Global Approaches: A Comparison of Building Energy Codes in 15 Countries

Rachel Young, American Council for an Energy-Efficient Economy

ABSTRACT

Integrating energy efficiency into building codes is a recognized strategy to reduce energy consumption in the residential and commercial sectors. Across the globe countries are independently designing and implementing energy efficiency policies and programs in residential and commercial buildings to decrease energy waste in the new building stock. This paper takes a national look at commercial and residential building codes in some of the world's largest economies, including the United States, the United Kingdom, China, Japan, Germany, France, Brazil, Italy, India, Russia, Canada, Australia, Mexico, Spain, and South Korea, to determine which countries are embracing energy efficiency through highly effective building codes. The paper lays out the status of building energy code stringency, technical requirements, enforcement, compliance, and energy intensity in buildings in each of the countries and highlights some national best practices for each element. The objective is to evaluate the most effective policies and shine a light on best practices to help nations learn from one another and achieve greater savings.

Introduction

Energy efficiency in construction standards is universally recognized as a practical and cost-effective way to achieve energy savings in residential and commercial buildings. Across the globe countries are independently designing and implementing energy efficiency policies and programs in residential and commercial buildings to decrease energy waste in the new building stock. Since efforts to increase energy standards in building codes are relatively disparate between countries, it is useful to analyze not only which countries seem to be designing well-crafted and comprehensive energy codes, but also which are effectively implementing and enforcing those standards. This paper takes a national look at commercial and residential building codes for new buildings in the world's largest economies, including the United States, the United Kingdom, China, Japan, Germany, France, Brazil,[1] Italy, India, Russia, Canada, Australia, Mexico, Spain, and South Korea.

In many countries the government has authority to mandate energy efficiency in buildings by creating national building codes that are often implemented by regions or municipalities. This paper will look at various government initiatives to increase energy efficiency in buildings as well as make an assessment of the comprehensiveness and stringency of the building codes. To do so, we are examining and scoring three elements of building energy codes: 1) building code stringency and comprehensiveness; 2) technical requirements included in the codes; and 3) enforcement mechanisms, including incentive packages and penalties. We will also include a discussion of the energy intensity of the total building stock to help contextualize energy use in each country.

[1] Since Brazil doesn't currently have robust building energy codes, they were excluded from the enforcement metric and the energy intensity metric.

We aim to determine which countries are embracing energy efficiency through highly effective building codes. To do so, we will showcase some of the international best practices to increase the energy efficiency in new buildings and conclude with overviews of the countries that most completely met all of the outlined metrics. The objective is to evaluate the most effective policies and shine a light on best practices to help nations learn from one another and achieve greater savings. Below, we lay out the specific metrics used to evaluate the building codes in each country and which countries are performing at the highest level in each category and some best practice efforts.

Building Energy Codes

Description

Countries can implement codes with various levels of stringency: voluntary codes, mandatory codes, or some mixture depending on the region or state. This stringency metric is a basic reporting of the status of the building codes in a country. In China, Canada, and the United States, the national government does not have authority to pass mandatory building codes; however, many states and provinces in those countries have adopted codes. In these cases we give partial credit ("mixed") if the majority of the population is within a jurisdiction with a code in place. In contrast, many countries create mandatory building energy codes that cover the entire country. For this paper, we look at the comprehensiveness of the building codes for each country.

Results

Table 1 shows the stringency of adherence to the codes and the types of buildings subject to the code "coverage" for the residential and commercial sectors. Often building codes only apply to specific types of buildings, such as single- or multifamily buildings in the residential sector. The more comprehensive the code, the more types of buildings the code applies to. In the commercial sector, "commercial" means offices, retail and wholesale outlets, hotels, hospitals, and educational buildings, unless otherwise specified. "Public buildings" means public offices, hospitals, and educational buildings, unless otherwise specified.

Out of the 4 possible points, countries are awarded 1 point if their codes are mandatory (for residential and commercial each), 0.5 points for mixed, and 0 points for voluntary or no code, giving a total possible point allocation of 2 for stringency. Countries can also earn up to 2 points for commercial and residential code coverage. For residential, 1 point is for coverage for both single- and multifamily housing. For commercial, the code must include all commercial and public buildings to receive 1 point. If the coverage is partial in either commercial or residential, they get 0.5 points (e.g., Germany).

