PNNL-17979

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

ASIA-PACIFIC PARTNERSHIP ON CLEAN DEVELOPMENT & CLIMATE

Country Report on Building Energy Codes in the United States

MA Halverson
B Shui
M Evans

April 2009

Pacific Northwest NATIONAL LABORATORY

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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Foreword

Buildings account for about 30% 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 (the U.S.). 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. These reports include country reports on building energy codes in each APP partner country and a comparative report based on the country reports. This particular report is the country report on building energy codes in the U.S.

Acknowledgements

This report owes its existence to the Asia-Pacific Partnership on Clean Development and Climate. We would like to thank all the APP partner countries and experts who collaborated on this project. We are particularly grateful to Dr. Seung-Eon Lee at the Korean Institute of Construction Technology for his oversight of the APP project under which this report was prepared (BATF 06-24). We would also like to thank Mark Ginsberg, Jean Boulin and Marc LaFrance from the U.S. Department of Energy for their leadership and financial support of this work.

Diana Shankle, manager of the PNNL Building Energy Codes Program, has provided moral and intellectual support for this project. Page Kyle reviewed this report. Alison Delgado and Kate Williams provided editorial assistance. We would also like to express our gratitude to several other individuals who supported or participated in the APP building energy code assessment in various capacities including Bing Liu, Robert G. Lucas, Sriram Somasundaram, Joe Huang, Bipin Shah, Elizabeth Malone, David Conover, Kay Killingstad, Paulette Land and Kim Swieringa. And we would like to acknowledge the Korean Ministry of Knowledge Economy and the Korea Energy Management Corporation which supported the publication of this report.

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1 Introduction and Background

1.1 A Glance at the Economy and Energy

The United States (U.S.) contributes to nearly one quarter of the world's economy, with a gross domestic product of US$13.8 trillion in 2007 (IMF, 2008).[1] As the world's largest energy producer, consumer and net importer, the U.S. also ranks first in reserves of coal, sixth in natural gas and eleventh in oil (EIA, 2008a). The U.S. had been the largest carbon emitter for years, although China surpassed it in 2006. That year, the U.S. released 5,903 Mt of carbon dioxide (EIA, 2008b).

1.2 Buildings Sector

The U.S. had 5 million commercial buildings in 2003, with total floor space in 6.7 billion square meters (67 billion square feet). Commercial buildings include, but are not limited to, office (17% of the total floor space of commercial buildings in 2003), mercantile (16%), warehouse and storage (14%), education (14%), and lodging (7%) (EIA, 2006).

In 2005, there were 111 million housing units in the U.S., with total floor space reaching 25.8 billion square meters (258 billion square meters). Residential buildings consist of single-detached houses (89% of total floor space of residential buildings in 2005)[2], multi-family apartments (9%)[3], and mobile homes (3%) (EIA, 2004, 2008a).

The buildings sector, including both commercial and residential sectors, is the second largest sectoral energy user in the U.S. after the transportation sector (Figure 1). In 2005, the buildings sector consumed 468 million tons of oil equivalent (Mtoe), or 29% of its final energy use [4] (IEA, 2007). Space heating is the largest end user for both commercial and residential buildings, followed by cooling and water heating for commercial buildings, and electric appliances (including lighting) and water heating for residential buildings.

1.3 Relevant Regulations

In response to the 1973 energy crisis, the U.S. began the development of energy codes and standards for buildings. The first standard developed was the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90 -75 Energy Conservation in New Building Design, published in 1975. In the same year, the Congress passed the Energy Policy and Conservation Act. ASHRAE/IES Standard 90.1 was first mentioned in a national energy policy act and was suggested to be established as an amended uniform national standard (Congress, 1975).

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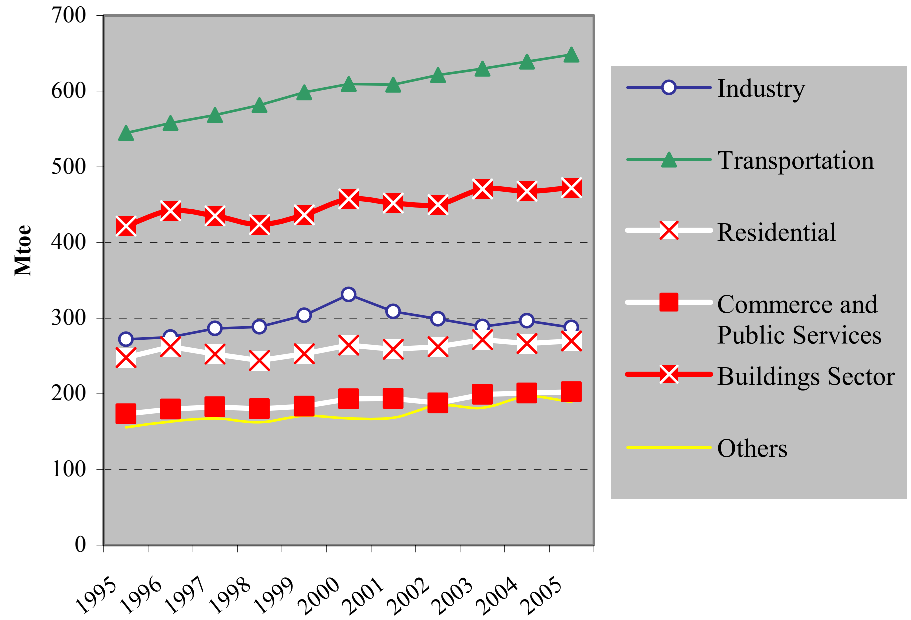
[1] Nominal gross domestic product, in current US dollars. On a purchasing power parity basis, the U.S. had the 5th largest economy in the world.
[2] The single-family houses (86.1% of the total floor space of residential buildings) refer to both single-detached houses (82.0%) and single-attached houses (6.1%).
[3] The multi-family apartments (9.0% of the total floor space of residential buildings) refer to both apartments in 2-4 unit buildings (3.3%) and apartments in more than 5 unit buildings (5.7%).
[4] It includes consumption of renewable and waste energy.

Figure 1 Energy Consumption by Sector in the U.S., 1990-2005



Notes: Energy consumption in this figure refers to final energy use, which includes consumption of renewable and waste energy; the sector "Others" includes agriculture, forestry, fishing, and non-specified and non-energy use.

Source: International Energy Agency, 2007

The Energy Policy Act of 1992 had significant impacts on the development of building energy codes. This law required the Department of Energy (DOE) to be actively involved in the development and deployment of building energy codes, with close collaborations 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 (CABO) Model Energy Code (MEC) of 1992 as the basis for 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."[5] The Energy Independence and Security Act of 2007, the most recent U.S. 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."

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[5] The structure of Energy Policy Act includes numbers of titles. A title includes a number of subtitles. A subtitle includes a number of subsections as "Sec.".

In the U.S., ASHRAE/IES Standard 90.1 is a model energy standard for the commercial design community. The International Energy Conservation Code (IECC), developed by the International Code Council (ICC) (the successor to the CABO MEC), is a model code for the code enforcement community for both residential and commercial buildings.

Since 1975, 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 1983, 1986, 1989, 1992, 1993, and 1995 by the CABO and in 1998, 2000, 2003, 2006 and the coming 2009 by the ICC.

1.4 Implementation

1.4.1 The Role of DOE

The Energy Policy Act of 1992 requires DOE to evaluate the latest version of ASHRAE 90.1 as it is released to determine if the new version saves more energy than the previous version for commercial buildings. If the new version does save energy, DOE is required to notify states of this fact, and states are required to adopt a new commercial code that meets or exceeds the provisions of the new version of ASHRAE 90.1. IECC is part of DOE's determination process for residential buildings (Bartlett et al., 2003).

