Danish Energy Management A/S

A part of Danish Management Group

Review of International Best Practice for the Building Control Bill, in relation to Energy Efficiency

UNDP - 00058178/
Removal of Barriers to Energy Efficiency and Energy Conservation in Buildings – PS/MAR2010/002

Preparation of Building Control Bill, Building Regulation and Code for Energy Efficiency and Compliance Mechanisms.

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1 Executive Summary

Energy efficiency is widely accepted as the most cost effective way to mitigate climate change and accounts for 50% of the potential to halve energy-related CO2 emissions by 2050.

This report has been prepared as background research to support the formulation of recommendations for the development of Regulation and Code for Energy Efficiency and Conservation in buildings for Mauritius.

The development for the above, is an initiative of the Ministry of Renewable Energy & Public Utilities to meet the goal regarding energy efficiency in the building sector: 00058178/Removal of Barriers to Energy Efficiency and Energy Conservation in Buildings – PS/MAR 2010/002, funded by GEF/UNDP and AFD.

A number of documents are reviewed in this paper, including:

- ICC International Energy Conservation Code 2009 (IECC)
- ANSI/ASHRAE/IESNA Standard 90.1-2007
- United Kingdom Building Regulations
- Danish Building Regulation (BR08)
- Passiv Haus Standard
- South African National Standard (SANS 204) (2008)
- Energy Efficiency Considerations in the Botswana Building Regulation (2007) – Draft
- The RTAA DOM (Réglementation Thermique, Acoustique et Aération - Départements d’Outre Mer)
- Building Code of Australia (2009)
- Malaysia Guidelines for Energy Efficiency in Buildings (2007) MS1525
- India Energy Conservation Building Code

The documents have common threads although different approaches have been taken.

The review of these documents provides useful background information for the development and implementation of the regulation, code and compliance mechanism, as well as the content of same. A table is included in Section 3 providing an overview of the documents reviewed.

The criteria use for the table are:

- Regulation method
- Climate definitions
- Building classification
- Compliance method
- Building Envelope
- Heating, Ventilation, Air Conditioning (HVAC)
- Lighting
- Electrical power
- Design guidelines
- Alternative compliance method

Section 15 provides a study of the relevance of the documents to Mauritius.

The potential barriers to the implementation of the code have been looked. The ones identified are:

- Lack of awareness and tools
- Absorptive capacity of stakeholders
- Climatic conditions
- Energy efficient equipment, materials and technologies – *availability, knowledge*
- Lack of equipment testing/certification for local products
- Lack of Life Cycle Costs analysis
- Compliance procedures – *additional resources required*
- Consumer behaviour – *uptake by market*
- Potential threat of regulatory system abuse

To conclude the recommendations are provided following the study and review of the documents.

The recommendations are that:

- One climatic zone is to be determined and defined
- The buildings to be categorized in two categories “Residential” and “Commercial”, with a further possibility to differentiate “Existing” and “New”.
- Building systems to be included in the code are similar to those treated in the reviewed documents: building envelope, HVAC, service hot water heating. Interior and exterior lighting and electrical power and motors
- The evaluation criteria to be the prescriptive requirements for the elements and systems, rather than an overall building performance evaluation. This is mainly due to the lack of data to create baselines, and the complexity of the exercise. As a first step simple verification tools shall be developed. Overall building performance can be added to the code once data has been collected from the Energy Audit programme.
- It is proposed to consider specifying solar hot water installations as a mandatory requirement, but for certain types of buildings only. For instance, it should be proposed for buildings which would have the highest usage of hot water, may be excluded from this requirement.
- It is recommended that a guidebook is developed for use with the code.

2 Introduction

Energy codes and standards provide minimum building requirements that are cost-effective in improving energy efficiency in buildings. The latter is very important, as buildings are estimated to account for about 30% of the energy consumption globally.

Mauritius being on the fast track of development, is experiencing a high rate of growth in new buildings, with developments of luxurious resorts, shopping malls, residential and beach villas, and other energy-intensive buildings. The initial design of a building can greatly influence the building’s future energy footprint, and therefore the implementation of energy codes can set the necessary standards for improving energy efficiency right at the beginning of a building project.

Energy codes are usually attached to the country’s Building Regulations or Building Act and cover the technical specifications and methodologies towards achieving the minimum compliance requirements. Some countries refer to their building energy regulations as codes and others as standards. All building energy codes and standards generally set out the requirements for energy efficiency, but they can differ in several aspects in different countries. The main differences lie in the scope, the mandatory requirements, and compliance mechanisms.

Building energy codes usually cover issues such as thermal and solar properties of the building envelope (walls, roofs, windows and other elements in contact with the external environment), heating, ventilation and air conditioning (HVAC), hot water supply and lighting. Some codes and standards may also cover issues such as natural ventilation and implementation of renewable energy. In some countries, different issues are considered under different codes or standards. For instance, the UK Building Regulations consist of fourteen “parts”, each covering specific issues separately; such as Fire Safety (Part B), Ventilation (Part F), Sanitation (Part G), etc. The requirements for energy efficiency in buildings are covered under Part L (Conservation of fuel and Power).

This report covers the review of energy codes in several countries across the world, with the purpose of analysing their historical backgrounds (code development and maintenance), compliance mechanisms, minimum requirements of aspects such as the building envelope, building services (HVAC, lighting, etc.), and contribution of renewable energy. The selection of countries was mainly based on factors such as proximity to Mauritius, climatic conditions, similarity in living and economic standards and access to different types of building materials. The energy codes selected for review are those of Reunion Island, South Africa, Australia, India, Malaysia, Botswana, England, Denmark and USA. Furthermore the voluntary energy efficiency approach Passive House Standards has been reviewed as a standard that goes even beyond national building codes

The aim of this report is to provide an insight into the building energy codes being reviewed, and to analyse how successful or unsuccessful their different approaches have been. Being in the initial stages of developing its own energy codes, Mauritius will benefit from countries around the world which have developed and implemented similar codes, by learning about issues such as how certain challenges were addressed and what measures were taken to overcome any barriers towards implementation of the energy codes.

2.1 Background

In 2009 Ministry of Renewable Energy & Public Utilities defined a Long-Term Energy Strategy 2009-2025 and Action Plan for The Republic of Mauritius. It puts great emphasis on developing the energy sector up to 2025 including development of renewable energy, reduction of the independence on imported fossil fuel and the promotion of energy efficiency.

One initiative to meet the goal regarding energy efficiency in the building sector is the project: 00058178/Removal of Barriers to Energy Efficiency and Energy Conservation in Buildings – PS/MAR 2010/002, funded by GEF/UNDP and AFD which includes consultancy for preparation of:

- A new Building Control Bill,
- Building Code for Energy Efficiency,
- Regulation to the new Building Control Bill on the subject of Energy Efficiency,
- Compliance Mechanisms

As part of the project is to review International Best Practice for the Building Control Bill, in relation to Energy Efficiency. The review collects, compare and evaluate selected International Energy Standards, Regulations and Codes with the aim to form the basis for the following development of Energy Efficiency related to the New Building Control Bill.

The overall project goal for the mother-project Removal of Barriers to Energy Efficiency and Energy Conservation in Buildings is to reduce GHG emissions sustainably through a transformation of the building energy efficiency market for existing and new buildings.

The project is intended to overcome barriers to energy efficiency in buildings in Mauritius and reinforce the development of a market approach to improving residential and non-residential building energy efficiency in both existing stock and future buildings.

2.2 Global Status of Energy Codes

During the past three decades, governments in both industrialized countries and the global south have initiated policies to reduce energy consumption in buildings. Most of these policies can be grouped into one of the following three categories: economic incentives (e.g. taxes, energy pricing), informational programs (e.g. energy awareness campaigns, energy audits), or regulatory requirements (e.g., codes or standards).