Table 1. Building codes by country

	Residential		Commercial		Points
Country	**Stringency**	**Coverage**	**Stringency**	**Coverage**	
Australia	Mandatory	One Family; Multifamily	Mandatory	Commercial and Public Buildings	4
Brazil	Voluntary	N/A	None/Proposed	N/A	0
Canada	Mixed	One Family; Multifamily	Mixed	Commercial and Public Buildings	3
China	Mandatory	One Family; Multifamily	Mixed	Commercial and Public Buildings	3.5
France	Mandatory	One Family; Multifamily	Mandatory	Commercial and Public Buildings	4
Germany	Mandatory	One Family; Multifamily	Mandatory	Commercial: Offices, Hotels, Hospitals; Public Buildings: Offices, Hospitals	3.5
India	Voluntary[1]	N/A	Mandatory[2]	Commercial and Public Buildings	2
Italy	Mandatory	One Family; Multifamily	Voluntary	Commercial and Public Buildings	2
Japan	Mixed	One Family; Multifamily	Mandatory	Commercial and Public Buildings	3.5
Mexico	None	N/A	Mandatory	All New Commercial Construction	2
Russia	Mandatory	One Family; Multifamily	Mandatory	Commercial Buildings	3
South Korea	Mandatory	One Family; Multifamily	Mandatory	Commercial and Public Buildings	4
Spain	Mandatory	One Family; Multifamily	Mandatory	Commercial and Public Buildings	4
United Kingdom	Mandatory	One Family; Multifamily	Mandatory	Commercial and Public Buildings	4
United States	Mixed[3]	One Family; Multifamily	Mixed[4]	Commercial and Public Buildings	3

[1] Does not directly address energy efficiency, but promotes innovative technology in the field.
[2] The code is voluntary until made mandatory by individual state governments.
[3] Thirty-two states have adopted or exceeded the 2009 IECC standards.
[4] Thirty-eight states have adopted or exceeded the ASHRAE Standard 90.1-2007.
Sources: Code status: IEA 2013a. Coverage: McDonald and Lausten 2013 and SBC 2013

Best Practices

China has established a relatively comprehensive building energy code system for new buildings (Shui and Li 2012). Mandatory requirements are set relevant to the two climate zones (North and South), with provisions outlined for thermal envelope components and energy efficiency requirements for heating, cooling, hot-water, and plumbing systems (McDonald and Lausten 2013). The Chinese codes provide two options for compliance: a prescriptive path, which provides detailed specifications for individual building components, and a performance

path, which requires that the proposed new building not consume more energy (in its design) than a reference building. The code includes provisions with design standards for all major climate zones and the main construction processes, including design, construction, acceptance, operation, and retrofit.

China also has a separate code for public buildings that was developed in 2005 to improve the energy efficiency of nonresidential buildings, including commercial, educational, and governmental buildings. Mandatory and voluntary energy performance criteria are outlined addressing thermal envelope components and energy efficiency requirements for heating, cooling, hot-water, and plumbing systems (McDonald and Lausten 2013).

France has also established a mandatory and comprehensive code system. As a member of the European Union, France was required to comply with the Electronic Energy Performance of Buildings Directive (EPBD) passed in December 2002.[2] France implemented the directive in 2005 by updating their National Building Regulation. These regulations cover both the residential and commercial sectors and are performance-based codes that require projects to show compliance with the maximum primary energy consumption standards. The 2005 regulation set a 15% efficiency rate, and a 40% efficiency rate goal, aimed to be met by 2020. Though this paper looks primarily at new buildings, it is also interesting to note and highlight that France's building regulation also sets minimum standards for existing buildings, and defines the necessary renovations for them. In addition to the mandatory building energy codes, France established complementary categories for efficient buildings and "White Certificate Trading," requiring energy suppliers to meet mandated targets for energy savings through their customers.

Technical Requirements

Description

For the technical requirements we analyzed what energy uses and functions were covered by the country's building codes. Below are the elements selected to evaluate the technical requirements for each country:

- **Insulation in Walls and Ceiling.** Insulating the "envelope" or "shell" of a house or commercial building includes adding insulation to prevent heat loss in the winter and heat gain in the summer.
- **Window U-Factor and Shading/Solar Heat Gain Coefficient.** The U-factor measures the rate of heat transfer through a window and rates how well the window insulates. The solar heat gain coefficient measures the fraction of solar energy transmitted and indicates how well the window blocks heat caused by sunlight.
- **Lighting Efficiency Requirements.** Minimum standards for high-efficiency lighting and lamps and/or lighting controls are included in some building codes.
- **Heating and Cooling Requirements.** Heating and cooling requirements refer to the efficiency of a building's heating, ventilating, and air-conditioning (HVAC) systems.
- **Air Sealing.** For residential buildings only. Sealing the "envelope" or "shell" includes getting rid of air leaks throughout a home, such as around windows and doors, and holes in attics, basements, and crawlspaces. These leaks can be sealed using caulk, spray foam, weather stripping, and other sealants.

[2] For more information, see here: http://www.epbd-ca.eu.