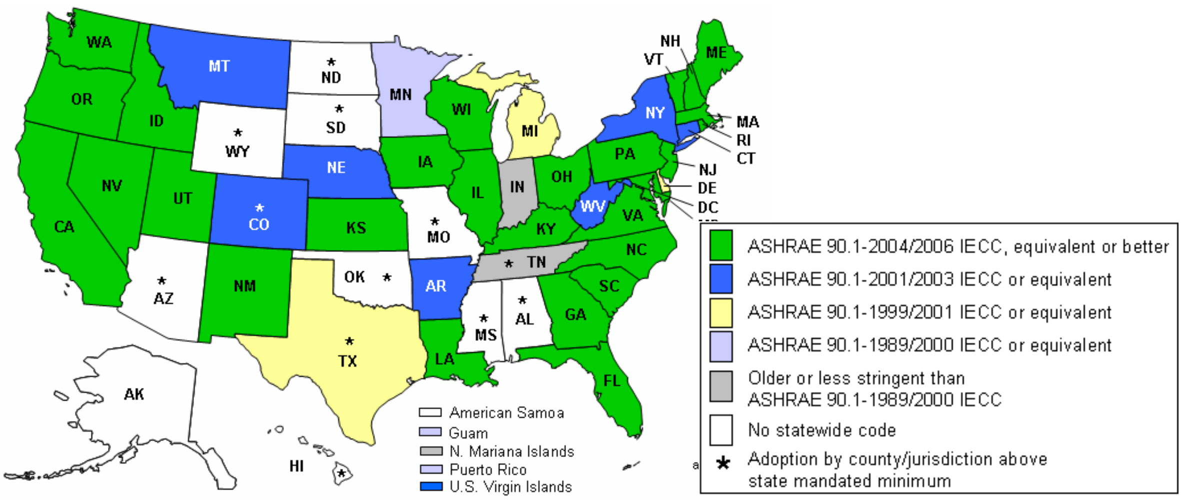
Since the early 1990s, DOE has been developing and providing free education and training material and software in support of the most recent IECC energy codes and ASHRAE 90.1. These materials are posted on a well-maintained U.S. DOE website, www.energycodes.gov. This website also updates news and events related to building energy codes.

DOE provides free energy code compliance software for download. The *REScheck* software is for residential buildings, and the *COMcheck* software is for commercial buildings. Both have been widely used by the compliance and enforcement community. In addition, DOE has invested heavily over many years in the development of whole building energy simulation tools, such as *EnergyPlus*.[6]

As part of the effort of promoting the adoption of building energy codes, DOE regularly updates code adoption maps and local jurisdiction contact information (Figures 2 and 3). In the maps, green means that the state has adopted the most recent building energy codes, blue and yellow indicate that the state uses a less recent version of the building energy code, and white indicates that no statewide code is in place. The status maps help not only to reflect the current status of a state, but also provide vivid comparisons on adoption status among states (DOE, 2008).

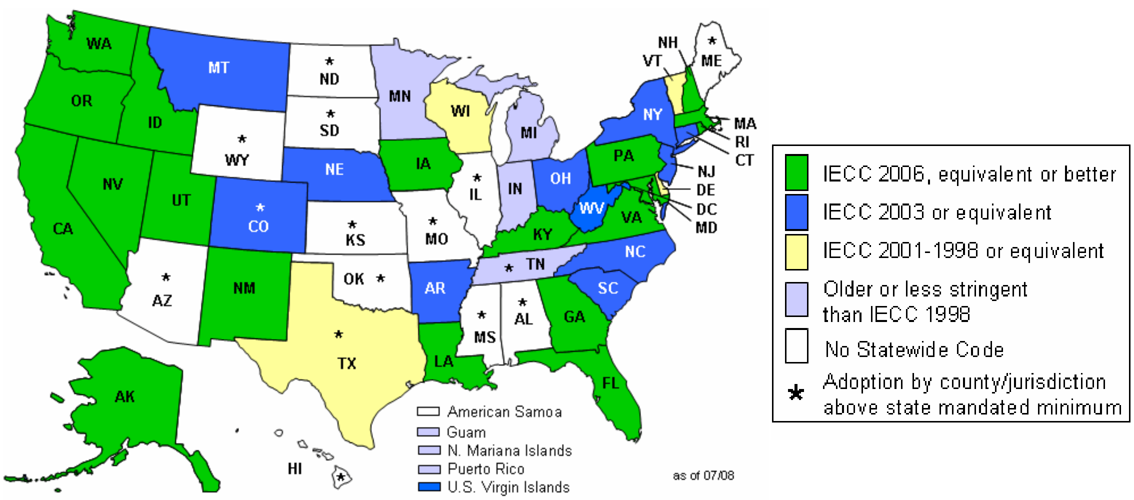
[6] See http://apps1.eere.energy.gov/buildings/energyplus/ for more information on EnergyPlus.

Figure 2 Status of Commercial Building Energy Codes by State



Source: DOE, 2008

Figure 3 Status of Residential Building Energy Codes by State



Source: DOE, 2008

1.4.2 The Role of State and Local Governments[7]

In the U.S., the implementation and enforcement of energy codes falls under the states and local jurisdictions that adopt the model energy codes. States may also develop their own codes independent of ASHRAE or ICC, and states such as California have done so with great success.

Adoption

Preceding the adoption or revision of an energy code, state and local governments often organize an advisory board, which includes stakeholders from design, construction, and enforcement communities. A chief responsibility of the board is to determine whether an energy standard and model energy code should be adopted. The board also considers the need to modify energy standards and model energy codes to integrate local preferences and construction practices, and may also offer information during the adoption process.

The adoption process starts with a change being initiated by a legislative or regulatory agency or stakeholders in the process. The proposal is then reviewed by a legislative or public process and any changes are incorporated into the proposal. After the legislation or regulation has been accepted and filed by the authority, the code is put into effect. There is a grace period between the adoption and the effective date of the legislation or regulation, which generally lasts from thirty days to six months (Bartlett et al., 2003).

Implementation

Communication and training are two key factors for the success of implementation. Communication should occur between the code-adopting bodies, the code-enforcing bodies, and the building construction community. Training must cater to the specific needs of building officials, architects, designers, engineers, manufacturers, builders and contractors, and building owners. A new code is more likely to be accepted and practiced when more training is being offered for the new code, as well as when attracting more publicity (Bartlett et al., 2003).

Enforcement

Enforcement of energy codes is practiced at both the state and local levels, and is particularly common in smaller states, in rural jurisdictions with no code officials, and for state-owned or financed construction. It has been observed that a single state agency tends to be more effective than enforcement run by several local agencies. When several state field inspectors work under one body, the building construction community is benefited by having only one point of contact. A single point of contact is crucial if a plan is reviewed by one office, which is generally the case. Without enough state resources at hand, plan reviews and construction inspections do not perform as well (Bartlett et al., 2003).

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[7] This section is edited from *Bartlett, R., Halverson, M.A., Shankle, D.L., 2003. Understanding Building Energy Codes and Standards. Pacific Northwest National Laboratory.* Pacific Northwest National Laboratory.

Advantages of local enforcement agencies include their close proximity to the construction site and their one-on-one interactions with the design and construction community—both of which serve as opportunities for greater direct enforcement during design and construction. However, because local jurisdictions differ and may lack the resources to support enforcement, enforcement at the local level is susceptible to noncompliance across a state. Noncompliance is avoided when a state code agency closely works with local governments to enforce the state code (Bartlett et al., 2003).

State and local governments may bring in third parties to conduct plan reviews. Often affiliated with professional organizations, most third party reviewers are experienced in solving and working with the complexities and subtleties of energy codes and standards; have access to better sources, references and contacts; and are more prepared to alleviate heavy workloads (Bartlett et al., 2003).

2 Building Energy Codes

2.1 History of Building Energy Codes

In the U.S., model energy standards, such as ASHRAE, are developed for the design community, and model codes, such as IECC, are developed for the code enforcement community (Bartlett et al., 2003).

ASHRAE 90 - 75 was the first building energy standard in the U.S., published in 1975. This was followed shortly by a codified version of these requirements known as the *Model Code for Energy Conservation*, published in 1977 by the National Council of States on Building Codes and Standards.

ASHRAE 90.1 has been issued in 1980, 1989, 1999, 2001, 2004, and 2007 for commercial buildings. ASHRAE Standard 90.2 has been issued in 1975, 1980, 1993, 2001, 2004, and 2007 for residential buildings. ASHRAE Standard 90.2 is used infrequently.

