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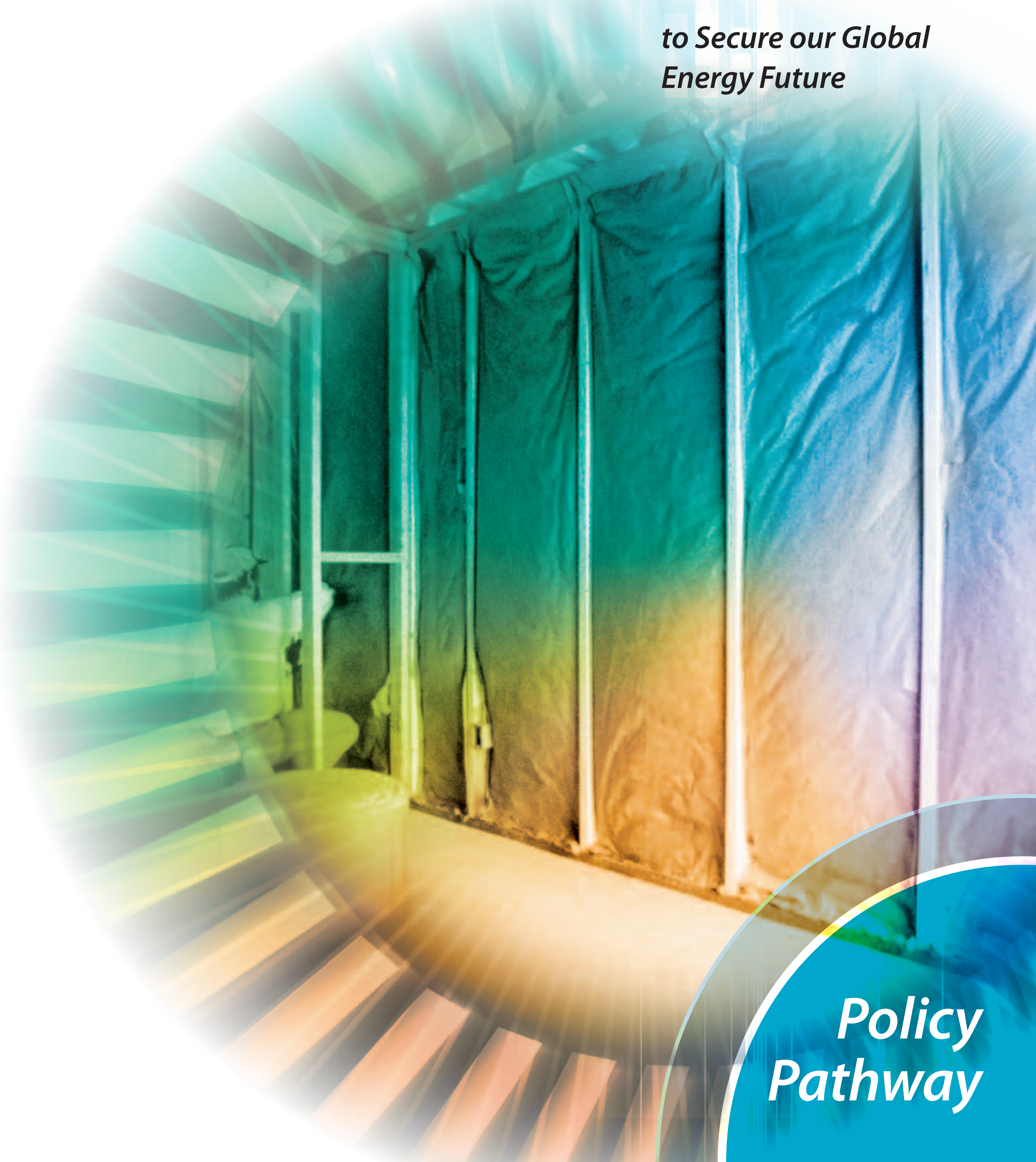

Policy Pathway

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Modernising Building Energy Codes

Buildings are the largest consumers of energy worldwide. In many IEA member countries, the buildings sector accounts for over 40% of primary energy consumption. Globally, the sector's final consumption doubled between 1971 and 2010, driven primarily by population increase and economic growth. The number of buildings will continue to increase, adding further pressure on energy supplies around the world. Global energy demand of buildings is projected to grow by an additional 30% by 2035.

In IEA member countries, where current buildings stock will remain in place for years to come, the main focus should be on renovation, through implementation of energy codes and minimum performance standards in existing buildings. In non-IEA countries, where more than half of the buildings stock needed by 2050 has yet to be built, new buildings should be designed to be low-energy consumers, with codes that specify strict performance standards. Comprehensive policy packages are needed to facilitate and promote the use of advanced building energy codes.

This joint IEA and UNDP report shares best practices and lessons learned among IEA member countries and non-IEA countries in improving energy efficiency in the building sector. The objective is to limit pressures on global energy supply, improve energy security and contribute to environmental sustainability.

Part of the IEA Policy Pathway series, Modernising Building Energy Codes to Secure our Global Energy Future *sets out key steps in the planning, implementation, monitoring and evaluation stages. The Policy Pathway series aims to help policy makers implement the IEA 25 Energy Efficiency Policy Recommendations endorsed by IEA Ministers (2011).*

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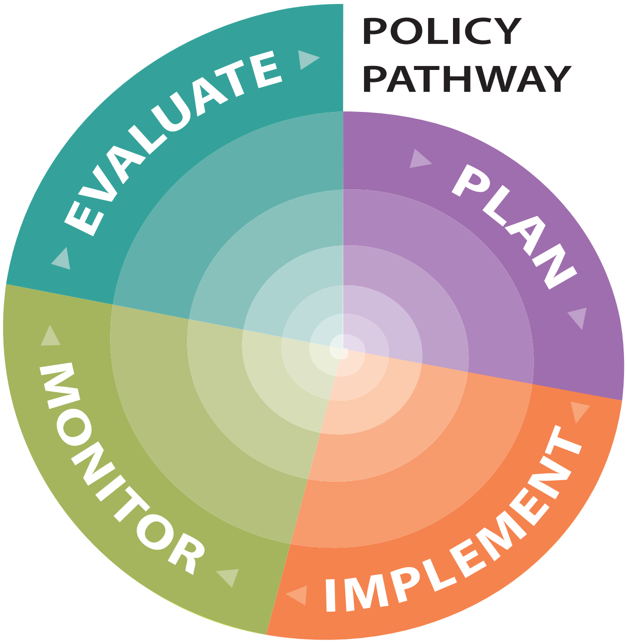
Modernising Building Energy Codes

to Secure our Global Energy Future

The IEA Policy Pathway series

Policy Pathway publications provide details on how to implement specific recommendations drawn from IEA 25 Energy Efficiency Policy Recommendations. Based on direct experience, published research, expert workshops and best-practice country case studies, the series aims to provide guidance to all countries on the essential steps and milestones in implementing specific energy efficiency policies.



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Energy Performance Certification of Buildings
A Policy Tool to Improve Energy Efficiency

The Policy Pathways series is designed for policy makers at all levels of government and other relevant stakeholders who seek practical ways to develop, support, monitor or modify energy efficiency policies in their home country and abroad. The pathways can also provide insight into the types of policies best adapted to the specific policy context(s) of different countries, so that each country derives the maximum benefit from energy efficiency improvements.

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International Energy Agency

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The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its mandate is two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply and to advise member countries on sound energy policy.

The IEA carries out a comprehensive programme of energy co-operation among 28 advanced economies, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency aims to:

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- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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Acknowledgements

This publication was prepared by the International Energy Agency's Directorate of Sustainable Energy Policy and Technology (SPT) and the Energy, Infrastructure, Transport and Technology (EITT) team of the Global Environment Facility (GEF) Unit in the United Nations Development Programme (UNDP).

Yamina Saheb, Head of the Sustainable Buildings Centre (IEA), was the project leader and the author of the publication. Aurelien Saussay, Charlotte Johnson, Alastair Blyth and Ankit Mishra from the IEA provided analysis of building energy codes and their impact in IEA member countries. Thomas Gueret from UNDP provided background information on the French and the Tunisian building energy codes. Manuel Soriano, Marina Olshanskaya, John O'Brien and Robert Kelly from UNDP provided analysis on the implementation of building energy codes in non-IEA countries. Shui Bin from the American Council for Efficient Energy Economy (ACEEE) provided input and analysis of the Chinese building energy codes. Additional inputs were provided by other IEA experts, especially Vida Rozite, Marc La France, Adam Brown, Cedric Philibert and Grayson Heffner.

Maria Van der Hoeven, Executive Director at the IEA, and Veerle Vandeweerd Director at UNDP offered strategic leadership. Didier Houssin, Director of SPT, and Marcel Alers, Head of EITT, contributed with important guidance and input. Philippe Benoit, Head of Energy Efficiency and Environment Division (IEA) and Benoit Lebot, Environment and Energy Group Practice Leader in West and Central Africa (UNDP) provided strategic guidance.

The work was guided by the IEA Energy Efficiency Working Party. Input and suggestions from the members of this committee and other IEA government officials are gratefully acknowledged.

Many experts from outside the IEA and UNDP provided input, commented on the underlying analytical work and reviewed the report. Their comments and suggestions were of great value. They include:

Jayson Antonoff	Institute for Market Transformation, United States
Diana Avasoo	WSP Environmental, Sweden
Andrew Atiken	Global Green Building Council, Australia
Emmanuel Bergasse	Bergasse International, Spain
Randall Bowie	Rockwool International, Sweden
Shui Bin	American Council for Energy Efficient Economy, United States
Celine Carre	Saint-Gobain, Belgium
Bertrand Cazes	Glass for Europe, Belgium
Olivier Chaudet	LaFarge, France
Aneta Ciszewska	Ministry of Economy, Department of Energy, Poland
Alain Cordier	Cordier International, France
Laurent Deleersnyder	European Commission, Belgium
Alison Delgado	Pacific Northwest National Laboratory, United States
Marina Economidou	Joint Research Centre, Italy
Meredydd Evans	Pacific Northwest National Laboratory, United States
Alpana Jain	Shakti Foundation, India
Rod Jansen	Energy in Demand, France
Williams Jeremiah	Department of Energy, United States
Adrian Joyce	EuroAce, Belgium
Roger Hitchin	Building Research Establishment, United Kingdom
Vanessa Higgins	Department of Resources, Energy and Tourism, Australia
Hans-olof Karlsson Hjorth	National Board of Housing, Buildings and Planning, Sweden
Markus Kottek	Carinthian Institute for Climate Protection, Austria
Satish Kumar	Schneider Electric, India
Jens Laustsen	Global Best Practice Network, France
Ian Lefevre	Exprimm, France
Solenn Le Guen	Ministry of Susainable Development, France

Romilly Madew	Australian Green Building Council, Australia
Bruno Mauvernay	Saint-Gobain, France
Armin Mayer	Johnson Control, United Kingdom
Ryan Meres	Institute for Market Transformation, United States
Shen Mi	Institute for Building Research, China
Tardif Michel	Natural Resources Canada
Adel Mourtada	Ecotech, Lebanon
Christopher Moore	Wuppertal Institute, Germany
Emeric Motte	Somfy, France
Ksenia Petrichenko	Central European University, Hungary
Bipin Shah	WinBuild, United States
McDoom Siddiq	Natural Resources Canada
Tanmay Tathagat	Environmental Design Solutions, India
Stefan Thomas	Wuppertal Institute, Germany
Constant Van Aerschot	Business Council for Sustainable Development, Singapore
Jean-Christophe Visier	Scientific Centre for Buildings, France
Hu Wen	Exprimm, France
Gi-Ho Yu	KEMCO, Korea
Nan Zhou	Lawrence National Berkeley Laboratory, United States

MaryRose Cleere helped with the editing of the first draft manuscript. Ilze Raath edited the manuscript with the support of Cheryl Haines. Production assistance was provided by the IEA Communication and Information Office: Muriel Custodio, Astrid Dumond, Rebecca Gaghen and Bertrand Sadin.

A number of workshops, meetings and interviews were held to gather essential input to this publication. The participants contributed valuable new insights, feedback and data for analysis. These workshops discussed the following topics:

- Building envelope technologies and policies workshop, IEA workshop, Paris, 17-18 November 2011.
- Regulatory and legal mechanisms to enhance energy efficiency in buildings, IEA-REA (Russian Energy Agency) Round Table, Moscow, 17 February 2012.
- Buildings energy efficiency policies: The bumpy road to effective implementation, IEA-WBCSD (World Business Council for Sustainable Development) workshop, Paris, 16 March 2012.
- Energy efficiency in buildings: key element of the global sustainable development agenda, IEA-UNDP side event at Rio+20 conference, 21 June 2012.
- Energy use and green buildings after great east earthquake in Japan, IEA-JSBC (Japanese Sustainable Building Consortium), MLIT (Ministry of Land, Infrastructure and Transport) and METI (Ministry of Economy, Trade and Industry), Tokyo, 24 February 2013.

The IEA-UNDP partnership on buildings energy efficiency policies was initiated in 2011 by Benoit Lebot (UNDP) and Yamina Saheb (IEA).

The work could not have been done without the financial support of the Japanese METI, the German Ministry of Economics and Technology and the in-kind contribution of the European Commission (EC), the Swedish Energy Agency, the US Department of Energy (DoE), the South Korean Energy Management Corporation (KEMCO), the French Ministry of Ecology, Sustainable Development and Energy, and the GEF.

Executive summary

Buildings are the largest consumers of energy worldwide and will continue to be a source of increasing energy demand in the future. Globally, the sector's final energy consumption doubled between 1971 and 2010 to reach 2 794 million tonnes of oil equivalent (Mtoe), driven primarily by population increase and economic growth. Under current policies, the global energy demand of buildings is projected to grow by an additional 838 Mtoe by 2035 compared to 2010 (IEA, 2012a), which is equivalent to the total current energy demand of the buildings sector of the United States and China combined. Buildings will therefore add substantial pressure on primary energy supply, if further policy action is not taken at a global level to improve their efficiency.

Buildings at the heart of the 21st century's challenges

In most IEA member countries, buildings currently account for more than 40% of primary energy consumption. The residential sub-sector remains the largest consumer of energy at a global level, and the non-residential sub-sector has increased its share since 1990, especially in emerging economies. Given the large share of energy consumed by buildings, it is crucial that the energy performance of this sector is improved to ensure long-term global energy security. This relationship is illustrated by the dynamics of natural gas consumption. Natural gas is the main primary energy source used for heating in the buildings sector in IEA member countries, and gas imports used for the buildings sector place a significant burden on many IEA economies (*e.g.* at the European Union (EU) level, total gas trade deficit represented 41% of the total trade deficit with the rest of the world in 2010). As a consequence, the inefficient use of energy in the built environment undermines energy security and increases dependency on unsustainable fuels. It also has negative social and environmental effects, such as generating greenhouse gas (GHG) emissions and adverse health impacts. Policy action to reduce the energy consumption of buildings is needed to help address a variety of societal challenges.

Building energy codes: the policy instrument to address buildings energy consumption

Building energy codes, also known in some countries as "energy standards for buildings", "thermal building regulations", "energy conservation building codes" or "energy efficiency building codes" are the key policy instrument used by governments to limit buildings' pressure on the energy sector and environment while providing occupants with comfort and modern living conditions. Effective building energy codes consist of a set of mandatory requirements designed to reduce the energy consumption of buildings. Building energy codes have been instrumental in reducing the overall energy consumption of the residential buildings stock over the last twenty years in IEA member countries. The achieved reductions range from 22% (*e.g*. Netherlands and Germany) to 6% (*e.g.* Southern European countries) of average annual energy consumption per dwellings. The variation in energy savings is due to the stringency of energy requirements and the approach used in the design of building energy codes. Countries use two different approaches in the design of their building energy codes.

Prescriptive approach

A prescriptive approach sets minimum energy performance requirements for each component of the building – windows, walls, and heating and cooling equipment. Two compliance paths are possible within this approach: (a) each component has to meet strict minimum energy performance requirements; or (b) trade-offs are allowed between the energy performance requirements of different components. The prescriptive approach has various shortcomings and does not reward synergies from the interaction of different components.

Performance approach

A performance approach requires an integrated design based on a holistic assessment of the building's energy performance. Energy requirements are set for a building's overall energy consumption. Some performance building energy codes also include prescriptive requirements on buildings' components and equipment. The performance approach optimises the savings potential by considering the interaction of different components. It gives more freedom to architects and developers to select the most efficient designs and technological solutions. The performance approach reduces the risk of foregoing untapped savings that might be locked in for decades given the long lifespan of buildings.

Two compliance paths are possible within this approach: (a) a model approach with minimum energy performance requirements that vary based on the size of the building; and (b) the overall performance approach, with standard energy performance requirements (and in some cases CO_2 emission reductions) for all building sizes.

Building energy codes: an expanding scope

Historically, the scope of building energy codes in developed economies only focused on new residential buildings. The scope was progressively expanded to include new non-residential buildings. More recently, building energy codes have expanded to cover existing buildings when they undergo renovation or alterations. Currently, building energy codes for new and existing buildings are mandatory in most IEA member countries. In non-IEA countries, progress has been made in recent years in the development of building energy codes. However, the coverage is usually limited to a portion of new buildings.

New waves of building energy codes: moving beyond traditional codes

Addressing energy sufficiency and energy supply

In addition to provisions that target energy efficiency improvement, advanced building energy codes include requirements associated with (a) energy sufficiency; and (b) supply from renewable energy sources. The French building energy code, presented as a case study, follows this path. It includes requirements on energy sufficiency and supply from renewable energy sources in addition to energy efficiency requirements

Energy sufficiency measures

The purpose of energy sufficiency measures is to reduce the amount of energy needed to operate and maintain a building. Energy sufficiency measures include requirements for the orientation of the building *vis-a-vis* the sun, its form, volume, placement with respect to surrounding buildings, and general daylight and sunshine requirements based on bio-climatic design principles. For economies with high construction rates, notably emerging economies, including energy sufficiency requirements in building energy codes can significantly reduce the energy demand of the future buildings stock. In IEA countries, where three-quarters of today's buildings stock will still be standing by 2050, the implementation of energy sufficiency measures to the envelope is generally limited to adapting the colour of roofs and walls to suit the local climate.

Supply from renewable energy sources

Buildings can also serve as a source of energy. Renewable energy sources generated by buildings can be used to supply thermal or electric energy, where technically feasible and economically viable. Thermal solutions include capturing solar heat gains to heat a space or water, using prevailing breezes for natural ventilation or heat pumps to extract heat or cold from the ground as well as using biomass for heating. Power-generating systems include photovoltaic systems and small wind or water turbines. By integrating renewable energy sources into buildings, they can be transformed from energy consumers to power generators capable of supplying energy to the grid.

Renewable energy sources could also be supplied from surrounding buildings or through district heating and cooling systems. The aim is to reduce the need for grid-based energy supplies and to back-up power, especially in countries where the grid supply is unreliable.

Considering the broader energy policy landscape when designing building energy codes

Buildings are complex systems with a variety of distinct, but interacting, dimensions: building envelopes and windows, heating, ventilation and air conditioning systems, interior lighting and behaviour of users. As a consequence, a multi-dimensional, holistic energy policy package is required to respond to the complexity of buildings and integrate the various factors that influence their energy consumption. Most advanced building energy codes are designed within a holistic energy policy package that considers economic and environmental national priorities and goes beyond the building itself to include land-use policies, minimum energy performance standards and labelling (S&L) schemes for buildings, buildings components, equipment and appliances. It is important to promote the alignment of energy performance requirements considered in different policy instruments. The Tunisian building energy code, presented as a case study, illustrates the alignment of minimum energy performance requirements set in a building energy code with those set in a buildings energy labelling scheme.

Considering the long-term economic and energy perspectives

Moreover, buildings have long lifespans, typically lasting for decades, and have correspondingly slow rates of turnover and renovation. Given these lengthy periods, the renovation of existing buildings provides a natural trigger and a unique opportunity to implement the energy provisions included in building energy codes. At the same time, getting it right in the first instance is very important to avoid locking in the savings potential for decades. Advanced building energy codes therefore set minimum energy performance that takes into account long-term economic and energy security considerations. This approach supports increasing the stringency of energy requirements within the codes to exploit improvements in technologies and changes in local environmental and socio-economic contexts. The Danish building energy code shows how the long-term perspective allows for stringency increase over time. Energy performance requirements have moved from 350 kilowatt hours per square metre per year (kWh/m^2/yr) in 1961 to nearly zero-energy building by 2020.