- **Technical Installations.** Building energy codes that contain details for technical installations of appliances and equipment and/or contain requirements for access to appliances for regular inspection
- **Design, Position, and Orientation.** Design requirements include architectural programming requirements for all the functions in the building and their relationship to one another, including energy efficiency targets, primary functions, occupancy and time of use, daylight potential and electric light requirements, indoor environmental quality standards, equipment and plug loads, acoustic quality, and safety and security.

Results

Tables 2 and 3 show the technical requirements within each country's code. Each country was allotted 0.25 points per technical requirement. Due to the constraints of the paper, this list and scoring does not include the stringency of the technical requirements, which would be an excellent area for additional research.

Table 2. Residential building code technical requirements

	Heating and Cooling Requirements	Insulation in Walls and Ceiling	Window U-Factor and Shading/Solar Heat Gain Coefficient	Air Sealing	Lighting Efficiency	Technical Installations	Design, Position, and Orientation	Points
Australia	X	X	X	X	X	X	X	1.75
Brazil	–	–	–	–	–	–	–	0
Canada	X	X	X	X	X	–	X	1.5
China	X	X	X	X	X	–	X	1.5
France	X	X	X	X	X	–	X	1.5
Germany	X	X	X	X	X	X	X	1.75
India	–	–	–	–	–	–	–	0
Italy	X	X	X	X	X	X	X	1.75
Japan	X	X	X	X	–	–	X	1.25
Mexico	–	–	–	–	–	–	–	0
Russia	X	X	–	–	X	X	–	1
South Korea	X	X	X	X	X	X	X	1.75
Spain	X	X	X	X	X	X	X	1.75
United Kingdom	X	X	X	X	X	X	X	1.75
United States	X	X	X	X	X	–	–	1.25

Sources: McDonald and Lausten 2013, CLASP 2011, Italy: Il Presidente della Repubblica 2005, Japan: Evans, Shui, and Lee 2009

Table 3. Commercial building code technical requirements

	Heating and Cooling Requirements	Insulation in Walls and Ceiling	Window U-Factor and Shading/Solar Heat Gain Coefficient	Lighting Efficiency	Technical Installations	Design, Position, and Orientation	Points
Australia	X	X	X	X	X	X	1.5
Brazil	–	–	–	–	–	–	0
Canada	X	X	X	X	–	X	1.25
China	X	X	X	X	–	X	1.25
France	X	X	X	X	–	X	1.25
Germany	X	X	X	X	X	X	1.5
India	X	X	X	X	X	X	1.5
Italy	X	X	X	X	–	–	1
Japan	X	X	X	X	–	X	1.25
Mexico	X	X	–	X	–	–	0.75
Russia	X	X	–	–	–	X	0.75
South Korea	X	X	X	X	X	X	1.5
Spain	X	X	X	X	X	X	1.5
United Kingdom	X	X	X	X	X	X	1.5
United States	X	X	X	X	–	–	1

Sources: McDonald and Lausten 2013, CLASP 2011, Italy: Il Presidente della Repubblica 2005, Japan: Evans, Shui, and Lee 2009

Best Practices

France has had prescriptive building energy efficiency requirements since 1995, and their first standard was implemented in 2005 when the EPBD requirements were released. In 2012 they set demanding performance expectations. Their code is a performance-based code that requires projects to show compliance with the maximum primary energy consumption, called the Cepmax coefficient. It requires that residential and nonresidential buildings use a maximum of 40–65 kilowatt-hours per square meter. It is the maximum conventional consumption of primary energy that considers thermal envelope components and most energy-consuming systems, including the HVAC, hot-water, lighting, heat recovery, and auxiliary systems (GBPN 2013). In addition to the technical requirements, France has comprehensive design and technical installation elements to their codes.

Australia established the energy efficiency component of its building code in 2003, and it allows for either a performance-based approach to compliance or a prescriptive approach based on requirements for specific building components (Shui, Evans, and Somasundaram 2009). The technical components of the building code are comprehensive and include provisions for energy efficiency installations, access and maintenance, design, and air movement.

Enforcement Mechanisms

Description

Ensuring the most effective enforcement of building codes is challenging for many countries because often the responsibility lies with local governments that may be understaffed and underfunded. In addition, it is difficult to obtain data on the levels of enforcement in each country for similar reasons. However, many efficiency experts agree that enforcement is one of the most important elements to the building energy code because it ensures compliance and effective savings. This metric is meant to document whether countries' building codes have mandatory enforcement, including local and third-party inspection and penalties for noncompliance. In addition, we look at whether inspection of the new buildings is performed. These metrics were inspired by the methodology of Global Buildings Performance Network (GBPN) as well as the ACEEE *International Energy Efficiency Scorecard* (McDonald and Lausten 2013; Hayes, Young, and Sciortino 2012).