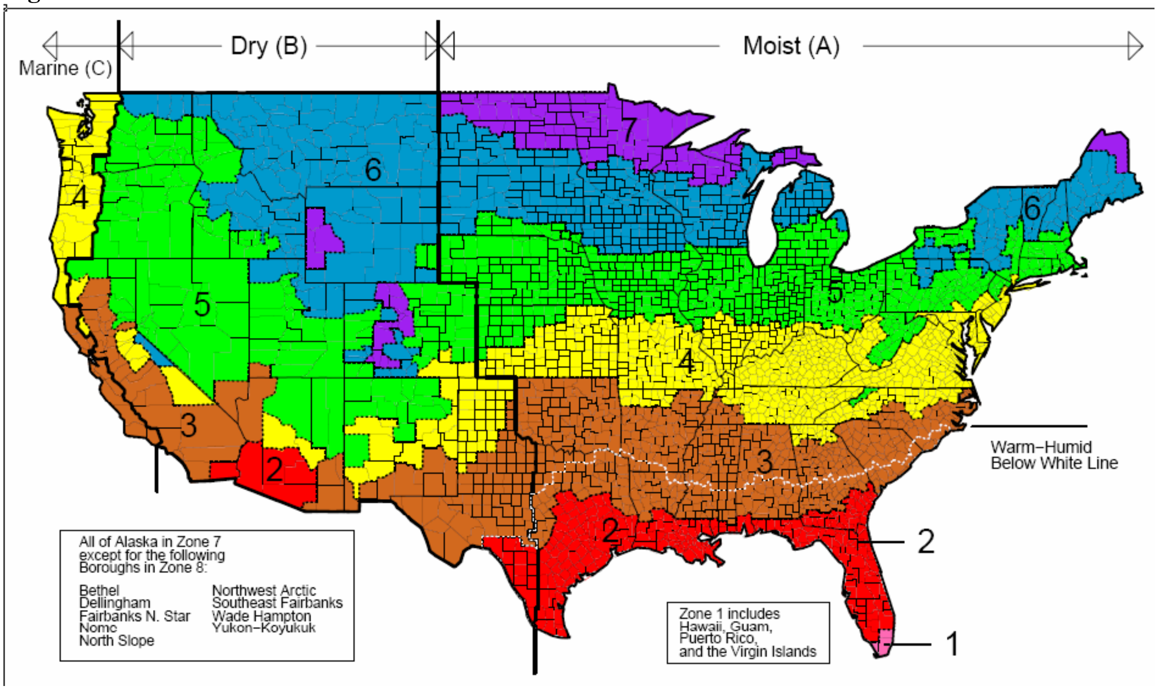
Model codes were issued in 1983, 1986, 1989, 1992, 1993, 1995, 1998, 2000, 2001 2003, and 2006 for commercial and residential buildings. CABO developed the codes between 1983 and 1995, and ICC developed the codes between 1998 and now.

In this section, ASHRAE 90.1-2007 and IECC 2006 are comparatively reviewed as building energy codes for commercial buildings, and IECC 2006 is reviewed as building energy codes for residential buildings.

2.2 Climate Zones

IECC 2004 Supplement was the first model energy codes to adopt a new climate zone map. Since then, the new eight climate zones have been adopted by ASHRAE 90.1 (Figure 4 and Table 1).

Figure 4 Climate Zones in ASHRAE 90.1 – 2007 and IECC 2006



Source: ASHRAE 90.1-2007

Table 1 Climate Zone Definitions

	Thermal Criteria in SI Units
1	5,000 < CDD 10 °C
2	3,500 < CDD 10 °C <= 5,000
3A and 3B	2,500 < CDD 10 °C <= 3,500 and HDD 18 °C <= 3,000
4A and 4B	CDD 10 °C <= 2,500 and HDD 18 °C <= 3,000
3C	HDD 18 ° C <= 2000
4C	2,000 < HDD 18 °C <= 3,000
5	3,000 < HDD 18 ° C <=4,000
6	4,000 < HDD 18 ° C <= 5,000
7	5,000 < HDD 18 ° C <= 7,000
8	7,000 < HDD 18 °C

Source: IECC 2006

2.3 ASHRAE 90.1-2007 and IECC 2006 for Commercial Buildings (Including High-Rise Multi-Family Residential Buildings)

ASHRAE 90.1-2007 applies to all commercial buildings (including high-rise multi-family residential buildings) that use fossil fuel or electricity, but not to "equipment or portions of building systems that use energy primarily for industrial, manufacturing, or commercial processes." ASHRAE 90.1-2007 does not apply to single-family homes, multi-family residential structures of three stories or fewer, manufactured houses (mobile homes), or manufactured houses (modular).

IECC 2006 covers both commercial buildings and low-rise residential buildings, but with separate chapters for each: Chapter 5 for commercial buildings and Chapter 4 for residential buildings. IECC 2006 does not contain explicit exemption for industrial, manufacturing, or commercial processes, but this issue is addressed in the building code adopted by the state or local jurisdiction, and in the legislation that applies the energy code to specific building types. The same state or local application would apply to ASHRAE 90.1-2007 as well.

Both ASHRAE 90.1-2007 and IECC 2006 set "minimum requirements for energy efficient design and construction of commercial buildings with a connected load of 500 kW or greater, or a contract demand of 600 kVA or greater, and a conditioned area no less than 1,000 square meters." The content structure of the ASHRAE 90.1-2007 and IECC 2006 are similar, though with different section numbers and titles (Table 2).

For ASHRAE 90.1-2007, the building shall comply with the mandatory provisions of the code[8] and either the prescriptive method[9] or the energy budget method[10]. For IECC 2006, the building shall comply with either the prescriptive method[11], or the Total Building Performance Method[12] in conjunction with the corresponding sections in IECC 2006[13].

[8] See § 5.4, § 6.4, § 7.4, § 8.4, § 9.4, and §10.4 of ASHRAE 90.1-2007.

[9] See § 5.5 (or the envelope tradeoff option of § 5.6), § 6.5, § 7.5 and § 9.5 or § 9.6 of ASHRAE 90.1-2007.

[10] See Chapter 11 of ASHRAE 90.1-2007.

[11] See § 502, § 503, § 504, and § 505 of IECC 2006 on an individual basis or with the applicable section of ASHRAE Standard 90.1-2004.

[12] See § 506 of IECC 2006.

[13] See § 502.4, § 502.5, § 503.2, § 504, § 505.2, § 505.3, § 505.4, § 505.6, and § 505.7 of IECC 2006.

Table 2 Essential Features of ASHRAE 90.1-2007 and IECC 2006 for Commercial Buildings

Section Number and Title for ASHRAE 90.1-2007	Corresponding Section for IECC 2006	Description
1 & 2. Purpose and Scope	Section 501 – General	Minimum requirements for energy efficient design and construction of commercial buildings with a connected load of >500 kW, or a contract demand of > 600 kVA, and a conditioned area of >1000 m^2
3. Definitions, Abbreviations, and Acronyms	Chapter 2 – Definitions	Terms, abbreviations and acronyms
4. Administration and Enforcement	Chapter 1 – Administration	Mandatory compliance for all applicable new buildings and major renovations to existing buildings
5. Envelope	Section 502 – Building Envelope Requirements	Mandatory provisions and either the prescriptive criteria or the tradeoff option
6. Heating, Ventilation and Air Conditioning	Section 503 – Building Mechanical Systems	Mandatory provisions and prescriptive criteria
7. Service Hot Water and Pumping	Section 504 – Service Water Heating	Mandatory provisions, including solar water heating for at least 1/5 of design capacity, unless systems use heat recovery
8. Electrical Power	Section 505 – Electrical Power and Lighting Systems	Mandatory requirements for power distribution systems
9. Lighting	Section 505 – Electrical Power and Lighting Systems	Mandatory provisions and prescriptive criteria for interior and exterior lighting features
10. Other Equipment	No comparable section (N.A.)	Mandatory requirements for motors
11. Energy Cost Budget Method	Section 506 – Total Building Performance Method	An alternative to the prescriptive requirements of the code based on whole building energy cost and applied to all building types covered by the code
12. Normative References	Chapter 6 – Referenced Standards	Required references to be used in conjunction with the code
Appendix A – Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations	Tables 102.1.3(1) to 102.1.3(3) for fenestration product rating provide minimal default tables	Methods of calculation for assembly U-factor, C-Factor, and F-factor for all envelope assemblies addressed in the code
Appendix B – Building Envelope Climate Criteria	Chapter 3 – Climate Zones	Tables of climate zones for counties in the U.S. states and territories, cities in Canadian provinces, and international cities
Appendix C- Building Envelope Tradeoff Method	N.A.	Procedure for calculating envelope performance factor (EPF) and tables for EPF coefficients for building envelope tradeoff method
Appendix D – Climatic Data	N.A.	The U.S. and U.S. Territories, Canadian, and international climatic data
Appendix E – Informative References	N.A.	Non-mandatory informative references to be used with the code
Appendix F – Addenda Description Information	N.A. (but changes from previous version marked in margins of text)	Description of addenda processed to ASHRAE 90.1-2004 to create ASHRAE 90.1-2007
Appendix G – Performance Rating Method	N.A.	Method for calculating energy performance that exceeds the level required by the code

Source: ASHRAE 90.1-2007; IECC 2006

2.3.1 Administration and Enforcement[14]

Administration

The ASHRAE 90.1-2007 has a suggested set of administrative requirements in Chapter 4 - Administration and Enforcement. IECC 2006 has a suggested set of administrative requirements in Chapter 1, Administration, which includes a sample ordinance for the adoption of IECC 2006. Since both of these codes are model codes, changes may be made by the states or local jurisdictions that adopt these codes.

