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Shaping the Energy Efficiency in New Buildings

A Comparison of Building Energy Codes in the Asia-Pacific Region

M Evans
B Shui
A Delgado

September 2009

Pacific Northwest
NATIONAL LABORATORY

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Executive Summary

Buildings account for about one-third of worldwide energy consumption, and much of this consumption footprint is locked in through the building design and construction. Building energy standards are an important tool to improve energy efficiency in new buildings. For example, China's residential energy standard requires new buildings to be 65% more efficient than buildings from the early 1980s. In the United States, building energy codes save over $1 billion in energy costs per year, and this figure is growing. Denmark was among the first countries to adopt comprehensive building energy codes in 1961, and since then it has seen average household energy consumption per unit of space drop substantially.

Building energy standards set requirements for energy efficiency. Standards vary between countries in several respects including the extent of their coverage, the specific requirements, means of attaining compliance and the enforcement system. (Some countries refer to their building energy regulations as codes and others call them standards.) This summary provides an overview of some key trends in building energy standards in the countries of the Asia-Pacific Partnership on Clean Development and Climate (APP).

Extent of Coverage

Building energy standards, at a minimum, usually cover insulation, and thermal and solar properties of the building envelope (walls, roofs, windows and other areas where the interior and exterior of a building interface). Most standards also cover heating, ventilation and air conditioning, hot water supply systems, lighting, and electrical power. Some cover additional issues such as the use of natural ventilation and renewable energy, and building maintenance. In some countries, not all the issues are considered in a single standard. For example, China's standards include lighting in a separate document. Within these broad categories, there are also numerous differences in what the specific requirements cover. Some countries have significant detail about the need to minimize condensation on insulation. Some countries (like India or Japan) have detailed requirements based on different types, sizes or orientations of buildings, for example, while others have simpler requirements for a broader range of buildings. The United States, India and Canada all have commercial building energy codes derived from standards produced by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), although specific requirements vary by country.

In addition, not all standards and codes cover the same types of buildings. For example, in India, the Energy Conservation Building Code applies to commercial and multi-family residential buildings but not to small residential buildings. In Japan, there are standards for both residential and commercial buildings, but the commercial buildings must have at least 300 square meters of floor space to be covered. Most countries that regulate both commercial and residential construction for energy efficiency have separate standards for each, although countries categorize the buildings differently. In India, Australia, Canada and the United States, the commercial building codes include high-rise multi-family residential buildings, while the residential building codes include low-rise multi-family residential buildings. In China, the residential standards regulate multi-family residences. This difference is important because, typically, commercial building requirements are somewhat more complex and cover more issues than those for residential buildings.

Specific Requirements

The specific energy efficiency requirements for new buildings vary between countries. For example, regarding lighting efficiency requirements in commercial or large buildings in the APP region, Australia has the most stringent requirements (7 to 10 watts per square meter), followed by India and the United States (both 10.8 to 11.8 watts per square meter), and China (11 watts per square meter). Japan and the Republic of Korea (South Korea) do not regulate lighting power density per se, although they regulate other aspects of lighting efficiency. It is more difficult to compare energy efficiency requirements for the building envelope because of varying climate conditions and construction practices. When comparing specific requirements for building components in similar climate zones, no single APP country consistently has the strongest requirements. India has particularly stringent requirements for walls, and in warm climate zones, it has the most stringent requirements in this area. Japan has the most stringent requirements for windows in commercial buildings, while in the United States requirements for roofs of single-family homes are particularly strong.

It is important, however, to consider the specific requirements in context. A high enforcement rate can have a larger impact on building energy efficiency than a small improvement in the requirements. Also, the requirements are based on the rated efficiency of the building components. Differences between countries in test protocols used to rate the efficiency of these components may result in higher or lower ratings for equipment that objectively has very similar efficiency. A comprehensive approach to building energy codes creates the most significant improvements in energy efficiency.

Means of Attaining Compliance

Building energy standards typically provide property owners some flexibility in meeting the energy efficiency requirements. This is important because the standard can be more stringent without impinging too severely on the ability of property owners to adapt buildings to their needs. There are several approaches to providing this flexibility. In many countries including India, the United States, Canada and Australia, the codes have four classes of requirements. The first are mandatory requirements that must be satisfied regardless of any other factors for a building to be considered in compliance. The majority of these codes are then made up of prescriptive requirements that are similar to the mandatory requirements in that they provide specific values and details. However, building designers may be allowed to "trade-off" some of the prescriptive requirements with others regarding the building envelope. The codes then provide rules on what can be traded-off and how. Finally, these codes also provide an option for compliance based on building energy performance instead of the prescriptive requirements. This last option allows a building designer to install less energy-efficient windows but a more energy-efficient air conditioning system, for example, if the total designed energy use falls within the required norms. There are several approaches to establishing the baseline for comparison under the building energy performance method. The United States uses cost as its reference metric, while some other countries base the reference metric on energy consumption.

South Korea and Japan take a different approach, establishing both mandatory requirements and a point system for a whole range of energy issues related to buildings. Each new building must have a minimum number of points either in total or by category. Buildings that exceed the minimum point requirement may be eligible for certain benefits, such as relaxation of some zoning rules.

Enforcement Systems

Enforcement is critical for the standard to have an effect. Not all countries have mandatory building energy standards. India, for example, has a voluntary code. Japan's standards are also technically voluntary, although Japan has recently adopted penalties for non-compliance that blur this distinction. The United States, Canada and Australia all adopt building standards at the local level. Not all jurisdictions in the United States and Canada have adopted their nation's model building energy codes. China has mandatory national codes, but provinces have the option to adopt more stringent local codes.

Some important issues regarding enforcement and the related impact of the code on energy use include: the point of compliance (design and/or construction stage), how buildings are reviewed or inspected and by whom, penalties and other incentives for compliance, training and information on the code, compliance tools such as code compliance software and inspection checklists, and equipment and material testing and ratings.

In the United States, Canada, Australia and South Korea, for example, the building design must be approved, and inspectors check the building for compliance at least once during construction. In Japan, the reviews only occur at the building design stage. China uses a combination of government employees and certified companies to check building designs and inspect the buildings for compliance. There is no single answer as to which system produces the highest level of compliance. For example, Japanese officials believe that Japan attains a high level of compliance in actual construction because Japan has a very well developed system of training and information dissemination on the building energy standards. Anecdotal evidence in the United States and other countries indicates that inspections do play an important role in attaining high levels of compliance. The U.S. Department of Energy is now developing methodologies to measure and track compliance.

The stringency of the national system for testing materials and equipment for their energy efficiency properties can also have a marked impact on the final energy consumption of a building. Most countries have a system of certified laboratories that test materials and equipment (like windows and air conditioners) and rate them for efficiency. These ratings then determine if the equipment in a building meets the building energy standard. Testing procedures vary between countries, and there is anecdotal evidence that even in countries with well established systems, ratings can differ by 10% or more based on the testing procedures.

Building energy standard compliance rates vary significantly between countries. What constitutes compliance may also vary, and not all countries consistently publish compliance data. That said, countries usually have lower compliance rates soon after they adopt or revise a standard, and when their enforcement system is not fully developed.

Conclusions

All APP countries have expressed a desire to improve energy efficiency in new buildings. More efficient new buildings will mean lower operating costs and emissions. Buildings can last 30 to 50 years or longer, and much of the energy consumption footprint is set with the initial design and construction of the building. Thus, building energy codes are an important tool for ensuring wise energy use. APP countries stand to gain by learning from the experience with building energy codes in other countries. This goes beyond just looking at specific requirements, where certainly there are measurable differences.

Countries can also learn from the implementation strategies and programs employed elsewhere. For example, Japan has an extensive system of public outreach and training that helps raise enforcement rates. Other countries, such as the United States and Australia, have developed tools like software and checklists to help local jurisdictions with enforcement. South Korea and Japan have taken an innovative approach to rewarding buildings and building owners that go beyond the basic standards by using a point system. This allows the standard to include items such as renewable energy as an option. China has also experimented with rewards at the local level, and the United States has tax credits for exceeding the standards.

This comparative report, and the seven country reports upon which it was based, can help countries understand the options and approaches to building energy codes that have worked elsewhere. It provides policy makers a menu of options to explore in strengthening their building energy code programs.

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Foreword

Buildings account for about 32% of all energy consumption globally and a significant share of greenhouse gas emissions. Building energy codes help ensure that new buildings use energy efficiently, and this can reduce building energy use by 50% or more compared to buildings designed without energy efficiency in mind. This is important because buildings typically last 30-50 years, and it is much less expensive and time-consuming to design for energy efficiency than to retrofit a building later. Based on the experience of the Asia-Pacific region, it is clear that building energy codes, when implemented, save energy and improve comfort in new buildings. By design, most building energy codes are cost-effective, saving consumers significant amounts of money on their energy bills.

The Asia-Pacific Partnership on Clean Development and Climate (APP) is a public-private collaboration to accelerate the development and deployment of clean energy technologies. APP partners include Australia, Canada, China, India, Japan, South Korea and the United States. APP countries account for more than half of the global economy, energy consumption, and greenhouse gas emissions. APP's Buildings and Appliance Task Force (BATF) provides a forum for APP partners to work together on energy efficiency in buildings and appliances. This report was prepared under the framework of BATF, in particular a BATF project called "Survey building energy codes and develop scenarios for reducing energy consumption through energy code enhancement in APP countries" (BATF-06-24).

At the request of the U.S. Department of Energy, the Pacific Northwest National Laboratory's Joint Global Change Research Institute has prepared a series of reports surveying building energy codes in the seven APP countries. This report compares building energy codes in the APP countries, looking at issues ranging from the history of code development to the specific requirements and the enforcement framework. The other reports in this series are country reports, providing an overview of the building energy codes and related policies in each APP country. They are available at: www.asiapacificpartnership.org/english/tf_app_building_codecountry_reports.aspx.

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1 Introduction and Background

1.1 Importance of Building Energy Codes

Building energy codes are a proven and cost-effective means of improving energy efficiency in new buildings (IEA 2007). Buildings account for about one-third of energy consumption globally and in the APP countries[1]. Several APP countries are experiencing high rates of growth in new buildings, particularly China and India. China, for example, will likely account for 50% of all new building space in the world through 2020. Because most of the energy "footprint" of a building is set with its initial design, building energy codes provide essential leverage for improving building energy efficiency. In the United States, for example, the U.S. Department of Energy's Building Energy Codes Program is estimated to have saved \$30-50 for every dollar the program has spent, thus saving over \$1 billion in energy costs in a year. This equates to \$7 billion in energy savings in residential buildings through 2010 and \$3.3 billion in energy savings in commercial buildings.[2]

This report begins with an overview of the building sectors in APP countries. Chapter 2 then provides background on the history of building energy codes in APP countries, outlining their progress in improving their building energy codes and implementation programs in recent decades. Chapter 3 compares the specific details of building energy codes in the APP region including the structure of the codes, issues they address, and the stringency of specific requirements. Chapter 4 highlights how the APP countries have approached compliance and implementation and covers a range of issues such as the enforcement framework, test protocols, compliance tools and public information. Chapter 5 provides conclusions. The report seeks to provide policy makers and building energy code officials with insights into successful approaches for a range of building energy code issues. In this way, APP countries can learn from each other as they address the challenges of improving energy efficiency in new buildings to address growing concerns about climate change and energy security.

1.2 Economics, Energy and Carbon Emissions

The seven APP countries accounted for 45% of the world's population (in 2007), 48% of its gross domestic product (GDP)[3], 51% of its primary energy consumption (in 2005) and 54% of its carbon dioxide emissions (in 2005). Four APP countries (the United States, China, Japan and India) are among the world's top five world economies, and are among the largest primary energy consumers and carbon emitters (Table 1).

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[1] The Asia-Pacific Partnership for Clean Development and Climate includes seven countries: Australia, Canada, China, Japan, South Korea, India and the United States.
[2] For more information, please see http://www.energycodes.gov/whatwedo/index.stm.
[3] The GDP is in purchasing power parity (PPP) for 2007.

Table 1 GDP, Primary Energy Consumption, and Carbon Emissions in APP Countries

	GDP (2007)		GDP (PPP in 2007)		CO_2 Emissions (2006)		Primary Energy Consumption (2006)	
	Current Prices in U.S. Dollars, Billions[1]	World Ranking	Current International Dollars, Billions[2]	World Ranking	Million Metric Tons[3]	World Ranking	Million Tons of Oil Equivalent	World Ranking
AUS	909	15	763	17	417	16	5.6	18
CAN	1,436	9	1,270	13	614	7	14.0	7
CHN	3,280	4	7,035	2	6,018	1	73.8	2
IND	1,101	12	2,997	4	1,293	4	17.7	5
JAP	4,382	2	4,292	3	1,247	5	22.8	4
KOR	970	14	1,202	14	515	9	9.4	11
USA	13,808	1	13,808	1	5,903	2	99.9	1

Sources: IMF 2008 and EIA 2008a

AUS is Australia, **CAN** is Canada, **CHN** is China, **IND** is India, **JAP** is Japan, **KOR** is South Korea and **USA** is the United States.

1.3 Building Sectors

With 45% of the world's population, APP countries also contribute to a large share of the global building area floor space.

Buildings in Canada accounted for total floor space of 2.2 billion square meters in 2005, 71% of which was in residential buildings and the remainder in commercial buildings (OEE, 2007). Most dwellings in Canada are detached single-family houses (67% of residential floor space in 2005), followed by apartments (21%), attached single-family houses (10%) and mobile homes (2%). There are four major uses of commercial buildings in Canada: offices (35% of commercial floor space), retail trade (17%), educational service (14%), and health care and social assistance (9%).

In China, by the end of 2003 existing buildings accounted for 38 billion square meters of floor space, 37% of which was in urban areas. In recent years, China has been adding 1.8 to 2 billion square meters of floor space annually, making it the world's largest market for new construction (Wu and Liu 2007; Wu et al. 2007). Of these new buildings, 60% are residential, 10% are industrial, and 30% are public or commercial[4] (Lang 2005).

In 2006, there were 32 million residential buildings in Japan totaling 3.4 billion square meters of floor space. Residential buildings consist of detached single-family houses (85% of total residential floor space), houses in the agriculture sector (6%), condominiums (5%) and mixed-use houses (4%). Japan also had 13 million non-

[4] This report uses the term "public" buildings as defined in China's regulations, which is similar to the idea of commercial buildings in other countries. Public buildings in China include government buildings but also other private buildings used for commerce or services. The term "public" buildings in China does not include residential buildings.

residential buildings in 2006, with total floor space of 0.7 billion square meters. Non-residential buildings include attached buildings (60% of the total floor space of commercial buildings in 2006), factories and warehouses (15%), mixed-use buildings (other than houses) (10%), offices, banks and retails (9%), and temples and religious buildings (4%) (Ministry of Internal Affairs and Communications, 2008).

In the United States, there were 5 million commercial buildings in 2003 totaling 6.7 billion square meters of floor space. Commercial buildings include, but are not limited to, offices (17% of the total floor space of commercial buildings in 2003), mercantile space (16%), warehouses and storage (14%), educational buildings (14%) and lodging (7%) (EIA 2006). In 2005, there were 111 million housing units in the United States totaling 25.8 billion square meters of floor space. Residential buildings include detached single-family houses (89% of total floor space of residential buildings in 2005)[5], multi-family apartments (9%)[6] and mobile homes (3%) (EIA, 2008b).

1.4 Building Energy Use

According to International Energy Agency data published in 2007, the APP countries accounted for 48% of the world total for building energy use in 2005, 45% for residential energy use and 59% of the commercial use. The United States, China and India are the top three largest building energy users, while China and the United States are the largest residential and commercial energy users, respectively (Table 2).

Table 2 Building Energy Use in APP Countries, 2005 (in thousand tons of oil equivalent)

Rank	Total		Residential		Commercial	
1	USA	472,514	China	331,502	USA	202,701
2	China	373,078	USA	269,813	Japan	61,505
3	India	168,771	India	156,840	China	41,576
4	Japan	116,248	Japan	54,743	Canada	31,085
5	Canada	62, 437	Canada	31,352	South Korea	19,231
6	South Korea	37,679	South Korea	18, 448	India	11,931
7	Australia	15,857	Australia	10,041	Australia	5,816
	% of the World	48%	% of the World	45%	% of the World	59%

Source: IEA 2007

Building energy consumption is a top final energy end use for each APP country. For example, in India, China, and Canada building energy use was the largest end use in 2005. India's 47% final energy use[7] included building energy use, 94% of which was residential energy use. Overall, building energy use in the APP region made up 31% of total final energy use, compared with 32% globally.

From 1995 to 2005, building energy use in South Korea, Australia and China posted more rapid growth than the world average. For example, South Korea's average annual growth rate for building energy use was 2.9%, while its annual growth rate for residential

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[5] Single-family houses refer to both detached and attached houses.
[6] Multi-family apartments refer to both apartments in 2-4 unit buildings and apartments in buildings with more than 5 units.
[7] Final energy use includes residential and waste heat in the International Energy Agency data.

energy use is 6.7%. China had the highest annual growth rate, 7.7%, for commercial energy use among APP countries (Table 3).

Table 3 Annual Growth Rate (%) in Building Energy Use in APP Countries, 1995-2005

Rank	Total		Residential		Commercial	
1	South Korea	2.9	South Korea	6.7	China	7.7
2	Australia	2.4	Australia	1.91	Australia	3.4
3	China	1.68	Japan	1.87	World	2.4
4	India	1.66	India	1.7	India	1.5
5	Japan	1.60	World	1.3	Japan	1.4
	World	1.5	China	1.1	South Korea	0.3
6	Canada	1.4	USA	0.8	Canada	0.0
7	USA	1.1	Canada	0.4	USA	0.0

Source: IEA 2007

1.5 Building Energy Codes and Standards[8]

The dictionary defines "code" as "a systematic statement of a body of law; *especially,* one given statutory force," or "a system of principles or rules."[9] The word "standard" is defined as "a basis for comparison; a reference point against which other things can be evaluated."[10] To describe minimum requirements for energy efficiency in buildings, most APP countries employ either "codes" or "standards." Some countries, such as Japan and South Korea, use the words "criteria" or "guidance" in describing their building energy requirements (Table 4). In some countries (like the United States) the term "guidance" can indicate a document that is not mandatory.

In this report, building energy "codes" and "standards" are used interchangeably. "Guidance" and "criteria" are also used for countries that use these terms as part of the English name of their building energy standards.

Table 4 APP Building Energy Codes and Standards Studied in this Report

Building energy codes/standards/criteria/guidance	
AUS	Building Code of Australia 2007 (BCA)
CAN	1. Model National Energy Code of Canada for Buildings 1997 (MNECB) 2. Model National Energy Code for Houses 1997 (MNECH)
CHN	1. Energy Conservation Design Standard for New Heating Residential Buildings 1995 2. Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone 2001 3. Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter Zone 2003 4. Design Standard for Energy Efficiency of Public Buildings 2005
IND	Energy Conservation Building Code 2007 (ECBC)

[8] This report reflects the most up-to-date information available at the time of printing. The report may not fully reflect the 2008 and 2009 updates to the Japanese Energy Conservation Law as the complete revised law was not available in English.
[9] For more information, please see www.merriam-webster.com/dictionary/code[1].
[10] For more information, please see www.websters-online-dictionary.org/definition/standard.

JAP	1. Criteria for Clients on the Rationalization of Energy Use for Buildings 1999 (CCREUB) 2. Design and Construction Guidelines on the Rationalization of Energy Use for Houses 1999 (DCGREUH) 3. Criteria for Clients on the Rationalization of Energy Use for Houses 1999 (CCREUH)
KOR	Building Design Criteria for Energy Saving 2008 (BDCES) Rules for Building Facility Criteria & Otherwise 2008 (RBFCO)
USA	1. International Energy Conservation Code 2006 (IECC) 2. ASHRAE Standard 90.1 - Energy Standard for Buildings except Low-rise Residential Buildings 2007 (ASHRAE 90.1)

1.6 Residential and Commercial Buildings

Australia, Canada, China, Japan and the United States have separate building energy codes for commercial and residential buildings. India and South Korea's building energy codes focus on buildings with large energy demands (Table 5).

Broadly speaking, the residential codes in Australia, Canada and the United States cover single-family homes and small multi-family residences, but not large, multi-family residences; the latter are covered under the commercial codes. China's residential building energy codes refer to multi-family apartment buildings. Japan's residential code covers both large and small residential buildings. The commercial building energy codes in Australia, Canada and the United States cover large, conditioned buildings, regardless of use, while the commercial or public building codes in China and Japan only cover large buildings used for non-residential purposes.

Table 5 Definition of Residential and Commercial Buildings in APP Countries

	Residential Buildings	Commercial Buildings
AUS	The Australian code covers all building issues so it applies to a wide range of structures. The residential energy efficiency provisions of the code apply primarily to: detached and attached single-family houses, and boarding houses, guest houses and hostels with a total area not exceeding 300 m^2 (BCA 2007).	The commercial energy efficiency provisions of the code apply primarily to: large residential buildings, office buildings, retail buildings, schools and health care buildings as well as laboratories and production buildings (BCA 2007).
CAN	Single-family houses of three stories or less (MNECH 1997).	New buildings and additions, including: 1) Buildings more than three stories in height, 2) Buildings of three stories or less having a building area of more than 600 m^2, and 3) Buildings of three stories or less in building height that contain non-residential space (MNECB 1997).
CHN	Multi-family apartment buildings.	Educational, governmental, commercial and industrial buildings.

