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INTERNATIONAL

CANADIAN EXPORTERS GUIDE TO U.S. RESIDENTIAL BUILDING CODES

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CANADIAN EXPORTERS GUIDE TO U.S. RESIDENTIAL BUILDING CODES

Prepared for CMHC by:

Bruce Gough
Energy Building Group Ltd.
P.O. Box 72004 Kanata North P.O.
Kanata, ON K2K 2P4

CMHC project manager Terry Robinson

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Glossary and links

Term—organization	Description—definition—Web address (add http://)
AAMA—American Architectural Manufacturers Association	www.aamanet.org/
ACCA—Air Conditioning Contractors of America	www.acca.org
ACH	air changes per hour
AFPA—American Forest and Paper Association	www.afandpa.org/
AFUE	annual fuel utilization efficiency
ANSI—American National Standards Institute	www.ansi.org/ The major standards agency in the U.S. It issues standards and registers other standards organizations, including both U.S national and international. Many standards are registered and issued jointly with another organization for example ANSI/ASTM. Standards for gas heating products, ceramic tiles, cement based products, plastic bathroom products. Select ANSI's electronic standards store, select a standards organization and category, select a standard in the list for a brief review.
ASHRAE—American Society of Heating Refrigerating and Air Conditioning Engineers	www.ashrae.org
ASTM—American Society for Testing and Materials	www.astm.org/ The major issuer of standards for building products such as wall and roof finishes. Many are issued jointly with ANSI. Select search for individual standards, enter key words and find standards, select and get brief description, order
AWPA—American Wood-Preservers Association	www.awpa.com/
Building America	www.eren.doe.gov/buildings/building_america/index.html
BAIHP—Building America Industrialized Housing Partnership	www.fsec.ucf.edu/bldg/baihp/index.htm
BOCA—Building Officials and Code Administrators (now part of ICC)	www.bocai.org/
BOMA—Building Owners and Managers Association	www.boma.org/
BCAP—Building Codes Assistance Project	www.bcap-energy.org/ BCAP provides assistance to states and municipalities in their efforts to adopt and implement both commercial and residential energy codes and supplies information about the status of state building energy codes.

Term—organization	Description—definition—Web address (add http://)
BSC—Building Science Corporation	www.buildingscience.com/ BSC supplies a set of excellent resources upon how to build with good building science across the U.S. BSC is a major agent for Building America.
BOPS	Builder Option Packages Prescribes compliance packages for ENERGY STAR in new houses.
CEC	California Energy Commission www.energy.ca.gov/title24/
Census Bureau	www.census.gov/
CABO	Council of American Building Officials (now the ICC)
CCMC—Canadian Construction Materials Centre	www.nrc-cnrc.gc.ca/ccmc/home_e.shtml
CMHC—Canada Mortgage and Housing Corporation	www.cmhc-schl.gc.ca/
CRI—Carpet and Rug Institute	www.carpet-rug.com/
CSA—Canadian Standards Association	www.csa.ca/
DOE—U.S. Department of Energy, Office of Building Technology, State and Community Programs	Multiple sites of interest: www.energycodes.gov/ www.eren.doe.gov/buildings/codes_standards/ www.eren.doe.gov/buildings/energy_tools/
ER—Energy Rating	A Canadian term for rating the heat losses, and solar gains in windows. Defined in CSA A440.2.
ELA—Equivalent Leakage Area	The total leakage area of all the points of a leakage in a house as determined by a fan depressurization test. For Canada it is defined in CGSB-149.10-M86 and is calculated at a reference pressure of 10 Pa. In the U.S. it is defined in ASTM E779, and calculated at 4 Pa.
EWC—Efficient Windows Collaborative	www.efficientwindows.org/
EEBA—Energy and Environmental Building Association	www.eeba.org/
EEM—Energy Efficient Mortgage (for more information see RESNET)	www.natresnet.org/herseems/default.htm
EF—Energy Factor	A rating of the seasonal efficiency of hot water heaters accounting for losses from the tank and the flue.
ERHA—Energy Rated Homes of America	www.erha.com/
ENERGY STAR—New homes	www.energystar.gov
ENERGY STAR—HVAC equipment	www.energystar.gov/products
ENERGY STAR—Roofing products	www.energystar.gov/products
ENERGY STAR—Windows	www.energystar.gov/products

Term—organization	**Description—definition—Web address (add http://)**
FIRM	Flood Insurance Rate Maps
FBFM	Flood Boundary and Floodway Maps
Florida—state codes	www.sbcci.org/floridacodes.htm
FSEC—Florida Solar Energy Center	www.fsec.ucf.edu/
FGBC—Florida Green Building Coalition	www.floridagreenbuilding.org/
USGBC—U.S. Green Building Council (LEED)	www.usgbc.org/
GBH—Green Built Home (Wisconsin)	www.wi-ei.org/GBH/
HERS–Home Energy Rating System—Technical Guidelines	www.natresnet.org/techguide/default.htm
HSPF	Heating season performance factor
HVI—Home Ventilating Institute	www.hvi.org/
HUD—U.S. Department of Housing and Urban Development	www.hud.gov/
HUD Code	www.hud.gov/offices/hsg/sfh/mhs/mhshome.cfm
IAPMO—International Association of Plumbing and Mechanical Officials	www.iapmo.org/iapmo/index.html
ICBO—International Conference of Building Officials (now part of ICC)	www.icbo.org/
ICBO-ES—International Conference of Building Officials Evaluation Service	www.icbo.org/ICBO_ES/ The largest existing evaluation service. Select any of: list of all reports, labs/ QC agencies, application information, acceptance criteria.
ICBO-ES Acceptance Criteria	www.icbo.org/ICBO_ES/Acceptance_Criteria/index.html
ICC—International Code Council	www.iccsafe.org
ICC-ES—International Code Council Evaluation Service	www.icc-es.org
ICF	Insulated Concrete Forms
IECC	International Energy Conservation Code (*see* ICC)
IRC	International Residential Code (*see* ICC)
KCMA—Kitchen Cabinet Manufacturers Association	www.kcma.org/
LVL	Laminated Veneer Lumber
LEED	Leadership in Energy and Environmental Design Green Building Rating System (*see* USGBC)
MEC	Model Energy Code (*see* CABO and NCSBCS)
MEC*check*	*See* RES*check*
Minnesota (State Building Code, with link to energy codes)	www.admin.state.mn.us/buildingcodes/rules/rules.html

Term—organization	**Description—definition—Web address (add http://)**
MNECH	Model National Energy Code for Houses (1997)—Canadian model code
MHI—Manufactured Housing Institute	www.manufacturedhousing.org/
MHRA—Manufactured Housing Research Alliance	www.mhrahome.org/pages/home.htm
Mold Source	www.themoldsource.com/starter.html
Mold Update—National Association of Mutual Insurance Companies	www.moldupdate.com/default.htm
NAFCD—National Association of Floor Covering Distributors	www.nafcd.org/
NAHB—National Association of Home Builders	www.nahb.org/
NASEO—National Association of State Energy Officials	www.naseo.org/
NBCC—National Building Code of Canada	irc.nrc-cnrc.gc.ca/irccontents.html
NCDC—National Climate Data Center	lwf.ncdc.noaa.gov/oa/ncdc.html
NFPA—National Fire Protection Association	www.nfpa.org/
NCSBCS—National Conference of States on Building Codes and Standards	www.ncsbcs.org/
NES—National Evaluation Service	www.nateval.org/ Select any of: Apply for a report, technical assistance, evaluation report listing, evaluation protocols
NFRC—National Fenestration Rating Council	www.nfrc.org/
NOFMA—Wood Flooring Manufacturers Association (formerly Oak Flooring MA)	www.nofma.org/
NWFO—National Wood Flooring Organization	www.woodfloors.org/
New York state energy code	www.dos.state.ny.us/code/energycode/toc.htm
NYSERDA—New York State Energy Research and Development Authority (link to ENERGY STAR in New York)	www.nyserda.org/residential/1-4family.html
Oc	on centre
OTFDC—One- and Two- Family Dwelling Code	(last published in 1995, see CABO, now the IRC)
OSB	Oriented Strand Board
REM/Rate	www.archenergy.com/rem/remrate.htm
RES*check*—formerly called MEC*check*	www.energycodes.gov/rescheck/

Term—organization	Description—definition—Web address (add http://)
RESNET—Residential Energy Services Network	www.natresnet.org/
SBCCI—Southern Building Code Congress International (now part of the ICC)	www.sbcci.org/
SEER	Seasonal energy efficiency ratio
SHGC	Solar Heat Gain Coefficient
SIPS	Structural Insulated Panels
SIPA—Structural Insulated Panel Association	www.sips.org/
State Web sites	The usual address for Web sites of state governments is www.state.xx.us, where xx is the two-letter code for the state. For example www.state.ny.us is the address for New York state. Search for *building codes* on state Web sites.
THX	Thermal Expansion Valve in air conditioning systems
UBC—Uniform Building Code	See ICBO
UL—Underwriters Laboratories Inc.	www.ul.com/ The main issuer of standards for combustion and electrical safety. A number of UL standards are harmonized with CSA standards. These tests (and other) may also be undertaken by the CSA. ulstandardsinfonet.ul.com/ Select catalog of standards, then view scopes of all current standards, select standard number and view.
ULC—Underwriters Laboratories Canada	www.ulc.ca/
USGBC—U.S. Green Building Council	www.usgbc.org/
Vermont ENERGY STAR Homes	www.vtenergystarhomes.com/
VSI—Vinyl Siding Institute	www.vinylsiding.org/
Washington (state)—energy and ventilation codes	www.energy.wsu.edu/buildings/wsec2001.htm
WDMA—Window and Door Manufacturers Association	www.nwwda.org/

Unit conversions

To convert from…	To…	Do this…
Btu	MJ	divide by 947.8
Btu	kWh	divide by 3412
Btu/h	W	divide by 3.412
Btu/h.ft.^{2}.F (U-value)	W/m^2.C (metric U-value)	multiply by 5.678
h.ft.^{2}.F/Btu (R-value)	m^2.C/W (RSI-value)	divide by 5.678
Cfm	l/s	divide by 2.119
Fpm	m/s	divide by 196.85
Ft.	m	multiply by 0.3048
ft.^{2}	m^2	multiply by 0.0929
ft.^{3}	l	multiply by 28.317
ft.^{3}	m^3	divide by 35.315
Fahrenheit	Celsius	subtract 32 then divide by 1.8
Gallons (U.S.)	litres	multiply by 3.636
Gpm	l/s	divide by 16.50
HDDF	HDDC	Approximate: divide by 1.8 then subtract 70
inches	millimeters	multiply by 25.4
inches w.g	Pa	multiply by 248.8
M.p.h.	km/h	multiply by 1.609
Perm	ng/(Pa.s.m^2)	multiply by 57.69
Pound (weight)	Kg	multiply by 0.454
Pound (force)	Newtons	multiply by 4.448
Psi	KPa	divide by 0.145
Psf	KPa	divide by 20.88
yd^3	M^3	multiply by 0.765

Common nails—pennyweight	Common nails—length in inches
6d	2”
8d	2 ½”
10d	3”
16d	3 ½”

Section 1 Introduction

Purpose

For those Canadian firms that are contemplating the export of housing or housing components, the United States is a compelling market. It is close, it is familiar, it is big and it is rich.

It is also different. The United States has a wider range of climate zones and endures more extreme weather than does Canada—from the cold of the north, to the humidity and hurricanes of the south, to the heat and deserts of the southwest. In addition to the environmental challenges, there are code and regulatory issues for Canadians. There are five, major, building code models in active use across the U.S. at this time. In addition, there are a number of codes developed by individual states or by major cities. Also, each state and municipality may apply additional regulations and approval requirements to the adopted model code. So an exporter who wishes to market to more than a single state may have to meet the requirements of more than one code and each state's individual regulations and approvals may differ in detail even if they use the same code. Further, each building code of itself is a large and complex document and a considerable effort is required to investigate and determine how the design and assembly of a house or a housing component may be required to adapt for compliance. For many Canadian housing manufacturers this neighbour to the south remains an uncertain and an unrealized market.

The purpose of this study is to help Canadian manufacturers of housing products gain an understanding of U.S. building codes and regulations for housing. The main focus is the International Residential Code, which is emerging as the prevailing standard for residential construction in the U.S. This study is also intended to provide a summary of the standards and approvals that may be required for code compliance of individual housing products in the United States.

Before delving into the details and the differences between the U.S. and Canadian residential codes it is important to recognize that there are many features in the U.S. codes that are similar to the Canadian. The common features include:

- wood-frame construction with sets of prescriptive structural span tables and fastenings;
- strip-footing foundation walls;
- forced-air heating and cooling;
- many similar products, including insulations, interior finishes, claddings, mechanical and electrical;
- a number of similar reference standards;
- conformance with the code prescription requirements diminishes or removes the requirement for professional design.

Contents

This Guide is divided into six sections:

- **Section 2** provides an overview of the different U.S. building codes and develops a rationale for focusing this work on the International Residential Code. Section 2 also provides a brief overview of some of the statistical characteristics of the U.S. housing market.

- **Section 3** summarizes the key differences between the International Residential Code and the National Building Code of Canada. Section 3 also provides a brief summary of some of the differences between the IRC and the UBC.

- **Section 4** provides a review of U.S. Energy Codes (MEC and IECC) and the ENERGY STAR Program. It also provides a summary of several state code requirements for efficiency and ventilation.

- **Section 5** provides a review of the Requirements for Manufactured Housing

- **Section 6** provides a summary of the standards and approvals that are required for selected housing products in the U.S.

- **Section 7** provides a brief set of conclusions and lists the next steps a new exporter might take.

By necessity there are a large number of organizations and acronyms identified in this Guide. “Glossary and links,” page viii, is a list of the acronyms of organizations that are mentioned in the Guide. Associated with each organization is a Web site address. The World Wide Web is an ideal starting point for exploring the resources and services of each organization, for contacting them directly and for discovering links to related sites and organizations.

Information about tariffs, export insurance, brokerage services and other items that may be required for export of products to the United States is beyond the scope of this Guide.

Units

The building codes and standards of the United States use the imperial or foot-inch system for measurements. While Canada is officially metric, this Guide uses the foot-inch system for all units of measure. This is simply for consistency with the intended market. The table on page xiii gives conversion factors for foot-inch units to metric.

Section 2 Overview of U.S. residential building codes

2.1 U.S. housing construction statistics

This subsection provides a quick profile of some of the characteristics of the new housing market in the United States. A series of charts have been prepared and are attached in Appendix A—U.S. Housing Characteristics (*see* page A-1). The information in the charts is based on U.S. Census results for 2001 and is broken out into four regions—the Northeast, Midwest, South and West. Some characteristics of the U.S. housing market are strongly typed due to climatic and geographic factors.

- A number of interesting differences can be observed from a Canadian perspective:
- The annual production including singles, multi-unit residential and manufactured housing is approximately 10 times that of Canada (1,800,000 vs. 205,000 in 2002).
- Most new houses are built in the South and in the West. The northern part of the Midwest and Western States, together with the Northeastern states, still represent a large market. These areas represent the closest and most similar markets for Canadian exporters.
- The volume of housing production in each of California, Florida and Texas alone equals or exceeds the size of all Canadian housing production.
- The annual production of manufactured housing in the U.S. is greater than the number of all housing completions in Canada.
- The proportional share of manufactured housing in the U.S. is higher than in Canada.
- Basements are found in just one-third of new U.S housing. Slab and crawl space foundations are common, particularly in the South and the West.
- 86 per cent of new U.S. homes have air conditioning.

2.2 Development of (U. S.) International Building Codes

In Canada, the Canadian Commission on Building and Fire Codes publishes the National Building Code of Canada (NBCC). The current version is the 1995 edition. Several provinces, including Ontario, Alberta and B.C., produce their own building codes, but they are based substantially upon the NBCC and in most sections they appear nearly identical (with the exceptions of 9.25 Thermal Insulation and 9.32 Ventilation).

In the United States the situation is quite different. For many years there were three organizations that developed and published building codes. Any of these codes were adopted at the discretion of the many state and municipal authorities across the U.S., producing a regionalized patchwork of code jurisdictions. The following is a brief summary of the various U.S. building codes and the regions where they were in effect in 1998, prior to recent changes. (The listing of geographic regions is approximate. In at least seven states there were no codes, or overlapping versions of the codes, depending on the municipality. At least two states, Wisconsin and New York, produced their own codes, as did a number of major cities.)

- BOCA, the Building Officials Code Administrators—the National Building Codes—Adopted in the north and east from Kansas to Maine above the Mason-Dixon line.

- ICBO, the International Conference of Building Officials—the Uniform Building Codes—Adopted west of the Mississippi, including Alaska and Hawaii.

- SBCCI, the Southern Building Code Congress International—the Standard Building Code—Adopted in the southeast.

Three other code-writing organizations that write specialized codes should also be mentioned.

- NFPA—the National Fire Protection Association produces the National Electrical Code, which has been adopted in most regions.

- IAPMO—the International Association of Plumbing and Mechanical Officials produces the Uniform Plumbing Code and since 1997 it has taken over management of the Uniform Mechanical Code from ICBO It has been adopted mainly west of the Mississippi like the other Uniform Codes.

- HUD—the U.S. Department of Housing and Urban Development produces a special code for manufactured houses that applies nationally and pre-empts state codes. See 5.2, page 55, for more information about this code.

In the residential sector there has been co-operation since 1972 between the three main code bodies (BOCA, ICBO, SBCCI) through the Council of American Building Officials (CABO). Together, they produced the CABO One- and Two- Family Dwelling Code (OTFDC). In the 1995 version of the OTFDC, the NFPA contributed the electrical section, making it appear that a unified approach to all future code development might be possible. Since at least 1989, CABO, together with the National Conference of States on Building Codes and Standards (NCSBCS) has published the MEC—the Model Energy Code. The MEC was last updated in 1995.

In 1994, the three major code bodies decided to tackle the problem of multiple codes at all levels and evolved their association in CABO into the International Codes Council, with the intent of producing a single, unified set of building codes. The result was the publication of the International Codes (I-codes) in 1998. Thus, the CABO OTFDC evolved into the International Residential Code (IRC) and the MEC evolved into the International Energy Conservation Code (IECC). The NFPA was also engaged to provide the electrical provisions of the IRC. The International Codes were subsequently updated to the current 2000 version and this Guide analyses the 2000 version. While this Guide was being prepared in 2003 a new version of the I-codes was released. The International Codes consist of a suite of co-ordinated codes that include:

- International Building Code (IBC)

- International Residential Code (IRC)
- International Energy Conservation Code (IECC)
- International Fire Code (IFC)
- International Fuel Gas Code (IFGC)
- International Mechanical Code (IMC)
- International Plumbing Code (IPC)
- International Private Sewage Disposal Code
- International Property Maintenance Code
- International Zoning Code
- ICC Electrical Code Administrative Provisions
- ICC Performance Code (soon to be released)

The association of the BOCA, ICBO and the SBCCI as the International Codes Council became a full merger in 2003. As a result the old model codes are no longer being updated.

Complicating matters somewhat, the NFPA and the International Association of Plumbing and Mechanical Officials (IAPMO) have joined together with the intention of publishing their own full building code in the near future, the NFPA 5000 Building Construction and Safety Code. Significantly, both the National Association of Home Builders (NAHB) and the Building Owners and Managers Association (BOMA) have come out against the NFPA 5000 and are firmly behind the International Codes.

2.3 Regional authority and adoption of U.S. building codes

While the International Codes have been available for adoption since they were introduced, it appears that the U.S. has entered what is now best termed a "code transition" period—the length of which is uncertain at this time. A substantial number of states have adopted the I-codes in whole or in part, while others still use one or more of the former codes. So what started in 1998 as looking like a patchwork of code authorities now (2003) still looks like—well—a patchwork of code authorities.

The patchwork of state codes results from the essential autonomy of American states. The authority for the adoption of building codes lies with and varies with each state. In some states, enabling legislation allows the state to adopt building codes or to write its own codes on a statewide basis. Some allow municipal authorities to amend state codes, some don't. Some states have no state building codes and the adoption of building codes is a matter only for municipal authorities. As well, the review cycle for changing codes varies from state to state and local authority. So a state or local authority that is not yet using the International Codes may not have reviewed its codes recently or may not have completed the review process. Some states have done a review and have decided to retain or modify the existing (non-International) codes. Even these states may yet adopt the International Codes in their next Code review cycle as the International Codes gain critical mass.

At present, one or more of the International Codes has been adopted either statewide or in municipalities in over 40 states. This is a very significant number but it can be misleading, since there are a large number of International Codes and the adoption in each state may range from most of the International Codes to just one or two of the less-significant codes. Where the International Codes have only been partly adopted, other model codes are still required.

A map in Appendix B (*see* page B-4) summarizes residential code requirements state-by-state as best as it could be determined early in 2003. Within the period of the preparation of this Guide it was necessary to update this information to reflect an increase in the number of states that have adopted the International Codes. The reader should be aware that adoption of model codes is subject to further changes as time progresses.

It is most important to check with the local municipal and the state building authority to confirm the building code in effect and the requirements of the authority for climatic and geographic design information, zoning, plan review, permits, fees, inspections and any other applicable regulations for flood hazard, energy conservation, accessibility, and so forth, before proceeding with any housing project in the U.S.

The map in Appendix B identifies 19 states that have adopted the IRC statewide. Many of these states have also adopted the IBC. The remaining 31 states reflect the diverse status of the state building codes across the U.S.

- Five states still use the OTFDC and other codes are adopted at the state level including the NBC (four), UBC (one). The IRC is the succeeding document to the OTFDC and it is possible that these states may move to the IRC.

- Sixteen states have some municipalities that have adopted the IRC.

- Fifteen have no state-wide residential codes—but other model codes are adopted at the state level including the UBC (six), SBC (four), IBC (three) or NBC (two). These codes encompass all building types and have basic requirements for residential construction. In 10 of these states the IRC has been adopted in some local municipalities.

- Six have state-written residential codes—and other codes are adopted at the state level including the UBC (three), IBC (two) and SBC (one). At least one state also allows local municipalities to adopt the IRC codes (Ohio).

- Five have no state building codes. In these states it is up to local municipality to adopt building codes. In all five, the IRC has been adopted in some local municipalities.

There are a number of significant exceptions to the adoption of the International Codes in the statistics. These include:

- States with codes based on the 97 UBC: California, Colorado, Kansas, Minnesota, Montana, Nebraska, Nevada, New Mexico, Washington and Wyoming.

- States with codes based on the SBC: Arkansas, Florida, Louisiana, Mississippi, and Tennessee.

- States with codes based on the NBC: Connecticut, Maine, New Jersey, Vermont, Virginia, West Virginia. The Washington, D.C. code is also based on the NBC.

2.4 Focus on the I-codes

While all the building codes identified in this study continue to be used in many states, and may be so for some time to come, *there is a clear trend toward the adoption of the International Codes*. Significantly, the former code organizations that wrote the UBC, the NBC and the SBC formally joined as the International Codes Council in the spring of 2003 and have ceased the further development of the old model codes. So the International Codes stand as the only complete, national model code system that is being actively reviewed and updated. (The update cycle is every three years, with the next release in 2006.) Not only are the I-codes more current, they may also be considered as more comprehensive and require more performance than the older codes. In the general case it could be argued that compliance with the I-codes should meet or exceed the requirements of the other codes—but not the other way around.

The focus of the remainder of this study is upon the International Codes and, in particular, on the International Residential Code.

2.5 Content of the International Residential Code (IRC)

The International Residential Code (IRC) is a prescriptive building code for the planning and construction of one- and two-family residential buildings in the U.S. This includes duplexed units in addition to single-detached dwellings. Townhouses are defined as three or more attached single-family dwellings and as such are covered by this code. It is intended only for residential occupancies while the NBCC, Part 9 includes other occupancies, which may occur in buildings less than three floors or 600 m^2.

The IRC is a very inclusive and comprehensive code. It internalizes many sections that are referenced to external sources, or not even covered in other codes. For example it includes much more extensive requirements than other American codes or the NBCC for wind, seismic zones, flood hazard, steel framing, insulated concrete forms (ICFs), fuel gas, mechanical plumbing and electrical. This makes the code bigger (over 500 pages vs. about 160 pages in NBCC Part 9). The language of the IRC is more readable than the NBCC. The organization and the presentation is more linear and requires less flipping back and forth. Clear examples of exemptions are presented immediately below any clause and are indented. The IRC includes many maps, figures and illustrations of details that are nearly totally absent in the code body of the NBCC. While it has a few shortcomings, on the whole the IRC is extensive and user-friendly.

The IRC developed from the former CABO OTFDC and clearly shows it heritage—the chapter-section numbers through to 14 in the IRC are nearly identical and the remainder within a few numbers. The sections of the IRC are organized with a letter and number system composed of letter-chapter-section-subsection. There are 43 chapters in total, the ordering of which corresponds closely with the sequence of construction on-site.

- R—10 chapters: administration, definitions, planning, foundations, floors, walls construction, wall covering, roof ceiling construction, roof assemblies, chimneys and fireplaces

- N—energy efficiency—one chapter

- M—mechanical—12 chapters

- G—fuel gas—one large chapter

- P—plumbing—eight chapters

- E—electrical—10 chapters

- Referenced standards—one chapter (Chapter 43)

- Appendixes for sizing and capacities of gas piping, sizing of venting systems of appliances with draft. hoods and b vents, exit terminals for mechanical draft. and direct venting systems, procedure for safety inspection of and existing appliance installation, manufactured housing used as dwellings, radon control, swimming pools, spas hot tubs, patio covers, private sewage disposal, existing buildings and structures, sound transmission.

Section 3 Differences between the U.S. IRC and the NBCC

A long list of differences both large and small resulted from an extensive line-by-line reading of the most recent versions of the two codes—the 2000 International Residential Code (IRC) and the 1995 National Building Code of Canada (NBCC Part 9). This list was then reduced to highlight the key differences, but the list remains large. The key differences are summarized under the following functional categories:

- Units
- Administration
- Climatic and geographic design criteria
- Wind
- Seismic provisions
- Accessibility
- Windows and glazing
- Minimum dimensions
- Fire and safety
- Acoustic separations
- Sound transmission
- Termites and decay
- Flood-resistant construction
- Alternative construction systems
- Foundations
- Wood framing
- Air, vapour and weather barrier systems

- Energy efficiency
- Mechanical ventilation and combustion air
- Mechanical and duct systems
- Fuel gas, plumbing and electrical
- Other appendixes

This review should be viewed as an introduction to the key differences of the International Residential Code. Those who are intending to export houses or housing products to the U.S. should follow this review with a more detailed study of the relevant sections of the IRC or other code in force in the destination state.

3.1 Units

The IRC and all American codes are presented in foot-inch units. See page xiii, for conversions to metric from foot-inch units.

Nails are named in pennyweight sizes. The bigger the penny, the bigger the nail. For example a 2-in. common nail is a six penny (6d), a 3 ½-in. common nail is a sixteen penny (16d) nail. A list of all the nail sizes referenced is in *Unit conversions* on page xiii.

3.2 Administration

Chapter One of the IRC describes a complete set of detailed provisions for administration. By comparison, the National Building Code of Canada (NBCC) references a separate document for administrative requirements. The end results may be similar but are summarized here because of the importance of this requirement.

The IRC provides a sample ordinance or law for the adoption of its Code by a state or municipality. The appendixes to the Code do not apply unless specifically referred to in the state or municipal law adopting the Code.

The sample ordinance creates a Department of Building Safety headed by an official who is in charge of other personnel and who enforces the provisions of the code with full authority to receive applications for permits, issue permits, review and approve construction documents, assess fees, perform inspections, approve service utilities connections, issue certificates of occupancy, assess violations and issue stop work orders. A board of appeals is also created to review appeals concerning the judgments of the building official or for specific variances in areas prone to flooding.

It is important to communicate with the building official before and during a project in any community to determine:

- The climatic and geographic criteria for the location, as required to be listed in Table R301.2 (1) by the local jurisdiction.

