

Chapter 77

Review of Building Energy Code and Its Implementation in Residential Sector: A Global Outlook



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Abstract Building energy code, standards, ratings, and labels provide minimum efficiency requirements for new, existing, and renovated buildings, ensuring reductions in energy use and emissions over the life of the building. Energy code is the subdivision of building codes, which establish baseline requirements and direct building construction. Yet, these codes will only be able to deliver outcomes when implemented. The study of building energy code needs to be considered in a consistent and comprehensive way in order to achieve low carbon development and future sustainable goals. This paper identifies the process and practices for establishing residential energy code, covering 12 countries globally, including comprehensive review for code coverage of buildings and its design, implementation context, revision schedule, penalties, incentives, materials, and certification schemes. This paper highlights a global scenario of energy code and approach followed by various countries and followed by recommended practices for India.

77.1 Introduction

Globally building floor space has expanded 65% since 2000, while energy/m² has improved by only 25% [1]. As per IEA, building energy codes set standards for the construction of buildings with better energy performance and are a proven method to reduce building energy consumption in buildings [2]. As of 2019, however, less than 75 countries have or are developing a mandatory or voluntary building energy code, and around 45% of those countries building codes cover just part of the buildings sector. Energy policy progress is not keeping pace with buildings sector growth [3]. Mandatory policies covered less than 40% of energy use and less than half of CO₂ emissions from buildings in 2017 [1]. To be in line with the sustainable development

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scenario by 2030: all countries need to establish mandatory building energy codes; new high-performance construction needs to rise from current 275 million m² to more than 5 million m² by 2030, increasing code coverage and stringency [3].

The buildings sector's share of the world's delivered energy consumption increases from about 20% in 2018 to 22% in 2050. Building energy consumption in non-Organization for Economic Co-operation and Development (OECD) countries increases at about 2% per year, about five times faster than in OECD countries, and surpasses that of OECD countries by 2025 [4]. India comes under the category of non-OECD country. Electricity remains the fundamental source of marketed energy consumption in the residential sector, and its use grows by 2.5% per year globally [5]. India and China remain the fastest-growing region in residential sector energy consumption. China adds the most residential energy consumption of any country (in absolute terms), while India experiences the fastest relative growth in residential energy consumption from year 2018 to 2050 [5]. Studies on global changes in residential energy consumption recommend on promotion of direct and indirect renewable energies to reduce energy consumption and increase in adoption of energy code and practices.

Energy policies can be successful only if they are enhanced by making them mandatory, targeting net-zero energy building, and increasing public awareness about new technologies. Stricter regulations especially in existing buildings need to be further stressed by focusing on both new technology development and more educationally-related approaches to energy saving. In a recent study on building codes and implementation states that by better understanding in implementing building energy codes, policymakers can improve the effectiveness of their code implementation systems.

77.2 Background

Integrating the element of energy efficiency with building codes is a recognized strategy which aims to reduce energy consumption in the residential and commercial sectors. Globally, countries are independently establishing building codes and implementing energy efficiency policies, programs in residential and commercial segments to decrease energy waste in the new and existing building stock.

In many countries, the central government has authority to mandate energy efficiency in buildings by forming national building codes which are often adopted and implemented by state regions and/or local municipalities. Model energy code is developed by national code development organizations for review and adoption by state and local governments and is mandatory in nature. The practice of development of code, approval, and enforcement varies considerably among nations. Stakeholders have realized that energy codes are one of the simplest, most effective tools available to reduce building energy use.

As a building's operation and environmental impact is largely determined by upfront decisions by consumers, energy codes present a unique opportunity to

assure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it is suggestively more expensive to achieve higher energy efficiency levels. Energy codes ensure that the building's energy use is involved as a fundamental part of the design and construction process. Socioeconomic development (improvement of human comfort levels and entertainment activities), architectural design, geography, and climate data are the main factors underpinning the energy consumption trend in residential buildings.

Building codes seek to address common barriers to energy-efficient building design. Buildings regulation set of legal and mandatory requirements for building design and their compliance provisions during the construction period aiming at promoting energy performance of building. Building envelope consists of walls, roof, and fenestration (openings including windows, doors, vents, etc.). Design of building envelope influences heat gain/loss, natural ventilation, and daylighting, which, in turn, determines indoor temperatures, thermal comfort, and sensible cooling/heating demand. Since building codes set minimum requirements for energy efficiency in buildings, several countries have developed voluntary standards, encouraging sustainability, and higher energy efficiency buildings.