IND	All new buildings with a connected load of 500 kW or more, or a contract demand of 600 kVA or greater, which generally includes buildings with conditioned floor space of 1,000 m^2 or more (ECBC 2008).	
JAP	Residential buildings of any size.	Commercial, educational, governmental and industrial buildings.
KOR	(1) Apartment buildings with over 50 households, (2) education/research/welfare or business buildings greater than 3,000 m^2, (3) hotels and hospitals over 2,000 m^2, (4) department stores with a centralized cooling/heating system and over 3,000 m^2, or (5) performance halls, gathering halls, and stadiums with total floor area over 10,000 m^2 (BDCES 2008). Smaller buildings are also covered under South Korea's Rules for Building Facility Criteria & Otherwise (RBFCO 2008).	
USA	Residential buildings three stories or less in height above grade (IECC 2006)[11]	New building and their systems, new portions of buildings and their systems, new systems and equipment in existing buildings, excluding 1) single-family houses, multi-family structures of three stories or less above grade, manufactured houses, 2) buildings that do not use either electricity or fossil fuel, or 3) equipment and portions of building systems that use energy primarily to provide for industrial, manufacturing or commercial processes (ASHRAE 90.1-2007).

1.7 Construction Trends

Standard construction practices differ significantly in APP countries. This is natural as buildings must meet the climate and cultural needs of the people that occupy them. Construction practices can have a major impact on building energy use. For example, in India the shift from more traditional architectural with massive walls toward office buildings made of glass and steel has led to a dramatic increase in the demand for air conditioning given the hot climate. Average Canadian new detached homes are probably around 280 square meters, which is smaller than those in the U.S., while high rise apartment buildings are likely consistent with those in the US.

While it is beyond the scope of this report to provide detailed statistical analysis of the differences in construction practices in different APP countries, it is important to highlight that these differences can influence building energy use. This is important in interpreting differences in the building energy codes of APP countries. The building energy codes in each country may also reflect these differences in construction practices. This section briefly touches on a few of the more important differences in construction trends.

Heavy versus light construction Residential buildings in Asia tend to have heavier construction than their counterparts in Australia, Canada and the United States. Heavy construction tends to have more thermal mass than light construction, which can make adopting strict energy requirements easier. Modern-style buildings do not have to rely on light construction, but they may often rely on significant amounts of glass and steel in their construction. Because of its solar heat gain and poor insulating characteristics, glass

[11] IECC 2006 has sections for both commercial and residential buildings. This description, based on Chapter 4 of IECC 2006, is only for residential buildings.

can significantly increase energy demand, particularly in warm climates. Glass with more efficient properties is available, but it is rarely as efficient as heavy construction, even though glass can also provide day-lighting, which can reduce lighting demand with appropriate controls.

Residential housing styles Single-family homes are the most common type of residential buildings in Australia, Canada, Japan and the United States. In contrast, townhouses and apartment buildings are the most popular types of housing in South Korea. Since apartment buildings are dominant in China, China's residential building energy codes focus on apartment buildings.

Within the category of residential houses, the western style of houses, such as those in Australia, Canada and the United States, are strikingly different in both appearance and inner construction compared to traditional styles of houses in Japan. For example, triple-fronted brick veneer is a popular housing style in Australia. This type of a house has a brick exterior, and its interior walls are supported by wood frames.[12] In a traditional house in Japan, any room in the main living area could be used as a living room, bedroom, dining room and study, which can be partitioned with a sliding door made of wood and paper[13]. Many modern houses in Japan are imported from other countries including the United States and Canada. As a result, such homes in Japan may become more similar to houses in the United States and Canada than traditional Japanese homes. In addition, houses in Japan usually have a shorter lifespan: 26 years versus 44 years for an average house in the United States.[14]

Overhangs and shading Window overhangs are popular in warm climates. Building energy codes in Australia, China and India have provisions for shading such as integrating shading into the calculation of performance requirements for windows (Australia, China and India) and requirements for installation of shading devices to reduce indoor energy consumption (Australia and China). The United States also has provisions for shading in commercial buildings.

Heating and air conditioning In the United States, Canada[15], Australia and South Korea, buildings tend to be sold already equipped with equipment for heating, ventilation and air conditioning (HVAC) and water heating.[16] This is not the case for residential buildings in China, for example. In China, room air conditioners and water heaters are usually installed by residents before or after they move in. As a result, there are no provisions regarding service water heating in China's residential building energy codes.

In most parts of Canada, heating is a necessity but air conditioning is not, while air conditioning is a must-have for most buildings in the United States. The Model National

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[12] For more information, please see www.homedesigndirectory.com.au/articles/ArchitecturalStyles.shtml.

[13] For more information, please see http://en.wikipedia.org/wiki/Housing_in_Japan.

[14] For more information, please see www.authorstream.com/Presentation/Reginaldo-39229-sem-japan-market-Opportunity-ChallengeChanging-Housing-Outline-Second-Largest-Situation-marke-Education-ppt-powerpoint/.

[15] There is an ongoing effort in Canada to maintain harmonization with United States' HVAC, lighting and power standards. While, overall, building energy code adoption is not consistent across Canada, compliance with product energy efficiency regulation is more or less consistent.

[16] Korean residential buildings tend to rely on district heating for heating. Relatively few residential buildings in Korea have air conditioning, though luxury high-rises increasingly do have air conditioning.

Energy Code of Canada for Buildings (MNECB) and the Model National Energy Code of Canada for Houses (MNECH) provide less stringent energy performance requirements with less comprehensive differentiation in types of air conditioning equipment compared to the United States standard, ASHRAE 90.1-2007. Air conditioning is increasingly popular throughout Asia, but in some countries, people are more willing to accept a greater range of indoor temperatures (hence reducing the energy bill for heating and air conditioning).

Some additional issues Building orientation is not regulated in the United States and Canadian building energy codes, but it is regulated in Australia, China, India, Japan and South Korea. China, South Korea and Japan recommend that the orientation of a housing unit should face south, for example.

Building energy codes do not contain provisions regarding housing size, though housing size is an important indicator of energy consumption. Average housing size varies among the APP countries.

1.8 Climate Zones

Some provisions of building energy codes, especially the thermal characteristics of the building envelope, are grouped by climate zones or geographic locations. For example,

a) The Building Code of Australia (BCA 2007) divides Australia into eight climate zones: 1) high-humidity summer, warm winter; 2) warm humid summer, mild winter; 3) hot dry summer, warm winter; 4) hot dry summer, cool winter; 5) warm temperate; 6) mild temperate; 7) cool temperate; and 8) "alpine" area.

b) Canada's MNECB 1997 and MNECH 1997 provide thermal characteristics of the building envelope by its ten provinces and two territories.[17]

c) China identifies five climate zones in its building energy codes for commercial buildings: 1) severe cold area A, 2) severe cold area B, 3) cold, 4) hot summer and cold winter (HSCW), and 5) hot summer and warm winter (HSWW). China's three residential building energy codes focus on three climate zones: 1) heating zones (a combination of severe cold area A and B, and cold); 2) HSCW; and 3) HSWW, respectively.

d) The Energy Conservation Building Code (ECBC 2007) divides India into five climate zones: 1) composite, 2) hot and dry, 3) warm and humid, 4) moderate and 5) cold.

e) In Japan, building energy codes for commercial buildings are differentiate between an ordinary zone (covering most of Japan), a cold zone (covering the far north), and a tropical zone. Building energy codes for residential buildings provide requirements for six zones. These zones are based on heating degree days, so for example zone IV covers areas with an average of 1,500 to 2,500 heating degree days per year. This zone covers Tokyo and much of the central-southern part of Japan.

[17] Neither building energy code covers Nunavut, a territory that joined Canada in 1999.

f) South Korea's building energy codes, the Building Design Criteria for Energy Saving (BDCES 2008) and RBFCO 2008, covers three regions: central, south and Jeju Island.

g) The United States building energy codes ASHRAE 90.1-2007 and International Energy Conservation Code (IECC 2006) cover eight climate zones: 1) very hot-humid and dry; 2) hot-humid and dry; 3) warm-humid, dry and marine; 4) mixed-humid, dry and marine; 5) cool-humid, dry and marine; 6) cold-humid and dry; 7) very dry; and 8) subarctic.

Generally, building energy codes in APP countries allow variations in climate and geographic conditions and provide relevant information on the definition and categorization of their climate zones and geographic coverage.

2 Development History

Denmark was among the first countries to adopt comprehensive building energy codes in 1961, and since then it has seen average household energy consumption per unit of space drop substantially (Lausten, 2008). Building energy codes are not new to the APP region. The United States was the first APP country to adopt a comprehensive building energy code, followed shortly thereafter by Japan and South Korea. As indicated by the timeline shown in Table 6, in the past 10-15 years, all APP countries have worked to strengthen their building energy codes and enforcement systems. As a result, many APP countries have seen impressive improvements in the energy efficiency of new buildings. Currently, several APP countries are considering even more radical improvements to their building energy codes. For example, the United States is considering a 30% improvement in the requirements for both commercial and residential buildings by 2010 and 2012, respectively. Climate change, energy security and consumer cost reduction are all drivers behind this trend.

The remainder of this section summarizes the development of building energy policy and codes in each APP country.

Table 6 Timeline for Building Energy Codes Development in APP Countries, 1975-2007[18]

		75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
AUS																																			
Commercial																													■	■	■	■	■	■	■
Residential																													■	■	■	■	■	■	■
CAN																																			
Commercial																								■											
Residential																								■											
CHN																																			
Commercial																																■			
Residential													■									■						■		■					
IND																																			
Commercial																																		■	■
JAP																																			
Commercial						■																				■				■			■		■
Residential							■													■						■				■			■		■
KOR																																			
Commercial/Residential						■	■				■			■	■													■		■	■				■
USA																																			
Commercial	MEC			■						■			■			■			■	■		■			■		■	■		■			■		
	ASHRAE	■					■									■										■		■			■			■	
Residential	MEC			■						■			■			■			■	■		■			■		■	■		■			■		
	ASHRAE	■					■													■								■			■			■	

[18] MEC is short for Model Energy Code. The 1977 MEC listed for the United States was known as the Model Code for Energy Conservation.

2.1 Australia

In the past, Australia's energy policy focused primarily on the supply side (IEA, 2005). However, the government has aggressively pursued energy efficiency in recent years. In 2004, the government published a widely quoted white paper entitled "Securing Australia's Energy Future," which included an examination of the potential of energy efficiency in reducing energy intensity and carbon emissions. The white paper announced several initiatives including the expansion of the Minimum Energy Performance Standards to cover buildings and more appliances (Australian Government, 2009; IEA, 2005).

With participation from all levels of the Australian government and from representatives of the building industry, the Australian Building Codes Board was officially founded by the Australian Commonwealth, state and territory governments in 1994 and reaffirmed in 2006. Key objectives of Australian Building Codes Board include: 1) maintaining and updating the BCA, 2) providing regulations to "aid the design, construction and use of buildings throughout Australia," and 3) supporting the governmental agenda on such issues as relating to climate change (ABCB, 2008).

The BCA offers technical provisions in one coding manual for the design and construction of buildings and other structures throughout Australia and allows for variations by climate zone. It covers structure, fire resistance, services, equipment, energy efficiency and certain aspects of health and amenities. Energy efficiency measures were introduced into the BCA in January 2003. On energy efficiency, the code allows for either a performance-based approach to compliance (compared to a reference building), or a prescriptive approach based on requirements for specific building components.

Since 2003, the BCA has been updated annually. This report was written based on BCA 2007; the most recent version is BCA 2009.

2.2 Canada

Natural Resources Canada is the main department of the Canadian government responsible for natural resources and energy. It has promoted energy efficiency and the use of alternative energy since the late 1970s. Natural Resources Canada's policy instruments include: regulation, financial incentives, leadership, information, voluntary initiatives, research and development funding, and technology demonstrations (OEE, 2006, 2009) The Office of Energy Efficiency of Natural Resources Canada, established in 1998, undertakes market transformation initiatives to improve energy efficiency. The Office of Energy Efficiency has initiated many influential projects and policies to promote building energy efficiency.

Canada approved its first comprehensive law on energy efficiency, the Energy Efficiency Act, in 1992.[19] This act gives the Government of Canada the authority to make and enforce regulations related to performance and labeling requirements for energy-

[19] A document entitled "Measures for Energy Conservation in Buildings" was published in 1978 and used as a guideline for federal and other government buildings, but the document was not written or published in code language.

consuming products (as well as doors and windows). The act only applies to products that are imported or shipped between provinces. The act also authorizes the Government of Canada to collect statistics on energy use and alternative energy (OEE, 2006, 2009).

Currently, Canada has seven national building codes[20], two of which, MNECB and MNECH, relate to building energy efficiency. The Canadian Commission on Building and Fire Codes, funded by code sales and the National Research Council, is responsible for developing and updating six of the model national codes.

The Canadian Commission on Building and Fire Codes prepared both MNECB and MNECH, and National Research Council first published them in 1997. National Research Council, Natural Resources Canada, the Canadian Electricity Association, and the provincial and territorial ministries of energy funded the research to develop the model code and the supporting software. MNECB and MNECH were heavily influenced by ASHRAE 90.1-1989.

In April 2008, National Research Council and Natural Resources Canada announced that they were joining forces to update MNECB. Natural Resources Canada is providing technical expertise and up to $5 million to support this initiative. National Research Council will publish the new energy code in 2011. The new code will complement the next version of the model national construction codes, which are scheduled for publication in 2010 (NRC, 2008).

2.3 China

Building energy efficiency issues in China have drawn increasing attention from the government since the mid-1980s, when China began its large-scale construction in urban areas (Huang, 2008). China's first Energy Conservation Law (released in 1997) addressed the importance of building energy codes in one of its 50 Articles. The revised Energy Conservation Law, released in 2007, has a separate Section[21] on Construction Energy Conservation, which includes seven articles directly or indirectly related to build energy codes.

The National Development and Reform Commission, the powerful administrative entity in charge of China's macroeconomic policies and development, issued the China Medium and Long-Term Energy Conservation Plan in 2004. The Plan revealed ambitious energy conservation targets for buildings in China: "During the Eleventh Five-year Plan period, new buildings should be strictly subject to the design standard of 50% energy conservation. Several major cities such as Beijing and Tianjin shall take a lead in implementing the 65% energy-saving standard. Reform of heat supply system shall be carried out in a full scale. In China's large and medium cities, a charge system based on thermal meter will be widely spread in district heating of residential and public buildings;

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[20] The other building codes are the 1) National Building Code of Canada, 2) National Fire Code of Canada, 3) National Plumbing Code of Canada, 4) National Farm Building Code, and 5) National Housing Code and Illustrated Guide.

[21] The sections under Chapter III Rational Use of Energy Conservation include: Section 1 General Provisions, Section 2 Industrial Energy Conservation, Section 3 Construction Energy Conservation, Section 4 Transport Energy Conservation, Section 5 Energy Conservation by Public Institutions and Section 6 Energy Conservation by Key Energy Consuming Entities.

small cities will be pilot of such practice. Energy saving retrofits for existing residential and public buildings shall be conducted in combination with urban reconstruction. Large cities are expected to improve 25% of building areas, medium cities 15% and small cities 10%."

In 2005, the Chinese government called for building a resource conserving and environmentally friendly society in its Eleventh Five-Year Plan. This plan is widely regarded as the roadmap for China's social and economic development for 2006 to 2010. In this newest national plan, ten priority programs related to energy conservation have been identified for meeting the goals of reducing energy intensity and mitigating primary pollutants by 20% and 10%, respectively, by the year 2010 compared to 2005 levels. Six of the ten priority programs are related to building energy efficiency: 1) energy conservation in buildings, 2) energy-efficient lighting, 3) energy conservation in governmental buildings and vehicles, 4) district heating and power generation, 5) recovery of residual heat and pressure, and 6) building the energy conservation monitoring and technological support system.

China has issued a series of national and industrial codes to promote building energy efficiency, including three design standards for residential buildings in different parts of China (published in 1995, 2001 and 2003, respectively) and one design standard for public buildings (2005). In addition, China has developed standards for lighting design in buildings (2004). Energy standards covering other building-related issues include: the technical specifications for the energy-efficient renovation of existing residential buildings in the heating zones (2001), the technical code for ground source heat pump systems (2005), the technical code for solar water heating systems in civil buildings[22] (2006), the standard for energy consumption surveys in civil buildings (2007) and the standard for energy-efficiency inspections of buildings (2007). In this report, building energy codes refer to design standards for public and residential buildings as well as the standards for lighting design.

The Ministry of Housing and Urban-Rural Development (the former Ministry of Construction) coordinates and develops China's national building energy codes. The China Academy of Building Research is the chief developer of nearly all of China's national building energy codes. On behalf of the Ministry of Housing and Urban-Rural Development, the Academy is responsible for explaining and maintaining China's building energy codes.

2.4 India

Recognizing that energy use and air pollution are important issues in India's buildings, India issued the National Housing and Habitat Policy in 1998. The Policy acknowledged the importance of construction techniques and materials in energy conservation. It also emphasized that the government should specify energy efficiency levels for different categories of buildings (IEA, 2008b).

In 2001, the Indian government enacted the Energy Conservation Act, which promotes energy efficiency and conservation domestically. The Energy Conservation Act mandated

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[22] Civil buildings refer to both residential and public buildings.

the creation of the Bureau of Energy Efficiency, which was established under the Ministry of Power in 2002. The Energy Conservation Act also authorized Bureau of Energy Efficiency to establish the ECBC.

The Bureau of Indian Standards issued National Building Code of India in 2005, which covered a range of structural, safety, and other design issues. Energy efficiency was marginally addressed (IEA, 2008b).

Under the direction of the Prime Minister, the government's Planning Commission issued the Integrated Energy Policy in 2006. This document identifies major areas with large potential for energy savings. Five of the 13 areas are related to the buildings sector including building design, construction, HVAC, lighting and household appliances.

In 2007, the Ministry of Power and Bureau of Energy Efficiency issued the ECBC —the first stand-alone national building energy code in India. While it is currently voluntary, ECBC establishes minimum energy efficiency requirements for the building envelope, lighting, HVAC, electrical system, water heating, and pumping systems.

2.5 Japan

Japan was hit hard by the 1973 oil crisis because its oil consumption contributed to 80% of its total primary energy demand at that time. Since then, the Japanese government has been committed to making energy efficiency one of its priorities in national development. Today, Japan has one of the most efficient economies in the world as measured by energy intensity.

Japan's Rational Use of Energy, or Energy Conservation Law, was first issued in 1979. Initially, it was primarily focused on promoting energy efficiency in the industrial sector. The law served as the foundation of Japan's energy efficiency policies and was updated numerous times including in 1983, 1993, 1998, 2002, 2005 and 2008[23]. The 2002 revision required owners of new commercial buildings larger than 2,000 square meters to submit energy saving plans to the government. The 2005 revision, which took effect in 2006, strengthened energy-efficiency measures for residential buildings and the construction sector. Owners of buildings with over 2,000 square meters must submit energy saving plans for renovation permits (IEA, 2008c, d, e and f). Recent revisions to the Energy Conservation Law expand the number of buildings for which energy saving plans are required; the revisions go into effect in 2009. The revisions require owners of small and medium-sized buildings (from 300 to 2,000 square meters) to submit energy saving plans before construction or renovations begin. Also, construction companies building more than 150 houses per year need to improve the energy performance of the houses they build.

Under the Energy Conservation Law, Japan has issued a set of building energy standards for commercial and residential buildings. The Criteria for Clients on the Rationalization of Energy Use for Buildings (CCREUB) was first issued in 1979, and the newest version was released in 1999 by the Ministry of International Trade and Industry and the Ministry of Construction. Two building energy standards relate to residential buildings: 1) Design and Construction Guidelines on the Rationalization of Energy Use for Houses

[23] Part of the 2008 version of the law will enter into force in April 2009 and the remainder in April 2010.

(DCGREUH) issued by the Ministry of Construction in 1980 and later revised in 1992, 1999, 2003, 2006 and 2008; and 2) Criteria for Clients on the Rationalization of Energy Use for Houses (CCREUH) issued by the Ministry of International Trade and Industry and the Ministry of Construction in 1980 and later revised several times between 1992 and 2008.

2.6 South Korea

In the wake of the oil crisis in the 1970s, South Korea established the Ministry of Power and Resources. The government then issued the Rational Energy Utilization Act in 1979 as a national law for energy efficiency and conservation. It also established the Korean Energy Management Corporation in 1980 to manage national energy efficiency programs and policies issued by Rational Energy Utilization Act (Ahn, 1998).

Recognizing that its economy is largely fueled by imported fossil fuels, South Korea has set the three E's (energy security of supply, economic efficiency and environmental protection) as its national goals for achieving sustainable economic development. The Ministry of Knowledge Economy (formerly the Ministry of Commerce, Industry and Energy[24]) is in charge of national energy policy.

From the mid-1970s to the mid-1990s, South Korea focused on improving energy efficiency in the industrial sector. Since the late 1990s, the government has promoted energy efficiency in the buildings and transportation sectors (Hong et al. 2007). For example, the government is preparing new, long-term energy conservation goals for the buildings sector. These goals are currently anticipated to reduce emissions by 30% in this sector by 2030, as compared with business-as-usual emissions.

South Korea issued its first mandatory building standard on insulation thickness in 1977, followed by building energy standards for several types of buildings in the next two decades. These standards covered offices, hotels, hospitals and residential buildings. These individual standards were integrated into the BDCES in 2001, which is mandatory for all types of residential and commercial buildings where high energy consumption is expected. Major revisions to BDCES were issued in 2003 (incorporated diverse high-efficiency appliances), 2004 (incorporated new technologies) and 2008 (incorporated renewable technologies and revised incentive structure for voluntary standards).

The BDCES was a product of intensive revision of existing standards and review of building energy codes of several countries including the United States, the United Kingdom, Germany, Japan and Canada. The South Korean government felt that complex codes like those in the United States may provide detailed rules but it preferred a simple approach to ease implementation in South Korea (Lee 2006). The BDCES underwent several revisions after 2001; the latest occurred in November 2008. This report reflects the November 2008 version of the standard.