Documentation[15]

To ensure compliance, plans and specifications should show all pertinent data and features of the building, equipment, and systems in sufficient detail to permit the authority having jurisdiction to verify that the building complies with the code requirements. In addition, the authority with jurisdiction may require supplemental information necessary to verify compliance with the code.

2.3.2 Envelope[16]

The building envelope shall comply with the mandatory provisions and either the prescriptive criteria or the tradeoff 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.

Mandatory Requirements

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.

Prescriptive Requirements

The prescriptive requirements (which are open to tradeoffs with alternate paths of compliance) cover requirements for roofs, opaque walls, below-grade walls, foundations, vertical fenestration (or wall window), and skylights. In ASHRAE 90.1-2007, the requirements for roofs and opaque walls (maximum U-factors of overall assembly and minimum R-values of insulation alone) are provided for eight climate zones and three different use-types of commercial building spaces (nonresidential, residential, and semi-heated). In IECC 2006, there is only one commercial building space type considered, and only R-values for building assemblies are provided. There is also a tradeoff for “cool roofs”[17] in ASHRAE 90.1-2007, which allows the installation of lowered amounts of insulation in climate zones 1-3. There is no comparable tradeoff in IECC 2006.

Vertical fenestration requirements are given U-factors and Solar Heat Gain Coefficient (SHGC) for window-to-wall ratios (WWR) of less than 40%, with certain “adjusted”

[14] See § 4 of ASHRAE 90.1-2007 and § 1 of IECC 2006.
[15] See § 5.7, § 6.7, § 7.7, § 8.7 of ASHRAE 90.1-2007, and § 104 of IECC 2006.
[16] See § 5 of ASHRAE 90.1-2007 and § 502 of IECC 2006.
[17] Cool roofs have initial solar reflectance of no less than 0.70 and an initial emittance of no less than 0.75.

SHGC requirements for overhangs, depending on the location and projection factors. There is no minimum visible transmittance requirement of glazing except if the envelope tradeoff method in ASHRAE 90.1-2007 § 5.6 is utilized. WWR is limited to a maximum of 40% for the prescriptive requirement.

Skylight (area limited to a maximum of 5% of the gross roof area) requirements are also provided in terms of maximum U-factors and SHGC for the eight climate zones.

Building Envelope Tradeoff Option

The building envelope complies with the code if the building envelope performance factor (EPF) of the proposed design is less than the standard design (which exactly complies with the prescriptive requirements). An envelope tradeoff equation is provided in Appendix C of the ASHRAE 90.1-2007. No envelope tradeoff is provided for IECC 2006, although DOE does provide software that utilizes the ASHRAE 90.1-2007 tradeoff method for IECC 2006. This software may be used in jurisdictions where it is deemed to comply with IECC 2006.

2.3.3 Heating, Ventilation and Air Conditioning[18]

All heating, ventilation and air conditioning (HVAC) equipment and systems shall comply with the mandatory provisions and the prescriptive criteria. 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.

Mandatory Requirements

The mandatory requirements are for minimum equipment efficiency levels, load calculations, controls, HVAC system construction (piping and ductwork), system balancing, and system commissioning. Cooling and heating equipment shall meet or exceed the minimum efficiency requirements.[19] Heating and cooling equipment not listed in the standard is not regulated by the standard.

Heating and cooling system design loads for the purpose of sizing systems and equipment are required to be determined "in accordance with generally accepted engineering standards and handbooks acceptable to the adopting authority."

Both ASHRAE 90.1-2007 and IECC 2006 list minimum equipment efficiencies. In the U.S., many equipment efficiencies are governed by minimum manufacturing standards promulgated by DOE. For most HVAC equipment, DOE's rulemakings are pre-emptive of requirements published in codes or standards. However, some pieces of equipment are not pre-empted by DOE rules. The most significant pieces of equipment not covered by federal rulemakings are chillers.

There are numerous control requirements in ASHRAE 90.1-2007. These include thermostatic controls for different building zones, set point overlap restrictions, off-hour controls, ventilation system controls, heat pump auxiliary heat controls, humidifier

[18] See § 6 of ASHRAE 90.1-2007 and § 503 of IECC 2006.
[19] See Tables 6.8.1A through 6.8.1J of ASHRAE 90.1-2007.

preheat controls, humidification and dehumidification controls, freeze protection and snow/ice melting controls, and ventilation controls for high occupancy areas. IECC 2006 has a somewhat reduced set of control requirements, but efforts are underway to add more control requirements to IECC 2009. IECC 2006 requires thermostatic controls, heat pump supplementary heat controls, set point overlap restriction, off-hour controls, and shut-off damper controls.

Both ASHRAE 90.1-2007 and IECC 2006 contain duct and plenum insulation, leakage requirements and a requirement for testing leakage on high pressure ducts. Piping insulation requirements cover heating systems with design operating temperatures greater than 40°C (104°F), cooling systems with temperatures less than 15°C (59°F). Piping insulation exposed to weather and cellular foam insulation shall be protected appropriately. Ductwork insulation requirements are provided for supply and return ducts depending on their location.

Both ASHRAE 90.1-2007 and IECC 2006 have system balancing requirements for air and hydronic systems. For example, a written balance report be provided to the owner (or designated representative) for HVAC systems serving zones with a total conditioned area exceeding 500 square meters (5,000 square feet). ASHRAE 90.1-2007 also requires that buildings larger than 5,000 square meters (50,000 square feet), except warehouses and semiheated spaces, must have detailed commissioning instructions for HVAC control systems.

Both ASHRAE 90.1-2007 and IECC 2006 also contain a separate set of requirements for "simple HVAC" systems. These requirements are based on the mandatory and prescriptive requirements found in the rest of the HVAC section. However, there are also specific requirements that apply to single zone systems served by unitary or packaged equipment. ASHRAE 90.1-2007 further limits the use of these requirements to buildings of one or two stories with a gross floor area of less than 2,500 square meters (25,000 square feet). IECC 2006 does not have a size limitation on buildings that may use the simple system requirements.

Prescriptive Requirements

The prescriptive HVAC requirements in ASHRAE -2007 address 9 topics: economizers[20], simultaneous heating and cooling limitation,[21] air system design and control,[22] hydronic system design and control,[23] heat rejection equipment,[24] energy recovery,[25] exhaust hoods,[26] radiant heating systems,[27] and hot gas bypass limitation.[28] IECC 2006 contains

[20] See § 6.5.1 of ASHRAE 90.1-2007.
[21] See § 6.5.2 of ASHRAE 90.1-2007.
[22] See § 6.5.3 of ASHRAE 90.1-2007.
[23] See § 6.5.4 of ASHRAE 90.1-2007.
[24] See § 6.5.5 of ASHRAE 90.1-2007.
[25] See § 6.5.6 of ASHRAE 90.1-2007.
[26] See § 6.5.7 of ASHRAE 90.1-2007.
[27] See § 6.5.8 of ASHRAE 90.1-2007.
[28] See § 6.5.9 of ASHRAE 90.1-2007.

similar sections that address the same requirements as follows: economizers,[29] simultaneous heating and cooling limitations,[30] air system design and control,[31] hydronic system design and control,[32] heat rejection equipment,[33] energy recovery,[34] exhaust hoods,[35] radiant heating systems,[36] and hot gas bypass limitation.[37]

The section on economizers[38] requires every cooling system with a fan to include an economizer with a large number of exceptions. IECC 2006 also addresses specific design requirements for both air and water economizers. Economizers must be integrated with the mechanical cooling system and must be controlled so that economizer usage does not impact building heating energy usage.

The simultaneous heating and cooling limitation[39] requires a number of control systems designed to prevent reheating, recooling, mixing of heated and cooled air, or other simultaneous operation of heating and cooling systems to the same zone. Controls include zone thermostatic controls, hydronic system controls, dehumidification and humidification system controls.

The section of air system design and control[40] requires that fan systems be designed to be energy efficient. It applies a fan system power limitation that limits the ratio of the design air flow rate to the fan system power and requires the use of variable air volume (VAV) fan control for motors larger than 10 horsepower.

The provisions on hydronic system design and control[41] require that hydronic systems be designed for variable flow, that flow in chillers or boilers not in use be reduced, that larger systems contain chilled and hot water temperature reset controls, and that water loop heat pump systems have valves to shut out flow to heat pumps when the compressor is off.

The section of heat rejection equipment[42] requires fan speed controls on motors of more than 7.5 horsepower.