- The construction documents and fees required for an application for a permit.

- Which building and energy codes apply.

- What inspections are required and who performs the inspections. In some areas people other than the building official may be permitted or required to conduct building inspections.

- Whether all or part of the construction documents need to be prepared by a design professional registered by statute in the local jurisdiction. The documents may include architectural, engineering or technical design of the foundation, structure, HVAC systems and envelope assemblies. Engineering design of the structure will at least be required for parts of the structure not covered in the body of the building code, such as trusses and non-standard beams and columns. Even if architectural or engineering design are not required, the housing exporter may find the services of professionals helpful to assure code compliance and assist with permit applications.

- Whether the construction plans and documents meet with local requirements for plan review and permit approvals.

- Other special requirements of the local jurisdiction for architectural appearance, zoning, energy conservation, accessibility, green building standards, fire and safety and so forth.

- The equivalency of alternative materials, design and methods of construction not specifically prescribed by the IRC code and whether tests are required to substantiate such by the proponent.

3.3 Climatic and geographic design criteria

Most of these criteria are familiar to Canadians and are embodied in the NBCC, but the number of criteria and the variation in the values is greater than in Canada. There are tables and maps throughout the IRC and the IECC to aid in establishing climatic and geographic criteria. The local building authority has final authority upon all the climatic and geographic criteria and is required to complete Table 301.2 (1) with appropriate values for:

- Wind speed—see maps on pages 28 to 32 of the IRC.

- Ground snow load—see maps on pages 33 and 34 of the IRC. Where ground snow loads are 70 psf or less, the requirements of the IRC apply. This is most areas in the U.S, excepting some areas in mountains of the Western States and Alaska. Otherwise engineering is required.

- Seismic design category—see maps on pages 24 to 26 of the IRC.

- Weathering probability for concrete—see map on page 27 of the IRC.
- Frost line—determined by local authority.
- Termite hazard—see map on page 35 of the IRC.
- Decay probability—see map on page 36 of the IRC.
- Winter design temperatures—see map on page 23 of the IRC, Appendix D of the International Plumbing Code or the winter design temperatures set by the local building authority. See also Chapter 3 of the International Energy Conservation Code.
- Flood hazard—set by local authority from flood hazard maps adopted by the local community.
- Climate zone—see Section N, *Energy Efficiency, Climate Zones by States and Counties*, Table N1101.2, pages 272 to 280.
- Radon zones—see Appendix F, *EPA Map of Radon Zones,* page 540, and the *High Radon Potential Counties* table, pages 541 and 542.

In addition, the International Energy Conservation Code (IECC) requires Table 302.1 to be completed with values for:

- Winter design dry-bulb—ASHRAE *Handbook of Fundamentals*
- Summer design dry-bulb—ASHRAE *Handbook of Fundamentals*
- Summer design wet-bulb—ASHRAE *Handbook of Fundamentals*
- Degree-days heating
- Degree-days cooling
- Climate zone—IECC, Chapter 3, Figure 302.1, pages. 12 to 62, has state maps of climate zone for each county.

3.4 Wind

There are no obligatory requirements for the determination of wind loads on buildings built under Part 9 of the NBCC. There are formulas in NBCC 4.1.8 for determining live loads on structures resulting from wind pressures. The reference velocity pressures for design are one in 10 years for cladding and structural deflection, and one in 30 years for strength of structural members and one in 100 for design of structural members in post-disaster buildings (NBCC 2.2.1). The NBCC 9.7.2.1

requires that windows meet wind load resistance category C1 of CSA—A440-M "Windows". NBCC A-9.7.3.2(1) provides additional design information based on three wind pressure loads on windows (0.4, 0.6, 0.8 kPa).

In contrast, the IRC R301.2.1 has a very explicit and important set of wind design requirements that are very different from those in the NBCC. These requirements result from the fact that coastal regions of the U.S., particularly those on the south and east coasts, are subject to very high wind conditions due to hurricanes.

The determination of the wind design pressures in the IBC/IRC are based on the methods published in ASCE 7-98 (American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures*). In the IRC, wind speed in m.p.h. is looked up on maps of the U.S. in Figure R301.2(4) in "Minimum Design Loads for Buildings and Other Structures." The values are based on the 50-year mean recurrence intervals. A number of areas located in mountains are denoted as special wind regions and require local knowledge.

Wind loads are determined from Table R301.2(2) in the IRC by wind speed and by component and wind zone. Loading for both windward and leeward surfaces is provided. These values are adjusted for roof height and exposure category by multipliers in Table R301.2(3) in the IRC. Wind exposure categories A, B, C and D are defined as terrain types in the IRC R301.2.1.4.

Wind load and design pressure calculations are required to be done by an architect or engineer for each building where the wind speed exceeds 110 m.p.h. In Florida this is required for all homes and buildings, even where the wind speed is less than 110 m.p.h.

Wind zones by wall and roof component are provided in Figure R301.2(8) in the IRC. There are three different wind zones defined for roof surfaces and two for walls. The definition of the roof zones change with roof pitch and include four-foot bands for edges and corners and mid areas. Walls have two different wind zones—one for areas within four feet of corners and the other areas.

Construction in regions where the wind speed exceeds 110 m.p.h. requires special engineering and is to be designed in accordance with one of four standards defined in R301.2.1.1

Wind Borne Debris Region is defined to be an area in hurricane-prone regions within one mile of the coast (Atlantic and Gulf Coasts) with a basic wind speed of 110 m.p.h. or greater; or where the basic wind speed is greater than 120 m.p.h., or Hawaii.

Windows must be protected from wind-borne debris or the building designed as a partially enclosed structure as per the IBC. That is, it must be designed to withstand the increase in pressure that results if the windows or doors are broken. Glazed opening protection must meet the large missile test of ASTM—E 1996 and ASTM—E 1886 without perforation. The large missile test uses a 9-ft., 2x4 traveling at 34 m.p.h. For one- and two-storey buildings, wood structural panels with a minimum thickness of 7/16 in. and a maximum span or 8 ft. are permitted for the protection of openings (R301.2.1.2).

Design loads for windows and doors are the same as those provided in Table R301.2(2) and adjusted for height and exposure per table R301.2(2) (R613.2). The basic wind speed in most non-coastal regions is 90 m.p.h. Exterior windows and glass doors are required to be tested by an approved independent laboratory and to be labelled to indicate the performance level and compliance with

AAMA/NWWDA 101/I.S.2. (R613.3). This label is used to judge that the window is appropriate for the design pressure for use in the wind zone where the building is to be located. The structural test of this standard rates the window at one of five pressure categories.

1. R 15 +/-22.5 psf (93.75 m.p.h.)
2. LC 25 +/-37.5 psf (121.03 m.p.h.)
3. C 30 +/-45.0 psf (132.58 m.p.h.)
4. HC 40 +/-60.0 psf (153.09 m.p.h.)
5. AW 40 +/-60.0 psf (153.09 m.p.h.)

The windows and doors must be tested and approved as a complete system. Site-built systems are only permitted if built and tested to the same standards—effectively they are not permitted in high-wind zones.

Windows and doors are required to be anchored to resist the design wind pressures and installed as recommended by the manufacturer. Figure R613.5 provides illustrations of eight accepted methods of anchoring windows and glass doors.

Mullions must be designed to carry the designated wind loads with a deflection of not greater than 1/175 with a factor of safety of 1.5 (R613.6).

Florida does not use the IRC, but the state code requirement for wind is based upon the same ASCE 7-98 standard with very similar results. In addition, Florida maintains a registry of window and door manufacturers whose products are approved for use in different wind speed areas. As of October, 2003 state law does not permit the use of products that are not approved and registered.

Other requirements of the IRC for high-wind areas are found throughout the body of the IRC code. They include added requirements for bracing and tie-downs of floor and wall and roof assemblies. These requirements are too numerous to list here.

Exterior wall claddings and roof finishes must withstand the same wind-design pressures and may require additional fasteners as stipulated in other areas of the IRC. For example, asphalt shingles are required to have a minimum of six fasteners per shingle where the roof is located where the basic wind speed is 110 m.p.h. or greater and the eave height is 20 ft. or greater above-grade, or is in a special wind zone (R905.2.6).

3.5 Seismic provisions

There are no special requirements for design due to earthquakes in the NBCC Part 9, except for the reinforcement of load-bearing masonry buildings more than one storey in height in zone 4 (9.20.1.2) and three storeys in height in zones 2 & 3 (9.20.15). For other building types, section 4.1.9 lists methods and formulas for determining live loads due to earthquakes and Appendix C lists seismic zones for Canadian locations in terms of acceleration and velocity and velocity ratios.

In contrast, the seismic requirements of the IRC are quite extensive. Six seismic design categories are defined in Table R301.2.2.1.1 in terms of short period design spectral response acceleration or S_{DS}. The U.S. seismic design categories are different from those in the NBCC. The categories are: A, B, C, D1, D2 and E, ranging from the least-severe acceleration to the most-severe.

The Seismic Design Category is determined by the building official (R301.2). To assist the building official, the IRC provides a map of the U.S. in Figure R301.2(2). More detailed maps of seismic zones are provided in the International Building Code (IBC). Additional information is presented in the IBC to help determine the modifiers for the S_{DS} based upon differing soil types.

Generally the regions of the highest seismic design categories occur mainly in South Carolina, the Ozark Mountains, the West Coast and Southern Alaska.

The seismic provisions of the IRC apply to buildings constructed in seismic design categories C, D1 and D2. The provisions for category C apply only to attached townhouses. Detached one- and two-family dwellings are exempt. Buildings in zone E must be designed in accordance with the IBC. There are no special seismic design requirements for Categories A and B (R301.2.2).

Buildings in Seismic Design Category E may be constructed according to Seismic Design Category D2 of the IRC if all exterior shear lines and braced panels are in one plane vertically through all floor levels; and if no floors are cantilevered; and if all the building is considered regular.

Conventional light frame construction is not permitted in irregular portions of structures in seismic design categories C, D1 and D2. The irregular portions then require engineered design (R301.2.2.7). There are 7 definitions of irregular building conditions dealing mainly with non aligned vertical shear walls, roofs or floors not supported by shear walls on all edges; where openings in floors or roofs exceed 12 ft.; where portions of a floor level are vertically offset, where shear walls do not occur in two perpendicular directions, or are constructed of dissimilar bracing systems. For more definition of shear walls refer to definitions of braced wall lines in IRC section 6.

Irregular buildings in seismic categories C, D1 and D2 are also required to have a lateral force-resisting system of engineered design (R301.2.2.9).

Anchored stone and masonry veneer construction is limited to the first storey in Seismic Design Category C and cannot exceed 127 mm (5”) thickness. It may only extend higher (R703.7) if the length of wall bracing required in R602.10.3 is increased by 1.5 times (R301.2.2.3).

The IRC lists a set of limitations for the dead-weight loads of different wall constructions and for floors and roofs. These limitations apply to buildings in seismic design categories C, D1 and D2. (R301.2.2 and R301.2.2.4).

Masonry construction in Seismic Design Category C must comply with R606.11.2 “Design of elements part of the lateral-force resisting system”.

The height of dwellings is limited in Seismic Design Categories D1 and D2 as follows:

- wood frame—three floors above grade;
- cold formed steel—two floors above grade;
- masonry construction in D1 as per R606.11.3 and D2 as per R606.11.4.

Other requirements of the IRC for seismic design requirements of specific types of assemblies are found in many places throughout the code, particularly for categories D1 and D2. They are too numerous to list here.

3.6 Accessibility

There are no special accessibility requirements under the IRC 326 except by reference to Chapter 11 of the IBC. The referenced standard in the IBC is ICC/ANSI A117.1. Under IBC 1103.2.4 detached one- and two-family dwellings are exempt. (This may also apply to townhouses). The NBCC also exempts detached houses and row houses from barrier-free requirements.

3.7 Windows and glazing

This section reviews the differences in the requirements for windows under the topics of light and natural ventilation, emergency escape and rescue openings, hazardous locations and site-built windows. The reader should also refer to additional requirements for windows described in the *Wind* (page 12) and *Energy Efficiency* (page 34) sections of this Guide.

Light and natural ventilation

Windows are required for lighting and for natural ventilation if openable. The differences between the requirements of the IRC R303 and the NBCC 9.7 and 9.32 are summarized in the following table.

Location	IRC R303 lighting	IRC R303 ventilation	NBCC 9.7 lighting	NBCC 9.32 ventilation
Basement rec rooms, unfinished areas	8% of floor area	4% of floor area	4% of floor area	3 ft.2 in., 0.2% of floor area
Bathrooms	3 ft. 2 in.	1.5 ft.^{2}	4 ft.^{2}	1 ft.^{2}
Kitchens	8% of floor area	4% of floor area	10% of floor area	3 ft.^{2}
Living rooms	8% of floor area	4% of floor area	10% of floor area	3 ft.^{2}
Bedrooms	8% of floor area	4% of floor area	5% of floor area	3 ft.^{2}

Table 1—Comparison of requirements for windows

The IRC exempts the requirement for openable windows where mechanical ventilation is provided and if the window is not required as an emergency exit by R310. It exempts any requirement for windows if both mechanical ventilation and electric lighting are provided. Please refer also to the *Mechanical Ventilation* section on page 34.

The NBCC accepts natural ventilation through windows only in the non-heating season (9.32.2). Mechanical ventilation is required during the heating season (9.32.3). For lighting, the NBCC exempts the requirement for windows in all rooms but living rooms and bedrooms if electric lighting is provided. It exempts a room from requiring openable windows except in bedrooms.

Emergency escape and rescue openings

The differences between the requirements of the IRC and the NBCC are compared in the following table.

Item	IRC	NBCC
Required locations	Bedrooms and habitable basement areas (R310)	Bedrooms (9.7.1.3)
Minimum area	5.7 ft.^{2} (R310.1.1)	3.77 ft.^{2} (9.7.1.3)
Minimum height Width (Note that only one minimum dimension can apply with the area requirement)	24” and area 20” and area (R310.1)	15” and area 15” and area (9.7.1.3)
Maximum height of sill	44” (R310.1)	59” recommended (A-9.7.1.3)
Minimum clearance in window well	3 ft. x 3ft. (R310.2)	Front clearance greater than 22” (9.7.1.4)
Additional requirements for window wells	If depth greater than 44” must be provided with a ladder. (R310.2.1) Any cover must be removable from interior side. (R310.4)	

Table 2— Comparison of requirements for windows openings for emergency escape

Hazardous locations

Safety or wired glass is required by the NBCC 9.6.6 in glass sidelight greater than 500-mm wide, or glass in storm doors or sliding doors and at shower or tub enclosures.

The IRC requires that glazing installed in hazardous locations must have a permanent label designating the type, thickness and the glazing standard (R308.1).

Glazing safety requirements must comply with the Consumer Product Safety Commission (CPSC) 16 CFR, Part 1201 criteria for Category I or Category II (R308.3). Glazing in doors and glazing less than 9 ft., 2 in. and within 18” of the floor and within 36” of a walking surface are required to meet Category I impact tests. Other hazard locations and glazing larger than 9 ft., 2 including sliding glass doors are required to meet Category II.

Hazardous locations are defined in the IRC (R308.4) for nine locations. These include glazing in doors, storm doors, sliding doors; around tub enclosures; sidelights adjacent to doors; any window panel greater than 9 ft.,2 in. and within 18" of the floor of the floor; all glazing in railings; around pools, or on stairway landings. Openings are not allowed in walls located within three feet of a fire separation (R302).

Site-built windows

Site-built windows are permitted only if they meet the IBC 2404, that is, they are built to all the same requirements as manufactured windows (R308.5)

3.8 Minimum dimensions

The minimum dimensions in the IRC tend to be larger than the Canadian. The following table describes these differences.

Item	IRC	NBCC
Minimum room areas	One large room—120 ft.^{2}; Kitchen—50 ft.^{2}; Other rooms—70 ft.^{2} (R304)	Living room—107.6 ft.^{2}; Dining room—56 ft.^{2};Kitchen—34.5 ft.^{2};Master bedroom—52.7 ft.^{2}; Other bedroom—37.7 ft.^{2}; Bathroom—23.7 f^2 (9.5.3.1)
Minimum dimension in a room	7.0' (R304)	No requirement
Minimum ceiling height	7.0' (R305)	Rooms—7.5'; Bathrooms/halls—6.9' (9.5.3.1)
Space around fixtures in bathrooms	See (R307)	No requirement
Hallway width	36" (R311.4)	34" (9.5.4.1)
Stair landings	Width—not less than stairway; length—36" (R312)	Width and length—not less than stairway width (9.8.4.1)
Stairway width	36", including. handrails (R314.1)	34" including handrails (9.8.3.3)
Stair max. riser height Stair min. tread run	7.75" 10.0" (R314.2)	7.9" 8.25" (9.8.3.1)
Stairway headroom	6.67' (R314.3)	6.4' (9.8.3.4)
Guards	When >30" above grade or floor Height 36" Side of stairs 34" (R316)	When >24" above grade or floor Height—35.4" (9.8.8)
Exit door width Exit door height	36" 6.67' (R311.1)	32" 6.5' (9.6.3.1)
Ramps max. slope	12.5% (R313.1)	10.0% (9.8.6.2)

Table 3— Comparison of minimum dimension requirements

3.9 Fire and safety

The NBCC 9.10 requirements for Fire Protection appear complex compared with those in the IRC due in part to the fact that the NBCC allows other-than-residential occupancies under part 9.

Fire separations of dwelling units

Fire-resistant construction is required for increased safety when dwelling units are located in close proximity, that is, in two dwelling homes or between attached townhouses.

A fire separation distance is defined in IRC R202 as the perpendicular distance to a lot line. Exterior walls located within three feet of a fire separation must have a one-hour minimum fire resistive rating *from both sides*. Projections cannot extend more than 1/3 of the distance or 12"—whichever is less. Projections extending within this space are required to have a fire-resistive rating on the underside of one hour. Openings are not permitted in a wall where the fire separation distance is less than three feet. Walls perpendicular to the line of the fire separation are exempt. This applies to detached homes and townhouses (R302). Class A, B or C roofing (ASTM E 108) is required where the edge of a roof is located within three feet of a property line (R902.1). The NBCC 9.10.14 requires a 45-minute fire rating where a detached dwelling is located less than four feet from a lot line. Openings are permitted only if the distance is greater than four feet.

The IRC requires that walls and/or floor assemblies separating units in *two-family dwellings* shall have a separation of not less than one hour (321.1). NBCC 9.10.8.1 requires a fire rating of 45 minutes for floors between units and NBCC 9.10.9.14 requires 45 minutes between suites and one hour if walls are separating dwelling units of two or more storeys.

The IRC requires that walls between townhouses be two structurally independent walls, each with a one-hour fire rating from both sides (R302) or one, common, two-hour fire rated wall if the walls contain no services (R321.2). The NBCC 10.11.2 (2) requires a two-hour rated firewall only where there are stacked dwelling units on either side of a firewall, otherwise a one-hour fire rating is required for party walls.

Roof surfaces of adjacent townhouses are required to be rated as class C or better (by ASTM E 108) (R902) or are required to have a fire-rated parapet wall separating the adjacent roof surfaces. The parapet wall is to have the same fire-resistance rating as the fire separation below. The parapet wall is to extend a minimum of 30" in height above the roof surface or to the height of any sloped roof surface within three feet that is higher (R321.2.2). Fire-rated parapets on roofs are required by the NBCC between units where the firewall is required to have a fire rating of two hours or more (then only 6" in height for two hours and three feet for a four-hour rating).

Fire-resistance ratings

The IRC references ASTM E 119 Standard Test Method for Fire Tests of Building Construction and Materials while the NBCC references CAN/ULC-S101-M Fire Endurance Tests of Building Construction and Materials. The standards are similar but it is not known at this point if they are the same or if American code officials will accept test results to the Canadian Standard.

No listing of fire-resistance ratings of assemblies is provided in the body of the IRC. The NBCC provides an extensive listing in A-9.10.3.1. of the Fire and Sound Resistance ratings of a large number of wall, floors, ceilings and roofs but this may not be useful for Canadian exporters due to the potential non-equivalence of the underlying standards.

Attached garages

The IRC requires a minimum of ½" gypsum board on the inside of the garage wall or ceiling structure separating an attached garage in a detached dwelling (R309). The NBCC 9.10.9.16 3) requires that the garage be an effective barrier to gas and exhaust fumes but does not require gypsum board.

Draftstopping and fireblocking

The IRC has two requirements for floor-ceiling assemblies that are finished on both sides. (NBCC 9.10.15 requires firestops in roof spaces and ceilings in sections of not more than 300 m^2 in area and not more than 60 m. in dimension. This effectively exempts most residential roofs or floors).

- Draftstopping is required to isolate concealed areas within floor assemblies in approximately equal areas which are not allowed to exceed 1,000 $ft.^2$ where the ceiling is suspended or where floor framing consists of open Web, truss-like members (R502.12).

- Fireblocking is required to cut off all concealed draft. openings both vertically in all walls and horizontally in floors to form an effective fire barrier between storeys and between the top storey and a roof space. The IRC provides a list of required locations and eligible fireblocking materials which include various wood sizes, ½" gypsum board and un-faced batt insulations (R602.8).

Foam plastics

All foam plastic and foam-plastic cores in manufactured assemblies shall have a flame spread rating of not more than 75 and a smoke development rate of not more than 450 (R318.1.1).

Foam plastic shall be separated from the inside of the dwelling by a minimum ½" gypsum board or an equivalent thermal barrier when tested to specific temperature rise conditions of ASTM E 119 (R318.1.2). The NBCC 9.10.16.10 specifically allows other coverings including plywood, fibreboard, hardboard, aspenite and metal.

The IRC lists a series of exemptions and alternative covering materials to the requirements of 318.1.1 & 2: doors (exempt), in masonry or concrete assemblies (1"), in roof assemblies (R803), in attics and crawl spaces (1-½ " mineral fibre insulation), siding backer board, and as interior trim (R318.2).

It is not clear whether the requirements of the IRC allow insulated concrete forms (ICFs) as common walls between townhouses or as detached houses within three feet of the lot line (R302).

Flame spread ratings of finishes

The IRC requires flame spread ratings and the smoke development index to be tested by ASTM E 84, *Standard Test Method for Surface Burn Characteristics of Building Materials*. The NBCC references CAN/ULC-S102-M *Test for Surface Burning Characteristics of Building Materials and Assemblies* and *Test for Surface Burning Characteristics of Flooring, Floor Covering and Miscellaneous Materials and Assemblies*. While presenting similar results the equivalency of these standards needs further investigation.

Wall and ceiling finishes are required by the IRC to have a flame spread rating of not more than 200 (R319) (NBCC 9.10.16.1 150, 200 in doors, bathrooms). Exceptions include most trim. The smoke development index is to be not more than 450. The NBCC requires a flame spread rating of 150 for interior finishes except allows 200 in bathrooms.

Alarms

The IRC requires a smoke alarm in each bedroom *and* in the vicinity of the bedrooms and one on each storey (R317). The NBCC 9.10.18.2 requires a smoke alarm on each floor level and one in *or* within 16.5 ft. of a bedroom.

NBCC 9.32.3.8 also requires a hard-wired carbon monoxide detector to be installed on the ceiling near the location of a solid fuel-burning appliance (wood fireplace or stove) and to be linked to the operation of smoke alarms. Recent changes in Ontario also require a CO detector in rooms adjacent to or above attached garages. There is no requirement for a CO detector in the IRC.

3.10 Sound transmission

The IRC Appendix K has two sound transmission requirements for walls and floors between dwelling units.

- **Airborne sound** Walls, ceilings and floors are required to have a Sound Transmission Class (STC) of not less than 45 when tested by ASTM E 90 (AK102). The NBCC 9.11 requires only the airborne STC but at a higher class value of 50.

- **Structural-borne sound** Floor and ceiling assemblies are required to have an impact insulation class (IIC) rating of not less than 45 when tested by ASTM E 492 (AK 103). There is no similar requirement in the NBCC.

No listings of STC or IIC ratings of assemblies are provided in the body of the IRC. The NBCC provides an extensive listing in A-9.10.3.1. of the STC ratings of a large number of wall, floors, ceilings and roofs.

3.11 Termites and decay

Termites

In Canada the risk of termites is low compared with that in the U.S. The NBCC 9.3.2.9 requires that wood structural elements not be within 18" of the ground unless pressure-treated with a toxic chemical where termites are known to occur. NBCC 9.15.5.1 requires that foundation walls of hollow masonry be capped in areas where termites may occur.

The IRC has a broader set of requirements since the frequency and degree of termite infestation is greater in the U.S. Areas favourable to termite damage are identified in figure R301.2(6) and as set by the building official on table R301.2(1). Only northern New England and the northern Prairie states are in the none-to-slight range.

The IRC requires subterranean protection against termites. The acceptable methods of subterranean control include chemical treatment of the soil, pressure-preservative-treated wood, naturally termite-resistant wood, physical barriers of metal or plastic shields (R324.1).

Heartwood of redwood and eastern red cedar are considered termite resistant.

Naturally resistant wood and preservative-treated wood can be used as a barrier only if the edges of joints can be inspected for termite shelter tubes (R324.3).

In areas of very heavy termite infestation (California and the southeast) foam plastic cannot be installed on or under the exterior face of foundation walls or slab foundations below grade. The clearance between foam plastics installed above grade and the ground shall be at least 6". Exceptions include buildings made entirely of non-combustible materials or pressure-preservative-treated wood, when an approved method of protection is provided, or when the foam plastic is on the interior of basement walls. (R324.4). The consequence of this is to limit the application of foam plastic insulation on foundations where there is the highest incidence of slabs on ground. See Energy Efficiency and related requirements of the IECC 502.

Decay

The NBCC 9.3.2.9 requires structural wood elements to be preservative-treated when either in contact with the ground or when within 150 mm (6") of the ground.

Figure R301.2(7) provides a map of the U.S. with areas of none-slight, slight-moderate and moderate-severe decay probability. The highest areas of decay probability are in the southeast. Much of the rest of the east and the west coast have a slight-to-moderate risk. In areas subject to decay damage, it is required that pressure-preservative-treated lumber (AWPA standards) or decay-resistant heartwood of redwood or black locust be installed in a set of seven well-defined locations (R323.1).

Additional locations for pressure-preservative-treated wood are specified for all wood in contact with the ground, for wood posts and columns inserted in concrete and for wood columns (R323.3.1).

All fasteners for pressure-preservative and fire-retardant-treated wood are required to be hot-dipped galvanized steel or stainless steel or silicon bronze or copper (R323.3).

3.12 Flood-resistant construction

There are no flood hazard measures in the NBCC. The IRC has an extensive list of requirements.

Flood hazard areas are not listed in the IRC since this is a very localized risk. They are determined by the National Flood Insurance Program and the current FIRM (Flood Insurance Rate Maps) and FBFM (Flood Boundary and Floodway Maps) or other flood-hazard maps adopted by the building authority. The investigation and assignment of the flood hazard zones is to be made by the local building authority and designated on IRC Table R301.2(1). Additional provisions in the IBC apply to floodways designated on the FIRM or FBFM maps.

All buildings erected in areas prone to flooding and classified as either flood hazard areas or coastal high-hazard areas are required to be constructed by the provisions of IRC R327.

The design-flood elevation is established as the 1-in-100 year elevation at peak depth of flood including wave action (R327.1.3).

A licensed land surveyor or registered design professional shall certify that the as-built building is in compliance with the design-flood elevation requirements (R327.1.9).

A set of requirements is provided for the design of structural systems, protection of mechanical and electrical systems by raising above-the-flood elevation, protection of water supply and sanitary sewage, the definition of acceptable materials for use below the flood elevation and requirements for manufactured homes (R327.1.1 to .8).