The BDCES and the RBFCO represent different types of sub-regulations under the framework of the Building Act. The RBFCO, first implemented in 1992, contains prescriptive requirements for insulation, but also for construction more broadly, including

[24]The Ministry of Energy and Resources was established in 1978 after the oil crisis and later integrated into the Ministry of Commerce, Industry and Energy.

safety.[25] By contrast, the BDCES specifically covers energy. For this reason, this report focuses primarily on the BDCES. Any references to the RBFCO in this report reflect the 2008 version of the standard.

2.7 The United States

In response to the 1973 energy crisis, the United States began developing energy codes and standards for buildings. The first standard developed was the ASHRAE Standard 90 - 75 Energy Conservation in New Building Design, published in 1975. That same year, the United States Congress passed the Energy Policy and Conservation Act. ASHRAE/IES Standard 90.1 was first mentioned in the national energy policy act, and it was suggested that it be established as an amended uniform national standard (Congress, 1975).

The Energy Policy Act of 1992 had significant impacts on the development of building energy codes. This law required the U.S. Department of Energy (DOE) to be actively involved in the development and deployment of building energy codes and to collaborate closely with states, local governments, and building code communities. DOE is also responsible for determining if new versions of model energy codes save energy. ASHRAE Standard 90.1 serves as the basis for DOE's formal determinations of energy savings for commercial buildings and high-rise multi-family residential buildings as mandated by the Energy Policy Act of 1992. The Energy Policy Act of 1992 also listed the Council of America Building Officials' Model Energy Code of 1992 as the basis for the DOE's formal determinations of energy savings for low-rise residential buildings.

Since then, building energy codes have attracted more coverage in national energy legislation. The Energy Policy Act of 2005 covered building energy codes in the subsections of "Federal building performance standards" and "Energy-efficient public buildings."[26] The Energy Independence and Security Act of 2007, the most recent United States energy legislation, underscores the important role of building energy codes in building energy efficiency in subtitles of "Residential Building Efficiency," "High-Performance Commercial Buildings," "High-Performance Federal Buildings," and "Healthy High-Performance Schools."

In the United States, ASHRAE/IES Standard 90.1 is a model energy standard for the commercial design community. IECC developed by the International Code Council (the successor to the Council of America Building Officials' Model Energy Code), is a model code for the code enforcement community for both residential and commercial buildings.

Since 1975, the ASHRAE Standard 90 has been issued (under the names 90A and 90.1) in 1980, 1989, 1999, 2001, 2004 and most recently in 2007. Model energy codes were issued in 1977, 1983, 1986, 1989, 1992, 1993 and 1995 by the Council of America Building Officials and in 1998, 2000, 2003, 2006 and the forthcoming 2009 by the ICC.

DOE is currently working with both IECC and ASHRAE to improve the residential and commercial energy codes by 30%. DOE's goal under this initiative is that by 2012 and 2010 (respectively) new buildings would be 30% more efficient than buildings built

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[25] Articles 21 and 22 of the RBFCO refer to the BDCES.

[26] The structure of the Energy Policy Act consists of a number of titles, which include a number of subtitles. A subtitle includes a number of subsections labeled as "Sec."

according to the current codes. This initiative also includes a goal to monitor and increase the compliance level at the state level to 90%.

2.8 Summary

Some of the important highlights in the development of building energy codes in APP countries include the following:

a) Australia has updated its building energy codes annually since 2003.

b) Building energy codes in Canada and India were highly influenced by the structure and development process of the United States ASHRAE 90.1 standard.

c) Australia, Canada, China, Japan and the United States have both commercial and residential building energy codes, while India has a building energy code for large buildings. China's residential and commercial codes also cover only large buildings. South Korea's building codes cover both commercial and residential buildings in the same document.[27]

d) The United States was the first APP country to develop both residential and commercial building codes in 1975.

3 Comparison of the Structure and Requirements of Building Energy Codes

3.1 Structural Comparison

The topics that codes cover vary across countries. Within the APP region, the English-speaking countries have codes that cover fairly similar issues, while the East Asian countries each have unique codes covering different sets of issues. The United States, Canada and India all have building energy codes developed from or based on ASHRAE standards. The Australian building energy code, while not directly patterned after ASHRAE, does approach building energy requirements in a fairly similar manner. The building energy codes in Australia, Canada, India and the United States all address such building components as building envelope, HVAC, lighting, service hot water, electrical power and the building performance approach. Commercial building energy codes often provide more detailed and stringent provisions than residential building energy codes that target single-family homes (except for India, which has only one code for large buildings).

The codes in East Asia are less homogenous compared to those described above. China's building energy codes are focused on the building envelope and HVAC; lighting is covered in a separate document. In Japan, the residential and commercial energy codes have very different structures and compliance paths. Both China and Japan have detailed residential building energy codes but in China the code covers only large residential

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[27] BDCES focuses on large-scale buildings, but South Korea's RBFCO applies to all buildings regardless of their size. It is mandatory and provides requirements for minimum U-values, air tightness of building and other issues for all commercial and residential buildings.

buildings, while in Japan, all residential buildings are covered. South Korea's building energy code focuses on buildings with high energy use and categorizes provisions into sections such as construction design, electrical design, mechanical design, and renewable energy facility design. The BDCES of South Korea and the Japanese commercial code both include a point scoring system, which makes it easier to include topics like building shape and orientation, renewable energy, and natural ventilation. (Prescriptive-based codes make it harder to include such a broad range of issues because all buildings must be able to comply, while point systems can encourage non-obligatory measures as well).

Table 7 compares the structure of building energy codes in the APP countries. It shows that codes in all countries cover building envelope and HVAC. The third and fourth most covered are service water heating and lighting, respectively. Building energy codes in most countries include building performance-based alternative solutions.

In addition, building energy codes in some countries address different issues that are not commonly discussed in other countries. Examples include individual sections on "Access for Maintenance" and "Energy Efficiency Installation" for commercial buildings in Australia (BCA 2007), "Manufactured Housing" for residential houses in Canada (MNECH 1997), provisions on operation and maintenance in "How to Live" for houses in Japan (DCGREUH 1999), and provisions for relaxed zoning restrictions on building size and a section on "Renewable Energy Facility Design Criteria" in South Korea's building energy codes (BDCES 2008).

Table 7 Structural Comparison of Building Energy Codes in APP Countries

	AUS		CAN		CHN				IND	JAP			KOR	USA	
Items	**BCA 2007**		**MNECB 1997**	**MNECH 1997**	**Commercial Buildings 2005**	**Heating Zone 1995, 2008**	**HSCW 2001, 2008**	**HSWW 2003**	**ECBC 2007**	**CCREUB 1999**	**Residential Design and Construction 1999**	**CCREUH 1999**	**BDCES 2008**	**ASHRAE 90.1-2007**	**IECC 2006**
	C	**R**	**C**	**R**	**C**	**R**	**R**	**R**		**C**	**R**	**R**		**C**	**R**
Envelope	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HVAC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Service Hot Water and Pumping	X	X	X	X	N.A.	N.A.	N.A.	N.A.	X	X	X	N.A.	X	X	X
Lighting	X	N.A.	X	X	X (in a separate code)	X (in a separate code)	N.A.	N.A.	X	X	N.A.	N.A.	X	X	N.A.[28]
Electrical Power	X	N.A.	X	X	N.A.	N.A.	N.A.	N.A.	X	N.A.	N.A.	N.A.	X	X	N.A.
Trade-offs and building performance approach	X	X	X	X	X	X	X	X	X	X	N.A.	X	X	X	X
Renewable energy	X	X	X	X.	N.A.	N.A.	N.A.	N.A.	X	X	N.A.	N.A.	X	X	X
Maintenance	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	X	X	X	N.A.	N.A.	N.A.

Note: C = commercial buildings, R = residential buildings, N.A = Not applicable. China has a separate code that covers lighting. In most countries that mention renewable energy in their building energy codes, renewable energy is not required, per se, but using site-generated renewable energy provides exceptions to certain code requirements.

[28] The 2009 version of the IECC now includes a provision for lighting.

3.2 Size Threshold for Compliance in New Buildings

Key Findings

- → APP countries have different size thresholds for compliance with building energy codes. This difference can result in important discrepancies in the energy efficiency of buildings that do not need to comply.
- → The codes in China and India cover only large buildings.
- → South Korea has minimum mandatory insulation requirements for all buildings and the BDCES provides additional requirements for large-scale buildings.
- → Japan has recently lowered the compliance threshold for commercial buildings from 2,000 to 300 square meters
- → Australia, Canada and the United States do not have a minimum size threshold for any type of conditioned building, although large residential buildings are regulated under the "commercial" code.

Countries maintain different size thresholds for buildings covered by their building energy codes. Australia, Canada and the United States have many single-family homes, and these countries typically have different sets of requirements for small residential and other buildings. In these cases, there may not be a minimum requirement; however, if a residential building is large, it may fall under the "commercial" or "building" code. India has a single code for large buildings. China has separate requirements for residential and other types of buildings, but both sets of requirements cover only large buildings. Japan has two separate codes – much like Australia, Canada and the United States – but it only regulates non-residential buildings of more than 300 square meters (it recently lowered this threshold from 2,000 square meters. Its residential code covers all residential buildings, and the difference of size is handled through envelope calculations that factor in the number of stories. Table 8 summarizes the compliance thresholds in the APP countries.

Table 8 Minimum Size of Buildings Regulated by Building Energy Code

	Residential	**Other Buildings**
AUS	No minimum	No minimum
CAN	No minimum	No minimum
CHN	Large buildings, but code has no specific definition	Large buildings, but code has no specific definition
IND	Approximately 1,000 m^2	Approximately 1,000 m^2
JAP	No minimum	300 m^2
KOR	50 households in building (BDCES) Minimum insulation for all buildings (RBFCO)	Depends on type: ex. offices, education and research: 3,000 m^2, hotels/motels 2,000 m^2 (BDCES) Minimum insulation for all buildings (RBFCO)
USA	No minimum	No minimum

3.3 Building Envelope

Key Findings

→ All countries have requirements regarding the building envelope in their building energy codes. These requirements cover thermal characteristics of building envelope components such as roofs, walls and windows.

→ Australia, China, India, Japan, South Korea and the United States address shading in their building energy codes. Australia, China, India, Japan and South Korea also mention orientation in their building energy codes.

→ In comparing U-factors for walls, roofs, floors and windows across four climate zones, no one country stands out as having consistently the most stringent requirements. India tends to have relatively low U-factors (or high efficiency requirements), although at present, the prescriptive requirements are not mandatory. Japan has relatively stringent requirements regarding windows in commercial buildings. China tends to have lower requirements than the majority of countries in many categories, but not by dramatic amounts. The United States in some categories has the most stringent requirements, and in others is the least stringent, particularly in the warmest zone. For example, the United States overall has the most stringent requirements for roof insulation in single-family homes. Canada has comparatively stringent envelope requirements for buildings heated with electricity, but generally less stringent requirements for other types of buildings.

Building envelope refers to building components that separate indoor space from outdoor space, exterior air or the ground. The main building envelope components include the roof, walls, floors, doors, windows and skylights. The thermal characteristics of the building envelope are widely believed to be the most important topic in building energy codes from the perspective of impact on energy use. Building energy codes in all APP countries cover building envelope requirements among one of the first issues addressed in the text of the codes (Table 8).

Table 9 Building Envelope in Building Energy Codes of APP Countries

	Section Title (s)	Main Content
AUS BCA 2007	Building Envelope	Building envelope must have insulation that complies with the Australian-New Zealand standards (AS/NZS 4859)[29]. There are detailed provisions on how insulation is to be installed, and requirements on the degree of thermal resistance in roofs, walls, floors and skylights.
	External Window	Energy efficiency characteristics of windows.
	Building Sealing	Building sealing for chimneys and flues, skylights, windows and doors, exhaust fans, construction of roofs, walls and floors, and evaporative coolers.

[29] AS/NZS 4859 provides general criteria, technical provisions and test procedures for building insulation.

CAN MNECB 1997 MNECH 1997	Building Envelope	"Components of the building envelope shall be in accordance with provincial, territorial or municipal building regulations, or, in the absence of such regulations, with the National Building Code of Canada." The mandatory envelope requirements also cover 1) above-ground components of the building envelope, 2) building components in contact with the ground, and 3) air tightness. The prescriptive requirements for the building envelope cover 1) the above-ground components of the building envelope and 2) special interior temperature conditions (which is only for MNECB).
CHN Commercial Buildings 2005	Design for Architecture and Building Thermal Engineering	The mandatory requirements for compliance, achieved with either the prescriptive requirements or trade-off options, include requirements for roofs, opaque walls, floors, vertical fenestration and skylights. The voluntary requirements for the inside surface temperature of thermal bridges in envelope, exterior window shading, natural ventilation, etc.
CHN Residential Building Codes in Heating, HSCW and HSWW Zones	Thermal Design for Architecture and Building Envelope (Heating and HSCW), Envelope (HSWW)	This section provides U-factors for building envelopes by outdoor temperature, shape coefficient, Window-to-Wall Ratio (WWR), orientation and other prescriptive criteria in the heating, HSCW, and HSWW zones.
IND ECBC 2008	Envelope	ECBC requires the building envelope to comply with the mandatory provisions and either the prescriptive criteria or the trade-off options. Building designers can also use the whole building performance provisions of the code to compensate for high performance in one area of compliance, such as the envelope, with somewhat lower performance in another (for example, lighting).
JAP CCREUB 2008	Heat Loss through the Building Envelope	This section includes a point system addressing specific insulation and window requirements, the orientation of outer walls and the building shape. Points required vary based on climate zone and building function.
JAP DCGREUH 1999	Thermal Insulation	This section provides three provisions related to the thermal insulation of the building envelope (building envelope design, insulation material construction and air-tight layers).
	Thermal Performance of the Building Envelope	This section requires that building components be insulated. Specifically, external roofs, ceilings, walls and floors should be insulated, while sheds, garages, attics, eaves, sleeve walls and verandas do not have to be insulated.
	Thermal Performance of Windows and Doors	This section provides the maximum heat transfer coefficient (U-factors) of windows and doors.

JAP CCREUH 1999	Maximum Annual Heating and Cooling Loads by Climate Zone	This section provides maximum allowable annual heating and cooling loads and related parameters and calculation methods.
	Standards for Equivalent Clearance Areas	This section defines equivalent clearance areas, which appear to relate to air exchange through the building envelope.
	Condensation Control	To prevent condensation that may reduce insulation performance and house durability, the property owner should prevent surface moisture condensation and moisture condensation within walls with proper measures.
KOR BDCES 2008	Construction Design Criteria	The Construction Design Criteria section includes both mandatory items and recommended items. The mandatory items cover thermal insulation and heat resistance requirements for the building envelope such as regional U-factor values by building envelope component and region-specific thicknesses of insulating materials. The recommended items provide suggestions on building orientation, sealing, active use of natural lighting, shading and natural ventilation for energy conservation.
USA ASHRAE 90.1-2007	Envelope	The building envelope shall comply with the mandatory provisions and either the prescriptive criteria or the trade-off option. Alternatively, the whole building energy cost approach in the Energy Cost Budget Method (ASHRAE 90.1-2007) or Total Building Performance Method (IECC 2006) may be used. The mandatory requirements cover requirements for insulation installation, window and door rating and building envelope sealing to minimize air leakage. This includes sealing of building envelope penetrations, vestibules and loading dock weather seals. In addition, the requirements cover how insulation, windows and doors should be labeled. The prescriptive requirements (which are open to trade-offs with alternate paths of compliance) cover requirements for roofs, opaque walls, below-grade walls, foundations, vertical fenestration (or wall window) and skylights.
USA IECC 2006	Building Envelope Requirements	This section provides mandatory and prescriptive provisions on insulation requirements, fenestration, air leakage, moisture control, maximum fenestration U-factor and solar heat gain coefficient (SHGC).

Based on the data availability and geographic location of APP countries, this section compares thermal characteristics of roof, external wall, floor and window for a generic 10-floor office building in hot, warm, cool and cold climate zones (Table 8). The comparison also includes China's residential buildings because they are mostly multi-family apartment buildings, and China has a growing stock of high-rise residential buildings. In addition, Figures 1 and 2 compare the wall and roof requirements for individual homes in the APP countries with separate codes for such buildings.

The comparison study is focused on four climate zones: hot, warm, cool, and very cold. The thermal criteria of these four climate zones are based on International Climate Zone Definitions of IECC 2006. Each zone contains cities of different countries (Table 9).

Table 10 Climate Zones and Cities Covered in the Comparison of Maximum U-factor for Building Envelope in APP Countries

Climate Zone	Thermal Criteria	Representative Cities
Hot	5,000 < CDD10 °C	Darwin (AUS), Hainan (CHN), New Delhi (IND) and Miami (USA)
Warm	2,500 < CDD10 °C <= 3,500 and HDD18 °C <= 3,000; HDD18 ° C <= 2000	Perth/Guildford (AUS), Shanghai (CHN), Shillong (IND), Tokyo (JAP), Inchon (KOR) and Atlanta (USA)
Cool	3000 < HDD18 ° C <= 4000	Thredbo (AUS), Vancouver (CAN), Lanzhou (CHN), Mukteswar (IND), Sapporo (JAP) and Chicago (USA)
Very cold	5,000 < HDD18 ° C <= 7,000	Calgary (CAN), Harbin (CHN), Leh (IND) and Duluth (USA)

Note: Thermal criteria are categorized based on International Climate Zone Definitions provided by IECC 2006. The hot zone corresponds to Zone 1 in IECC 2006, the warm zone corresponds to Zone 3, the cool zone to Zone 5 and the cold zoon to Zone 7.

Some general explanations and observations of the comparison study include:

- Australia provides minimum total R-value by region and building type for roofs, walls and floors. For windows, two calculation methods are employed to estimate aggregate conductance and aggregate solar heat gain for buildings. These window indicators are not directly comparable to the window U-factor and SHGC used in other countries.

- Canada provides maximum U-factor by principal heating fuel and types of roof and floors. For windows, the building energy codes provide maximum overall U-factors by WWR and type of fenestration.

- China provides maximum U-factor for commercial buildings by its five climate zones. U-factors in cold and very cold regions are also differentiated by a coefficient related to the building shape. Both U-factors and shading coefficients are employed as key indicators for windows. For residential buildings, a thermal inertia index is introduced into the thermal characteristics of the building envelop in heating zones. A building component with a thermal inertia index higher than 2.5 is defined as heavy construction.

- Compared to other APP countries, India has relative simple data structures for thermal insulation of the building envelope. Maximum U-factors for roof, walls, and floor are categorized into five climate zones and by operating hours such as daytime buildings and 24-hour buildings. Maximum U-factor and SHGC are two indicators for windows.

- Japan employs a point system for thermal insulation requirements of the building envelope. The minimum total score is 100. There are three score levels for walls and roof and seven for windows. The lowest score for most components is zero.

This study selects the midpoint score levels for comparison (specifically, the second score level for roofs and walls, and the fourth to sixth levels for windows).[30] Japan's building energy codes place heavy emphasis on SHGC. For example, the highest score for SHGC is 90 (for most of Japan), 50 (in the cold zone), and 170 (in the tropical zone), while the highest score for U-factors of walls and windows, respectively, is 30.

- South Korea also uses a point system to measure building performance in the BDCES. The minimum score should be 60 for the whole building (including construction and mechanical and electronic design criteria). For the building envelope, there are five levels of thermal requirements. South Korea provides minimum R-value by region for roofs, walls and floors for all buildings. For the envelope of large building, there are five levels of thermal requirements (overall envelope U-value) that are calculated by averaging the U-value both window and wall which varies depending on window to wall ratio. The RBFCO provides additional prescriptive requirements for insulation; the envelope analysis relies on the RBFCO requirements.
- The maximum U-factors in the United States commercial building energy codes are categorized by building materials. U-factor and SHGC are two indicators for window thermal insulation.

Four countries have jurisdictions in the hot climate zone including Australia, China, India, and the United States. In this zone, Australia has the most stringent requirements for roofs and floors, while India has the most stringent requirements for walls. The United States has comparatively stringent requirements for roofs and solar heat gain coefficient in windows. It has a wide range of requirements for walls, and the least stringent requirements for floors. China has relatively weak requirements in all categories, but it is not the least stringent in any single category. Figure 1 shows a comparison of the roof requirements in this zone, while Table 10 provides a more comprehensive comparison of all the key envelope requirements in this zone. Each of the comparative tables in this section highlight one country under each component. This is the country that has the most stringent requirements (for the majority of its commercial buildings) in a given category.

Several factors can affect the stringency of envelope requirements in different countries. Energy prices vary among countries. Most countries conduct cost-benefit analyses of the requirements before adopting them; differences in energy prices can lead to different recommendations on cost-effective requirements. Stakeholders can also play an important role, particularly in countries that use some type of stakeholder process or allow public comment before revising their standards. Insulation manufacturers may play a particularly active role in one country, while windows manufacturers may be more prominent in another. In some cases, if an industry like insulation is less vocal, it may also indicate that there are few products available on the local market. The products available and the role of industry can thus affect the requirements adopted.

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[30] We selected the midpoint levels instead of the maximum U-factors because Japan's commercial code has no maximum in most categories. In addition, since Japan does not have prescriptive commercial requirements – only trade-off ones – it was important to pick numbers that would lead to a building that complied, but did significantly exceed the compliance level in order to provide a good point of comparison.