The energy recovery provisions[43] require exhaust air energy recovery on systems greater than 5,000 cubic feet per minute (cfm) and with a minimum outdoor air supply of 70% of

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[29] See § 503.4.1 of IECC 2006.
[30] See § 503.4.5 of IECC 2006.
[31] See § 503.4.2 of IECC 2006.
[32] See § 503.4.3 of IECC 2006.
[33] See § 503.4.4 of IECC 2006.
[34] See § 503.2.6 and § 503.4.6 of IECC 2006.
[35] Not addressed in IECC 2006; possibly addressed in 2006 International Mechanical Code (IMC).
[36] Not addressed in IECC 2006.
[37] Not addressed in IECC 2006.
[38] See § 6.5.1 of ASHRAE 90.1-2007.
[39] See § 6.5.2 of ASHRAE 90.1-2007.
[40] See § 6.5.3 of ASHRAE 90.1-2007.
[41] See § 6.5.4 of ASHRAE 90.1-2007.
[42] See § 6.5.5 of ASHRAE 90.1-2007.
[43] See § 6.5.6 of ASHRAE 90.1-2007.

the design supply air quantity. This section also requires that condenser heat recovery for any building that operates 24 hours a day has a total heat rejection capacity of 6 million Btu/h and a design service water heating load of 1 million Btu/h.

The section on exhaust hoods[44] requires kitchen hoods larger than 5,000 cfm to be provided with makeup air sized to 50% of exhaust air volume. Fume hoods systems greater than 15,000 cfm must include either VAV systems, direct makeup air, or heat recovery.

The provisions on radiant heating systems[45] require that radiant heating is used when heating is required for unenclosed spaces.

The hot gas bypass limitation[46] restricts the use of hot gas bypass to cooling systems that have multiple steps of unloading or continuous capacity modulation.

2.3.4 Service Hot Water [47]

All service water heating equipment and systems shall comply with the mandatory and prescriptive provisions. 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.

Mandatory Requirements

The mandatory requirements in ASHRAE 90.1-2007 cover load calculations, service water heating piping insulation and controls (such as temperature, temperature maintenance, outlet temperature, and circulating pump), pools (pool heaters and pool covers), and heat traps. Swimming pools shall be provided with a vapor retardant pool cover on or at the water surface. Pools heated to more than 32°C (90°F) shall have a pool cover with a minimum insulation value of R-2.1 (R-12). Exceptions are pools deriving more than 60% of their energy from site-recovered energy or a solar energy source.

IECC 2006 has nearly identical mandatory requirements, with the exception of load calculation, temperature maintenance control, or circulating pump control requirements.

Prescriptive requirements for service hot water equipment include permission to use a single boiler to provide both space heating and service water heating if one of three conditions is met:

- The standby loss of the equipment meets a specific formula.
- It can be demonstrated that using a single heat source saves more energy than separate units.
- The energy input of the single system is less than 150,000 Btu/h.

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[44] See § 6.5.7 of ASHRAE 90.1-2007.
[45] See § 6.5.8 of ASHRAE 90.1-2007.
[46] See § 6.5.9 of ASHRAE 90.1-2007.
[47] See § 7 of ASHRAE 90.1-2007 and § 504 of IECC 2006.

IECC 2006 does not have such provisions on a single boiler.

2.3.5 Electrical Power [48]

Electric equipment and systems should comply with the prescriptive requirements. Alternatively, the whole building energy cost approach in the Energy Cost Budget Method (ASHRAE 90.1-2007) may be used.

Mandatory Requirements

Mandatory requirements in ASHRAE 90.1-2007 include feeder and branch circuit voltage drop only. No corresponding requirement is found in IECC 2006.[49] IECC 2006 does include a requirement for separate electrical meters for individual dwelling units in buildings having multiple dwelling units.

2.3.6 Lighting [50]

Lighting systems and equipment that apply to interior spaces of buildings, exterior building features and exterior building grounds should comply with the code's mandatory provisions and the prescriptive criteria. 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.

Mandatory Requirements

Mandatory requirements in ASHRAE 90.1-2007 cover lighting control, tandem wiring, exit signs, exterior building grounds lighting, and exterior building lighting power. IECC 2006 contains identical provisions.

Prescriptive Requirements

Prescriptive requirements are provided in terms of interior lighting power (building area method or the space-by-space method) and exterior lighting power requirements. IECC 2006 contains similar requirements, but does not include the space-by-space method.

2.3.7 Other Equipment [51]

General purpose Design A and Design B motors shall comply with the mandatory requirements. 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.

Mandatory Requirements

Mandatory requirements in ASHRAE 90.1-2007 are provided for general purpose Design A and Design B motors only. IECC 2006 does not address motors, as the motors listed in ASHRAE 90.1-2007 are also specified as minimum manufacturing standards in the Energy Policy Act of 1992.

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[48] See § 8 of ASHRAE 90.1-2007 and § 505 of IECC 2006.

[49] However, these same requirements are found in footnotes to a table in the National Electrical Code, where they may be enforced separate from IECC.

[50] See § 9 of ASHRAE 90.1-2007 and § 505 of IECC 2006.

[51] See §10 of ASHRAE 90.1-2007.

2.3.8 Whole Building Performance Method [52]

A building complies as long as it meets all the mandatory criteria and the estimated annual energy use of the proposed design is less than the standard design. Chapter 11 of ASHRAE 90.1-2007 and Section 504 of IECC 2006 present the whole building performance method, entitled "Energy Cost Budget Method" and "Total Building Performance Method", respectively.

ASHRAE 90.1-2007 also contains a separate Performance Rating Method in its Appendix G. This method is used to determine performance that is better than ASHRAE 90.1-2007. The Performance Rating Method in ASHRAE 90.1-2004 is the basis of the US Green Building Council's Leadership in Energy and Environmental Design (LEED) Version 2.2 energy points. This method provides more flexibility than the Energy Cost Budget Method, but it is not designed for simply showing compliance.

2.3.9 Test Procedures Referenced in ASHRAE 90.1-2007 [53]

ASHRAE 90.1-2007 references many test procedures. The details of these test procedures are beyond the scope of this country report. Interested readers can find details in Chapter 12, Normative References.

2.4 IECC 2006 for Low-Rise Residential Buildings

IECC 2006 for low-rise residential buildings (Table 3), mainly covered by its Chapter 4, states that 1) residential buildings shall comply with mandatory provisions of certificate, air leakage, moisture control, maximum fenestration U-factor and SHGC, and systems (such as controls, ducts, mechanical system piping insulation, etc),[54] and either 2a) prescriptive provisions of general and special insulation and fenestration criteria of building envelope,[55] or 2b) performance provisions of simulated performance alternatives.[56]

[52] See §11 of ASHRAE 90.1-2007 and § 506 of IECC 2006.
[53] See § 12 of ASHRAE 90.1-2007 and § 6 of IECC 2006.
[54] See Sections 401, 402.4, 402.5, 402.6 and 403 of IECC 2006.
[55] See Sections 402.1 through 402.3 of IECC 2006.
[56] See Section 404 of IECC 2006.

Table 3 Essential Features of IECC 2006 for Residential Buildings

Section Number and Title	Description
Chapter 4 Residential Energy Efficiency	
Section 401 – General	Compliance and permanent certificate
Section 402 – Building Envelope Requirements	Mandatory and prescriptive provisions
Section 402.1 General (Prescriptive)	Insulation and fenestration criteria, R-value computation, U-factor alternative and total UA[57] alternative
Section 402.2 Specific Insulation Requirements (Prescriptive)	Insulation requirements for ceilings, mass walls, ceilings, walls and floors, basement walls, slab-on-grade floors, crawl space walls, etc.
Section 402.3 Fenestration (Prescriptive)	U-factor, glazed fenestration SHGC, glazed fenestration exemption, opaque door exemption, thermally isolated sunroom U-factor and replacement fenestration
Section 402.4 Air Leakage (Mandatory)	Building thermal envelop, fenestration air leakage and recessed lighting
Section 402.5 Moisture Control (Mandatory)	Building design for moisture control and vapor retarder installation if necessary
Section 402.6 Maximum Fenestration U-Factor and SHGC (Mandatory)	The tradeoff of the area weighted average maximum fenestration U-factor and SHGC
Section 403 – Systems (Mandatory)	Mandatory provisions and prescriptive criteria
Section 403.1 Controls	Controls for heating and cooling system, and heat pump supplementary heat
Section 403.2 Ducts	Insulation, sealing and building cavities
Section 403.3 Mechanical System Piping Insulation	Insulation requirements for mechanical piping system
Section 404.4 Circulating Hot Water Systems	Insulation requirements for circulating hot water system
Section 404.5 Mechanical Ventilation	Mechanical ventilation requirements
Section 404.6 Equipment Sizing	Size requirements for heating and cooling equipment
Section 404 – Simulated Performance Alternative	An alternative to the prescriptive requirements

Source: IECC 2006

2.4.1 Building Thermal Envelope[58]

Residential building envelopes should comply with the prescriptive provisions and mandatory provisions, as described below.