In addition, many countries have implemented incentives and disincentives to help push contractors and home builders to comply with the codes. In this paper, we wanted to capture these efforts and shine a light on some of the most robust policy packages. We examine three ways that codes are enforced:

- **A:** The country has specific policy packages and incentives that complement or motivate compliance with building codes. Such mechanisms can include green loan programs, financial schemes and incentives, and public incentives including tax credits, and some countries will even give owners incentives such as relaxed building height and size restrictions, such as in Japan.
- **B:** If the building does not comply with the code, then they are refused permission for occupancy or construction.
- **C:** Enforcement of building codes includes fines and fees for noncompliance.

Results

Tables 4 and 5 lay out the enforcement standards by country in the residential and commercial sectors as well as their inspection requirements and whether the country has any of the above incentives or disincentives for compliance. A country can have more than one of these incentives in place, and the most robust packages are in countries that have all three elements (A, B, and C). We did not take into account the stringency of any enforcement approaches, we simply report whether a country has enforcement standards in place. More details on these policy packages can be found in the references.

Table 4. Residential energy building code enforcement standards

Country	Are there enforcement standards?	Code enforcement type	A, B, C
Australia	Accreditation or approval of materials or components and issuing of certificates of occupancy or compliance. Incentives for building efficiency, such as green loans program, voluntary building industry initiatives, national rating systems	Inspections during and after construction. Fees and charges for noncompliance	A, C
Canada (Ontario)	Local enforcement with third-party inspection. Schemes and incentive programs are available.	During construction; post-completion inspection of boilers; inspection of HVAC systems. Refusal of permission to occupy, refusal of permission to construct, and fees for noncompliance	A, B, C
China	Local enforcement with third-party inspection	On-site inspection occurs during construction. Refusal of permission to occupy, refusal of permission to construct, and fines for noncompliance	B, C
France	Local enforcement with third-party inspection. Accreditation of applicants and inspection. Label schemes, subsidies, funds, loans, tax incentives, levies, obligations, white certificates, audits, feed-in tariffs, training schemes	During construction and post-completion. Refusal of permission to occupy and fines for noncompliance	A, B, C
Germany	Accreditation of applicants. The government-owned banking group Kreditanstalt für Wiederaufbau (KfW) plays a central role in the promotion of energy savings by providing subsidies.	None. Refusal of permission to occupy and refusal of permission to construct for noncompliance	A, B
India	None	None	None
Italy	A forum among central government ministries, regions, provinces, and communes, supported by various agencies and bodies that facilitate monitoring implementation	Inspection of boilers and air-conditioning, but procedure is still under discussion	A, C
Japan	Local enforcement, mandatory reports submission with review by local authorities. Encourages more efficient building designs by giving owners incentives like access to relaxed building height and size restrictions and financial support for very efficient buildings.	No inspection for compliance	A
Mexico	None	None	None
Russia	Regional and local administration and enforcement	Energy audits post-completion, prior to occupancy	None
South Korea	Local government building officials execute the codes. The property owner must fill out an energy-saving worksheet and submit it to local governmental offices to obtain a building permit.	Local governments may audit the buildings after construction.	A, B

Spain	Local enforcement with third-party inspection. Grants for energy efficiency in buildings (2004–20), gas and electricity tax revenue disbursed to regional governments and topped up with private funds (65%), and the grants are proportional to different energy requirements and efficiency measures related to the codes and the energy performance certificate labels.	During construction and post-completion. Refusal of permission to occupy and refusal of permission to construct for noncompliance	A, C
United Kingdom	Local enforcement, accreditation of applicants, post-occupancy control. Energy performance certificates, positive labeling for building beyond the minimum building code level, energy offsets/green certificates	During construction	A
United States	Local enforcement, third-party inspection, post-occupancy control commissioning requirements. Sales and use tax exemption for renewable energy equipment, solar renewable energy certificates. Local option—Clean Energy Loan Program, Be SMART Home Efficiency Loan Program, Be SMART Multifamily Efficiency Loan Program, Home Energy Loan Program	During construction, post-occupancy airtightness testing required prior to compliance. Refusal of permission to occupy and refusal of permission to construct for noncompliance	A, B

Sources: McDonald and Lausten 2013, Australia: Shui, Evans, and Somasundaram 2009, Italy: EPBD 2011 and IEA 2013c, Mexico: Liu, Meyer, and Hogan 2010. Russia: IEA 2013c, South Korea: Evans et al. 2009