Figure 1 Comparison of Roof U-factor Requirements in the Hot Zone

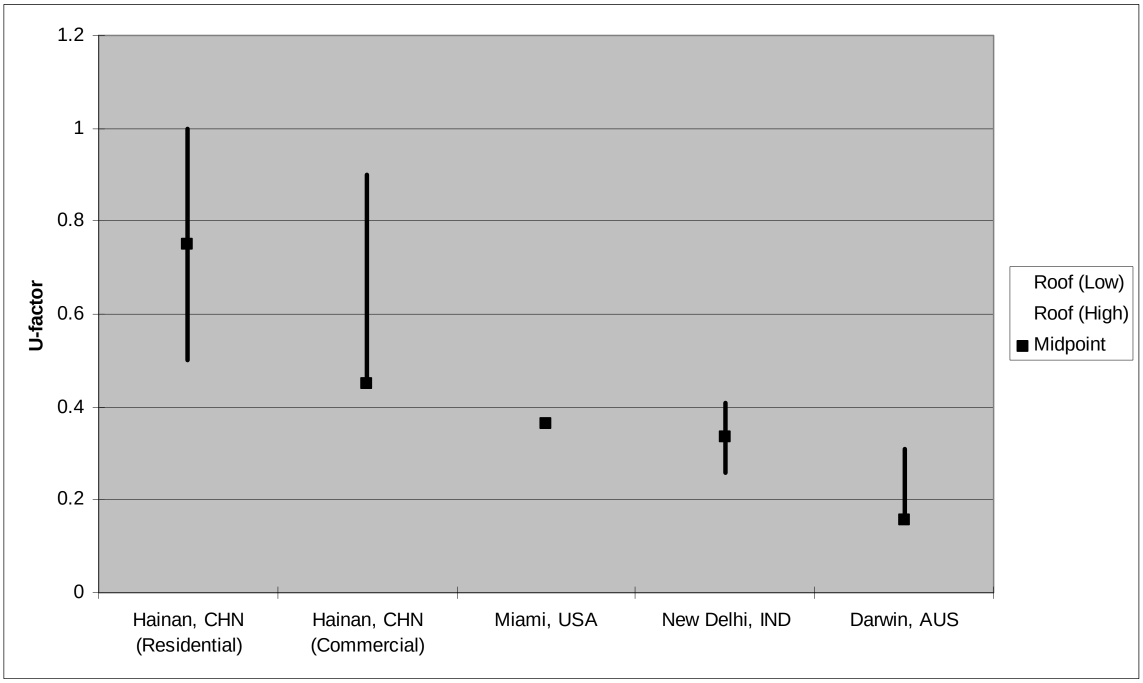


Table 11 Thermal Characteristics of Roofs, Walls, Floors and Windows in the Hot Zone

Cities	Maximum U-factors W/(m²·K)			Window Indicators
	Roof	External Wall	Suspended Floor	
Darwin AUS	0.31	0.56	0.67	Aggregate conductance factor not directly comparable with u-factors[31]
Hainan CHN	0.90	1.50	1.50	Maximum U-factor: **3.0** to 6.5 by WWR; shading coefficient, SC (east, south and west / north): 0.50/0.60 to 0.35/0.45 by WWR
	Heavy construction: 1.0, light construction: 0.5	*Heavy construction:1.0 to 2.0*	*N.A.*	*Maximum U-factor: **2.00** to 6.50 by WWR and outdoor conditions*
New Delhi IND	0.41 (Others) 0.26 (24-hour buildings),	0.41	N.A.	Maximum U-factor is 3.30, and maximum SHGC is **0.20** to 0.25

[31] RE Horne (2005) International comparison of building energy performance standards.

Miami USA	0.36 (Insulation above deck) to 0.37 (Metal building)	3.30 (Mass), 0.64 (Metal building), 0.70 (Steel framed)	1.83 (Mass), 1.99 (Steel-joist)	Maximum U-factor: 6.81, SHGC: 0.25, SHGC of north window: 0.33 to 0.61

Note: *Italicized* text refers to residential buildings. Shaded boxes and bold text highlight the most stringent requirements in a given category in the table. When countries have a range of requirements to cover different types of situations, the midpoint of this range is used as the point of comparison. N.A. = Not applicable.

Six countries have towns or cities in the warm zone including Australia, China, India, Japan, South Korea and the United States. South Korea has the most stringent requirements for roofs, followed closely by India and the United States. India appears to have more stringent requirements for walls, followed by South Korea and the United States. Japan has the strictest thermal requirements for windows followed by the United States. There is a significant difference in the requirements for roof and walls in China and Japan compared to the other countries in this climate zone. At the same time, for large office buildings in a warm climate, solar heat gain through windows is typically the most important envelope issue for energy efficiency. Figure 2 highlights the wall values, while Table 11 provides details on all the major envelope requirements.

Figure 2 Comparison of U-factor Requirements for External Walls in the Warm Zone

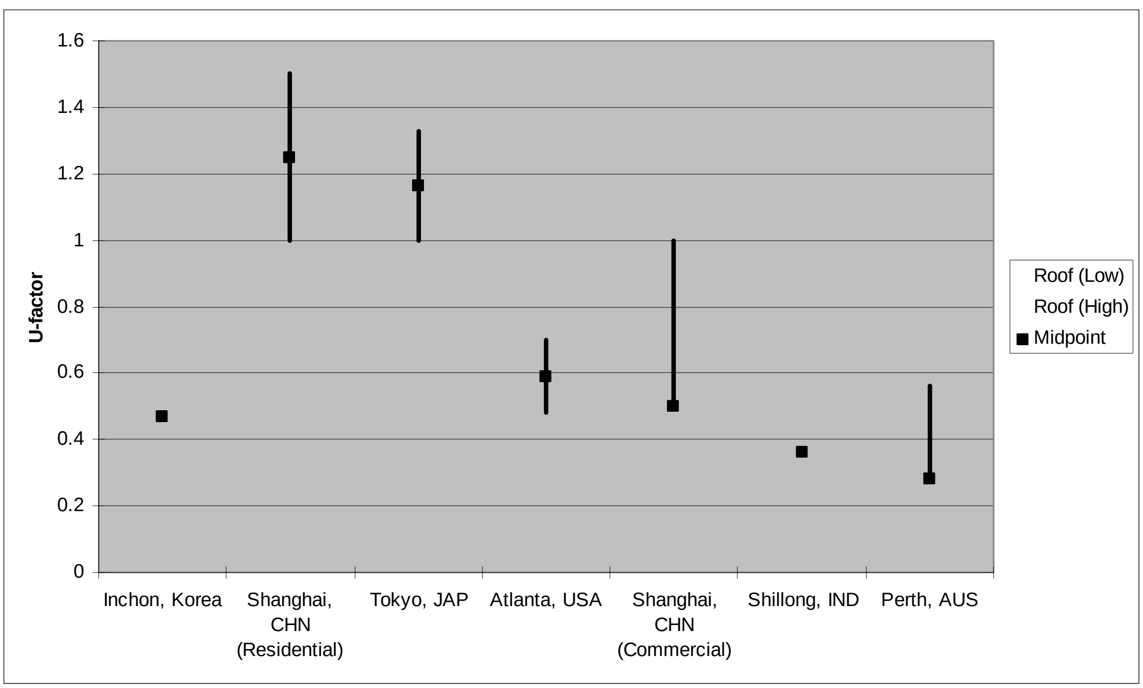


Table 12 Thermal Characteristics of Roofs, Walls, Floors and Windows in the Warm Zone

Cities	Maximum U-factors W/(m²·K)			Window Indicators
	Roof	External Wall	Suspended Floor	
Perth/ Guildford AUS	0.31	0.56	N.A.	Aggregate conductance factor not directly comparable with U-factors[32]
Shanghai CHN	0.70	1.00	1.0	Maximum U-factor: 4.7 to 2.5 by WWR; SC: 0.55/- to 0.40/0.50 by WWR
	Heavy construction: 0.8 to 1.0	*Heavy construction: 1.0 to 1.5*	*2.0*	*Maximum U-factor: 2.50 to 4.70 by WWR and outdoor conditions*
Shillong[33] IND	0.41 (Others) 0.26 (24-hour buildings)	**0.35** (Others) to 0.37 (24-hour buildings)	N.A.	Maximum U-factor is 3.30, and maximum SHGC is 0.51
Tokyo[34] JAP	1.52 to 0.76	1.33 to 1.00	N.A.	Maximum U-factor is 2.50 to **1.00**, SHGC: 0.30 to **0.15**.
Inchon[35] KOR	0.29	0.47	0.35 (Floor heating) to 0.41(Non floor heating)	Maximum U-factor: 3.0 (Apartment) to 3.4 (Commercial)
Atlanta USA	0.27 (Insulation above deck) to 0.37 (Metal building)	0.70 (Mass), 0.64 (Metal building), 0.48 (Steel framed)	0.61 (Mass), 0.30 (Steel-joist)	Maximum U-factor: 3.24 to 2.61 by WWR SHGC: 0.39 to 0.19 by WWR, SHGC of north window: 0.49 to 0.26 by WWR

Note: *Italicized* text refers to residential buildings. Shaded boxes and bold text highlight the most stringent requirements in a given category. When countries have a range of requirements to cover different types of situations, the midpoint of this range is used as the point of comparison. N.A. = Not applicable.

[32] For more information, please see R.E. Horne et al. 2005. International comparison of building energy performance standards, http://www.abc.net.au/4corners/content/2007/20070625_efficiency/RMIT.pdf.
[33] The ECO-III project office in India kindly provided information on climate conditions in India's major cities, which we used in this analysis.
[34] The maximum U-factor presented for Japan's commercial building energy codes represents the values in the midpoint score for each category in Japan's scoring system.
[35] The maximum U-factor in Korea building energy codes is applied to all buildings regardless of building size and usage based on the RBFCO. In some specific cases, it is possible that more stringent requirements from the BDCES could apply based on the BDCES's scoring system.

Six countries have jurisdictions in the cool zone including Australia, Canada, China, India, Japan and the United States. Australia has the strongest roof requirements, followed by certain categories of buildings in Canada, India and the United States. India has the highest thermal requirements for walls, followed by the wall requirements in Canada for electrically heated buildings, and China (commercial buildings with a shape coefficient between 0.3 and 0.4). Canada has the most stringent requirements for elevated floors. Japan has the highest U-values for windows. Figure 3 highlights the range of maximum U-factors for windows in the cool zone across the APP region. Table 12 below provides more detail on all the envelope requirements in this zone.

Figure 3 Comparison of Window U-factor Requirements in the Cool Zone

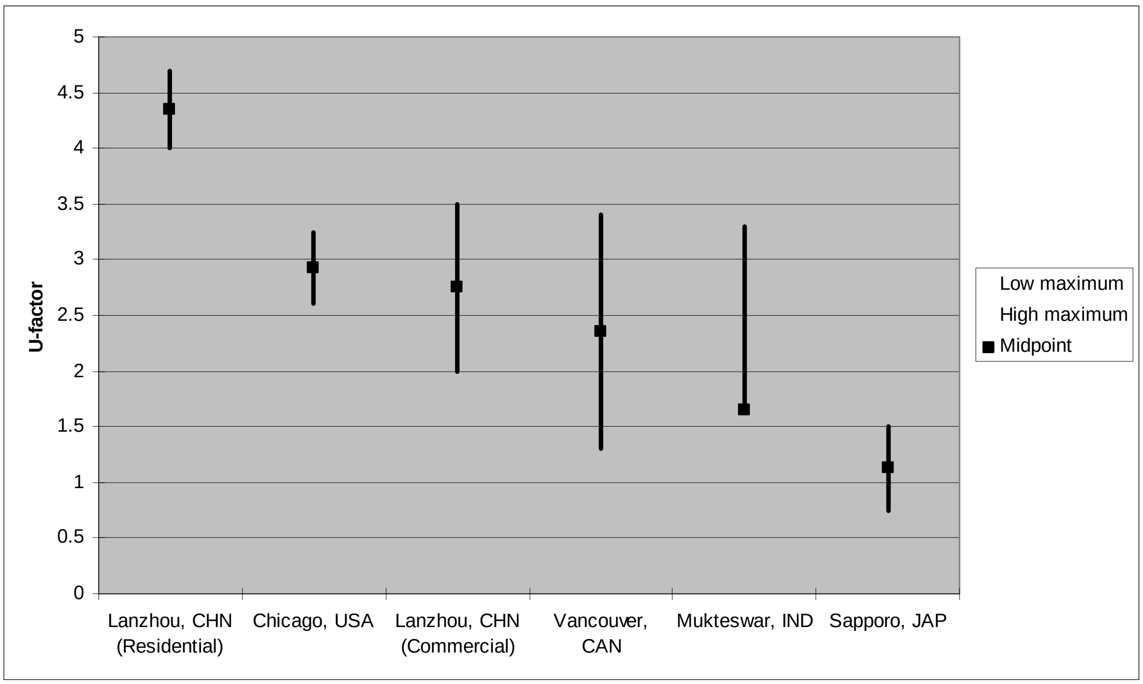


Table 13 Thermal Characteristics of Roofs, Walls, Floors and Windows in the Cool Zone

Cities	Maximum U-factors W/(m²·K)			Window Indicators
	Roof	Wall	Floor	Window
Thredbo AUS	0.23	0.56	0.40	Aggregate conductance factor not directly comparable with U-factors[36]
Vancouver CAN[37]	0.23 (Type II[38]), 0.41 (Type III[39] Electricity), and 0.47 (Type III Others[40])	0.45 (Electricity), 0.81 (Others)	**0.22** (Type I), 0.41 (Type II Electricity), and 0.47 (Type II Others)	Maximum U-factor: 1.90 to 1.30 (Electricity) and 3.40 to 1.70 (Others) by WWR
Lanzhou CHN[41]	0.45-0.55	0.50-0.60	0.50-0.60	Maximum U-factor: 3.5 to 2.0 by WWR; SC: 0.70 to 0.50
	0.50-0.70	*0.62-1.10*	*0.50*	*Maximum U-factor: 4.70 to 4.00*
Mukteswar IND	0.41 (Others) 0.26 (24-hour buildings)	**0.35** (Others) to 0.40 (24-hour building)	N.A.	Maximum U-factor is 3.30, and maximum SHGC is 0.51
Sapporo JAP	1.52 to 0.76	0.76 to 0.38	N.A.	Maximum U-factor is 1.50 (excluded 1.50) to **0.75**; solar heat gain coefficient is 0.30 (excluded 0.30) to **0.05**
Chicago USA	0.36 (Insulation above deck) to 0.37 (Metal building)	0.70 (Mass), 0.64 (Metal building), 0.48 (Steel framed)	0.50 (Mass), 0.30 (Steel-joist)	Maximum U-factor: 3.24 to 2.61 by WWR SHGC: 0.49 to 0.26 by WWR, SHGC of north window: 0.49 to 0.36 by WWR

Note: *Italicized* text refers to residential buildings. Shaded boxes and bold text highlight the most stringent requirements in a given category. When countries have a range of requirements to cover different types of situations, the midpoint of this range is used as the point of comparison. N.A. = Not applicable.

Canada, China, India and the United States all have jurisdictions in the very cold zone (in India, these jurisdictions are in certain mountainous regions). Canada has the strongest

[36] RE Horne (2005) International comparison of building energy performance standards.
[37] Vancouver International A mentioned in ASHRAE 90.1-2007.
[38] Type II of roof and Type I of floor refer to parallel-chord trusses and joist-type roofs.
[39] Type III of roof and Type II of floor refer to all other roofs (e.g., concrete decks with rigid insulation).
[40] "Others" refer to other principal heating sources, such as propane, oil, heat pumps and natural gas.
[41] The Chinese envelope requirements in the cold and very cold zones vary based on the shape of the building. We have provided the range.

thermal requirements for roofs, floors and windows because it has particularly stringent requirements for electrically heated buildings. Canadian U-factors for buildings with natural gas heating are much lower. The United States has the most stringent requirements for walls. Excluding Canada's electrically heated buildings, India has the most stringent wall requirements and China has the most stringent window U-values. China's thermal requirements for opaque building envelope components for commercial buildings are average for this climate zone. Figure 4 highlights the window U-factors, while Table 13 provides details on the range of requirements in the very cold climate zone.

Figure 4 Comparison of Wall U-factor Requirements in the Very Cold Zone

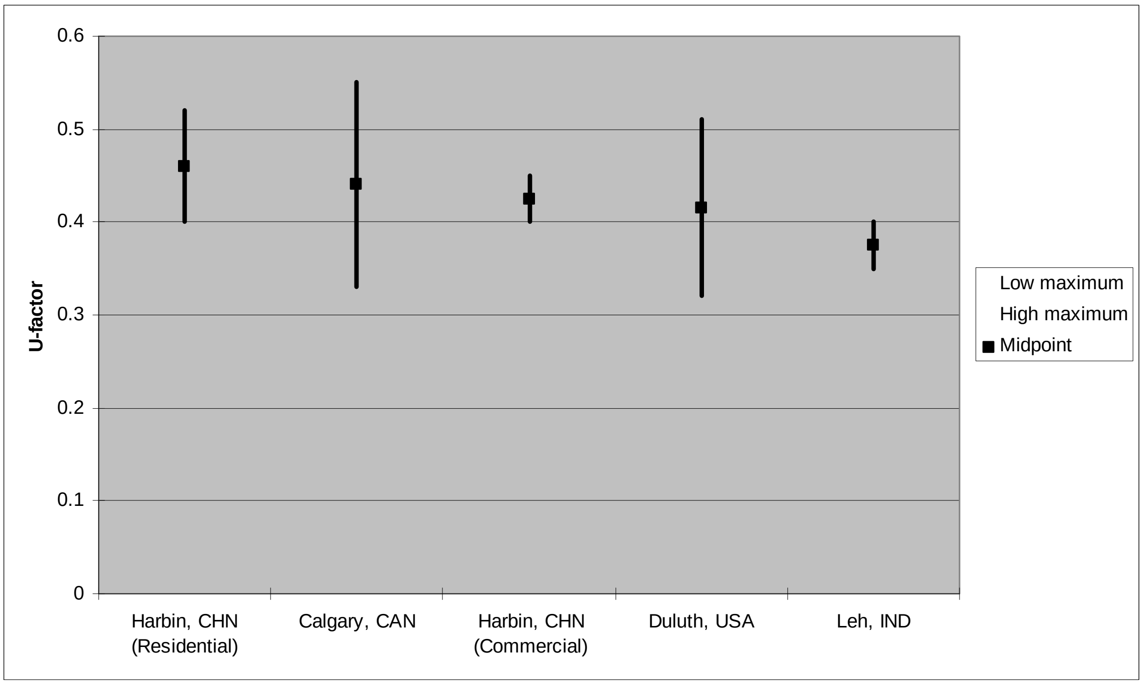


Table 14 Thermal Characteristics of Roofs, Walls, Floors and Windows in the Very Cold Zone

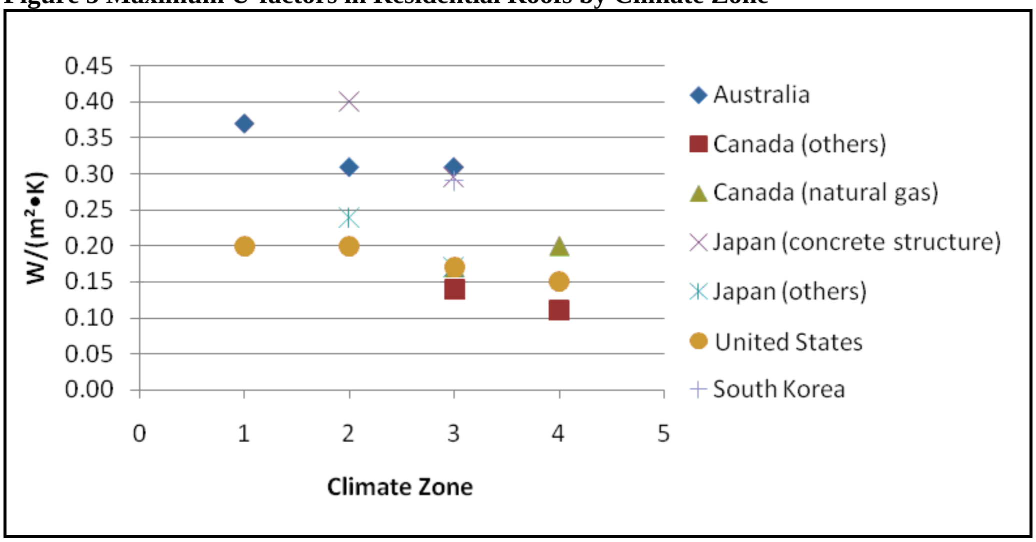
Cities	Maximum U-factors W/(m²·K)			Window Indicators
	Roof	Wall	Floor	Window
Calgary CAN	**0.23** (Type II), 0.29 (Type III non natural gas), and 0.47 (Type III natural gas)	0.33 (Non natural gas), 0.55 (Natural gas)	**0.22** (Type I), 0.29 (Type II by electricity and other), and 0.47 (Type II Others)	Maximum U-factor: 2.80 to **1.40** (Non natural gas) and 3.40 to 1.90 (Natural gas) by WWR.
Harbin CHN	0.30-0.35	0.40-0.45	0.40-0.45	Maximum U-factor: 3.0 to 1.7 by WWR
	0.30-0.50	*0.40-0.52*	*0.30 to 0.52*	*Maximum U-factor: 2.5*

Leh IND[42]	0.41 (Others) 0.26 (24-hour buildings),	0.35 (Others) to 0.40 (24-hour building)	N.A.	Maximum U-factor is 3.30, and maximum SHGC is 0.51
Duluth USA	0.36 (Insulation above deck) to 0.37 (Metal building)	0.51 (Mass), **0.32** (Metal building), 0.36 (Steel framed)	0.50 (Mass), 0.30 (Steel-joist)	Maximum U-factor: 3.24 to 2.61 by WWR SHGC: 0.49 to 0.36 by WWR, SHGC of north window: 0.69

Note: *Italicized* text refers to residential buildings. Shaded boxes and bold text highlight the most stringent requirements in a given category. When countries have a range of requirements to cover different types of situations, the midpoint of this range is used as the point of comparison. N.A. = Not applicable.