Prescriptive Requirements

The building thermal envelope shall meet the prescriptive requirements of insulation and fenestration criteria specified by climate zones (Table 4). An assembly with a U-factor equal to or less than the ones in Table 4 shall be permitted as an alternative to the defined

[57] UA is a value equal to the U-factor of an assembly times the assembly area.
[58] See § 402 of IECC 2006.

R-value (Table 5). If the total building thermal envelope UA is less than or equal to the total UA resulting from using the U-factors in Table 4 (multiplied by the same assembly area as in the proposed building), the building should be considered in compliance with Table 4. The UA calculation method should be consistent with the ASHRAE *Handbook of Fundamentals* and should include the thermal bridging effects of framing materials.

Table 4 Insulation and Fenestration Requirements by Component [a]

Climate zone	Fenestration U-factor	Skylight[b] U-factor	Glazed fenestration	Ceiling R-value	Wood frame wall	Mass wall R-value	Floor R-value	Basement[c] wall r-value	Slab[d] r-value &	Crawl space[c] wall
2	0.75	0.75	0.4	30	13	4	13	0	0	0
3	0.65	0.65	0.40[e]	30	13	5	19	0	0	5 /13
4 except Marine	0.4	0.6	NR	38	13	5	19	10 /13	10, 0.61m	10 /13
5 and Marine 4	0.35	0.6	NR	38	19 or 13+5[g]	13	30[f]	10 /13	10, 0.61m	10 /13
6	0.35	0.6	NR	49	19 or 13+5[g]	15	30[f]	10 /13	10, 1.219m	10 /13
7 and 8	0.35	0.6	NR	49	21	19	30[f]	10 /13	10, 1.219m	10 /13

Notes:
a. R-values are minimums. U-factors and SHGC are maximums. R-19 shall be compressed into a 2 × 6 cavity.
b. The fenestration U-factor column excludes skylights. The SHGC column applies to all glazed fenestration.
c. The first R-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.
d. R-5 shall be added to the required slab edge R-values for heated slabs.
e. There are no SHGC requirements in the Marine zone.
f. Or insulation sufficient to fill the framing cavity, R-19 minimum.
g. "13+5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25 % or less of the exterior, insulating sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25 percent of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.

Source: IECC 2006

Table 5 Equivalent U-Factors[a]

Climate zone	Fenestration U-factor	Skylight U-factor	Ceiling U-factor	Frame wall U-factor	Mass wall U-factor	Floor U-factor	Basementc wall U-factor	Crawl spacec wall U-factor
1	1.2	0.75	0.035	0.082	0.197	0.064	0.36	0.477
2	0.75	0.75	0.035	0.082	0.165	0.064	0.36	0.477
3	0.65	0.65	0.035	0.082	0.141	0.047	0.36	0.136
4 except Marine	0.4	0.6	0.03	0.082	0.141	0.047	0.059	0.065
5 and Marine 4	0.35	0.6	0.03	0.06	0.082	0.033	0.059	0.065
6	0.35	0.6	0.026	0.06	0.06	0.033	0.059	0.065
7 and 8	0.35	0.6	0.026	0.057	0.057	0.033	0.059	0.065

Notes:
a. *Nonfenestration U-factors shall be obtained from measurement, calculation, or an approved source.*

Source: IECC 2006

This section also provides specific insulation requirements for ceilings with/without attic spaces, mass walls, floors, basement walls, slab-on-grade floors, crawl space walls, masonry veneer and thermally isolated sunroom insulation.

The prescriptive provisions of fenestration include U-factor, glazed fenestration SHGC, glazed fenestration exemption, opaque door exemption, thermally isolated sunroom U-factor, and replacement fenestration.

Mandatory Requirements

The mandatory requirements for air leakage covers:

- Building thermal envelope - the sealing methods between dissimilar materials should allow for differential expansion and contraction,
- Fenestration air leakage - windows, skylights and sliding glass doors should have an air infiltration rate of no more than 1.5 $L/s/m^2$, and swinging doors no more than 2.6 $L/s/m^2$, and
- Recessed lighting - the luminaries installed in the building thermal envelope should be sealed to limit air leakage between conditioned and unconditioned spaces.

The mandatory requirements for moisture control suggest that building design should not create conditions of accelerated deterioration from moisture condensation. An approved vapor retarder should be installed on the warm-in-winter side of the thermal insulation if the above-grade frame walls, floors and ceilings are not ventilated to reduce moisture.

2.4.2 Systems (Mandatory)[59]

The mandatory provisions for controls require that at least one thermostat should be provided for each separate heating and cooling system. The mandatory provision for ducts require that insulation should be installed for supply, return ducts, ducts in floor trusses, mechanical system piping, and circulating hot water systems. All ducts, air handlers, filter boxes, and building cavities used as ducts should be sealed. Building framing cavities should not be used as supply ducts. Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating. Heating and cooling equipment should be sized in accordance with Section M1401.3 of the *International Residential Code.*

2.4.3 Simulated Performance Alternative (Performance)[60]

This section establishes criteria for an alternative compliance method to the prescriptive requirements by using simulated energy performance analysis of heating, cooling, and service water heating energy.

This performance compliance is based on simulated energy performance and requires that a proposed residence (proposed design) have an estimated annual energy cost that is less than or equal to the annual energy cost of the standard reference design. The calculation tool employed is not brand or name specific. However, minimal capabilities of the software are specified. Approval shall be permitted.

[59] See § 403 of IECC 2006.
[60] See § 404 of IECC 2006.

3 Other Developments

3.1 DOE's Activities related to Building Energy Codes

A central vision of DOE's Building Technology Program, which includes Building Energy Codes initiative, is to realize marketable, net-zero energy buildings[61] through the development of conservation technologies and practices. DOE's goal is to have marketable zero energy homes by 2020 and zero energy commercial buildings by 2025 (DOE, 2009).

The key building programs include Building America, Building Energy Codes, Commercial Building Energy Alliances, High Performance Commercial Buildings, and Appliances and Commercial Equipment Standards. In addition, DOE supports a broad range of activities designed to facilitate widespread adoption and use of energy saving practice and technologies, such as EnergySmart Schools and EnergySmart Hospitals.

For more details please refer to Appendix 1,
www1.eere.energy.gov/buildings/program_areas.html and
www1.eere.energy.gov/buildings/deployment.html.

3.2 ENERGY STAR

ENERGY STAR is a joint program of the U.S. Environmental Protection Agency (EPA) and DOE that promotes building energy efficiency through energy efficient products and practices. The program includes ENERGY STAR Products, ENERGY STAR home improvement, ENERGY STAR New Homes, and ENERGY STAR Building and Plants.

For more details please refer to Appendix 2, and www.energystar.gov/.

3.3 U.S. Green Building Council and LEED

The U.S. Green Building Council (USGBC) has helped the development of LEED since 1994. LEED is a voluntary, consensus-based national rating system for sustainable buildings. There are five key areas addressed in LEED (1) sustainable site development, (2) water savings, (3) energy efficiency, (4) materials selection and (5) indoor environmental quality. The current LEED rating systems were developed for the following nine building categories:

- LEED for New Construction,
- LEED for Existing Buildings: Operations & Maintenance,
- LEED for Commercial Interiors,
- LEED for Core & Shell,
- LEED for Schools,
- LEED for Retail,
- LEED for Healthcare,

[61] A net-zero energy building can greatly reduce needs for energy through efficiency gains (60% to 70% less than conventional practice) with the balance of energy needs supplied by renewable technologies.

- LEED for Homes, and
- LEED for Neighborhood Development (pilot).

For more details please refer to Appendix 3, and www.usgbc.org/.

3.4 Green Building Initiative and Green Globes[62]

Adapted from Green Globes™ Canada in 2004, Green Globes™ U.S. offers an online assessment protocol, rating system, as well as guidance for green building design, operation and management. The interactive, flexible and inexpensive system uses third party verification to provide market recognition of a building's environmental aspects. The current U.S. website provides the following tools:

- Green Globes™ New Construction,
- Green Globes™ Continual Improvement for Existing Buildings,
- Green Globes™ LCA Credit Calculator, and
- Green Globes™ Rating/Certification.