Table 5. Commercial energy building code enforcement standards

Country	Are there enforcement standards?	Code enforcement type	A, B, C
Australia	Accreditation or approval of materials or components and issuing of certificates of occupancy or compliance. Incentives for building efficiency, such as green loans program, voluntary building industry initiatives, national rating systems	During and after construction. Fees and charges for noncompliance	A, C
Canada (Ontario)	Local enforcement, third-party inspection. Schemes and incentive programs are available.	During construction and post-completion. The inspection includes boilers and HVAC systems.	A, B, C
China	Local enforcement with third-party inspection. Green Building Rating Systems, Green Olympic Building Assessment System, Evaluation Standard for Green Building	During construction. Refusal of permission to occupy and refusal of permission to construct for noncompliance	B, C
France	Local enforcement, third-party inspection, accreditation of applicants	Inspection occurs during construction and post-completion.	A, B, C
Germany	Accreditation of applicants. The government-owned banking group Kreditanstalt für Wiederaufbau (KfW) plays a central role in the promotion of energy savings by providing subsidies.	During construction and post-completion. Refusal of permission to occupy and refusal of permission to construct for noncompliance	A, B

India	Local enforcement, accreditation of applicants	During construction and post-completion. Refusal of permission to occupy and refusal of permission to construct for noncompliance	B
Italy	A forum among central government ministries, regions, provinces, and communes, supported by various agencies and bodies that facilitate monitoring implementation	Post-construction inspection of boilers and air-conditioning, but procedure is still under discussion	A, C
Japan	Local enforcement, mandatory reports submission with review by local authorities	No inspection for compliance	None
Mexico	The code has not been enforced due to a lack of adoption by local governments into their building construction regulations. Municipalities that are in charge of setting construction rules for their territories have not made any efforts to include energy efficiency requirements in their building codes. The building energy efficiency code has thus not become effective.	None	None
Russia	Regional and local administration and enforcement. They have certificates called Energy Passports. They are mandatory in public buildings and integrated into the code process for all new buildings.	Energy audits post-completion, prior to occupancy	None
South Korea	Local government building officials execute the codes. The property owner must fill out an energy-saving worksheet and submit it to local governmental offices to obtain a building permit. Buildings that rate highly are eligible for financial incentives, like low-interest loans. The Korean Energy Management Corporation is planning to provide financial support to energy-efficient activities, including cogeneration, energy savings, and the use of renewable energy.	Local governments may audit the buildings after construction.	A
Spain	Local enforcement, third-party inspection. Grants for energy efficiency in buildings (2004–20), gas and electricity tax revenue disbursed to regional governments and topped up with private funds (65%), and the grants are proportional to different energy requirements and efficiency measures related to the codes and the energy performance certificate labels.	During construction and post-completion. Refusal of permission to occupy and refusal of permission to construct for noncompliance	A, C
United Kingdom	Local enforcement, accreditation of applicants, post-occupancy control. Energy performance certificates, positive labeling for building beyond the minimum BC level, energy offsets/green certificates	On-site during construction	A
United States	Local enforcement, third-party inspection, post-occupancy control commissioning requirements. Sales and use tax exemption for renewable energy equipment, solar renewable energy certificates, local option—Clean Energy Loan Program, Be SMART Home Efficiency Loan Program, Be SMART Multifamily Efficiency Loan Program, Home Energy Loan Program	During construction, post-occupancy airtightness testing required prior to compliance. Refusal of permission to occupy and refusal of permission to construct for noncompliance	A, B

Sources: McDonald and Lausten 2013, Australia: Shui, Evans, and Somasundaram 2009, Italy: EPBD 2011 and IEA 2013c, Mexico: Liu, Meyer, and Hogan 2010. Russia: IEA 2013c. South Korea: Evans et al 2009

Best Practices

GBPN and others agree that enforcement is one of the most challenging aspects of building energy codes, but one of the most important aspects of ensuring that codes are implemented and savings are realized. Many countries couple building energy codes with incentives and robust policy packages, such as financial incentives and low-interest loans. Few countries have noncompliance fees, particularly in the commercial sector, and only France and Canada have all three kinds of enforcement mechanisms in both residential and commercial codes.

Canada's most advanced building code, which has not been evenly implemented across the country, contains some comprehensive energy efficiency policies, incentives, and disincentives. Specifically, the Ontario Building Code's enforcement includes on-site inspection during and after the completion of a building. They also require certification and inspection of boilers and HVAC systems. Enforcement, as with nearly all building codes, is performed by localities, but the Ontario code also requires a third-party inspection and provides training for inspectors. They also have supporting measures to help incentivize energy efficiency in residential and commercial buildings, though their incentives are less robust than countries such as France or some states in the United States.

France is leading the way in supporting measures. They incentivize and reward initiatives beyond the building energy code. They also have robust labeling and certificate schemes that include grants, subsidies, loans, tax incentives, and trading schemes. For example, France's scheme for new residential buildings, called the Prêt à Taux Zéro+, or "Zero-Interest Loan +" provides loans to homeowners for their primary residence to encourage home buyers to purchase highly energy-efficient homes (SBC 2013). This is only one of several loans and tax credits available for energy efficiency improvements (French Property 2014).