APP countries that also have codes addressing energy requirements for individual homes are Australia, Canada, Japan and the United States. Figures 5 and 6 look at the requirements for walls and roofs in such buildings across a range of climate zones in the APP countries. Not surprisingly, requirements become more stringent in the colder climate zones. Overall, the United States has the most stringent requirements for insulation in roofs among these four countries but no single country appears to have the most stringent wall requirements across all the climate zones.

Figure 5 Maximum U-factors in Residential Roofs by Climate Zone[43]

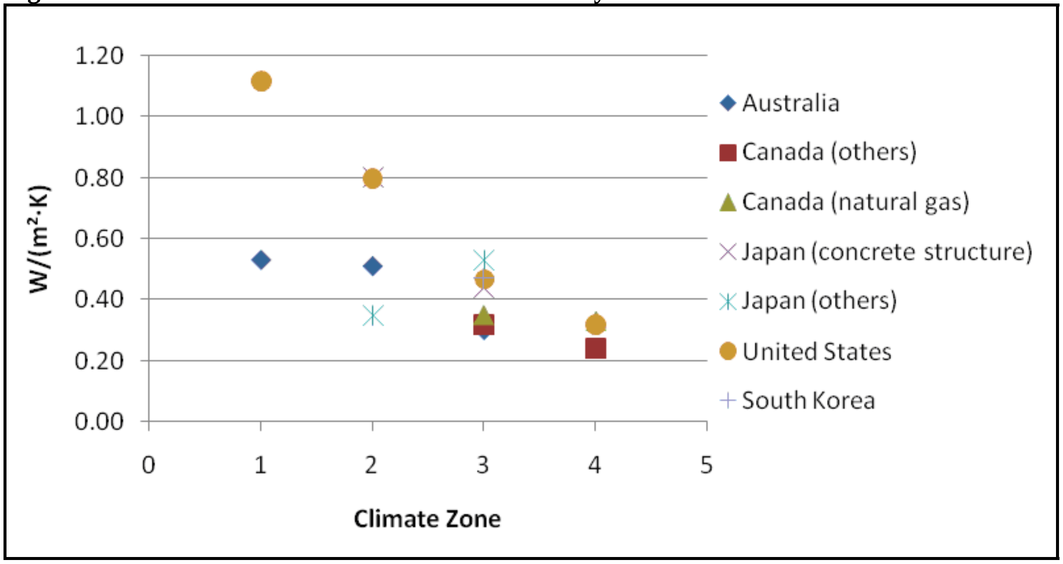


Note: Climate zone 1 is hot, 2 is warm, 3 is cool, and 4 is very cold. See Table 9 for detailed descriptions of these zones.

[42] For more information, please see www.usc.edu/dept/architecture/mbs/papers/ecs/94_aeshim/himalayas_94.html.

[43] The maximum U-factor for residential roofs in South Korea (0.29 $W/m^2 \cdot K$) is cited in RBFCO.

Figure 6 Maximum U-factors in Residential Walls by Climate Zone[44]



Note: Climate zone 1 is hot, climate zone 2 is warm, 3 is cool and 4 is very cold. See Table 9 for detailed descriptions of these zones.

3.4 HVAC

Key Findings

→ All APP countries have an HVAC section in their building energy codes.

→ For HVAC equipment, most countries refer to other equipment standards and/or present energy performance standards in their HVAC section.

→ China, Japan and South Korea address natural ventilation in their building energy codes.

HVAC refers to heating, ventilation and air conditioning equipment and systems in buildings and houses. As the most important mechanical component of a building, HVAC contributes to a major share of building energy use; hence, it is covered by all building energy codes in APP countries.

Three sections in BCA 2007 (Australia) cover HVAC including 1) building sealing (such as chimneys and flues, windows and doors, exhaust fans and others), 2) air movement (such as ventilation openings) and 3) air conditioning and ventilation systems (such as equipment efficiency).

Building energy codes in Canada, China, India and the United States (ASHRAE 90.1–2007) provide both mandatory and prescriptive provisions on HVAC (Table 15).

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[44] The maximum U-factor for residential walls in South Korea (0.47 W/m^2·K) is cited in RBFCO.

Table 15 HVAC in the Building Energy Codes of Canada, China, India and the United States

		Mandatory	Prescriptive
CAN	MNECB 1997 MNECH 1997 Asterisked items appear only in the MNECB.	Equipment sizing/air distribution systems/air intake and outlet dampers/piping for heating and cooling systems/pumping system design*/equipment installed outdoors/electric heating systems*/recessed heaters/air distribution systems serving space with special requirements*/ temperature controls/ humidification/ shutoff and setback* Equipment efficiency/ documentation*	Fan system design*/cooling with outdoor air*/control of heating, ventilating and air-conditioning systems*/heat recovery
CHN	Commercial 2005	Heating/ventilation and air conditioning/heating and cooling sources for heating and air conditioning systems/monitoring and control	Heating/ventilation and air conditioning/heating and cooling sources for heating and air conditioning systems/monitoring and control
	Residential-Heating 1995	Heating systems/piping and ductwork	Heating system design
	Residential-HSCW 2001	System design of cooling source/heating source/ventilation and air adjustment	System design of cooling source/heating source/ventilation and air adjustment
	Residential-HSWW 2003	System design of cooling source/heating source/ventilation and air adjustment	System design of cooling source/heating source/ventilation and air adjustment
IND	ECBC 2008	Natural ventilation/minimum equipment efficiencies/controls Piping and ductwork/system balancing/condensers	Economizers/variable flow hydronic system
USA	ASHRAE 90.1-2007	Equipment efficiencies/verification and labeling/ load calculations/controls/ HVAC system construction and insulation/completion requirements	Economizers /simultaneous heating and cooling limitation/air system and control/hydronic system design and control/heat rejection equipment/energy recovery/exhaust hoods/radiant heating system

There is an ongoing effort in Canada to maintain harmonization with HVAC, lighting and power standards in the United States. Like Australia, Japan covers HVAC in several sections of its building energy codes (Table 16). Unlike other APP countries, Japan puts a heavy emphasis on ventilation in residential houses (DCGREUH 1999 and CCREUH 1999).

Table 16 HVAC in Japan's Building Energy Codes

Commercial	Residential	
CCREUB 2008	**DCGREUH 1999**	**CCREUH 1999**
1. Air conditioning and heating 2. Mechanical ventilation (except for air conditioning and heating)	1. Ventilation plans 2. Heating, cooling and hot water supply plans 3. Airflow plans 4. Information on Building Operations and Maintenance ("How to Live")	1. Condensation control 2. Ventilation volume 3. Prevention of indoor air contamination from heating and hot water systems 4. Planned operation of heating and cooling systems 5. Ventilation routes for heat dissipation

South Korea's building energy code covers HVAC in two sections, construction design criteria and machinery design criteria, with both mandatory and recommended provisions (Table 17).

Table 17 The Main Focus of HVAC Requirements in South Korea's Building Energy Code

	Construction Design Criteria	Machinery Design Criteria
Mandatory Items	Dew condensation/prevention and sealing	Design temperature of HVAC/minimum efficiency of pump/pipe insulation/ Outside air conditions/heat supply and transmission facilities
Recommended Items	Layout/sealing/ventilation	Indoor temperature/heat supply facilities/air conditioning facilities /water distribution facilities/ventilation and control facilities

ASHRAE 90.1-2007 (United States) provides comprehensive minimum efficiency requirements to a variety of air-conditioning equipment by a wide range of size category including 1) electronically operated unitary air conditioners and condensing units; 2) electronically operated unitary and applied heat pumps and water chilling packages; 3) electrically operated packaged terminal air conditioners, packaged terminal heat pumps, single-package vertical air conditioners, single-package vertical heat pumps, room air conditioners and room air-conditioner heat pumps; 4) warm air furnaces and combination warm air furnaces/air-conditioning units, warm air duct furnaces, and unit heaters; 5) gas and oil fired boilers; and 6) centrifugal chillers.

MNECB (Canada) covers minimum energy performance of air-conditioning equipment with fewer categories compared to ASHRAE 90.1-2007. Since MNECB was issued in 1997, most of its performance requirements have been less stringent than the same category in ASHRAE 90.1-2007 (Table 18).

Table 18 Equipment Performance Standards for Air-cooled Unitary Air Conditioners – Electrically Operated (Except Packaged Terminal Air Conditioners and Room Air Conditioners)

Class	CAN (MNECB)	USA (ASHRAE 90.1–2007)
73-222.7 kW (250,000 – 760,000 Btu/h)	EER = 8.5 IPLV = 7.5	EER: 9.3 – 9.5 (before 1/1/2010); 9.8 – 10.0 (as of 1/1/2010); IPLV: 9.5 – 9.7
> 222.7 kW (760,000 Btu/h)	EER = 8.2 IPLV = 7.5	EER: 9.0 – 9.2 (before 1/1/2010); 9.5 – 9.7 (as of 1/1/2010); IPLV: 9.2 – 9.4

ECBC 2007 (India) refers to other Indian standards and ASHRAE 90.1-2004 for most air-conditioning equipment. ECBC 2007 provides minimum energy performance of air-cooled chiller, centrifugal water-cooled chiller, and rotary screw and scroll compressor. While the minimum energy performance of centrifugal chillers in ASHRAE 90.1-2007 is categorized by both the exiting chilled water temperature and the condenser flow rate, the requirements of ECBC 2007 are much simpler (Table 19).

Table 19 Minimum Efficiencies for Centrifugal Chillers

Class	IND (ECBC 2007)	USA (ASHRAE 90.1-2007)
< 530 kW (or < 150 tons)	COP = 5.80 IPLV = 6.09	COPstd = 5.00, COP: 3.84 to 7.09 IPLVstd = 5.25, NPLV = 4.52 to 8.35
>= 530 kW and <= 1050 kW (≥ 150 and <= 300 tons)	EER = 5.80 IPLV = 6.17	COPstd =5.55, COP: 4.24 to 7.83 IPLVstd = 5.90, NPLV = 4.52 to 8.35

BCA 2007 (Australia) covers the minimum energy efficiency ratio for packaged air-conditioning equipment (such as air conditioner and heat pump) and refrigerant chillers. Japan provides minimum efficiency standards for air conditioning in commercial buildings as part of a scoring system. South Korea does not provide specific requirements for the energy efficiency performance of air-conditioning equipment in its code because many building occupants install HVAC after the building is constructed.

3.5 Service Water Heating

Key Findings

→ Service water heating is covered in the building energy codes of all APP countries, except China.

→ Most countries refer to the energy performance requirements of service water heating in equipment standards, but they may also present energy requirements in the building energy code itself.

→ Equipment energy efficiency, insulation and controls are the most frequently addressed issues in the section on service water heating. Other issues are pools (Canada, India, and the United States), solar water heating (India, Japan, South Korea and the United States), air pollution (Japan), and water conservation (Canada).

Service water heating refers to heating of water for domestic or commercial purposes but not for space heating. The section on service water heating standards often focuses on 1) the energy efficiency of water heating equipment/systems, 2) insulation, 3) controls, and 4) pools (Table 20). Other issues addressed by individual APP countries include solar water heating and water conservation.

Table 20 Major Issues Covered under Service Water Heating in Building Energy Codes in APP Countries

<table>
<tr><th rowspan="3">Items</th><th colspan="2">AUS</th><th colspan="2">CAN</th><th>IND</th><th colspan="3">JAP</th><th>KOR</th><th colspan="2">USA</th></tr>
<tr><th colspan="2">BCA 2007</th><th>MNECB 1997</th><th>MNECH 1997</th><th rowspan="2">ECBC 2007</th><th>CCREUB 2008</th><th>DCGREUH 1999</th><th>CCREUH 1999</th><th rowspan="2">BDCES 2008</th><th>ASHRAE 90.1-2007</th><th>IECC 2006</th></tr>
<tr><th>C</th><th>R</th><th>C</th><th>R</th><th>C</th><th>R</th><th>R</th><th>C</th><th>R</th></tr>
<tr><td>Equipment /system efficiency</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td rowspan="4">N.A.</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Insulation</td><td rowspan="3">N.A</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Controls</td><td rowspan="2">N.A.</td><td>X</td><td>X</td><td>N.A.</td><td>X</td><td rowspan="2">N.A.</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Pools</td><td>X</td><td>X</td><td>X</td><td>N.A.</td><td>N.A.</td><td>X</td><td>X</td></tr>
</table>

Note: C = commercial buildings, R = residential buildings, N.A = Not applicable. China does not include service water heating in its building energy codes.

Equipment/System Efficiency Using energy-efficient water heating is addressed by all the building energy codes studied except for those of China, which does not include service water heating in its commercial and residential building energy codes.
In BCA 2007 (Australia), the thermal efficiency of a gas-fired water heater, such as a boiler in a heating system for a building, must meet a thermal efficiency 0.75 to 0.83, and 0.76 to 0.80 for an oil-fired system. For design and installation of a hot water supply system for sanitary and food preparation, the BCA references AS/NZS 3500.4.

MNECB (Canada) requires that service water heating equipment complies with the relevant federal, provincial or territorial standard and act; in the absence of such a standard and act, the energy efficiency performance requirements in MNECB should be met. ASHRAE 90.1-2007 (the United States) and MNECB cover similar types of water heating equipment (Table 21), with some differences in size categories. Japan's commercial code also has requirements regarding equipment and system efficiency.

Table 21 Service Water Heating Equipment Performance Standards

Class	CAN (MNECB)	USA (ASHRAE 90.1-2007)
Electric: > 12 kW	SL <= 0.30 + 27/Vt	20+35 √V, SL, Btu/h
Oil-fired storage-type: ≤ 30.5 kW, where capacity > 190L	0.59 – 0.0019 V	0.59 – 0.0019 V

ECBC 2007 (India) refers to other Indian standards for equipment efficiencies.

Insulation Thermal insulation of water heating piping, storage, and ductwork is important to improve system energy efficiency.

- Australia mandates that central heating water piping located in an unconditioned space must be thermally insulated to achieve fixed minimum R-values ranging from 0.2 (the hottest zone) to 0.6 (the coldest zone). Heating and cooling ductwork and fittings must be sealed against air loss and achieve set minimum total R-values ranging from 0.4 (for fittings across all zones) to 1.5 (for heating-only systems or refrigerated cooling-only systems in the coldest zone) (BCA 2007).
- Commercial building energy codes in both Canada and the United States provide minimum pipe insulation thickness and insulation conductivity for hot water systems (MNECB 1997 and ASHRAE 90.1-2007). The United States requires circulating service hot water piping in a residential house to be insulated to at least R-2 (IECC 2006); for houses in Canada this value is R-1.5 (MNECH 1997).
- India requires piping for heating systems with a design operating temperature of 60^{o}C or higher to have at least R-4 insulation and R-2 for heating systems with a design operating temperature of less than 60^{o}C (ECBC 2007).
- South Korea requires a minimum insulation thickness of between 25 mm and 50 mm, depending on the pipe diameter for hot water piping. For cold water pipes, the range is between 25 mm and 40 mm with the goal of preventing condensation. For boilers and other heat generation systems, the insulation thickness must be between 25 mm and 70 mm.

Controls Canada requires service water heating systems with storage tanks in buildings and houses to be equipped with automatic temperature controls and shutdown controls for any storage capacity over 100 liters (MNECB 1997 and MNECH 1997).

Japan's building energy codes promote the use of controls for water heating in commercial buildings (CCREUB 1999).

Service water heating system controls in the United States commercial buildings include temperature controls, temperature maintenance controls, outlet temperature controls, and circulating pump controls (ASHRAE 90.1-2007). Residential building codes require that "automatic-circulating hot water system pumps or heat trace shall be arranged to be conveniently turned off automatically or manually when the hot water system is not in operation."

Pools Canada, India and the United States have similar provisions on swimming pools, which cover pool heaters, time switchers and pool covers.

Solar water heating India's code requires the use of solar water heating in residential facilities, hotels, and hospitals with a centralized system to provide at least one fifth of the design capacity heating (ECBC 2007). South Korea has provisions for solar water heating in BDCES 2008. Solar water heating should have active demand control to maximize daytime consumption and reduce heat storage capacity, and an integrated control system installed between the solar heating and auxiliary heat source (BDCES 2008). Codes in Australia, Japan and the United States also provide exceptions to other requirements when solar water heating is used.

Air pollution When installing a combustion-type heating or hot water supply system in residential houses, the Japan residential standard encourages property owners to take measures to minimize contamination of the inside air (CCREUH 1999).

Water conservation Canada has mandatory provisions on water conservation for commercial buildings (MNECB 1997) and non-mandatory provisions for residential houses (MNECH 1997).

3.6 Lighting

Key Findings

- → Most APP countries cover lighting in their commercial building energy codes, but none cover it in their residential building energy codes. China covers lighting in a separate code.
- → Lighting energy efficiency (or lighting power density) and lighting controls are the most commonly addressed issues.
- → Australia has the most stringent energy efficiency requirements for lighting in office buildings.

Lighting energy efficiency is part of the building energy codes for commercial buildings in six APP countries. The lighting energy efficiency provisions cover lighting in interior and exterior spaces and lighting controls. Lighting power density (in watts per square meter) is employed as a key indicator for the assessment of lighting energy efficiency. Australia, Canada, China, India and the United States provide maximum lighting power density by building and/room function (Table 22), while Japan and South Korea do not express their lighting requirements as lighting power density.

Table 22 Maximum Illumination Power Density in Offices (W/m^2)

	Maximum Illumination Power Density in Offices
AUS	7 (artificially lit to an ambient level of less than 200 lx[45]) and 10 (artificially lit to an ambient level of 200 lx or more).
CAN	18.3 (> 25000 m^2) to 20.4 (0 to 200 m^2).
CHN	11 (current value[46]) and 9 (target value[47]) for general offices and meeting rooms, and 18 (high-class offices, design offices).
IND	10.8 (building area method) and 11.8 (space function method).
JAP	Japan gives lighting efficiency in lumens per watt, not watts per m^2. The commercial code also has requirements that factor in the lit area and the distance between the light source and the work space. Efficient task lighting receives high scores in this weighted system.
KOR	The BDCES has mandatory efficiency standards for each lighting fixture or lamp, but does not regulate the power density of the building as a whole. There are also requirements for controls, such as motion-sensors and the controls to allow occupants to turn off the lights in a specific part of a room. Extra points are given to buildings with a high share of LED lights.
USA	10.8 (building area method) and 11.8 (space function method).

[45] lx is an international standard unit for luminance.
[46] The current values refer to the values required or recommended by the lighting standard.
[47] The target values are the values to be in use in accordance with the decisions made by related administrative agencies.

China has a separate lighting standard, the Standard for Lighting Design in Buildings (2004), which covers energy efficient design for lighting in residential, commercial and industrial buildings. None of the residential building energy codes in APP countries cover lighting. In the countries that have special codes for single-family homes (Australia, Canada and the United States), this is probably because many lighting fixtures are often added after the building is built.

3.7 Electric Power

Key Findings

- → Australia, Canada, India, South Korea and the United States have individual sections on electric power. China and Japan do not provide specific sections and subsections on this topic.
- → Power sections/subsections cover such main issues as 1) efficiency of distribution, 2) transformers, 3) motors, 4) power control, 4) metering and 5) documentation.

Electric power refers to electric equipment and systems associated with buildings and houses. The building energy codes of Canada, India, and the United States have individual sections on this issue. Australia integrates power controls into a section titled Artificial Lighting and Power. A section titled Electric Facility Design Criteria in South Korea's building energy codes provide a subsection on electric power. China and Japan do not provide a specific section or subsection in their building energy codes (Table 22).

Table 23 Major Covered Issues in Electric Power of Building Energy Codes in APP Countries

<table>
<tr><th rowspan="3">Items</th><th colspan="2">AUS</th><th colspan="2">CAN</th><th>IND</th><th>KOR</th><th colspan="2">USA</th></tr>
<tr><th colspan="2">BCA 2007</th><th>MNECB 1997</th><th>MNECH 1997</th><th rowspan="2">ECBC 2007</th><th rowspan="2">BDCES 2008</th><th>ASHRAE 90.1-2007</th><th>IECC 2006</th></tr>
<tr><th>C</th><th>R</th><th>C</th><th>R</th><th>C</th><th>R</th></tr>
<tr><td>Efficiency of distribution</td><td rowspan="3">N.A.</td><td rowspan="7">N.A.</td><td>N.A.</td><td rowspan="3">N.A.</td><td>X</td><td>X</td><td>X</td><td rowspan="4">N.A.</td></tr>
<tr><td>Transformers</td><td>X</td><td>X</td><td>X</td><td rowspan="4">X</td></tr>
<tr><td>Motors</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Power Control</td><td>X</td><td>X</td><td>X</td><td>N.A.</td><td>X</td></tr>
<tr><td>Metering</td><td rowspan="3">N.A.</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Documentation</td><td>X</td><td rowspan="2">N.A.</td><td>X</td><td rowspan="2">N.A.</td><td></td><td rowspan="2">N.A</td></tr>
<tr><td>Others</td><td>N.A.</td><td>X</td><td>N.A.</td></tr>
</table>

Note: C = Commercial buildings, R = Residential buildings, N.A = Not applicable.

The main issues in a power section/subsection include 1) efficiency of distribution, 2) transformers, 3) motors, 4) power control, 4) metering, 5) documentation and 6) others.

Efficiency of Transmission and Distribution Systems India requires that the power distribution system losses not exceed 1% of the total power usage (ECBC 2008). South Korea mandates that the main line voltage drop must comply with the Korea Electric Association's indoor wiring regulations (BDCES 2008).

