step codes (sometimes also referred to as "stretch" and "reach" codes) are voluntary provisions (or alternative compliance paths) which provide incentives to builders to extend energy performance beyond the minimum energy code requirements, providing opportunities for greater levels of energy efficiency. Step codes also mandate base levels of energy efficiency. While the above-code provisions are voluntary, they are commonly introduced with the intention that they will become mandatory in the future. Step codes allow jurisdictions to train the building and development communities in advanced practices before the underlying energy code is improved, thus helping to facilitate code compliance in the future. By providing the building industry more time to adjust to code changes, step codes have been shown to provide smooth and market-friendly transition to more energy efficient buildings.

In the United States, jurisdictions such as California, New York City, Washington State, and Massachusetts have all implemented and successfully enforced "reach" energy provisions and offered ample training opportunities as part of the process. In the City of Kimberley in British Columbia, Canada, the British Columbia Energy Step Code has reduced construction delays when new provisions are rolled out for builders who are familiar with the step code. Builders who are unfamiliar with the codes have had to adapt quickly to mandated changes made in the City of Kimberley. The city has found that as builders become more familiar with the changes and adapt to the step codes, they find ways to streamline the process because they realize that this is the direction that the market is moving towards. These outcomes help to prepare jurisdictions for code adoption and enforcement in the future. In short, step codes appear effective in incentivizing above-code, high efficiency buildings.

However, the step codes themselves are just one piece of a larger strategy to build capacity for code adoption and enforcement. British Columbia uses a combination of strategies to build capacity prior to adopting a code. For example, British Columbia has an online course on its step code which helps realtors with the sale of homes. Additionally, there are several programs that provide training. The Building Official's Association of British Columbia, Community Energy Association, Canadian Homebuilders Association, British Columbia Hydro, and British Columbia Housing are all programs that help licensed builders with education and certification. One benefit of the Community Energy Association is that it targets all segments of the industry: contractors, inspectors, sub-trades, and realtors. Other strategies that the city has implemented to facilitate compliance with mandatory codes are incentives, mid-construction air tightness testing, and provincial and federal rebates. For example, mid-construction testing assures air tightness goals are achievable and repairable prior to the installation of drywall. While step codes are part of code design and not compliance, they signal to the market years in advance where the code is going, so supply chains and capacity are ready. Used in combination with other strategies, they can greatly facilitate code compliance verification in the future.

4.3. Utilizing a data driven approach to improve code implementation

A data-driven approach can help jurisdictions assess and target their efforts to improve code compliance. Data-driven means using data to target areas of improvement and make data-informed decisions. It can also be helpful in leveraging energy efficiency incentives to financing improvements. For example, the U.S. Department of Energy and Pacific Northwest National Laboratory (PNNL) developed a data-driven methodology to conduct field studies and statistical analysis on state-level impacts of building energy codes. This method analyzes data and ranks compliance measures on their impact on energy cost and the resources required to verify compliance. This method targets high-impact measures that are also cost-effective. Targeting more cost-effective and high-impact compliance measures using data can help make future code compliance decision making more affordable and effective (Rosenberg et al. 2016).

Several U.S. states have conducted before and after field studies on code compliance. The studies sampled actual residential buildings during construction using the methodology developed by PNNL. This data helped to inform the specific measures that should be considered the focal point for compliance-improvement programs within the state. The states targeted training programs based on what they learned in the initial field study. In Alabama, the training involved curriculum partnership with a community college; in Kentucky, it emphasized circuit riders; while in North Carolina, the updated training included multimedia snippets combined with onsite training (Williams 2019). The trainings focused on areas such as duct tightness, lighting, and wall insulation. Following the training, the states, in partnership with the U.S. Department of Energy, then conducted follow-up field studies which showed significant improvement in the targeted measures and areas that the trainings emphasized.