Energy Intensity

Energy intensity of the commercial and residential building stocks are affected by a number of variables related to building use, including the efficiency of buildings, the size of buildings, and how heavily buildings are heated and cooled, but building energy codes can play a role in lowering the energy consumption per floor space. For the purpose of this paper, we included energy intensity to give context to each country's energy use in their building stocks. Energy consumption in residential and commercial buildings is calculated using the most recent data available for total energy consumption from IEA divided by the floor space of the building stock. To normalize these results, we factored in differences in seasonal temperatures. We took the average of the total heating and cooling degree-days from ChartsBin[3] (2011a and 2011b), and divided energy consumption over floor area by the heating and cooling factor for that country.

[3] Note: Degree-days = per capita/national average
Weighted by population = national total; it is simply the degree-day average for a particular country multiplied by its population. The average heating and cooling needs of an entire country can be determined by applying population weightings to the degree-day calculations generated for locations within a country. Using population to weight the degree-day data ensures that large metropolitan areas will be accorded more weight than calculations from sparsely populated areas so that the national average reflects the heating and cooling needs faced by the "average" citizen of that country (with some facing more, and others facing less) (Baumert and Selman 2003)

This calculation helps account for the varying impact of temperature when making comparisons of a country's energy use in buildings.

Results

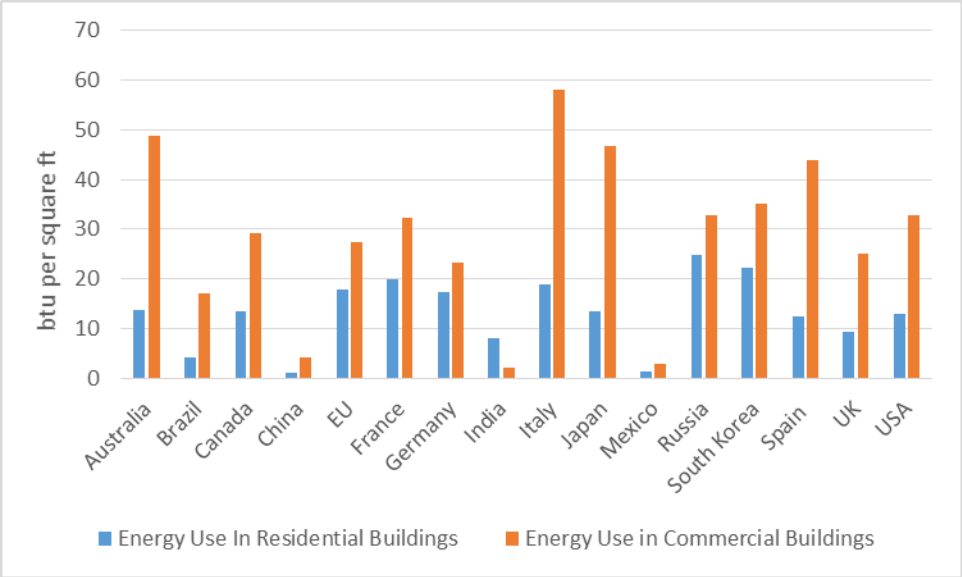

Figure 1. Energy intensity of current total residential and commercial building stock (2011).
Note: Intensities are normalized for weather using ChartsBin (2011a, 2011b). Sources: Energy consumption: IEA 2013b. Floor space: BPIE 2011, Australia: Langham et al. 2010, India: In-country contact, Japan: Statistics Japan 2008 and IEEJ 2014, Russia: Lychuk et al. 2012, South Korea: KOSTAT 2010, Mexico: Navigant 2014

China, India, and Mexico have the lowest energy intensities for both residential and commercial buildings, due in part to lower energy service levels than many of the other countries analyzed. Italy and South Korea have the highest energy intensities in the commercial sector and Russia has the highest in the residential sector, followed by South Korea. This metric does not imply causation between new building codes and total energy intensity of the national building stock. Though this is an interesting element to help contextualize energy consumption in each country, we did not include energy intensity in the overall scoring of building codes (see next section).

Conclusions

There are many ways to evaluate the effectiveness of energy efficiency building codes across countries, and this paper aims to take a snapshot of 15 countries and four elements of building energy codes and the energy intensity of the entire building stock. There are many polices that were not included in this paper, such as building labeling, retrofit policies included in codes, disclosure policies, and processes for updating building codes. However, based on the current metrics, countries that are leading the way with regard to the overall effectiveness of energy efficiency building codes include France, China, Australia, and Spain.

Table 6 shows a summary of every country and the points assigned to each of the elements evaluated in this paper. The building energy code point allocation is explained in the above section and is the sum of the residential and commercial code points. For technical

requirements, each country is awarded 0.25 points per technical requirement within their building code. In addition, countries got 1 point per enforcement mechanism (A, B, or C), 6 points total for residential and commercial sectors.