Flood-hazard areas not prone to wave action

The lowest floor, including any basement floor below grade, is required to be elevated to or above the design-flood elevation. Enclosed areas, such as crawl spaces and garages may be below the design-flood elevation and have additional requirements. (R327.2)

Coastal high-hazard areas subject to waves

All parts of structures within coastal hazard areas shall be elevated so that the lowest portion of all structural members supporting the lowest floor are located at or above the design-flood elevation. Basement floors below grade on all sides are prohibited. The use of fill for structural support or beneath buildings is prohibited. All structures are to be supported on pilings of columns with adequate bearing to resist the combined wave and wind loads (R327.3).

A registered design professional shall certify that the design and methods of construction for coastal high-hazard areas comply with the IRC criteria (R327.3.5).

3.13 Alternative construction systems

One of the most distinctive features of the IRC is the inclusion of provisions for a number of new and alternative construction systems that are either absent in the NBCC or referenced to other external standards. Each of the alternative systems is provided with useful illustrations of key details that explain terms and provide references to relevant code paragraphs.

Insulated concrete forms (ICF)

There are no provisions in the 1995 NBCC for the use of ICFs. The Canadian Construction Materials Centre (CCMC) has published evaluations for a number of systems but detailed installation requirements must be supplied by the manufacturer.

The IRC provides a detailed set of provisions for the use of ICFs in basement walls and in above-grade main walls. Use of the IRC requirements or the American Concrete Institute (ACI) 318 exempts requirements for an architect or engineer stamp on the drawings. The application of ICFs in the IRC is limited to certain dimensions, two floors in height and only in seismic design categories A, B, or C. The IRC requirements for flat ICF walls also apply to conventionally formed concrete walls (R612).

ICFs in foundation walls The IRC R404.4 includes tables of the required backfill height and reinforcing requirements by soil group type for flat ICF walls of varying thicknesses, for waffle-grid ICF walls and for screen-grid ICF walls.

ICFs in above-grade walls The IRC R611 contains 19 pages of provisions for the use of ICFs in walls, including provisions for:

- flat ICF walls of varying thicknesses, for waffle-grid ICF walls and for screen-grid ICF walls,
- tables of required reinforcing for various maximum wind speeds, relating maximum wall heights and concrete thicknesses,
- illustrations of the construction of ICF lintels and tables of allowable clear spans,
- minimum percentages of solid wall required in seismic category C,
- requirements for floor and roof connections.

Steel framing

NBCC 9.24 provides two pages of provisions for the use of steel studs in non-load bearing walls. Load-bearing systems must receive a CCMC evaluation and comply with a guide developed by the CCMC. The IRC provides more detailed requirements for structural walls and adds provisions for the use of steel framing in floors and roofs.

Steel floor framing IRC R505 consists of a full section of 12 ½ pages with provisions for the use and layout of steel floor joists including joist sizes, fastening, connections, anchoring, spans, bracing, cantilevers, splicing and openings.

Steel wall framing IRC R603 is a full section of 43 pages with illustrations prescribing the use and framing layout of steel studs and tracks, including stud sizes, fastening, floor connections, foundation anchoring, tables of wind speeds and stud thickness requirements, splicing, header spans over openings, jack and king stud requirements at headers, braced wall line requirements and tables of uplift connection requirements by wind speed and roof span.

Steel roof framing IRC section R804 is a section of 12 pages with provisions for the use and layout of steel rafters and ceiling joists, including sizes, fastening, connections, anchoring, spans, bracing, splicing, cantilevers, openings and high-wind tie downs.

Wood foundations

Wood foundation walls may be used in Canada but the NBCC 9.15.1.3 simply references CAN/CSA-S406 for the design and installation of wood foundations.

The IRC references American Forest and Paper Association (AFPA) Report No.7 for the design and installation of wood foundations and provides detailed requirements in the code in sections R401.1 to R406.3. Wood foundations walls in seismic design categories D1 and D2 are required to meet the anchorage and fastening requirements of braced wall lines in R602.11. (See 3.16 *Braced Wall Lines,* page 31.)

3.14 Foundations

Foundation anchorage

NBCC 9.23.6.1 requires anchorage of a building frame to a foundation by means of 1/2" bolts spaced at 8 ft. on-centre (oc) and embedded 4" in the foundation.

The IRC requires wood sill plates to be anchored at a maximum of 6 ft. oc and within 12" of the ends of each plate section, and embedded 7" in concrete or masonry. Anchor bolts are to be 1/2" but foundation anchor straps are also permitted at the same spacing. In Seismic Design Categories D1 and D2 the anchor bolt spacing is reduced to 4 ft. oc and anchor bolts are also required at interior bearing walls, on interior braced wall lines. Larger washers are also required (R403.1.6).

Footings on or adjacent to slopes

IRC R403.1.7 presents a series of requirements that limit the proximity of building (footings) on or adjacent to slopes steeper than 33 per cent. The limits are (with *h* as the height of the slope):

- *h*/2 for buildings adjacent to an ascending slope to a maximum of 15 ft.,
- *h*/3 for buildings adjacent to a descending slope to a maximum of 40 ft.

- where the slope is steeper than 45 degrees the starting setback point at the top and bottom points of the slope are defined by lines drawn as if the slope were 45 degrees from the actual bottom and top, respectively.

Depth

The minimum depth of foundations is prescribed in NBCC 9.12.2 to be 4 ft. on clay or undefined soils. It may be decreased in coarse-grained soils or as based upon local experience but generally not to less than the depth of frost.

IRC also permits *Frost Protected Shallow Foundations*. Footings are not required to extend below the frost line when the building is heated and the edge of the foundation is protected by insulation installed vertically and horizontally and with R-values provided in table R 403.3. Additional insulation is required around the corner areas. The table uses the air freezing index to determine the amount and extent of the insulation, defined as degree days below 32ºF, which may be obtained from an accompanying map (R403.3).

Concrete and masonry walls

IRC provides a series of tables for the construction of concrete and masonry walls that relate the thickness and amount of reinforcing of the wall, with the height of the wall, the backfill height and the soil classification. The soils are classified by the Unified Soil Classification System and result in different and more detailed requirements than in Canada (R404). Additional requirements are presented for concrete and masonry walls located in Seismic Design Categories D1 and D2 (R404.1.4).

The IRC provides requirements and illustrations for pier and clay masonry curtain walls. These are not permitted in Seismic Design categories D and E (R404.1.5.1). This type of foundation is not found in Canada.

Cripple walls

The IRC names the frame wall built over stepped foundation walls a cripple wall. This name also applies in Canada, where it is also called a pony wall. The IRC provides additional anchorage and bracing details for cripple walls in Seismic Design Categories D1 and D2 (R602.11).

Drainage layer

There are no specific provisions in IRC or NBCC for drainage layer systems adjacent to foundation walls as contained in OBC 9.14.2.1.

3.15 Wood framing

Framing lumber

NBCC 9.3.2.1 requires lumber to be graded by the National Lumber Grades Authority's (NLGA) "Standard Rules for Canadian Lumber." NBCC 9.3.2.5 requires a moisture content of not less than 19 per cent at time of installation.

The IRC requires load-bearing dimension lumber for joists, beams, girders, studs, rafters, trusses and ceiling joists to be marked and comply with U.S. Department of Commerce DOC PS20 "American Softwood Lumber Standard" (502.1, 602.1, 802.1). The IRC does not reference NLGA grading but the American Lumber Standard Committee (ALSC), which administers grading accreditation according to PS20, does recognize NLGA grading. Fire-retardant treated wood is stipulated to meet a moisture content requirement of 19 per cent (R802.1.3.2).

Structural sheathing

Structural sheathing is required to conform to DOC PS 1, DOC PS 2 or CSA 0437.0-93 OSB and Wafer Board, CSA-0325.0-92 Construction Sheathing, the latter being Canadian standards.

Prefabricated wood I-joists.

Structural capacities and design provisions are to be established and monitored in accordance with ASTM D 5505 (R502.1.4).

Wood trusses.

The IRC has a set of provisions for wood trusses that require engineering design to comply with ANSI/TP 1. Truss design drawings with a detailed list of design information requirements are required to be submitted to and approved by the building official (R502.11, R802.10).

Design and construction

The design and construction of wood framing in the IRC is similar to that in Canada. IRC presents a large number of differences in detail resulting from high wind and seismic requirements. These are too numerous to list and should be read carefully by anyone intending to build for a high-wind location or a building in Seismic Design Categories D1 or D2.

IRC provides a number of drawings that identify the major framing concepts and terms used in floor, wall and roof assemblies and which contain cross references to related provisions in the Code.

- Wood floor framing—Figure R502.2
- Wood wall framing—Figure R602.3 (2) and others

- Wood roof framing—Figure R802.5.1 and R606.10(1)

Terminology

Several elements of framing have different names in the IRC than those used in the NBCC. Most of these terms are also used in Canada.

NBCC	IRC
beam	girder
lintel	header
studs at sides of openings	jack stud
roof joist	rafter with ceiling finish

Table 4—Comparison of NBCC and IRC terms

Span tables

NBCC provides 20 span tables for floor joists, ceiling joists, roof joists, roof rafters, beams and lintels. The IRC provides similar tables but it is difficult to compare the span tables in the IRC with those in the NBCC due to differences in the presentation, loading conditions and allowable deflections. For example:

- The IRC span tables for ceiling joists and rafters with a ceiling finish are determined on the basis of a deflection of 1/240 span, regardless of the type of finish. NBCC 9.4.3.1 requires a deflection limit of 1/360 span for roof joists and rafters with a plaster or a gypsum board finish and 1/240 for other finishes. On this basis it is to be expected that allowable spans for these elements be longer in the IRC. In the case of rafters with no ceiling finish both codes allow a deflection of 1/180 of the span.

- In the case of floor joists the permitted deflections is 1/360 of span for both IRC and NBCC. However, NBCC 9.23.9.4 allows increased spans based on whether strapping, bridging or both are applied to the joists, the shortest span being for joists with strapping. IRC requires bridging or strapping only on 2x12 joists at 8' 0" (R502.71) and does not account for their effect in the span tables.

Despite these differences Table 5 summarizes an attempt to compare the spans for a sample of framing members of different elements in both codes. The comparison uses #2 Spruce Pine Fir (SPF) lumber as defined in each code. Efforts were made to ensure that the span conditions were similar.

Element/Conditions	Size	IRC	NBCC
Floor Joists		R502.3.1(2)	Table A1 (strapping)
16" oc Dead-load IRC 20 psf, live load 40 psf	2x8 2x10	11.5' 14.08'	11.02' 13.0'

Girders/Built-up beams		R502.5(2)	Table A6
Centre, supporting one floor, 28' building width	3-2x8 3-2x10	6.25' 7.58'	8.04' 9.84'
Headers/Lintels		R502.5(1)	Table A17 (+ 5%)
Roof, ceiling and 1 centre-bearing floor, 50 psf snow, 28-ft. width, non-structural sheathing	2-2x4 2-2x6 2-2x8	2.42' 3.58' 4.50'	2.89' 4.10' 4.95'
Ceiling joists		R802.4(1) (1/240)	Table A3 (1/360)
416" oc Uninhabitable, no stairs, no storage (deflection of ceiling 1/240 NBCC 1/360)	2x6 2x8	16.92' 22.33'	14.6' 19.19'
Rafters		R802.5.1(6)	Table A7
16" oc no ceiling finish (1/180), 50 psf snow	2x6 2x8	9.75' 12.33'	10.76' 14.14'

Table 5— Comparison of spans for wood framing—#2 SPF lumber

It appears that the spans for wood framing are more conservative in the IRC than in the NBCC based on the following considerations:

- The spans for headers, girders and rafters without a ceiling are shorter in the IRC.
- The spans of the ceiling joists are longer in the IRC but that is accounted by the more limited deflection allowance in the NBCC for that element.
- The spans of the floor joists are longer in the IRC, but only in the case of strapping with the joists in the NBCC. In the case of the 2x8 it has longer spans in the NBCC when used with bridging or bridging and strapping.

Please note that the foregoing is for illustration purposes only and other circumstances may not lead to the same result. An exporter must comply with the IRC span tables since compliance with the NBCC may not meet IRC standards.

Steel beams with wood framing

NBCC 9.23.4.3 provides a span table for steel beams supporting floors in dwellings. *The IRC provides no information for the use of steel beams in floors*, so an exporter will have to get steel beams approved by an engineer or use other materials.

Fastening

Fastening Table R602.3(1) "Fastener Schedule for Structural Members" is a comprehensive table and includes fastenings for all structural members of floors, walls, roofs, bracing sheathing, structural panels, subflooring, and so on. A conversion from the U.S. penny weight nail sizes is in

"Unit conversions", page xiii. Galvanized roofing nails have a heavier weight for their length and Table 602.3(1) lists the lengths of roofing nails. The lengths of equivalent 16 ga. wire staples for fastening 1" lumber and structural sheathing panels are also listed in Table R602.3(1).

Roof tie-down

Roof assemblies subject to wind-uplift. pressures of 20 psf or greater must be provided with tie-down connections as reviewed in table R802.11. The wind-uplift. pressures are determined in Table R301.2(2) and adjusted for height and exposure. A continuous load path is required to secure the roof structure to the foundation. There are no requirements in the NBCC for roof tie-downs.

Drilling and notching

Table 6 summarizes the differences between the IRC and the NBCC.

Item	**IRC (R502.8)**	**NBCC (9.23.5)**
Location of notch	Top or bottom of joist	Top of joist
Distance from bearing end	Within 1/3 span	Within ½ joist depth
Maximum depth	1/6 joist depth, ¼ at joist end	1/3 joist depth
Drilling diameter	1/3 joist depth	¼ joist depth
Location	Not less than 2" from edge	Not less than 2" from edge

Table 6— Comparison of requirements for drilling and notching

Headers/Lintels

Wood structural panel box headers may be constructed in accordance with Table R602.7.2 and Figure R602.7.2. The box headers consist of vertical cripple studs spaced the same as the wall studs with structural panel faces fastened on one or both sides in either 9" or 15" depths. The advantage of the box header is that it is insulated to the same level as the wall. There is no similar prescriptive allowance in the Canadian codes.

Jack studs

NBCC requires a minimum of one jack stud to bear under the end of a lintel and that it be adjacent to a full-height stud. Single studs without a jack are permitted by the NBCC if the opening is less than the required stud spacing and not located in adjacent stud spaces (9.23.10.6). The span tables for lintels in the NBCC require 3"- bearing under each end of a lintel when the span is greater than 9.84 ft.

The IRC span table for headers (R502.5(1)) shows the required number of jacks required at the end of a header with every size and condition of the opening. No less than one is required and the transition to two jacks varies with the floor and roof loading configurations as well as the opening size, but is generally well less than 9.84 ft. of span. Openings designated with the minimum of one jack are allowed to support the header with an approved framing anchor (metal) and delete the jack.

3.16 Wall bracing and braced wall lines

Wall bracing is implicitly part of the NBCC in the requirement for sheathing (9.23.16). But the IRC has much more extensive and explicit requirements for wall bracing in wood-frame walls (R602.10). Wall bracing is required to prevent racking of structural walls under vertical structural loads and from horizontal loads imposed by winds and earthquakes. Wall bracing in wood-frame construction is achieved by the application of either diagonal bracing or by the use of structural panels. (Note that the IRC also has requirements for wall bracing and braced wall lines for other types of construction including ICF, masonry and steel framing.)

Braced wall lines are the structural bearing walls in a house—normally the exterior walls. Braced wall lines are required to have offsets of no greater than 4 ft. with a maximum of 8 ft. in a single line. Braced wall lines are required to be made with braced wall panels. As a minimum, braced wall panels are required in braced wall lines at each end and at each 25 ft. oc. The required amount of braced panel is expressed as a percentage of the braced wall line length (Table R602.10.3). The percentage amount varies with the type of bracing system and increases by Seismic Category, wind speed and the number of overlying floor levels in a house. For houses in Seismic Categories A or B and with a wind speed of 100 m.p.h. or less the required amount of braced panel is not less than 16 per cent for single or two storey homes.

There is no minimum requirement for the spacing of braced wall lines from one another except in Seismic Design Categories D1 and D2, in which case they must not be less than every 25 ft. in both plan directions (R602.10.11). There are also restrictions on the height of openings next to braced wall panels (R602.10.5).

Eight methods of constructing braced wall panels are described (R602.10.3). These include 1x4 wood or equivalent metal diagonal braces, 5/8" diagonal wood boards, wood structural panels, ½" structural fibreboard sheathing, ½" gypsum board sheathing, particleboard wall sheathing, Portland cement plaster and hardboard panel siding. The minimum length of braced panels for most methods is 48". Gypsum board finished braced wall panels must be a minimum of 96" if covered only on one side (R602.10.4).

When continuous wood structural panel sheathing is provided the percentage amount of braced wall panel in a wall line is reduced but not eliminated. There are restrictions on the minimum length of each braced panel and upon the height of openings next to braced wall panels (R602.10.5). Wood structural panel sheathing at corners is required to be installed and fastened as in Figure R602.10.5.

Engineering design of braced wall lines is required when a building does not comply with the requirements of section R602.10 (this includes wind speeds in excess of 110 m.p.h.).

Bracing in seismic design categories D1 and D2 shall be provided with both exterior and interior braced wall lines. Spacing between braced wall lines will not exceed 25 ft. in both plan directions. Additional requirements for bracing in seismic design categories D1 and D2 are provided including cripple wall bracing, wall anchorage interior braced wall panels (R602.10.11). Note there are also additional requirements for seismic design and the alignment of braced wall lines as described in regular construction (R301.2.2.7).

3.17 Air, vapour and weather barrier systems

Air barrier

NBCC 9.25.3 requires a continuous air barrier system to prevent excessive condensation of air travelling from inside to out and from the exterior inward to ensure comfortable conditions for the occupants. There is a requirement in the IRC Section N1102.1.10 for air-sealing measures to control air leakage (and in IECC 501.1.4). There is otherwise no performance level required for the air barrier in terms of measured air leakage in either the IRC/IECC or in the NBCC (or any provincial code).

Vapour barrier

Similar to NBCC 9.25.4, IRC 322 requires a vapour retarder to be installed on the warm-in-winter side of the insulation in all framed elements of the building envelope. Beyond this there are a number of differences in the IRC that are important for Canadians to understand:

- A vapour retarder is defined in the IRC to be a material having a permeance (U.S.) of 1.0 or less. This compares with the NBCC, which defines a vapour barrier as 0.78 perm and requires a 0.26 perm when a wall construction incorporates a low-permeance cladding or sheathing.

- No particular materials are specified or excluded in the IRC as vapour retarders except that they are required to be tested for vapour permeance by ASTM E 96. The NBCC specifies three standards for vapour barriers, one for sheet polyethylene, one for other materials and one for (painted) coatings on gypsum board.

NBCC Part 9 makes no exceptions to the requirement for a vapour barrier on the warm side of all building elements. IRC 322, however, allows a number of exceptions to the requirement for a warm in winter side vapour retarder including:

- in construction where moisture or freezing will not damage the materials;

- where the framed cavity or space is ventilated to allow moisture to escape;

- in counties identified with a footnote in Table N1102.2—that is, climate zones number 7 or less that are warm and humid with less than 3,500 HDDF—annual heating degree days Fahrenheit—located mainly in the Southeast.

These warm and humid areas experience conditions of vapour flow from the outside to inside which predominates for most of the year since the interior is both cooler and dryer than the outside due to air conditioning. Moisture may otherwise accumulate against the exterior side of a vapour retarder placed on the interior surface in the designated climates zones. The use of interior finishes such as vinyl-coated wallpapers or low-perm paints can lead to significant moisture and mold problems in these climates.

NBCC clause 9.25.1.2 specifically permits an inboard and an outboard vapour barrier condition to exist. It allows any sheet or panel material with low air leakage and a low-permeance rating to be located on the exterior of an assembly if the ratio of R-values of the exterior-located sheet and finish divided by that of the inboard materials exceeds values in a table. This helps reduce the likelihood that any moisture vapour emanating from the inside will condense within the wall, since the outboard sheet insulation effectively raises the temperature of the condensing surface. Where this condition exists, NBCC 9.25.4.2 2 requires a low-permeance, inner vapour barrier of not greater than 0.26 perm (15 ng/Pa.s.m2). There is no similar term in the IRC, though this does not mean it may not be permitted.

Weather barrier

NBCC 9.23.17 requires a wall-sheathing membrane of breather-type paper beneath all exterior wall cladding materials, except in the case of sheet-type products with sealed joints. It also excludes the requirement in the case where non-wood based, insulated, sheathing-board-type products are installed. NBCC 9.27.3 has a number of provisions for flashing and control of rainwater with wall cladding systems.

The IRC has a similar requirement for weather-resistant sheathing paper, which is to consist of asphalt-saturated felt complying with ASTM D226 or other approved material. Table 703.4 lists the requirement for a weather-sheathing paper. Compared with the NBCC requirement, there are a number of applications where paper is not required—including under most siding materials including aluminum, hardboard, vinyl and horizontal wood sidings and vertical wood sidings with lapped or batten joists.

Neither NBCC Part 9 nor the IRC has a requirement for a vented and pressure-balanced rainscreen system under wall claddings. The next version of the NBCC will have a requirement for a rainscreen in Maritime regions.

Exterior Insulation Finish systems (EIFS)

The NBCC has no requirement for EIFS wall cladding. The IRC requires that all EIFS shall have a weather-resistive barrier applied between the underlying water sensitive building components and the exterior insulation and a means of draining water to the exterior of the veneer (R703.9).

Roofing underlayment

The NBCC does not require underlayment under asphalt shingles, except for eave protection when it is required to extend a minimum of 1 foot within the inside face of the bearing wall (9.26.5 and 9.26.6), or at valleys. The IRC requires underlayment beneath asphalt shingles to cover the entire roof. Two layers are required for low-slope applications defined as 2 to 4:12 slopes (R905.2.7).

The IRC also requires special treatment of underlayment at eaves for ice protection in areas where the average daily temperature in January is 25°F or less. An ice barrier is required, which is to consist of at least two layers of underlayment cemented together or a self-adhering, polymer-modified bitumen sheet extending from the eave edge to at least 24" inside the exterior wall line (905.7.1).

3.18 Energy efficiency

IRC Section N1100 describes an extensive set of minimum prescriptive criteria for the envelope components and the mechanical equipment in houses.

The requirements in IRC Section N are based upon the 2000 International Energy Conservation Code (IECC), principally Chapter 6 for the minimum prescriptive criteria for building assemblies. The IECC also contains two additional performance-based compliance paths for houses, which are referenced in the IRC Section N.

The IECC is an important document. It is reviewed, along with efficiency compliance paths for houses, in 4.2 "The International Energy Conservation Code" on page 40.

The requirements for energy efficiency in the IRC/IECC differ substantially with Canadian requirements in any of the provincial codes. The NBCC does not stipulate the requirements for insulation and mechanical equipment leaving that choice to individual provinces. The performance-based compliance options of the IECC are not available under any current provincial code.

3.19 Mechanical ventilation and combustion air

See 3.7 "Windows and glazing" on page 16 for a discussion of natural ventilation through windows.

A major difference between the NBCC and the IRC is the requirement for mechanical ventilation. NBCC 9.32 sets forth a detailed requirement for mechanical ventilation in all residential units that has stipulated flow rates and which has both supply and exhaust flows in equal amounts and cross-linked controls. It also includes provisions for the distribution system, the use of HRVs (9.32.3.11) and measures for protection against depressurization and combustion gas spillage with makeup air (9.32.3.8). (Ontario 9.32 has requirements for mechanical ventilation but they and the requirement for pressure control are simpler than in the NBCC). The requirements in the NBCC are derived in part from CSA F326-M91 "Residential Mechanical Ventilation Systems," which is the referenced standard in Part 6 of the code.

The IRC does not contain an explicit requirement for mechanical ventilation. It is strictly optional and is required only if windows are not openable nor of the size reviewed in 3.7 "Windows and glazing" on page 16. The mechanical ventilation system must then be capable of 0.35 ACH in the room or it must be a whole-house system capable of supplying outdoor air at a rate 15 cfm per occupant. The number of occupants is based on the number of bedrooms plus 1 (R303.1).

The minimum ventilation for a bathroom without openable windows is required to be 50 cfm for an intermittent fan and 20 cfm for continuous systems (R303.3). These are the same flow requirements for bathrooms as in Canadian codes.

The IRC does not contain any specific requirements to control depressurization resulting from the operation of ventilation systems that may cause spillage from combustion appliances similar to the NBCC. There is a reference in M1701.2 that the air requirements for the operation of exhaust fans, kitchen ventilation systems, clothes dryers and fireplaces shall be considered in determining the adequacy of a space to provide combustion air. This statement is intended to require the installation of combustion air supply openings in most U.S. homes. This may be considered similar in effect to "makeup" air in the NBCC or CSA F326 except there are no performance or test requirements. See combustion air below.

Combustion air

In Canada the requirement for combustion air supply for fuel combustion appliances is left. to installation standards for the type of fuel, including CSA B139 (oil), CSA B149 (gas) and CSA B365 (solid fuel). Except for direct-vent appliances, it is generally required to supply outside air in an insulated duct to terminate near the combustion appliance. The sizing of the duct is set forth in the relevant standard.

Requirements for combustion air do not apply to fireplaces, fireplace stoves or direct vent appliances. An exterior air supply is required for factory-built and masonry fireplaces to insure proper combustion (R10005).

The IRC allows combustion air to be drawn from within the building in buildings of "ordinary" tightness. The room with the combustion appliance is required to have a volume of 50 $ft.^3$ per 1000 Btuh input (M1701).

Where a building is of "unusually tight construction," combustion air shall be obtained from outdoors as per M1703 (M1701.1 and M1702.3). Two openings are required, one within 12" of top of enclosure or room and one within 12" from the bottom. Each opening is to be sized at a minimum of 1 in^2 for each 4,000 Btuh input for vertical openings through ceilings, or 1 in^2 per 2,000 Btuh for horizontal openings through walls.

"Unusually tight construction" is defined descriptively in R202 as a house with walls and ceilings with a continuous vapour retarder of 1 perm or less, windows and doors with weatherstripping, caulk and sealants area applied to joints around windows and doors frames. In other words—a new house in Northern areas.

Other U.S. ventilation standards and codes

There is some activity in the U.S. toward developing a revised mechanical ventilation standard and a number of states do require mechanical ventilation in their building codes or as part an incentive program.

ASHRAE 62.2P is a new draft of a standard for mechanical ventilation published in November, 2002. It is proposed to require a continuous mechanical ventilation rate of 7.5 cfm x (# bedrooms +1) + 0.01 $cfm/ft.^2$. Thus, a 2,000 $ft.^2$ house with three bedrooms requires a base continuous ventilation rate of 50 cfm. Additional "spot" or intermittent ventilation would also be required for demand ventilation in bathrooms. The base continuous rate of ventilation compares to the principal fan rates defined in the OBC and the NBC. The same house would require a Total Ventilation Capacity of 140-150 cfm under CSA F326 and a principal fan flow of 65-70 cfm under the Canadian codes.

While ASHRAE 62.2 is too late to be incorporated in the current 2003 edition of the International Codes, it is possible that it may be included in the next edition cycle, which is expected in 2005 or 2006.

Certain states do have ventilation and pressure control requirements in the current version of their state building codes. These states include California, Minnesota, Washington and Wisconsin. In addition there are other states, such as New York and Vermont, that include requirements for mechanical ventilation as part of the ENERGY STAR incentive program.

3.20 Mechanical and duct systems

Heating and cooling equipment sizing

NBCC 6.2.1.3 references CSA-F280 for the size of the heating appliance in residential buildings. In the IRC the sizing of heating and cooling equipment is based on building loads calculated in accordance with Air Conditioning Contractors of America (ACCA) Manual J or other approved methods (M1401.3). The methods in the standards are similar but differ in the determination of below grade heat loss and air infiltration.

Duct systems

Since most houses in the U.S. are built upon crawl space or slab foundations it is common to find HVAC equipment and ducts located in unconditioned crawl spaces or attics. Heat losses from ducts and equipment located in these spaces can be a major source of energy consumption, so the IRC has measures intended to reduce these losses.