Transformers Canada requires that transformers must comply with the relevant federal or local energy-efficiency standards, or in the absence of such standards, with good practice (MNECB 1997). India sets mandatory requirements on maximum allowable losses for dry type and oil-filled distribution transformers, respectively. It also requires measurement and reporting of transformer losses (ECBC 2008). South Korea mandates installing energy-efficient transformers and transformer monitors (BDCES 2008).

Motors Canada mandates that most motors in buildings must comply with the standards of the Canadian Standards Association. This provision does not apply to certain motors, such as elevator motors (MNECB 1997). India provides mandatory requirements on energy-efficient motors including motor efficiency, ratings, nameplates, rewinding practices, and certificate (ECBC 2008). South Korea suggests the installation of energy-efficient induction motors and an energy-efficient system for the control of elevator motors (BDCES 2008). Japan's commercial code has requirements on motors used for lifting (primarily elevators).

Power Control Australia building energy codes provides prescriptive requirements on power control in the interior artificial lighting. In addition, time switches must control the power supply to boiling or chilled water storage units (BCA 2007). Canada mandates that power controls must include switches or timers, with or without manual overrides. The controls must be inside the commercial building and residential houses (MNECB and MNECH 1997). South Korea recommends the configuration of controllers on banks of transformers and demand controllers for peak times (BDCES 2008).

Metering Dwelling units and suites in Canada must have individual metering to ensure billing accuracy. Electrical distribution systems with a load-carrying capacity over 250 kVA must be able to monitor the energy consumption of each tenant or service with a connected load of 100 kVA or more. Each house must have an individual meter. Monitoring is required for commercial buildings but not for residential houses (MNECB 1997 and MNECH 1997).

In India, electric metering should be installed for recording energy, demand, total power factor, and/or voltage dependent on service capacity (ECBC 2008). South Korea and the United States recommend the installation of individual electricity consumption meters in each dwelling unit (BDCES 2008 and IECC 2006) and each rental space in commercial buildings (BDCES 2008).

Documentation Canada specifies the documentation requirements for compliance of commercial buildings (MNECB 1997). India requires maintaining a record of design calculations for power distribution system losses (ECBC 2008). The United States requires drawings (such as a diagram of the building electrical distribution system and floor plans indicating location and area served for all distribution) and manuals (such as equipment rating and operation manuals) to be submitted to the building owner (ASHRAE 90.1-2007).

3.8 Trade-off and Building Performance Approach

Key Findings

→ Most APP countries offer two alternatives to the prescriptive requirements: trade-offs for the building envelope requirements and a building performance approach that encompasses a range of building energy requirements. In most APP countries, there are also certain mandatory requirements that must be met regardless of any alternative options. The approach to building performance varies between APP countries. The United States employs an energy/cost/budget method, which is an energy cost-based type of building performance that differs from other energy consumption-based building performance approaches.

→ Japan and South Korea employ a scoring or point approach, which falls somewhere between a trade-off and performance approach. In Japan's commercial code, each section of the code is scored separately, making it more akin to the trade-off alternatives in countries with prescriptive requirements. Japan's commercial and residential codes both also have performance requirements based on energy consumption per square meter. In South Korea, all the requirements in the building energy code are scored together, making it more like a performance approach. South Korea also has prescriptive insulation requirements in its general building code.

→ China has adopted a hybrid approach: first, the building performance approach is used to determine the difference in energy consumption between a designed and a reference building, then the difference is adjusted using the trade-off approach.

Australia lists two types of building performance approaches for buildings. For dwellings, the thermal calculation method is employed to comply with the Australian Building Codes Board's Protocol for House Energy Rating Software. Each dwelling unit has an energy rating of not less than 3 stars. For commercial buildings, the codes set maximum regional annual energy allowances (in megajoules per square meter) by fuel and building types, with a separate section devoted to the methodology to calculate annual energy consumption. There are also provisions for trade-offs and a building performance approach for houses.

China's commercial building energy codes combine the performance approach and trade-off approach. First, annual energy consumption is calculated and compared for heating and cooling of a reference and designed building. Second, the trade-off approach is used only if the value of a designed building is higher than the reference case. A similar combination approach also applies for residential building codes.

Japan's and South Korea's building energy codes for commercial buildings adopt a scoring approach: the desired measures that lead to higher building energy efficiency are scored with higher points. Differing from its commercial building energy codes, Japan's residential building energy codes have prescriptive measures instead of scored ones, though with both the residential and commercial codes in Japan, there are performance-based metrics as well.

South Korea has a recommended building energy efficiency rating system based on the performance approach. However, in some areas such as new towns, municipal governments may require that their new buildings obtain a higher level label for energy efficiency than specified in the building code. In addition, South Korea is preparing a new performance-based code which sets requirements for maximum annual energy usage. Accordingly, after 2010, buildings over 10,000 square meters will be required to submit annual energy consumption and a CO_2 emission report to the government. These documents must be calculated by the performance approach.

Canada and India adopt compliance paths similar to that of the United States including options of simpler trade-offs and building performance standards. Each major section (such as building envelope, HVAC, hot water service, lighting, and electric power) contains mandatory provisions followed by either prescriptive provisions or a building performance approach, which often leads to a separate section. A trade-off approach is introduced in the section on building envelope. Some differences in building energy codes of these three countries include the following:

- Canada. The section on building energy performance compliance lists the conditions and limitations of applying the building performance approach and refers to two other complementary documents for details of calculation procedures. In the section on building envelope, two trade-off approaches–simple trade-offs and computer-assisted trade-offs–are alternative options to prescriptive provisions.
- India. An ECBC appendix titled Whole Building Performance Method provides details on modeling requirements for calculating a reference and designed building. The building trade-off calculation method for the envelope performance factor is introduced in another appendix.
- The building performance approach in the United States' ASHRAE 90.1-2007 uses the energy/cost/budget method, which compares the annual energy costs of a reference building and a design building. The cost-oriented building performance approach differs from other building performance approaches that often use indicators of energy consumption for comparison. In the section on building envelope, a trade-off approach is introduced and details on the calculation of the envelope performance factor appear in an appendix. In the HVAC section, a simplified approach[48] is an alternative to the mandatory provisions, prescriptive provisions, and the energy/cost/budget method. In the lighting section, the building area method and space-by-space method are two trade-off approaches offered. The United States' residential building energy code, IECC 2006, offers two alternative compliance approaches (in addition to the prescriptive path): the trade-off approach for the building envelope and a simulated performance approach for the whole house.

3.9 Renovations

Some countries require any renovation or addition to meet the code, while others establish a threshold. If renovations are required to meet the code, they must typically meet all relevant aspects of the code. For example, Canada's codes specify that renovations of at least 10 square meters in buildings and homes must meet the building energy code requirements. In the United States, ASHRAE 90.1-2007 considers any addition beyond the existing building envelope or alteration to an existing, regulated building to fall under the code. IECC 2006 generally requires any additions, alterations, renovations or repairs to meet the code.

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[48] The simplified approach is an optional path for buildings of less than two stories (2323 m^2 or 25,000 ft^2) and according to where the HVAC system complies with certain provisions listed in the HVAC section.

In countries that only require that large buildings meet the code, renovations can play an interesting role because additions can put buildings over the compliance threshold. India's code requires that additions, together with the entire building, must comply if the total size of the new building exceeds the minimum compliance threshold. India's code also requires that certain types of alterations must meet the code if the existing building falls within the regulated size limits (these include certain alterations to the building envelope, HVAC systems and other systems related to energy). China is considering a separate code that would regulate renovation of buildings in the coldest parts of that country.

3.10 Operations and Maintenance

Only a few APP countries include requirements within the building energy code on how a building is operated once it is built. Japan's residential standard includes information on building operations and maintenance in a section called "How to Live," which covers issues such as preventing incomplete combustion in heating systems, preventing condensation and ensuring proper ventilation. Likewise, owners of houses and buildings must provide local authorities with reports on maintenance every three years. Australia's code has a section on maintenance whose objective is "to reduce greenhouse gas emissions by efficiently using energy throughout the life of the building". This applies only to non-residential buildings and spaces. This section requires that the building's services be able to use energy efficiently and continually meet the required standard. It applies to systems such as adjustable or motorized shading devices, time switches and motion detectors, room temperature thermostats, heat transfer equipment, and others. Other countries have programs to promote energy efficiency in existing buildings, but they do not include requirements or other details in their building energy codes. This is probably because, in most cases, the point of control for the building energy codes is with the building permitting process, and after that, enforcement is difficult.

4 Enforcement and Compliance

4.1 Enforcement Framework

Key Findings

→ Local governments in all APP countries have a major role in verifying code compliance for all or part of a building's design. However, some countries (e.g., China, Japan and the United States) may bring in third parties to oversee the design stage. This is common in China but rare in the other countries. In other countries, such as South Korea, the national government may also take part in code enforcement during this stage (through the Korean Energy Management Corporation). If there are third parties, they are usually certified and appointed by local governments.

→ Building inspections are performed by local governments in Australia, Canada, South Korea and the United States. As in the design stage, third parties may also be involved in inspections in the United States, although this is rare.

- → Japan only supervises the building design, and does not inspect buildings for energy code issues.
- → China relies heavily on third parties, both in the design review and in inspections.
- → India does not enforce its voluntary code. Since state and local governments would need to adopt the code for it to become mandatory, these governments would likely have a large role in enforcement, as they do with other building code issues.
- → Several APP countries provide penalties and incentives to encourage code compliance. Common consequences for non-compliance include prohibiting a property owner from occupying a building, publishing the names of non-compliant property owners and issuing fines. Rewards for compliance commonly involve one or more of the following: monetary awards, relaxation of zoning requirements for a building, low interest rates from banks and other lending institutions, and tax benefits.

Strong building codes are an effective and low-cost approach to improve energy efficiency. However, without stringent enforcement by officials and compliance from the construction industry, building codes do not deliver the promised energy savings.

Enforcement of building codes encompasses several stages of building construction and is carried out by different bodies of government or the private sector. The first element of enforcement or point of control is at the design stage. All APP countries except India have local governments oversee this stage, albeit to different degrees (India's code is voluntary, so there is no enforcement framework currently). In most cases, this means that local governments oversee the process and conduct the actual reviews. This is true in Australia, Canada, South Korea, Japan and the United States. South Korea, Japan and the United States also in some cases allow third parties to verify designs, although in most such cases, local governments review the verification of the designs. For example, in South Korea, the Korea Energy Management Corporation may be asked to verify designs for local governments. In Japan, local governments review and approve all building designs. However, third parties, referred to as "designated confirmation bodies," first validate building designs (Cabinet Office of Japan 2006).

Enforcement is just as crucial during building construction and before a building is certified for occupancy. Local governments in Australia, Canada, South Korea and the United States perform building inspections. With small buildings, inspections will typically take place twice: once during construction (before the interior walls are sealed) and once before the building is put into operation. Large buildings, on the other hand, may require a series of inspections as construction takes place at different paces in different stories of the building. In Japan, there are no inspections for building energy code requirements. China relies primarily on third party entities for inspections and there is typically one inspection. India does not yet enforce its code. In the United States, China and other countries there is a growing effort to verify and document compliance rates. For example, in the United States, recent legislation sets a goal of 90% enforcement of the building energy codes, and the U.S. Department of Energy is developing detailed methodologies for tracking compliance rates.

Chinese local governments also designate certified independent organizations to verify design compliance to codes. These organizations are appointed by city governments through their respective construction administration departments. There are no central standards for certification. Local or central government officials may randomly check the results.

Appendix A summarizes the entities that carry out inspections and what incentives for compliance each country has established.

Box: Spotlight on Use of Third Parties

Third parties are an important option for quickly expanding enforcement capabilities in countries that have until recently, not consistently reviewed designs or inspected buildings for compliance with their codes. Several APP countries have experience with third party verification at either the design review or inspection stage. Hence, it seems useful to highlight this experience and potentially useful lessons.

In Japan, designated confirmation bodies, such as the Building Center of Japan, verify building designs before local governments approve the designs. These bodies are officially approved by a government agency (the Building Center of Japan was approved by the Ministry of Construction in 1965). The designated confirmation bodies of Japan abide by the regulations set out in the Building Standard Law of Japan.

In South Korea, local government building officials enforce the codes for new buildings as part of the building permitting process. The property owner of the proposed building is required to complete an energy-savings worksheet signed by a licensed architect, mechanical engineer and electrical engineer. The Korean Energy Management Corporation may also take part in reviewing the worksheets, but ultimately the decision to approve the design is made by local government officials.

In the United States, local jurisdictions or states enforce the building energy codes and these codes are adopted at the local level. The same is true in Canada, where enforcement falls under the authority of provincial and territorial governments. Although the United States state and local jurisdictions typically verify building designs and inspect buildings, in a few jurisdictions, state and local governments may also allow third parties to verify building designs. This can take different forms. In Wisconsin, for example, certified building designers must sign the occupancy permit, indicating that the construction matches the design. Designers who do not properly verify construction in this jurisdiction can lose their licenses, which provides a strong incentive. In Fairfax County, Virginia, developers can hire certified third parties to speed the inspection process, but the third party cannot have a financial interest in the project.

Third-party reviewers not only lessen the workload but also tend to be more experienced in solving the complexities and subtleties of codes and may have access to other sources and contacts (Bartlett et al., 2003). The disadvantage of third parties is that they may have a conflict of interest and as such, they may not have an incentive to highlight design errors. It has been observed in the United States that enforcement is more successful when local and state governments work together to enforce codes (Bartlett et al., 2003).

4.2 Testing and Rating

Key Findings

→ Energy ratings given to materials and equipment help builders, owners and code enforcement officials determine if using them would allow a building to meet the building energy code. However, the criteria used to rate materials and equipment (i.e., the test standards identified in most codes) often differ from one country to the next. This may have implications on imported building materials.

→ APP countries are leading a project that aims to harmonize test protocols.

→ India's experience demonstrates how critical it is for countries to tailor their test protocols to local conditions (e.g., climate and available resources) to ensure the targeted energy efficiency level is achieved.

Testing and rating compliance of buildings and building materials to code is essential to ensure energy efficiency. The energy ratings given to materials and equipment help builders, owners and code enforcement officials determine if using them would allow a building to meet the building energy code. For example, if the code specifies a U-factor for a wall, knowing the R-value of the insulation that goes into the wall is critical to establishing the wall's U-factor. Building energy codes typically reference test standards that must be used when establishing the energy rating of a product. Two examples can highlight the importance of test standards:

1. Air conditioners in India tend to operate at about 30% below stated efficiency levels of the equipment because of the extremely hot climate. Specifications for the design of air conditioners are based on standards that meet the average seasonal weather conditions of the United States. India currently does not have its own test standards for air conditioners. A test protocol designed for Indian conditions would likely encourage manufacturers to design and produce air conditioners that operate more efficiently in very hot climates.
2. Identifying differences in testing protocols becomes particularly important relevant to importing building materials. For example, upon testing windows imported from a foreign country, some United States cities have found that the R-values may vary by as much as 10% from those indicated by the rating. It is therefore beneficial to take into account differences in test standards applied in other countries. The North American Energy Working Group, for example, is working to verify that test protocols for room air conditioners in the United States, Canada and Mexico are identical or nearly identical (NAEWG, no date).

Appendix B contains examples of the test standards referenced in each APP country's building code and identifies some of the major testing agencies or certification associations involved in testing equipment and materials for energy efficiency.

Several APP countries reference International Organization for Standardization (ISO) standards in their codes (e.g., Canada and Japan). Given the differences that exist between test standards of each country, ISO has attempted to achieve harmonization of test procedures. However, for every ISO standard there may be several test protocols.

In response to this need, APP is leading a project that aims to reach harmony between test protocols including harmonizing test procedures for electric motors (BATF-06-01),[49] test procedures for HVAC (BATF-06-04) and window rating procedures (BATF-06-25). Project details are available to the public on the APP website: http://www.asiapacificpartnership.org/english/project_roster.aspx.

Table 24 identifies which testing protocols are referenced in the code(s) of each APP country for some of the major building components under review (insulation, HVAC, windows and lighting).

Table 24 Referenced Test Standards in Codes

	Insulation	HVAC	Windows	Lighting
AUS	Yes	Yes	No	No
CAN	No	Yes	No (but references an American Society for Testing and Materials test standard for windows)	No (except fluorescent ballasts)
CHN	Yes (presents protocol)	Yes (presents protocol)	Yes (presents protocol)	Yes
IND	No	Yes	No (but references an American Society for Testing and Materials test standard)	No
JAP	Yes	No	Yes	No
KOR	Yes	No (but mentioned in the product standard)	Yes	Yes
USA	Yes	Yes	Yes	No (except fluorescent ballasts)

4.3 Compliance Software and Tools

Key Findings

→ There are three major policy approaches to compliance software among APP countries: 1) some countries (e.g., Australia) develop detailed protocols or requirements for compliance software that allow many software developers to issue products while ensuring consistent results, 2) some governments (e.g., Canada, Japan and the United States) pay for the development of compliance software that is then free-of-charge, and 3) other countries have a less formal policy on code compliance software because their codes are relatively simple (e.g., South Korea) or they rely on private companies to develop software (e.g., China). Some countries adopt several approaches, for example, developing detailed protocols, but also funding software development and offering some software for free.

[49] BATF is short for the Buildings and Appliances Task Force.

→ Other commonly used tools among APP countries are checklists and guides or manuals, which are often available online.

As shown in Tables 25 and 26, several APP countries promote software and other tools such as manuals to further assist the building industry in testing for code compliance. In broad terms, there are three policy approaches to compliance software. The first is to develop detailed protocols or requirements for compliance software that allow many software developers to issue products while ensuring consistent results. Such is the case with Australia, where the Australian Building Code Board publishes detailed protocols for software development entitled, "House Energy Rating Software" and "Building Energy Rating Software," which software developers use to self-verify whether their software meets the corresponding protocol's verification procedures. Thus, despite the wide variety of building software available in Australia compared to other countries, computer programs such as Accurate (government produced) or BERSPro (privately developed) all meet the protocol guidelines. Similarly in the United States, the Home Energy Rating System program uses an energy efficiency software package that is based on specifications outlined in IECC 2006.[50]

Governments in some countries pay for the development of software that is then free of charge, which is the second approach. In Japan, for example, the Ministry of Land, Infrastructure, Transport and Tourism has sponsored the development of CASBEE—software updated in 2007 that promotes implementation of the building code by evaluating the environmental performance of buildings, including energy efficiency.[51] Although voluntary, some local authorities have adopted and tailored the software to local conditions (e.g., according to their climate and prioritized policies). In Osaka City and Nagoya City, for example, buildings that earn a high ranking using CASBEE are eligible for subsidies from their respective city governments. The software can also help discourage noncompliance. In Kawasaki City, for example, CASBEE rankings for residential buildings must be displayed on sales advertisements.

Canada and the United States also offer free software, which is yet another incentive to encourage code compliance. This is also a way to promote a uniform methodology of code compliance verification nationwide. This is especially important in the three countries where use of the software may be voluntary (Japan) or where building codes may not be consistent in every province or state (Canada and the United States).

The third approach is to have a less formal policy on code compliance software. This can mean that either software is not heavily used for compliance or that private companies develop software. However, without detailed protocols and rules for the calculations in the software, the software may vary significantly from developer to developer and produce inconsistent results.

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[50] A home energy rating consists of an analysis of residential construction plans and onsite inspections. For more information, please see http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_HERS.
[51] CASBEE evaluates a building on the following aspects: energy efficiency, resource efficiency, local environment, and indoor environment. For more information, please see http://www.ibec.or.jp/CASBEE/english/methodE.htm.

Table 25 Compliance Software

Software Methodology Described in Codes	
AUS BCA 2007	Yes
CAN MNECB	Yes (refers to another document[52])
CAN MNECH	Yes (refers to another document[53])
CHN	No
IND	No
JAP	No
KOR	No
USA IECC 2006	Yes
USA ASHRAE 90.1-2007	Yes

See Appendix C for a more detailed review of the different types of software employed in each APP country.

Table 26 Compliance Tools

	Existing Tools	Description
AUS BCA 2007	Australian Building Codes Board website: www.abcb.gov.au	Contains issues of the Australian Building Regulation Bulletin since 1997 (biannual magazine); BCA amendments and releases; certificates of conformity; energy standards and documents; building surveyor and certifier accreditation documents; and energy education documents. Offers building codes and construction books for sale.
CAN[54] MNECB 1997	Guide: "Performance Compliance for Buildings: Specifications for Calculation Procedures for Demonstrating Compliance to the Model National Energy Code for Buildings Using Whole Building Performance" (May 1999)	Supplement to Part 8 of the MNECB 1997 Available free of charge on the Canadian Codes Centre of the Canadian Commission on Building and Fire Codes website

[52] "Trade-off Compliance for Buildings: Specifications for Calculation Procedures for Demonstrating Compliance to the MNECB" published by the Canadian Commission on Building and Fire Codes.
[53] "Trade-off Compliance for Houses: Specifications for Calculation Procedures for Demonstrating Compliance to the MNECH" published by the Canadian Commission on Building and Fire Codes.
[54] For more information, please see http://irc.nrc-cnrc.gc.ca/codes/home_E.shtml.