Ensuring effective implementation of building energy codes

Implementation of building energy codes faces a complex institutional and policy landscape. Several factors, such as (a) the fragmentation of the buildings sector into multiple stakeholders with limited resources and, sometimes, conflicting interests, (b) the misalignment of energy requirements with other policy instruments (such as land-use policies and labelling schemes) that impact the buildings sector, and (c) the lack of technical expertise and knowledge of buildings science, make the implementation of building energy codes difficult especially in countries with low institutional and human capacities.

A critical factor for effective implementation of building energy codes is compliance-checking and enforcement. Governments need to check compliance and enforce their building energy codes to ensure that regulations on paper translate into action on the ground. The Chinese governmental monitoring of local municipalities' compliance-checking is a good illustration of a coordinated multi-level governmental effort (government, local authorities) to improve compliance rates. The Swedish case shows how compliance-checking can be conducted during the operational phase of a building. Both the Chinese and Swedish compliance-checking procedures are presented as case studies.

One way to increase compliance rates is to strengthen the capacity of sector specialists by providing training, and conducting awareness-raising campaigns and demonstration projects, particularly when introducing building energy codes for the first time.

Into the future

Overall, building energy codes are designed to improve energy services, including comfort for occupants at low-energy consumption. The ultimate objective is to transform buildings from energy consumers to energy producers. Future updates to building energy codes will target nearly zero- energy consumption and will include all end-uses. This target can be achieved by moving to a comprehensive holistic approach in which: (a) energy demand is reduced by "energy sufficiency" measures; (b) energy consumption is reduced by using efficient building components and equipment to meet that energy demand; and (c) renewable resources are used to generate heat and electricity, thereby reducing buildings' net energy demand. The combination of these three pillars – energy sufficiency, energy efficiency and supply from renewable energy sources – represents the modern approach to designing effective building energy codes.

In addition, as buildings become more energy efficient, greater attention should be given to the operation of the building and the maintenance of its systems and equipment. Other aspects of a building's energy consumption to consider in the future are embodied energy (namely the energy required to produce building materials and to construct buildings) as well as usage patterns (how buildings are used by their occupants). These factors represent, over the lifetime of a building, increasingly important drivers of energy consumption for buildings with successfully reduced energy consumption through the energy sufficiency and efficiency measures described above.

International collaboration to achieve global efficient buildings stock...

The challenges of the projected increase of energy consumption due to the built environment vary by country. In IEA member countries, much of the future buildings stock is already in place, and so the main challenge is to renovate existing buildings stock. In non-IEA countries, more than half of the buildings stock needed by 2050 has yet to be built. The challenge for these countries is to ensure that new buildings are designed to be low-energy consumption.

In order to help policy makers from all over the world implement the buildings aspects of the IEA 25 Energy Efficiency Policy Recommendations, the IEA and the UNDP partnered to analyse current practices in the design and implementation of building energy codes. The aim is to consolidate existing efforts and to encourage more attention to the role of the built environment in a low-carbon and climate-resilient world. The IEA relies on forty years of experience in the design and the implementation of building energy codes in its member countries while UNDP relies on over 20 years of experience, data and information from across the world to provide technical support and policy advice to non-IEA countries. This joint IEA-UNDP Policy Pathway is the result of this collaboration between the two organisations. Sharing lessons learned between IEA member countries and non-IEA countries is critical to spreading best practices, limiting pressures on global energy supply, improving energy security, and contributing to environmental sustainability.

A Policy Pathway for developing and implementing building energy codes..........

This publication provides the pathway for the effective and successful implementation of building energy codes. The pathway includes four phases: plan, implement, monitor and evaluate. These phases include a series of steps and actions for governments to follow. The choice and sequencing of these steps and actions will vary depending on the current development of building energy codes in each country.

The phases included in the Policy Pathway are as follows:

- **Planning phase**: identifies the necessary steps and indicators to consider at the design stage of the building energy code.
- **Implementation phase**: highlights the steps to ensure effective implementation of the building energy code.
- **Monitoring phase**: proposes methodologies using indicators defined at the planning phase for compliance-checking and tracking.
- **Evaluation phase**: suggests different evaluation approaches. The objective is to design an evaluation strategy to inform developers of building energy code of the necessary changes they should consider for the next update.

The Policy Pathway checklist for policy makers for the development and implementation of building energy codes includes ten steps in four phases (Table ES1).

Table ES1 Policy Pathway action checklist for implementation of building energy code

		DONE
PLAN	❶ Define and adopt the objectives, scope and norms	○
	❷ Define modalities to support implementation and enforcement	○
	❸ Set a supportive policy context	○
IMPLEMENT	❹ Organise awareness campaigns	○
	❺ Develop training materials and provide training	○
	❻ Develop necessary tools for compliance-checking and tracking	○
MONITOR	❼ Analyse compliance trends at local level	○
	❽ Communicate compliance results and enforcement actions openly	○
EVALUATE	❾ Generate different metrics and evaluate implementation gaps at national level	○
	❿ Update building energy codes regularly based on lessons learned from the evaluation	○

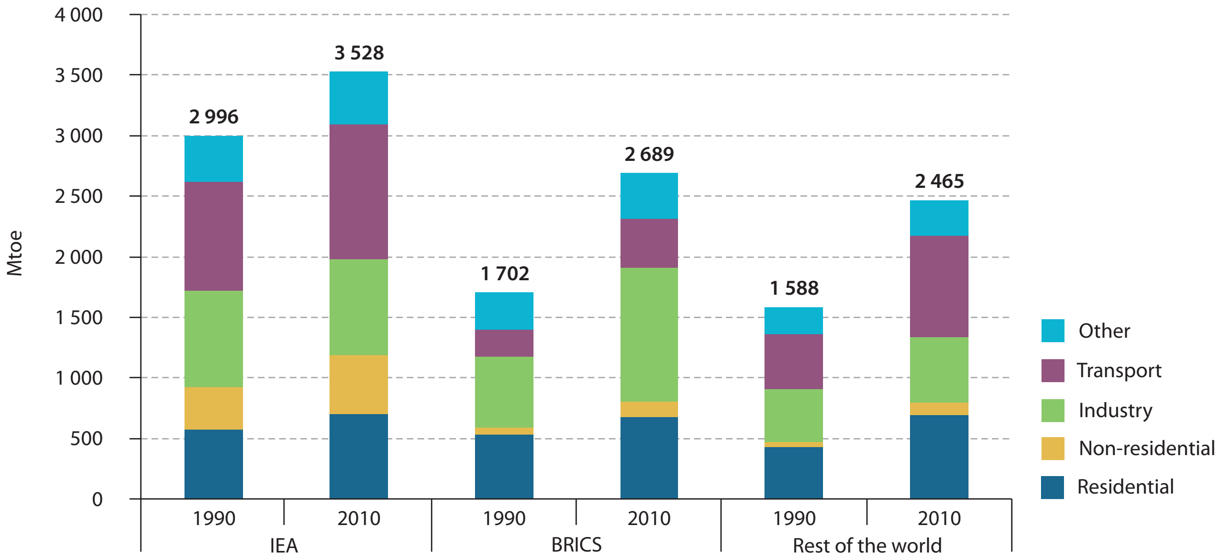
Introduction: the buildings sector at the heart of the 21st century's energy challenges

From buildings to energy security

Buildings are the largest consumers of energy. The sector's global final energy consumption doubled between 1971 and 2010 to reach 2 794 Mtoe, driven by population increase and economic growth. Under current policies, global energy demand from buildings is projected to grow by an additional 838 Mtoe by 2035 compared to 2010 (IEA, 2012a). This is equivalent to the current energy demand of the buildings sector in the US (United States) and China combined. Most of this growth will result from the increase of buildings' energy use in non-IEA countries. The growing energy consumption of buildings is expected to exert heavy pressure on the global primary energy supply unless effective policy action is taken at a global level (IEA, 1994).

In most IEA member countries, buildings currently account for more than 40% of primary energy consumption. The residential sub-sector remains the largest consumer of energy at a global level, and the non-residential sub-sector has increased its share since 1990, especially in the BRICS (Brazil, Russia, India, China and South Africa) countries (Figure 1).

Figure 1 Global final energy consumption per sector

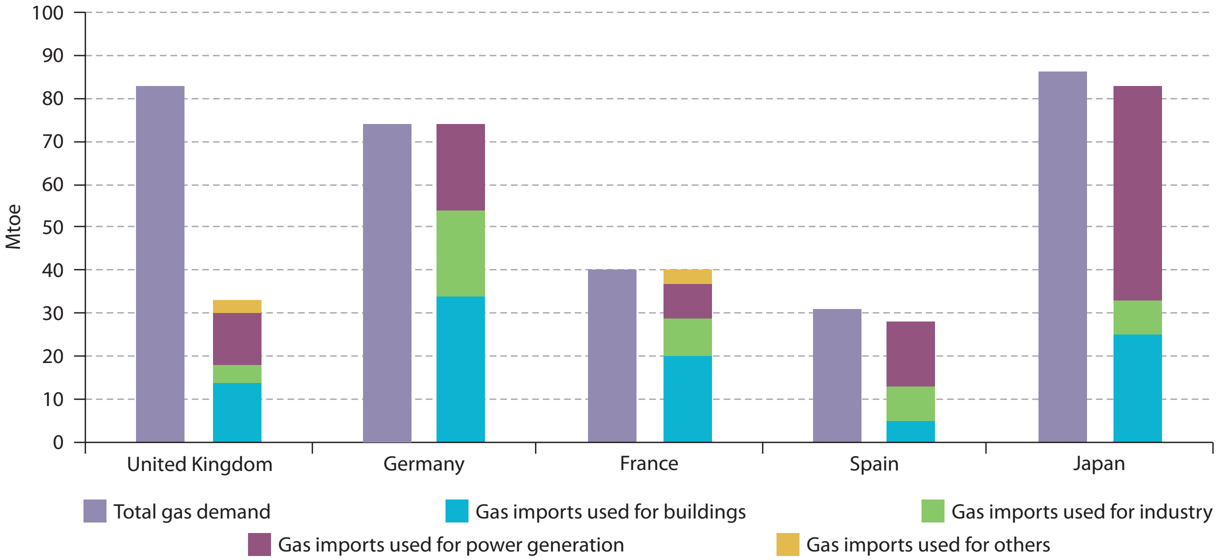


Source: Unless otherwise indicated, all material in figures and tables derives from IEA 2012 data and analysis.

Given the extent of energy consumed by buildings, improving the energy performance of this sector is crucial to ensuring long-term global energy security and reducing energy expenditures. This relationship is illustrated by the dynamics of natural gas consumption. Natural gas is the main energy carrier used for heating in the buildings sector in IEA member countries; in 2010, gas consumed by buildings accounted for 58% of total final gas consumption. Gas imports have a significant impact on the balance of trade of most IEA member countries (*e.g.* at the EU level, total gas trade deficit represented 41% of the total trade deficit with the rest of the world in 2010). As a consequence, the buildings sector plays a pivotal role in gas dependency and vulnerability to primary energy source disruption of most IEA member countries (Figure 2).

In non-IEA countries, the buildings' energy mix still consists predominantly of traditional biomass (*e.g.* 44% of buildings' energy consumption in the BRICS countries and 53% in the rest of the world). However, its dominance in these countries is declining and there is a surge in the use of electricity and oil products, which now represent 16% and 11% of the buildings' energy mix respectively.

Figure 2 Impact of the buildings sector on gas imports of selected countries



From buildings to economic growth

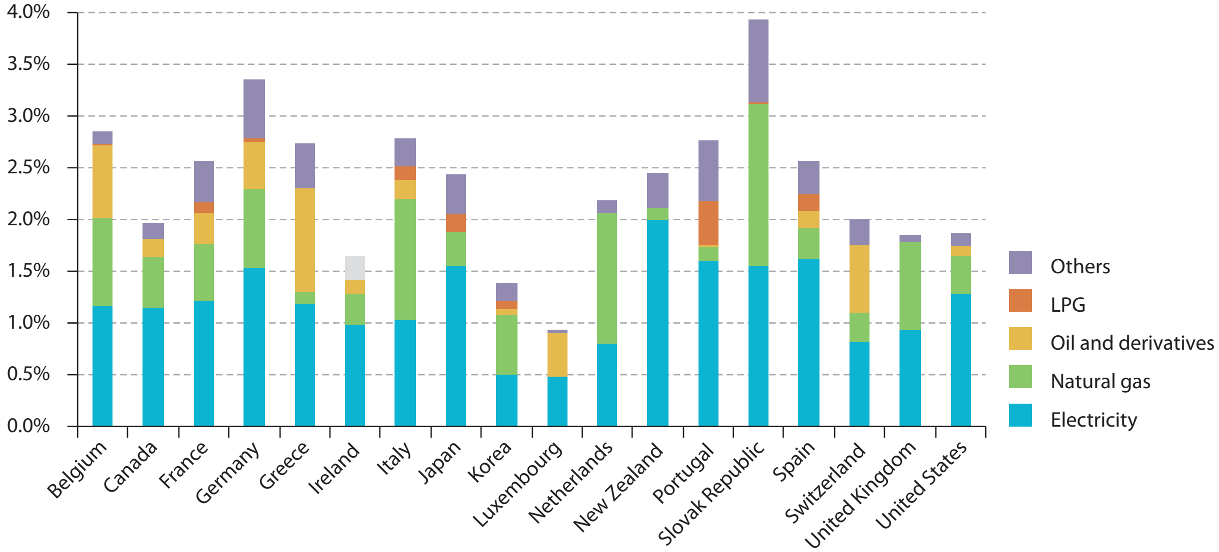
The buildings sector accounted for 8% of global GDP (USD 4.9 trillion) in 2010 (GC, 2012) which makes the sector a key component of the global economy. In IEA member countries, where the buildings' renewal rate is less than 1%, the buildings sector will nonetheless continue to play a major economic role driven by the energy renovation of existing buildings.

Estimates show that cost-effective energy retrofits of 40% of the United States' buildings stock by 2020 will require USD 500 billion of public and private investment, but will directly and indirectly generate approximately 625 000 sustained full-time jobs (CAP, 2009). For the EU, estimates show that cost-effective building energy retrofits may generate a permanent annual economic benefit of USD 134 billion to USD 225 billion, depending on the level of investment made between 2012 and 2020 (CE, 2012). Energy renovation of existing buildings will also reduce households' energy expenditures, which in 2010 represented more than 3% of GDP in Germany and the Slovak Republic, and more than 2% in most other IEA member countries (Figure 3).

In the US, cost-effective energy retrofits could save consumers USD 32 billion to USD 64 billion a year in energy costs, or USD 300 to 1 200 a year for each individual family (CAP, 2009).

An ambitious energy renovation action plan in IEA member countries would also engage various market-actors in a green growth strategy by strengthening the labour market through career training and local job creation, boosting innovation, enhancing competitiveness and creating new business opportunities for local industry (OECD, 2012). It would also increase governments' income through direct and indirect taxes (*e.g.* value-added tax, property taxes and payroll), which could be extended over several decades as the net employment effect of buildings energy renovation last for several decades.

Figure 3 2010 Yearly residential energy consumption expenditures as a share of GDP in IEA member countries

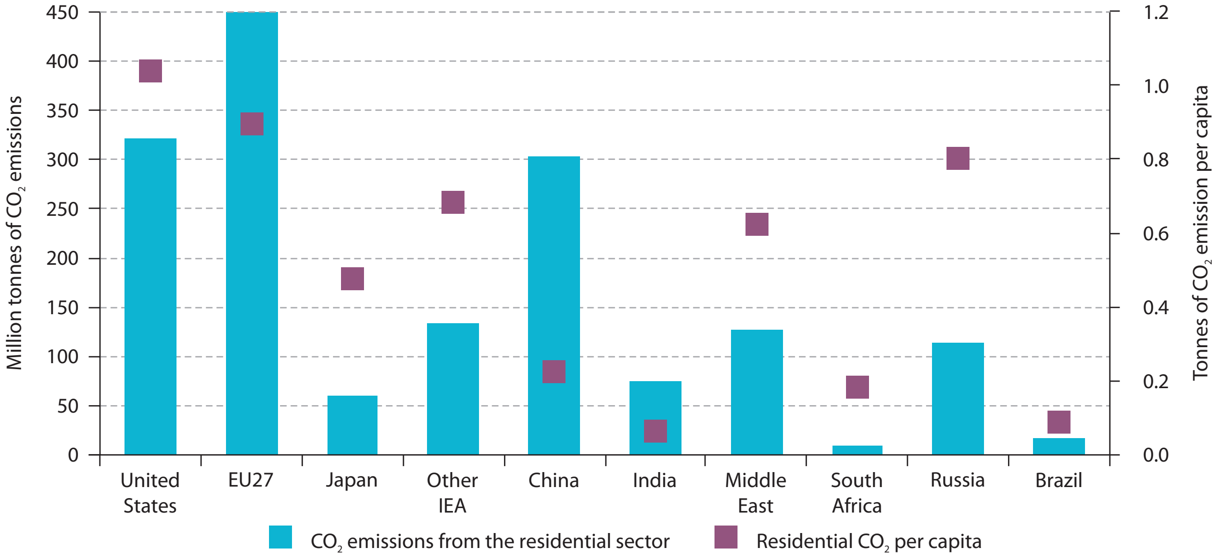


In non-IEA countries, where more than half of the buildings that will exist in 2050 have yet to be built (IEA, 2010a), the challenge is to ensure that new buildings are designed to be low-energy consumption. This would help governments to provide their citizens with modern living conditions while freeing up resources over the longer term to meet the education, health, sanitation and other sustainable development goals set out in the United Nations' Millennium Development Goals.

From buildings to the climate challenge

Energy consumed by buildings generates significant GHG emissions (Figure 4). The total CO_2 emissions from all buildings in the EU countries taken together are greater than those from buildings in the United States or China largely as a result of three factors: the age of the existing buildings, the cold climate and the use of gas for heating. However, the residential CO_2 emissions per capita are lower in the EU compared to the US. This is mainly due to the smaller size of homes in EU countries. The transformation of the buildings sector would reduce energy consumption and, by extension, related GHG emissions, helping to delay the lock-in of CO_2 emitting infrastructure and leaving the door open to a 2°C climate scenario (IEA, 2012a).

Figure 4 2010 CO_2 emissions from the residential sector in selected countries/regions



From buildings to the challenges of health and well-being for all

Buildings consume energy to provide human well-being and comfort. Although human comfort is partially influenced by a variety of contextual, behavioural and cultural factors, buildings and their equipment determine the acceptable level of comfort for indoor air temperature, radiant temperature, humidity and air speed (ASHRAE, 2004).

Among other things, building energy codes enable policy makers to mitigate the effects of weather on occupants' health. In both cold and hot climates, governments are challenged by the frequency and the intensity of extreme weather conditions, and their impact on comfort and health. The heat wave experienced across Europe in August 2003 and the severe winter weather of December 2010 demonstrated the vulnerability of the elderly and low-income families to energy precariousness in some countries, including the United Kingdom, France, Bulgaria, Romania and the United States. Most of the excess seasonal deaths (*i.e.* the surplus number of deaths occurring in winter or summer compared with the average number of deaths occurring during the year) were attributed to thermal stress and poor quality housing. In the EU, the winter variation in mortality between 1988 and 1997 was low in countries with high insulation requirements and high in countries with poor insulation requirements (Table 1). In the United States, over 100 deaths were attributed to the heat in Philadelphia in 1993, more than 700 in 1995 in Chicago and about 400 in California in 2006 (Alberini, *et al*. 2008).

Table ① Coefficient of seasonal variation in mortality (CSVM) and domestic thermal efficiency in EU-13

	CSVM	*Cavity insulation (% house)*	*Roof insulation (% house)*	*Floor insulation (% house)*	*Double glazing (% house)*
Finland	0.10	100	100	100	100
Germany	0.11	24	42	15	88
Netherlands	0.11	47	53	27	78
Sweden	0.12	100	100	100	100
Norway	0.12	85	77	88	98
Denmark	0.12	65	76	63	91
Belgium	0.13	42	43	12	62
France	0.13	68	71	24	52
Austria	0.14	26	37	11	53
Greece	0.18	12	16	6	8
United Kingdom	0.18	25	90	4	61
Ireland	0.21	42	72	22	33
Portugal	0.28	6	6	2	3

Source: Geddes, 2011.

The need for policy intervention

Because of the many potential benefits that could be realised from policy action in the buildings sector, the IEA recommends in its 25 Energy Efficiency Policy Recommendations that governments "*require all new buildings, as well as buildings undergoing renovation, to be covered by energy codes and meet minimum energy performance standards (MEPs) that aim to minimise life-cycle costs. Energy codes and MEPs should be enforced, regularly strengthened and take a holistic approach that includes the building envelope and equipment*"

To support policy makers around the globe in the design and the implementation of their building energy codes, the IEA and the United Nations Development Programme (UNDP) have worked together on this joint publication. The aim is to share best practices and ensure worldwide understanding of building energy codes as the "cornerstone" policy instrument to tackle buildings' energy consumption.