India took a step forward in late 2018, developing its first national model building energy code for residential buildings. The Energy Conservation Building Code for Residential Buildings is designed to be enforced simply while also improving occupant's thermal comfort and enabling the use of passive systems [6]. Implementation of ENS will have the potential for energy savings to the tune of 125 billion units of electricity per year by 2030, which is equivalent to about 100 million ton of CO₂ emission. The code sets minimum performance standards for building envelope to limit heat gains and limit heat loss through it, also for adequate natural ventilation and adequate daylight potential [6]. The situation with ECBC code under EC ACT 2001 is that till date, it remains voluntary code with no mandates in most of the states in India. ECBC-R also has the same challenges, that it might take years, before they become mandatory in most of states.

77.3 Methodology

Understanding code and its implementation requires a clear picture on what all code constitute and what does not. Also, it is required to understand the difference between various terminologies used like code, labels, standards, and rating system. Building codes are often mistaken as building energy labels and building standards. An energy label for building constitutes consumer information on the performance of a product (the building). A building rating system is a tool that evaluates the performance of a building and its impact on the environment [7]. It comprises a predefined set of criteria relating to the design, construction, and operations of buildings. Energy standards describe how buildings should be constructed to save energy cost-effectively [7].

The diversity in residential building energy code and implementation practice among different countries poses challenges for measuring building energy code

implementation and impact. This paper covers a systematic review of building energy code and their implementation systems, analyzing building energy code in 12 countries across the world and recommends on the best practices. To compile the information needed regarding the code and current practices, the reviewed literature has been accessed from data available over government websites and global networks. The key categories have been defined initially for data collection, namely code coverage, code implementation, revision and incentive structure, building material and certification and then processed further. In addition, a number of countries have implemented programs to evaluate the effectiveness of building energy code.

77.3.1 Review on Global Approaches

Building energy code tends to set minimum energy efficiency levels, but these energy savings are never realized unless states and localities implement them. This section highlights the comprehensive review of building codes and its implementation across all 12 countries. Figure 77.1 displays the timeline of year of code adoption among these countries. It showcases two versions: Current and earlier. The current versions are the revised or currently opted versions in the respective country. Earlier versions are previous versions which were implemented but not in order now.

India launched their residential energy code in late 2018, although for commercial buildings the code into picture in 2007. Developed countries have opted the code in earlier years and they have also released the revised versions.

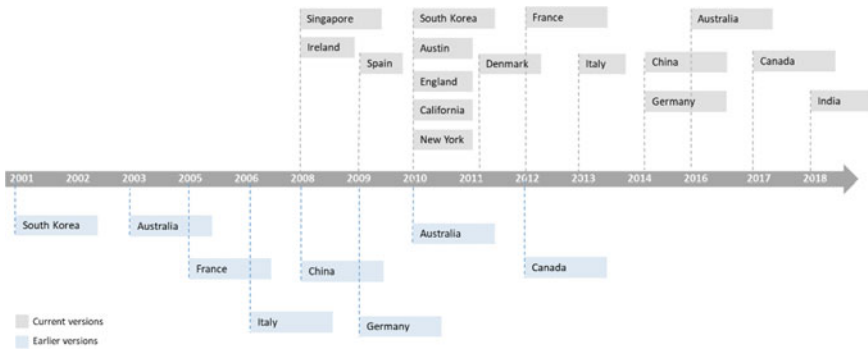


Fig. 77.1 Timeline of code adoption

77.3.2 Code Coverage

The first step in ensuring that building energy efficiency requirements apply to a significant part of buildings and have an impact on energy-intensive buildings is code coverage. Countries may have varied practices when it comes to what a code covers. Depending on the country, the code shall only apply to definite types or size of buildings; it may cover a comprehensive range of energy uses or only the building envelope. It may or may not apply to planned renovations. It is also important to note that code coverage is one way to consider the scope of implementation. Table 77.1 reflects code coverage for different countries with in depth information.

It can be observed that Italy, USA, Australia and China have not defined any building size threshold for new and existing buildings in their code. Australia, Singapore, Spain, and Turkey have threshold limits defined for renovations. Australia, China, France, Germany, Italy, South Korea, Spain, United Kingdom, and USA have included of renewable energy as a parameter in over all measures covered for building. In Turkey, buildings larger than 20,000 m² must use renewable energy. Most of the countries have made mandatory for their states to adopt the code.