	Canadian Codes Centre	In addition to user's guides, the Centre provides commentaries and seminars to the construction industry explaining the aim and application of code requirements.
CAN[55] MNECH 1997	Guide: "Performance Compliance for Houses: Specifications for Calculation Procedures for Demonstrating Compliance to the MNECH 1997 Using Whole Building Performance"	Supplement to MNECH 1997 available free of charge on the National Resource Council website
	Canadian Codes Centre	In addition to user's guides, the Centre provides commentaries and seminars to the construction industry explaining the aim and application of code requirements.
CHN	Code for Acceptance of Energy-Efficient Building Construction	The document serves as a guide for achieving construction quality and acceptance for the building envelope (wall, window, door, roof and floor), heating, HVAC systems, lighting, monitoring and controls for new construction and additions and retrofits of existing buildings.
IND ECBC	ECO-III website: http://www.eco3.org/	The Energy Conservation and Commercialization Project Phase-III (ECO-III) is a collaborative project between the Government of India and the U.S. Agency for International Development, which promotes widespread commercialization of energy-efficient technologies. The website contains updated information on projects, events and has relevant documents available for download.
JAP	Manual: "Quality Performance Evaluation: Manual for Building Materials"[56] Guide: "A Quick Look at Housing in Japan" (August 2008)[57]	A protocol outlining how to carry out performance evaluations that will be in compliance with the provisions of Article 37 Item 2 of the Building Standard. A 68-page booklet that explains the housing policy in Japan with editorial cooperation from the Ministry of Land, Infrastructure, Transport and Tourism. The booklet reports changes in the housing situation and housing policy in Japan.

[55] For more information, please see http://irc.nrc-cnrc.gc.ca/codes/home_E.shtml.
[56] For more information, please see www.bcj.or.jp/src/en/services/BMManual.pdf.
[57] For more information, please see www.bcj.or.jp/en/services/reference.html.

KOR	Manual for 'Building Design Criteria for Energy Saving,' approved by the Ministry of Land, Transport and Maritime Affairs (http://www.kemco.or.kr/building/v2/; written in Korean)	A comprehensive implementation guide that supplements the building code. The guide contains detailed instructions on how to comply with the code. It includes a web-based manual and calculation tool.
USA	Building Energy Codes Resource Center (http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter)	A system developed to provide users with information about energy codes (applies to both IECC 2006 and ASHRAE 90.1-2007) and beyond code technologies. The following media types are available: articles, graphics, online tools (e.g., design advisor, room air conditioner cost estimator, back-of-the-envelope calculator), presentations and videos.

4.4 Training and Public Information

Key Findings

- → All APP countries offer training seminars on building codes but the content and frequency of training varies.
- → Some seminars provide instructions on how to implement specific code provisions (e.g., HVAC or insulation).
- → Other seminars instruct specifically on how to ensure compliance to codes and rating schemes (e.g., Australia).
- → Several APP countries offer training guides or manuals and regularly updated websites that offer current information on code compliance protocols and regulations. This is one of the most inexpensive, yet effective, methods for encouraging code compliance.

There are training seminars that encompass a wide range of subjects related to building energy codes across APP countries. Several APP countries hold training seminars that provide instructions on how to implement certain provisions of the code such as specifications on HVAC (e.g., Canada) or insulation (e.g., Japan). An Australian institute even hosts a training course specifically dedicated to instructing on how to ensure compliance with mechanical services codes, standards and rating schemes of HVAC systems design (ABCB, 2009).

Dissemination of information is one of the most effective, and at the same time most inexpensive, methods for promoting code compliance. In the United States, it is crucial because of the varying codes adopted across the country. Since the early 1990s, DOE has hosted a website (www.energycodes.gov) that provides free education and training material as well as software in support of the latest IECC and ASHRAE 90.1 codes (DOE, 2008a). To encourage the adoption of energy codes, the website's featured adoption maps and local jurisdiction contact information are regularly updated thus providing a clear comparison of states that have adopted the most updated building energy codes, states that have an older version of the codes in place and states that have no statewide code enforced.

South Korea's building code provides a comprehensive manual prepared by KEMCO, which is intended to give the user all the information required to comply with the building code.

A list of some of the most prominent training courses and information materials provided in each country is available in Appendix D. The table in Appendix D illustrates the diverse approaches each APP country is undertaking and the different stakeholders involved.

4.5 Some Innovative Programs and Summary

International comparisons can be helpful to policy makers by giving them an indication of what is successful elsewhere. Implementation programs are integrally linked with many aspects of a country's political system and policy approach. As such, there is no single right answer to what is innovative. Each country has something innovative that may be useful elsewhere. This section outlines a few overarching ideas and highlights some examples of innovation.

Effective implementation of building energy codes requires a comprehensive approach. The elements that are typically needed include:

- Training to help code officials and the building design and construction communities understand the requirements and how to meet them.
- Tools such as checklists or compliance software to ease the job of checking for compliance.
- Review of building designs and inspections of actual construction.
- Incentives for compliance.

Countries vary quite a bit on the details of these elements. Some countries reach out to a broader spectrum of stakeholders in their training than do others, and training programs may cover different issues in different countries. Japan has very extensive training programs for its building energy codes. For example, the Japanese government recently funded over 100 training seminars over several months regarding a single set of changes to the existing code. The training covers a range of issues related to energy efficiency in buildings, not just meeting the minimum requirements of the code.

Most countries have at least one type of compliance tool, usually at a minimum a standardized format for compliance checklists. Many also have software to aid with compliance checking, particularly when trade-off methods are used for compliance. The software varies in the consistency of the results it produces and whether or not it is freely available. The United States, for example, has a longstanding program to provide free software that local jurisdictions can rely on to implement their codes. Ensuring that the software is free is important in the United States because it encourages local jurisdictions to adopt the national model standards. Countries where codes are adopted centrally may not need to provide such software free of charge, though they will still need to ensure that the available software provides accurate and consistent results.

While all countries with mandatory codes review building designs, not all countries inspect actual construction. Experience in other fields like pollution monitoring and policing of speed limits indicates that actual checks on compliance do improve compliance. Jurisdictions with strong inspection programs like California have seen significant improvements in building energy efficiency—to the point that per capita electricity consumption has been stable for decades despite major economic growth over that period. To our knowledge, besides anecdotal evidence, there are no broad surveys that compare the results of building energy code enforcement programs across jurisdictions with varying practices.

South Korea has set up a system requiring several checks, including the signatures of both a certified architect and a certified engineer, as well as onsite inspection by local government officials. South Korea has seen enforcement of its building energy codes go from low levels to more than 50% compliance with this approach in recent years. China has developed an inspection system relying heavily on third-party inspectors. These third parties must pass exams to obtain certification as building energy code verifiers. This has allowed China to rapidly increase the number of inspectors, although there are also questions about the potential conflict of interest of such private inspectors and the rigor of the certification procedures in some localities. China's approach may be innovative and of interest to India, for example, in that India too will likely want to consider options for inspecting buildings once India's jurisdictions adopt the ECBC.

Almost all countries with building energy codes have some incentives for compliance, but the specific incentives vary. In some jurisdictions, building owners are not allowed to occupy a building until the building passes inspection for compliance with the building energy code. This means that if there is a problem, a building would have to be retrofitted to comply, which would be expensive and quickly get the attention of builders and owners. This approach exists in several APP countries including Australia, South Korea, and the United States. China has also recently adopted rules giving local building energy code enforcement organizations this option. Another approach is to give fines for non-compliance. Japan and China have recently updated their rules to provide for fines for non-compliance. In addition, Japanese code officials can publicize the names of property owners who fail to submit information on the energy design of their buildings. South Korea has rules that allow building owners to access several benefits for designing buildings that exceed the minimum requirements. Under South Korea's point system, a building must score a minimum of 60 to meet the mandatory standard. High scores (more than 70) make building owners eligible for subsidized financing and/or relaxation of certain legal requirements (e.g., maximum floor space index and maximum building height). This is an interesting way to encourage building owners to exceed the minimum standard. Both Japan and China have also experimented with such an approach in certain localities. Other countries like the United States, Australia and Canada have systems set up to reward high-performance buildings, but these systems are not as integrally linked to the code compliance system.

The question of innovation depends on perspective and needs. For countries that want to expand their inspection capabilities rapidly, China has created an interesting system of certifying third-party verifiers or inspectors. The United States and Australia might find South Korea’s approach of providing incentives for exceeding the minimum standards in a structured, integrated way to be innovative. Some APP countries might find interesting insights from the specific requirements that have proven feasible in Australia or Japan, for example. These are just a few examples of how countries might benefit by observing what has worked elsewhere.

5 Conclusions

APP countries have all indicated a strong interest in improving building energy efficiency. Each APP country has one or more building energy codes. The codes have become more stringent and complex over time. The codes cover a range of issues that affect building energy use. The insulating properties of the building envelope (the walls, roof, windows, etc.) make up the majority of the requirements in most countries. The codes in most countries also promote the efficiency of HVAC, hot water supply, and lighting systems. Many countries also include certain site-specific renewable energy options as alternatives to other requirements (for example, solar water heating).

Codes in all countries provide some degree of flexibility. There are several approaches: trade-off options for building envelope requirements, scored point systems for the range of requirements and whole building energy performance compliance paths. This flexibility enables the codes to be more stringent while still allowing for a wide range in building types.

APP countries have taken many different approaches to implementing their codes. Most APP countries require the review of building designs for compliance with the building energy code and inspection of actual construction to ensure that it matches the design. Some countries have local building code officials conduct the reviews and inspections, while others may rely primarily on certified third-party reviewers and inspectors. Countries use both carrots and sticks to increase compliance rates. Carrots include free training and compliance software as well as incentives for buildings that exceed the code requirements such as low-interest financing and relaxation of certain zoning requirements. To discourage non-compliance, some countries refuse to permit occupancy until codes are met or give fines. APP countries have also developed a range of tools to help building designers and builders comply with codes.

Energy use in buildings accounts for approximately one-third of the total energy use in APP countries. APP countries will likely account for the overwhelming majority of projected new construction worldwide between now and 2020. China alone will account for half of new global construction. Buildings in APP countries last an average of 20 to 50 years, and it is much easier to change the energy footprint of a building when it is built than to retrofit it later. Hence, buildings constructed in APP countries in the next decades will have a major impact on global energy consumption trends through much of the remaining century. Building energy codes provide an effective and important tool in promoting energy efficiency in new construction, which in turn can help APP countries meet their environmental and energy security goals.

Appendix A – Enforcement Framework

	Point of Control			Incentives for Compliance	
	Design Verification	Inspections		Penalties	Rewards
		Authority	Frequency		
AUS BCA 2007	State and territorial governments, but must follow national mandatory minimum energy efficiency requirements (ABCB, 2008).	State and territorial governments, but must follow national mandatory minimum energy efficiency requirements (ABCB, 2008).	Inspections during and after construction (Australian Institute of Building, 2004).	If building does not pass inspection, building owners are not allowed to occupy building.	Some local governments currently provide incentives for compliance. For example, in the city of Prospect, if ceiling insulation, in-home energy monitors and/or hot water services are replaced with gas-boosted solar water heaters, then money is awarded (Civic Centre, 2008).
CAN MNECB 1997 and MNECH 1997	Provinces have authority over building codes, but enforcement generally falls to municipalities (J. Clark, personal communication).	Five third-party agencies appointed by national government, specifically Natural Resources Canada and	Number and types of inspections vary depending on provincial or municipal guidelines[58]	If a building is in non-compliance, then province and territory governments usually withhold construction and occupancy permits and/or issue fines.	If building design has operating energy performance 25% > same building constructed to the MNECB minimum requirements, then builder owner receives a monetary reward (usually twice the value of energy savings

[58] Some provinces have inspection authorities which are generally active in rural areas or smaller towns, but there are no federal authorities present in these areas. In the case of Vancouver and Montreal, the cities have unique constitutional capabilities, which allow them to adopt building codes without provincial consent. The provincial and municipal authorities have the same punitive powers. Enforcement varies widely with the large cities approaching levels achieved in California (J. Clark, personal communication).

	Point of Control			Incentives for Compliance	
	Design Verification	Inspections: Authority	Inspections: Frequency	Penalties	Rewards
CAN MNECB 1997 and MNECH 1997, continued		Standards Council of Canada, however, most enforcement falls to municipalities (NAEWG, 2002; J. Clark, personal communication)			predicted for the first year of operations (Pope and Dubrous, 2001). Incentive program lasted from 1996-2004.[59]
CHN	Certified independent organizations appointed by city governments through their construction administration departments.[60]	Certified independent organizations appointed by city governments through their construction administration departments.[61]	At least once during construction	If building design is not approved by certified independent drawing verification center, then construction is not allowed to begin. If construction has started without approval, then construction of building will be suspended and a specified	If the building exceeds the requirements of the code, then some jurisdictions allow limited relaxation of zoning requirements for the building.

[59] From 1996 to 2004, Natural Resources Canada carried out the Commercial Buildings Incentive Program, an initiative to promote the adoption of the Model National Energy Code for Buildings, to encourage increased energy efficiency in commercial buildings and to assist in the reduction of greenhouse gas production from the commercial buildings sector (Pope and Dubrous 2001). CBIP evaluated the performance of the proposed design by comparing it to a reference building constructed with representative envelope, lighting, and HVAC systems. The program evaluation took a whole-building performance approach.
[60] However, the Ministry of Housing and Urban-Rural Development (national government) is responsible for supervising overall code enforcement efforts.
[61] However, the Ministry of Housing and Urban-Rural Development (national government) is responsible for supervising overall code enforcement efforts.

	Point of Control			Incentives for Compliance	
	Design Verification	Inspections		Penalties	Rewards
		Authority	Frequency		
CHN, continued				time limit will be granted to make corrections. If a building does not pass inspection, then building owners are not allowed to occupy the building and it cannot be sold.	
IND ECBC	None currently[62]	None currently	N.A.	N.A.	N.A.
JAP	Local government or third-parties (referred to as “designated confirmation bodies”) (Cabinet Office of Japan, 2006)	None required	N.A.	If property owner fails to submit information on energy design, then name of property owner is publicized Fines for non-compliance	If invest in energy conservation projects, including energy-efficient buildings, then qualify for low interest loans (APEC Energy Working Group, 2006) Also, in some jurisdictions, buildings are eligible for relaxation of certain zoning requirements.

[62] Since the code is voluntary, there are no mandatory inspections, and audits of existing buildings are voluntary as in other countries. According to ECO-III staff, for other parts of the building code that are now mandatory, inspections are done by local governments.

	Point of Control			Incentives for Compliance	
	Design Verification	Inspections		Penalties	Rewards
		Authority	Frequency		
KOR	Local government or Korea Energy Management Corporation; final approval by local government (Lee, 2006)	Local government	During construction and upon completed construction. Local governments may also audit the buildings after construction (BAI, 2006).	If building does not pass inspection, then building owners are not allowed to occupy building Fines for non-compliance and products[63] are prohibited from being produced and sold (IEA-DSM, 2009).	If minimum requirements are exceeded (>60 points), subsidized financing (e.g., low-interest loans) and/or relaxation of zoning requirements (e.g., ability to build one extra story, or have a slightly larger building footprint).
USA ASHRAE 90.1-2007 and IECC 2006	State and local governments (usually local), but may bring in third parties (Burby et al., 2000; Bartlett et al., 2003)	State and local governments (usually local), but may bring in third parties (Burby et al.,2000; Bartlett et al., 2003)	Number and types of inspections vary depending on local jurisdiction guidelines (DOE, 2002)[64]	If building does not pass inspection, building owners are not allowed to occupy the building. Building owners must pay for modifications to bring the building up to code.	If commercial building saves at least 50% of heating and cooling energy of a building that meets ASHRAE 90.1-2007, a tax deduction is awarded of up to $1.80 per square foot (DOE, 2008b).[65] If contractors build homes that reduce heating and cooling energy consumption relative to IECC and

[63] Includes electric air conditioners and lighting products (e.g., incandescent bulbs, fluorescent lamps and self-ballasted lamps).
[64] However, five site inspections are commonly implemented to verify energy features: 1) Pre-inspection, 2) Foundation inspection, 3) Framing inspection, 4) insulation inspection and 5) Final inspection (DOE 2002).
[65] The tax incentive is effective through December 31, 2013 (DOE 2008).

	Point of Control			Incentives for Compliance	
	Design Verification	Inspections: Authority	Inspections: Frequency	Penalties	Rewards
USA ASHRAE 90.1-2007 and IECC 2006, continued					supplements by 30% or 50%, they are awarded a $1,000 credit or $2,000, respectively (DOE 2009). Also, some jurisdictions consider faster permitting for buildings that exceed the code.

Note: N.A. = Not applicable.

Appendix B – Building Testing Agencies and Examples of Test Standards in each APP Country

	Testing Agencies and Certification Associations	Examples of Test Standards Referenced in Code (or featured test protocols)[66]
AUS	Numerous testing laboratories at the industry, State and territory levels (ABCB, 2008). BCA defines *registered testing authority* as: • An organization registered by National Association of Testing Authorities to test in the relevant field; or • An organization outside Australia registered by an authority recognized by the National Association of Testing Authorities through a mutual recognition agreement; or • An organization recognized as being a *registered testing authority* under legislation at the time the test was undertaken. National Association of Testing Authorities (NATA, 2009)	Standards referenced in BCA 2007: Australian Standard: • AS/NZS 4859.1 Materials for the thermal insulation of building (prescribes test and calculation reports) (ACBC, 2008) • AS 3823 Performance of electrical appliances – air conditioners and heat

[66] The list of test standards and protocols is not exhaustive.

	Testing Agencies and Certification Associations	**Examples of Test Standards Referenced in Code (or featured test protocols)[66]**
AUS, continued	• Leading accrediting organization for energy efficiency • Private, non-profit organization; endorsed by the government • also responsible for the accreditation of inspection bodies and serves as Australia's Good Laboratory Practices compliance monitoring authority for the OECD Principles of Good Laboratory Practices. • Applies international assessment criteria—ISO/IEC 17025, plus National Association of Testing Authorities' own regulations (Foster, 2004) • Its labs are exclusively for standards development and compliance programs in Australia (Foster, 2004)	pumps: test methods – ducted air conditioners and air-to-air heat pumps– testing and rating of performance) Other Standards: British Standards: • BS 7190 Assessing thermal performance of low-temperature hot water boilers using a test rig
CAN	Canada (Natural Resources Canada and the Standards Council of Canada) recognizes five entities to certify the energy efficiency of products and to accordingly provide a verification mark under the Energy Efficiency Regulations (NAEWG, 2002): 1. Air-Conditioning and Refrigeration Institute 2. CSA International 3. Intertek Testing Services NA Inc. 4. Intertek Testing Services NA Ltd., and 5. Underwriters Laboratories, Inc. Test standards for water heating are also referenced in the code (NRC, 1997). The standard on lighting (CAN/CSA-C654-M91) referenced in MNECB 1997, which applies for industrial, commercial and residential buildings, provides the measurements to test the efficiency of fluorescent lamp ballasts for use in fluorescent luminaries (NRC, 1997).	Standards referenced in MNECH 1997: Canadian Standards Association: • CAN/CSA-C446-94 Standard Methods of Test for Rating the Performance of Heat-Recovery Ventilators Other Standards: American Society for Testing and Materials: • C 177-85 (1993) Standard Test Method for Steady-State Heat Flux Measurement and Thermal

	Testing Agencies and Certification Associations	**Examples of Test Standards Referenced in Code (or featured test protocols)**[66]
CAN, continued		Transmission Properties by Means of Heat Flow Meter Apparatus • E 283-91 Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen (also in MNECB 1997). Code also references "Performance Compliance for Houses: Specifications for Calculation Procedures for Demonstrating Compliance to the Model National Energy Code for Houses Using Whole House Performance" prepared by Canada's National Research Council (NRC, 1997). Standards referenced in MNECB 1997: Canadian Standards Association: • C390-93 Energy Efficiency Test Methods for Three-Phase Induction Motors

	Testing Agencies and Certification Associations	Examples of Test Standards Referenced in Code (or featured test protocols)[66]
CAN, continued		(Air Conditioning) • CAN/CSA-C439-88 Standard Methods of Test for Rating the Performance of Heat-Recovery Ventilators • CAN/CSA-C654-M91 Fluorescent Lamp Ballast Efficacy Measurements Method for Calculating the Thermal Resistance of Building Assemblies (Appendix C)
CHN	The National Center for Quality Supervision and Test of Building Engineering (NCQDE, 2009): • Established by the China Academy of Building Research • Holds numerous labs that test for building structure, building material testing, chemical material, air conditioning and cleaning, water supply and drainage, door/window and curtain wall, building energy efficiency, building foundation, building acoustics, and illumination China's Standard Certification Center • Formerly known as the China Certification Center for Energy Conservation Products • A quasi-governmental agency founded and owned by government but acting as a non-profit and independent third-party certification body (Tienan, 2006) • Covers lighting products, building materials (e.g., windows and sealed insulating glass unit) and industry products (e.g., air compressors line traps for air conditioning power	Protocols referenced in China Design Standard for Energy Efficiency of Buildings in Hot Summer and Cold Winter Zone 2001: Building day lighting and Calculation of Average Thermal Conductivity Coefficient of Exterior Envelope Wall (Annex A) Protocols referenced in China Design Standards for Energy Efficiency of Residential Buildings 2003: Methods for Calculation of the

	Testing Agencies and Certification Associations	Examples of Test Standards Referenced in Code (or featured test protocols)[66]
CHN, continued	system and power control devices) (Tienan, 2006) • Leading the development and implementation of China's energy efficiency endorsement label, now used as a requirement for energy-efficient products in some government procurement programs (ELI, 2005; Tienan, 2006)	Annual Cooling and Heating Consumptions or Consumption Simplified Method to Calculate the Annual Air-Conditioning and Heating Electricity Consumption Factor of Buildings (Appendix A) Method to Calculate Factors M_H and M_C for Exterior Shading Devices (Windows) (Appendix B) Building codes do not reference any test standards.
IND	India currently does not have facilities to test the thermal properties of certain building materials, which include insulation, masonry, roofing materials and other types of materials. ECBC 2007 also references India's standards for water heaters and for dry-type transformers (and a note that oil-type transformers should go by Central Electrical Authority norms).	Standards referenced in ECBC 2007: Indian Standards: • Air Conditioners and Boilers • Water Heaters Other Standards: American Society for Testing and Materials: • Solar reflectance and emittance (under the section of the code on cool roofs) Protocols referenced in ECBC 2007: Procedure for determining Fenestration product U-Factor and Solar Heat Gain Coefficient (Appendix D)