Insulation is required around ducts located in unconditioned spaces or outside the building to the following minimum levels (M1601):

- R5 when the duct is outside the conditioned space but within the building,
- R8 when the duct is outside the building, and
- R8 on the exterior of a duct located in an envelope assembly.

All joints of ducts shall be made substantially airtight by means of tapes, mastic gasketing or other approved closure system (M1601.3.1). No differentiation is made whether all the ducts are located within the conditioned space or not. There is no such comparable requirement in any Canadian building code.

3.21 Gas, plumbing and electrical

The IRC contains extensive and detailed sections for

- G—Fuel gas—one large chapter
- P—Plumbing—eight chapters
- E—Electrical—10 chapters

The requirements of these sections are too large to be included in this review. The major difference with Canadian building codes is the presence of these sections in the IRC. In Canada these requirements are not included in the body of the code but are simply referenced to other standards or codes.

For exporters of prefabricated panels or modular homes, compliance with the plumbing and electrical requirements is required. Section E3300 is based on the NFPA 1999 National Electrical Code (NEC). Electrical wiring and boxes need to be UL-stamped for use in dwellings in the U.S. For exporters of manufactured houses to the U.S. these components must be either dual-stamped UL and CSA, or must originate in the U.S.

3.22 Manufactured housing used as dwellings

Appendix E (eight pages) provides administrative requirements for manufactured houses including applications, permits, fees and inspections. It also deals with issues of site servicing, foundation systems, skirting, exits, piers, anchorage and ties.

It does not provide any standards for the design and construction of the manufactured housing unit but references the standards of the Housing and Urban Development (HUD) "The Manufactured Home Construction and Safety Standard."

3.23 Radon control

Appendix F of the IRC contains six pages. It provides a set of requirements and illustrations for a number of radon control and venting systems. The methods utilize sealing of the below-grade areas and installation of active or passive subslab depressurization systems. These measures are similar to those recommended in NBCC 9.13.8.2.

Table AF101 lists high radon potential (Zone 1) counties in the U.S.

The Canadian action level for radon gas is 22 pCi/l (picoCuries per litre), which is significantly higher than the 4 pCi/l recommended by the EPA in the U.S.

3.24 Differences between the IRC and other U.S. codes

For this Guide, it was not practical to undertake an in-depth review of the other building codes in order to make comparisons with the IRC. It is recommended that where any of these codes apply the exporter should obtain and review a copy of the relevant code.

An exception is made for a very brief comparison between the IRC and the Uniform Building Code (UBC). The UBC is still the primary code for all construction in several states, including California, Washington, Minnesota and Nevada. Some western states also use the UBC but allow other codes at the local level, including both the OTFDC and the IRC for residential buildings, so both the UBC and IRC may be encountered at the local level.

The UBC consists of three separate Volumes. Volume 1 covers Administrative, Fire Safety and Life Safety and Field Inspection Provisions. It contains requirements for the shell construction of the building including excerpts from Volume 2 for light framing. Volume 2 contains Requirements for Structural Engineering Design. Volume 3 contains Material, Testing and Installation Standards. The UBC is a building code for all types of buildings and does not isolate the residential requirements in one area. The UBC references the other codes in the series, including the Uniform Mechanical Code (UMC), the Uniform Plumbing Code (UPC) and the National Electrical Code. The requirements of these documents are not summarized in the basic UBC and must be examined separately.

Wind The UBC does not include the same wind requirements of the IBC/IRC since they are not based on ASCE 7-98 but an earlier version ASCE 7-95. The UBC Appendix Chapter 23 "Conventional Light Frame Construction in High Wind Areas" applies where the basic wind speed is from 80 to110 m.p.h. The wind definitions are in Volume 2, Section 1616—1618.

Energy conservation The 97 UBC has no requirements in the code body for insulation or for energy conservation. The Appendix Chapter 13 references the 1995 MEC (Model Energy Code) but this is only required where a state or local authority has adopted this appendix as set forth in section 101.3

Minimum window areas The UBC requires larger window areas: 10 per cent for day lighting, five per cent for ventilation. This compares with eight per cent and four per cent in the IRC.

Underfloor ventilation 2306.7 The UBC requires venting of underfloor crawl spaces similar to the NBCC or the IRC. But, unlike the IRC 408, the UBC does *not allow non-vented crawl spaces* where the space is supplied with conditioned air, the exterior walls are insulated and the ground surface is covered with an approved vapour retarder.

Trusses in floors and roofs The UBC contains no specific requirement for truss design information (IRC 502.11.4 R802.10.1)

Steel framing The UBC contains no information on Steel Framing. It references the American Institute of Steel Construction Standards (AISCS)

Insulated concrete forms There are no specific requirements in the UBC.

Section 4 Energy codes and programs

Energy code requirements in the U.S. are important to the housing exporter since they have a significant impact on the composition of the individual roof, wall, floor and window assemblies, the permitted area of windows, the specification of the mechanical system efficiencies and optional requirements for post-construction tests and inspections.

There are two model energy codes in use across the United States: the Model Energy Code (MEC) and the International Energy Conservation Code (IECC). The two codes are very similar since the MEC has evolved into the IECC. The next subsection provides a brief review of the development of these two energy codes. This section then provides an in-depth review of the IECC. A summary is provided of the differences between the MEC and the IECC but the MEC is not reviewed in any further depth since they are otherwise similar.

A number of states have special energy code requirements that are additional to those of the model energy codes. As examples, the special energy requirements of the states of California, Florida, Minnesota and Washington are reviewed in Appendix D, "State energy codes," page D-1. These states place greater emphasis on performance analysis and post construction tests and inspections. Three have requirements for mechanical ventilation.

There are a number of features of U.S. energy codes that differ from Canadian code requirements for energy efficiency:

- The prescriptive requirements of the MEC/IECC are generally more stringent than current requirements in Canadian building codes.
- American energy codes define alternative compliance paths, which are based on the analysis of a home's energy performance.
- Those same performance-based analysis methods in U.S. energy codes are the same as those used to assess compliance with incentive programs for energy efficiency in the U.S. These include ENERGY STAR and Building America, which are both reviewed as part of this section.
- Canadian builders are not familiar with options of analysis or performance-based methods of compliance for code compliance. While the Model National Energy Code for Houses (1997) has some general similarities to U.S. energy codes regarding alternative compliance paths, this code has not been adopted by any province.

4.1 The Model Energy Code (MEC)

Prior to the formation of the International Codes Council (ICC) and the publication of the International Energy Conservation Code (IECC), CABO worked together with the National Conference of States on Building Codes and Standards (NCSBCS) to produce the MEC—the Model Energy Code. There were several versions from the late 1980s through to 1995, the last issue of the MEC.

With the *Federal Energy Policy Act* of 1992, all states were required to review and adopt energy codes in buildings. The Act established the MEC as the reference standard for energy performance in residential buildings. This prompted many states to adopt the then-current version of the MEC, the Model Energy Code (1993), or to develop their own code that achieved the performance level of the MEC.

In 1995, CABO assigned all rights and responsibilities for the MEC to the International Codes Council, which produced the first issue of International Energy Conservation Code (IECC) in 1998. The IECC is the successor to the MEC and the two are very similar in organization and requirement. The *Energy Policy Act* has been amended to reference the IECC in place of the MEC.

While many states have adopted the International Codes, the MEC is still widely referenced in the U.S. The MEC is the basis of codes for many state, which have not adopted the International Codes since the Uniform Building Code (UBC) and other older codes do not have integral requirements for energy efficiency. And, the MEC is still significant nationally, since it is the reference for systems analysis for energy efficiency ratings in houses in the U.S. (*see* 4.3 "HERS and ENERGY STAR," page 47).

A map in Appendix B, "State code status," page B-4, summarizes the status of energy codes on a state-by-state basis. A total of 19 states have adopted the IRC, which is linked to the IECC. Many of these states have also adopted the IECC for all buildings. A further three states have adopted the IECC. A total of 12 states have adopted the MEC in various editions. Another five have produced their own energy codes, which add more requirements to the MEC. A total of 11 states have no state energy code, but a number of these have municipalities that have adopted energy codes at the local level including the IRC/IECC (four) and the MEC (two).

4.2 The International Energy Conservation Code (IECC)

The IECC provides *three compliance paths* for residential buildings that are set forth in Chapters 4, 5 and 6. Chapter 6 is the most straightforward, containing a set of minimum prescriptive requirements for the envelope components—the same as are presented in section N1100 of the IRC.

The IECC provides two additional chapters for residential buildings which do not meet the requirements of Chapter 6 (*see* 4.2.1 below) or if the proponent simply wishes to use alternative paths for compliance. The other methods of compliance require increasing levels of analysis but offer the builder increasingly more choices for meeting the requirements.

The IECC divides the U.S. into 19 climate zones based upon annual Heating Degree Days Fahrenheit (HDDF). The climate zones are generally divided in increments of 500 degree days, though zones 13, 15 and 17-19 encompass a larger range. Chapter 3 contains a detailed map of each state showing the climate zone of each county in the state.

A number of requirements are the same in each compliance route:

- The IECC requires certification of the thermal performance of insulation and windows that is not required in Canadian codes.

- The minimum equipment efficiencies are set in Chapter 5, sections 503 and 504, but apply to each of the compliance alternatives in Chapters 4, 5 and 6 (and IRC Section N). The minimum envelope requirements of Chapters 5 and 6 are not dependent on the fuel type used for space conditioning or water heating. This approach differs from that in the MNECH, where different envelope requirements are required for different heating fuel types.

- The thermal resistance of blown-in or sprayed insulation is required to be certified and provided by the installer at the job site. Markers must be provided in attics/roofs every 300 ft.^{2} indicating in 1"- high numbers the depth of the insulation (601.3.1)

- Windows are required to be labelled and certified by the manufacturer for the overall U-value (by NFRC 100), the Solar Heat Gain Coefficient (SHGC) (by NFRC 200) and air leakage (by AAMA/WDMA 101/I.S.2). When a manufacturer has not determined these values by test default U-Values and SHGC will be assigned from Tables 102.5.2(1), 102.5(2) and 102.5.2(3) (601.3.2).

- The maximum area-weighted SHGC for windows in climates with less than 3500 ADD is 0.4 (602.2).

Chapters 4, 5 and 6 of the IECC are reviewed in this Guide in reverse order since that corresponds to the linking with the IRC Section N and to the degree of difficulty of their application. Chapter 5 is reviewed in two parts: the first for mechanical equipment and the second for the building envelope.

4.2.1 Chapter 6—simplified prescriptive requirements for residential buildings

The prescriptive requirements of Chapter 6 are the same of those in the IRC Section N, Chapter 11. The corresponding table or item number in the IRC Section 11 is identified by substituting the number 11 for 6 in any table or item number in the IECC Chapter 6.

Chapter 6 provides energy efficiency requirements for residential buildings:

- Type A-1: detached houses with a glazing area that does not exceed 15 per cent of the gross area of exterior walls.

- Type A-2: rowhouses with a glazing area the does not exceed 25 per cent of the gross area of exterior walls.

- Which are located in a climate zone of less than 13,000 HDDF (that is, in all climate zones except central and northern Alaska. See IECC Chapter 3 and as listed in the IRC Table N1101.2).

Residential buildings of Types A-1 or A-2 with a glazing area which exceeds the stipulated limits, or which are located in a climate with more than 13,000 HDDF, must meet the requirements of Chapters 4 or 5 of the IECC.

Mechanical systems (603)

Equipment efficiencies for mechanical equipment are referenced to Chapter 5.

Building envelope (602)

IECC Chapter 6 provides one simple table (602.1) which lists the minimum R-values of all envelope assemblies and the maximum window U-value of windows for 17 different ranges of climate expressed by Heating Degree Days Fahrenheit (HDDF). The R-values in the table are nominal and consist of the insulating materials only, so the user of IECC Chapter 6 (or IRC Section N) cannot add the resistance of finish materials to the total value, nor is the user required to perform calculations of the effect of framing members on the overall thermal Resistance of the assemblies.

For northern states with more than 6,000 HDDF, the requirement for windows is a maximum U-value of 0.35. This translates as double-glazing with Low-E glass and an argon gas fill. Doors without glazing must have a maximum U-value of 0.35 (602.1.3).

Several additional tables are provided for minimum R-values for steel-frame walls (602.1.1.2) and mass walls (602.1.1.1(1)). All steel-frame walls are required to have additional sheathing board insulation and the combined nominal resistance values exceed those for wood-frame walls. This requirement is intended to compensate for the increased thermal bridging effect of the steel framing.

Mass walls are defined to be masonry, concrete or thick, solid-wood walls. The thermal resistance requirements for mass walls are moderately lower than those required for nominal wood-frame walls in Table 602.1. This reflects the increased degree of difficulty in insulating this type of wall and the positive effect that a mass wall can have upon reducing air conditioning loads in warm climate zones. If the mass wall is insulated on the exterior side or the insulation is integral though the assembly (as in log walls or ICF walls) the permitted R-value is lower in milder climates compared to other types of mass walls. The permitted resistance values of the masonry or concrete component is stipulated in Table 602.1.1.1(2).

Where a raised-heel truss or other means of construction permit the full depth of roof insulation to continue over the exterior wall top plate, a lower value of roof insulation is permitted (602.1.2). Where R38 is required R 30 is permitted and where R 49 is required R 38 is permitted.

The minimum R-values for floors must be *increased to that required for ceilings* when more than 25 per cent of the floor is exposed (602.1.4).

Basement wall insulation is required to be provided to a depth of 10 ft. below grade (602.1.5). This is, effectively, the full height of the wall, which differs from Ontario where it is only required to a depth of 2 feet below grade.

Crawl space wall insulation is required if the crawl space is not vented to the outside (602.1.7). The insulation is required to extend to the level of the exterior grade then extend down 2 ft. or horizontally 2 ft., or both. Any exposed earth is required to be covered with a continuous vapour retarder with a perm rating of 1.0.

For slab-on-grade floors (602.1.6) with a top edge above grade or 12" or less below grade, the required R-value may be applied to the outside or the inside of the foundation wall. The insulation shall extend downward or down and then horizontally until the distance stipulated in table N1102.1 is reached. Slab insulation is not required in areas of very heavy termite infestation. Where this exception is used compliance will be demonstrated for the building envelope by using IECC 502.2.2 or 502.2.4.

Air Leakage (602.1.10) says that all joints, seams, penetrations, openings around window and door frames and other sources of air leakage in the building envelope shall be sealed to limit uncontrolled air leakage. There is no air-leakage test or target air-leakage rate defined in the IRC, similar to the NBCC and all provincial building codes in Canada.

On the whole, IRC/IECC prescriptive requirements for the building envelope are significantly higher than the prescriptive requirements of Canadian codes. While the Model National Energy Code of Canada for Houses (MNECH) comes closest to the level and the intent of the IRC/IECC, it has not been adopted by any Canadian province. Table 7 compares the IRC/IECC prescriptive requirements for a type A1 single detached house located in Ottawa (8700 HDDF, 4600 HDDC) with those for the MNECH 1997 (Ontario, natural gas) and the Ontario Building Code (OBC 1997).

Assembly	**Units**	**IRC N/IECC Chapter6**	**MNECH (97-gas)**	**OBC (1997)**
Glazing	Maximum area	15% of gross wall area	20% of above-grade floor area	No maximum
	Maximum U-value NFRC 100, or equal.	0.35 (effectively Low-E, argon)	0.37 (ER converted to U-value)	Double glazed
Ceiling	Minimum nominal R-value	R49	R31	R31
Wall	Minimum nominal R-value	R21	R16.5	R17
Floor	Minimum nominal R-value	R21—49	R26	R25
Basement wall	Minimum nominal R-value	R18 (full height)	R12 (full ht)	R8 (2 ft. bg*)
Slab perimeter	Minimum nominal R-value	R14, (2 ft. bg*)	R9 (2 ft. bg*) if ext and slab edge not insulated	R8 (2 ft. bg*)
Slab	Minimum nominal R-value	none	R9 full under slab if < 2 ft. bg*	none
Crawl space wall	Minimum nominal R-value	R20 (2 ft. bg*)	R12 (full ht)	R8 (2 ft. bg*)
Air leakage	ACH	Descriptive, no performance	Descriptive or Can. ELA 2.0 cm^2/m^2	Descriptive, no performance
*bg = below grade				

Table 7— Comparison of minimum requirements for envelope components (IRC vs. MNECH and OBC— 8700 HDDF)

4.2.2 Chapter 5—mechanical systems and equipment, hot water

The requirements for mechanical systems are presented in the IECC Sections 503 and 504. These requirements apply to the IRC Section N as well as to all three compliance paths in the IECC for residential buildings.

Sections 503 and 504 present several tables of minimum efficiencies for mechanical equipment. These are based upon the 1987 National Appliance Energy Conservation Act (NAECA). The efficiency of mechanical equipment is not identified in the NBCC or in provincial building codes. It is generally regulated by provincial legislation or by references to specific standards for the type of equipment (and is thus difficult to determine). The following table compares the minimum equipment efficiencies of the 2000 IECC/IRC with comparable Canadian standards as referenced in the MNECH 97 and used in Ontario.

Equipment type	Efficiency units	IRC N/IECC Chapter 5	Ontario/MNECH 97 (referenced standards)
Split-system, air-cooled heat pump	HSPF	6.8	5.9
Gas- or oil-fired furnaces and boilers	AFUE	78%	78%
Split-system air conditioner	SEER	10.0	10.0
Electric water heater	EF	0.93-(0.00132 x U.S. gal.)	0.93-(.000349 x litres)
Gas water heater	EF	0.62-(0.0019 x U.S. gal.)	0.62-(0.0019 x U.S. gal.)
Oil water heater	EF	0.59-(0.0019 x U.S. gal.)	0.59-(0.005 x litres)

Table 8—Comparison of minimum requirements for heating and cooling equipment

In addition to equipment efficiencies, the IECC presents a number of important requirements, which are highlighted for Canadians:

- Load calculations are required for sizing HVAC systems and equipment (503.3.1).
- Heat pumps with supplementary electrical heating must have controls that phase in the electric heating only when the heat pump cannot supply all the demand (503.3.2.3).
- Insulation requirements are listed for pipe and ducted systems (503.3.3).
- All low-pressure duct systems operating at a static pressure of less than 2" water gauge (wg) must be sealed with welds, mastics or tapes. Only longitudinal locking joints on sheet metal ducts are exempted from this requirement. (503.3.3.4.2). Tapes and mastics are required to be listed and labelled with UL 181A and UL 181B (503.3.3.4.3).

- An air transport factor is defined for cooling systems to be the ratio of the sensible heat removal/supply and return fan power input. It is required to be not less than 5.5 (503.3.6)

Why are the Americans so concerned about duct leakage?

In Canada most houses have conditioned basements and most forced-air ducts are run from the basement to other rooms following within the conditioned space of the building. In the U.S. many more houses are built over unconditioned crawl spaces or on ground slabs. Although these are practices that should be avoided, it is common to see forced-air systems in unconditioned crawl spaces and attics in houses across the U.S. It is particularly common to find air conditioning systems with ducts and air handlers located entirely within unconditioned attics. Any air leakage from ducts outside the building shell is an energy loss.

4.2.3 Chapter 5—residential building design by component performance approach

Chapter 5 provides *four* methods for trade-off analysis of the U-values of envelope components of a house. Three of the four methods require calculations of the overall U-values as reviewed below:

Compliance by performance on an individual component basis (502.2.1)

It is required to calculate the overall U-value of the individual elements of the envelope (for example, walls, roof/ceiling, floors, slabs, foundation walls) accounting for the effect of framing members and for the U-values of windows and doors in walls. It is required that the overall U-value of each element not exceed values, which are illustrated in charts and which decrease by HDDF. The effect is such that as the window and/or door U-values are decreased the wall U-value should increase and vice versa.

Rules are provided for determining the U-value of steel-frame walls. A separate set of tables is provided for the maximum overall U-value permitted for mass walls.

Compliance by total building envelope performance. (502.2.2)

This method requires development of a total U-value of all the individual elements of the envelope of the house. First, this calculation is based upon the compliance of all components in 502.2.1. Then it is re-calculated as the individual elements are changed in the proposed design. This calculation must account for the effect of framing members and all windows and doors. The designer may vary the U-value of any component. It is required that the overall U-value of the proposed design not exceed that of the base case.

Compliance by acceptable practice on an individual component basis

Section 502.2.3 is similar to the requirement of 502.2.1, except the U-values of the component assemblies are looked up in a set of Tables provided in an appendix to the IECC (pp. 188-193). The tables in the appendix provide illustrations of the assemblies and provide a number of common variations of each type of assembly with their corresponding, pre-calculated average U-value. The overall U-values of the walls and roofs must still be calculated by combining those of the opaque walls with that of the glazing areas.

Compliance by prescriptive specification on an individual component basis

Use of this method does not require any calculations of U-values. Section 502.2.4 is similar to the prescriptive requirements of Chapter 6, except it presents a set of eight additional tables with prescriptive minimum R-values of opaque components and maximum U-values of glazing. Each table represents the prescriptive requirements for different percentages of window area compared to the gross wall area of the house, including less than or equal to eight per cent, 12 per cent, 15 per cent, 18 per cent, 20 per cent or 25 per cent for detached houses and 20 per cent, 25 per cent and 30 per cent for attached houses. The R-values in the tables are nominal and do not include the effects of framing members except for the U-value requirements of windows.

Two tables are provided that provide equivalent steel-framed wall assemblies to those required for wood-frame walls. Two similar tables are provided for mass walls.

4.2.4 Chapter 4—Residential building design by systems analysis

Chapter 4 describes an entirely analytical, performance-based route for meeting the requirements of the IECC where the designer can assess the effect of all of the elements of the design. Compliance is achieved if the annual energy consumption of the proposed design is equal to or lower than that of the standard Design. The standard design is identical to the proposed design in terms of geometry and location. The use of Chapter 4 methods allows a designer to evaluate the effect of different mechanical equipment efficiencies, air leakage, ventilation and renewable energy sources as well as envelope U-values to determine energy consumptions. The renewable analyses include all of passive solar, other solar, geothermal and wind.

The annual energy analysis of both the proposed and the standard design requires the use of computer tools that evaluate the annual energy consumption of the heating, cooling and hot water heating equipment. Residential buildings of 5000 ft.^{2} or less are exempt from hourly analysis methods but are required to use performance correlation methods derived from full year hourly analysis. No specific software tools are identified, but there are a number of American software tools that meet these requirements (*see* 4.3 HERS, page 47). The IECC allows the local chief building official to approve the software used for compliance with Chapter 4.

Chapter 4 stipulates the requirements for the specifications of the assemblies and systems of the Standard Design. These are quite technical and are reviewed in Appendix C, "Standard design, IECC," page C-1.

4.2.5 REScheck

The trade-off methods of Chapter 5 of the IECC require a large amount of calculations that are onerous to do long hand. REScheck is a software package than can be used to perform the trade-off analyses of Chapter 5 of the IECC to produce compliance packages of components for individual houses. REScheck was originally developed in support of the MEC and was called MECcheck. It has been extended and renamed to work with the requirements of the IECC. A copy can be obtained as a free download from the U.S. Department of Energy, Building Energy Codes (*see* REScheck in "Glossary and links," page viii).

4.2.6 Differences from the Model Energy Code (MEC)

Since the IECC is the successor to the MEC, the two codes are very similar. Most of the technical content of the MEC concerning residential buildings was carried into the IECC, but the IECC made a number of changes, which are summarized below.

- Chapter 3 was expanded to include the climate zone maps of all the states.
- Section 502.2.4 "Compliance by prescriptive specification on an individual component basis" was added.
- Tables of default window U-values were updated with references to new editions of the ASHRAE *Handbook of Fundamentals*.
- SHGC was limited to a maximum of 0.4 in cooling-prone climates with less than 3500 HDDF
- Some of the input variables used for the definition of the standard design in Chapter 4 have been changed. These include shading coefficients, control systems parameters, internal heat gains, and air distribution loss factors.
- The IECC does not specify software evaluation or verification procedures for the software. The IECC gives building officials the authority to approve compliance tools.

4.3 HERS and energy efficiency programs

Energy efficiency ranks as one of the major concerns for purchasers of homes in the U.S. Energy costs may be higher in many U.S. locations than in Canada, particularly considering electricity used for air conditioning. The U.S. is also concerned about global issues regarding energy policy, including the reduction of dependence upon imported fuels and the environmental impact of fuel exploitation and combustion. As a result, a number of incentive programs for energy efficiency in houses may apply in certain states, depending on state legislation, or nationally, as in the case of ENERGY STAR (*see* "ENERGY STAR," page 49). These programs are designed to encourage homeowners to buy homes that exceed the energy efficiency requirements of the building codes.

An energy-efficiency rating system for houses was developed in the U.S. in the early 1990s to provide a consistent and credible technical basis for determining the eligibility of a house for financing or for other efficiency incentive programs. The system is called HERS—the Home Energy Rating System. A definition of a uniform HERS system was first published in 1995. A copy of the current technical standards is available from the Residential Energy Services Network (RESNET).

The technical basis of the HERS is Chapter 4 of the 1993 MEC* and is termed the Reference House. Chapter 4 defines a computerized assessment of the annual energy use of the house as if built with standard thermal parameters, and then as it is to be built. The HERS Reference House is assigned a rating of 80, on a scale of 0-100, and each one-point change in the HERS score of the proposed house represents a five per cent change in energy consumption.

> **Note** The analysis specified in Chapter 4 of the MEC is nearly the same as that in Chapter 4 of the IECC. There has been no change in the underlying HERS analysis method despite the fact that the MEC has evolved into the IECC and there have been some changes that affect the rating of the standard home as reviewed in the previous subsection. For example, a study has indicated that homes built to the requirements of the IECC, Chapter 4, may result in a HERS score closer to 81 in cold climates and closer to 83 in warm climates and in California.

Additional information may also be provided with the HERS rating. This might include an estimate of the annual cost of energy and a translation of the points into a number of stars rating (one being the lowest and five the best).

Initially, most HERS ratings were applied to existing homes as part of insulation and weatherization incentive programs. Increasingly, HERS ratings are being applied to new houses for purposes of energy code compliance or for the ENERGY STAR incentive program.

The HERS Council evaluates and accredits private software tools that may be used to produce HERS ratings. Examples of HERS-approved tools include REM/Rate, EnergyGauge USA, and Micropas (California). HERS ratings may only be produced by accredited HERS raters, who are trained and licensed to perform HERS ratings and to perform inspections on houses for testing and compliance verification.

The benefits of a HERS rating for a home include:

- HERS ratings may also be used to determine compliance with energy codes under Chapter 4 of the IECC or the MEC. This should be checked by the individual exporter with the local building official.

- Eligibility for an ENERGY STAR home label (reviewed in "ENERGY STAR," page 49).

- A number of important lenders in the U.S. make Energy Efficient Mortgages (EEM) available for new and existing homes. EEMs either account for the energy cost savings in assessing the mortgage amount available or they add a two per cent "stretch" to the debt-service ratio of the mortgage applicant, raising it from 28 to 30 per cent. Either way the mortgage amount is increased, covering the cost of the energy efficient measures in proportion to the energy cost savings. This type of incentive financing is not available in Canada.

- In mid-2003, there were at least two bills undergoing hearings in the U.S. House and Senate to provide builder credit incentives for energy efficient housing (H.R.4 and S. 507). The bills propose to provide either $1,250 or $600 for a new house that is 30 per cent or more efficient than the 2000 IECC. Both propose to provide $2,000 for a home that is 50 per cent better. The determination of the eligibility of new houses for this incentive would be based on HERS ratings. There are no similar programs or tax incentives in Canada.

In Canada, NRCan has developed an energy-rating program called EnerGuide for Houses. At present this program applies only to existing houses, although it is planned to expand it to new houses. While the Canadian EnerGuide for Houses produces a rating on a 0-100 scale, the numerical assessment and the rating formulation are quite different than the U.S. HERS rating and the results are not comparable. There are no programs in Canada at present that provide financial incentives for energy efficiency in new housing.