This Policy Pathway is divided into four sections. The first section highlights the history and current status of building energy codes around the world. The second section outlines the key elements of advanced building energy codes. The third section analyses the challenges to effective implementation of building energy codes. The fourth section sets out steps and actions necessary for the effective and successful implementation of building energy codes.

What are building energy codes?

Overview

Building energy codes, also known as "energy standards" for buildings, "thermal building regulations", "energy conservation building codes" or "energy efficiency building codes" are the key policy instrument used by governments to reduce the energy consumption of buildings. Such codes consist of a set of mandatory minimum energy performance requirements designed to regulate energy use in buildings. They cover both new buildings and existing buildings undergoing renovation or alteration. Architects and engineers use the functional energy requirements stated in building energy codes to design buildings that meet the required standards (IEA, 2008).

Evolution over time

Setting rules for construction is not new. It goes back to the Babylonian Hammurabi's law (1750 BC). Among the 282 laws that regulated his reign, six concerned the construction of houses and penalties for builders in case of non-compliance (IEA, 2008). Historically, building regulations were usually initiated in response to disasters, such as fire, epidemics and earthquakes. The first building regulations were, therefore, concerned with construction and fire safety, as well as occupant health. In the twentieth century, governments started including energy provisions, first in the existing building codes and, subsequently, in a separate document typically referred to as "building energy codes".

Over time, building energy codes have evolved in response to national priorities. The drive towards regulating thermal conditions started after the Second World War (Figure 5) and was initiated by the health problems caused by poor insulation in cold climates. In the 1960s, rising living standards and increased demand for better comfort levels led to an increase in insulation requirements. The oil crisis of 1973-1974 and the need to reduce oil dependency were the catalyst for IEA member countries to develop specific building energy codes to reduce energy imports used for buildings. In the 1990s, climate change concerns led to the development of more stringent energy requirements for buildings. Today, most advanced building energy codes are designed to promote the development of a low-energy and low-carbon buildings stock in the short to medium term.

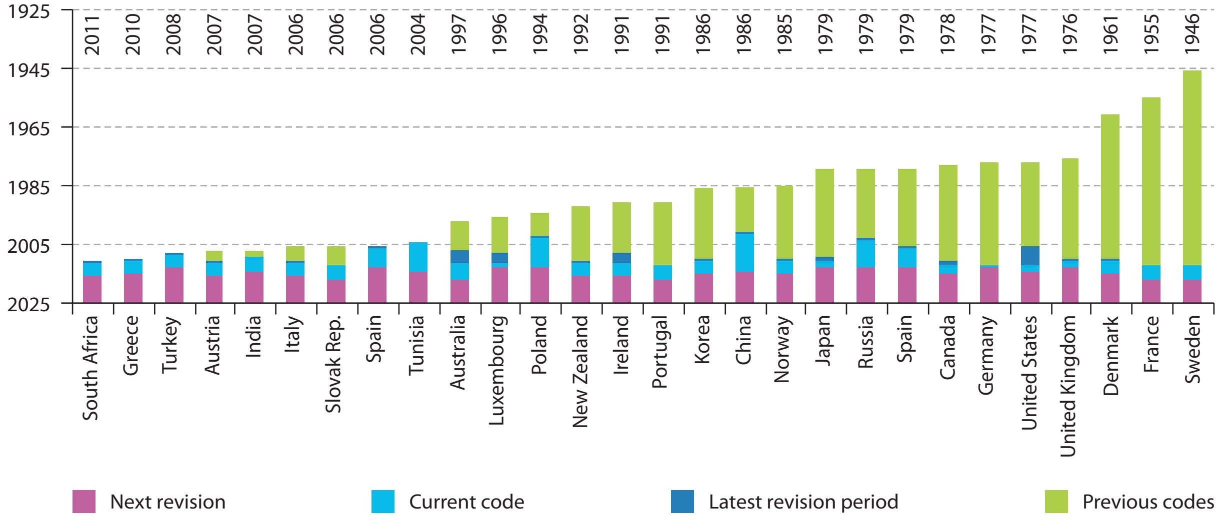
From prescriptive to performance building energy codes

This Policy Pathway distinguishes between the prescriptive approach to the design of building energy codes, and the performance approach. Each approach sets out two different compliance paths.

Prescriptive building energy codes

Prescriptive building energy codes set minimum energy performance requirements for each building component. These types of codes usually include permissible levels of heat loss for windows, roofs and walls, and/or efficiency levels for heating, cooling and lighting equipment. The prescriptive approach was developed in the 1970s and is the simplest way to set minimum energy performance requirements. However, this approach is quite restrictive and leaves less flexibility and less room for architects and engineers to innovate, as the compliance path requires each requirement to be met individually. In recognition of this, a trade-off compliance path was introduced in the 1980s to offer more flexibility in building design. The trade-off is usually made between energy requirements of the building envelope and those of heating and cooling equipment. In general, using the prescriptive approach does not allow designers to maximise the savings potential as the interactions between different buildings' components are not taken into account.

Figure 5 Progress in implementing building energy codes in the IEA countries, the BRICS and Tunisia



Performance building energy codes

Performance building energy codes require the overall building to be considered as one single system. A good understanding of building science and sophisticated software are needed to deal with the multiple factors that influence energy performance and their interactions. Factors to consider in the calculation methodology include: the building form and orientation; daylight, solar gains and shading; the share of glazed areas; building inertia; thermal bridges; natural and mechanical ventilation; indoor comfort; internal loads from appliances, equipment and occupants; the performance of different building components and equipment; and the use of renewable energy sources and automatic controls. The energy performance of a building is calculated on the basis of the annual energy needed to meet the user's level of comfort. This may vary per building type (*e.g.* housing, health, education buildings), local climate zone and usage pattern. Building energy performance is usually expressed either in terms of primary energy per useful surface area, given in kWh/m^2/yr, or in terms of CO$_2$ emissions per useful surface area. The performance approach allows for more synergies, such as using more glazed areas where greater daylight is needed while compensating for energy losses by selecting well-insulated windows.

Performance building energy codes also include prescriptive minimum energy performance, or alternatively, maximum allowable energy consumption, of buildings' components and systems.

The progress made in building science made it possible, beginning in the 1990s, to model energy consumption for individual buildings. This has led to the development of a model compliance path.

Designers build their own reference building, using the maximum allowed energy performance requirements for each building component and equipment; and the software calculates the maximum allowed energy consumption for the reference building. The energy consumption of the building under design is estimated using the same software but taking into account the performance of the building's components and equipment actually selected. The total energy consumption of the building considered should not exceed that of the reference building. One drawback of the model approach is the variation of maximum allowed energy consumption per reference building. A variant of the model compliance path is to set a minimum requirement for the overall thermal value. In this case, the model approach is called an energy frame path.

In response to increasing environmental and climate concerns, the model approach has evolved from minimum energy performance requirements that vary from one reference building to another to standard energy performance requirements or allowable CO_2 emissions for each building type in each climate zone. Under this regime, architects and developers are encouraged to use an integrated building design based on a holistic assessment of standard energy performance requirements pre-defined for each building type in each climate zone.

An evolving scope

The scope of building energy codes has evolved both in terms of the type of buildings they cover and geographically. Initially, their scope included only new residential buildings. Subsequently, it was expanded to include new, non-residential buildings. More recently, their reach has expanded to cover existing buildings when they undergo renovation or alteration.

Today, building energy codes are implemented for new and existing residential and non-residential buildings either on a mandatory basis, a voluntary basis or a combination of the two (mixed implementation). However, implementing the codes on a mandatory basis is likely to be the only effective way of achieving the desired changes. Figures 6, 7, 8 and 9 illustrate the use of these different approaches around the world for (a) new residential buildings; (b) existing residential buildings; (c) new non-residential buildings and (d) existing non-residential buildings.

Information on energy requirements included in building energy codes from IEA member and non-IEA countries has been brought together in the IEA Buildings Energy Efficiency Policies (BEEP) database (Box 1).

Box 1

Buildings Energy Efficiency Policies (BEEP) database

The IEA has developed the Buildings Energy Efficiency Policies (BEEP) database.

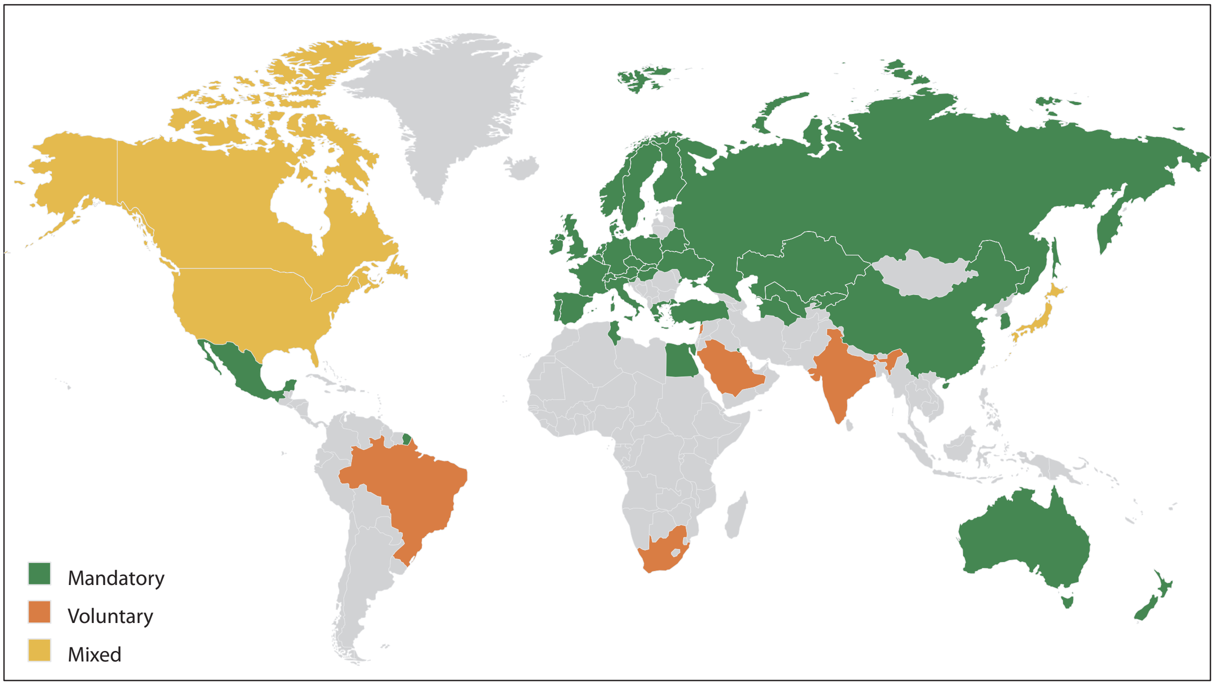
BEEP provides detailed information on the requirements included in 448 building energy codes (34 countries). BEEP enables users to research specific information on each building energy code, such as the energy requirements included in the code and the compliance path and rates.

BEEP also includes detailed information on 240 labelling schemes and 219 incentive programmes and, where available, BEEP provides information on the zero-energy building strategy developed by each country.

The aim of BEEP is to share information on each policy instrument developed and/or implemented by IEA member countries and BRICS countries. When similar information is available in other countries, it is also included.

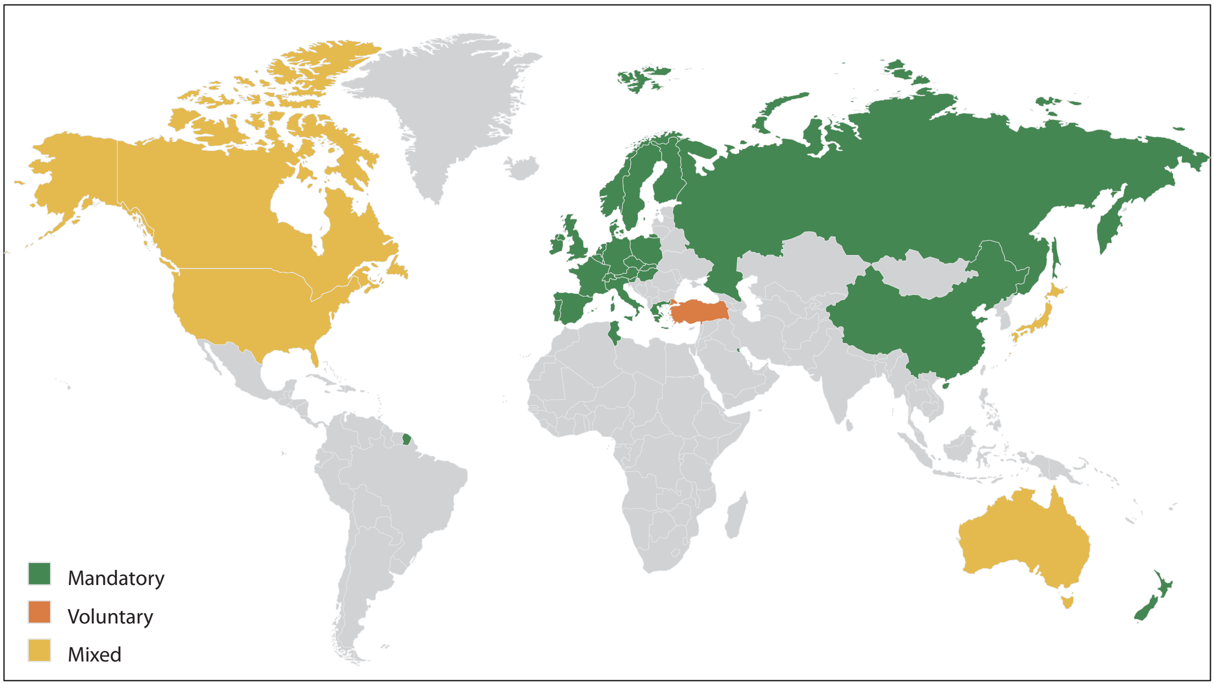
The IEA offers free access to BEEP at:
www.sustainablebuildingscentre.org.

Figure 6 Status of building energy codes implementation for new residential buildings



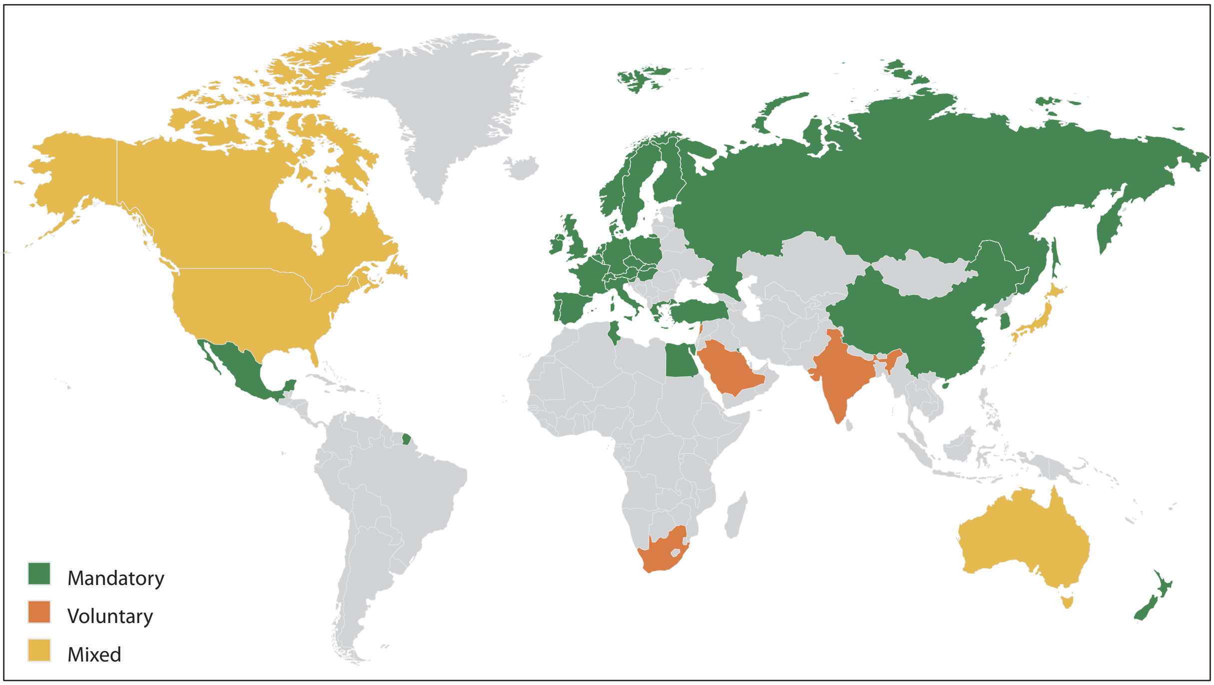
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Figure 7 Status of building energy codes implementation for existing residential buildings



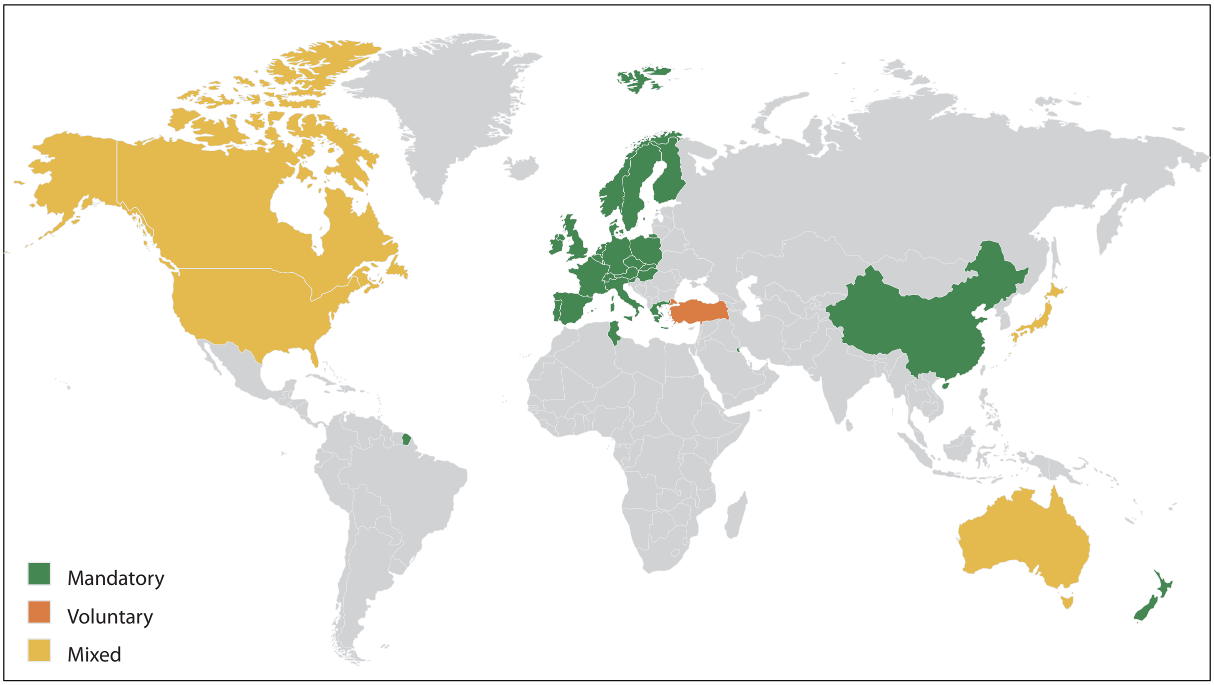
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Figure 8 Status of building energy codes implementation for new non-residential buildings



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Figure 9 Status of building energy codes implementation for existing non-residential buildings



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Going beyond traditional building energy codes

There are three important but distinct ways in which the traditional approach to building energy codes is evolving and which should continue into the future to maximise the savings potential from this sector. They involve: (a) increasing the breadth of factors that determine the energy consumption of buildings; (b) expanding the variety of policy instruments that need to be addressed as complementary to building energy codes; and (c) addressing the challenges and opportunities provided by the long lifespans of buildings. These aspects are addressed below.

Improved path to low-energy and low-carbon buildings: energy sufficiency, energy efficiency and renewables

Traditional building energy codes focus mainly on improving the efficiency of the energy used to achieve the same level of energy services. However, a new wave of building energy codes provides a comprehensive and effective path to low-energy and low-carbon buildings by requiring: (a) energy sufficiency measures, designed to reduce the need for energy services; (b) energy efficiency measures, which reduce the amount of energy needed to generate the energy service; and (c) the use of renewable energy sources, notably resources generated by the building itself or its proximate surroundings. Getting it right from the start and getting it right now are particularly important in the buildings sector, given the long lifespan of buildings in most countries and the fact that in non-IEA countries more than half of the buildings that will exist in 2050 have yet to be built (IEA, 2010a).