Table 6. Summary of all metrics with points

	Building energy codes	Technical requirements in residential	Technical requirements in commercial	Enforcement mechanisms for residential	Enforcement mechanisms for commercial	Total points
China	3.5	1.5	1.25	3	3	**12.25**
Australia	4	1.75	1.5	2	2	**11.25**
South Korea	4	1.75	1.5	2	2	**11.25**
United Kingdom	4	1.75	1.5	2	2	**11.25**
France	4	1.5	1.25	2	2	**10.75**
Canada	3	1.5	1.25	2	2	**9.75**
Spain	4	1.75	1.5	1	1	**9.25**
United States	3	1.25	1	2	2	**9.25**
Germany	3.5	1.75	1.5	0	1	**7.75**
Russia	3	1	0.75	2	1	**7.75**
India	2	0	1.5	2	2	**7.5**
Brazil	0	0	0	3	3	**6**
Japan	3.5	1.25	1.25	0	0	**6**
Italy	2	1.75	1	1	0	**5.75**
Mexico	2	0	0.75	0	0	**2.75**

[1] Canada got a high score overall, but was not highlighted because its code does not apply across all provinces and this paper looked heavily at the code in Ontario.

China has a rapidly growing building stock, including rapid urban development and demolition of older buildings. As a result, new building energy codes are highly effective at reducing energy consumption (Amecke et al. 2013). China's energy efficiency policy is driven at the federal level and carried out by provinces and municipalities, and they have designed their plans around their Eleventh Five-Year Guideline (IEA 2013c). China's building energy efficiency standards require new buildings to be up to 65% more efficient than buildings from the early 1980s. The code also includes extensive technical items and addresses building design, position, and orientation. China also has enforcement mechanisms that include incentives and penalties for noncompliance.[4]

Australia's building energy code was introduced in 2003 and allows for either a performance-based approach to compliance or a prescriptive approach. Their code is updated annually and includes guidance to help meet their compliance requirements. Australia's states

[4] For more information on the enforcement details in China, see: http://www.pnl.gov/main/publications/external/technical_reports/PNNl-19247.pdf.

and territories adopt and implement the building energy code. The procedures for administration include issuing permits, inspection during and after construction, issuing certificates of occupancy and compliance, fees for noncompliance, and review of enforcement standards. It covers all the technical requirements outlined in the above section of this report, including technical installation requirements and design elements making the code robust and inclusive.[5]

France's achievements in creating robust energy efficiency codes in their residential and commercial buildings have been outlined extensively in the best practice sections of this paper. France has taken numerous steps to advance stringent building energy codes and has worked extensively to help make them comprehensive and to ensure enforcement.[6]

Spain's building energy efficiency requirements have both prescriptive and performance-based elements. Their codes cover residential and nonresidential buildings and require a performance-based reference building calculation (manual or simulation) to show compliance for most building types. A prescriptive path can be used for buildings in specific locations. This path covers many technical requirements such as the thermal envelope and energy efficiency standards for HVAC, hot-water, lighting, and auxiliary systems. In addition, their code covers design, position, and orientation of building as well as requirements for technical installations. Spain also has a fairly robust enforcement system that includes several complementary certifications, such as labeling for buildings that go beyond the minimum standard requirements.[7]

References

Amecke, Hermann, Jeff Deason, Andrew Hobbs, Aleksandra Novikova, Yang Xiu, Zhang Shengyuan. 2013. *Buildings Energy Efficiency in China, Germany, and the United States*. http://climatepolicyinitiative.org/wp-content/uploads/2013/04/Buildings-Energy-Efficiency-in-China-Germany-and-the-United-States.pdf. Climate Policy Initiative.

[BPIE] Buildings Performance Institute Europe. 2011. Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings. http://dl.dropbox.com/u/4399528/BPIE/HR_%20CbC_study.pdf. Brussel, Belgium: Buildings Performance Institute Europe.

Baumert, Kevin and Mindy Selman. 2003. Data Note: Heating and Cooling Degree Days. http://cait.wri.org . Washington D.C.: World Resource Institute.

ChartsBin statistics collector team 2011a, Worldwide Cooling Needs, ChartsBin.com, viewed 4th March, 2014, <http://chartsbin.com/view/1030>.

ChartsBin statistics collector team 2011b, Worldwide Heating Needs, ChartsBin.com, viewed 4th March, 2014, <http://chartsbin.com/view/1029>.

[5] For more information on Australia's building codes, see here: http://ee.ret.gov.au/sites/default/files/documents/04_2013/building_our_savings.pdf.
[6] For more information on France's building energy code, see here: http://energycodesocean.org/state-country/france.
[7] For more information on Spain's building energy code, see here: http://energycodesocean.org/state-country/spain.