77.3.3 Code Adoption

Implementation of energy code is generally approved by state and local bodies that are responsible for code compliance, enforcement, and training. This process ensures that new construction attains the required level of efficiency. Australia, Canada, China, India, Italy, and USA follows three-tier government system: National government develops the code, adopts national code to state requirements, and the local jurisdiction contributes in enforcing the code. For France, Germany, Singapore, South Korea, Turkey, and UK, the central government develops and adopts the code and the local jurisdiction contributes in enforcing the code. Enforcement may occur at both the design and during construction. At the design phase, an enforcement agency shall verify that plan for the building meets the specified energy efficiency requirements, while at the construction part, the code official or third party checks that construction matches with the code compliance. The built changes may also go through design review and on-site inspections. Compliance checks are divided into three phases: design, construction, and pre-occupancy checks. Australia, Canada, China, France, Germany, Italy, Singapore, USA have developed code compliance resource kits. There are training programme and tools in several countries to enable implementation of building energy code. India has launched a compliance tool for ECBC-R for evaluation and reporting. Table 77.2 reflects code adoption for different countries.

Table 77.1 Global outlook on code coverage

Country	Code	Code type	Building size threshold	Elements	Coverage
Australia	Building code of Australia	Mandatory	None for new; for renovations >2,000 m ²	Envelope, HVAC, service water heating, lighting, electric power, renewable energy, maintenance	Entire country
Canada	National energy code of Canada for buildings	Mixed	All new buildings, except residential buildings >600 m ²	Envelope, HVAC, service water heating, lighting, electric power, maintenance	Entire country
China	Design standard for energy efficiency of residential buildings	Mandatory	None	Envelope, HVAC, service water heating, electric power, renewable energy(not in all codes); lighting is in a separate code	Entire country, but rural residential code is voluntary (~45% of population is rural)
France	Energy performance of buildings directive (EPBD)	Mandatory	All new residential buildings must adhere to the standard; must have energy consumption level less than 50 kWh/m ² /pa and 80 kWh/m ² for existing buildings	Envelope, HVAC, service water heating, lighting, electric power, renewable energy, maintenance	Entire country
Germany	Energy performance of buildings directive (EPBD)	Mandatory	All residential buildings, except for those meant for use less than four months a year	Envelope, HVAC, service water heating, lighting, electric power, renewable energy, maintenance	Entire country

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Table 77.1 (continued)

Country	Code	Code type	Building size threshold	Elements	Coverage
India	Eco-Niwas Samhita (ECBC-R)	Voluntary	All residential buildings and residential parts of 'mixed land-use projects,' both built on a plot area of $\geq 500 \text{ m}^2$	Openable window-to-floor area, visible light transmittance, thermal transmittance of roof, rETV for building envelope	Entire country (Urban India)
Italy	EPBD	Mandatory	None	Envelope, HVAC, service water heating, lighting, electric power, renewable energy	Entire country
Singapore	Code for environmental sustainability of buildings	Mandatory	None for new; all new and existing buildings that undergo major retrofit with floor area of $\geq 2000 \text{ m}^2$	Envelope, HVAC, service water heating, lighting, electric power, maintenance	Entire country
South Korea	Building design criteria for energy saving	Mandatory	All residential buildings >50 households	Envelope, HVAC, service water heating, lighting, electric power, renewable energy, maintenance	Entire country
Spain	CTE	Mandatory	All residential buildings where a major renovation of more than 25% of the envelope is carried out	Envelope, HVAC, service water heating, lighting, electric power, renewable energy, maintenance	Entire Country
Turkey	TS 825	Mandatory	None for new; for existing buildings compliance with the latest version when retrofits affect at least 15% of area	Envelope; buildings larger than 20,000 m ² must use renewable energy or cogeneration	Entire Country

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Table 77.1 (continued)

Country	Code	Code type	Building size threshold	Elements	Coverage
United Kingdom	Energy performance of buildings directive (EPBD)	Mandatory	All new buildings, and existing buildings >1000 m ² in England and wales; None for Northern Ireland	Envelope, HVAC, service water heating, lighting, electric power, renewable energy, maintenance	England and Wales have separate code, whereas Northern Ireland follow ED
United States	ASHARE and ICC	Mixed	None	Envelope, HVAC, service water heating, lighting, electric power, renewable energy	42 states adopted statewide codes; 8 rely on either national/local codes