Energy sufficiency measures

Energy sufficiency measures are designed to reduce the extent of energy services (*e.g.* heating, cooling and lighting) needed to operate and maintain the required comfort level in a building. Sufficiency measures comprise a set of non-technological solutions related to the design of a building and its daily management and operation. These measures go beyond the construction of the building as a stand-alone item, but rather place the building within its broader environmental context. The building's orientation *vis-a-vis* the sun, its placement with respect to surroundings, daylight and sunshine requirements based on bio-climatic design principles (*i.e.* orientation, volume, natural and urban shade) are considered. The form, volume and orientation of the building, the ratio of glazed areas, the colour of roofs and walls (Box 2), and the use of natural shading are the main factors that need to be considered when meeting the requirements for energy sufficiency at the design stage.

For economies with high construction rates, including energy sufficiency requirements in building energy codes will significantly reduce the energy demand of the future buildings stock. In IEA member countries, where three-quarters of today's buildings stock will still be standing by 2050 and the size, location and orientation of existing buildings cannot be altered, the implementation of energy sufficiency measures for the building envelope is limited to adapting the colour of roofs and walls to the climate.

Another important aspect of energy sufficiency relates to the temperature set-point. In many buildings, temperatures are fixed at a certain temperature, irrespective of the weather, season or time of day. In buildings with energy sufficiency requirements, temperatures may be allowed to vary within a defined range (*e.g.* from 18°C to 27°C) according to external environmental conditions. This strategy relies on the users adapting their clothing (removing or putting on a sweater) in response to the evolving indoor environment rather than requiring the building's heating or cooling system to adjust, thereby avoiding additional energy use.

Box 2

Requirements on the use of cool roofs in the US building energy codes

The 1990 American Standard for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) was the first building energy code to include prescriptive requirements on solar reflectance (how much light roofs should reflect) and minimum thermal emissions (how efficiently roofs shed heat) of roofs for air-conditioned buildings.

In 2005, prescriptive requirements on the use of cool roofs were added to the Californian building energy code (Title 24, 2010). Today, most warm states in the United States include prescriptive requirements on the use of cool roofs.

The use of cool roofs can reduce the demand for air conditioning by up to 20%. In warm climates with high cooling energy demands, cool roofs reduce peak power demand and transfer less heat to the outdoor environment, thus slowing urban smog formation due to power generation and improving human health and outdoor comfort (Akbari, 2012).

Source: www.coolrooftoolkit.org/knowledgebase/global-cooling-updates-reflective-roofs-and-pavements
http://www.energy.ca.gov/title24/

In 2005, Japan initiated a dress code programme, "Cool Biz" (Box 3), with the aim of reducing summer peak load by encouraging more informal attire than suits. This allowed for higher indoor temperatures during the summer and lowered consumption of air conditioning. Similar dress codes have since then been promoted in South Korea and the United Kingdom.

Energy efficiency requirements

Energy efficiency measures are technological solutions that are designed to provide energy services at lower levels of energy consumption. As described in the previous section, the most advanced building energy codes consider a building as one single system and set minimum energy performance requirements for the regulated loads (heating, cooling, ventilation, lighting and hot water) of the overall building. Performance energy codes for new buildings start with the improvement of the envelope by optimising its performance through insulation and air tightness requirements. Unnecessary energy losses are reduced, thereby minimising the need for heating and cooling systems and removing the need to invest in additional power plants. The next step is

Box 3

The Japanese "Cool Biz" dress code to reduce energy needs

In 2005, the Japanese Ministry of Environment (MoE) encouraged central government ministries and other office buildings to set their air conditioning at 28°C during the summer and launched the "Cool Biz" dress code campaign.

The aim of the campaign was to encourage staff to wear clothing that is better suited to higher temperatures, namely trousers made from materials that breathe and absorb moisture and short-sleeved shirts without jackets and ties. As part of the campaign, government representatives adopted the Cool Biz dress code; the Prime Minister was frequently interviewed without a tie or jacket.

The MoE conducted a web-based survey to evaluate the impact of the Cool Biz dress code. The results indicated that 95.8% of the respondents knew about the Cool Biz campaign and 33% of 562 respondents answered that their offices had set the air conditioner thermostat higher than in previous years. Based on these figures, the MoE estimated that the Cool Biz campaign resulted in the reduction of CO_2 emissions equivalent to that of about one million Japanese households for one month (LBNL, 2006b).

In 2011, the Cool Biz campaign was included in the Japanese government's Electricity-Supply Demand Emergency response.

Source: www.inive.org/members_area/medias/pdf/Inive/IAQVEC2007/Murakami_2.pdf.

to set minimum energy performance requirements for each equipment and system to ensure the most efficient available technologies are used.

Strengthening energy efficiency requirements for existing buildings is more complex to implement. The energy performance of a building envelope, or the components and equipment therein, is only likely to be improved at normal renewal or planned maintenance intervals, often only after the building has been occupied for several decades. The lock-in effect risk is high in the case of existing buildings, especially if investments are made on a component by component basis, rather than considering the building as a whole. For example, highly efficient and expensive windows can be installed, but if the walls are poorly insulated, the energy efficiency improvement will not be maximised as would be the case if the walls were properly insulated. Moreover, making an expensive investment in energy efficient windows may constrain the investor's financial ability to make further improvements as the next step would be to invest in better insulated walls, which would require new windows with a thickness that corresponds to the new insulated walls. Overall, performance building energy codes for existing buildings limit the lock-in effect more than prescriptive energy codes because they allow architects to take a holistic approach that can yield stronger results when renovation takes place, including the sequencing of interventions (*e.g.* insulating roofs and walls first, then selecting windows and heating systems adapted to their newly insulated environment).

Generating energy supply from renewable energy sources

Supply from renewable energy sources is the third strategic driver to achieve a low-energy and low-carbon buildings stock. Renewable energy sources reduce the need for grid-based energy supplies and sometimes produce a surplus. In countries with unreliable or unavailable grid supply, energy from renewable sources is useful for providing back-up power. Integrating renewable energy sources into buildings can transform the buildings sector from an energy consumer to a power generator that supplies energy to the grid (IEA, 2011).

Renewable energy generated by the building itself or from its surroundings can be used to supply thermal and/or electric energy where technically feasible and economically viable. This would reduce the need for off-site energy generation and therefore can lower GHG emissions resulting from buildings' energy consumption. Renewables can be used in various forms for thermal systems, such as through the capture of solar heat gains for space or water heating, the use of biomass for heating, prevailing breezes for natural ventilation, or heat pumps that extract heat or cold from the ground. Electricity generation can be produced through the use of photovoltaic systems and also strategically located mini wind turbines on the roofs of certain buildings or in the neighbourhood. District heating and cooling systems driven by energy from renewable sources could also be used.

The three-pronged approach outlined above has been used by the 2012 French building energy code for new buildings described below.

Case study 1

The French 2012 building energy code for new buildings: the three-pronged approach in practice

The 2012 building energy code added requirements on energy sufficiency measures and the overall energy performance of regulated loads (heating, cooling, ventilation, hot water and lighting). It also included the existing requirements on comfort temperature in summer time and strengthened those on the use of renewable energy sources.

A new indicator called the "bio-climatic indicator" has been introduced. The aim is to reduce energy needs by maximising the use of bio-climatic design principles such as solar gains, shading and daylight. The bio-climatic indicator is calculated by dividing the weighted needs for heating, cooling and lighting by the net floor area of the building. The maximum allowed value for this indicator is provided for each building type and each climate zone. Compliance with energy sufficiency measures requires architects to demonstrate that the bio-climatic indicator of each new project is better than the bio-climatic value for the climate zone and the building type considered.

The maximum primary energy consumption allowed for regulated loads is determined by the building energy code for each climate zone and each building type. The national average primary energy consumption is 50 kWh/m^2/yr. New buildings should not exceed this value. The building energy code provides adjustment coefficients per building type, climate zone and altitude.

Renewable energy sources, including biomass and district heating systems, have to be used when technically feasible and economically viable. For electricity production, architects may choose to use photovoltaic panels. To avoid compensating for poor building design by using renewable energy sources produced by the building itself, the building energy code allows no more than 12 kWh/m^2/yr of building energy production. The 2012 building energy code for new buildings also sets requirements for the air tightness of the building envelope and demands a blower-door test (Box 10) to check compliance with this requirement.

During the early stages of building design, the developer is responsible for complying with energy sufficiency, energy efficiency requirements and the summer comfort temperature level by providing a calculation of the summer comfort index. To issue land-use permits, local authorities require a description of how each requirement will be met. For construction permits, the use of sophisticated software accredited by the Scientific Centre for Buildings (CSTB) and a compliance report issued by a third party are required. This report has to include details on the proposed solutions for meeting the energy performance requirements and the summer comfort index as well as a feasibility study for the use of local renewable energy.

During the construction phase, field inspections may occur. Once completed, detailed calculations of the technical solutions implemented to comply with each of the three requirements must be submitted to the local authority.

The 2012 building energy code update entered into force at the end of October 2011 for office and education buildings, in early March 2012 for parts of social dwellings and in early January 2013 for all other building types.

Source: Unless otherwise indicated, all material in figures and tables derives from IEA-UNDP analysis of French building energy code available at: www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000022959397&dateTexte=&categorieLien=id.

Towards a modern approach

The three-pronged approach outlined above needs to be articulated at three levels: (a) strategy, (b) policy instruments, and (c) policy measures. At the strategic level, the first step is to reduce energy needs; the second step is to reduce energy consumption; and the third step is to supply buildings with clean energy solutions. The policy instruments in which the three steps should be included go beyond building energy codes and include complementary policies such as land-use policies, and S&L policies for buildings components, equipment and appliances. To ensure the effective implementation of the modern approach, each policy instrument should include requirements relating to policy measures, such as bio-climatic design principles and mandatory minimum energy performance requirements (Figure 10).

Figure 10 The path to follow at the design stage to achieve low-energy and low-carbon buildings

	1 **Energy sufficiency**	2 **Energy efficiency**	3 **Renewable energy**
Energy strategy	■ Reduce energy needs	■ Reduce energy consumption	■ Reduce CO_2 emissions by using renewable energy
Policy instrument	■ Land-use policies ■ Building energy codes	■ Building energy codes ■ S&L policies	■ Land-use policies ■ Building energy codes ■ S&L policies for equipment
Policy measure	■ Bioclimatic design principles ■ Use of passive solutions	■ Mandatory S&L for: ▪ overall building energy performance ▪ building elements and equipment	■ Mandatory share of supply from renewable energy sources ■ Mandatory S&L for equipment

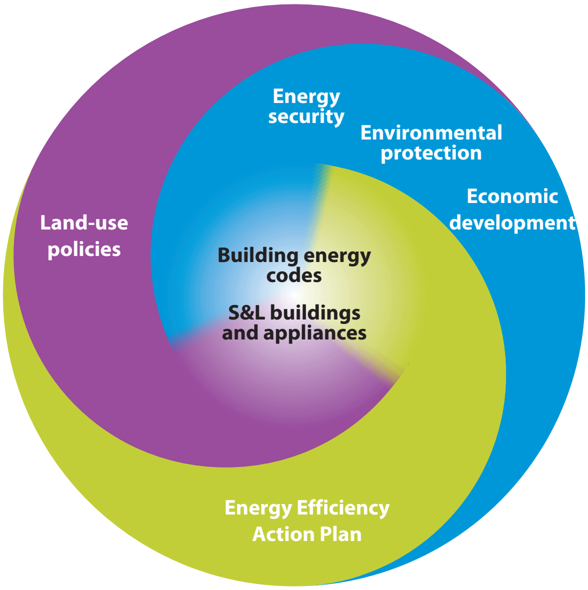
Considering the broader policy landscape when designing building energy codes

A comprehensive integrated approach

Buildings are complex systems. Their energy consumption is shaped by interactions between their design, location, orientation, volume, function, installed equipment and usage pattern. Building energy codes need therefore to be flexible, allowing for consideration of local environmental and socio-economic contexts and adaptation to changing technologies. As a consequence, building energy codes should be designed to go beyond building-specific energy considerations and take into account broader objectives of economic development, environmental protection and energy security (Figure 11).

Moreover, energy performance requirements included in building energy codes need to be aligned with those considered in land-use policies, labelling policies (both those for buildings and

Figure 11 Policies affecting buildings' energy consumption



those for appliances and equipment) and renewable energy policies. In IEA member countries, and some others such as China, Russia and Brazil, renovation policies also play an important role in the implementation of building energy codes for existing buildings. Policy makers need to ensure that energy requirements are considered when buildings are renovated.

Land-use policies

As described above, land-use policies have a long-term effect on building energy needs, and so are central to energy sufficiency measures. Effective land-use policies allow for the efficient use of natural sources such as natural shading, daylight and sunshine to reduce heating, cooling and lighting demand (OECD, 2010). Spatial planning determines the placement of the built environment, its orientation and the use of natural features including sources of energy.

Land-use policies may determine the actual location and position of the building, which in turn determine its orientation, purpose and size, and whether or not trees must be used for shading. Integrated energy urban planning policies that consider the resulting energy impacts of all development concerns (*e.g.* land-use planning, transport system planning) can reduce buildings energy consumption during their construction and lifetime operation. Building energy codes should consider the requirements of land-use policies to calculate the amount of shading needed and the position of the shade and its effects at different periods of the year when setting minimum energy performance requirements. Greater attention should be given to heat waves, especially in hot climates.

Generally, land-use policies include density requirements. Some cities and local authorities allow an increase in density when buildings are constructed or renovated to very low-energy consumption standards (*e.g.* The French law (Fr, 2005) setting guidelines for energy policies authorises city councils to increase density up to 30% above the limit set in local city planning in the case of residential developments with low-energy buildings).

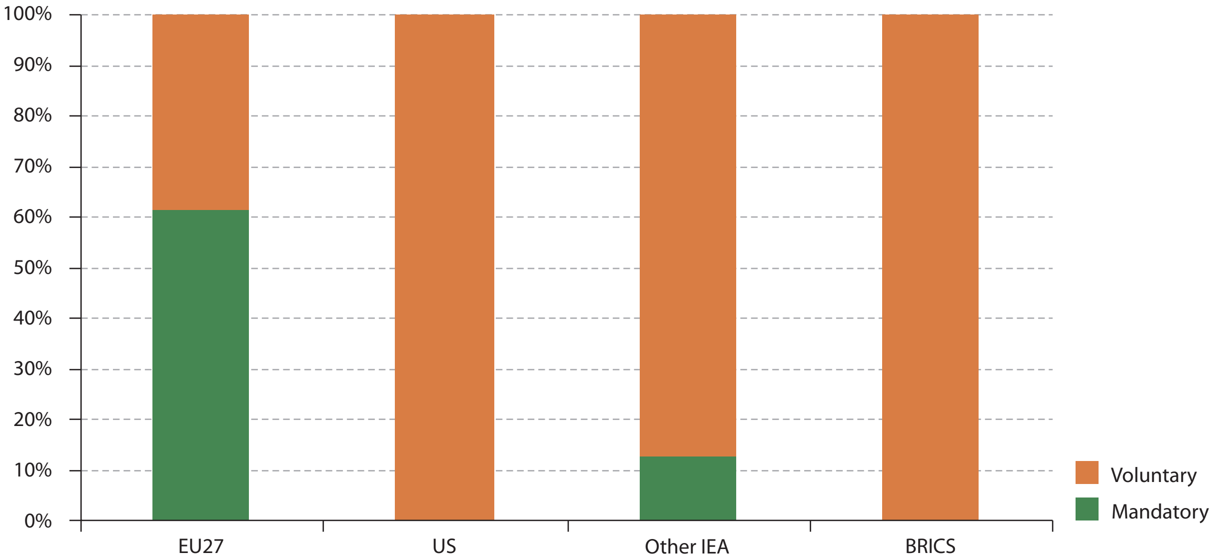
Labelling policies

Labelling policies, used for buildings, buildings components, appliances and equipment are meant to provide information to investors, buyers and residents on the energy performance of buildings. The aim of such policies is to influence property developers and consumers, and to promote efficiency improvements of both new and existing buildings.

For buildings

The implementation of building labels varies across countries. Most IEA member countries have implemented mandatory labelling schemes for both new and existing buildings. In the US and the BRICS countries, labelling schemes are mostly implemented on a voluntary basis (Figure 12).

Figure ⑫ Status of implementation of labelling schemes for buildings



To avoid confusion in the market, the energy rating which is included in the building energy label should be based on the energy requirements described in the building energy code. The best energy grade in the label should correspond to the targeted long-term minimum energy performance requirement. The intermediate energy grade should correspond to the minimum energy performance requirement of the current building energy code.

The lowest energy rating should correspond to the performance of least efficient buildings in the national market.

The Tunisian building energy code provides a good illustration of well-designed complementary policies through the alignment of the energy rating in the building label with the energy requirements in the code as described in case study 2.

Case study 2

Alignment of energy requirements in building labelling with those building energy code in Tunisia

Tunisia's building energy labelling scheme was developed in parallel with the building energy code in 2004. The building energy code and the building energy label became mandatory for office buildings exceeding 500 m^2 in July 2008 and for residential buildings, with the exception of single-family houses, in June 2009.

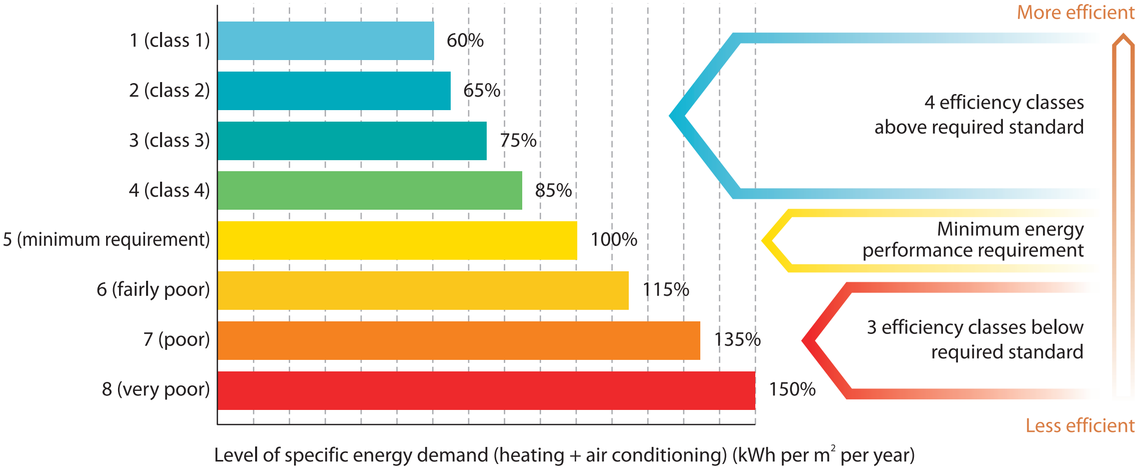
Tunisia's building energy code is an overall performance code. Requirements are set on the maximum annual energy needs allowed for heating and cooling per building type in each climate zone to reach the level of comfort required for the occupants without using heating and/or cooling systems.

Tunisia's building energy label establishes an energy rating for existing buildings, new buildings and long-term energy efficient buildings. The energy rating, which ranges from one to eight, is based on estimated energy needs for heating and cooling, using the calculation methodology of the building energy code.

The reference value in the labelling scheme corresponds to the maximum energy needs allowed by the current building energy code (i.e. 60 kWh/m^2/yr for residential buildings). The reference value is set at 100% in the label and corresponds to energy grade 5. The label includes three grades below this requirement and four grades above it. The low-efficiency grades correspond to buildings with energy needs that are 15%, 35% and 50% higher than the current requirement, while the more efficient grades correspond to buildings with energy needs 15%, 25%, 35% and 40% lower than the maximum energy needs allowed by the building energy code (Figure 13).

Source: compiled by the author from UNDP, GEF, Med-ENEC and AFD evaluation reports.

Figure 13 Energy grades on the Tunisian building energy label



Source: National Energy Management Agency of Tunisia.