A comprehensive investigation on the worldwide status of energy standards for buildings in 81 countries has been carried out by Kathryn Janda, Senior Researcher, Lower Carbon Futures, Environmental Change Institute, Oxford University. Data is gathered though an on-line survey, reports and appropriate web-sites.

Figure 1. Overview of Energy Codes prevalence in 81 countries, 2009.

It is found that in 2009 some 61 of the 81 countries have some kind of mandatory and/or voluntary existing standard, 11 countries had proposed standards and 9 countries had no standards.

The survey also shows that even though many countries do not have energy standards for buildings, there is evidence of other kind of programs to promote energy efficiency or energy conservation in buildings. Initiatives like energy labeling for appliances are widespread among in many countries not having general requirements to energy usage in buildings.

In the European Union, regulation for energy efficiency in buildings is mainly based on the directive for Energy Performance in Buildings – Directive 2002/91/ED of the European Parliament and of the Council of 16 December 2002 (EPBD). Each member countries have to set standards for overall Energy Performance for buildings and require calculations as shown in the figure below. It is up to each individual member state to develop models for energy performance, and requirement shall be revised at least every 5 year. In these years, most of the states updates energy efficiency standards every second year.

Annex 1
1. The methodology of calculation of energy performances of buildings shall include at least the following aspects:
(a) Thermal characteristics of the building (shell and internal partitions, etc.). These characteristics may also include air-tightness;
(b) Heating installation and hot water supply, including their insulation characteristics;
(c) Air-conditioning installation;
(d) Ventilation;
(e) Built-in lighting installation (mainly the non-residential sector);
(f) Position and orientation of buildings, including outdoor climate;
(g) Passive solar systems and solar protection;
(h) Natural ventilation;
(i) Indoor climatic conditions, including the designed indoor climate.

Figure 2. Calculation requirements set in EPBD.

In North America and Canada each individual state is responsible for setting energy standards. The ASHRAE standard (American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc) and IECC (International Energy Conservation Code) are mainly based on model codes built on prescriptive efficiency requirements or trade off models where buildings are compared to a model building. Most states have implemented regulations based on the ASHRAE standards for commercial and larger residential buildings and the IECC codes for small residential buildings.

Australia and New Zealand has developed a very successful 5 star system for rating energy efficiency in both residential and commercial buildings used to drive the marked towards a higher efficiency than minimum requirements set by national government.

On behalf of an overall survey of international energy efficiency codes and standards a number of appropriate codes have been selected for elaborated review related to Mauritius conditions.

3 Selected Codes and Standards

Code	Country
USA	
ICC International Energy Conservation Code 2009 (IECC)	ÚSA
ANSI/ASHRAE/IESNA Standard 90.1-2007	USA
EUROPE	
United Kingdom Building Regulations	England
Danish Building Regulation (BR08)	Denmark
Passiv Haus Standard	Voluntary
AFRICA	
South African National Standard (SANS 204) (2008)	South Africa
Energy Efficiency Considerations in the Botswana Building Regulation (2007) - Draft	Botswana
ASIA – PACIFIC - INDIA	
The RTAA DOM (Réglementation Thermique, Acoustique et Aération - Départements d'Outre Mer)	Reunion
Building Code of Australia (2009)	Australia

Malaysia Guidelines for Energy Efficiency in Buildings (2007) MS 1525:	Malaysia
India Energy Conservation Building Code	India

Figure 3. Selected Building Codes and Regulations

Tables 1a and 1b provide an overview of the reviewed documents under several criteria.

Criteria\Standard	USA - IECC	India - ECBC	Malaysia	USA - ASHRAE	UK - Part L	Reunion - RTAA DOM
REGULATION METHOD						
			Approval of a Standard as a Malaysian Standard is governed by the Standards of Malaysia Act 1996 (Act 549). MS 1525:2007 was developed by the Technical Committee on Energy Efficiency in Buildings under the authority of the Building and Civil Engineering Industry Standards Committee.		The energy efficiency requirements are conveyed in Part L of Schedule 1 to the current UK Building Regulations (2006).	The RTAA DOM is in the form of a decree, which amends the “Code de la construction et de l’habitation” (Code of construction and housing) on specific provisions for French Overseas Departments. The RTAA DOM only came in force as of the 1st May 2010 and therefore all applications for a building permit made after this date, need to comply with the requirements of the RTAA DOM. The RTAA DOM sets requirements for new residential buildings in the Overseas Departments and Territories of France, which include the departments of Guadeloupe, Guyana, Martinique and Reunion Island.
COMPLIANCE METHOD						
		The building shall comply with the	Compliance will be established if, the design	Compliance documents shall show all the	In order to meet the requirements of the Part	The RTAA DOM consists of three sets

		mandatory provisions, wholebuilding performance methods, and the prescriptive methods for either envelope, HVAC or lighting. Administrative requirements relating to permit requirements, enforcement, interpretations, claims of exemption, approved calculation methods, and rights of appeal are specified by the authority having jurisdiction.	building annual energy use, does not exceed the base building annual energy use as calculated by the same simulation program; and if the energy performance rating for equipment or components specified in the design building are not less than the rating used to calculate the base building energy consumption. Exceptional compliance: Utilisation of on-site renewable energy sources (such as photovoltaic) or siterecovered energy, is encouraged or exceed the energy used by the design building as simulated as per the requirement here, Modelling or simulation of the Base building need not be performed.. The annual energy consumption of the design building is permitted to be reduced by subtracting 100% of the annual renewable energy or siterecovered energy utilised.	pertinent data and features of the building, equipment, and systems in sufficient detail to permit a determination of compliance by the building official and to indicate compliance with the requirements of this standard. Supplemental information necessary to verify compliance with this standard, such as calculations, worksheets, compliance forms, vendor literature, or other data, shall be made available when required by the building official.	L of the UK Building Regulations, buildings are to meet the minimum energy performance requirement specified in the regulations. This is referred to as the Target CO2 Emission Rate (TER), measured in kg/m2/year. The actual emission rate of a building must be less than TER in order to comply with the Part L requirements. Since October 2008, every new building is required to have an Energy Performance Certificate (EPC), which provides a diagnostic of the building's general information, energy performance and recommendations for improvement. A Display Energy Certificate (DEC) is required for public buildings larger than 1000m2 which are occupied or part occupied by public authorities or by institutions providing public services and therefore frequently	of regulations: thermal regulations, regulations for acoustics and regulations for ventilation. The RTAA DOM sets out requirements for the minimum level of performance that needs to be achieved for those aspects. Compliance would be to meet the prescriptive requirements of the RTAA DOM.

					visited by the public.	
BUILDING CLASSIFICATION						
	Commercial and residential	buildings or building complexes that have a connected load of 500kW or greater or a contract demand of 600 kVA or greater	Commercial and residential	New buildings and their systems	New dwellings	New residential buildings only
		Except buildings that do not use either electricity or fossil fuel and, equipment and portions of building systems that use energy primarily for manufacturing processes		New portions of builings and their systems	Existing dwellings	
				New systems and equipment in existing buildings	New non-domestic buildings	
				Except for single-family houses, multi-family structures of three stories or fewer above grade, and manufactured houses (mobile homes and modular)	Existing non-domestic buildings	
CLIMATE DEFINITIONS						
	Three classes of climate are defined, relating to precipitation / moisture: Marine, Moist and Dry.	Composite; hot and dry; warm and humid; moderate; cold		Unites States locations; International locations	One climate zone is used for the whole of UK.	The island is divided into 2 climate zones: windward and downwind areas.