77.3.4 *Revision Schedule, Incentives and Penalties*

Code revision may demand innovation that creates better products and encourages economic development. State and local building codes need to keep up with ongoing innovations in building energy, science, and technology. Some code developers push for a six-year code cycle and some for three. Incentives and penalties in the code ensure that the interests of stakeholders are aligned with the desired policy outcome, such as code implementation. Conventionally, central and state governments employ penalties, to achieve compliance. For India: Penalties for non-compliance with energy provisions in codes are decided at the state level. Currently, no state has penalties for non-compliance. Various countries offer exemptions on tax and low-interest rate on implementation of codes. India has no incentive scheme, although there are various rating programme which offer state wise incentives. Table 77.3 reflects information about code revision, incentives and penalties.

77.3.5 *Building Material and Certification*

Building materials with labels evidently state that they are tested for energy performance properties. Code officials may easily verify that materials are aligned with the code-compliant design or not, or if tested and labeled materials are being used. Thus, having a method for testing, rating, and labeling properties of the materials makes it easier for all stakeholders to ensure buildings are made from high-performance products. Except Australia, Italy, and India, all other countries have a mandatory provision for testing, rating and labeling building materials. Canada and India have voluntary

Table 77.2 Code adoption

Country	National	Region/State/Province	Local party
Australia	Develops performance requirements of national construction code	Adopts code; adapts national code to state requirements, including adaptations to climate zones	Enforces code
Canada	Develops code; provides tools, training and resources; issues model building codes	Adopts code; adapts national code or have their own codes	Enforces code
China	Develops and adopts code	Adopts national code to state requirements, including adaptations to climate zones	Enforces code
France	Develops and adopts code; supports accreditation; coordinates with EU	None	Enforces code
India	Develops code; provides training and resources	Adopts national code to state requirements, including adaptations to climate zones	Enforces code
Italy	Provides technical support for code development and accreditation; coordinates with EU	Adopts code and technical guidelines; supports accreditation	Enforces code
Singapore	Develops and adopts code	None	Enforces code
South Korea	Develops and adopts code; provides assistance to local governments	None	Enforces code
Spain	Develops and adopts code; coordinates with the EU	Determines forms of inspection	Enforces code
Turkey	Develops and adopts code and regulation; offers training and energy auditing; raises public awareness	None	Enforces code
United Kingdom	Develops and adopts code and regulation	None	Enforces code
United States	Develops code and regulation	Adopts code, adapts national code to state requirements	Enforces code

based certification system. Turkey initially required certification on thermal insulation which is separate from building performance certification. Australia, USA, and China have building energy code evaluation programs. Table 77.4 reflects information about building materials and certification.

Table 77.3 Code revision, incentives, and penalties

Country	Schedule	Incentives	Penalties
Australia	Irregular	Grants are offered	Denying construction permits, suspension or loss of license, refusal of permission to occupy
Canada	Every 5 years	Tax credits and low-interest loans to improve energy efficiency in buildings	Denying construction permits, suspension or loss of license, publication of names of property owners who fail to comply
China	Irregular (<=5 years)	Multiple tax incentives: investment regulation tax, income tax and a value-added tax	Denying construction permits, suspension or loss of license, refusal of permission to occupy, publication of names of property owners who fail to comply
France	6 years, in coordination with EU	Exemption from property tax	Suspension or loss of license, refusal of permission to occupy
Germany	Ad hoc, in coordination with EU	Provides subsidized loans and interest rates	Denying construction permits,
India	Not mentioned	There are no incentive schemes	Not defined yet
Italy	Ad hoc, in coordination with EU	Offers a number of incentives for building retrofits	Denying construction permits,
Singapore	No clear schedule	Subsidies for building upgrade and Green Mark Incentive Scheme for New Buildings	Denying construction permits, Suspension or loss of license
South Korea	Every 4 years	Low-interest loans, tax incentives, technical support and public recognition	Denying construction permits
Spain	Every 5 years	Several types of incentives and capital grants for energy efficiency and low-interest rate loans	Not defined yet
Turkey	Irregular	None	Refusal of permission to occupy
United Kingdom	Irregular	Exemption from the stamp duty tax	Denying construction permits
United States	Every 3 years	Incentive programs and Lower interest rate loans for energy-efficient construction	Denying construction permits, suspension or loss of license, refusal of permission to occupy