For buildings components, appliances and equipment

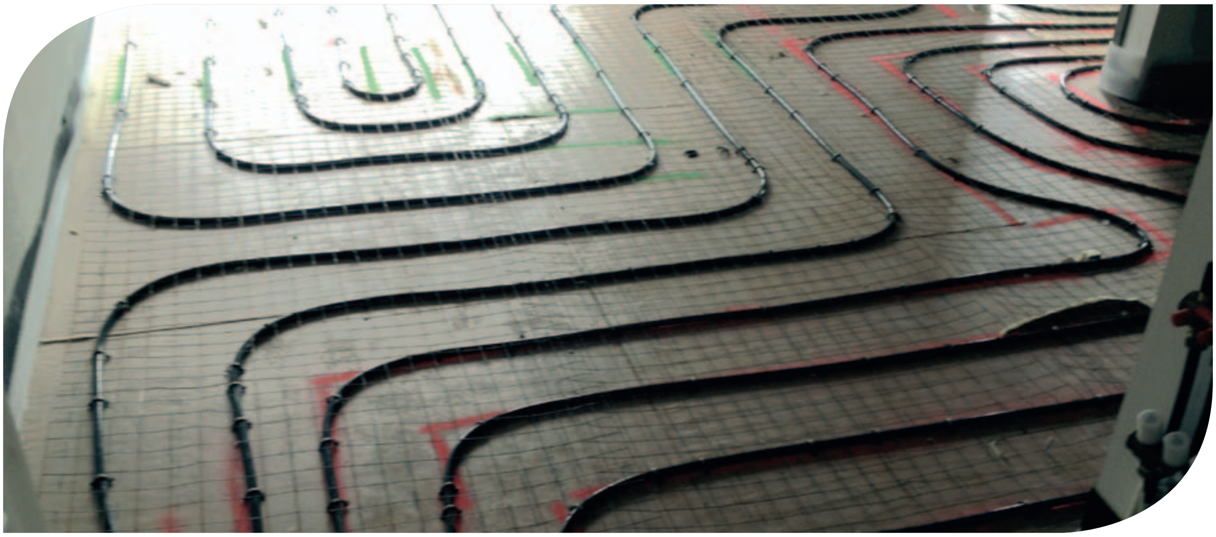
Labelling policies are also used to provide information on the energy performance of building components, appliances and equipment. The objective is to raise awareness and provide consumers with simple accessible information to drive them towards the best-performing products. In addition, some countries implement labelling policies for buildings' components so that it is clear that the building matches the approved design and code.

Policies for buildings' components such as windows and glazed areas are usually implemented on a voluntary basis, with the notable exception of South Korea, where energy efficiency policies for windows became mandatory in June 2012. The aim is to reduce the impact of windows on the overall energy performance of the building. The whole windows system, including shading devices, shutters, blinds and reflection, should be considered when setting energy requirements for windows and other glazed areas.

Energy balances of windows and their impact on the overall energy performance of buildings depend on the types of windows used, the number of layers of glass, the coating applied on the glass, the gas used between the layers, the distance between the layers and the type of frame and materials, climatic conditions and orientation of the glazing areas. Blinds, shutters and shading devices used to reduce light transmission, avoid overheating or decrease heat losses also affect the overall performance of the building.

Energy efficiency policies for windows and other glazed areas usually include requirements on thermal transmittance (U-values), glass values (G-values) which indicate the amount of sunlight that can penetrate each pane of glass, solar heat gain coefficients (SHGC), visible light transmission (VLT) and shading factors (SC) as well as air tightness. The aim is to balance the primary function of windows, allowing natural daylight into the building, with the three other functions; ventilation, solar heat gains and heat losses.

A number of countries (the United States, Canada, China, some EU countries and Australia) have also implemented voluntary labelling policies for insulation products. Heating, cooling and ventilation equipment, water heaters and lighting products are regulated under labelling policies. In most IEA member countries, labelling policies are combined with mandatory minimum energy performance requirements policies and implemented on mandatory basis.



Renewable energy policies

Building energy codes have to be aligned with national and local renewable energy strategies since, as described above, one objective is to transform the buildings sector from an energy consumer into an energy producer. The most advanced building energy codes integrate the use of local energy sources such as daylight and sunshine to reduce heating, cooling and lighting needs. They also include the use of energy from renewable sources in the calculation of the overall energy performance of the building.

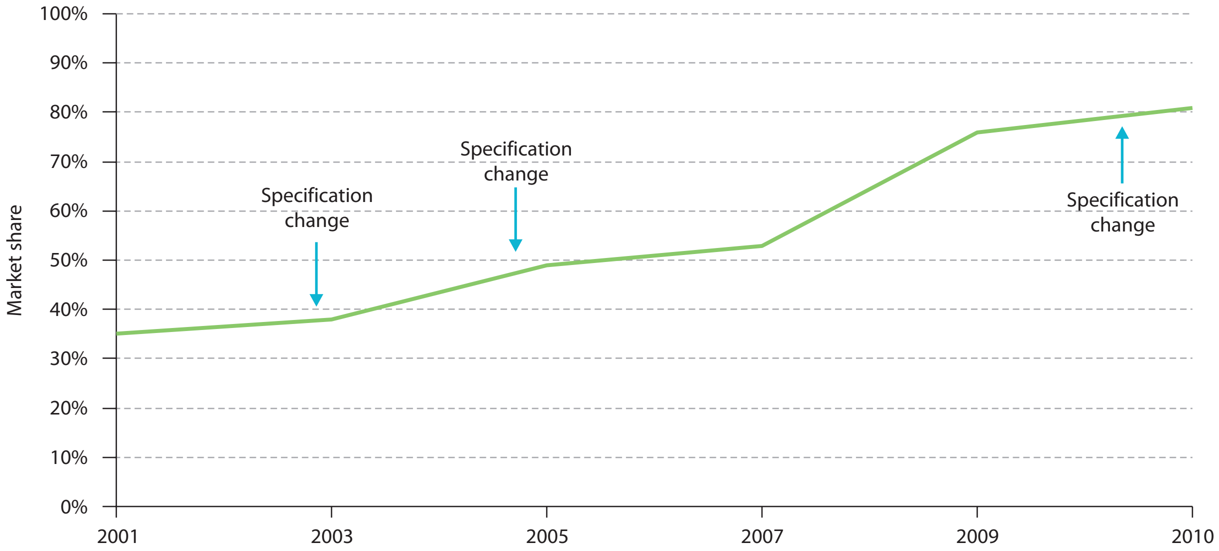
Sustainable technology policies

Buildings' components and equipment technologies are constantly developing. However, new and efficient technologies often take a long time to penetrate the market-place due to an initial lack of information about their energy-saving potential and cost-effectiveness. Gaining buy-in from the entire building chain, from suppliers to installers, on the effectiveness and reliability of new and efficient technology takes time because the buildings sector may suffer from a lack of know-how among professionals, a lack of leadership and low interest in pursuing energy efficiency improvements (WBCSD, 2009).

Deploying efficient technologies can be accelerated by increasing the stringency of building energy codes and taking into account Research, Development and Demonstration (RD&D) policies for building-related technologies. The high penetration of ENERGY STAR windows in the United States over the past ten years – despite the increasingly stringent energy requirements – is a good example of the effects of this acceleration (Figure 14).

Well-designed buildings energy efficiency policies help establish a scale of production large enough to reduce unit costs, making efficient technologies more attractive in the market-place. Countries and regions where zero-energy building targets have already been announced in national energy efficiency action plans will encourage investment and competition in smart and efficient technologies. The increase in market share of low-energy buildings will, in turn, reduce the cost of smart and efficient technologies in the coming years.

Figure 14 Market share of ENERGY STAR labelled windows



Source: ENERGY STAR, 2012.

The need for an overarching policy framework

The complexity of energy consumption of buildings requires the design of an overarching energy policy framework that includes, in addition to building energy codes, energy labelling and renewable energy policies. The comprehensive energy policy framework developed by the European Union could serve as a basis for other countries (Box 4).

Box 4

The EU overarching policy framework to achieve a low-energy and low-carbon buildings stock

The EU considers energy efficiency as a valuable means to:

- *improve energy security by reducing its primary energy consumption and energy imports;*
- *mitigate climate change by reducing its GHG emissions;*
- *boost economic growth by accelerating the spread of innovative technological solutions and improving the competitiveness of European industry.*

The EU places energy efficiency at the core of its 2020 energy strategy to reduce primary energy consumption by 20%. To achieve this target, the EU adopted the Energy Efficiency Directive (EED), Directive (2012/27/EU), on 25 October 2012, which establishes a common framework of measures to promote energy efficiency. The EED lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy. Additionally, it provides for establishing indicative national energy efficiency targets for 2020.

For the buildings sector, the EED includes provisions to establish a long-term strategy that would mobilise investments for renovating the existing national buildings stock. Member states are required to include their renovation strategy in their national energy efficiency action plans, which must be updated every three years. The Directive also makes it mandatory for governments to renovate annually at least 3% of the total floor area of heated and/or cooled buildings owned and occupied by the central government. Renovated buildings have to meet the minimum energy performance requirements set out in the Energy Performance of Building Directive (EPBD).

The Energy Performance Building Directive, (EPBD, 2002/91/EC), first published in 2002, stipulates that EU member states enhance their building energy codes by introducing mandatory minimum energy performance requirements for all new buildings and existing buildings of more than 1 000 m^2 when undergoing major renovations.

The Directive also introduced a mandatory labelling scheme called the Energy Performance Certificate (EPC) for new and existing buildings, as well as the mandatory inspection of heating, cooling and ventilation systems. Revised in 2010, the EPBD recast, Directive (2010/31/EU), extended the mandatory minimum energy performance requirements for existing buildings to those with a useful floor area over 250 m^2.

The EPBD recast introduced the cost-optimum methodology (Box 5) to determine minimum energy performance requirements for buildings and buildings' components. The aim is to shift the focus from end-user and upfront investment perspectives to a societal perspective and a life-cycle cost calculation methodology.

The EU overarching policy framework to achieve a low-energy and low-carbon buildings stock (continued)

The recast has also made it mandatory for member states to consider the use of renewable energy sources in buildings.

Furthermore, the EPBD recast also focused on improving the mandatory labelling scheme for buildings. By June 2012, EPCs were mandatory in all commercial announcements; their display was then extended to non-residential buildings of more than 250 m^2. Member states are required to make information available to end-users regarding the energy consumption of buildings.

The EPBD recast stipulates that by 1 January 2021, all new buildings in the EU 27 must have "nearly zero-energy" consumption. In the meantime, EU member states are required to develop national plans to increase the market share of nearly zero-energy buildings with differentiated energy requirement targets per building type and with the public sector leading by example. Member states will set targets to stimulate the transformation of the existing buildings stock.

National plans will address various aspects:

- *A definition of nearly zero-energy buildings that reflect national and local conditions, and include a numerical indicator of primary energy use expressed in kWh/m^2 per year.*
- *Intermediate targets to improve the energy performance of new buildings by 2015, with the objective of reaching nearly zero-energy buildings by 1 January 2021.*
- *Information on policies and measures adopted at national levels for the promotion of nearly zero-energy buildings.*

From January 2013, the EC will evaluate the national plans and publish a report every three years on the progress made by member states to increase the number of nearly zero-energy buildings. The EC may propose new policy measures to increase the market share of nearly zero-energy buildings and encourage best practices to transform the existing buildings stock to nearly zero-energy consumption.

To support member states, the EC launched Concerted Action (CA) in 2007 to promote dialogue and the exchange of best practices among countries. The aim is to find common approaches to the most effective implementation of EU building policy package frameworks.

In addition to the Building Directive, the EC regulates the consumption of appliances and equipment by setting minimum energy performance requirements for energy-using products, as specified in the Ecodesign Directive (2005/32/EC) and its update (2009/125/EC).

The EC also requires that industry provide consumers with information on the energy performance of energy-using products by affixing a label on each product, as specified in the Labelling Directive (2010/30/EU).

The EU promotes energy efficiency through the Intelligent Energy Europe Programme, the Covenant of Mayors, and research and development. Intelligent Energy Europe funds non-technical projects related to energy efficiency. The Covenant of Mayors brings together local and regional authorities that voluntarily commit to increase energy efficiency and the use of renewable energy sources in their territories. Signatories aim to meet and exceed the EU objective of reducing CO_2 emissions by 20% by 2020.

Overarching policy strategies, plans and communications also encourage energy efficiency such as the Energy Efficiency Plan (published in March 2011) and the Energy Roadmap 2050 (published in December 2011).

Source: compiled by the author

Adjusting over time: the implications of buildings' long lifespans ....

Energy renovation policies

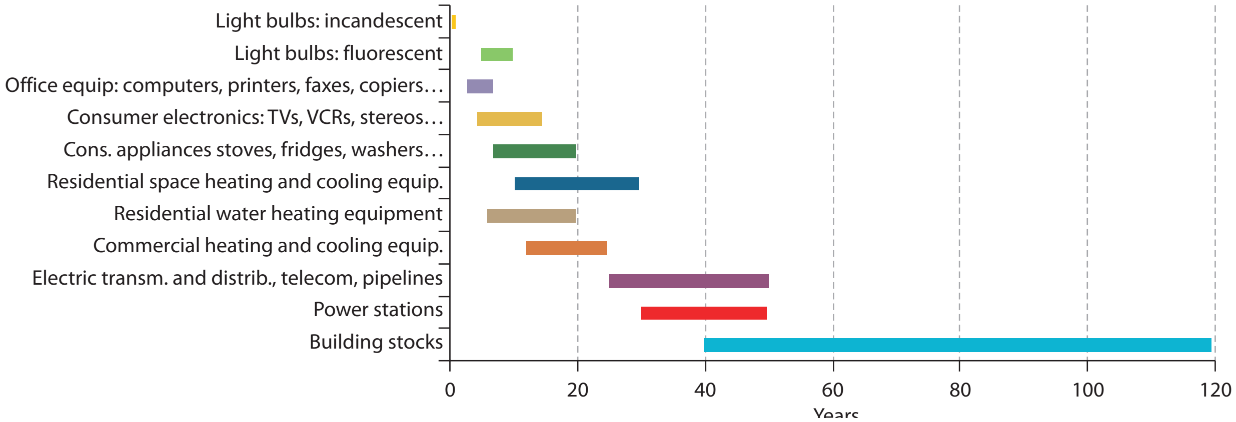
Building energy codes apply to existing buildings undergoing renovation as well as the construction of new buildings, although for renovations there are often exceptions as described above such as minimum floor areas below which some of the conditions set out in energy codes may not apply. The interplay of renovation policies and building energy codes is significant because buildings have long lifespans in most countries. Renovations can, therefore, become important levers for improving energy efficiency beyond the original design parameters. On average, residential buildings are renovated, in most IEA member countries, every 30 years to 40 years for the envelope, and 10 years to 15 years for heating and cooling systems (Figure 15), (IEA, 2002). Non-residential buildings are renovated on average every 15 years to 20 years. The driver behind technical renovation cycles is usually a need to improve operational efficiency, living quality, comfort level, appearance and to increase the asset value of the building.

Technical renovation cycles are a unique opportunity to implement building energy codes for existing buildings. They provide governments, owners of buildings and investors with a compelling opportunity to improve the overall performance of buildings. Combining the upgrade of the building with an energy upgrade reduces energy bills, allowing energy savings to contribute to the cost of the upgrade.

In February 2013, the Finnish government adopted a new regulation to improve the energy efficiency of buildings during renovation and alteration works. The Finnish renovation regulation defines the minimum energy performance requirements for renovations that are subject to a licence, or that involve a change in use or the renewal of technical systems. It includes extensive basic repairs and renovation of a building façade, as well as the renewal of technical systems such as heating ones that usually require a building permit.

For public buildings, the European Energy Efficiency Directive (EED) made it mandatory for governments to renovate annually at least 3% of the total floor area of heated and/or cooled buildings owned and occupied by the central government. Renovated buildings have to meet the minimum energy performance requirements set out in the EPBD and transposed to national building energy codes (Box 4).

Figure 15 Average time frame for replacement of building component and equipment in residential buildings



Adapting the stringency of energy requirements to technological changes over time

Building energy codes should be dynamic, with a regular increase in the stringency of energy requirements in order to realise low-energy buildings and accelerate the deployment of best available technologies and construction materials. The stringency of minimum energy performance requirements and the timeframe to achieve low-energy buildings will vary according to the technical capacity of the country and its technological development. As demonstrated by the Danish energy code described in case study 3, there is a large benefit in informing market-actors as soon as possible about the next level of stringency of energy requirements. This allows market-players to plan technology development which in turn avoids delays in implementation.

Case study 3

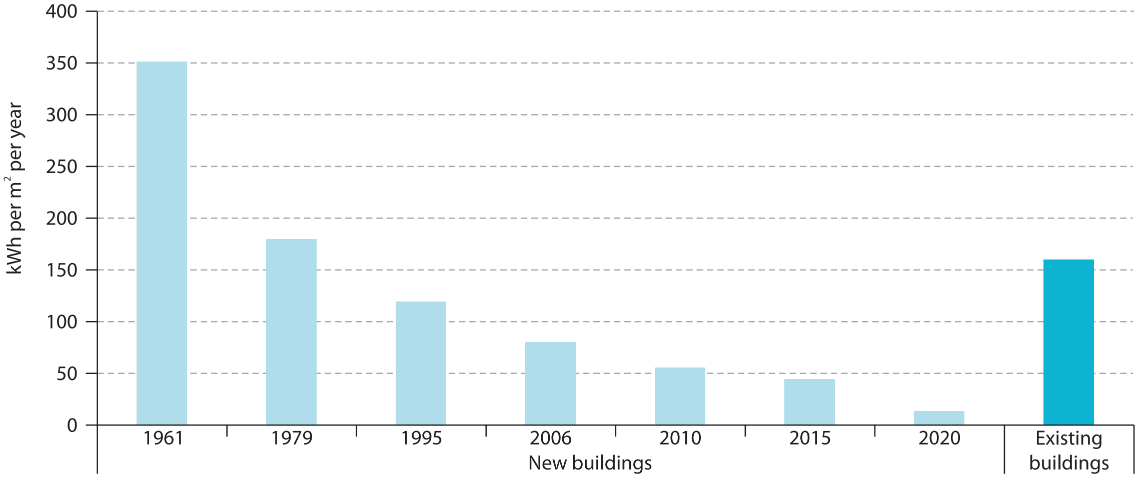
Stringency increase of energy requirements over time in the Danish building energy code for residential new buildings

The Danish energy code for residential buildings was adopted for the first time in 1961. Energy requirements are set for cooling, heating and ventilation. The stringency of energy requirements and inspirational targets for the future are decided at national level by all parties in the parliament. Over time, it has increased from 350 kWh/m^2/yr in 1961 to nearly zero-energy consumption by 2020.

Each new update of the building energy code has provided provisions for the next level of stringency: for example, the 2010 update included the requirements for 2015 (Figure 16). The aim throughout has been to give a clear signal to market-actors and avoid delays in future implementation.

The current building energy code is overall performance and includes minimum energy requirements for some individual components of the building.

Figure 16 Evolution of stringency of energy requirements in the Danish building energy code



Source: SBI/Aalborg University, 2013.

Past experience in IEA member countries has also shown that minimum energy performance requirements should be set considering the long-term macroeconomic perspective, rather than shorter term financial investment returns. The proposed European cost-optimum methodology (Box 5) to set minimum energy performance requirements gives guidance on the use of macroeconomic and financial cost-optimum calculations for each building type and each climate zone. It considers the overall life-cycle cost analyses of the building (30 years for residential and 20 years for non-residential) for each proposed efficiency measure. The objective is to enhance innovation, accelerate the deployment of the most efficient technologies and avoid the lock-in-effect (Mulder, 2005). The long-term perspective provides a better approach to supporting the stringency increase of energy requirements by considering low-discount rate. Ambitious energy requirements can generate increased economic benefits, and also reduce operation costs over a building's lifetime.

Box 5

The European cost-optimum methodology to set minimum energy performance requirements

The recast of the Energy Performance Building Directive (EPBD, 2010) requires member states to set minimum energy performance requirements with a view to achieving cost-optimal levels.

To ensure consistency of cost-optimum levels across EU countries, the EC developed a methodological framework that specifies rules for comparing energy efficiency measures. These measures incorporate renewable energy sources and packages as well as variants of such measures, based on the primary energy performance and the cost attributed to their implementation. The methodology framework prescribes the calculation of cost-optimal levels from macroeconomic and financial viewpoints, but leaves it up to the member states to choose which calculation will become the national benchmark against which minimum energy performance requirements will be assessed.

The methodology requires energy performance to be referred to as primary energy demand, expressed in kilowatt hours per square metres of useful floor area of a reference building. The calculation period is 30 years for residential and public buildings and 20 years for non-residential buildings. This allows for the use of low-discount rates. In addition, the cost-optimum level for minimum energy performance requirements for building components and systems (heating, ventilation, cooling, lighting, and water heaters) installed in existing buildings has to be calculated. The calculations should take into account both the interaction of each building component with the entire reference building and other building components.