	Ten classes of climate are defined relating to Dry Bulb temperature heating and cooling degree days.					The codes however sometimes refer to areas at certain altitudes (e.g. for prescribing U-value or solar factor limits)
	Any particular climate therefore falls into one of the three moisture classes and one of the temperature classes.					
BUILDING ENVELOPE						
Envelope	The code includes specifications for U-factors, R-values for wall and roof elements and SHGC (solar heat gain coefficient) values for fenestration elements.	The mandatory requirements specify that U-factors, SHGCs shall be determined, and indicate how these shall be determined, without setting any requirements for their values.		The mandatory requirements for insulation, fenestration and doors, and air leakage shall be used to determine compliance	Requirements for limiting U-values vary depending on whether building is new or existing and whether domestic and non-domestic. Different U-value limitations are given for existing buildings depending on whether the existing elements are replaced, or retained and upgraded.	Requirements for the performance of the building envelope are specified to reduce the solar gains. Requirements are for vertical and horizontal structures.
	It also includes requirements for control of air leakage and control of moisture.	They also specify maximum air leakage rates for fenestrations and doors as 2.0l/s-m2, and require that all openings in the envelope be sealed.		Provision for conditioned, semiheated and unconditioned spaces in the prescriptive part, shall be complied with	The building fabric should be constructed to a reasonable quality so that: a. The insulation is reasonably continuous over the whole building envelope; and b. the air permeability is	A structure is defined as 'horizontal' if its angle to the horizontal plane as seen from inside the building is less than 60 degrees, and a structure is defined as 'vertical' if its angle to the

					within reasonable limits.	horizontal plane as seen from inside the building is greater than 60 degrees.
	The prescriptive requirements are similar to those for residential buildings, but include additional building elements that are found in commercial buildings.				For new domestic and non-domestic buildings, the Part L documents state that a reasonable limit for the design air permeability is 10m3/(h.m2) @ 50 Pa.	
Roofs	The R-value of the insulating material in commercial buildings shall be based on construction materials used in the roof assembly	Roofs are required to comply with either a max. assembly U-factor, or min. R-value for insulation. A minimum reflectance of .7 is required for roofs with slope of <20°.	A maximum U-value is defined for roofs that have no skylights. For roofs that do have skylights, a Roof Thermal Transfer Value (RTTV) is defined that combines the various thermal transfer values for the roof surfaces and skylights into one value. It has units of Watts per metre squared (W/m^2).	Tables 5.5-1 through 5.5-8. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.	For *new* domestic and non-domestic buildings, all roof types need to comply with an area-weighted limiting U-value of 0.25 and individual roof element limiting U-value of 0.35. For existing buildings, different limiting U-values are provided for new roof element in extensions, depending on whether itis pitched roof with insulation at ceiling level, pitched roof with insulation at rafter level, and flat roof with integral insulation.	A “solar factor” S is specified for opaque roofs as follows: S ≤ 0.03 In the higher zones of Reunion (atitudes > 800m), a minimum insulation is required for roofs, and is defined by limiting U-value of 0.5 $W/m^2.K$.

			Daylight credits are allowed for skylights, subject to certain conditions.	High Albedo roofs; above-grade wall insulation; below-grade wall insulation; floor insulation; slab-on-Grade floor insulation; opaque doors		Roofs should not to contain any windows or transparent/ translucent material, except for buildings which are located at an altitude greater than 800m.
Opaque walls	Walls are classified as above-grade and below-grade walls. They comply with a mimimum R-value for insulation	Similarly, walls are required to comply with either a max. assembly U-factor, or min. R-value for insulation.	The approach to the building envelope is to define an Overall Thermal Transfer Value (OTTV). This is a weighted summation of the thermal transfer properties of all the envelope elements that make up the walls of the building. (This is not specifically stated, but can be assumed from the definition and the later sections of the Code that define properties for other envelope elements including the roof and the floor.) It has units of Watts per metre squared (W/m^2).	R-values, U-factor, C-factor or F-factor	For new domestic and non-domestic buildings, the limiting U-value is 0.35 for walls. In existing buildings, for new roof in an extension, the limiting wall U-value = 0.3 Retained walls should be upgraded to U-value 0.35 if the existing wall U-value > 0.7	The “solar factor” S is specified for opaque walls as follows: S ≤ 0.09 In the higher zones of Reunion (atitudes > 800m), the limiting U-value required for walls is 2.0 $W/m^2.K$.

Fenestration	For vertical fenestration, maximum U-factor and SHGC are based on the window projection factor.	Fenestration requirements include the following: Maximum area weighted U-factor, and Maximum area weighted SHGC. Vertical fenestration is limited to max. 40% of gross wall area in the Prescriptive Method.		Gross wall areas and gross roof areas shall be calculated separately for each space-conditioning category for the purposes of determining compliance	In new domestic and non-domestic buildings, windows and curtain walling area-weighted U-value should be < 0.22 In existing buildings, retained windows should comply with overall limiting U-values or be upgraded. Upgraded windows should comply with an overall limiting U-value of 1.8, or 1.2 if measured at centre pane.	The solar factor requirement for windows has been set as follows in RTAA DOM: Windows adjacent to an air-conditioned space: $S \leq 0.25$ Windows adjacent to an un-conditioned space: $S \leq 0.65$
				U-factors and SHGC, fenestration area		
Building envelope trade-off		A trade-off option is allowed whereby improved performance in one envelope element can be offset against lower performance in another.				
HVAC						
Mechanical systems	Control systems are required to include a thermostat for each zone.		Various requirements for HVAC systems are specified	Minimum equipment efficiencies - standard rating and operating conditions, and nonstandard conditions	For non-domestic buildings, the performance of air handling plant would need to consist of: a. suitably efficient air handling plant; and	Where mechanical ventilation is required, minimum air extraction rates are specified for different types of houses (2 bed, 2 bed or >3 bedrooms) and for

					b. effective control systems.	different utility spaces (kitchen, toilets, and bathrooms).
	Specifications are included for insulation of ducts, etc.		Sizing method to be based on the ASHRAE handbook, with indoor conditions specified; control systems; CoP for various equipment types			
	Mechanical systems are to be sized in accordance with Code M1401.3 International Residential Code.				Table 35 of the Non-domestic Heating, Cooling and Ventilation Compliance Guide (NBS, 2006) specifies the limits to (Specific Fan Power) SFP of mechanical ventilation systems in new buildings.	For living spaces, the following minimum outdoor air exchange rates are required : • Bedrooms: ≥ 20 m3/h • Living room/ dining room/ lounge: ≥ 40 m3/h
	Design loads shall be determined in accordance with the procedures described in the ASHRAE Fundamentals Handbook.				For domestic buildings, reasonable provision would be to install mechanical ventilation systems which also have specific fan powers and heat recovery efficiency not worse than the following:	The mechanical ventilation systems have the option to be switched off by means of control equipment when air conditioning is not in use.

	HVAC system performance requirements are specified, e.g. COP for a wide range of different equipment types.				SFP for continuous supply and continuous extract = 0.8 L/s.W SFP for balanced systems = 2.0 L/s.W Heat recoevery efficiency = 66%	In addition, all living spaces should make provision for the later connection of a ceiling fan or have a ceiling fan installed as from the construction of the building.
	More detailed control requirements are specified than those for residential buildings, including a requirement for a deadband between heating and cooling setpoints, and setback controls for zones that are not continuously occupied.					
HVAC system construction and insulation						
Natural ventilation	Ventilation shall be in accordance with Chapter 4 of the International Mechanical Code	Natural ventilation is required to comply with the design guidelines for natural ventilation in National Building Code of India.				It is required that there is an uninterrupted flow of air through the living spaces of the building via external openings, by designing the building such that there are openings on different orientations of the building and in internal walls

		Minimum equipment efficiencies (COP) are specified for a number of types of equipment. Others are required to conform to AHSRAE 90.1-2004 #6.4.1.				Openings ae required in at least two facades in different orientations, and the minimum area of window openings for buildings at an altitude < 400m is 20% opening area on one façade. For buildings at an altitude between 400m and 800m, at least 15% opening is required on one façade. Buildings at an altitude greater than 800m do not have a minimum requirement with regards to window-to-wall ratio.
						Limits are also provided for the positioning of windows for better natural ventilation.