Digitalization efforts also use data to automate and improve consistency. Mechanisms such as webtools can streamline the compliance checking process by automatically checking the codes for compliance and turning manually entered data automatically into results and reports. An example of this is the U.S.'s REScheck and COMcheck online code compliance tools. Builders can submit their inspection information online, selecting the relevant local jurisdiction, and the code inspector has their own section of the online portal with review and checklist functions. These platforms streamline the inspection process and secure the projects historically in databases. If the project is non-compliant, the project gets flagged, and the builders must address the problem accordingly. Also, the data allows local jurisdictions and the U.S. Department of Energy to have more building stock information. These online tools provide a data-driven approach for addressing compliance and making code compliance more efficient.

4.4. Utilizing remote inspections to check compliance when beneficial

A growing practice across countries is the adoption of virtual inspections. Initially, this was due to their potential cost and time savings benefits but became increasingly adopted out of necessity during the COVID-19 pandemic. Depending on the distance between the inspector and the building site, virtual inspections can save significant amount of time and money. They can also provide increased access to outlying or spread-out jurisdictions. Virtual inspections can provide strong archiving capabilities, creating historical documentation on a building's energy compliance. Remote inspections also feed into increased digitalization efforts, which can be tied to the data driven approach to influence future energy codes. All these measures can help build capacity to check compliance.

One example are inspections in remote First Nations communities in northern Canada which have become more affordable with far less travel time and costs, allowing more buildings to be inspected for compliance. Numerous jurisdictions in the United States, including Los Angeles City and County, North Las Vegas, and Arlington and Alexandria, Virginia (just outside Washington, D.C.) have also been using remote virtual inspections for several different project types, including those covered by energy codes (e.g., HVAC system swap outs and foundation inspections). The ICC has developed several documents including a *Recommended Practices for Remote Virtual Inspection and a Model Program for Online Services: Permitting, Plan Review and Remote Inspection* to assist jurisdictions in implementing such programs. Additional energy specific resources are in development including a joint ICC and Residential Energy Services Network *Standard on Remote Virtual Inspections for Energy and Water Performance*.

5. Conclusions

Jurisdictions across the world vary in their methods behind enforcing code compliance. However, there are similar challenges, including a lack of trained staff for inspections, lack of accreditation and training, and need for more guidance on assessing implementation rates. Several jurisdictions have introduced practices that have successfully tackled some of these challenges. Jurisdictions that have used third-party inspectors, for example, have been able to expand their capacity for enforcing their codes significantly. Requiring accreditation and training of inspectors and official endorsement of third parties can make inspections even more consistent and effective. Step or stretch codes provide code officials with more time to get up to speed with future building energy requirements. Transregional frameworks that incorporate trainings as well as dedicated building energy associations that work closely with national or local governments have aided in providing capacity for consistent training and accreditation of code officials. Utilizing data driven approaches help jurisdictions assess and target their efforts to improve code compliance.

While all these practices have merit on their own, the jurisdictions that have experienced the greatest success in code enforcement have utilized a combination of these approaches. More holistic approaches can prevent unintended consequences. For example, while a system of third-party assessors is often necessary to help build capacity for inspections, accreditation and robust training is critical to ensure the consistency and quality of inspections. Regardless of the strategy, the experiences of the jurisdictions discussed in this report reflect the importance of strengthening the institutions for code enforcement and implementing a holistic strategy whenever a new or updated code is introduced.

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Appendix A. Survey questions

EBC Building Energy Codes Survey on Code Compliance Practices

This short questionnaire is an initial information gathering task for the Energy in Buildings and Communities Programme (EBC) Building Energy Codes Working Group (BECWG) to help understand common challenges and practices across EBC countries associated with building energy code compliance. The questionnaire will inform an EBC BECWG report on this topic. While codes across nations vary in format and approach, many nations face the same compliance issues, such as requiring faster and easier methods to verify codes.

We recognize that there are a variety of terms used for the regulations for existing buildings. We ask survey respondents to use whichever term is used in their jurisdiction.

ENFORCEMENT

1. Does your country have a common set of practices for energy code compliance (e.g., plan review and field inspections)?