The methodology consists of four steps:

- *Establish, for each building type, at least one reference building for new buildings and, at least, two reference buildings for existing buildings subject to major renovation.*
- *Identify energy efficiency measures for both new and existing buildings. These measures should include alternative high-efficiency systems such as district energy supply systems and other renewable energy systems. Energy efficiency measures/packages/variants identified to calculate cost-requirements have to meet currently applicable minimum energy performance requirements as well as support schemes, if applicable.*
- *Calculate primary energy demand for space heating, cooling, ventilation, domestic hot water and lighting as a result of applying such measures and/or packages of measures for a reference building. Energy produced on-site is deducted from the primary energy demand.*
- *Calculate the macroeconomic and financial costs in terms of Net Present Value (NPV) for each reference building.*

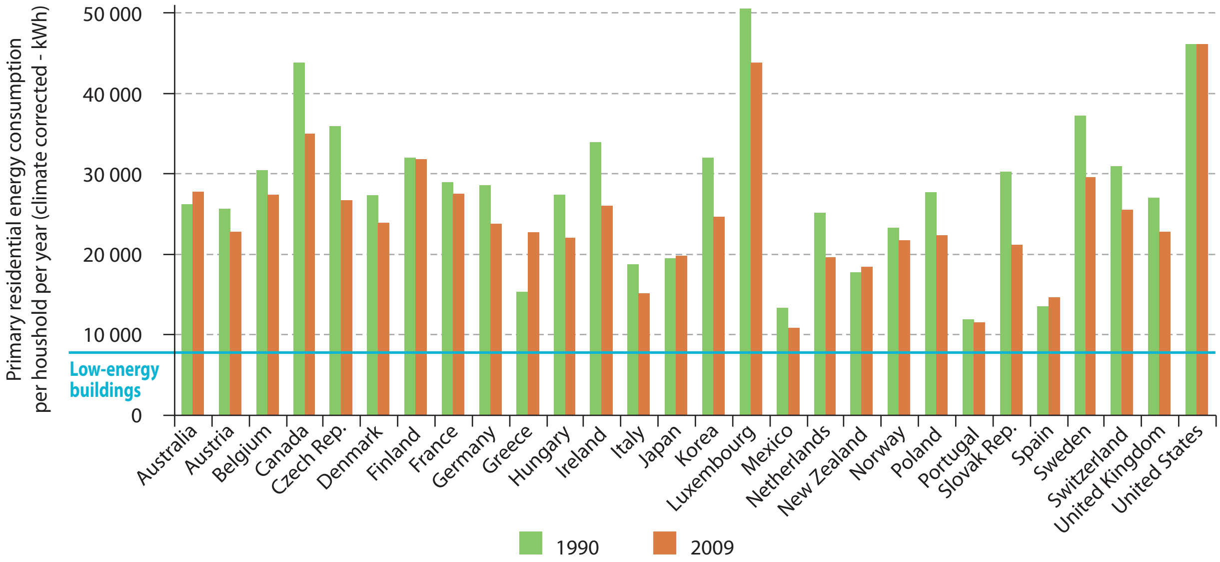
Source: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2012:115:0001:0028:EN:PDF.

Challenges to effective building energy codes

Building energy codes have proven their effectiveness in reducing buildings' energy consumption in IEA member countries (Figure 17). However, there is still room for improvement, if a low-energy buildings stock is to be achieved by 2050. Policy makers face a number of challenges when designing and implementing building energy codes, including the fragmentation of the buildings sector, difficulties with governance structures, misalignment of energy requirements in different policy instruments, and a lack of technical expertise and knowledge of building science.

All these challenges are particularly pronounced in developing countries, where governance structures, technical and institutional capacities tend to be weaker than in IEA member countries, in addition to the lack of data to establish baselines (SE4ALL, 2013). Energy savings, or "negawatts", are intangible and invisible, and thus often overlooked by policy makers. A lack of financial resources makes addressing the challenges of designing and implementing building energy code even more acute, especially when a country is designing its building energy code for the first time.

Figure 17 Climate corrected annual residential primary energy consumption per household in kWh



Fragmentation of the buildings sector

The buildings sector involves a number of uncoordinated private and public actors – often with conflicting interests – including energy and buildings authorities at both national and local levels, owners, users, investors, developers, designers, engineers, suppliers of energy, material and equipment, and other contractors (Figure 18). Interest in and knowledge of energy issues varies considerably among these actors. Moreover, the buildings sector typically suffers from a lack of leadership on energy efficiency improvements (WBCSD, 2009).

Figure 18 Fragmentation of the buildings sector

Absence of baseline information

In a vast majority of developing countries, there is little or no information and statistics that describe the buildings stock or its energy consumption (SE4ALL, 2013). In IEA member countries, the accuracy of the information available varies from one country to another. Without minimum information to establish and understand the baseline, it is hard for policy makers and building stakeholders to initiate the work to promote energy efficiency and to include buildings in a climate mitigation strategy.

Disjointed governance structure

Building energy codes are usually designed and developed by a national or federal organisation that reports either to the ministry of construction, the ministry of local governments or the ministry of energy. Implementation and compliance-checking are typically the responsibility of local authorities; enforcement is typically the responsibility of national or regional authorities. Few countries have a co-ordination body to ensure that national priorities are well understood by local authorities and, conversely, that local issues are recognised by national authorities. Consequently, local constraints are typically not taken into account in the design of building energy codes, resulting in delayed implementation and non-compliance.

Misalignment of energy requirements in different energy policies

As described in the previous section, policy instruments that affect the energy consumption of buildings go beyond building energy codes and include land-use policies, energy performance labelling schemes, energy efficiency action plans, energy security policies and economic policies (Figure 11). While building energy codes are critical for achieving a low-energy buildings stock, these objectives can be undermined if energy reduction targets and requirements in other energy policies are not aligned with those in building energy codes. Lack of co-ordination and rigour has led, in some countries, to contradictory energy requirements for buildings.

Lack of technical expertise and knowledge of building science

Buildings are complex systems: designing building energy codes requires advanced knowledge of building science. Building stakeholders in both IEA member countries and non-IEA countries usually do not have access to appropriate training materials and educational programmes to help them better understand energy efficiency in light of the complexity of buildings.

Lack of financial resources

The design, implementation, enforcement and evaluation of building energy codes require financial resources. Agencies responsible for policy making, implementation and enforcement in both IEA member countries and non-IEA countries generally lack adequate financial resources. Resources generated from land-use and construction permit fees, and international funds such as the GEF in the case of developing countries are usually not sufficient to cover all aspects of building energy code development and implementation.

Lack of ambition when setting minimum energy requirements

From an economic perspective, minimum energy performance requirements should be set at the optimal level that generates the highest economic return for society, and requires a long pay-back period. However, many countries set minimum energy requirements at the financial cost-effective level of the investment, which has a short pay-back period. In doing so, these countries lower their ambition, thus locking in a portion of the savings potential over the lifetime of the building, missing opportunities to scale up the deployment of efficient technologies, and limiting reductions in their buildings stock's energy consumption.

Lack of monitoring and evaluation

Monitoring the implementation of building energy codes and evaluation of their impact are usually not included in the policy design of most countries. As a result, it is difficult to estimate accurately the effectiveness of building energy codes.

The pathway described in the following section should help energy codes developers and implementers to address the challenges described above when designing and implementing building energy codes.

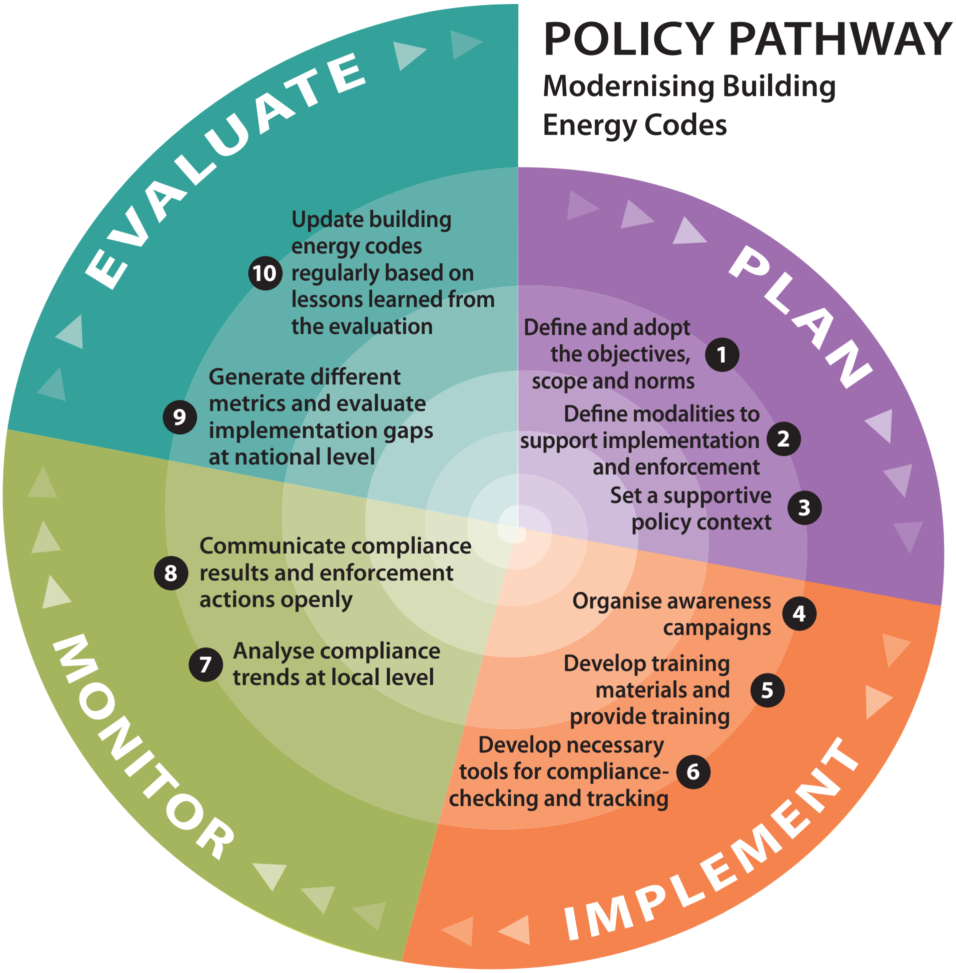
How to deliver an effective building energy code?

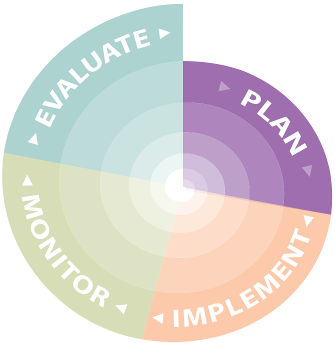
The pathway to improving energy efficiency within the buildings sector through the deployment of energy codes includes four phases – plan, implement, monitor and evaluate. This section provides actionable guidance to policy makers based on an extensive analysis of country experiences and the review of good and innovative practices. Steps and actions do not have to be implemented sequentially; countries can select those steps and/or actions missing in the design of their building energy code. Among other things, this flexibility allows building energy codes to be adapted to country-specific contexts.

- **Planning phase**: identifies the necessary steps and indicators to consider at the design stage of the building energy code.
- **Implementation phase**: highlights the different steps to ensure effective implementation of building energy codes.
- **Monitoring phase**: proposes methodologies using indicators defined at the planning phase for compliance-checking and tracking.
- **Evaluation phase**: suggests different evaluation approaches. The objective is to design an evaluation strategy to inform developers of building energy code of the necessary changes they should consider for the next update.

POLICY PATHWAY

Modernising Building Energy Codes





PLAN

Careful planning helps to ensure that building energy codes can be effectively implemented, monitored and enforced. The planning should be transparent and should involve the full array of buildings sector stakeholders to ensure that their diverse perspectives are taken into account, to improve the quality of policy design, and to prepare the ground for ultimate adoption and implementation (IEA, 2010b).

The planning phase includes (a) defining the objectives and coverage of the code based on the baseline assessment; and (b) designing the critical mechanisms to support effective implementation and compliance-checking. Moreover, a modern building energy code will look to ensure synergies with the complementary policies that make up an effective buildings energy policy package (as described in the preceding section). Policy makers need to define the scope (which building types and climate zones to target first); the process of introduction into the regulatory framework (*e.g.* laws, decrees); the methodology to set minimum energy performance requirements; the governance structure; the mechanisms to raise funding needed to implement the code (especially with respect to compliance-checking and enforcement); the indicators for monitoring; and the methodologies for evaluation.

❶ *Define and adopt the objectives, scope and norms*

Objectives are usually defined in the overarching policy framework, which sets principles and long-term goals based on country-specific priorities. These include energy security, economic, social and environmental objectives. The aim is to set the basis for making rules and guidelines to provide the overall direction for energy efficiency policies for buildings.

Define and adopt regulatory framework

Building energy codes should be implemented on a mandatory basis for all building types and have provisions that allow codes to be strengthened over time, in step with improved technical capacity and enforcement instruments. New constructions and those undergoing renovation should comply with minimum energy performance requirements as specified in the building energy code. The aim is for governments to achieve a low-energy buildings stock by a specified year and to establish baselines for further policy action.

Full implementation of the mandatory building energy code for all building types can be scaled up over time, depending on the technical capacity and technological development of the country. Planning the implementation in advance is, therefore, crucial as credibility will be easily lost, if the scheme lacks a secure foundation. Making building energy codes mandatory means that all stakeholders need to understand their responsibilities to ensure compliance.

Policy makers need to define the scope (which building types and climate zones to target first) and the process for introducing building energy codes into the regulatory framework (laws, decrees, etc.). A detailed action plan is required for full implementation of building energy codes, with a clear implementation strategy and phases for each building type. The implementation action plan should be widely shared with stakeholders for feedback prior to its adoption.

Countries that are developing and implementing a building energy code for the first time could, for example, decide to prioritise particular building types. Prioritising how the building energy code is implemented should be based on a long-term forecast of the energy demand of each building type, national technical capacities of the country and socio-economic considerations. For example, countries facing energy precariousness could initially target their codes towards the construction and renovation of social housing. Not only would this reduce energy demand overall, but it would reduce energy costs for low-income families and reduce public expenditures on social programmes such as fuel supplements.

The scope and the implementation steps are usually included in the legal framework.

Define and adopt the necessary norms

Define methodology to set minimum energy performance requirements

Minimum energy performance requirements should be set to achieve their macroeconomic cost-optimal level, precisely at levels where improvement is technically feasible and economically justified. The EU cost-optimum methodology (Box 5) illustrates how to set minimum energy requirements at the macroeconomic cost-optimum level. A holistic approach, based on an integrated design that considers the energy performance of the entire building, is required to maximise the savings potential and avoid the lock-in-effect as buildings last a long time. NPV calculations should consider the lifetime of the building (30 years for residential and 20 years for public and non-residential buildings) and low-discount rate.

Establish baselines and reference buildings

Before designing building energy codes, governments need to collect data on their buildings stock. An inventory of the existing buildings stock – including construction methods, construction materials, buildings equipment technologies, and energy consumption per end-use – is a pre-requisite to establishing the baseline in current building practices, energy consumption and technologies. Countries usually identify representative buildings (called "reference buildings") and extrapolate energy performance and demand for the overall buildings stock.

Baselines are needed to set realistic, minimum energy performance requirements. The ideal is for countries to build a national database of their buildings stock over time, using information provided by building energy label and metering campaigns. National databases should be made available to all market-actors.

Determine climate zones for the country

Building energy codes need to be adapted to local climatic conditions, as these conditions have a significant effect on building energy demand. Cooling and heating needs directly correlate with differences in temperature and humidity between indoor and outdoor areas. In cold climates, solar heat gains will usually be beneficial, if the building is properly designed. In hot climates, solar gains adversely affect comfort levels and typically increase cooling needs.

Defining heating and cooling needs (*i.e.* hourly heating degree-days and cooling degree-days for each climate zone of the country) is a critical step in designing building energy codes. Climatic and geographical zones also affect levels of daylight entering the building and the energy needed for artificial lighting. Thus, daylight levels also need to be assessed.

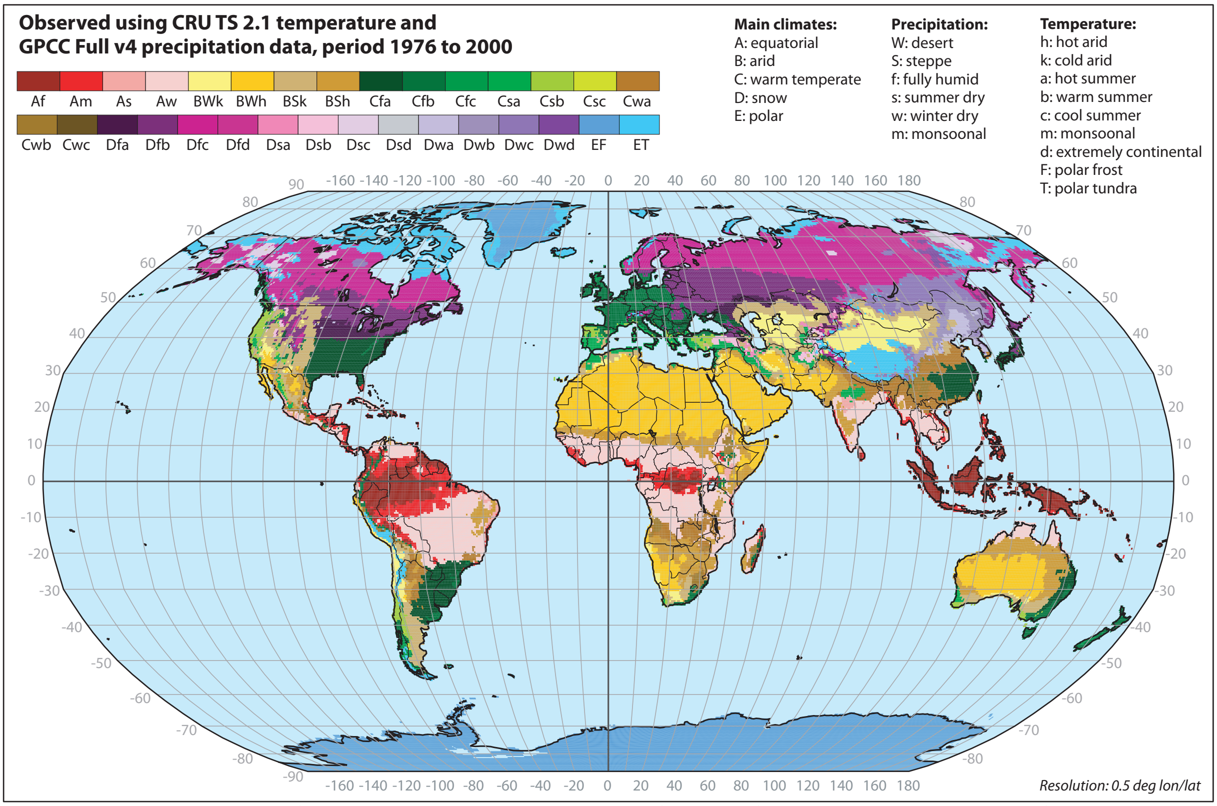
Climate scientists have established overall planetary climate classification systems; the most widely used being the Köppen-Geiger climate classification (Box 6) which provides an overview of global climate zones.

Box 6

Köppen-Geiger climate classification system

- *The Köppen-Geiger climate classification system provides a broad picture of climate zones on the planet with five main sub-divisions (Figure 19).*
- ***Tropical and equatorial climates** are characterised by constant high temperature (at sea level and low elevations) 12 months of the year with average temperatures of 18°C or higher.*
- ***Dry and arid climates** are characterised by the fact that precipitation is less than potential evapo-transpiration and temperature range between 21°C and 28°C.*
- ***Temperate and warm climates** have an average temperature above 10°C in their warmest months (April to September in the Northern Hemisphere), and an average temperature between -3°C and 18 °C in their coldest months.*
- ***Continental and snow climates** have an average temperature above 10°C in their warmest months and an average temperature below -3°C in their coldest months.*
- ***Polar climates** are characterised by average temperatures below 10°C all year.*

Figure 19 World map of Köppen-Geiger climate classification based on observed data from 1976 to 2000



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: Köppen-climate classification 2013.

While the global climate map provides an initial basis for climate zoning, a deeper understanding of local climate zoning is needed when designing building energy codes to better incorporate local (sub-national) climate variations.

The Californian building climate zone map (Figure 20) is a good illustration of the detailed climate zoning required for an effective design of building energy codes. Moreover, zoning can also consider climate change forecasts – *i.e.* how heating, cooling and lighting energy needs might evolve in the future.

Figure 20 Californian building climate zones map

Building climate zone description

"Building Climates Zones" or *California Climate Zone Descriptions* for *New Buildings California* is divided into 16 climatic boundaries or climate zones, which is incorporated into the energy efficiency standards (energy code). Each climate zone has a unique climatic condition that dictates which minimum efficiency requirements are needed for that specific climate zone. For an example; Climate zone 12 is bounded by other surrounding climate zones such as 11, 16, 13, 4, 3, and 2 and each with its unique weather characteristics. In climate zone 12 it is required for construction to install an R-38 in the ceilings, R-19 in the walls and high efficiency glass. Other climate zones may use less and have other efficiency requirements.