HVAC equipment control	Requirements specified for thermostatic controls with a deadband of 2.8ºC, off-hour controls, shutoff damper controls, snow melt system controls	Requirements for control systems include timeclocks and thermostats with a deadband of 3°C, with separate heating / cooling equipment thermostats interlocked to prevent simultaneous heating / cooling.		Load calculations; zone thermostatic controls; setpoint overlap restrictions; off-hour controls; ventilation system controls; heat pump auxiliary heat control; air system and design control; hydronic system design and control	**Min. control for cooling plant:** Multiple cooling modules should be provided with controls to provide the most effi cient operating modes for the combined plant. **Min. control for cooling system**: Each terminal unit capable of providing cooling must be capable of time and temperature control either by its own, or remote, controls • In any given zone simultaneous heating and cooling shall be prevented by a suitable interlock	
HVAC prescriptive requirements	Prescritive requirements for smaller HVAC systems include economisers and variable flow hydronic systems.	Prescritive requirements for smaller HVAC systems include economisers and variable flow hydronic systems.				For air-conditioned buildings or rooms with air conditioning, adequate ventilation within these areas is to be provided as per the provisions for mechanical ventilation.
		Larger systems are required to comply with ASHRAE 90.1-2004 #6.5.				

Energy recovery	Energy recovery ventilation systems are required, with some exceptions.			Exhaust air; service water heating		
Exhaust hoods energy recovery				Kitchen hoods; fume hoods		
Duct and pipe	Duct and pipe insulation and leakage are controlled.	Insulation and sealing of pipework and ducts are specified.		Duct and plenum insulation and leakage; piping insulation	Reasonable provision would be demonstrated by insulating pipes, ducts and vessels to standards that are not worse than those set out in the Non-domestic Heating, Cooling and Ventilation Compliance Guide (NBS, 2006) and Domestic Heating Compliance Guide (NBS, 2006).	
Service water heating	Service water heating requirements are specified, including efficiency of the heating equipment and various requirements for the distribution and control systems.	Solar water heaters or heat recovery systems must be provided to supply at least 20% of design capacity for residential facilities, hotels and hospitals.		Load calculations, equipment efficiency, service hot water piping insulation, service hot water heating system controls, pools, heat traps	Guidance in the Non-domestic Heating, Cooling and Ventilation Compliance Guide (NBS, 2006) and Domestic Heating Compliance Guide (NBS, 2006) should be followed, with regards to: a. the use of an appliance with an efficiency not less than that recommended for its type and; b. the provision of controls that meet the minimum control requirements for the particular type of	According to the RTAA DOM requirements, all new homes must be fitted with a solar hot water system, which should amount to at least 50% of the hot water demand.

					appliance and heat distribution system.	
		Heated pools are required to have a cover, unless solar heated				
LIGHTING						
	Automatic shut off control (typically by occupancy sensors) is required for buildings >465m2.	Occupancy sensors in buildings >500m2 for offices <30m2, meeting rooms, classrooms and storage spaces.	Recommended average lighting levels for various activities are specified.	Lighting control - automatic lighting shut-off; space control	For office, industrial and storage areas in all building types, the average initial efficacy should be no less than 45 luminaire-lumens/circuit-Watt.	
	Daylight switches are required to all exterior lights.	Switches in each room.	Maximum lighting loads (W/m^2) are specified for different classes of buildings.		For any other non-domestic buildings, an average initial (100 hour) lamp plus ballast efficacy of not less than 50 lamp lumens per circuit-Watt is required.	

	Lighting power is controlled by specifying maximum installed capacity for various indoor and outdoor spaces, generally in terms of W/m2.	Daylight dimmer switches in daylighted areas >25m2.	Lighting control requirements are specified to ensure that lights can be switched off when not needed, and to allow daylight energy savings strategies to be implemented.		For domestic buildings, the requirement is to provide lighting fittings (including lamp, control gear and an appropriate housing, reflector, shade or diffuser or other device for controlling the output light) that only take lamps having a luminous efficacy greater than 40 lumens per circuit-Watt.	
	Lighting systems shall be provided with controls	Daylight switch to all exterior lights.			Lighting controls should be present so as to avoid unnecessary lighting during the times when daylight levels are adequate or when spaces are unoccupied.	
Interior lighting power		Two alternative methods are provided for determining the max. interior lighting power.		Building area method or space-by-space method		
Exterior lighting power		Limits to exterior lighting power are defined for various locations, such as entrances, exits and facades.		All exterior lighting shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours		
ELECTRICAL POWER						

Electrical power	metering electrical energy consumed	Transformer losses.; Energy efficiency motors; Power factor correction; Metering requirements	Various requirements for electrical power and distribution are specified, including limits to the sizing of motors, minimum motor efficiencies, power factor correction, etc.			
DESIGN GUIDELINES						
Architectural and passive design strategy			The Code includes a section on design strategies for achieving energy efficiency including the following aspects:			
			Orientation and geometry; Arrangement of windows and other fenestration elements; Sunpath diagram; Façade design; Natural ventilation; Strategic landscaping			
ALTERNATIVE COMPLIANCE METHODS						

Simulated performance alternative	Simulated performance may be used as an alternative to the 'deemed to satisfy' requirements. In this case the applicant is required to demonstrate that the proposed building has equivalent or lower energy cost than a standard reference building that meets the 'deemed to satisfy' requirements, using software that meets certain standards.					
	Specifications are given for the characteristics of both the standard reference building and the proposed building.					
Simulated performance alternative	The simulated performance alternative applies in the same way as for residential buildings.					
	(Commercial energy efficiency) ASHRAE/IESNA Standard 90.1, Energy Standard for Buildings Except for Low-Rise Residential Buildings, may be used as an alternative to this code.					

Table 1a. Overview of reviewed documents

Criteria\Standard	Australia - BCA	Denmark	Passiv House Standard	South Africa	Botswana
REGULATION METHOD					
	The BCA is given legal effect by building regulatory legislation in each State and Territory. This legislation consists of an Act of Parliament and subordinate legislation which empowers the regulation of certain aspects of buildings and structures, and contains the administrative provisions necessary to give effect to the legislation. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation and therefore the BCA must be read in conjunction with that legislation. Compliance with the Performance Requirements can only be achieved by: (a) complying with the Deemed-to-Satisfy Provisions; or (b) formulating an Alternative Solution which: (i) complies with the Performance Requirements; or (ii) is shown to be at least equivalent to the Deemed-	The Danish Building Regulation dated 2008 (BR08) is a national and mandatory regulation that describes the overall functional requirements related to erection of all new buildings, extensions to buildings, conservation of and any other alterations to buildings and any significant change of use of buildings and finally with the demolition of buildings. Any building permit application much include a calculation of the building energy consumption or a calculation of heat loss depending on building type and heating level. All calculations much be done in accordance to methods set out in SBI Guideline 213 Energy Demands of Buildings (energy frames) or DS 418 Calculation of heat loss from buildings (individual constructions). The energy performance framework covers the total needs of the building for supplied energy for heating, cooling, domestic hot water and electricity.	The Passive House concept is in general a comprehensive voluntary, beyound standard approach to cost-efficient, high quality, healthy and sustainable construction.The definition of a Passive House is: “A building in which a comfortable indoor climate can be obtained without a traditional heating or cooling system”. A Passive House Certificate can be obtained for two different building classes – Buildings for Residential Use and Buildings for Non-Residential use. Verification of energy design for a Passive House must be carried out with the aid of the 'Passive House Planning Package' (PHPP). At the core of the package are worksheets for heating energy balances (annual demand or monthly method), heat distribution and supply, electricity demand and primary energy demand.	In October 2008 the SANS 204 was published as a National Standard for “Energy Efficiency in Buildings “. The South African National Standards for Energy Efficiency is currently a voluntary standard including 3 parts, but are expected to become part of the SANS 10400 National Building Code later in 2010, whereupon it will be compulsory for all new buildings to comply with these minimum standards. Compliance with the SANS 204 requirement shall be done through a rational design prepared by a competent person (qualified mechanical or electrical engineer), by: • Demonstrating that requirements for a maximum energy demand depending on building classification and climate zone are met • Providing a certificate of compliance to the local authority as part of the requirements for obtaining an occupancy certificate. • For artificially ventilated or air-conditioned buildings the energy rating shall be	A Draft Energy Code for Buildings in Botswana has been prepared in 2007. The code is largely based on The Building Code of Australia (BCA) and the IEEC Energy Code focusing on large scale buildings and is under implementation in the existing Building Regulation. The code apply to all buildings with a floor area of more than 500 m2 other than simgle dwelling residential buildings. Each Code section includes statements of “Performance Requirements” consisting of conceptual qualitative requirements. In the first version of the code quantitative requirements are avoided since these may vary due to the different climate zones in the country, but can easily be amended in future. For each performance requirement “deemed-to-satisfy” provision that is approved as meeting the requirements are defined. Alternative solutions in