4.4 ENERGY STAR

ENERGY STAR is a national *voluntary* labelling program for energy efficient appliances and homes that is supported by the U.S. Environmental Protection Association (EPA) and the U.S. Department of Energy (DOE). For new homes, the ENERGY STAR standard requires a rating of 86 or better when measured by the Home Energy Rating System (HERS). Thus, an ENERGY STAR home is 30 per cent more energy efficient than the HERS Reference Home.

ENERGY STAR operates as a partnership program. Individual states, builders, manufacturers, raters and inspectors sign partnership agreements with the DOE. Normally, a branch of the state government is designated as the local ENERGY STAR "provider" and manages the quality assurance (QA) aspects of compliance and inspections by HERS raters and inspectors. The individual states may also add requirements to ENERGY STAR (both Vermont and New York add requirements for ventilation).

Most ENERGY STAR houses are traditional, site-built homes, but the standard may also be applied to modular, panel and manufactured houses and specialized procedures have been developed for these sectors. (HUD has recently become a partner in the promotion of ENERGY STAR in manufactured housing). The growth of the use of the ENERGY STAR label for new houses in the U.S. is reflected in recent statistics: 31,000 homes were labelled in the 12 months ending July, 2002, compared to 17,000 in the previous 12 months ending July, 2001. Over the next 10 years, EPA estimates that the energy and green house gas reductions that will result from the construction of ENERGY STAR-labelled new homes will be the equivalent of removing 3 million cars from the roads.

Application and compliance with ENERGY STAR

The steps required for participation in ENERGY STAR by a builder are summarized below.

- The builder signs a partnership agreement with ENERGY STAR. This agreement formalizes the rules for use of the ENERGY STAR label and commits the builder to build at least one ENERGY STAR home in the next 12 months. No special training is required of the builder.

- Select the Energy Efficient Features that will be applied to the house. The builder has two choices for compliance:

    1. Builder Option Packages (BOPS). The BOPS provide a simple prescriptive route to meeting the performance requirements of ENERGY STAR. The BOPS consist of tables of alternative component by component specifications that have been pre-calculated to meet the requirements of ENERGY STAR in each of the 19 different climate zones. The BOPS are similar to the Chapter 5 options in the IECC but have been reformulated by ENERGY STAR to meet a HERS rating

of 86. The builder may choose which BOP to implement by his/her own judgment, or with advice from other service providers.

2. HERS ratings. A HERS rating is an evaluation of the energy performance of the building plans and specifications to determine if the house will meet the ENERGY STAR requirement of 86. The HERS rating requires use of a HERS rater who can provide more innovative options than the BOPS and may also provide other consulting services.

- Build the house(s). This also may involve training of the builder's staff and contractors to perform the new features.

- Obtain Third Party Verification and the ENERGY STAR labels. To be labelled as ENERGY STAR**,** homes must undergo an inspection and evaluation of the features selected for the home by an independent third party inspector/provider. Only after the house's features have been verified may the builder label a home as ENERGY STAR. All the efficiency features of the home are checked and tests of the duct leakage and air leakage of the house envelope are done to confirm the implementation and effectiveness of the selected features of the house. If the HERS compliance route was chosen the as-built results of the inspection and tests are re-analysed to confirm the house's rating.

The process differs for producers of modular, structural insulated panel (SIPS) or manufactured houses. The assessment of the necessary features may vary depending upon the range of climate zones that the manufacturer is distributing to but uses either the HERS rating analysis or BOPS. These types of homes require factory inspections of the ENERGY STAR features that are not readily inspected on-site. A factory inspection list is developed for this inspection. In addition the factory inspections may be undertaken on a random 15 per cent sample for large volume builder, defined as one who produces more than 85 ENERGY STAR homes a year.

Features of an ENERGY STAR home may include:

- Tight construction
- Tight ducts
- Improved insulation
- High-performance windows
- Ventilation systems
- High-performance heating and cooling systems

While ENERGY STAR encourages "tight" construction and ventilation, the basic ENERGY STAR and HERS documentation of NASEO does not specifically require a mechanical ventilation system with stipulated rates, or any required inspection procedures for the ventilation system and/or depressurization testing. But while there is no reference to a technical ventilation standard, ENERGY STAR and HERS do permit tighter construction, ventilation and heat recovery to count as part of the energy credits of the HERS rating. There is a limit of a minimum of 0.35 ACH (seasonal) via the MEC/IECC Chapter 4, but HERS and the rating software permit mechanical ventilation to count in a tight home such that the total of the natural infiltration and the mechanical ventilation is 0.35 ACH (seasonal) and energy credits are permitted for heat recovery ventilation.

A number of individual states do require mechanical ventilation as part of their ENERGY STAR program for new houses, or as part of the state building code. These states include California, Washington, Minnesota, Wisconsin, New York, Vermont and perhaps others. The exporter is advised to contact ENERGY STAR in any individual state to determine the ventilation requirements.

An exporter is advised to exclude any spillage-susceptible combustion equipment and not use high capacity kitchen range exhaust hoods to avoid potential problems with depressurization and combustion gas spillage. This is a requirement in Minnesota and perhaps in other states.

To a Canadian builder, this list of energy efficient features is similar to those found on R-2000 houses in Canada. There are, though, a number of significant differences. ENERGY STAR has no specific requirement for a level of airtight construction, for ventilation or for any particular feature. It only requires that the HERS rating achieve 86, howsoever that is done. On the other hand, R-2000 requires a very airtight construction of 1.5 ACH @ 50 Pa and R-2000 requires a ventilation system in conformance with CSA F326, a Canadian standard for residential mechanical ventilation systems. In addition, R-2000 requires the house to meet an energy consumption target. The R-2000 energy target is determined by formulation and does not relate to a code-based reference specification, as does ENERGY STAR. R-2000 also has a substantial list of requirements for minimum ratings for windows, environmental features, fireplaces and so forth.

It is likely that an R2000 home would meet the ENERGY STAR requirement when evaluated by the HERS rating software, however this analysis was not done as part of this review. The HERS rating standard design starts with a very high level of air leakage by comparison with the assumed average new Canadian house (that is about 11.4 versus 3.6 ACH@50) and can thus result in a very large air-infiltration credit when it is reduced to R-2000 levels. An R-2000 house that just meets the energy target is close to 40 per cent better than a home built to the Ontario Building Code and with 3.6 ACH@50 Pa air leakage. However, Canadian provincial code envelope requirements are substantially lower than the IECC prescriptive levels.

4.5 Building America

Building America is a program of the U.S. Department of Energy (DOE) that was conceived to support home producers to produce quality homes that use less energy without costing more to build. To fulfil this mission, Building America employs several specialized consulting firms that work with the participating builders in the program. A building company may participate in the program if it is a large builder, if the company agrees to build at least one test home and if it agrees to implement some of the program recommendations within its production houses. Most of the work to date is with site built builders. One of the consulting agencies is directed to work with a consortium of manufactured housing producers.

Building America may not apply to exporters of Canadian housing to the U.S. but it is mentioned here since it has become a forum for development and testing of better and more cost effective building methods that should be of interest to all builders. The publications and reports produced by Building America are quite useful as a resource to potential Canadian housing exporters to the U.S.

All Building America homes must meet ENERGY STAR for new homes, that is, achieve a HERS rating of 86 or better. In addition there are requirements for the mechanical systems including:

- Base-rate, ventilation-controlled mechanical ventilation at a minimum base-rate of 20 cfm per master bedroom and 10 cfm for each additional bedroom will be provided when the building is occupied.

- Intermittent spot ventilation of 100 cfm will be provided for each kitchen and all kitchen range hoods must be vented to the outside—no recirculating hoods. Intermittent spot ventilation of 50 cfm or continuous ventilation of 20 cfm when the building is occupied will be provided for each washroom/bathroom.

- All combustion appliances in the conditioned space must be sealed-combustion or power-vented. Specifically, any furnace inside conditioned space will be a sealed-combustion unit. Any water heater inside conditioned space will be power-vented or direct, power-vented unit.

- All ducts and air-handling equipment must be inside the conditioned space.

Building America is not just an efficiency program. Some sophisticated analysis and testing work has been done to identify and then solve building science, costing and servicing issues for U.S. builders, including: advanced framing systems design, seismic and wind loading design, ventilation and heating systems design, moisture control in buildings, drying potential analysis of building envelope assemblies, innovative heating distribution systems, as well as post-occupancy servicing and costing analysis.

4.6 Indoor air quality (IAQ), mold and ventilation

There has been an increasing incidence of complaints arising from problems of moisture damage, decay, mold growth and other IAQ problems in new houses that are built to code. There are no explicit code requirements to recognize or to provide solutions to these types of problems. However, the situation has generally been seen to have increased over the last decade and has been linked with increased levels of insulation and airtightness in buildings. Also, our society and particularly that in the U.S., is increasingly litigious.

There have been a number of reports in the press concerning lawsuits over air quality in homes and other buildings. There have been a number of notable out-of-court settlements. Builders in U.S. are finding it increasingly difficult to obtain liability insurance to cover these risks.

In response, homebuilders and researchers are starting to apply a number of solutions to solve the problems that may lead to IAQ problems, mold and decay in houses. These solutions should include a combination of the following:

- Apply sound construction details to provide surface drainage and protection against water leakage from the building exterior.

- Apply building science to develop construction assemblies which reduce the risk of condensation within assemblies from external or internal vapour sources and which encourage drying of any moisture within the assemblies.

- Provide ventilation systems to remove humidity and other air borne contaminants.

- Reduce contaminants at source by choosing interior finishes, trim, cabinetry and furnishings with low emissions of volatile organic compounds (VOCs).

The development and description of specific methods to solve these problems is beyond the scope of this Guide. But it is an active and important topic that should be considered by all builders including those intending to export to the U.S.

For further help and information the reader is referred to the Web sites in the “Glossary and links,” page viii, under the headings of BSC, EEBA, and The mold update.

4.7 Green buildings

There has been a growing interest in both Canada and the U.S. in “green” or sustainable building technologies and standards. From the green perspective energy efficiency is an important issue, but is only one part of a broader vocabulary. This may include air quality, minimal waste production, recycling, low-impact materials selection, sustainable site development, neo-traditional community planning and more. In many cases these emerging technologies are difficult to evaluate in quantitative terms of immediate financial benefit, energy savings or environmental gain.

For example, the Florida Green Building Council (FGBC) has developed standards for certification of new residential buildings with a Florida Green Home Designation. The standard consists of a scorekeeping checklist with categories for Building Energy, Appliance and Lighting Energy, Water, Site, Health, Materials, Disaster Mitigation and General. In order to receive the designation a new home must achieve a minimum rating of 200 out of a possible 400 points.

Other examples of American organizations that have produced green rating systems are:

- the U.S. Green Building Council (the LEED—Leadership in Energy and Environmental Design, although this is for non-residential buildings);

- Green Built Home (Wisconsin)

To this point the application of green requirements is voluntary. There is no requirement in any of the model building codes for the application of green requirements, residential or otherwise. Nevertheless it is worthwhile for interested residential builders to monitor these standards and assess the marketability of the various green features.

CMHC has developed a guide entitled *Tips on Selling in the U.S. Green Building Market*, which is available free from the CMHC Web site at www.cmhc.ca

Section 5 Requirements for manufactured and other factory-built houses

5.1 Types of factory-built houses

Canadian exporters of houses to the U.S will fall somewhere in this broad category. The term factory-built is used in this report to represent a house that is assembled to some degree in a factory and then delivered to the site, where it is set on a foundation, anchored and finished. The set and finish is normally done by a local builder who has purchased the factory-built unit or who is working in association with the factory builder. The foundation and anchorage parts of the factory-built home are subject to the code and local inspection processes of the local Building Official (see the IRC Appendix E for manufactured houses). In addition, factory-built houses may be subject to special approvals and in-plant inspection requirements depending upon the type of factory-built home. The different types of factory-built houses include:

Manufactured houses—Normally the term "manufactured" applies to units that were formerly called "mobile homes." They are factory-built with all services, cabinetry, windows, doors and finishes installed and then delivered to the site. The manufactured home is designed to be towed on its own chassis or wood-beam frame using removable wheels or "bogies." The house is then secured to the site with a pier-and-anchor system and attached to the services. While a skirt may be erected around the perimeter, the manufactured house does not need a walled foundation and contains no stairs. The resulting house is one floor in height and has a low-pitched roof and looks, well—like a mobile home. To confuse the issue, some manufactured houses may also be referred to as modular or "multi-wides," since two or more "manufactured" units may be joined on-site. The manufactured housing industry in the U.S. is very large, indeed it is larger than the entire Canadian housing industry in terms of number of units. The U.S. has a special national code for manufactured houses—the HUD Code 3280 (see page 57)—which includes design approval and factory inspections.

Modular houses—A housing unit that is assembled in a factory as two or more six-sided modules. Each module represents a structural bay on the plan with full-height walls and a ceiling. Each module is fully assembled in the factory with the partitions, services, cabinetry and finishes installed. The modules are loaded onto trailers and are transported to the site where they are lifted onto a walled foundation and are joined horizontally and vertically to complete the house. The local builder supplies a foundation with services and does the finishing work. The finishing includes the joints between modules, the insulation and finishing of the basement, the connection of electrical, water supply and waste services, the installation of heating and water heating equipment and the connection of the HVAC distribution. The resulting home may be one or more floors in height and looks like a site-built home on a foundation. Modular houses are designed and approved for permits following the normal state and or municipal code requirements. Plan approval by a registered professional engineer is required. In addition, some states, such as New York, require prior state-plan approval and certification of the modular homebuilder on either a house-by-house or system basis. Site inspections by the local building official are required for the work of the local builder including the foundation, the supply of electrical, water and waste services, the installation of heating, cooling, and water heating equipment and the connections of distribution systems for such.

Panelized houses—A housing unit in which the wall, floor and roof components are factory assembled but are shipped flat and not assembled to form the enclosure until at the intended site. Where the panels are assembled from wood framing, the panels are normally delivered empty of insulation and services to enable normal code compliance inspections on-site. The panellized house may consist only of the panels or may include other components required for the final assembly of the house on-site, such as trusses, windows and doors, finishes, cabinets and so forth. Panelized houses are designed and approved for construction permits following the normal state and or municipal code requirements. Approval by a registered professional engineer and/or architect may be required.

SIPS—Houses made from structural insulated panels (SIP). The SIP consists of a core of foam insulation bonded between two layers of OSB or LVL in sizes ranging from 4x8 to 4x24 ft. and varying in thickness from 4-12". The panels form rigid, load-bearing panels that can be used as walls, ceilings, roofs or floors. Exterior walls and roof panels contain insulation within the assembly, which is hidden from view. As a result factory inspections and certification of this type of panel are required. The SIP house is otherwise shipped flat and then assembled on-site. The SIP house is often combined with post-and-beam structural members that are precut in the factory and assembled on-site. SIP houses are designed and approved for construction permits and inspected following the normal state and or municipal code requirements. The IRC does not contain any prescriptive section for the approval of SIPS, so it should be assumed that the SIPS components will be treated as an engineered system and will required engineering approval of the SIPS system and certification of the SIPS by inspection of the SIPS produced in the factory. Approval by a registered professional engineer and/or architect of the building design may also be required.

Precut houses—A housing unit in which the wall, floor and roof framing members are pre–cut and marked in a factory but are shipped as cut and are not assembled until at the intended site. The precut house may consist only of the framing members or may include other components required for the final assembly of the house on-site such as trusses, sheathing, windows and doors, finishes, cabinets and so forth. Precut houses are designed and approved for construction permits and inspected following the normal state and or municipal code requirements. Approval by a registered professional engineer and/or architect may be required.

Log homes—Similar to a precut home, but the walls are made of solid wood material, which is precut in a factory then shipped and assembled on-site. Log houses are designed and approved for construction permits following the normal state and or municipal code requirements. Approval by a registered professional engineer and/or architect may be required. The log home exporter should carefully review the requirements of section N or the IRC. In northern regions of the U.S. the log home may have to use the IECC Chapter 5 for compliance, which contains special tables for log walls (see mass walls).

5.2 HUD 3280—The *National Manufactured Housing Construction and Safety Standards Act*

HUD 3280, commonly referred to as the "HUD Code," is a special standard for the construction of manufactured houses in the United States. Manufactured homes are not normally assembled near the intended site of delivery and are difficult to inspect and administer under the normal codes processes. The HUD code was developed to provide a consistent level of assembly and quality assurance for manufactured houses yet still meet the special requirements for economy and portability. The HUD Code is the only pre-emptive national housing standard in the U.S and the requirements cannot be reduced or increased by any state. A copy of the HUD Code may be freely obtained from HUD or downloaded from the HUD Web site. *See* HUD in "Glossary and links," page viii.

The HUD code sets forth the requirements as a series of subparts:

- 101-Subpart B—Planning considerations
- 201-Subpart C—Fire safety
- 301-Subpart D—Body and frame construction requirements
- 401-Subpart E—Testing—structural, including windows and glass doors)
- 501-Subpart F—Thermal protection
- 601-Subpart G—Plumbing systems
- 701-Subpart H—Heating cooling and fuel burning systems
- 801-Subpart I—Electrical systems

A major departure of the HUD Code from other codes is that the requirements are largely performance-based rather than prescriptive. A performance code provides the most freedom in selecting or developing different approaches to meet the requirements, but also requires more thorough documentation of the analyses and methods used to comply with the intent of the code. A number of the unique and performance-based requirements of HUD 3280 are reviewed below:

- Minimum room and hallway dimensions are generally smaller (for example, hallways 28")

- Subpart D does not provide tables of spans for different framing systems. Instead it provides a description of the required loading on the elements of the structure and regional variations for location due to wind and snow. Subpart E describes the load tests that are required to test the construction to confirm that it carries the imposed loads.

- Subpart F describes overall U-value targets (per square foot of envelope) that must be met in each of three different climate zones. There are no specific targets for individual wall, window, roof and floor components. The overall U-value must be determined according to the 1989 ASHRAE Handbook of Fundamentals. Air-supply ducts located in ceiling or floor cavities must be considered in the overall U-value calculation. Credits are provided for heating and cooling equipment that is more efficient than *The National Appliance Energy Conservation Act of 1987* (NAECA). Alternatively, according to 3280.508 (f), manufactured homes may demonstrate compliance by showing that the proposed design results in the same or less annual energy use as a "base case" house built to the overall U-value target. This alternative is similar to that in Chapter 4 of the IECC, although the definition of methods and minimum requirements is much less explicit.

- A "Heating certificate" is defined and is required to be permanently fixed to the interior of the manufactured home in a location that is visible to the homeowner (3280.510). Similar requirements apply for a "Comfort Cooling Certificate" (3280.511).

- A ventilation system is required in addition to air infiltration and that provided by windows. The ventilation system is required to provide a minimum of 0.1 ACH or 0.035 cfm per $ft.^2$ floor area and may be by mechanical means or passive or both. The ventilation system is required to be balanced and is not allowed to create a positive pressure in U-value zones 2 and 3 nor a negative pressure in zone 1. (3280.103)

- Windows and sliding glass doors must comply with AAMA 1701.2-1985 "Primary Window and Sliding Glass Door Voluntary Standard for Utilization in Manufactured Housing." The interior and exterior pressure tests shall use the design window loads required in 3280.305. All such windows and doors are required to be certified and labelled compliant with AAMA 1701.2-1985. To be certified windows must be tested by an independent quality assurance agency upon sample production units according to AAMA 1702.2-1985 and the production facility must be inspected at least twice a year (3280.403). Windows and sliding glass doors to be located in Wind Zones II and II must have window openings designed to receive shutters or other protective covers such as plywood.

It is difficult to compare the performance-based requirements of HUD 3280 to the prescriptive requirements of other codes, such as the IRC, without having detailed plans prepared under each code. A prescriptive code may tend to be more conservative in specifying the size of structural components since it must anticipate a variety of sheathing materials and site conditions that are not directly assessed as a system. In this sense, the load and test requirements of the as-built components of the HUD Code may permit better structural-cost optimization, since it is tested as a complete system. The overall U-value requirements of the HUD Code do appear to be similar but lower than those presented in 502.2.1 of the IECC. A comparison of a small 40x8x8-ft. unit indicates that an overall U-value of 0.072 results in a climate of 7000 HDDF under the IECC compared to the 0.079 required by the HUD Code. If the size of the unit were doubled, the IECC standard would result in an overall U-value of 0.063, significantly lower than the HUD Code. Certainly the requirements for windows are lower, as they are only for either single glazing plus a storm or with insulating glass in U-value Zone 3.

CSA-Z240 MH is a Canadian series of standards for manufactured houses. CSA-Z240 MH resembles a building code. The requirements of Z240 are a derivative of the prescriptive requirements of NBCC, but do differ in a number of areas—although it is the policy of the NBCC that only a single code should apply to all houses produced in Canada A-2.1.4.1.(1). Z240 MH also adds requirements for the transport of the product, which are not part of the NBCC.

The reader is referred to a previous study by CMHC which compares the differences between the Canadian Codes and the U.S. HUD 3280 (L.J. O'Riley & Associates Inc., *Revitalization of the manufactured housing industry in Canada to provide affordable housing effectively*, CMHC order number PE0338). The study indicates that the requirements in the Canadian codes cause manufactured housing to be more expensive in Canada than manufactured housing produced to the HUD Code in the U.S. and it is reasoned that this is leading to a decline in market penetration by manufactured housing in Canada. The study presents a case for the development of a code similar to HUD 3280 in Canada in order to reduce the cost differential between the U.S. and Canadian manufactured housing products. While following the Canadian standards may meet or exceed the requirements of

HUD 3280, a Canadian producer of manufactured homes for export to the U.S. should build to the requirements of HUD 3280.

5.3 Compliance inspections for manufactured homes

HUD defines a number of certification and inspection requirements for manufactured houses. Two permanent labels are required to be attached to the outside of each unit by the manufacturer:

- A "Data Plate" is defined and is required to be attached to each manufactured home in a visible location. The data plate includes information about the manufacturer, the serial number of the unit, a list of major factory-installed equipment, references to the roof-load zone and the wind-load zone for which the home is designed and the name of the agency that approved the design. (3280.5)

- A "Certification Label" is defined and is required to be attached to each mobile home at the rear, right-hand side. The label is an attestation by the manufacturer of conformity to the HUD Code at the time of manufacture. (3280.11).

HUD 3282 defines the quality assurance inspection procedures that are required of a manufacturer for compliance with HUD 3280. HUD 3282 requires two levels of inspection of the production of manufactured homes. The first is an approved third party, called the *Design Approval Primary Inspection Agency* (DAPIA), which approves the engineering design of the home; approves the manufacturer's quality assurance manual for the plant and co-ordinates the other third party inspector, the production Inspection Primary Inspection Agency (IPIA). The IPIA conducts inspections of homes produced in the factory to assure conformity with the approved design.

The selection of the inspection agencies will require consultation with HUD and with the destination state and/or municipality. The consideration of time and cost may favour any HUD-accredited or approved inspection agency that is located in Canada.

In addition, the inspections may be performed by CSA. CSA-A277 "Certification of Factory Built Houses" is a standard that describes a procedure whereby an independent certification agency can review the quality assurance features of a housing factory and make periodic unannounced inspections. Through suitable labelling, it provides assurance to building officials that those components that cannot be inspected on-site comply with a building code and/or other requirements of the authority where the unit will be delivered. The standard is non-code specific and inspections may be provided by CSA for Canadian manufacturers exporting to areas in the U.S. for any code. The potential exporter is advised to check that the CSA would be recognized and accepted by HUD and the destination state and/or municipality as the third party, in-factory inspector.

HUD has become a partner in the ENERGY STAR program for new houses. Compliance with ENERGY STAR requires inspections in the factory. *See* "4.4 ENERGY STAR," page 49.

5.4 Compliance approvals and inspections for other factory-built homes

Modular homes are fully or near-fully assembled and finished at a plant remote from the intended house site. If the finishes are applied, is not possible to inspect this type of house on-site for many of the aspects of code compliance, since the structural elements, insulation, electrical wiring, plumbing piping and HVAC ducting are embedded in the structure and covered when delivered to the site. Similar to HUD Code houses, it is required by state and municipal building officials that this type of house be inspected *in the factory* by an accredited third party for compliance with the design plans and for the code requirements of the intended point of delivery/erection. After setting the modular house on the foundation, the modular home is subject to the normal code inspections process

SIP panels may s. also require a similar type of third party, state-approved factory inspection for the assembly of the SIPS. Panellized, precut and log houses are erected on-site and lend themselves to the normal code and inspection process. These types of housing should be able to avoid the issue of third party factory inspections, but will require other normal engineering approvals of the structure.

For selection of third party inspectors, Canadian producers of modular and manufactured houses should use an organization that is accredited or approved by the export destination state and/or municipality. A firm with offices in Canada may help reduce the travel time and costs of the inspections. A number of private firms are active in Canada for these purposes. In addition, the inspections may be performed by CSA under CSA-A277 as reviewed for the HUD Code.

Additional approvals and certification may be required for manufacturers of modular housing, depending upon the destination state and/or municipality. For example, in New York state it is required that a manufacturer of modular homes obtain state certification and approval of the modular home plans on either a "house-by-house" basis or a "systems" basis. This requires the hiring of an approved engineering firm to stamp and approve each plan or the "systems" plans. A "systems" basis refers to approval of all the module configurations contained in the standard plans intended to be used by the manufacturer; theoretically, only minor deviations from the approved "system" plans are permitted without state approval. Such approvals may take weeks or months to obtain, so most manufacturers opt for a full systems approval. System approvals must be kept up-to-date with changes in the underlying codes and standards and must be renewed every two years.

The potential exporter of manufactured or modular homes needs to make a serious commitment to the export market. It is estimated by an Ontario-based exporter of modular homes that researching the codes, communicating with state officials and obtaining the engineering approvals and accreditations required an initial investment in time and money of over $100,000 for New York alone.

5.5 Other support for manufactured and factory-built housing

The Building America program has a component termed the Industrialized Housing Partnership, which is administered through the Florida Solar Energy Centre (FSEC) of the University of Central Florida (UCF). The partnership provides support to builders of manufactured homes, modular homes and "production" homes. While Canadian producers of "industrialized" housing may not be eligible for direct support under Building America, much information has been produced that should be of interest to Canadian exporters.

Section 6 Product approvals: Compliance with U.S. codes and standards

Most of the products used to build houses are required by both the U.S. and the Canadian codes to comply with industry standards that stipulate the test methods and performances required of the product. The testing and evaluation of compliance with a standard and other codes requirements is normally undertaken in one of two ways.

Conventional products are tested to the requirements of the appropriate industry standard. The standard tests are done by laboratories that are approved by the standard and the code organizations. In many cases, particularly for fuel-burning equipment, electrical equipment, roofing and flooring this should then be sufficient to obtain approvals in the U.S.

In the case of new products for which there are no standards referenced in the codes, or in the case of moisture and insulating products, where there are multiple standard requirements, a manufacturer should obtain an evaluation by an "evaluation service." The evaluation service publishes and distributes the results of the evaluations to building officials and the building industry so that it is not necessary for other building officials to repeat the evaluations. The cost of submitting products for evaluation and testing is the responsibility of the manufacturer.

6.1 Standards for building products

The standards that apply for a particular building product will depend on the local state or municipal building code for which the product is destined. In many areas, this will be the IRC, but as reviewed in "2.3 Regional authority and adoption of U.S. building codes," on page 5, it may also be other codes. In many cases, the referenced standards are similar in different codes. In addition, the local state code or municipal codes may have requirements additional to the underlying code. The Canadian housing exporter should also be aware that the local building official is empowered to be the final authority for determining the acceptability of a method or product type (see R104.11.1 Tests). In the case of new technology, the building official has the authority to require standard tests as evidence of compliance, or in the absence of recognized and accepted test methods, the building official may approve the test procedures and the testing agency. Normally the building official will accept reports issued by an evaluation service.