The *Climate Zone Description Manual* was developed from weather tapes information, which are modeled in approved simulation program to include modeling of new commercial and residential buildings. Such simulations established a base line to be cost effective with energy code. Therefore The *Climate Zone Description Manual* describes each climate zone boundaries and list most California cities with its associated climate zone number. For Example; Sacramento is climate zone 12, San Francisco is climate zone 3 and Lake Tahoe is climate zone 16. The climate zone must be first determined before any new or renovation construction is began in order to ensure the proper efficiency energy features are used for that specific Climate Zone.

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: California Energy Commission 2013.

❷ *Define modalities to support implementation and enforcement*

The effectiveness of building energy codes depends, to a large extent, on their proper implementation and enforcement. Accordingly, at the planning stage, it is important to define mechanisms that will support these objectives.

Define a clear governance structure and institutional arrangement

A clear, well-defined governance structure should be decided at the early stages of the planning phase to ensure that building energy codes are implemented effectively. It is critical to assign programme responsibility within the public sector and to allocate the financial and human resources needed for implementation (IEA, 2010b). Moreover, it is important to ensure that each organisation involved in the governance process has a clear mandate and well-defined responsibilities, with no conflicts of interest. A co-ordination body, such as a national building bureau or other government authority, should act as the focal point for developing, implementing, compliance-tracking, monitoring and evaluating the regular updates of the building energy code. The exact legal structure must be adapted to a country's political and legal context and the existing governance structure for other building codes such as those related to safety and earthquake to ensure proper co-ordination of building policies.

Define funding mechanisms to secure financial resources

Funding mechanisms to secure financial resources have to be defined to run the robust and comprehensive administrative system needed to develop and implement building energy codes. Funding has to be found to cover indirect costs related to data management, awareness campaigns, RD&D and training. In countries where building energy codes are already established, building permit fees are frequently used to cover the cost of running and administering these codes. In some countries, they are supplemented with additional national funding (Box 7).

In both IEA member countries and non-IEA countries, governments have to define a sustainable funding mechanism to maintain a high compliance rate and regular updates of building energy codes, and to run the overall scheme. In developing countries, international funds such as the GEF can be mobilised to co-finance the development of building energy codes.

Regional collaborations among neighbouring countries with similar climate zones, similar construction techniques, practices and building materials can help cut the cost of developing training materials and compliance software, thereby fostering knowledge exchange. The EU concerted action initiative (Box 4) is a good example of such regional collaboration.

Decide on compliance and evaluation methodologies and indicators

Compliance-checking is critical to ensure effective implementation of building energy codes. Indicators and methodologies to be used for compliance-checking need to be defined at the early planning phase to ensure that all stakeholders have a good understanding of their responsibilities.

Various compliance and evaluation approaches can be implemented. Most advanced compliance-checking methodologies include reviews of plans and calculations to determine whether the building plans submitted for a construction permit comply with the requirements set out in building energy codes. This should be followed by on-site field inspections (using a compliance checklist) of a statistically representative number of buildings. The aim is to check whether buildings have been built according to the plans submitted and the code. As part of the on-site inspections envelope air leakage can be assessed by means of a blower-door test (Box 10). The last stage of compliance-checking takes place once the building has been occupied through the metering of energy consumption; usually two years after first occupancy of the building.

Prior to the national or regional evaluation of code implementation, local authorities should conduct their own evaluations to better understand local needs and challenges. Local authorities can either do so themselves or hire an accredited third party to evaluate compliance rates. Self-assessment has the advantage of building capacity within the local authority (US-DoE, 2010). Evaluation by a third party presents a high risk of conflict of interest as engineering firms are usually also sub-contracted by developers and builders for their own evaluation.

In any case, building departments should report all code infractions, including those addressed by contractors (US-DoE, 2010). This helps governments better understand the challenges of implementing building energy codes. It also provides local authorities with tailored training tools to improve compliance rates.

Compliance and evaluation indicators should be quantitative to avoid subjective decision-making by the inspector or the evaluator. Indicators could include the percentage of each building type that complies with the overall energy performance requirements and the percentage of each building type that complies with blower-door test requirements. The evaluation could include analyses of the differences between building type compliance rates.

Involve stakeholders and market-actors

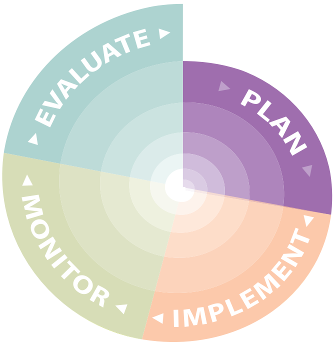
In the early stages of the planning phase, governments should involve all stakeholders, including consumer organisations, and clearly communicate their aims and how these fit into national or supranational long-term energy strategies. In most IEA member countries, the regulatory body organises a public hearing process prior to the adoption of the new building energy code. The public hearing process begins in the early planning phase and provides a forum for discussing project needs, major implementation issues and potential socio-economic and environmental effects. IEA analysis of the public hearing process in its member countries shows that effective and continuous co-ordination between government bodies and market-players helps to address the fragmentation challenge of the building sector (Figure 18), raises awareness of energy issues among stakeholders, and prevents delays in implementation.

❸ *Set a supportive policy context*

As described in the preceding section, the effectiveness of building energy codes will be determined by a variety of complementary policies.

Consider complementary policies

The complementary policies to consider include land-use policies, building renovation policies, standards and labelling (S&L) policies for buildings, building components, appliances and equipment, renewable energy policies and sustainable technology policies. Energy requirements in complementary policies should be aligned with those requirements included in building energy codes to create synergies and avoid confusion in the market.



IMPLEMENT

It is essential to raise awareness, inform and educate all stakeholders about the benefits of building energy codes and the importance of their effective implementation. Widespread understanding of the purpose of building energy codes and their benefits is known to increase public acceptance (IEA, 2010b).

❹ *Organise awareness campaigns*

Awareness campaigns are a critical aspect for supporting the implementation of building energy codes. Local and/or regional energy agencies should be tasked with raising awareness about energy issues and building energy codes. This will increase confidence in the information provided and reduce the risk of conflict of interests that industry representatives may face. Accurate and pertinent information about building energy codes and energy consumption should be disseminated through easily accessible databases that should be kept updated.

Two types of campaigns should be planned and conducted: the first should target industry, including architects, designers, engineers, developers, construction industry and finance experts and the second should target buildings' occupiers.

Organise awareness campaign directed at industry

Awareness campaigns directed at industry must ensure that all market-actors clearly understand what building energy codes mean for their professions, the steps they need to take to ensure that codes are effectively implemented, and the enforcement actions governments could take in the case of non-compliance.

Organise awareness campaigns directed at buildings' occupiers

Awareness campaigns directed at buildings' occupiers usually aim to better inform them about the impact of usage patterns on buildings' energy consumption and on the use of a building's energy performance as a rental or purchase indicator. Public information campaigns to highlight the benefits of building energy codes should be based on the information contained in building energy labels.

❺ *Develop training materials and provide training*

Building energy codes are often not easily understood by stakeholders. Training materials and compliance software should be developed by governments and made available free of charge to all practitioners to ensure broad usage (Box 7).

Training materials and compliance software need to be developed in parallel with the legal framework to ensure their availability once the legal framework has been adopted, thereby avoiding delays in implementation. Training could be provided by government agencies, universities and community colleges.

Develop long-term training strategy

Governments need to establish a long-term training strategy to ensure that practitioners understand how building energy codes should be implemented and how compliance-checking should be performed. Training has to be given to architects, engineers, urban planners, builders, developers, installers, financial advisers and inspectors, and to all other parties involved in the design, construction, renovation and maintenance of buildings. Education courses for professionals should also include courses on energy issues.

Training should not only cover technical knowledge, but also provide an understanding of the holistic approach and the integrated design to ensure that these principles become an intrinsic part of the design and operation of both new buildings and existing buildings that are being renovated. In countries where building energy codes are being implemented for the first time, it is often worth including demonstration buildings as part of the training strategy (Box 8).

Box 7

US-DoE support to the implementation of building energy codes

The US-DoE, through its Building Energy Codes Programme (BECP) resource centre, provides technical assistance and a comprehensive collection of information and resources.

The resource centre includes frequently asked questions, publications, model adoption policies, compliance software and tools, and training/e-learning modules based on best practices.

Practitioners can also submit their questions to the BECP team through a web-based help desk. The centre answers questions raised by state building officers and builders, thereby addressing issues related to building energy codes.

The US-DoE provides two types of compliance software: one for residential buildings and another for non-residential buildings. Both software applications are available online to all practitioners, free of charge.

The US-DoE developed procedures and tools to help states and jurisdictions measure and report compliance with their building energy codes. The online application ("Score + Store") can be used to track the implementation status of building energy code in each state.

States also use the "Score + Store" application to collect, store and evaluate their compliance information and calculate their overall compliance rate. Information captured in the tool is accessible only to the relevant state and its contractors.

Resource centre: www.energycodes.gov/resource-center.

Score + Store database: https://energycode.pnl.gov/ScoreStore/login.

Box 8

Demonstration projects to build capacity in non-IEA countries

The design and the implementation of building energy codes in non-IEA countries face the challenges of lack of technical capacity and data on buildings 'energy consumption. To overcome these obstacles, international donor agencies such as GEF provide funding for technical assistance through demonstration projects.

Demonstration projects consist of the design of pilot buildings that include the energy efficiency measures considered in the building energy code. They represent a unique opportunity to develop baseline information (energy consumption, cost of energy efficiency measures, performance characteristics of local construction materials) and training materials for market-actors involved in the buildings sector. Demonstration projects help raising awareness about the importance of building energy code to reduce buildings' energy consumption.

With GEF funding, UNDP has implemented several demonstration projects in non-IEA countries. The most successful ones include:

- *New energy efficient public building in Kyrgyzstan: UNDP-GEF teamed up with the Government of Turkey to design and construct a new school building based on an integrated building design approach. The project shows that an integrated building design and overall performance approach can yield results that significantly exceed code requirements with only 5% increase in the construction costs.*

The building has an average annual energy consumption of 50 kWh/m^2/year while mandatory energy performance requirement under the new building energy code is 100 kWh/m^2/year.

Demonstration projects to build capacity in non-IEA countries (continued)

- *New residential energy efficient building in Armenia: UNDP-GEF and the Swiss Development and Cooperation Agency provided technical support to the Government of Armenia for the construction of an efficient pilot building. Energy consumption of the pilot building is three times less than the one of the reference building. The implementation of energy efficiency measures increased the construction cost by 7% while reducing occupiers 'energy bills by 60%. This aspect is particularly important because the building was constructed for low-income families.*
- *Retrofit of public buildings in Uzbekistan: UNDP-GEF teamed up with the State Committee for Architecture and Construction for the implementation of the revised building energy code for existing buildings when they undergo renovation. Six public buildings including schools and hospitals have been considered under this project. The implementation of energy efficiency measures required by the new building energy code allowed for 65% savings compared to the baseline.*

Source: compiled by UNDP experts from UNDP-GEF evaluation reports.

Review existing construction profession capacities

The first step to consider in a long-term training strategy is to review the technical capacity in the existing construction professions, the undergraduate educational programmes and continuing professional development programmes. The aim is to understand what types of training are necessary and provide the market with well-skilled building energy code developers and implementers (IEA, 2010b).

Develop training material and compliance software

The second step of the long-term training strategy is to develop training materials, including compliance software. In most countries, compliance software is usually accredited by the government's building or energy department. Compliance software should be based on the calculation methodology agreed in the planning phase and made available free of charge to all practitioners (Box 7).

Deliver training on compliance software

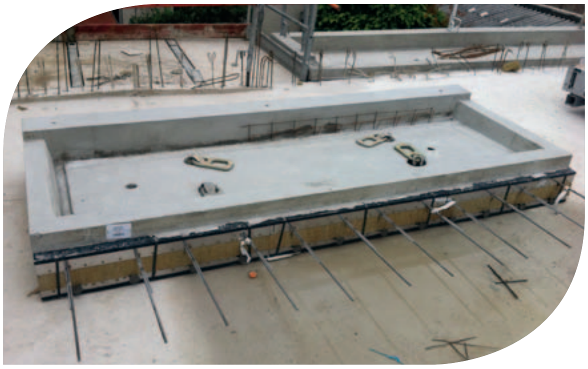
The third step of the long-term training strategy is to deliver the training. Training on compliance software should be provided to all public and private sector actors involved in the design and/or implementation of building energy codes.

❻ *Develop necessary tools for compliance-checking and tracking*

Governments need to check compliance and enforce their building energy codes to ensure that the policy instrument does not lose its credibility. Taking action in the case of non-compliance is a healthy sign and does not imply that the government failed to implement its building energy code.

Compliance and enforcement procedures have to be well documented to ensure that all stakeholders are fully aware of requirements and sanctions. These sanctions have to be stringent enough to discourage non-compliance (IEA, 2010 b &c). Compliance software and enforcement procedures should be made available to all stakeholders free of charge (Box 7).

The costs of compliance-checking are usually covered by permit revenues. However, since compliance-checking requires significant manpower, national governments may need to supply additional resources to support local authorities and improve compliance-checking (Box 7). Alternatively, local authorities can use their



tax revenues. In developing countries, international funds, including funding for Nationally Appropriate Mitigation Actions (NAMAs) (Box 9), could be used for building energy efficiency activities and provide the needed financing to support local authorities with the compliance-checking process.

Compliance should be assessed regularly during the design, construction stages, prior to the occupancy of the building and when the building is occupied for both new buildings and existing buildings being renovated or extended (Figure 21), by using the indicators and methodology defined at the planning phase. Local authorities are usually in charge of compliance-checking and on-site inspection as they tend to be in direct contact with the local design and construction community and closer to the construction site.

Box 9

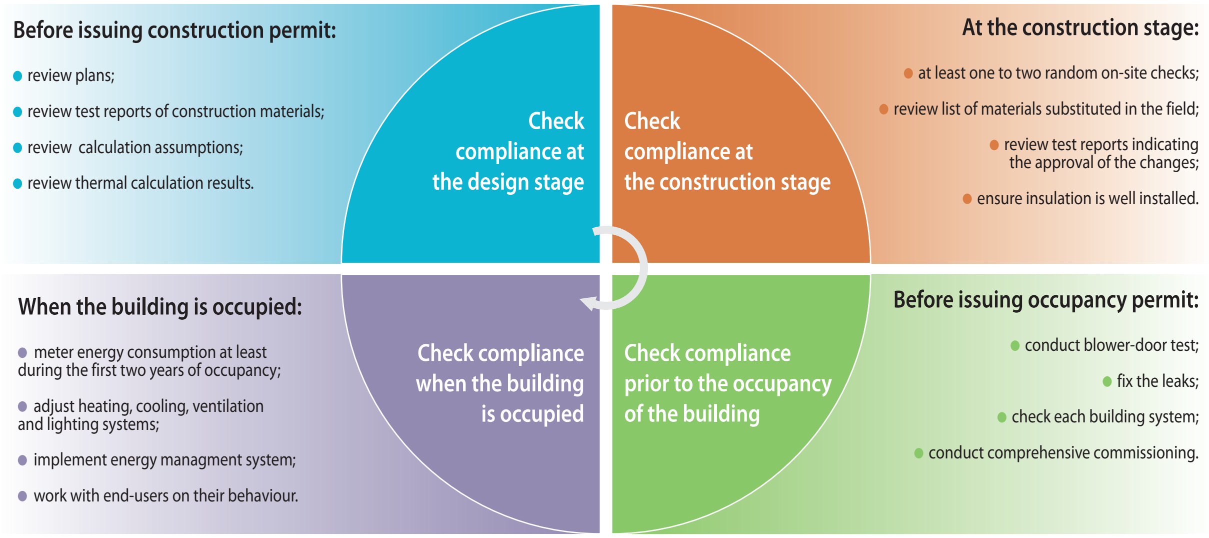
International initiatives to support scaling up low-energy buildings in non-IEA countries

Non-IEA countries could apply for international funding for NAMAs aiming to reduce GHG emissions. Improving energy efficiency of the built environment is likely to appear as a NAMA in every economy and building energy codes are to become the heart of NAMAs. Mexico is the first country to submit a comprehensive NAMA aiming to improve the efficiency of the buildings sector by implementing a building energy code.

The United Nations Sustainable Energy for all (UN-SE4ALL) initiative which seeks to achieve by 2030 universal access to electricity and safe household fuels, also includes the buildings sector as one of the sectors to target for the efficiency improvement.

Source: compiled by UNDP experts from various UN reports.

Figure 21 Compliance-cycle to ensure effective implementation of building energy code



Check compliance at the design stage

At the design stage, developers should self-assess, either using their own staff or an accredited third party, to see if their project complies with building energy code requirements. Calculation results and criteria used to calculate minimum energy performance have to be submitted to local authorities for compliance-checking before construction permits can be issued. Local authorities review the plans, calculation results (including the assumptions considered), and test reports related to construction materials. The objective is to check if the building plans and materials submitted for construction permits comply with the requirements of the building energy code.

Check compliance at the construction stage

At the construction stage, compliance-checking requires random on-site checks of buildings and their systems. Inspectors assess if a building has been built according to the plans and the code. In small buildings, there should be at least two inspections: one during construction and one upon completion. In large buildings, numerous inspections are needed as construction takes place in various phases.

On-site inspectors should also review the list of materials substituted in the field and the test reports indicating the approval of the changes.

Check compliance prior to the occupancy of the building

Prior to the occupancy of the building, inspectors should conduct a blower-door test before issuing occupancy permits. The aim is to locate air leakage sites in the building envelope and help the builder to fix leaks and thus reduce energy losses (Box 10). Comprehensive commissioning of the building is also required to test and check each building system.

Check compliance after the building is occupied

When the building is occupied, compliance with building energy codes should be checked by metering the energy consumption for at least the first two years of occupancy to better understand usage patterns and to allow for adjustment of heating, cooling, ventilation and lighting systems. The Swedish compliance-checking procedure illustrates how to implement compliance-checking after the building is occupied.

Case study 4

Swedish compliance-checking procedure when the building is occupied

The Swedish compliance-checking procedures include checking compliance two years after the building is occupied.

For each new construction project, a meeting is held between the developer and the building board of the municipality to decide the compliance-checking procedure to consider.

Three options are possible. The first option consists of compliance-checking based on an estimate of the energy performance of building. The second option consists of compliance-checking of the measured energy consumption of the building two years after it is occupied. The third option is a combination of options one and two.

For the first two years, the building board of the municipality gives the developer an interim permit of use. In case of non-compliance, the developer must stop using the building until corrections have been made. Developers usually pay a fine in the event of non-compliance.

In addition to compliance-checking after the building is occupied, an energy label (EPC) based on measured energy consumption is required two years after the occupancy of new buildings.

Source: Swedish National Board of Housing, Building and Planning, 2013

Box 10

Blower-door test to measure compliance of a building's air tightness

A "blower-door test" is used to measure the compliance of building air tightness. This test physically locates air leakage sites in the building envelope so that they can be fixed, thereby reducing energy losses.

A blower-door fan is a powerful variable-speed fan that mounts into the frame of an exterior door. The fan pulls air out of the building, lowering the air pressure inside. The higher outside air pressure then flows in through all unsealed cracks and openings. Conversely, the blower-door fan can increase the pressure inside by blowing air into the building.

To prepare for a blower-door test, all exterior doors and windows are closed and all interior ones are opened. All heating, cooling and ventilation systems, including mechanical exhaust devices, have to be turned off, and fireplaces and any other operable dampers closed. Ventilation systems have to be sealed to ensure that the system only measures air-flows through leakages in the building shell.

A blower-door fan is temporarily sealed into an exterior doorway using the door-panel system; the exterior pressure sensor is then positioned in a location shielded from wind and direct sunlight.

The test starts by sealing the face of the fan. Indoor air is blown out of the building to produce a pressure difference of 50 pascals (Pa) between inside and outside, when a single-point test is carried out. Alternatively, a multi-point test can also be performed, where the blower-door fan speed is adjusted to maintain a series of indoor-outdoor pressure differentials.

A variety of blower-door air tightness metrics can be produced using a combination of pressure differentials and fan airflow measurements. One common metric is the building air change per hour at a specified pressure, typically at 50 Pa. This value is calculated by dividing the heated air leakage by the heated indoor air volume. Air change rates vary depending on the ventilation type. In the case of a naturally ventilated building, the limit for air change per hour is 3.0 volumes per hour. In the case of a mechanically ventilated building, the limit is 1.6 volumes per hour.