	to-Satisfy Provisions; or (c) a combination of (a) and (b).	Electricity is not included in dwellings. Even if the energy performance framework has been complied with, the design transmission loss (excluding the loss from windows and doors), may not exceed certain values.		displayed through annually reports on energy usage. SANS 204 - Part 1 covers the occupancies of public buildings, offices and hotels; other buildings shall comply with the provisions of SANS 204-2 and 3	order to meet the overall performance requirements may be proposed, but shall be supported by an approved assessment method (building simulation programs e.g.).
COMPLIANCE METHODS					
		Any building permit application much include a calculation of the building energy consumption or a calculation of heat loss depending on building type and heating level. All calculations much be done in accordance to methods set out in SBI Guideline 213 Energy Demands of Buildings (energy frames) or DS 418 Calculation of heat loss from buildings (individual constructions).	Verification of energy design for a Passive House must be carried out with the aid of the 'Passive House Planning Package' (PHPP). At the core of the package are worksheets for heating energy balances (annual demand or monthly method), heat distribution and supply, electricity demand and primary energy demand. A comprehensive checklist defines the minimum criteria for the content of calculations. Furthermore the following documentations shall be delivered together with the application: • Drawings • Technical Specifications and	Compliance with the SANS 204 requirement shall be done through a rational design prepared by a competent person (qualified mechanical or electrical engineer), by: • Demonstrating that requirements for a maximum energy demand depending on building classification and climate zone are met • Providing a certificate of compliance to the local authority as part of the requirements for obtaining an occupancy certificate. • For artificially	Each Code section includes statements of “Performance Requirements” consisting of conceptual qualitative requirements. In the first version of the code quantitative requirements are avoided since these may vary due to the different climate zones in the country, but can easily be amended in future. For each performance requirement “deemed-to-satisfy” provision that is approved as meeting the requirements, e.g. maximum U-values for specific building components. Alternative solutions in order to meet the overall performance requirements may be proposed, but shall be

			data sheet for energy consuming appliances • Verification of air tightness in the building envelope	ventilated or air-conditioned buildings the energy rating shall be displayed through annually reports on energy usage. The building service systems should be inspected by a responsible person (building owner/person acting on his behalf) and a certificate should be provided to the local authority.	supported by an approved assessment method (building simulation programs e.g.).
BUILDING CLASSIFICATION					
	Different dwelling types	New buildings	Residential buildings	All new buildings except government subsidized housing	All buildings with a floor area greater than 500 m2 other than single dwelling residential buildings
	Office buildings used for professional or commercial purposes	Extensions to buildings	Non-residential buildings		
	Building which is for carpark or storage or display of goods for wholesale	Conservation of and any other alterations to buildings and any significant change of use of buildings			

	Laboratory	Demolition of buildings			
	Public building				
	Non-habitable building				
CLIMATE DEFINITIONS					
	8 climatic zones are defined, ranging from Northern areas to Southern "Alpine" areas	One Climatic Zone: Temperate Climate	Temperate Climate; Central Europe locations	Six climatic zones defined for interior/coastal areal; Cold, temperated, hot, sub-tropical, arid	No defintion of Climatic Zones in draft code.
BUILDING ENVELOPE					
Envelope	Building envelope performance requirements are specified for roofs and ceilings, walls and floors, and are generally divided for various building classes and climate zones. Building envelope performance requirements are specified through limiting R-values.	Mandatory requirements for U-values for all building enevelope elements and figures for linear heat loss shall be complied with. (Involves buildings heated to at least 5 oC)	Mandatory requirements for U-values for external construction elements and linear heat loss shall be complied with.	Mandatory requirements for R-values spcefied for buildings envelope elements.	Building fabrics must have a level of thermal performance to facilitate the efficient use of energy for heating and cooling
	Sufficient openings must be provided and distributed in a building so that natural light, when available, provides a level of illuminance appropriate to the function or use of that part of the building. Natural lighting must be provided either through windows or rooflights.	Mandatory requirements for design transmission loss may not exceed specified values set for single storey buildings and multiple storey buildings.	List of calculation results from the U-Values worksheet, building element data bank. Heat transfer coefficient calculations in accordance with DIN EN ISO 6946	Various air-leakage requirements are defined for windows and doors.	

		Air leakage in building envelope may not exceed 1.5 l/sm2	Air leakage in building envelope may not exceed 0.6 time the house volume per hour, and must be tested by a "Blower Door Test"	Builiding envelope and openings in specific climatic zones shall be designed to minimise infiltration. Sealing or close fitting af ceiling, wall and floorjunction are required for some climatic zones.	
Roofs	Different R-values are provided for roofs and ceilings based on the climate zone and the solar abosrbance value of the upper surface.			Reflective insulation shall be installed and supported. Thermal performance values (U-values and SHGC) for roof lights shall be complied with.	Alternative 1: Shall be deemed to comply with max. U-values for different external surface reflectances Alternative 2: Annual energy gain and max. Daily heat gain shall not be more than for a building complying with Alternative 1.

Opaque walls	R-values are prescribed for external walls, except for opaque non-glazed openings in external walls such as doors (including garage doors), vents, penetrations, shutters and the like; and an earth retaining wall or earth-berm, in other than climate zone 8. The prescribed R-values vary depending on the climate zones. There is flexibility on the R-values prescribed, whereby they can be reduced if for example a wall is south facing or adequately shaded by an overhang.				Shall have max. U-value of 2.5 W/m2K
Fenestration	The glazing in each storey, including any mezzanine, of a building must be considered such that the total U-Values and SHGCs are assessed for the combined effect of the glass and frame, so as to reduce air-conditioning energy consumption attributable to glazing. Internal glazing need also be assessed if it is located between an un-conditioned and conditioned space.		U_W-value determination. Characteristic values of glazings and frames. Determination of shading coefficients and influence of window orientation	Aggregate air-conditioning energy value shall be calculated by taken SHGC, U-value, shading conditions, energy constants for specific climatic zones into account. Table values for air-conditioning energy shall be complied with.	Alternative 1: Overall fenestration ares shall not exceed 40% of total wall area. Alternative 2: Annual energy gain and max. Dailyi heat gain shall not be more than for a building complying with Alternative 1.