[CLASP] Collaborative Labeling & Appliance Standards Program. 2011. Global S&L database. http://www.clasponline.org/en/ResourcesTools/Tools/SL_Search Washington, DC: Collaborative Labeling & Appliance Standards Program.

[EPBD] Energy Performance of Buildings. 2011. Implementing the energy performance of buildings directive (EPBD): Featuring Country Reports 2010. http://www.slideshare.net/coneledigital/implementing-the-energy-performance-of-buildings-directive-epbd-2010. Brussels, Belgium: Energy Performance of Buildings.

Evans, M., H Chon (UMD), B Shui, S-E Lee (KICT). 2009. *Country Report on Building Energy Codes in Republic of Korea*. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17851.pdf. Oak Ridge, TN: Pacific Northwest National Laboratory.

French Property. 2014. Home Energy Conservation in France. http://www.french-property.com/guides/france/building/renovation/energy-conservation/. French-Property.com

GBPN (Global Buildings Performance Network). 2013. "Policy Tool for New Buildings." http://www.gbpn.org/databases-tools/purpose-policy-comparative-tool

Hayes, Sara, Rachel Young, and Michael Sciortino. 2012. The ACEEE 2012 International Energy Efficiency Scorecard. Research Report E12A. http://www.aceee.org/research-report/e12a. Washington D.C.: American Council for an Energy-Efficient Economy.

[IEA] International Energy Agency. 2013a. *Modernising Building Energy Codes: To Secure of Global Energy Future*. http://www.iea.org/publications/freepublications/publication/PP7_Building_Codes_2013_WEB.pdf. Paris France: International Energy Agency.

[IEA] International Energy Agency. 2013b. Data Services (2013 edition). Paris, France: International Energy Agency.

[IEA] International Energy Agency. 2013c. Energy Efficiency Policies and Measures Database. Paris, France: International Energy Agency.

[IEEJ] The Institute of Energy Economics, Japan. 2014. IEEJ Energy Journal. http://eneken.ieej.or.jp/en/publication/ .

IL Presidente Della Repubblica. 2005. Presidential Decree 02.04.2009 No. 59 Regolamento di attuazione dell'articolo 4, comma 1 http://www.energia.provincia.tn.it/binary/pat_agenzia_energia/normativa/DPR_59_2009.1248339845.pdf.

[KOSTAT] Statistics Korea. 2010. Korea Statistical Yearbook, the 57th edition. http://kostat.go.kr/portal/english/resources/2/1/4/index.static.

Langham, Ed, Chris Dunstan, Gilles Walgenwitz, Patrick Denvir, Aleta Lederwasch and Juliet Landler. 2010. *Building Our Savings: Reduced Infrastructure Costs from Improving Building Energy Efficiency*. http://ee.ret.gov.au/sites/default/files/documents/04_2013/building_our_savings.pdf. Institute for Sustainable Futures and Energetics.

Liu, Feng, Anke S. Meyer and John F. Hogan. 2010. *Mainstreaming Building Energy Efficiency Codes in Developing Countries: Global Experiences and Lessons from Early Adopters.* http://elibrary.worldbank.org/doi/pdf/10.1596/978-0-8213-8534-0. World Bank Working Paper No. 204. Washington D.C.: The International Bank for Reconstruction and Development/The World Bank

Lychuk, T., M. Evans, M. Halverson, V. Roshchanka. 2012. Analysis of the Russian Market for Building Energy Efficiency. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22110.pdf

McDonald, Niamh and Jens Lausten. 2013. *A Comparative Analysis of Building Energy Efficiency Policies for New Buildings*. http://www.gbpn.org/databases-tools/purpose-policy-comparative-tool. Paris, France: Global Buildings Performance Network.

Navigant. 2014. Global Building Stock Database: Commercial and Residential Building Floor Space by Country and Building Type: 2011-2021. http://www.navigantresearch.com/research/global-building-stock-database. Washington D.C.: Navigant Research.

[SBC] Sustainable Buildings Centre. 2013. Building Energy Efficiency Policies Database. http://www.sustainablebuildingscentre.org/pages/beep.

Shui Bin and Li Jun. 2012. *Building Energy Efficiency Policies in China*. http://www.aceee.org/sites/default/files/publications/researchreports/e129.pdf . Washington D.C.: The American Council for an Energy-Efficient Economy.

Shui Bin, M. Evans, and S. Somasundaram. 2009. *Country Report on Building Energy Codes in Australia*. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17850.pdf. Oak Ridge, TN: Pacific Northwest National Laboratory.

Statistics Japan. 2008. Housing and Land Survey. http://www.stat.go.jp/english/data/jyutaku/index.htm