When the measured value exceeds the air change limit, one has to look for leaks using a smoke pencil and establish positive pressure. It is then possible to identify and see from the outside of the building where the smoke is escaping through the building envelope. The speed of the incoming air is then measured with a thermal anemometer and leaks could be fixed. Alternatively, an infra-red camera could be used to identify air leaks.

Usually air leaks come from the junctions between building components (walls, roofs, windows) or between buildings' components and equipment (heating, cooling, ventilation and electrical).

Source: interviews conducted by the author with the construction industry.

Enforce building energy codes

An enforcement body should be established to control and oversee the inspectors' work (US-DoE, 2010). To avoid conflicts of interest, an accredited independent third party should be appointed. Inspectors employed for plan reviews, on-site inspections and blower-door tests should be accredited by the enforcement body to ensure good quality compliance-checking and to limit corruption.

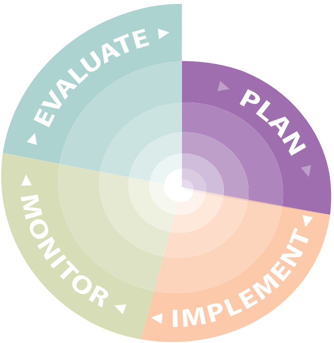
Penalties in the case of non-compliance with building energy codes typically include fines, demolition, and refusal of building occupancy permits or imprisonment in some countries (IEA, 2012b).

Track compliance at local level

Tracking progress of how effectively a building energy code is being implemented is important for governments. This tracking will be used later for evaluating and updating the building energy code. Inspectors should report all code infractions, including those addressed by contractors, to avoid over-estimation of compliance rates (US-DoE, 2010).

Local authorities need to develop databases that include all the indicators pre-defined at the planning phase for compliance-tracking. It is highly recommended to build on existing data collection systems as this will enhance the overall data collection system, avoid duplication and reduce compliance costs. Advanced data collection systems should be established to collect, store and evaluate compliance information and trends. It is recommended to have only one single focal point for compliance-tracking at the local level, although there may be numerous inspectors in the field. The US "Store + Score" online application developed by US-DoE could serve as a good practice example for central data collection systems to evaluate compliance trends (Box 7).

Data collected are later used by the national co-ordination body at the evaluation phase to ensure that results are prepared objectively and consistently, allowing for a better understanding of training needs and progress made.



MONITOR

During the monitoring phase, compliance rates could be assessed and gaps in implementing building energy codes identified. Municipalities should establish a process to report, aggregate and analyse compliance rates at each stage (design, construction, prior to occupation and when the building is occupied) for each building type.

7 Analyse compliance trends

Analyse compliance trends at local level

Municipalities should assess building energy code compliance for each building type at each stage (design, construction, prior to occupancy and when the building is occupied). A statistically representative sample of constructed buildings for each building type should be monitored. Compliance rates could be based on the percentage of buildings that pass the assessment and/or the average number of requirements met by each individual building.

8 Communicate compliance results and enforcement actions openly

Communicate compliance trends openly

Publishing compliance results and enforcement actions gives more credibility to governments and local authorities. It raises awareness about the importance for builders to comply with the regulations and also enables consumers to make informed choices when selecting building firms. Experience from countries such as Australia show that "naming and shaming" usually creates competition between different market-players and increases compliance rates. The Chinese governmental monitoring of local municipalities 'compliance-checking, presented as case study 5, is a good illustration of a coordinated multi-level governmental effort (government, local authorities) to improve compliance rate.

Errors in compliance assessment should be addressed immediately and communicated openly.

Encourage public debate on compliance trends

Governments and municipalities should encourage open debate about compliance trends. Disclosure of compliance assessments gives credibility to companies that comply with building energy code requirements and identifies those companies that do not. Communicating compliance and non-compliance rates and subsequent penalties usually improves compliance trends.

Case study 5

Chinese governmental monitoring of local municipalities' compliance-checking

In 2005, the Chinese government launched numerous national policies and projects to enforce the implementation of building energy codes. The first step was the "Code of Acceptance", adopted in 2007 to address compliance during the construction stage. The Code of Acceptance makes compliance with building energy efficiency requirements mandatory once the construction project is completed. It includes specific provisions to comply with building energy code requirements related to walls, curtain walls, doors, windows, roofing, flooring, and heating, ventilation and cooling systems.

Since the adoption of the Code of Acceptance, developers must demonstrate that their projects comply with building energy codes at the design and construction stages. To do so, they hire a certified drawing inspection company once the architectural plans have been drafted. The selected drawing inspection company analyses the drawings, using compliance software, and issues a compliance report which is then sent to the developer and the local quality supervision agency.

The construction permit is issued by the local construction administration department, based on the drawings and assessment of the compliance report carried out by the local quality supervision agency. During the construction stage, the developer hires an engineering supervision company, different from the drawing inspection company, to supervise the construction company, conduct on-site inspections in order to ensure that the construction complies with the building energy codes requirements. Inspections are scheduled and continue throughout the construction stage.

The local authority's quality supervision agency conducts both scheduled and random inspections during the construction stage. In the case of non-compliance with either the building energy code or the Code of Acceptance, the construction company is ordered to improve its work to meet compliance requirements. Once the construction project is completed, the local construction department issues an occupancy permit based on the report prepared by the local authority's quality supervision agency.

Compliance-checking is required for any new residential community of 50 000 m^2 or more. For non-residential buildings, compliance-checking is mandatory for projects with a total investment over USD 49 000 as well as for projects supported by foreign aid and loans.

In addition to compliance-checking by local authorities, the government has organised annual inspection campaigns to assess energy requirement compliance since 2005. For the purpose of such inspections, cities are selected on a random basis but the capital city of every province covered by the inspection campaign is automatically included. Small cities and rural areas are usually not included. The annual inspection campaigns are conducted by government officials and building energy code experts from research institutes as well as local code officials (who do not inspect their own provinces, cities or counties).

The inspection checks if building energy codes and other buildings energy efficiency policies have been implemented properly. The annual government monitoring checks the submitted drawings and software calculations; in some cases on-site visits are also conducted. If a project fails the random on-site inspection, non-compliance documents are issued. It gives recommendations on how to improve compliance. The construction company has 30 days to correct the failure and report back to the Ministry of Housing. If, after 30 days, the building still fails, the construction company is fined.

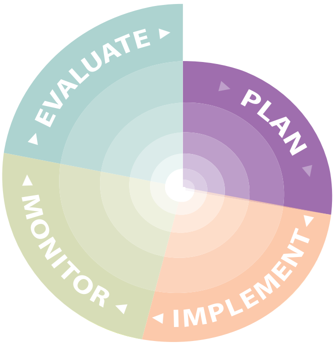
Penalties for non-compliance are specified in the Energy Conservation in Civil Building Law issued in 2006.

Chinese governmental monitoring of local municipalities' compliance-checking (cont.)

- *Developers are fined between USD 33 000 and USD 81 000 if there is evidence that they directly or indirectly encouraged the building architecture firm and/or construction company to violate any mandatory requirement in building energy codes. Architecture firms are fined between USD 16 000 and USD 49 000 if drawings do not meet the energy requirements specified in building energy codes. If the architecture firm fails to correct flaws three times over two years, it is suspended and its qualification downgraded or revoked.*
- *Construction companies are responsible for rectifying any flawed construction activity detected by the inspection company. In the case of serious violations, the construction company must pay 2% to 4% of the construction contract costs as a penalty. The certification of the violating company may also be downgraded or suspended.*

Compliance results and enforcement actions are made available online on a government website. Since the Code of Acceptance has been adopted, China has experienced improved compliance rates in urban areas. The need for compliance-checking and building energy code enforcement was reaffirmed in the 12th Five-Year Plan.

Source: Shui Bin (2012).



EVALUATE

Evaluation determines whether building energy codes meet national objectives by identifying gaps and failures in the design and implementation of building energy codes. Evaluation can then be used to improve compliance rates and code revisions. Countries that allocate sufficient human and financial resources and regularly evaluate their building energy codes have a better understanding of the impacts of their policies. Governments should ensure that evaluations are conducted on a similar basis across all local authorities, so that implementation can be compared and experiences shared.

❾ *Generate different metrics and evaluate implementation gaps at national level*

Calculate evaluation metrics for each building type

Metrics to evaluate gaps in building energy code design and implementation should be determined in the planning phase. Evaluation should target each building type individually, but should also be aligned with the monitoring taking place at the local level. National evaluation metrics could include the percentage of buildings checked which comply and/or, for each individual building checked, the average percentage of requirements that comply. This, in turn, creates compliance rates at the national level which can be used to estimate the energy-saving achieved.

Evaluation can also include questionnaires and interviews with the implementers of building energy codes, inspectors and practitioners, which can shed some light on the challenges in the field. This information can help to develop better training materials. However, it is highly recommended that qualitative criteria are limited to avoid interviewer bias.

The use of consistent methodologies across municipalities and centralised databases, such as the US "Score+ Store" online application (Box 7), helps to ensure that data are consistent.

❿ *Update building energy codes regularly based on lessons learned*

Use evaluation results for the next code's revision

Building energy codes have to be updated on a regular basis (usually every three to five years) to ensure that they are aligned with international best practices and technological developments. This will enable countries to capture more energy savings. Updates need to balance the practicality of responding to policy changes, the technological context, the time it takes to reflect on the exact nature of the changes, and the need to provide a stable regulatory environment for architects, builders, consumers and implementers (IEA, 2010a).

Updating building energy codes provides an opportunity for governments to fill the gaps identified through evaluation and to address their new national priorities.

A clear upstream signal is sent to industry and other stakeholders when building energy codes are updated with new, long-term energy demand reduction targets and ambitious minimum energy performance requirements as demonstrated by the Danish case study. This also allows sufficient time for preparation and adjustment, and enhances RD&D development of efficient solutions.

Conclusions and future considerations

Building energy codes have proven their effectiveness in reducing energy demand in the buildings sector when they are: (a) properly implemented; (b) strictly enforced; and (c) well aligned with other policies that impact buildings' energy consumption. The most advanced building energy codes focus on overall energy performance and regard the building as one single system. Such codes reduce lock-in effects, accelerate deployment of efficient technologies, provide more freedom to architects and developers, and facilitate compliance-checking.

The path to a low-energy and low-carbon buildings stock should include requirements on energy sufficiency measures, energy efficiency measures and the use of renewable energy sources. This path should be based on an analysis of the economic returns of the national, long-term energy demand reduction targets and will, in turn, provide for increasing stringency of building energy codes as technologies improve.

Due to the complexity of the energy consumption of buildings, unskilled stakeholders find it difficult to understand building energy codes. Steps and actions described in this Policy Pathway may not be simple or straightforward for everyone at every step of the way. For this reason, it is important to ensure that all actors involved in the planning, construction and managment of buildings understand building energy codes and their practical application. Capacity building, training and support are needed for all stakeholders at every stage of the process, in IEA member countries and non-IEA countries.

Governments have to secure sufficient financial and human resources to ensure that building energy codes are effectively implemented. In some countries, there might be a need to establish new government organisations to ensure well-co-ordinated actions and steps, and to streamline the development and implementation of building energy codes. Streamlining leads to more efficient administrative procedures, improves customer services and provides financial savings for local and national authorities while avoiding overlaps and duplication. Streamlining should be based on in-depth analyses of the strengths and weaknesses of the entire building energy code process. Inefficiencies in the regulatory framework and administrative areas should also be considered in the streamlining process.

Governments need to check compliance and enforce their building energy codes to maintain the policy instrument's credibility. Taking action on non-compliance is a healthy sign and not evidence of any failure of the government to implement the building energy code. The results from monitoring compliance and actions to address non-compliance should be communicated openly to all stakeholders. One aim is to better understand implementation difficulties, which can be useful when revising the building energy code.

The ultimate objective of building energy codes should be to move buildings from net energy consumers to net energy producers. By increasing the stringency of energy requirements each time building energy codes are updated, it is possible to move towards nearly zero-energy consumption for the overall building, including all its appliances and equipment. Using renewable energy sources from the building itself and other neighbouring buildings can help with this transformation, and is key to achieving net energy production from buildings.

In addition, as buildings become more energy efficient, greater attention should be given to the operation of the building and the maintenance of its systems and equipment. Other aspects of buildings' energy consumption to consider in the future are embodied energy (*i.e.* the energy required to produce building materials and to construct buildings) and usage patterns (how buildings are used by their occupants). In fact, life-cycle analysis of energy consumption of existing low-energy buildings shows that the share of embodied energy from the overall energy consumption of a low-energy building over its lifetime is much higher than that of an inefficient building. Similarly, usage patterns also become increasingly important as buildings become efficient, as the manner in which buildings are used also becomes a relatively larger driver of overall energy consumption. Consequently, as we move to designing more energy efficient buildings through energy sufficiency, energy efficiency and other measures, policy makers should look to these aspects of buildings 'energy management, embodied energy and usage patterns to extract further energy savings.

Although progress has been made in the development and implementation of building energy codes in most emerging economies and some developing countries, international sharing of best practices is still needed, among all countries, to better inform policy makers and other stakeholders of new approaches and to help reduce costs and time needed to design and implement these policies.

Buildings in all countries will remain an important part of our future; addressing their energy consumption and exploiting their potential to produce energy is a key to moving towards a sustainable energy future.

Table ② Summary of building energy code policy pathway critical steps and actions

Four phases	*10 critical steps*	*24 actions*
PLAN	❶ Define and adopt the objectives, scope and norms	● *Define and adopt regulatory framework* ● *Define and adopt the necessary norms*
	❷ Define modalities to support implementation and enforcement	● *Define clear governance structure and institutional arrangements* ● *Define funding mechanisms to secure financial resources* ● *Decide on compliance and evaluation methodologies and indicators* ● *Involve stakeholders and market-actors*
	❸ Set a supportive policy context	● *Consider complementary policies*
IMPLEMENT	❹ Organise awareness campaigns	● *Organise awareness campaigns directed at industry* ● *Organise awareness campaigns directed at buildings' occupiers*
	❺ Develop training materials and provide training	● *Develop long-term training strategy* ● *Review existing construction profession capacities* ● *Develop training material and compliance software* ● *Deliver training on compliance software*
	❻ Develop necessary tools for compliance- checking and tracking	● *Check compliance at the design stage* ● *Check compliance at the construction stage* ● *Check compliance prior to occupancy of the building* ● *Check compliance when the building is occupied* ● *Enforce building energy code* ● *Track compliance at local level*
MONITOR	❼ Analyse compliance trends at local level	● *Analyse compliance trends at local level*
	❽ Communicate compliance results and enforcement actions openly	● *Communicate compliance trends openly* ● *Encourage public debate on compliance trends*
EVALUATE	❾ Generate different metrics and evaluate implementation gaps at national level	● *Calculate evaluation metrics for each building type*
	❿ Update building energy codes regularly based on lessons learned from the evaluation	● *Use evaluation results for next code's revision*

Annex: references related to the case studies

For policy makers seeking more information on the case studies included in this publication, the following list of references, without being exhaustive, could serve as a useful tool.

Case study 1: the French building energy code (page 27)

- Règlementation thermique 2012 : Un saut énergétique pour les bâtiments neufs (French Ministry for Sustainable Development).
- Arrêté du 26 octobre 2010 relatif aux caractéristiques thermiques et aux exigences de performance énergétique des bâtiments nouveaux et des parties nouvelles de bâtiments (Journal officiel de la république Française).
- Les chiffres clés du bâtiment (ADEME, 2012).
- Plan bâtiment durable (French Ministry for Sustainable Development).

Case study 2: the Tunisian building energy code (page 31)

- Evaluation finale du programme de règlementation thermique en Tunisie (PNUD)).
- L'efficacité énergétique dans le bâtiment en Méditerranée (Plan bleu, 2011).
- Promoting energy efficiency in buildings (GEF-UNDP).
- Arrêté du 1er Juin 2009 fixant les spécifications techniques minimales visant l'économie dans la consommation d'énergie des projets de construction et d'extension des bâtiments à usage résidentiel (Journal officiel de la république Tunisienne).

Case study 3: the Danish building energy code (Page 37)

- Energy efficiency requirements in building codes (IEA,2008).
- Building regulations (Danish Ministry of Economic and Business Affairs).

Case study 4: the Swedish building energy code (page 54)

- Building regulations BBR 10 (Swedish Board of Housing, Building and Planning).
- Swedish building regulations (PAROC).

Case study 5: the Chinese building energy code (page 58)

- Enforcing building energy codes in China, progress and comparative lessons (ACEEE).
- Building Energy Efficiency Policies in China, status report (GBPN, 2012).
- Design Standard for Energy Efficiency in Residential Buildings in the Hot Summer and Cold Winter Zone (Chinese Ministry of Housing and Urban-Rural Development).
- Code of acceptance (Chinese Ministry of Housing and Urban-Rural Development).

Glossary

Air change per hour: is a measure of how many times the air within the building is replaced.

Building's inertia: is the capacity of the building envelope to stock energy during the day and then to use it during the night, notably thermal storage.

Commissioning: is the process of assuring that all systems and components of a building are designed, installed and tested according to the operational requirements of the owner or final client.

Compliance: is a state whereby the implementation of the building energy code is in accordance with the established specifications in the code.

Compliance software: is a calculation tool based on the methodology defined in the building energy code. The tool is used to check compliance with the energy requirements considered in building energy codes.

Energy performance labelling schemes: are also known as Energy Performance Certificate or Energy Passport for buildings. They provide information on the energy performance of a building.

Enforcement: refers to the legal actions taken by governments in case of non-compliance to building energy code specifications.

Evaluation: looks at the outcome of the overall building energy code at a national level. It examines the longer term results from a societal perspective. It identifies best practices as well as unsuccessful activities and actions. The aim is to provide information for the revision of building energy codes.

Final energy consumption: refers to the energy that is supplied to the consumer for all final energy uses, such as heating, cooling and lighting.

Lock-in effect: describes the energy savings that are not going to be realised due to unambitious and insufficiently stringent energy requirement targets for buildings, building components and equipment.

Monitoring: refers to observing, supervising and keeping under review. It involves measuring compliance with building energy code specifications, data collection and analysing progress made during implementation. Monitoring is usually undertaken at a local level.

Primary energy consumption: is the direct use of energy at the source, or the crude energy supplied to the user which has not been subjected to any conversion or transformation process.

Thermal bridge: is a localised area of the building envelope where the heat flow is different in comparison with adjacent areas.

Temperature set-point: the point at which a thermostat has been set to provide the desired comfort.

Positive pressure: is a pressure within a building that is greater than the environment that surrounds the building.

S&L policies: Standards and Labelling policies. Standards policies set minimum energy performance requirements for buildings, building components and equipment while labelling policies provide information on buildings' energy performance.

List of acronyms

AFD	French Development Agency
ACEEE	American Council for Efficient Energy Economy
ASHRAE	American Standard for Heating, Refrigeration and Air-conditioning Engineers
BEEP	Buildings Energy Efficiency Policies
BECP	Building Energy Codes Programme
BRICS	Brazil, Russia, India, China, South Africa
CA	Concerted Action
CSTB	Scientific Centre for Buildings (France)
CSVM	Coefficient of seasonal variation in mortality
DoE	Department of Energy
EED	Energy Efficiency Directive (of the EU)
EC	European Commission
EITT	Energy, Infrastructure, Transport and Technology
EPBD	Energy Performance of Buildings Directive (of the EU)
EPC	Energy Performance Certificate
EU	European Union
GEF	Global Environment Facility
GHG	Greenhouse gas
GDP	Gross Domestic Product
KEMCO	South Korean Energy Management Corporation
kWh/m_2/yr	kilowatt hours per square metre per year
MED-ENEC	Energy Efficiency in the Construction Sector in the Mediterranean
MEPS	Minimum Energy Performance Standards
METI	Japanese Ministry of Economy, Trade and Industry
MoE	Ministry of Environment
Mtoe	Millions of tonnes of oil equivalent
NAMAs	Nationally Appropriate Mitigation Actions
NPV	Net Present Value
Pa	Pascal
S&L	Standards and labelling
UNDP	United Nations Development Programme

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This publication is the result of a collaborative effort between the International Energy Agency (IEA) and the United Nations Development Programme (UNDP). Thanks are given to the Japanese Ministry of Economy, Trade and Industry and the German Ministry of Economics and Technology for funding provided for this publication

OECD/IEA, 9 rue de la Fédération, 75739 Paris Cedex 15, France
and
United Nations Development Programme (UNDP) 304 East 45th Street, New York, NY 10017, USA

Printed in France by the IEA

Cover design: IEA
Cover photo: © GraphicObsession
Inside photos: Hedi Calabrese and Benjamin Pont from ELAN-Bouygues and Marina Olshanskaya from UNDP,
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