Table 77.4 Building material and certification

Country	Building materials	Certification
Australia	Reference standards included in codes. There is no national labeling scheme for energy-efficient building products	NatHERS (asset rating for residential buildings) or NABERS (operational rating for new and existing non-residential buildings)
Canada	Buildings materials is tested and certified by the Canadian standards association (CSA) and voluntary certification and labeling schemes also exist, such as Energy STAR Canada (for boilers, windows, doors, heat pumps, and others)	Canada has voluntary building rating schemes, such as Super E (housing standard developed by Natural Resources Canada), Energy STAR (for commercial and new residential buildings) and EnerGuide rating system
China	Building materials are rated in China, but is not mandatory	Energy performance certificates are issued based on both design of the building and post-occupancy energy efficiency
France	Some of the standards include: HQE, EN 15,804 and EN 15,977	Article 9 of RT2012 stipulates that EPCs are mandatory at time of sale and rental since 2007 and voluntary energy endorsement label
Germany	Germany adopted CE marking under the construction products regulation (305/2011/EU-CPR), which covers energy economy and heat retention	An energy performance certificate is required in course of implementing EU’s Energy Performance of buildings directive, via amendment of the energy saving ordinance
India	–	The BEE/GRIHA/ IGBC star rating system exists independently of the code
Italy	Italy does not currently have a system for testing, rating and labeling building materials, with the exception of voluntary third party certification	An EPC is required when selling or renting a property (building or building unit), when undergoing major renovation and for larger public buildings
Singapore	Singapore green labeling scheme labels bricks, tiles, insulation, windows, and many types of other materials. Singapore green building product (SGBP) certification takes into consideration the product life cycle and impact on the environment	BCA Green Mark is a green building rating system which evaluates a building for its environmental impact and performance
South Korea	Rating of building materials: windows, insulation, HVAC, lighting	Building energy performance certificate under the housing performance grading indication system, and a voluntary scheme: Korean green building certification program

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Table 77.4 (continued)

Country	Building materials	Certification
Spain	The Spanish association for standardization and certification is responsible for developing technical standards and certification programs	The energy performance certificate provides an estimate of an annual primary energy consumption and classify buildings based on CO2 emissions into classes A-G based on estimate of energy use
Turkey	Turkey follows European CE marking, which is mandatory for construction materials and cover energy economics	The thermal insulation requirements are separate from the energy identity certificates. The building performance certificates have been recently introduced
United Kingdom	The building regulations (England and Wales) 2010 and the building regulations (Northern Ireland, 2010) require rating of building materials through the various acceptable schemes. The UK accreditation service holds a schedule of testing laboratories	Energy performance certificates are not a voluntary labeling scheme, they are mandatory for all new buildings and when an existing building is sold or let
United States	Building materials are rated in the USA. Random sampling of materials is used with testing, which are conducted by certified laboratories. There are specific labels for windows, and labels are also required on some types of insulation	Energy performance certificates identified: HERS, home energy score, ASHRAE building EQ

77.4 Conclusion

There are numerous ways to assess the effectiveness of energy efficiency building codes globally, and this paper aims to give an overview of 12 countries and five elements of building energy code or review. There are many polices that were not included in this paper, such as building labeling, retrofit policies, commercial codes, and other mechanisms. However, based on the current parameters analyzed, countries that are leading the way with respect to the overall effectiveness of residential codes are USA, France, China, and Australia. This study analyzed country-specific information: Code coverage, code adoption, revision schedule, code compliance, penalties, incentives for implementation, building material, and energy certification. Most of the countries have made mandatory for their states to adopt the code. India follows voluntary code system. Penalties for non-compliance of the codes are decided at the state level in India. Currently, no state has penalties for non-compliance. Most of the countries deny on construction permits as a penalty. Australia, Canada, China, India, Italy, and USA follow three-tier government system: National government

develops the code, adopts national code to state requirements, and the local jurisdiction contributes in enforcing the code. Australia, Canada, China, France, Germany, Italy, Singapore, USA have developed code compliance resource kits. India has launched a compliance tool for ECBC-R for evaluation and reporting. It provides a comprehensive summary of compliance status of all the mandatory compliance criteria of the code, for the proposed design.

This research highlights the importance of code, its components and implementation mechanism. By better understanding the range of practices in implementing building energy code, policymakers can improve the effectiveness of their code implementation systems.

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