For more details please refer to Appendix 4, www.thegbi.org/home.asp, and www.greenglobes.com/default.asp.

3.5 National Green Building Standard[63]

The International Code Council (ICC) has recently completed the National Green Building Standard (ICC-700), which provides guidance for safe and sustainable building practices for residential construction, including both new and renovated single-family to high-rise residential buildings. ICC-700 is consistent and coordinated with the ICC's International codes[64]. ICC-700 addresses land conservation, rainwater collection, construction of smaller homes to conserve resources, energy performance (starting at 15% above the requirements of the baseline 2006 IECC), the use of low Volatile Organic Compound (VOC) materials, and homeowner education on proper maintenance and operation to maintain its green status throughout its life cycle. ICC-700 will be available in Spring 2009.

For more details please refer to the ICC press release at www.iccsafe.org/news/nr/2009/0130_ICC700.html or the ICC order form for ICC-700 at www.iccsafe.org/e/prodsearch.html?words=9551S08.

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[62] The section is edited from the information provided by the websites of www.thegbi.org/home.asp, and www.greenglobes.com/default.asp.

[63] The section is edited from the information provided by the ICC press release at www.iccsafe.org/news/nr/2009/0130_ICC700.html.

[64] ICC uses the term I-codes to describe its International codes. These include the International Energy Conservation Code, the International Mechanical Code, the International Building Code and other ICC codes.

4 Conclusions

The U.S. has been developing building energy standards and codes for more than thirty years. The development is mainly driven by federal legislation, undertaken by private sector code developers, and supported by DOE. The U.S. building code development communities, such as ASHRAE and ICC, have formed open and efficient technical review and development procedures for developing building codes.

States, local governments and DOE form a regulatory infrastructure to promote compliance, implementation, and enforcement of building energy codes. For example, DOE has invested in research and development of building technologies, provided free software (such as compliance tools and building energy simulation tools) and education and training materials, and initiated development and deployment programs (such as EnergySmart Schools). The states and local governments work closely with the federal government and building code communities to adopt and customize the national model codes.

In recent years, many building energy efficiency initiatives for building energy codes have been launched by both the building code community and governmental agencies in order to achieve building energy efficiency and reductions in carbon emissions.

Appendix 1 DOE's Activities Related to Building Energy Efficiency

Building America: This program conducts and supports research, development, and demonstration activities that will produce cost-effective homes that use up to 70% less energy. The program partners with more than 270 companies comprised of architects, engineers, builders, equipment manufacturers, material suppliers, community planners, mortgage lenders, and contractor trades.

Building Energy Codes: This program supports the development of more stringent and easier to understand building energy codes. It does so by developing downloadable compliance tools and materials and providing technical and financial assistance to help states adopt, implement and enforce building energy codes.

Commercial Building Energy Alliances: The goal of this program is to minimize the energy use and environmental impact of commercial buildings. The Commercial Building Energy Alliances brings together representatives from a variety of business sectors to work toward this goal. The program currently focuses on retail, commercial real estate and institutional buildings.

High Performance Commercial Buildings: A program working with architects, engineers, builders, contractors, owners and occupants to optimize building performance, comfort and savings through a whole building approach to design and construction.

Appliances and Commercial Equipment Standards: Working with product manufacturers, designers, utilities, consumers and other government agencies, this program area develops test procedures and sets minimum efficiency standards for residential appliances and commercial equipment.

EnergySmart Schools: Endorsed by the National School Boards Association (NSBA), DOE sponsors the EnergySmart Schools initiative to reduce schools' energy use and to provide better learning environments for children. DOE also helps school districts by disseminating information about financing opportunities, providing training to building industry professionals, and weaving together broad networks of public and private partners.

EnergySmart Hospitals: The goals of the initiative include promoting an efficiency improvement of 20% in existing buildings and 30% in new construction over current standards. This would increase efficient and renewable energy applications in hospitals, reducing energy use and operating costs, and creating healthier healing and work environments.

For more details please refer to www1.eere.energy.gov/buildings/program_areas.html and www1.eere.energy.gov/buildings/deployment.html.

Appendix 2 ENERGY STAR related to Building Energy Efficiency

ENERGY STAR Home Improvement: ENERGY STAR aims to improve home energy efficiency with energy star products (such as insulation and sealing products), and provide technical support to home owners (such as an interactive home energy advisor website, and a database for finding qualified home energy auditors).

ENERGY STAR New Home: The homes meet strict guidelines for energy efficiency set by the U.S. EPA. These homes are at least 15% more energy efficient than homes built to meet the 2004 International Residential Code (IRC), and include additional energy-saving features that typically make them 20–30% more efficient than standard homes. The U.S. database of builders who offer ENERGY STAR qualified homes is also provided. Several ENERGY STAR initiatives are developed to target commercial and industrial buildings. The ENERGY STAR Challenge is a national call-to-action to improve the energy efficiency of America's commercial and industrial buildings by 10 percent or more. Challenge participants and their members are encouraged to take as many of these actions as possible, including 1) designing commercial buildings to be energy efficient, 2) measuring and tracking energy use, 3) developing a plan for energy improvements, 4) making energy efficiency upgrades, and 5) becoming an Energy STAR Partner, etc.

ENERGY STAR Initiative for Commercial Buildings: First introduced in 1999, the energy performance of commercial and industrial facilities is scored on a 1-100 scale and those facilities that achieve a score of 75 or higher are eligible for the ENERGY STAR certification, indicating that they are among the top 25% of facilities in the country for energy performance. Commercial buildings that have earned the ENERGY STAR certification use on average 35% less energy than similar buildings and generate one-third less carbon dioxide. ENERGY STAR for buildings has been seen as a symbol of an organization that is working to reduce global warming and its impacts.

ENERGY STAR Products: The program is applied to 50 different kinds of products, including:

- Appliances (Refrigerators & Freezers, Room AC, Water Coolers, etc.),
- Heating & Cooling (Air-source Heat Pumps, Boilers, Central AC, Ceiling Fans, Furnaces, Geothermal Heat Pumps, Home Sealing and Insulation, Light Commercial, Programmable Thermostats, Room AC, Ventilating Fans, etc.),
- Home Envelope (Home Sealing (Insulation and Air Sealing), Roof Products, Windows, Doors, & Skylights),
- Home Electronics (DVD Products, Home Audio, Televisions, VCRs, etc.),
- Office Equipment (Computers, Copiers and Fax Machines, Monitors, etc.),
- Lighting (Compact Fluorescent Light Bulbs, Decorative Light Strings, etc.)
- Commercial Food Service (Commercial Dishwashers, Commercial Fryers, etc.), and
- Other Commercial Products (Roof Products, Vending Machines, Water Coolers, etc.).

For more details please refer to www.energystar.gov/.

Appendix 3 LEED

The U.S. Green Building Council (USGBC) is a non-profit organization committed to expanding sustainable building practices. The USGBC helped develop LEED (Leadership in Energy and Environmental Design), a voluntary, consensus-based national rating system for developing high-performance, sustainable buildings. Unlike building energy codes which often address building energy efficiency, LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: (1) sustainable site development, (2) water savings, (3) energy efficiency, (4) materials selection and (5) indoor environmental quality. The current LEED rating systems were developed for the following nine building categories:

LEED for New Construction: The rating system is designed to guide and distinguish high-performance commercial and institutional projects, including office buildings, high-rise residential buildings, government buildings, recreational facilities, manufacturing plants and laboratories.

LEED for Existing Buildings: The rating system helps building owners and operators measure operations, improvements and maintenance on a consistent scale, with the goal of maximizing operational efficiency while minimizing environmental impacts. LEED for Existing Buildings addresses whole-building cleaning and maintenance issues (including chemical use), recycling programs, exterior maintenance programs, and systems upgrades. It can be applied both to existing buildings seeking LEED certification for the first time and to projects previously certified under LEED for New Construction, Schools, or Core & Shell.

LEED for Commercial Interiors: The system is the green benchmark for the tenant improvement market. It is the recognized system for certifying high-performance green interiors that are healthy, productive places to work; are less costly to operate and maintain; and have a reduced environmental footprint. LEED for Commercial Interiors gives the power to make sustainable choices to tenants and designers, who do not always have control over whole building operations.

LEED for Core & Shell: The green building rating system is geared towards designers, builders, developers and new building owners who want to address sustainable design for new core and shell construction. Core and shell covers base building elements such as structure, envelope and the HVAC system. LEED for Core & Shell is designed to be complementary to the LEED for Commercial Interiors rating system, as both rating systems establish green building criteria for developers, owners and tenants.