	Testing Agencies and Certification Associations	Examples of Test Standards Referenced in Code (or featured test protocols)[66]
IND, continued		Calculations: Building Envelope Trade-off Method (Appendix E)
JAP	General Building Research Corporation of Japan (ReaD, 2004): • Officially recognized by the Ministry of International Trade and Industry, based on Section 34 of the Civil Code of Japan; established in 1964 • Certifies and inspects building materials in accordance to the Industrial Standardization Law (building-plan confirmation and onsite inspection conforms to the Building Standard Law of Japan) • Performs technical appraisal of new building materials and high-rise structures • Conducts calibration of testing instruments and certification of the quality and compliance of systems to the ISO 9001 standards • Member of Japanese Industrial Standards Certification Bodies Association Compliance testing of building components and construction equipment are based on Japanese Industrial Standards and other standards (ReaD, 2004).	Standards referenced in DCGREUH 1999 and CCREUB 1999: Japanese Industrial Standard: • JIS R3107-1998 Heat Resistance of Glass Plates and Methods of Calculating Heat Transfer Coefficient in Construction • JIS A1420-1994 Heat-insulation Performance Test Methods for Heat-insulation Materials and Structural Materials for Housing • JIS R3106-1998 (Test Methods for Transmittance, Reflectance, Emissivity and Insulation Acquisition Coefficient of Glass Plates)
KOR	BDCES references testing and material standards mostly from the Korean Agency for Technology and Standards. In other cases, BDCES either spells out the testing procedure in itself or references other government provisions such as: the Provisions for Efficiency Control Machinery & Materials (MKE 2008-99) and the Provisions for Facilitating the Distribution of Highly Efficient Energy Machinery & Materials (MKE 2008-218). These provisions, in turn, reference Korea Industrial Standards from Korean Agency for Technology and Standards.	Korea Standard • KSL9016: Test Methods for Thermal Transmission Properties of Thermal Insulations; • KSF2277: Thermal Insulation:

	Testing Agencies and Certification Associations	Examples of Test Standards Referenced in Code (or featured test protocols)[66]
KOR, continued	Korean Agency for Technology and Standards is a government agency under Ministry of Knowledge Economy, originally established in 1883 and recognized as National Standardization Body in 1999. Korean Agency for Technology and Standards is responsible for developing Korea Industrial Standards, the primary reference for testing and material standards in BDCES. Testing is performed by various nationally accredited testing agencies (both governmental and non-governmental). Those relevant to building energy code include: (year established) • Korea Institute of Construction Materials (1994) • Korea Electric Testing Institute (1970) • Korea Institute of Lighting Technology (1999) • Korea Institute of Construction Technology (1984) • Korea Energy Appliances Industry Association (1983) Alternatively, large buildings far exceeding energy efficiency can be certified for High-Efficiency Energy Building (MKE 2008-14) directly from the Korean Energy Management Corporation. The Korea Institute of Energy Research, the Korea Institute of Construction Technology and the Korean Energy Management Corporation are responsible for testing these buildings' total energy efficiency (instead of individual component efficiencies). The test standards are outlined in the Building Energy Efficiency Rating System (MKE 2008-14).	Determination of Steady-State Thermal Transmission Properties—Calibrated and Guarded Hot Box • KSF2278: Test Method of Thermal Resistance for Windows and Doors
USA	Widely recognized certification associations include: • American National Standards Institute • National Fenestration Rating Council • National Institute of Standards and Technology International Standards Association (develops and publishes standards):	Standards referenced in ASHRAE 90.1-2007: American Society for Testing and Materials: • ASTM C177-97: Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmittance

	Testing Agencies and Certification Associations	Examples of Test Standards Referenced in Code (or featured test protocols)[66]
USA, continued	• American Society for Testing and Materials Test standards for water heating and cooling are also referenced in the code (ASHRAE 90.1-2007). With the exception of lamps, third-party certification is not mandatory (NAEWG, 2002). For lamps, the U.S. Department of Energy, through the National Institute of Standards and Technology, certifies certain laboratories for testing and certification.	Properties by Means of the Guarded-Hot-Plate Apparatus National Fenestration Rating Council: • NFRC 100-2004 Procedure for Determining Fenestration Product U-Factors Underwriters Laboratories, Inc.: • UL 181A-94 Closure Systems for Use with Rigid Air Ducts and Air Connectors • UL 181B-95 Closure Systems for Use with Flexible Air Ducts and Air Connectors Other Standards: International Organization for Standardization: • ISO 13256-1 (1998) Water-Source Heat Pumps—Testing and Rating for Performance—Part 1: Water-to-Air and Brine-to-Air Heat Pumps Standards referenced in IECC 2006: American Society for Testing and Materials: • E 283—04 Test Method for Determining the Rate of Air Leakage Through

	Testing Agencies and Certification Associations	Examples of Test Standards Referenced in Code (or featured test protocols)[66]
USA, continued		Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen U.S. Department of Energy: • 10 CFR Part 430, Subpart B, Appendix E (1998) Uniform Test Method for Measuring the Energy Consumption of Water Heaters National Fenestration Rating Council: • 100—01 Procedure for Determining Fenestration Product U-Factors—Second Edition Sheet Metal and Air Conditioning Contractors National Association, Inc. • SMACNA—85 HVAC Air Duct Leakage Test Manual

Appendix C – Compliance Software

	Software Methodology Described in Codes	Existing Software	Accessibility	Description
AUS BCA 2007	Yes[67]	AccuRate[68] BERSPro, FirstRate 5, Beaver/ESP, IES Apache, TAS, ICE, TRACE 700, Carrier E20-II eQUEST, VisualDOE, EnergyPlus	Provided by Australia's national science agency: Commonwealth Scientific and Research Organisation. Software is easily accessible, but must be purchased. Privately developed software; for purchase A suite of U.S. Department of Energy software adapted by Team Catalyst in Australia; Accessible for download on the internet	AccuRate • Primarily for residential buildings • The national benchmark software • Provides house thermal energy ratings • Second-generation software product (Australian Building Codes Board Protocol for House Energy Rating Software Version 2006.1 is suitable for assessing second generation software) BERSPro • Primarily for residential buildings • Simulates and analyzes the thermal performance of houses in Australia • Second-generation software product • Meets the Australian Building Codes Board's Protocol for House Energy Rating Software Version 2006.1 FirstRate 5 • For houses • Integrates AccuRate calculation engine Beaver/ESP, IES Apache, TAS, ICE, TRACE 700, Carrier

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[67] The Australian Building Code Board develops detailed protocols for the software called House Energy Rating Software and Building Energy Rating Software (http://www.abcb.gov.au/go/whatweredoing/workprogram/projectsae/energy/eesoftware). Software developers self-verify whether their software meets the protocol using the protocol's verification procedures. Software developers are not required to register their software with the Australian Building Code Board.

[68] For more on the software used in Australia, please see http://www.dip.qld.gov.au/docs/planningdocs/corporate/publications/building_codes/newsflash/2007/NewsFlash262.pdf.

	Software Methodology Described in Codes	Existing Software	Accessibility	Description
AUS BCA 2007, continued			free of charge	E20-II, eQUEST, VisualDOE, EnergyPlus • For Class 3, 5, 6, 7, 8 and 9 buildings (mostly non-residential) • Meets the Australian Building Codes Board's Protocol for Building Energy Analysis Software Version 2006.1 • eQUEST, VisualDOE and EnergyPlus are mostly simulation programs
CAN[69] MNECB 1997	Yes (referred to another document)[70]	EE4, EE4 Code[71], BILTRAD	Software provided by CanmetENERGY within Natural Resources Canada; accessible on the internet free of charge	EE4 • Applies all of Natural Resources Canada's validation of new building design rules to confirm that a design is at least 25% more energy efficient than if every element of the building envelope, lighting, HVAC and service water systems were constructed to meet MNECB 1997 requirements. • Uses a performance path approach EE4 Code • Aligns strictly with MNECB[72] • Compares proposed building design with building of similar reference design built strictly to MNECB level • Reports differences in energy performance for HVAC, envelope, lighting and service hot water • Uses a performance path approach

[69] For more information, please see http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/software_tools.html.
[70] "Trade-off Compliance for Buildings: Specifications for Calculation Procedures for Demonstrating Compliance to the MNECB" published by Canadian Commission on Building and Fire Codes.
[71] EE4 and EE4 Code are being replaced with software based on eQuest.
[72] In contrast to EE4 Code, EE4 credits some efficiency measures (e.g., controls) that were not included in the code.

	Software Methodology Described in Codes	Existing Software	Accessibility	Description
CAN MNECB 1997, continued				BILTRAD • Compares the energy efficiency of your envelope design to the prescriptive requirements outlined in MNECB • Uses a trade-off approach
CAN[73] MNECH 1997	Yes (referred to another document)[74]	HOUSTRAD and HOT2®EC	Software provided by CanmetENERGY within Natural Resources Canada; accessible on the internet free of charge (Natural Resources Canada, 2009)	HOUSTRAD • Verifies house envelope energy code compliance through the trade-off path: windows or walls of the house do not follow prescriptive requirements but overall annual energy use is equal to or better than the reference house HOT2®EC • For building designs that do not meet prescriptive or trade-off paths; uses a performance path approach • Requires the user to demonstrate that the building, as designed, will not have a calculated energy consumption that is greater than it would have been if the building was designed to meet the prescriptive requirements • Requires a computer analysis to verify that the building will be as energy efficient as the same house designed using the Prescriptive compliance requirements

[73] For more information, please see http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/software_tools.html.
[74] "Trade-off Compliance for Houses: Specifications for Calculation Procedures for Demonstrating Compliance to the MNECH" published by Canadian Commission on Building and Fire Codes.

	Software Methodology Described in Codes	Existing Software	Accessibility	Description
CHN CHN, continued	No	Commercial software	There are numerous commercial software packages on the market.	The government does not promote any given software package, although it has noted that the existing software can produce inconsistent results.
IND ECBC	No	No	N.A.	The code is currently voluntary. Compliance software may eventually be part of a package to introduce mandatory enforcement.
JAP	No	CASBEE[75]	Initiated with the support of the Housing Bureau, Ministry of Land, Infrastructure, Transport and Tourism in April 2001. Software available for download on the internet free of charge.	• A voluntary program that supports building energy efficiency and implementation of the building energy code • Includes several software tools available for download, including CASBEE for: o New Construction o Existing Building o Renovation o Home (Detached House)
KOR	No	No, but simple web-based calculation sheet available	N.A.	South Korea's building energy code is based on a 60-point checklist. This approach means that compliance software may not be as critical in handling building energy performance.
USA IECC 2006	Yes	RES*check* REM/Rate Home Energy	Maintained by the U.S. Department of Energy's Pacific Northwest National Laboratory; free of charge Developed by a private firm; licensed annually to	• Purpose is to simplify and clarify code compliance with IECC, Model Energy Code and several state codes • Offers both trade-off and prescriptive approaches to demonstrate compliance • Residential code compliance and rating software developed specifically for Home Energy Rating System providers

[75] For more information, please see http://www.ibec.or.jp/CASBEE/english/index.htm.

	Software Methodology Described in Codes	Existing Software	Accessibility	Description
USA IECC 2006, continued		Rating Software[76]	Home Energy Rating System providers.	• Calculates heating, cooling, hot water, lighting, and
USA IECC 2006, continued				appliance energy loads, consumption and costs for new (and existing) single and multi-family homes. • States and cities that adopt IECC 2006 can choose to use these tools
		EnergyGauge USA	Developed by the Florida Solar Energy Center, a partner in the U.S. Environmental Protection Agency Energy Star® Homes program, a partner in the U.S. Department of Energy *Building America* program. The software is available for purchase on the internet.	Complies with all requirements of the IECC for energy code compliance calculations and reporting and with all national accreditation procedures and technical guidelines for Home Energy Rating Systems, including the "HERS BESTEST" procedures.
USA ASHRAE 90.1-2007	Yes	COM*check*	Maintained by the U.S. Department of Energy's Pacific Northwest National Laboratory; available free-of-charge on the internet	• Offers both trade-off and Prescriptive approaches to demonstrate compliance • For the prescriptive approach, the user can use the web-based application "COM*check* Prescriptive Package Generator" to generate his/her own code-compliant insulation and window packages instead of following pre-

[76] For more information, please see http://www.archenergy.com/products/rem/rem_rate/.

	Software Methodology Described in Codes	Existing Software	Accessibility	Description
USA ASHRAE 90.7-2007 Continued				defined prescriptive packages
		ENVSTD and LTGSTD[77]	Maintained by the U.S. Department of Energy's Pacific Northwest National Laboratory; available free-of-charge on the internet	• Allows user to make compliance calculations to determine whether a building design meets envelope and lighting system performance requirements of DOE's Interim Energy Conservation Performance Standards for New Commercial and Multifamily High-Rise Residential Buildings • Provides the envelope trade-off option in Standard 90.1-2007 and comes with a Users Manual.

Note: Calculation procedures may include standard reference design, input values or other factors. The list of software in the column "existing software" provides an overview of some of the main software packages available; in some countries, there are private software packages, not all of which are listed here.

Appendix D – Training and Public Information

	Training	Public Information
AUS BCA 2007	Australian Institute of Refrigeration, Air Conditioning & Heating • Nationally recognized training on BCA • Courses include: Apply the provisions of the BCA and the relevant state and territory Acts and Regulations; Ensure Compliance With Mechanical Services Codes, Standards and Rating Schemes to HVAC Systems Design; Find Your Way With Section J; Carbon Detectives – Operation: Energy Audit; BCA for HVAC Practitioners – What	The Australian Building Codes Board keeps the public updated on available courses on BCA with "BCA Training Gateway" (ABCB, 2009). By accessing the BCA Training Gateway website or telephoning, it is possible to find out which university or (technical and further education) TAFE is conducting training on the BCA or when the next industry association seminar will be held. The Australian Building Codes Board is also currently developing a range of training modules, called Resource Kits, to raise awareness of BCA provisions within the Australian building and

[77] For more information, please see http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=134/pagename=alpha_list.

	Training	Public Information
AUS BCA 2007, continued	Are You Missing? The Australian Ministerial Council on Energy also sponsors training related to the BCA, for example, on energy rating software and energy rating.	construction sector. The Resource Kits are intended to provide updated and consistent information on BCA and are also designed to assist with training needs.
CAN MNECB 1997	The Office of Energy Efficiency and its stakeholder organizations offer training on how to interpret and apply MNECB.	Natural Resources Council posts training materials and workshops for new and existing buildings on its website (http://oee.nrcan.gc.ca/) Other information sources: • Provincial and municipal governments • Canadian Home Builders Association • Canadian Association of Home & Property Inspections
CAN MNECH 1997	The Ontario Ministry of Municipal Affairs and Housing and its counterparts in other provinces have hosted training seminars on the building energy code and energy efficiency in houses. There are also specialized courses and online modules on issues like HVAC, building envelope and code updates.[78]	
CHN	MOHURD and CABR have organized numerous training activities during and after the release of building energy standards. China has also cooperated with other countries on training courses related to building energy codes. For example, the U.S. Department of State is sponsoring work by CABR and the Pacific Northwest National Laboratory to enhance code implementation through training in two Chinese cities. The World Bank has also sponsored training on	The MOHURD website (http://www.cin.gov.cn/jnjp/) provides updates on policy developments, regulations and industry news on building energy efficiency. Non-governmental websites (e.g., www.china5e.com) also provide policy updates and local news related to building energy efficiency. Local government websites also provide code-related information, such as notices for meetings, regulatory changes and permit documents.

[78] For more information, please see the Ontario Ministry of Municipal Affairs and Housing website (www.obc.mah.gov.on.ca/site4.aspx) and the British Columbia government website (www.bcbuildinginfo.com/display_topic.php?division_id=2&topic_title_id=38&topic_id=165).

	Training	Public Information
CHN, continued	building code enforcement as part of an energy efficiency project in Tianjin, involving White Box Technologies (a United States firm) and others.	
IND ECBC	The Bureau of Energy Efficiency is considering developing code compliance software and training programs for code inspectors and enforcers. According to the Bureau of Energy Efficiency, from 2004-2008, six national certification examinations have been successfully conducted in 23 centers all over the country (Chakarvarti, 2008). The USAID-sponsored ECO-III project is developing training modules. It has also developed courses on building energy simulation. The India Green Buildings Council is also conducting training workshops on energy management and low-cost energy efficiency in existing buildings.	The ECO-III project is developing an implementation guide to the ECBC The Indo-German Energy Program, a collaboration between the Government of India and Germany's Ministry of Economic Cooperation and Development, also contributes to the implementation of the Energy Conservation Act of India (2001). The program hosts a website called Energy Manager Training (www.energymanagertraining.com). The website includes information on learning material on energy management; case studies/best practices that were undertaken by industry; energy-efficient equipment with their specifications and information on equipment manufacturers/vendor/suppliers; details of manufacturers associations/energy audit firms; energy audit guidelines; energy audit instruments; useful websites where information on energy management is available; and energy related events (seminars/training programs/conferences/task forces, etc.).
JAP	Institute for Building Environment and Energy Conservation (http://www.ibec.or.jp/) • Holds training seminars to support implementation of the Energy Conservation Law • Includes training on: building design, construction techniques, insulation and perimeter annual load/quantity of energy consumed calculation, which act	Under the Sustainable Building Reporting System, many cities provide tools and information to help improve the energy efficiency of new buildings. Some cities also publish summaries of all new building energy saving plans and some encourage energy efficiency by allowing builders to build taller or larger buildings than would be allowed otherwise if the building designs rank high on energy efficiency.

	Training	Public Information
JAP, Continued	as the support for enforcement of the Energy Conservation Law • In an effort to diffuse the changes in the latest amendment of the Energy Conservation Law, about 100 training sessions on the amended Energy Conservation Law were held all around Japan in April 2009 and similar sessions will continue to be held in the future.	Other cities provide construction subsidies or low-interest loans for residential buildings that rank high in energy efficiency. Rankings are determined using the software CASBEE (see section on Compliance Software and Other Tools in this report). The Institute for Building Environment and Energy Conservation also publishes detailed guidebooks on the energy efficiency standards.
KOR	According to law, KEMCO holds training programs for energy managers and operators of heat-using equipment and facilities in order to update their skills, in addition to enhancing their safety control proficiency. The Korean Energy Management Corporation offers various kinds of training and educational courses.	The code references a comprehensive handbook entitled, "Manual for 'Building Design Criteria for Energy Saving,' prepared by the Korean Energy Management Corporation and approved by the Ministry of Land, Transportation and Maritime Affairs.
USA ASHRAE 90.1-2007	DOE, through the Pacific Northwest National Laboratory, offers a range of in-person and web-based training courses on both ASHRAE and IECC. DOE also offers energy code assistance through its Ask an Expert program. ASHRAE offers professional development seminars (one day): • Complying with Standard 90.1-2007 • Exceeding the Requirements of Standard 90.1-2007 ASHRAE also offers Short Courses (half-day): • Complying with Standard 90.1-2007: HVAC/Mechanical • Exceeding Standard 90.1-2007	Since the early 1990s, DOE has been developing and providing free educational and training materials and software in support of the most recent IECC energy codes and ASHRAE 90.1. These materials are posted on a frequently updated website: www.energycodes.gov. This website also updates news and events related to building energy codes in its Building Energy Code Resource Center. Other Information Source: American Society of Home Inspectors

	Training	Public Information
USA ASHRAE 90.1-2007	ASHRAE e-learning • Web-based training • Includes HVAC systems, Fundamentals of ASHRAE Standard 90.1, 90.1 for Architects, Fundamentals of Sustainable Buildings	
USA IECC 2006	See above for DOE-sponsored training and information. In addition, IECC holds several training institutes with courses such as: • Residential Building Inspections (Foundation inspection, Floor and ceiling framing inspection) • Residential Mechanical Inspections (air duct inspections)	

Acronyms

APP	Asia-Pacific Partnership on Clean Development and Climate
AS/NZS	Australian-New Zealand standards
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
AUS	Australia
BATF	Buildings and Appliances Task Force (of the APP)
BCA	Building Code of Australia
BDCES	Building Design Criteria for Energy Saving (South Korea)
CAN	Canada
CCREUB	Criteria for Clients on the Rationalization of Energy Use for Buildings (Japan)
CCREUH	Criteria for Clients on the Rationalization of Energy Use for Houses (Japan)
CHN	China
DCGREUH	Design and Construction Guidelines on the Rationalization of Energy Use for Houses (Japan)
DOE	U.S. Department of Energy
ECBC	Energy Conservation Building Code (India)
ECO-III	Energy Conservation and Commercialization, Phase-III
GDP	Gross domestic product
HSCW	Hot summer and cold winter (referred to in China's Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone 2001)
HSWW	Hot summer and warm winter (referred to in China's Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter Zone 2003)
HVAC	Heating, ventilation and air conditioning
IECC	International Energy Conservation Code
IND	India
ISO	International Standardization Organization
JAP	Japan
KOR	South Korea

lx	luminance (international standard unit)
MEC	Model Energy Code (United States)
MJ/m^2	Megajoule per square meter
MNECB	Model National Energy Code of Canada for Buildings
MNECH	Model National Energy Code of Canada for Houses
PPP	Purchasing power parity
RBFCO	Rules for Building Facility Criteria & Otherwise (South Korea)
SHGC	Solar heat gain coefficient
USA	United States
WWR	Window-to-wall ratio

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