2a. What measures or stages of enforcement do you have in place to help verify implementation of the building energy code?

a. Review Plan
b. Review test reports of construction materials
c. Review calculation assumptions and results
d. Other: ____________

2b. Do any of the measures/stages mentioned in question 2a apply to specific building types (e.g., residential buildings, commercial buildings, government buildings, etc.), or do they apply to all building types?

3. Compliance check during construction: During construction, is there at least one on-site inspection? If yes, does it apply to any specific building types?

4a. Compliance check prior to occupancy: What kind of compliance checks do jurisdictions perform prior to occupancy of the building?

a. Inspection of air leakages and other issues identified during prior inspections
b. Comprehensive commissioning
c. Airtightness (blower-door) test
d. Other: ____________

4b. Do the compliance checks indicated in question 4a apply to any specific building types or do they apply to all building types?

5. For which building components/technologies are challenges related to compliance most prevalent (e.g., measures associated with lighting, HVAC, windows, insulation; measures newly integrated into the code; poor quality materials; other)? Please explain below.

CAPACITY BUILDING AND EDUCATION FOR COMPLIANCE

6a. Do you have education and capacity building programs that support code implementation? If yes, please describe in a few words these programs and clarify who these programs target (e.g., national government ministries, regional/local agencies, building designers, third-party enforcement agencies, etc.).

6b. If you answered yes to the previous question, have the programs been effective? (If you answered no to question 6a, indicate "not applicable")

7a. What are some of the largest institutional or capacity-building related challenges? Please indicate which apply below.

a. Lack of staff to check building plans/designs at the construction permit stage
b. Lack of staff to inspect buildings
c. Not all buildings inspected
d. Conflicts of interest in checks (where there are private inspectors/auditors/code officials)
e. Lack of understanding of the code
f. Lack of simulation capacity/certification
g. Lack of capacity to install measures correctly
h. Other: ____________

7b. Optional: If needed, please explain or elaborate more on your response to question 7a below.

8. Are the major challenges institutional/systemic (e.g., staffing, capacity, and structure of checks) or more targeted to specific measures? Please explain.

PENALTIES AND OTHER MECHANISMS FOR IMPROVING COMPLIANCE

9. Are there penalties for non-compliance with energy provisions in codes (e.g., no penalty, fine, rejection of construction permit, suspension/loss of license, a publication of names of property owners who fail to comply, etc.)? If yes, please elaborate.

COMPLIANCE ASSESSMENT

10. Does your country conduct assessments on the rate, effectiveness of compliance, and trends (i.e., not just at the building level, but in terms of how successfully codes are implemented nationally)? If yes, in a few words, please describe the assessments.

(If you replied no to the previous question, please skip to question 17.)

11. Are these assessments national or regional?

12. Are assessment methodologies/protocols available? If yes, who develops the methods?

13. Are common/consistent methodologies used? Please describe the method(s) and indicate whether they are based on a single method or a combination of methods (e.g., checklist approach, compliance % rates, impact modeling across a geographic region)?

14. Are the assessments repeated? If yes, how often are the assessments conducted?

15. What have you learned from these assessments?

16. Are the findings from the assessment linked to complementary policy instruments, such as national energy savings or environmental goals, or building benchmarking and transparency efforts?

OTHER

17. Is there a jurisdiction that stands out as a model for other jurisdictions or excels with respects to implementing its energy code, achieving energy savings, etc.? If yes, could you describe how it has achieved its success with its building energy code?