	The assessment of the glazing performance is done by considering the “aggregate air-conditioning energy value” which is calculated by adding the air-conditioning energy value through each glazing element			Aggregate conductance and solar heat gain shall not exceed table values.	
Building envelope trade-off		Trade-off options is allowed for individual building elements, but requirements for individual U-values shall be complied with		Trade-off options is allowed for individual building elements, but requirements for individual U-values shall be complied with	Trade-off options is allowed for individual building elements
HVAC					
Mechanical systems	When the mechanical ventilation is provided by means other than an air-conditioning system and the air flow rate is more than 1000 L/s, the system should have a fan power to air flow rate ratio of 0.5 W/(L/s) without filters or 0.75 W/(L/s) with filters for a general mechanical ventilation system.	Mechanical balanced ventilation with heat recovery is mandatory in shool and day-care facilities.	No central heating system is allowed in passive houses.	Various requirements for HVAC systems are specified for the two buildings classes a) natural environmental control and b) artificial environmental control	Deemed-to-sastisfy solutions shall comply with sections from IECC.
	ventilation system, must be capable of being deactivated when the building or part of the building served by that system is not occupied.	Various efficiency and max. power consumption requirements for HVAC systems are specified	Mchanical balanced ventilation with heat recovery	Efficiencies for cooling and heating equipment shall be in accordance with ASHRAE 90.1, listed in a table.	

	For carpark exhaust, when serving over 40 vehicles, mechanical ventilation should be controlled by an atmospheric contaminant monitoring system, and should maintain an average minimum air-change rate of 0.5 ACH other than when the carpark is not occupied for a period of more than 2 hours.				
	Ceiling fans are required as part of compliance and must be permanently installed, have a speed controller and serve the whole room, with the floor area that a single fan serves not exceeding:				
	(i) 15 m2 if it has a blade rotation diameter of not less than 900 mm; and (ii) 25 m2 if it has a blade rotation diameter of not less than 1200 mm.				

HVAC system construction and insulation		Requirements for insulation of piping and storage tanks for hot water shall be complied with	Recommendations for design of piping and ducts. Distribution losses; DHW requirement and losses	Requirements for insulation of piping and storage tanks for hot water shall be complied with	
Natural ventilation	For adequate natural ventilation, the building must consist of permanent openings, windows, doors or other devices which can be opened with an aggregate opening or openable size not less than 5% of the floor area of the room required to be ventilated.			Buildings with natural environmental control shall coply with requirements defined in SANS 204-2:2008 on all topics regarding building envelope, HVAC sytems etc. as for other buildings.	

	Opening should be to a suitably sized court, or space open to the sky; or an open verandah, carport, or the like; or should "borrow" natural ventilation from an adjoining room.				

HVAC equipment control	When serving more than one sole-occupancy unit, air-conditioning zone or area with different heating and cooling needs, the system should: (a) thermostatically control the temperature of each sole-occupancy unit, zone or area; and (b) not control the temperature by mixing actively heated air and actively cooled air. An air-conditioning unit or system must be capable of being deactivated when building is not occupied. In a Class 3 (communal residential) building, the system should not operate when any external door, including a door opening to a balcony, patio, courtyard or the like is open for more than 1 minute. The system should also be capable of controlling the temperature of a sole-occupancy unit at a different temperature during sleeping periods than during other periods	Heating and cooling systems must be equipped with automatic regulation for individual control in individual rooms. For mechanical ventilation VAV regulation shall be possible.	Ventilation control equipment	Air-conditioning system shall be provides with control systems for comfort puposes, and systems shall be energy efficient. Temperature, humidity and zone control systems are required in air-conditioned facilities.	

HVAC prescriptive requirements	Other than where a packaged air-conditioning unit is used, the system should have a variable speed fan when its supply air quantity is varied. Where the air-conditioning system provides the required mechanical ventilation, the system should have an outdoor air economy cycle.	Prescriptive requirements for HVAC systems, including heating, boilers, oil fired boliers and small-scale CHP-plants < 120 KW	Prescriptive requirements for heat recovery units. Air flow rates, exhaust air/supply air balancing, pressurization test results	Prescriptive requirements for CAV and VAV Fan Systems; Fan Motor Power. Pumps for water side systems shall comply with efficiency requirements.	
Energy recovery		Energy recovery in ventilation and cooling sytems		Energy recovery in ventilation and cooling sytems	
Exhaust hoods energy recovery					
Duct and pipe	The HVAC system should have any supply and return ductwork adequately sealed and insulated in accordance with the specifications of the code.	Duct, pipes and adjustment equipment shall be insulated.		Leakage of duct works shall comply with SANS 10173. Friction loss shall not exceed specific figures.	

Service water heating	A hot water supply system for food preparation and sanitary purposes, other than a solar hot water supply system in climate zones 1, 2 and 3, must be designed and installed in accordance with Section 8 of Australian Standards AS/NZS 3500.4 (Plumbing and drainage - Heated water services). Heaters must achieve a thermal efficiency in accordance with BS 7190 and use reticulated gas where it is available at the allotment boundary.		Calculation of the fraction of DHW provided by the solar system	SWH is mandatory in all new buildings, unless it is not technically feasible. Minimum R-values for piping insulation shall be met. Hot water usage should be minimizedl, recommendations are provided in SANS 10152-1. SWH shall cover at least 50% of energy consumption for Hot Water.	In buildings with a installed water heating capacity more than 10 W/m2 floor area a minimum of 70% consumption shall be covered by SWH or process waste heat recovery
			Performance ratio of heat generator Compact building services unit. Performance ratio of heat generator Boiler		
LIGHTING					
	In a sole-occupancy unit of a Class 2 building or a Class 4 part of a building, the lamp power density or illumination power density of artificial lighting must not exceed: - within the building: 5 W/m2 - on a verandah or balcony of the building: 4 W/m2.	Specific light levels for various activities shall be complied with	Caculations for lightning are required	Minimum lighting level shall be determined, and recommendations for light level, power and energy consumption is listed in table.	Electrical Lighting shall comply with IECC section 505.

	Where lamps are used that have a transformer or ballast, the transformer or ballast must be of the electronic type.	Working areas, occupiable rooms in sinstitutions, teaching rooms, dining areas and habitable rooms must have sufficient daylight access.		Working areas, occupiable rooms in sinstitutions, teaching rooms, dining areas and habitable rooms must have sufficient daylight access.	
	Halogen lamps must be separately switched from fluorescent lamps.	Requirements for sufficient daylight access shall be complied with. Calculation of daylight factors shall be made.		Designers are encouraged to use daylighting.	
		Guidelines and standards specifies recommendations for: Lighting quality, -levels, -control and -zoning.			
Interior lighting power					
Exterior lighting power					
ELECTRICAL POWER					
Electrical power		Various requirements for minimum motor efficiencies are specified.	Electricity requirements	Power Factor correction.	Electrical power shall comply with IECC section 505.
			Auxiliary electricity requirements	Appliances (including elevators/lifts) fitted in new buildingsshall have an energy rating where available and office equipment as well where applicable.	Sub-meters shall be installed in multi-storey buildings with floorarea more than 500 m2. Each floor > 500 m2 shall have individual sub-meter.
DESIGN GUIDELINES					

Architectural and passive design strategy		Guidance for building lay-out, design and design approached are available. Guiding standard data and soloutions are available for orientation, geometry, glazing arrangement etc.	Comprehensive design guideline and checklist for building lay-out, building elements and all energy consuming building installations.	Guidelines for glazing assesments and general information on roof and ceilings contructions.	
				Diagrams for building orientation and energy consumption for various locations.	
ALTERNATIVE COMPLIANCE METHODS					
Simulated performance alternative					Alternative solutions to the deemed-to-satisfy solution may be proposed, and may include trade-offs between different building elements (not building systems). It is accepted if it can be documented with computer simulations that the alternative performance matches results from a deemed-to-satisfy solution.
Simulated performance alternative					

Table 1b. Overview of reviewed documents

4 ICC International Energy Conservation Code 2009 (IECC)

4.1 Introduction

The International Energy Conservation Code (IECC) 2009 is a model code that regulates minimum energy conservation requirements for new buildings. The code addresses energy conservation requirements for all aspects of energy uses in both commercial and residential buildings.