In the case of the I-codes, the IRC (Chapter 43) and the IECC (Chapter 9) contain a complete listing of all the standards which are referenced in the body of the code with a cross reference to the code section number. In some cases, the referenced standards may be the same as those required by codes in Canada. There has also been some effort to produce harmonized industry standards for building products that apply or will apply in both Canada and the U.S. This is particularly so in the case of UL/CSA standards for electrical safety and for windows and doors.

A list is provided of the major standards organizations that are referenced in the IRC and their Web site addresses. Instructions are provided to help the reader obtain further information on the standards issued by each organization. The standard organizations provide a list of *approved testing labs* that can undertake the required tests on a fee basis. Further subsections of this Guide provide a more complete listing of the industry standards required by the IRC that apply to different types of building products.

6.2 Evaluation services

Evaluation services facilitate acceptance of new building products and technology by reviewing the industry standard test results and issuing reports of the ability of the technology to satisfy the requirements of the model codes and any limitations on the use of the technology. The evaluation reports are used by builders, architects and building officials to determine code compliance of a new product or technology.

In Canada, the Canadian Construction Materials Centre (CCMC) evaluates new construction products for compliance with the applicable standards and requirements of the building codes. Any standard tests required by CCMC may be done in approved, private testing laboratories.

In the U.S. a similar service was offered by the evaluation arms of the different codes organizations including BOCA, ICBO ES, SBCCI PST & ESI and the National Evaluation Service (NES). With the recent integration of BOCA, the SBCCI and ICBO into the ICC, it was decided to consolidate the former independent evaluation services of each and that of the NES into a new single program called the ICC-ES. The new service was created on the same date as the integration of the ICC, March 31st, 2003. The new ICC-ES will continue to recognize any "legacy" evaluations that were submitted before March 31st 2003 and approved by the former evaluation services. The realization of a single EVALUATION SERVICE with an integrated set of codes will allow product manufacturers broader acceptance without the need for repeated evaluations to the requirements of different building codes.

> **Note** Since the CCMC is not a member of the ICC it is likely that an evaluation done by the CCMC may not be recognized by the U.S. building officials.

6.2.1 Evaluation procedure

In 2003, the administrative rules and procedures of the ICC-ES were not finished and published. Until they are, Canadian manufacturers should refer to the rules and procedures of the pre-merger evaluation service organizations. The following is a brief description of the process applied by ICBO-ES for an evaluation application:

- Submission of an application form to ICBO-ES The application is normally submitted with supporting information, such as product description/drawings and test reports, along with appropriate fees to cover the cost of the evaluation. The base cost may be near $6,000 to $10,000 US. Standard tests by approved laboratories are additional to this cost.

- ICBO ES assigns a member of its technical staff to evaluate the data and work with the applicant to make sure compliance is proven, either with the code or with *acceptance criteria* approved by the ICBO ES Evaluation Committee,

- A report is be issued if the applicant has satisfactorily answered all questions raised by ICBO ES staff, and has fulfilled all the applicable standards requirements and acceptance criteria,

- The reports will be posted on the ICBO-ES Web site and distributed as hard copy or on CD-ROM to building departments and other subscribers. Reports are initially issued for one year, after which they are re-examined and may be reissued at one- or two-year intervals

6.2.2 Acceptance criteria

An evaluation service may develop a set of rules, or acceptance criteria, to determine whether a new type of product is compliant with standard tests and code requirements. Different acceptance criteria are applied to different types of products and should be available for review from the evaluation service. Some of the acceptance criteria of the ICBO-ES are identified below by product type:

- AC04 sandwich panels
- AC14 prefabricated wood I-joists
- AC24 exterior insulation and finish systems
- AC37 vinyl siding
- AC 47 structural composite lumber
- AC 94 product specific wood shake and shingle roofing systems
- AC130 prefabricated wood shear panels
- AC 138 prefabricated wall panels using wood I-studs
- AC 176 composite wall and roof panel systems with an expanded polystyrene core and spray- or trowel-applied cementitious facings.
- AC 196 fabricators of wood panel wall systems

A complete listing of the ICBO-ES acceptance criteria is published on the Web (*see* "Glossary and links," page viii).

6.2.3 Approved testing laboratories

The ICC-Accreditation Service (ICC-AS) was formed to approve and accredit laboratories which perform tests on building materials and products and perform quality control inspections at manufacturing locations. For laboratories and agencies, accreditation by ICC-AS requires that they meet international standards for testing labs and inspections, and that applicants for an evaluation report may use the accredited lab reports and services as evidence of standard tests and code compliance. Until the accredited lab listing is published by ICC-AS, it is recommended that any Canadian manufacturer contact the individual organizations that merged to form the ICC for this information, such as the ICBO-ES.

6.3 Standards by product type

6.3.1 Cabinetry and flooring

There are no referenced standards for cabinets or flooring products in the IRC. A number of organizations are identified, which provide guidance and voluntary standards for flooring products. Wall and ceiling finishes only are required by IRC Section R319 to be tested by in accordance with ASTM E 84-98 for a flame-spread classification of not greater than 200 and a smoke-developed index not greater than 450. It can be assumed that similar requirements should be met by cabinetry, which is not specifically exempted as trim in IRC Section 319. Similar requirements may be assumed to apply to floors since the tests themselves are calibrated and referenced to the flame spread of select red-oak flooring as part of the test procedure—ASTM E-84-98e "Standard Test for Surface Burning Characteristics of Building Materials."

Cabinets

ANSI/KCMA A161.1-1995, Performance and Construction Standard for Kitchen and Vanity Cabinets, is a voluntary testing and certification standard for cabinets administered by the Kitchen Cabinet Manufacturers Association (KCMA).

Flooring

For additional information on flooring products please refer to the following organizations (*see* "Glossary and links," page viii).

- NAFCD—The National Association of Floor Covering Distributors. A major organization of distributors of all kinds of floorings. Links to many other organizations.

- CRI—The Carpet and Rug Institute. The CRI administers two voluntary labelling programs for carpet products, including an IAQ Green label.

- NWFO—National Wood Flooring Organization. A voluntary organization with information about all types of wood flooring products, including natural, solid, pre-finished, engineered and acrylic-impregnated or laminate flooring.

- NOFMA—The Wood Flooring Manufacturers Association (formerly oak flooring) Web site includes voluntary standards for grading and certification, an online handbook for installing wood floors.

For ceramic tile and vinyl flooring products there are a number standards issued by ANSI and ASTM.

6.3.2 Engineered wood products

Engineered wood products are used for structural framing in place of conventional lumber. They include structural panel sheathing, trusses, I-joists and laminated veneer products that are not specifically included in the span tables of the building codes.

Wood roof and floor trusses are normally designed on a house-by-house basis. It is required by the IRC that floor or roof trusses be designed and stamped by an engineer and that design drawings must be submitted with the delivery on-site. The content of the design drawings must include the items reviewed in R502.11.4 and R802.10.1 of the IRC. See also the wind, seismic and snow loading requirements of R301 and TPI I-95 National Design Standard for Metal Plate Connected Wood Truss Construction (Truss Plate Institute)

I-joists and laminated veneer products normally seek a systems evaluation for general use. The reader is advised to refer to the acceptance criteria of the evaluation service provider (*see* "6.2 Evaluation services," page 61). See also:

- ASTM D 5055 Prefabricated Wood I-joists (used by CCMC as basis of evaluation), outlines the qualification process for flexural strength and creep, shear, flange end-joints, stiffness, end bearing and web openings. These values are converted to Limited States Design (LSD). Then confirm that the engineered-floor design meets loading and deflection requirements and vibration. Then manufacturer produces span tables for end-users. Associated with new joist systems, special evaluations may be required for new types of rimboards that replace traditional lumber headers.

Wood structural panel sheathing

- U.S. Department of Commerce, National Institute of Standards and Technology DOC PS 1-95, Construction and Industrial Plywood

- DOC PS 2-93 Performance Standard for Wood-Based Structural-Use Panels

- CSA 0437 or CSA 0325 when made in Canada

- APA E30-98 APA Design and Construction Guide Residential and Commercial (APA/EWA Engineered Wood Association)

6.3.3 Panellized systems

There are no referenced standards in the IRC for panellized systems. Panellized systems for walls, floors or roofs that consist of conventional wood or steel framing may be built to the framing requirements of the IRC. If those panels are shipped to site without coverings on both sides they may be inspected by the normal code process by the building official.

Other types of panellized systems that use non-conventional framing materials or arrangements, or that cover both sides of the panel, will normally require engineering systems approval and quality assurance inspections in the plant during manufacture. The exporter should review the evaluation criteria of the evaluation service for the type of panellized product, such as those used by ICBO-ES.

The structural design must carry the special wind, seismic, dead- and snow-load requirements of the R301. The design of wall panels must also consider the requirements of R602.10 for wall bracing.

6.3.4 Heating, ventilation and air conditioning equipment (HVAC)

The evaluation and testing of HVAC equipment is normally done by the standards bodies rather than code evaluation services. The relevant standards bodies are the CSA and the UL. There have been efforts to produce harmonized standards, so that certification under either CSA or UL may be equivalent. Alternatively, CSA or CSA International may be approved as testing laboratories for a variety of U.S. standards for various types of mechanical equipment. The exporter should contact either or both standards organization and discuss the certification requirements for the destination export market.

- UL 1995-98 Standard for Safety for Heating and Cooling Equipment (a UL/CSA harmonized standard).

- There are many additional UL standards that apply to chimneys; factory-built fireplaces; household electric storage tank water heaters; factory-made air ducts and air connectors; heat pumps; low-temperature venting systems; oil-fired boiler assemblies; oil-fired central furnaces; oil-fired floor furnaces; oil-fired wall furnaces; oil-fired storage tank water heaters; fireplaces; stoves; heating-water supply and power-electric, oil-burning stoves; room heaters; and solid-fuel type venting systems for gas-burning appliances—categories II, III, and IV.

- ANSI Z21 is a broad standard for fuel-gas appliances, with many different parts for different appliances including gas water heaters, gas-fired room heaters vented and un-vented, gas-fired low-pressure steam and hot water boilers, gas-fired summer air conditioning appliances, vented gas fireplaces and so forth.

- UL 1812-2 Heat Recovery Ventilators (HRVs) intended for connection to duct systems that interconnect rooms or spaces within buildings.

- HVI certification of ventilation products may be required, particularly for HRVs in those states with ventilation codes.

- ASHRAE 62-89 Ventilation for Acceptable Indoor Air Quality is not referenced in the IRC but is a standard for ventilation. ASHRAE 62.2P, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings is under review.

- ACCA Manual J-86 Residential Load Calculation (Heating and Cooling). This is similar in many respects to CSA F280, but the methods presented for below-grade heat losses and for air infiltration are quite different. The Manual J also includes a section for manufactured homes.

- ACCA Manual D-95 Residential Duct Systems. This compares with the HRAI Residential Air Systems Design.

ENERGY STAR-labelled furnaces have a rating of 90 per cent AFUE or greater, and are about 15 per cent more efficient than the minimum federal efficiency standards. AFUE is a measure of heating efficiency.

ENERGY STAR-labelled, split-system central air conditioners have a rating of ≥13 SEER*/≥11 EER*. ENERGY STAR-labelled single-package equipment including gas/electric package units have a rating of ≥12 SEER*/ ≥10.5 EER*.

The following are the criteria for ENERGY STAR-labelled geothermal heat pumps:

- Open loop: ≥3.6 COP [*co-efficient of performance*] (H); ≥16.2 EER [*energy efficiency ratio*] (C)
- Closed loop: ≥3.3 COP [*co-efficient of performance*] (H); ≥14.1 EER [*energy efficiency ratio*] (C)
- Direct expansion (DX): ≥3.5 COP [*co-efficient of performance*] (H); ≥15 EER [*energy efficiency ratio*] (C)

6.3.5 Siding and roofing

Siding

The requirements for siding materials and installation are reviewed in section R703 of the IRC. Table R703.4 reviews the type of siding, the requirement for sheathing paper, the type of support and fasteners. There are relatively few referenced standards for siding materials themselves. Please refer also to the Acceptance Criteria of the Evaluation Service providers (*see* ICBO-ES, ICC-ES "Glossary and links," page x).

- AHA A135.6 American Hardboard Association Hardboard Siding
- ASTM D 3679-02 Standard Specification for Rigid Poly Vinyl Chloride (PVC) Siding.

There are a number of additional ASTM standards which are not directly referenced in the IRC and which relate to siding.

- ASTM D4756-02 Standard Practice for Installation of Rigid Poly Vinyl Chloride (PVC) Siding and Soffit
- ASTM C725-90 (1998) Standard Specification for Semi-dense Mineral Fiber Siding
- ASTM D6777-02 Standard Test Method for Relative Rigidity of Poly Vinyl Chloride (PVC) Siding
- ASTM E119-98—Standard Test Method of Building construction and Materials (Fire ratings)

- Cedar Shake and Shingle Bureau—CSSB-97 Grading Rules for Wood Shakes and Shingles; Grading and Packing Rules for Certigrade Red Cedar Shingles

- American Wood-Preservers Association (AWPA) C9-97 Plywood—Preservative Treatments by Pressure Process, C15-98 Wood for Commercial-Residential Construction Preservative Treatment by Pressure Process

Except for Table 703.4m, there are no other standards referenced in the IRC for metal and aluminum siding, wood siding or brick. Special design criteria for structures and claddings are reviewed in the Chapter 3 of the IRC. These include wind speed and loads (R301), exterior walls with a fire separation of less than 3 feet (R302), protection against decay (R323 for wood siding having a clearance of less than 6” from the ground and protection against termites (R324). EIFS are required to have a drainage layer and weather resistive barrier applied between the exterior insulation and the underlying water sensitive construction. The weather-resistive barrier shall conform to ASTM D226 Type 1 or equivalent.

Roofing

The requirements for roof coverings materials and installation are reviewed in section R905 of the IRC. In comparison with sidings, the number of referenced standards is quite extensive. Please refer also to the wind-loading requirements of section R301and refer to the Acceptance Criteria of the Evaluation Service providers (*see* ICBO-ES in “Glossary and links,” page x).

- Class A, B and C (fire-resistant) roof coverings are required to be tested by UL 790 or ASTM E108.

- Wood shingles and shakes—ASTM E 108 and ASTM D 2898, including rain test, intermittent flame test, spread of flame test, burning brand test and flying brand test.

- Fire-retardant treated shingles and shakes to be treated according to AWPA C1.

- ASTM D225 or D3642 Asphalt shingles.

- ASTM D 226 Type 1 or ASTM D4869 Type 1 underlayment.

- ASTM D 1970 Self–adhering polymer modified-bitumen sheet.

- ASTM F 1667 Fasteners.

- ASTM C406 Slate shingles.

- Wood Shingles—Cedar Shake and Shingle Bureau CSSB Grading Rules for Wood Shakes.

- Clay and tile—ASTM C 1167.

- Absorption of concrete roof tiles ASTM C 140.
- Freeze-thaw resistance ASTM C 67.
- Mineral-surface roll roofing ASTM D 224, D249, D371 or D 3909.
- Metal roof covering standards are listed in Table R905.10.3 (9 standards).
- Modified bitumen roofing material standards listed in Table R905.11.2.
- Thermoset single-ply roofing RMA RP-1,2,3 or ASTM D4637 or CGSB 37-52M.
- Thermoplastic single-ply roofing ASTM D4434 or CGSB 37-54M.
- Sprayed polyurethane foam ASTM C 1029.
- Liquid-applied coatings ASTM C836, C957, D1227, D3468.
- Roof insulation applied above deck with an approved roof covering FM 4450 or UL 1256.

Roof products intended for climates with cooling driven-loads may be labelled under the ENERGY STAR Program. ENERGY STAR-labelled roof products must meet the following criteria:

- Low slope roofs must have an initial solar reflectance of $\geq$0.65. After three years, the solar reflectance must be $\geq$0.50.
- Steep slope roofs must have an initial solar reflectance of $\geq$0.25. After three years, the solar reflectance must be $\geq$0.15.

6.3.6 Windows and doors

The following standards are referenced in the IRC 2000 for windows and doors:

- ANSI/AAMA/NWWDMA 101/I.S.2-97 Voluntary Specifications for Aluminum, Vinyl (PVC) and Wood Windows and Glass Doors.
- NFRC 100-97 Procedure for Determining Fenestration Product U-factors (voluntary).
- NFRC 200-95 Procedure for Determining Fenestration Product Solar Heat Gain Coefficients at Normal Incidence (voluntary).
- ASTM E 330-97 Standard Test Method for Structural Performance of Exterior Windows, Glazed Curtain Walls and Doors by Uniform Static Air Pressure Difference.

- ASTM E1886-97 Standard Test Method for Performance of Exterior Windows, Glazed Curtain Walls, Doors and Storm Shutters Impacted by Missiles and Exposed to Cyclic Pressure Differentials.

- ASTM E1996-99 Specification for Performance of Exterior Windows, Glazed Curtain Walls, Doors and Storm Shutters Impacted by Wind-Borne Debris in Hurricanes.

At least two states (Florida and California) also require windows to be certified for NFRC 300 Visible Light Transmittance while also meeting a maximum SHGC of 0.4.

The cost of getting window products certified is expensive. First there are many standards and second it is required for each product line of windows. This is a problem for smaller exporters.

A new standard for windows and doors has been developed, based upon the AAMA/NWWDMA 101 and the CAN/CSA A440. The intent of this standard was to expand the content of 101 to comply with requirements of all the different codes in the U.S. and in Canada. The result is termed the North American Fenestration Standard and it has been approved by AAMA and WDMA in the U.S. Certification to NAFS-1 started in the U.S. in January, 2002 and it is intended to be incorporated into the ICC code development cycle, as a replacement for AAMA/NWWDMA 101. While intended to produce a harmonized standard, the NAFS-1 has not been approved for adoption in Canada. A joint committee was meeting to produce a revised version of the NAFS (2) during 2003, and it may incorporate changes requested by Canadian interests.

A new standard is under preparation by NWWDA/AAMA termed The Joint Entry Door Task Group (JEDTG). CSA is meeting with the JEDTG with the intent of developing a harmonized exterior door standard for North America. The JEDTG is planning to be incorporated into the IECC 2006 code cycle.

The standards of the NFRC for rating of U-values, SHGC, and visible light transmission are voluntary in the IRC and IECC. However, the look-up tables that are used as an alternate are punitive, that is, they are set at a worse level than may be achieved through testing to serve as an incentive for use of the NFRC ratings. A Thermal Harmonization Task Force is to be formed which will define a standard based upon those of the NFRC and of CSA 440.2.

Windows receiving credits under ENERGY STAR for new houses must have an NFRC rating. Windows and doors are rated as ENERGY STAR-compliant according to the following table. These requirements are no higher than is presently required for windows under the IECC, Chapter 6.

	Windows and doors		**Skylights**	
	U-value	**SHGC**	**U-value**	**SHGC**
Northern Region (>6000 HDDF)	0.35	Any	0.60	Any
North Central (3500-6000HDDF)	0.40	0.55	0.60	0.40
South Central (3500-6000HDDF)	0.40	0.40	0.60	0.40
Southern Region (<3500 HDDF)	0.65	0.40	0.75	0.40

Table 9—Maximum U-values and SHGC for ENERGY STAR windows

It is arguable that in northern regions there should be minimum values of SHGC to ensure increased levels of passive solar heat gains and reduced heating loads. This is seen as a weakness of the present ENERGY STAR ratings for windows, since solar blocking windows would rate as well in the northern region but would not perform as well when installed in a home. A similar argument can be made for cool mild climates, like the Pacific Northwest, that are currently restricted to a maximum SHGC of 0.4.

Section 7 Conclusions

- U.S. codes and standards are more similar to those of Canada than any other export market, but there are many differences that exporters need to be aware of.

- American building codes are sophisticated and are changing rapidly to higher levels of performance and harmonization. The International Codes are being adopted increasingly across the U.S. For most housing exporters, the International Residential Code (IRC) is the most significant model code to work with since it is adopted in the most states.

- But there are many exceptions. Individual states and municipalities may have their own code or use different model codes or may apply additional requirements to the state or adopted model code.

- Any notions that Canadians hold that our codes and standards are superior to those in the U.S. or, that compliance with Canadian codes and standards should result in approval in the U.S., are not true.

- The IRC code is more comprehensive and inclusive than Canadian codes, with many additional construction methods and subcodes included as part of the main code body. These include: insulated concrete forms, steel framing, fuel gas, plumbing and electrical.

- Many requirements are different: minimum dimensions, some fire and safety provisions and provisions for termites and flooding.

- Many requirements are more stringent: the IRC has many added provisions for wind and seismic design, resulting in more structural requirements for wall bracing, anchorage and for window certification and they apply in all areas, not just in high-wind and seismic areas.

- The IRC/IECC has extensive provisions and options for energy efficiency and the prescriptive requirements are higher than in Canada. Only Canadian requirements for mechanical ventilation are superior to those in the U.S. codes, but the Americans are moving rapidly to upgrade those requirements and a number of individual states have ventilation requirements.

- The Americans have developed an energy rating system for houses called HERS which is based upon the performance analysis methods in their codes: the MEC/IECC.

- ENERGY STAR is an important efficiency incentive program for new houses and components that is operating in many states and is based upon HERS ratings.

- Some types of manufactured housing will require inspection and certification of the Canadian production facilities for approval and export to the U.S.

- Acceptance and certification of Canadian building products in the U.S. may require the application of different test standards and evaluations by U.S.-certified labs and evaluation services. Canadian tests standards may apply in some cases, but generally do not.

7.1 Recommended next steps for new exporters

- For a specific state investigate the state code and any related housing regulations and incentive programs. Go to the state Website and find the information (see Glossary under State).

- For a specific municipality contact the office of the building official and obtain any other information regarding additional requirements, climatic design, building permit approvals and inspections, incentive programs and specific product approvals.

- Contact CMHC International for assistance with establishing contacts in the United States.

- Get a copy of the Code—in many states this will be the IRC. In others it may be the UBC or a state produced code. The I-codes are not expensive for example, $50 US for the IRC. The HUD Code is available for free.

- Design the building in compliance with the applicable code and standards. Determine whether architectural and engineering approvals are required by the building official.

- Obtain a copy of the applicable energy Code. Normally this will be the MEC or the IECC. Decide on the most appropriate energy compliance path. The simplest compliance route is by Chapter 6 Prescriptive methods. (Note that Chapter 6 Prescriptive requirements are included in Section N of the IRC)

- Consider applying for an ENERGY STAR label for new housing or components. This will require additional measures for energy efficiency and inspections for certification.

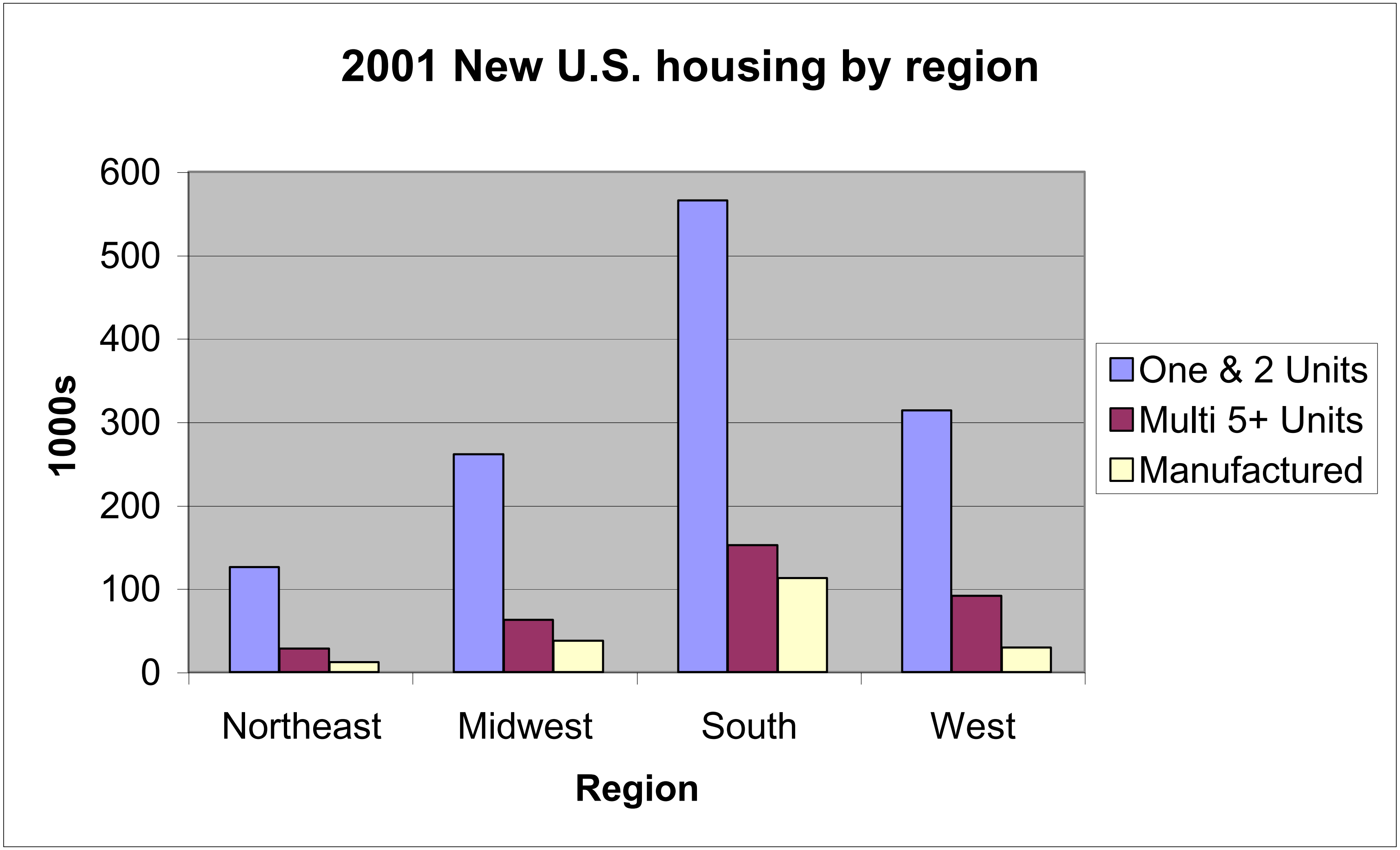
- For types of manufactured housing arrange to have in plant inspections and certifications as required by destination state and municipality or HUD.

- For individual product approvals check with local building official concerning the acceptability of Canadian test standards, evaluations and certifications and /or check with the governing model code authority.