18. Optional: Please clarify your responses to any of the questions in this survey or add additional information below.

Appendix B. Overview of codes and institutional set up

EBC Member Country[1]	Building Energy Codes	Code Developer	Code Adopter	Code Enforcer
Australia	National Construction Code (NCC)[2] which incorporates energy efficiency measures (commercial and residential)	National government (Australian Building Codes Board)	States and territories	States and territories with support from third parties
Canada	• National Energy Code of Canada for Buildings (NECB) (commercial and residential) • National Building Code of Canada (NBC) (for smaller buildings; commercial and residential)	National government (Canadian Commission on Building and Fire Codes)	Provinces and territories	Provinces and territories, sometimes with the help of third parties
United Kingdom (England and Wales)	National Building Regulation Part "L": Conservation of Fuel and Power (commercial and residential)	National government	National government with support of local authorities	Local authorities with support from third parties
India	• Energy Conservation Building Code (ECBC) (commercial buildings) • Eco-Niwas Samhita (residential buildings)	National government (Bureau of Energy Efficiency)	States and local governments (called "Urban Local Bodies")	States and local governments (called urban local bodies), sometimes with the help from third parties

[1] Apart from Federal buildings, Brazil does not currently have mandatory building energy codes (it has voluntary energy efficiency labeling schemes). Thus, Brazil was not included in this table. A new Brazilian initiative that begun in 2020 aims to establish a mandatory model in residential, non-residential and public sectors by 2022.

[2] The NCC comprises the Building Code of Australia (Volumes One and Two) and the Plumbing Code of Australia. While the Building Code of Australia contains the most energy efficiency measures, the Plumbing Code applies to the energy efficiency of hot water services.

EBC Member Country[1]	Building Energy Codes	Code Developer	Code Adopter	Code Enforcer
Italy	Legislative Decree (LD) 192/05 (later modified by LD 311/06 and LD 63/2013) (commercial and residential)	National government[1]	Regions and autonomous provinces	Regions and autonomous provinces, with support from third parties
Japan	Energy Conservation Law (commercial and residential)	National government (Ministry of Business Innovation and Employment)	National government	Mostly state or provincial and local governments with support from third parties (called "designated confirmation bodies"), but national government also provides oversight and accreditation
New Zealand	New Zealand Building Code (NZBC) (commercial and residential)	National government (Ministry of Business Innovation and Employment)	National government with support from regions	Regional agencies at the local level (called "Building Consent Authorities") with support from other stakeholders[2]
Portugal	• Regulation of Energy Performance of Residential Buildings (REH) (residential buildings) • Regulation of Energy Performance of Trade and Services Buildings (RECS) (service buildings)[3]	National government [ADENE (Agency for Energy)]	National government with support from provincial jurisdictions	Provincial jurisdictions

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[1] To develop the codes, a Conference of Regions and Autonomous Provinces (*Conferenza Stato-Regioni*) coordinates between the national and regional governments through committees and working groups made up of various stakeholders. In addition, the National Agency for New Technology, Energy and Sustainable Economic Development (ENEA) support the development of current financial instruments and upcoming new energy certification guidelines through a voluntary consultation mechanism called *Tavoli di Lavoro 4E*. Regional and local governments issue technical guidance for codes implementation and are responsible for design reviews and enforcement.

[2] An owner (or their agent) must acquire a building consent before beginning construction. A builder or installer may be required to certify that some parts of a building have been constructed in accordance with the building consent.

[3] Decree-Law 78/2006 also established the Buildings Energy Certification System (SCE) in Portugal which mandates that new and refurbished residential and service buildings obtain an energy certificate in any construction, purchase, or lease process.

EBC Member Country[1]	Building Energy Codes	Code Developer	Code Adopter	Code Enforcer
Turkey	• The National Standard of Thermal Insulation Requirements for Buildings (TS 825) (residential and commercial) • Building Energy Performance Regulation (residential and commercial)	National government [Ministry of Energy and Natural Resources General Directorate for Renewable Energy (GDRE) and Ministry of Environment and Urbanization]	National government (GDRE) with support from municipalities	Municipalities with support from third parties (construction inspection companies during construction phase)
United States	• American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1 (commercial) • International Energy Conservation Code (residential)	• ASHRAE develops the commercial code • International Code Council (ICC) develops the residential code[1]	State and local jurisdictions	State and local jurisdictions

[1] The national government participates in the building energy codes development process. Also, some states, such as California, Washington, and Florida develop their own codes outside of the ASHRAE and ICC processes.