The first edition of the IECC 1998 was based on the 1995 edition of the Model Energy Code promulgated by the Council of American Building Officials (CABO).

4.1.1 Climate definitions

Three classes of climate are defined, relating to precipitation/moisture: Marine, Moist and Dry.

The climate zone for any location outside the United States shall be determined by applying Table 2(a) and then Table 2(b).

Table 2(a): International climate zone definitions

MAJOR CLIMATE TYPE DEFINITIONS
Warm-humid Definition—Moist (A) locations where either of the following wet-bulb temperature conditions shall occur during the warmest six consecutive months of the year: 1. 67°F (19.4°C) or higher for 3,000 or more hours; or 2. 73°F (22.8°C) or higher for 1,500 or more hours
Dry (B) Definition—Locations meeting the following criteria: Not marine and $P_{in} < 0.44 \times (TF - 19.5)$ [$P_{cm} < 2.0 \times (TC + 7)$ in SI units] where: P_{in} = Annual precipitation in inches (cm) T = Annual mean temperature in °F (°C)
Moist (A) Definition—Locations that are not marine and not dry.

For SI: °C = [(°F)-32]/1.8; 1 inch = 2.54 cm.

Table 2(b): International climate zone definitions

ZONE NUMBER	THERMAL CRITERIA	
	IP Units	SI Units
1	9000 < CDD50°F	5000 < CDD10°C
2	6300 < CDD50°F ≤ 9000	3500 < CDD10°C ≤ 5000
3A and 3B	4500 < CDD50°F ≤ 6300 AND HDD65°F ≤ 5400	2500 < CDD10°C ≤ 3500 AND HDD18°C ≤ 3000
4A and 4B	CDD50°F ≤ 4500 AND HDD65°F ≤ 5400	CDD10°C ≤ 2500 AND HDD18°C ≤ 3000
3C	HDD65°F ≤ 3600	HDD18°C ≤ 2000
4C	3600 < HDD65°F ≤ 5400	2000 < HDD18°C ≤ 3000
5	5400 < HDD65°F ≤ 7200	3000 < HDD18°C ≤ 4000
6	7200 < HDD65°F ≤ 9000	4000 < HDD18°C ≤ 5000
7	9000 < HDD65°F ≤ 12600	5000 < HDD18°C ≤ 7000
8	12600 < HDD65°F	7000 < HDD18°C

For SI: °C = [(°F)-32]/1.8

4.2 Administrative Provisions

4.2.1 Scope

The code is intended to provide flexibility to permit the use of innovative approaches and techniques to achieve the effective use of energy. It is not intended to abridge safety, health or environmental requirements contained in other applicable codes or ordinances. It is also not intended to prevent the use of any material, method of construction, design or insulating system not specifically prescribed herein, provided that such construction, design or insulating system has been approved by the code official as meeting the intent of this code.

4.2.2 Applicability

The code shall not be used to require the removal, alteration or abandonment of, nor prevent the continued use and maintenance of an existing building or building system lawfully in existence at the time of adoption of the code. Historic buildings are also exempt from this code.

However, additions, alterations, renovations or repairs to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portion(s) of the existing building or building system to comply with this code.

Spaces undergoing a change in occupancy that would result in an increase in demand for either fossil fuel or electrical energy shall comply with this code.

Any non-conditioned space that is altered to become conditioned space shall be required to be brought into full compliance with this code.

Where a building includes both residential and commercial occupancies, each occupancy shall be separately considered and meet the applicable provisions for residential and commercial buildings.

4.2.3 Enforcement mechanisms

Construction documents and other supporting data should be submitted in one or more sets with each application for a permit.

The construction or work for which a permit is required shall be subject to inspection by the code official. The building shall have a final inspection and not be occupied until approved. Moreover, the building shall be re-inspected when any work or installation does not pass an initial test. The code official is authorized to, in writing, suspend or revoke a notice of approval issued under the provisions of this code wherever the certificate is issued in error or where it is determined that the building is in violation of any ordinance or regulation or any of the provisions of this code.

A fee for each permit shall be paid as required, in accordance with the schedule as established by the applicable governing authority. No permit will be issued until the fees have been paid nor shall an amendment to a permit be released until the additional fee, if any, has been paid.

Whenever the code official finds any work regulated by this code being performed in a manner either contrary to the provisions of this code or dangerous or unsafe, the code official is authorized to issue a stop work order. Any person who shall continue any work after having been served with a stop work order, except such work as that person is directed to perform to remove a violation or unsafe condition, shall be liable to a fine.

4.3 Code maintenance and development

The IECC is kept up to date through the review of proposed changes submitted by code enforcing officials, industry representatives, design professionals and other interested parties.

The contents of the code are subject to change both through the Code Development Cycles and the governmental body that enacts the code into law.

4.4 Building envelope

4.4.1 Residential Energy Efficiency

4.4.1.1 Building thermal envelope

The building thermal envelope shall meet the requirements of Table 1 based on the climate zone.

Table 3. Insulation and fenestration requirement by component

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	1.2	0.75	0.30	30	13	3/4	13	0	0	0
2	0.65[j]	0.75	0.30	30	13	4/6	13	0	0	0
3	0.50[j]	0.65	0.30	30	13	5/8	19	5/13[f]	0	5/13
4 except Marine	0.35	0.60	NR	38	13	5/10	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.35	0.60	NR	38	20 or 13+5[h]	13/17	30[g]	10/13	10, 2 ft	10/13
6	0.35	0.60	NR	49	20 or 13+5[h]	15/19	30[g]	15/19	10, 4 ft	10/13
7 and 8	0.35	0.60	NR	49	21	19/21	38[g]	15/19	10, 4 ft	10/13

Three classes of climate are defined, relating to precipitation/moisture: Marine, Moist and Dry (Figure 4).