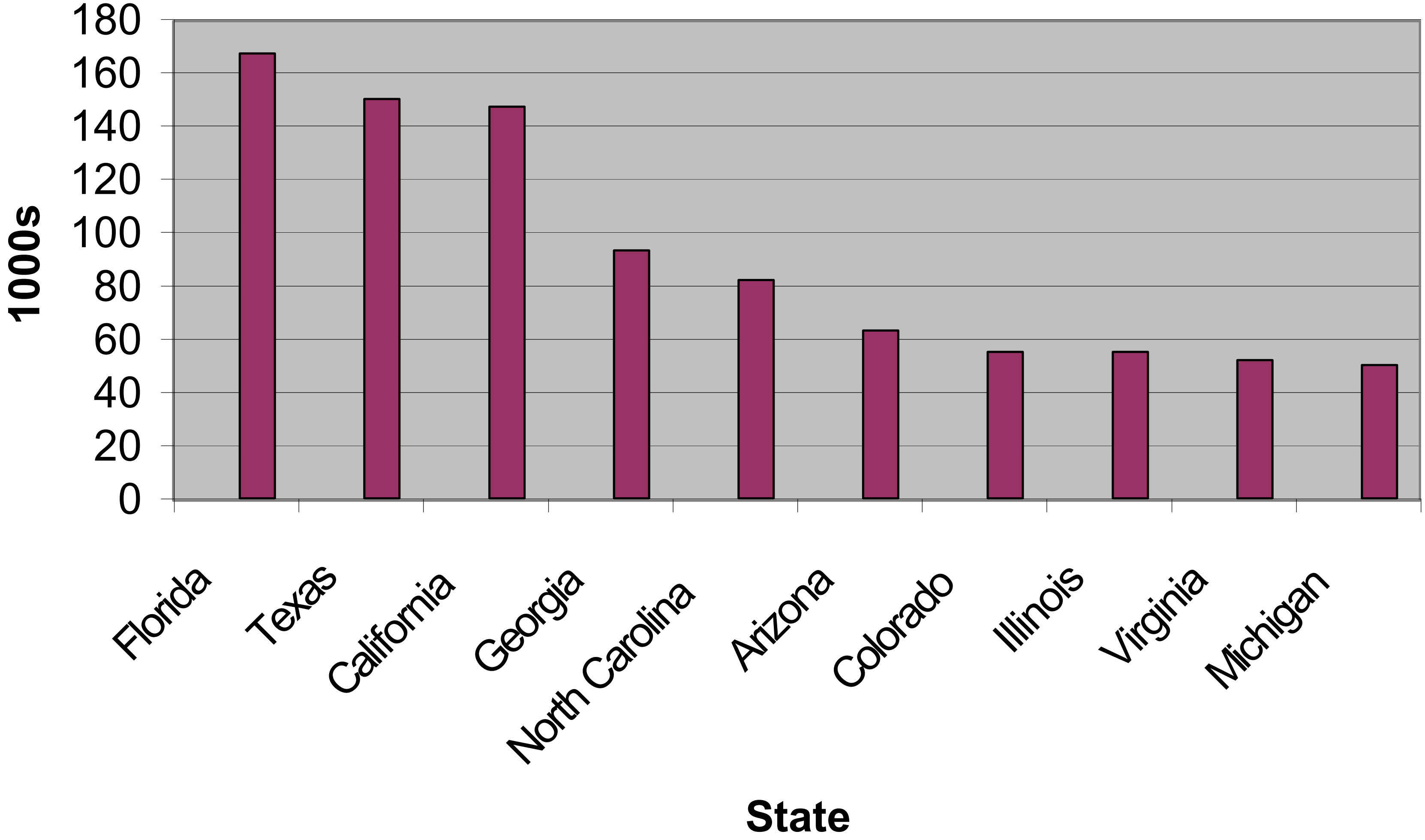
- For individual products manufacturers—Get standard tests done on the product as required. Determine whether a Canadian lab is certified to do the required tests.

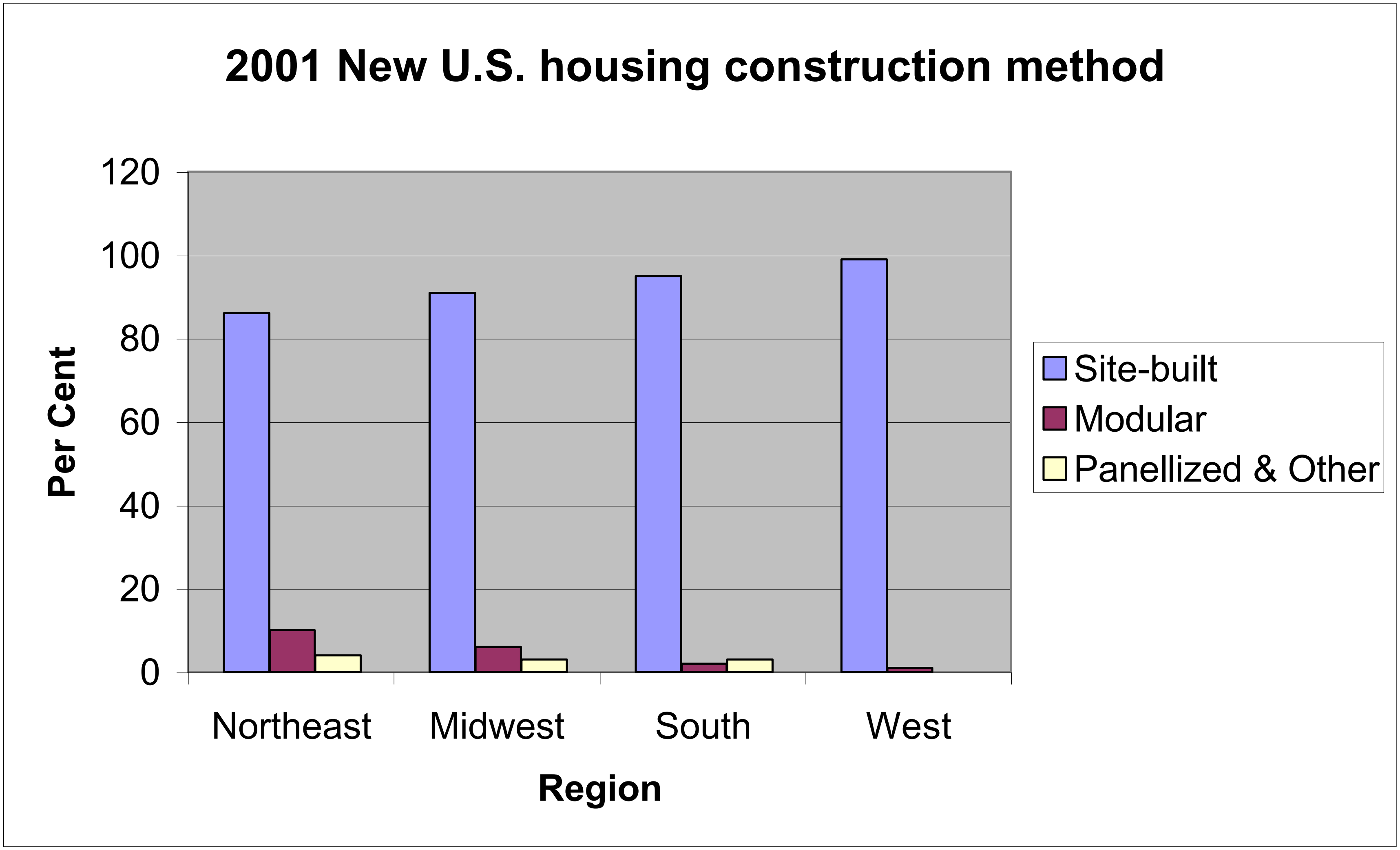
- Contact the ICC–ES to determine whether an evaluation is required.

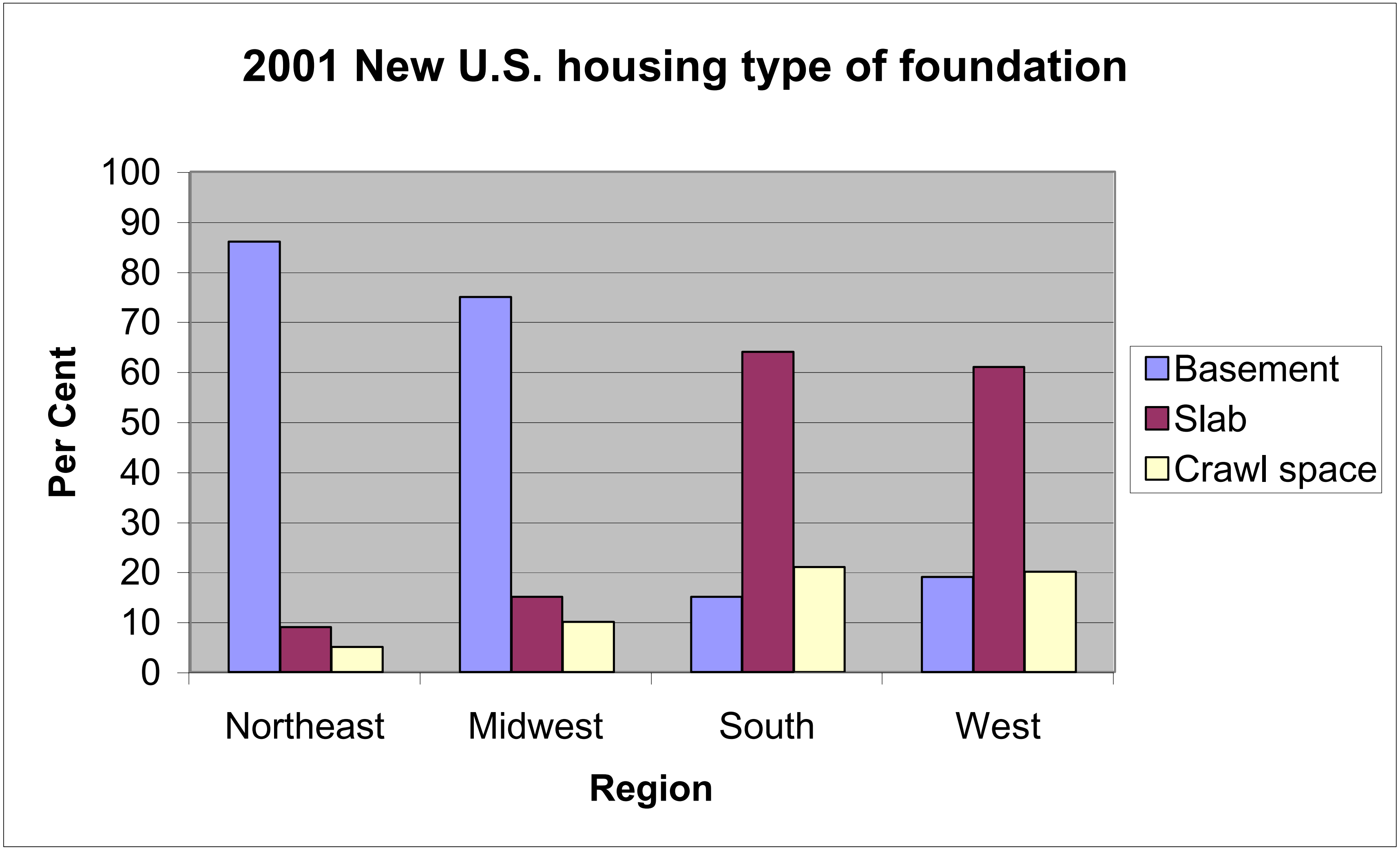
Appendix A U.S. housing statistics


2001 New U.S. housing by region
600
500
400
300
200
100
0
1000s
Northeast
Midwest
South
West
Region
One & 2 Units
Multi 5+ Units
Manufactured

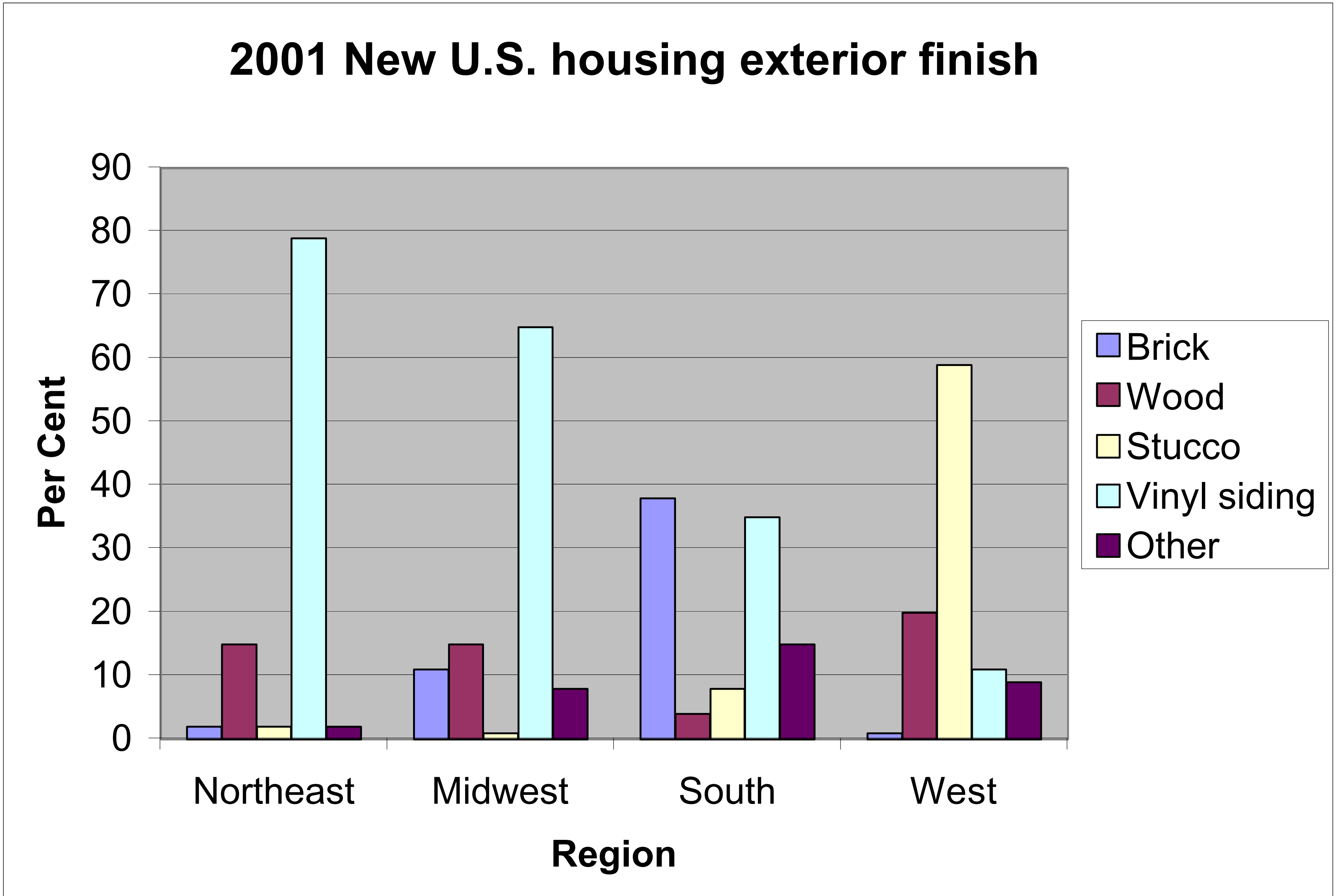
2001 New U.S. housing top 10 states

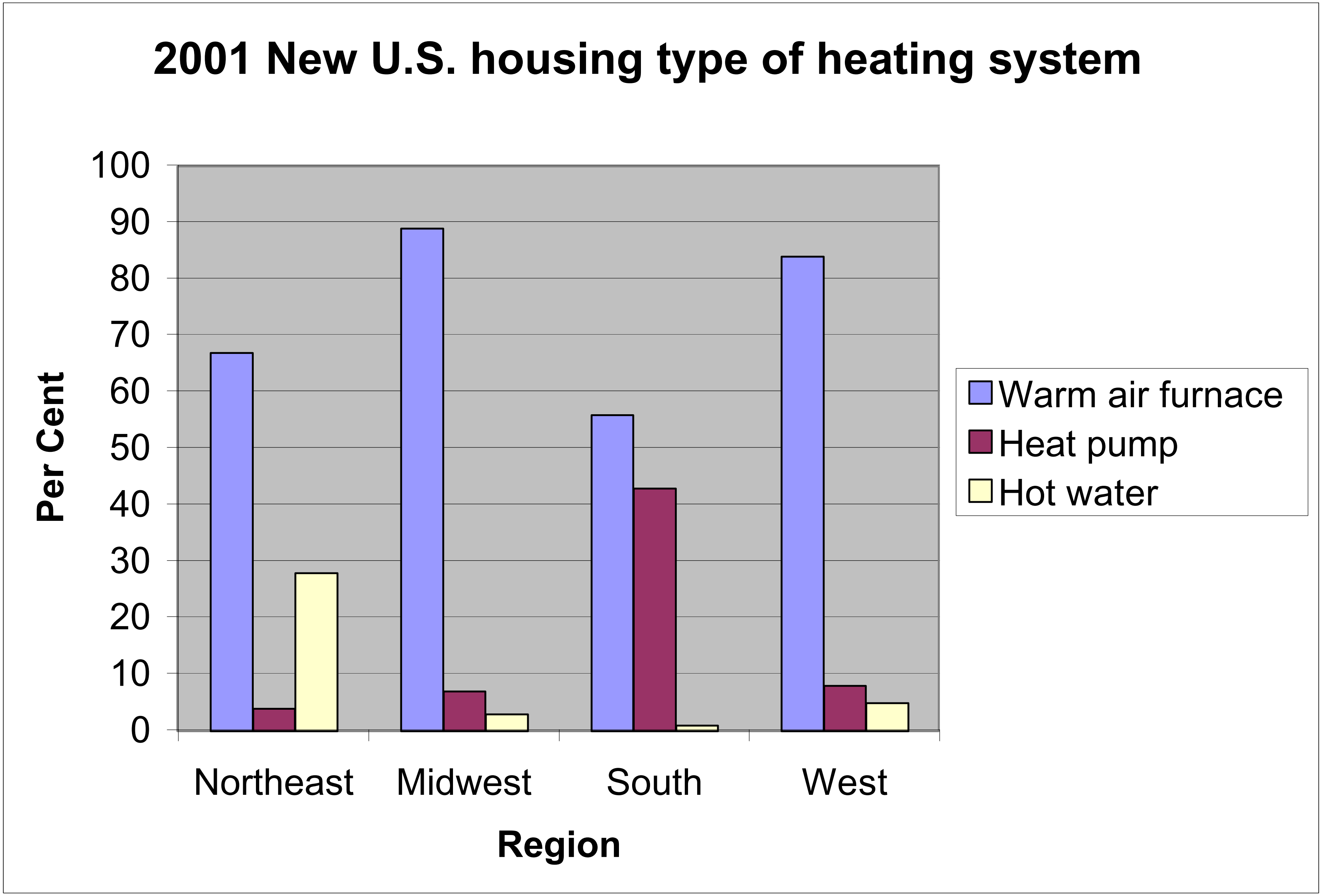


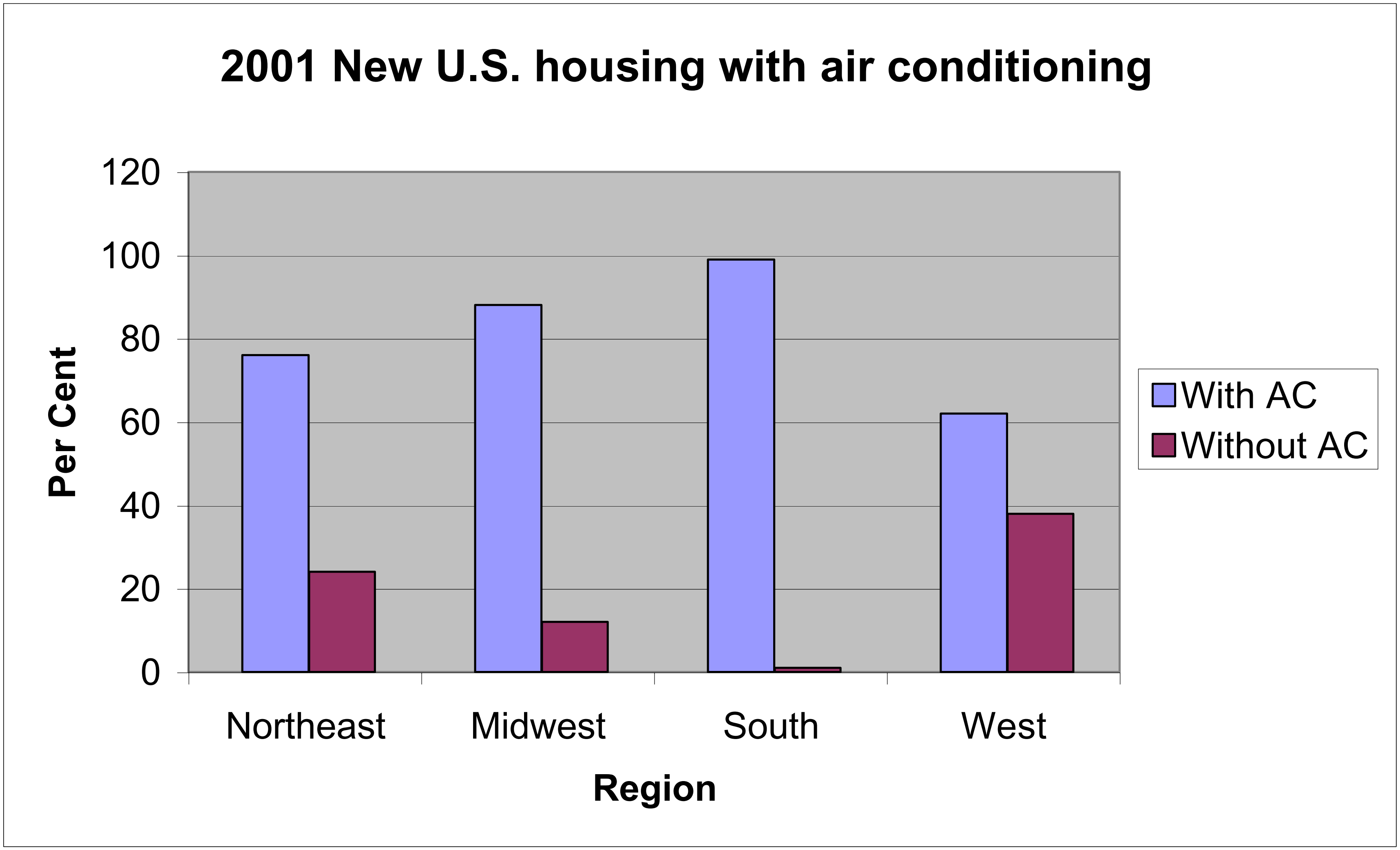

2001 New U.S. housing construction method
Per Cent
120
100
80
60
40
20
0
Northeast
Midwest
South
West
Region
Site-built
Modular
Panellized & Other



2001 New U.S. housing type of foundation
Per Cent
100
90
80
70
60
50
40
30
20
10
0
Northeast
Midwest
South
West
Region
Basement
Slab
Crawl space

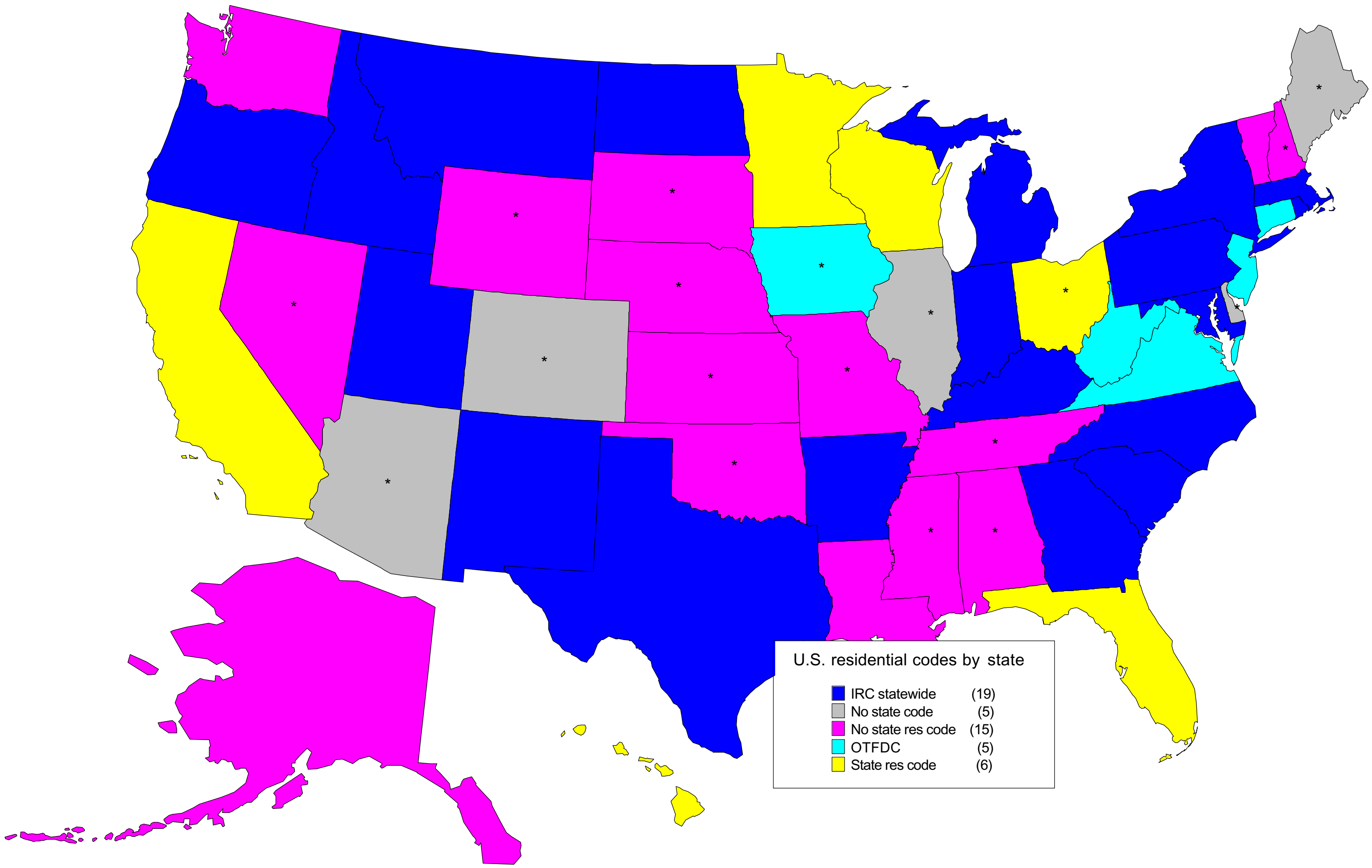

2001 New U.S. housing exterior finish
Per Cent
90
80
70
60
50
40
30
20
10
0
Northeast
Midwest
South
West
Region
Brick
Wood
Stucco
Vinyl siding
Other


2001 New U.S. housing type of heating system
Per Cent
100
90
80
70
60
50
40
30
20
10
0
Northeast
Midwest
South
West
Region
Warm air furnace
Heat pump
Hot water


2001 New U.S. housing with air conditioning
Per Cent
120
100
80
60
40
20
0
Northeast
Midwest
South
West
Region
With AC
Without AC