LEED for Schools: The rating system recognizes the unique nature of the design and construction of K-12 schools. Based on the LEED for New Construction rating system, it addresses issues such as classroom acoustics, master planning, mold prevention and environmental site assessment.

LEED for Retail (a pilot): The pilot recognizes the unique nature of the retail environment and addresses the different types of spaces that retailers need for their distinctive product lines.

LEED for Healthcare: The green building rating system was developed to meet the unique needs of the health care market, including inpatient care facilities, licensed outpatient care facilities, and licensed long term care facilities. LEED for Healthcare may also be used for medical offices, assisted living facilities and medical education and research centers. LEED for Healthcare addresses issues such as increased sensitivity to chemicals and pollutants, traveling distances from parking facilities, and access to natural spaces.

LEED for Homes: The rating system promotes the design and construction of high-performance green homes. A green home uses less energy, water and natural resources; creates less waste; and is healthier and more comfortable for the occupants. Benefits of a LEED home include lower energy and water bills; reduced greenhouse gas emissions; and less exposure to mold, mildew and other indoor toxins. The net cost of owning a LEED home is comparable to that of owning a conventional home.

LEED for Neighborhood Development (a pilot): The rating system integrates the principles of smart growth, urbanism and green building into the first national system for neighborhood design. LEED certification provides independent, third-party verification that a development's location and design meet accepted high levels of environmentally responsible, sustainable development. LEED for Neighborhood Development is a collaboration among USGBC, the Congress for the New Urbanism and the Natural Resources Defense Council.

LEED projects are in progress in forty one different countries, including Canada, Brazil, Mexico and India. Olympic Village in Beijing earned a LEED Gold Certification in August 2008.

For more details please refer to www.usgbc.org/.

Appendix 4 Green Globes™

Green Globes™ U.S. was adapted from Green Globes™ Canada in 2004. In the U.S., Green Globes™ is owned and operated by the Green Building Initiative (GBI). In 2005, GBI became the first green building organization to be accredited as a standards developer by the American National Standards Institute (ANSI), and began the process of establishing Green Globes as an official ANSI standard.

The Green Globes system delivers an online assessment protocol, rating system and guidance for green building design, operation and management. It is interactive, flexible and affordable, and provides market recognition of a building's environmental attributes through third-party verification. The current U.S. website provides the following tools:

Green Globes™ New Construction: A web application that provides a means for architects, engineers, and construction professionals to evaluate, quantify, and improve the environmental friendliness and sustainability of new building projects and major renovations. It is easy to learn and use, and readily integrates into modern AEC workflows as part of a new design project or major renovation.

Those projects that score high on the Green Globes rating scale, and incorporate the sustainability enhancement suggestions coming from the tool should consume fewer fossil fuels, reduce green house emissions, conserve water, reduce other forms of pollution, minimize impact on the land surrounding the buildings, and offer a better environment for occupants. Green Globes helps building owners and managers identify opportunities to reduce operating expenses and find cost savings in energy, water, and waste disposal throughout the life of the building.

Green Globes™ Continual Improvement for Existing Buildings: The tool delivers a comprehensive, thorough, and practical means for evaluating, rating, and improving the environmental footprint and/or sustainability of commercial buildings. As an online tool, it provides a convenient, practical, and effective means for building owners and property managers to reduce the environmental impact of the buildings they own and operate.

Green Globes Existing Buildings integrates best building management and operations practices within the tool and provides a means to facilitate awareness as well as implementation by offering improvement suggestions and web links to green building technology. If implemented, these suggestions are intended to help owners to save energy, minimize greenhouse emissions, conserve water resources, and reduce other forms of pollution.

Green Globes™ LCA Credit Calculator: The calculator enables architectural design and engineering teams to fully understand the ecological impact of different choices in building materials for a new construction project. LCA considers materials over the course of their entire lives and takes into account a full range of environmental impact indicators—including embodied energy, solid waste, air and water pollution, and global warming potential. It provides LCA results for hundreds of common building assemblies in low- and high-rise categories-including exterior walls, roofs, intermediate floors, interior walls, windows, and columns and beams. The LCA calculator is a free, downloadable, and easy to use software tool that is based on the ATHENA® Impact Estimator for Buildings. Design teams utilizing the LCA calculator as part of their design process for new buildings receive education credits within the Green Globes New Construction assessment protocol and rating system.

Green Globes™ Rating/Certification: The system grants recognition and certification in the design, construction, or operation of commercial buildings. Green Globes rating and certification provide a proven, credible, and recognized means to address the increasingly important environmental concerns of owners, investors, customers, and residents/occupants.

Building projects that have completed either the New Construction self assessment or the Continual Improvement for Existing Buildings assessment, and scored a minimum threshold of 35% of the 1,000 available points are then eligible to schedule an independent, third party review and site assessment that leads to formal Green globes Rating. Depending on the points scored after the independent third party assessment, buildings are assigned a green globes rating of one to four green globes, and are awarded a plaque for recognizing their environmental achievements.

For more details please refer to www.thegbi.org/home.asp and www.greenglobes.com/default.asp.

List of Acronyms

ANSI	American National Standards Institute
APP	Asia-Pacific Partnership on Clean Development and Climate
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BATF	Buildings and Appliance Task Force (BATF-06-24 refers to a BATF project called "Survey building energy codes and Develop Scenarios for reducing energy consumption through energy code enhancement in APP countries")
CABO	Council of America Building Officials
CDD	Cooling degree day
cfm	Cubic feet per minute
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EPF	Envelope performance factor
GBI	Green Building Initiative
HDD	Heating degree day
HVAC	Heating, Ventilation and Air Conditioning
ICC	International Code Council
IEA	International Energy Agency
IECC	International Energy Conservation Code
IRC	International Residential Code
LEED	Leadership in Energy and Environmental Design
MEC	Model Energy Code
NSBA	National School Boards Association
OECD	Organisation for Economic Co-operation and Development
SHGC	Solar Heat Gain Coefficient
USGBC	U.S. Green Building Council
VAV	Variable air volume
WWR	Window-to-wall ratios

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9. IEA, 2007. Energy Balances of OECD Countries (2007 edition).
10. IMF, 2008. World Economic Outlook Databases, www.imf.org/external/ns/cs.aspx?id=2, January 2009, (Accessed).

Useful Websites

1. U.S. DOE Building Energy Codes Program, www.energycodes.gov/
2. U.S. DOE Building Technology Program, www1.eere.energy.gov/buildings/
3. Commercial Building Energy Consumption Survey, www.eia.doe.gov/emeu/cbecs/contents.html
4. Residential Building Energy Consumption Survey, www.eia.doe.gov/emeu/recs/contents.html
5. ENERGY STAR, www.energystar.gov/
6. LEED Rating System, www.usgbc.org/DisplayPage.aspx?CategoryID=19
7. Green Globes, www.greenglobes.com/default.asp

The Asia-Pacific Partnership on Clean Development and Climate

The Asia-Pacific Partnership on Clean Development and Climate is an innovative new effort to accelerate the development and deployment of clean energy technologies.

Partner Countries

APP partners Australia, Canada, China, India, Japan, Republic of Korea, and the United States have agreed to work together and with private sector partners to meet goals for energy security, national air pollution reduction, and climate change in ways that promote sustainable economic growth and poverty reduction. The Partnership will focus on expanding investment and trade in cleaner energy technologies, goods and services in key market sectors. The Partners have approved eight public-private sector task forces covering:

- Aluminum
- Buildings and Appliances
- Cement
- Cleaner Use of Fossil Energy
- Coal Mining
- Power Generation and Transmission
- Renewable Energy and Distributed Generation
- Steel

The seven partner countries collectively account for more than half of the world's economy, population and energy use, and they produce about 65 percent of the world's coal, 62 percent of the world's cement, 52 percent of world's aluminum, and more than 60 percent of the world's steel.

Buildings and Appliances Task Force

Reducing our use of energy for buildings and appliances decreases the demand for primary energy and is a key means to deliver better economic performance, increase energy security and reduce greenhouse gas and air pollutant emissions. Partner countries have recognized for some time the importance of cooperating on energy efficiency for buildings and appliances, and have already taken a range of bilateral and other collaborative actions in this area. As the Partners represent a majority of the world's manufacturing capacity for a diverse range of appliances, we have the potential to drive significant regional and global improvements in energy efficiency in this sector. The Partners will demonstrate technologies, enhance and exchange skills relating to energy efficiency auditing, share experiences and policies on best practices with regard to standards and codes, as well as labeling schemes for buildings, building materials and appliances.

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