Appendix B State Code Status

U.S. residential codes by state



* denotes state where IRC may be adopted by local authorities

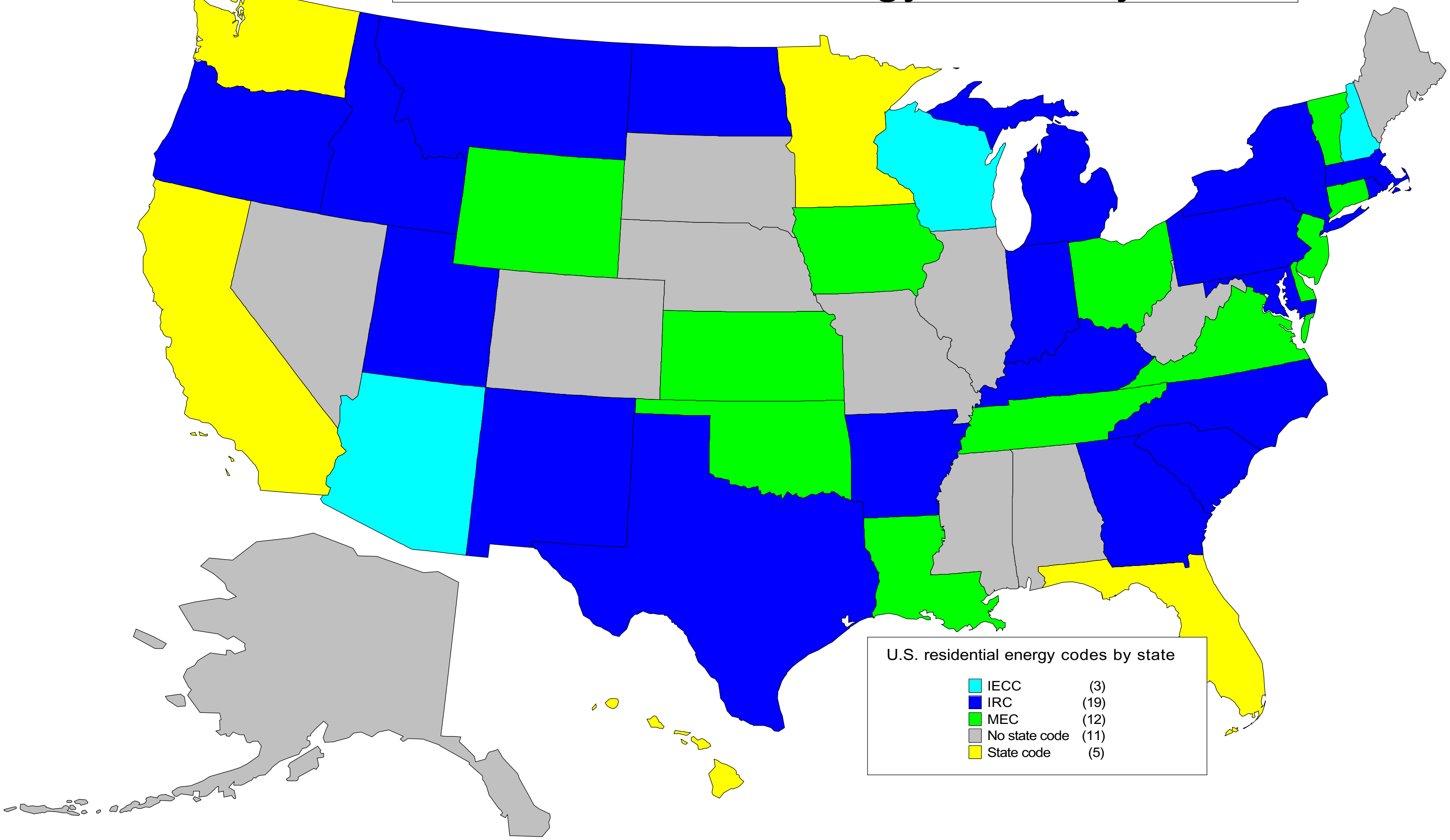
Residential Codes by State

Revised on 13/01/03

	IRC Statewide	OTFDC	State Res Code	State Building Code	IRC Locally	Comments
Alabama			No	SBC	X	
Alaska			No	IBC		Title 18 - state funded residential
Arizona			No	No	X	
Arkansas	X			IBC		
California			X	UBC		Title 24
Colorado			No	No	X	
Connecticut		X		NBC		
Delaware			No	No	X	
District of Columbia		X		NBC		
Florida			X	SBC		
Georgia	X			IBC		
Hawaii			X	No		Title 11, Ch. 14
Idaho	X			IBC		
Illinois				No	X	
Indiana	X			UBC		
Iowa		X		UBC	X	
Kansas			No	UBC	X	
Kentucky	X			IBC		
Louisiana			No	SBC		
Maine			No	No	X	
Maryland	X			IBC		
Massachusetts	X			IBC		
Michigan	X			IBC		
Minnesota			X	UBC		
Mississippi			No	SBC	X	
Missouri			No	IBC	X	IBC for state buildings
Montana	X			IBC		
Nebraska			No	UBC	X	
Nevada			No	UBC	X	
New Hampshire			No	IBC	X	
New Jersey		X		NBC		
New Mexico	X			IBC		
New York	X			IBC		
North Carolina	X			IBC		
North Dakota	X			IBC		
Ohio			X	IBC	X	Ohio Basic BC, Ch. 13
Oklahoma			No	NBC	X	
Oregon	X			UBC		
Pennsylvania	X			IBC		
Rhode Island	X			NBC		
South Carolina	X			IBC		
South Dakota			No	IBC or UBC	X	
Tennessee			No	SBC	X	
Texas	X			IBC		
Utah	X			IBC		
Vermont			No	NBC		Vermont Fire Prevention and BC for rental homes
Virginia		X		NBC		
Washington				UBC		IBC under consideration
West Virginia		X		NBC		
Wisconsin			X	IBC		WI Uniform Dwelling Code Ch 20-25
Wyoming			No	UBC	X	

Notes: Abbreviations stand for the International Residential Code (IRC), One and Two Family Dwelling Code (OTFDC), International Building Code (IBC), Uniform Building Code (UBC), Standard Building Code (SBC), National Building Code (NBC

U.S. residential energy codes by state



States w ith no code generally allow voluntary adoptions by local jurisdictions

Residential Energy Codes by State

Revised on 13/01/03

	IRC	IECC	MEC	State Energy Code	IRC Locally	Comments
Alabama				No	X	MEC Locally
Alaska				No		ASHRAE 90.1 for state owned residential
Arizona		X			X	
Arkansas	X	X				
California				X		Title 24, Part 6
Colorado			X		X	MEC on multi family residential
Connecticut			X			
Delaware			X		X	
District of Columbia						
Florida				X		FBC, Ch. 13
Georgia	X					MEC other buildings
Hawaii				X		Hawaii Model Energy Code
Idaho	X					
Illinois				No	X	
Indiana	X					MEC other buildings
Iowa			X		X	
Kansas			X		X	
Kentucky	X					
Louisiana			X			
Maine				No	X	state Energy Efficiency Performance Standards
Maryland	X					
Massachusetts	X					
Michigan	X	X				
Minnesota				X		Minnesota State Building Code
Mississippi				No	X	
Missouri				No	X	
Montana	X					
Nebraska				No	X	IECC state buildings
Nevada				No	X	Regulations for the Conservation of Energy in New Buildings
New Hampshire		X			X	
New Jersey			X			
New Mexico	X					
New York	X					
North Carolina	X					
North Dakota	X					
Ohio			X		X	
Oklahoma			X		X	
Oregon	X					
Pennsylvania	X					
Rhode Island	X					
South Carolina	X					
South Dakota				No	X	
Tennessee			X		X	IECC locally
Texas	X					
Utah	X	X				
Vermont			X			
Virginia			X			
Washington				X		Washington State Energy Code, CH 51-11
West Virginia				No		
Wisconsin		X				
Wyoming			X		X	

Notes: Abbreviations stand for the International Residential Code (IRC), International Energy Conservation Code (IECC), Model Energy Code (MEC)

Appendix C Standard design specifications, IECC

A summary is provided of the requirements for the specifications of the assemblies and systems of the Standard Design, of Chapter 4 of the International Energy Conservation Code (IECC). These requirements are very similar to those of the HERS Reference House.

- The geometry and size of the Standard Design is the same as the Proposed Design.
- The maximum U-value of walls and windows is stipulated in tables which vary by annual degree day groupings (402.1.1)
- The window areas of the Standard design are to be 18 per cent of the conditioned floor area and equally distributed around the four major faces of the building (402.1.3.1), and are to be unshaded by overhangs and so forth (402.1.3.1.3).
- The SHGC of the windows, inclusive of frame and glass areas is 0.4 for HDDF <3500 and 0.68 for HDDF =>3500. (this contrasts with no minimum requirement for ENERGY STAR rated windows where for HDDF =>3500) (402.1.3.1.4)
- The heating control temperature is 68°F and cooling 78°F.
- Heat storage of the interior and structure is specified in (402.1.3.3). Internal Heat Gains are set as per (402.1.3.6).
- The average seasonal air changes per hour (ACH) of air infiltration is calculated as the Normalized Leakage* times the Weather Factor*. The Normalized Leakage for the Standard Design is 0.57.
- ***Note*** that when the Proposed Design takes a credit for reduced ACH levels a post-construction blower door test is required using ASTM E779. No energy credit is granted for ACH seasonal levels below 0.35 (402.1.3.10). (ASTM E 779 is conducted similar to CGSB-149.10-M86. The result of the test is often presented in terms of air changes per hour at 50 Pa pressure—ACH@ 50 Pa. The limit of 0.35 ACH (seasonal) is interpreted by the HERS rating software to include continuous mechanical ventilation systems with or without heat recovery. This is similar to the limit of 0.3 ACH imposed by the HOT2000 software upon the combined air leakage and ventilation of R-2000 homes.)
- A Distribution Loss Factor (DLF) is required to be applied to ducts located outside and inside the conditioned space for both heating and cooling. An Adjusted System Efficiency is developed based upon the equipment efficiency *times* the DLF *times* the percentage of the ducts outside *plus* equipment efficiency *times* the DLF *times* the percentage of the ducts inside. For the Standard design the default DLF is 0.80 for ducts located outside the conditioned space and 1.0 for ducts inside (402.1.3.9).
- ***Note*** that a credit for an improved DLF can only be claimed if the ducts are tested after construction and confirmed to be "substantially leak free." That is, the leakage when

tested by pressurization to 25 Pa is found to be equal or less than five per cent of the total air flow measured through the air handler or furnace. The development of the DLF in the Proposed Design also includes an assessment of the Distribution System Energy Impacts, which may include the assessment of heat gains and losses through conduction as well as air leakage through the ducts located outside the conditioned space.

*What are *Normalized Leakage* and *Weather Factor* and what do they mean in terms of ACH?

Normalized Leakage (NL) is a novel term for Canadians, even those familiar with the R-2000 Program. The Normalized Leakage is approximated for a single storey house as the ACH @ 50 Pa divided by 20 (where ACH is the air changes per hour measured at 50 Pa depressurization).

The Weather Factor is pre-calculated dependent upon weather records of wind and temperature and is looked up in ASHRAE Standard 136 from the nearest weather station to the site. The Weather Factor ranges from a low of 0.6 in the warmest and most sheltered parts of Hawaii to a high of 1.20 in the coldest and windiest parts of Alaska. The default Normalized Leakage of 0.57 represents a tested ACH@50 of 11.4, which is approximately triple that for average houses in Canada -3.6 ACH @ 50 Pa. This implies that a large credit may result for airtightening measures when applying Chapter 4 analysis methods for compliance.

Appendix D State energy codes

Special state energy code requirements

A number of states have produced their own energy codes that differ or add additional requirements to those of the MEC and the IECC. This appendix provides a review of those for the states of California, Florida, Minnesota and Washington. This review shows some of the variety and complexity that can be found in the American codes. The reader is advised to contact the state and the municipality of interest directly to obtain further information about the codes and incentive programs that may apply to builders and exporters.

California

The state of California has been a leader in energy conservation and environmental concerns over the past two decades. Many of the increased efficiency regulations for motor vehicles, both in the U.S. and Canada, had their origin in California. A similar process may be underway in the development of requirements for efficiency and conservation in buildings. Over the past three years the state experienced severe electrical energy shortages, with a series of rolling blackouts and increased energy costs. As a consequence, the state's code requirements for energy efficiency in buildings, which were already extensive, were revised early in 2001 to require more conservation measures and verification procedures. California has probably the broadest set of requirements and incentives of any state for efficiency in new houses, including computerized modelling and compliance verification inspections.

Title 24, Part 6—*The Energy Code*

The building code of California is described by legislature as Title 24. It is based upon the Uniform Building Code (UBC). The standard for energy conservation is described in Part 6 of Title 24. It appears to be based upon the MEC, but adds many new requirements. (For a complete review refer to the Residential Manual, California Energy Commission). The following section contains a brief review of some of the highlights of the California Energy Code as it applies to new houses. These include:

Climate zones—16 different climate zones are defined with standards for each zone.

Mandatory measures—Minimum levels of insulation and equipment efficiencies that apply regardless of which compliance path is chosen.

Prescriptive packages—The simplest but least-flexible compliance method. The prescriptive packages consist of sets of minimum levels of insulation for selected components, equipment efficiencies, radiant barriers, maximum U-values, SHGC for windows, duct sealing and AC charge/TX valve verification. There are two sets of prescriptive packages: D & C. Package C applies only to houses that are electrically heated and where no natural gas is available.

Performance methods—This is similar to Chapter 4 compliance in the MEC/IECC. The performance method requires the use of Approved Computer Methods (ACM), which are approved by the California Energy Commission (CalRes, Energy Pro, MicroPas) This performance-compliance method is used more than the prescriptive packages. While it requires more effort, it also results in more flexibility in meeting the code. The computer program calculates the energy use of a proposed design and that of the standard design, that is, the same building but as if built to the mandatory and prescriptive requirements of Package D. The energy use includes both space conditioning and water heating energy use. To comply, the energy use of the proposed design cannot exceed that of the standard design.

A number of the individual features of the California Energy Code requirements are novel for Canadians and are identified below:

- Documentation. A number of official forms are required to be completed for permit approval and for completion. The forms document the choice of compliance option, whether prescriptive or performance, and which choices were made for either route, the mandatory measures, field verification and compliance testing, and various installation certificates of the installing contractors. Many parts of the documentation are required to be copied to the homeowner.

- Radiant barriers are required in most climate zones to reduce air conditioning loads. Radiant barriers are metal foil sheets that are applied under roofs and over attic end walls that reduce the absorbed solar heat gain within roofs and unconditioned attics.

- The prescriptive compliance route Package D requires duct-leakage testing and efficiency rating testing by a HERS rater in every climate zone. It also requires verification of the AC charge (refrigerant charge in an air conditioner) and airflow or verification of the installation of a TX valve (Thermal Expansion Valve) on the air conditioner by the HERS Rater. (A set of alternatives to Package D replaces the duct sealing /AC charge and TX valve requirements with even higher-performance windows and higher-efficiency equipment efficiencies.)

- Return air ducts in HVAC systems ducts must be separately ducted, not panned or soft-ducted within the structure.

- Part 6 requires a mechanical ventilation system if a credit is taken for airtightness better than a specific leakage area (SLA) of 3. If the airtightness is measured to be below 1.5 SLA, mechanical supply is also required and house depressurization must not be less than -5 Pa. (Specific Leakage Area is a term not used in Canada. It is 10,000 x Leakage area/floor area. It can be approximated by ACH/2, or to put into terms more commonly used in Canada ACH=2xSLA. The default airtightness for a house is a default SLA is 4.9 for houses with ducted HVAC systems and 3.8 without.)

- A vapour barrier is not required on the warm side of the construction in most climate zones. A vapour barrier is required only in zones 14 and 16.

A number of requirements in California are similar to those in the MEC / IECC:

- All ducts are required to be sealed. Cloth-backed duct tape is only allowed for sealing ducts if used with a mastic and draw-bands.

- Duct leakage must be measured at less than 6 per cent of the total flow through the forced-air system and verified by a HERS rater. Duct leakage is measured by pressurizing the forced-air system including both supply and return sides, with all grilles sealed at a pressure of 25 Pa and comparing the leakage with the total flow through the air handler in its normal operational state.

- If no credit is taken for duct sealing in the performance method, a default leakage of 22 per cent is assumed in the software.

- Duct efficiency—the efficiency of a ducted system—is determined based on number of factors of which air leakage is but one. Others include duct location, insulation, surface area and the design of the duct system. If credits are taken for the duct efficiency beyond default levels, verification of all the improvements by a HERS inspector is required. Among the inspections is a review and conformance inspection with a duct layout and sizing design which is done to the requirements of ACCA Manual D and testing of the delivered airflows in each room to within 15 per cent of the design flows.

- All windows (and doors with more than 50 per cent glass area) are required to have labels attached for inspection compliance showing the ratings by NFRC (National Fenestration Rating Council) ratings of NFRC 100 (U-value) and NFRC 200 (SHGC) and a description of the product (for example, double Low E, argon filled). In addition, they are required to be rated by NFRC 300 Visible Light Transmittance.

HERS raters and CHEERS

HERS raters are inspectors who perform analysis and conservation consulting services and verification inspection services. The California Home Energy Efficiency Rating System (CHEERS) has been approved by the California Energy Commission as a HERS provider to oversee the certification of HERS raters providing Title 24 field verification and diagnostic testing. HERS raters are required to be independent, third-party organizations without any financial interest in the builder or the contractor performing the installation services for the builder.

ENERGY STAR in California

Most HERS raters in California also deliver ENERGY STAR ratings with the Title 24 compliance analyses. This combination helps makes the performance-compliance route popular since the ACM software performs both Title 24 and ENERGY STAR ratings. Compliance with ENERGY STAR brings the incentive of a widely recognized program and eligibility for Energy Efficient Mortgages (see HERS section).

Florida

The building code of the state of Florida is based on the Standard Building Code (SBC). Florida has recently (2001) incorporated a number of revisions that requires all counties to use the Florida Building Code and which bring the Florida Building Code closer to the International Codes regarding wind design and some aspects of energy efficiency.

Florida references the same standard (ASCE 7-98) and brings the similar technical requirements for wind loading as contained in the International Codes (both IBC and the IRC) that were reviewed in 3.4 "Wind," on page 12). It is necessary to get a professional architect or engineer to determine the *Dp* or design wind pressure for every new home built in Florida—and to meet all the loading requirements for the structure and windows in the wind zone determined by the house location.

The Florida Building Code requires that all windows and glass doors be tested and labelled for water resistance, air leakage, wind-load deflection, structural tests, SHGC, U-value and more (If U-value and SHGC are not done by NFRC methods, tables of default values are provided in the Code).

When designing window glazing for the south there a number of issues which need to be considered that make the product different from those intended for cold northern climates. First, low SHGC factors are required for windows in the south both by the Florida Code and by the IECC: a maximum SHGC of 0.4. In order to maintain for natural day-lighting a high visible transmittance (VT) of light is required by Florida, similar to California. To meet both criteria, glazings with a high light-to-solar-gain ratio (LSG) are preferred. This type of glass is available and has specially optimized properties to reject high-energy invisible light but allow visible light to pass. This type of glass product differs from the Low-E coatings developed for northern climates that maximize total solar transmittance while reflecting long-wave radiation back within the building. This type of glazing would increase cooling loads if used in the south.

A new window product approval system became effective Oct. 1, 2003. All new buildings must use only approved products where required by code. These products include panel walls, exterior doors, roofing, skylights, windows, shutters and more. All regulated building products must obtain the required testing and approvals and apply to be listed by the state. The state will maintain a database and list of approved products.

A new inspection requirement for forced-air systems (Section 601.4) came into effect in Florida in March, 2002. The code specifies that the pressure difference between a room with a closeable door (except bathrooms and laundry rooms) and central space have a pressure difference of no greater than 2.5 Pa. It has been found that the pressure differences induced by forced-air systems are large due to imbalances between supply and return-air pressures, which result in high levels of mechanically induced air leakage. The Florida code has introduced a simple test and performance level to reduce these problems. There is no similar requirement yet in any other jurisdiction in North America.

Energy efficiency (Chapter 13)

Two compliance paths are available:

- Prescriptive (methods B and C)—sets of features that allow a builder to meet the code without analysis and testing.
- Performance (method A) – A computer software evaluation that determines a the energy performance of the home and whether it is better than that of a "baseline" or standard home, that is, the same house built to a set of minimum specifications. More than 90 per cent of applicants for energy code compliance choose this route. Unlike California, there are no minimum mandatory specifications when using the performance compliance method. The software required for compliance evaluation is EnergyGauge. The enables the builder and evaluator to determine which combination of features best meet the

targeted performance. Credits may be selected for various properties of the envelope and windows, for mechanical system efficiencies and for duct leakage and duct system efficiency. If the builder takes a duct system credit this must be tested by a state-approved performance tester prior to issuance of a Certificate of Occupancy. Similar to California, leakage from ducts must not exceed five per cent.

ENERGY STAR for new homes is available in Florida using the same HERS ratings system and testing and verification as in other areas. EnergyGauge software will perform both ENERGY STAR ratings as wells as those required for the Florida Energy Code. The designated provider is the Florida Solar Energy Center (FSEC), a research institute of the University of Central Florida

As of Oct. 1, 2003, Florida law authorized property owners to elect to use private providers to review plans and inspect construction for compliance with the Florida Building Code and local amendments.

Minnesota

The Minnesota State Building Code is based on the Uniform Building Code with amendments (97 UBC). It includes an energy code that was originally based upon the 1993 MEC. In addition, it includes requirements for mechanical ventilation and there are special requirements to control depressurization and combustion gas spillage in houses. All building contractors and trades and manufactured home installers must be licensed by the state. Manufacturers of combustion appliances are required to provide certification to the state of the level of depressurization that the appliance can operate without spillage.

The Minnesota Energy Code gives residential builders two options for meeting the requirements of the energy code:

Option A—Category 1, Alternate method, Chapter 7670

- Air-sealing of the envelope is required, either by following a set of prescribed measures or verifying by a post-construction air-leakage test to ASTM 779-87 with a result of not more than 0.24 cfm/ft.^{2} of conditioned space when measured at 50 Pa. (In a house of 3,000 ft.^{2} space this translates into a measured leakage rate of 720 cfm @ 50 Pa. If the average height were 8.5 ft., this translates to an ACH @ 50 Pa of 1.7. This is similar to that required for R-2000 in Canada.)

- Airflows in forced-air systems must be balanced (no spec. provided).

- Envelope U-values must be determined by a "Cookbook," which is a prescribed set of options for walls and windows. It also includes a set of minimum requirements for ceiling insulation, entry doors, rim-joist insulation, floors over conditioned space, foundation insulation and windows. There is no maximum U-value for windows under Option A except that all windows must be double-glazed with vinyl or wood frames.

- Alternatively to the "cookbook", performance, calculations of the overall U-value for walls and windows must be less than of 0.110 Btuh/ft^2.F . This is similar to the MEC/IECC Chapter 5, Compliance by Total Envelope Performance.

- Window U-values must be as rated by NFRC or by use of tables in the 1993 ASHRAE Handbook. That is, the overall U-values include the average of the frame, centre glass and edge areas. Wall U-values must be overall averaged for the effect of wall framing members and include different formulations for wood or steel framing.

- A systems analysis design option is permitted which is the same as the MEC, Chapter 4. Apparently this is rarely used in Minnesota.

- Mechanical ventilation is required and is to supply the larger of the (number of bedrooms plus 1) times 15 cfm, or the volume of house ($ft.^3$) times .00583. The system may be an exhaust-only type or may have balanced supply and exhaust flows.

- All combustion equipment is required to be sealed or power-vented.

- If a solid (wood) fuel fireplace is installed, a makeup air system is required for each individual exhaust device that exceeds 300 cfm capacity.

Option B—Chapter 7672

Chapter 7672 is a new set of requirements that came into force in April of 2000. It encompasses more prescriptive options and details than Chapter 7670. Only the major differences are highlighted below.

- The minimum heating system efficiency is increased to 90 per cent.

- The maximum U-value for windows is decreased to 0.37. Lower wall U-values are included in the "Cookbook" tables. The "Cookbook" tables allow differing minimum levels of foundation insulation.

- The total ventilation rate is increased to 0.5 cfm/ft^2. The background rate (#bedrooms +1 x 15 cfm) is required to be provided by a continuously operated system. The remainder is to be supplied by intermittent-use, supplemental (spot) fans. A schedule of ventilation fans is required to be completed. Requirements for balanced or exhaust-only ventilation systems are similar in many respects to CSA F326. Ventilation air must be supplied to individual rooms by coupling with the forced-air system or through dedicated ductwork.

- The depressurization protection measures have been significantly increased. Makeup air is required to be supplied and matched to each depressurizing exhaust device when spillage equipment is present. There are 4 prescriptive paths that can be followed which allow more flexibility with the type of spillage combustion equipment that may be installed. Two of the makeup air paths permit passive air openings to be installed for each depressurizing device. A table is provided for sizing the passive makeup air systems.

A schedule of powered, makeup air systems is also provided with a section on the aggregate makeup system.

- As an alternate a depressurization field test may be used. The maximum depressurization levels for various appliances are more restrictive and more detailed than stipulated in Canada's CSA-F326.

At least two software tools are available for assisting with Minnesota's Energy code:

- Mn*check*—A software program to assist in determining energy code compliance in Minnesota for residential buildings. MN*check* is now part of the national MEC*check* software.

- Guide Lines – A software program that assists in meeting the residential ventilation and depressurization protection requirements of Chapter 7672.

There may be changes coming to the Minnesota Energy Code. A report entitled *Implementation of Minnnesota's Residential Energy Code* was submitted to the State Legislature in January, 2002, by the MN Management Analysis Division. Amongst its recommendations were the following:

- Remove the Minnesota Energy Code requirements of Chapter 7670 and Chapter 7672 and replace them with the IECC.

- Any requirement for residential mechanical ventilation should be placed in the state mechanical code rather than the energy code. This will retain the requirement for mechanical ventilation since there is none in the IECC.

Washington state

The Washington State Building Code, Title 51, is based on the 1997 Uniform Building Code with amendments. Part 11 describes the Washington State Energy Code. The State of Washington Energy Code is based upon the 1995 MEC and bears a strong resemblance to the current IECC (including the same Chapter numbers). It provides for three compliance paths for houses:

1. Systems analysis—Chapter 4

2. Component performance—Chapter 5

3. Prescriptive—Chapter 6

Worksheets and *Excel* spreadsheets are available to help with the required calculations of Chapter 5. For more information please refer to 4.2 "International Energy Conservation Code," page 41.

Title 51 Part 13 ventilation and indoor air quality

Residential occupancies are required to comply with one of two options as described in section 302 or 303. Both sections 302 and 303 have the similar requirements for ventilation flows and controls:

- Source-specific exhaust ventilation is to be provided in all wet rooms, that is, kitchens, bathrooms, laundry rooms and rooms with swimming pools. Source-specific ventilation is not required to run continuously. The source-specific flow rates are stipulated in Table 3-1. For continuous systems, bathrooms are required to exhaust 20 cfm and kitchens 25 cfm. For intermittent systems, bathrooms are required to exhaust 50 cfm and kitchens 100 cfm. These rates are similar to the rates in CSA F326, except the requirements for kitchens are lower (60 cfm).

- Whole-house ventilation is required to have flows as stipulated in Table 3-2. The table lists both minimum and maximum ventilation flow rates by ranges of floor area of houses, and by the number of bedrooms. For example, a four-bedroom home of 2,001 to 2,500 ft.^{2} must provide a minimum of 100 cfm and a maximum of 150 cfm.

- Whole-house systems must be capable of continuous operation. They must have controls with a 24-hour clock timer that is set to operate a minimum of eight hours per day. There is no requirement that the control of the source-specific ventilation be linked with any of the whole-house ventilation systems.

Section 302 is a general requirement for systems designed for continuous flow. Whole-house ventilation is required to be supplied by outdoor air, which is to be distributed to individual rooms or by integration with a forced-air system. There is no requirement that the continuous exhaust and supply airflows be the same. Section 302 makes no prescriptive configurations of the ventilation systems. Compliance with 302 can be done by showing engineering flow calculations or by testing airflows.

Section 303 provides four descriptions of prescriptive, whole-house ventilation systems that largely avoid requirements for flow calculations or measured flow testing:

- **With Exhaust Fans (303.4.1)—**Exhaust fans may provide the whole-house ventilation flow with fan flows rated at 0.25 inches wg and with a sone rating of 1.5 or less. Supply air inlets to individual rooms are required, unless the house has a forced-air distribution system.

- **Integrated With a Forced Air System (303.4.2)—**This system consists of a supply air duct leading from the outside to the return of a forced-air system. The supply air duct is required to be sized according with Table 3-5. The supply air duct is required to have one of a motorized, shut-off damper, a flow-balancing damper set to achieve the minimum flow or a flow-regulating device in the return air.

- **Using a Supply Fan (303.4.3)—**This system consists of an in-line fan that supplies outside air to the house. The distribution may be a separate duct system or by means of a forced-air system. Table 3-6 is used for sizing the outdoor, air-supply duct (the sizes are smaller than in 3-5). The supply-air volume is required to be regulated and set to meet minimum and maximum flows by either a calibrated manual volume damper or an automatic flow-regulating device.

- **Using a Heat Recovery Ventilation (HRV) System (303.4.4)—**An HRV may provide the whole-house ventilation. It is required only to meet the minimum flows in Table 3-2, and not the maximum. Balancing dampers and flow-measuring grids are required to be installed. Outside air ducts are required to be not less than 6" in diameter.

There is no specific, pressure-testing requirements for ventilation systems to regulate pressure differentials for purposes of control of spillage from combustion appliances. Fireplaces are required only to have tight-fitting doors and an outdoor air supply.

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