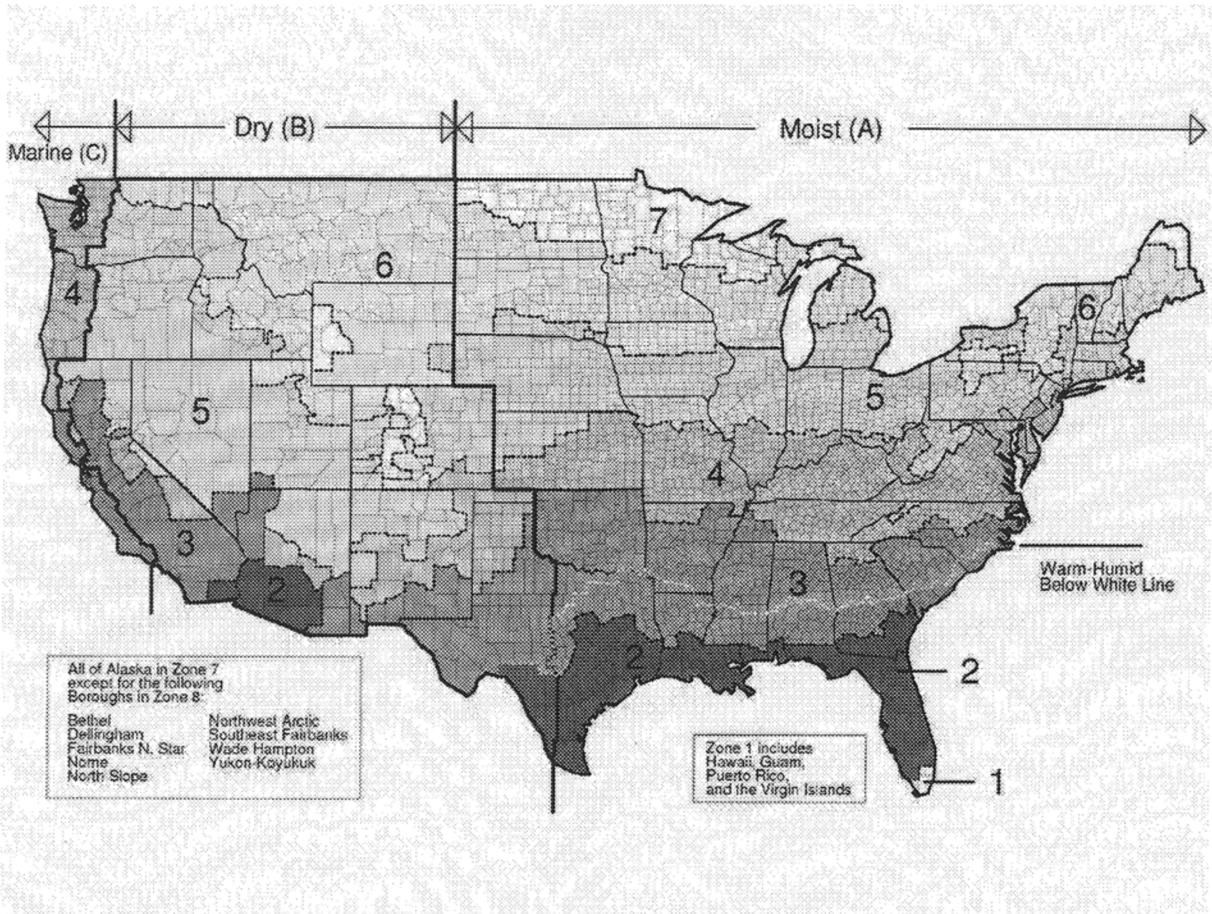


Figure 4. Climate zones

It also includes requirements for air leakage. The building envelope should be durably sealed to limit infiltration.

An area-weighted average of fenestration products >50% glazed will be permitted to satisfy the SHGC requirements; 1.4 m2 of glazed fenestration per dwelling unit would be exempt from U-factor and SHGC requirements.

Windows, skylights and sliding glass doors shall have an air filtration rate of no more than 1.5 L/s/m2 and swinging doors no more than 2.6 L/s/m2.

Curtain wall, storefront glazing and commercial-glazed swinging entrance doors and revolving doors shall be tested for air leakage at 75 Pa in accordance with ASTM E 283.

4.4.1.2 Mechanical Systems

Mechanical systems are to be sized in accordance with Code M1401.3 International Residential Code

There should be at least one thermostat for each separate heating and cooling system.

Specifications are included for insulation of ducts. Supply ducts in attics shall be insulated to a minimum of R-8 and all other ducts shall be insulated to a minimum of R-6.
All ducts, air handlers, filter boxes and building cavities used as ducts shall be sealed.

Mechanical systems piping should be insulated to a minimum of R-2 for circulating hot water systems.

Pools shall be provided with energy-conserving measures.

4.4.1.3 Simulated performance alternative

The analysis includes heating, cooling and service water heating energy only. Compliance based on simulated energy analysis requires that a proposed design should have an annual energy cost that is less or equal to the annual energy cost of the standard reference design using software that meets certain standards.
Specifications are given for the characteristics of both the standard reference building and the proposed building.

4.4.2 Commercial Energy Efficiency

The requirements of ASHRAE/IESNA Standard 90.1, Energy Standard for Buildings except for Low-Rise Residential Buildings, can be used as an alternative to this code.

ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

Standard reference number	Title	Referenced in code section number
119—88 (RA 2004)	Air Leakage Performance for Detached Single-family Residential Buildings	Table 405.5.2(1)
140—2007	Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs	506.6.1
146—1998	Testing and Rating Pool Heaters	Table 504.2
ANSI/ASHRAE/ACCA Standard 183—2007	Peak Cooling and Heating Load Calculations in Buildings Except Low-rise Residential Buildings	503.2.1
13256-1 (2005)	Water-source Heat Pumps—Testing and Rating for Performance—Part 1: Water-to-air and Brine-to-air Heat Pumps (ANSI/ASHRAE/IESNA 90.1-2004)	Table 503.2.3(2)
90.1—2007	Energy Standard for Buildings Except Low-rise Residential Buildings (ANSI/ASHRAE/IESNA 90.1-2007)	501.1, 501.2, 502.1.1, Table 502.2(2)
ASHRAE—2005	ASHRAE Handbook of Fundamentals	402.1.4, Table 405.5.2(1)
ASHRAE—2004	ASHRAE HVAC Systems and Equipment Handbook-2004	503.2.1

IESNA Illuminating Engineering Society of North America
120 Wall Street, 17th Floor
New York, NY 10005-4001

Standard reference number	Title	Referenced in code section number
90.1-2004	Energy Standard for Buildings Except Low-rise Residential Buildings	501.1, 501.2, 502.1.1, Table 502.2(2)

Figure 5. Lists of referenced standards applied

4.4.2.1 Building Envelope

The prescriptive requirements include general insulation and fenestration criteria, U-factors, specific insulation for roof assembly, walls (above-grade and below-grade walls), floors, slabs and opaque doors and fenestration.

For vertical fenestration, the maximum U-factor and SHGC shall be as specified in Table xx, based on the window projection factor.

Table 4. Building envelope requirements: Fenestration

CLIMATE ZONE	1	2	3	4 EXCEPT MARINE	5 AND MARINE 4	6	7	8
Vertical fenestration (40% maximum of above-grade wall)								
***U*-factor**								
Framing materials other than metal with or without metal reinforcement or cladding								
U-factor	1.20	0.75	0.65	0.40	0.35	0.35	0.35	0.35
Metal framing with or without thermal break								
Curtain wall/storefront *U*-factor	1.0	0.70	0.60	0.50	0.45	0.45	0.40	0.40
Entrance door *U*-factor	1.20	1.10	0.90	0.85	0.80	0.80	0.80	0.80
All other *U*-factor[a]	1.20	0.75	0.65	0.55	0.55	0.55	0.45	0.45
SHGC-all frame types								
SHGC: PF < 0.25	0.25	0.25	0.25	0.40	0.40	0.40	0.45	0.45
SHGC: $0.25 \leq$ PF < 0.5	0.33	0.33	0.33	NR	NR	NR	NR	NR
SHGC: PF ≥ 0.5	0.40	0.40	0.40	NR	NR	NR	NR	NR
Skylights (3% maximum)								
U-factor	0.75	0.75	0.65	0.60	0.60	0.60	0.60	0.60
SHGC	0.35	0.35	0.35	0.40	0.40	0.40	NR	NR

NR = No requirement.
PF = Projection factor (see Section 502.3.2).
a. All others includes operable windows, fixed windows and nonentrance doors.

CSA

Canadian Standards Association
5060 Spectrum Way
Mississauga, Ontario, Canada L4W 5N6

Standard reference number	Title	Referenced in code section number
101/I.S.2/A440—08	Specifications for Windows, Doors and Unit Skylights	402.4.4, 502.4.1

NFRC

National Fenestration Rating Council, Inc.
6305 Ivy Lane, Suite 140
Greenbelt, MD 20770

Standard reference number	Title	Referenced in code section number
100—04	Procedure for Determining Fenestration Product U-factors—Second Edition	303.1.3
200—04	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence—Second Edition	303.1.3
400—04	Procedure for Determining Fenestration Product Air Leakage—Second Edition	402.4.2, 502.4.1

WDMA Window and Door Manufacturers Association
1400 East Touhy Avenue, Suite 470
Des Plaines, IL 60018

Standard reference number	Title	Referenced in code section number
AAMA/WDMA/CSA 101/I.S.2/A440—08	Specifications for Windows, Doors and Unit Skylights.	402.4.4, 502.4.1

Figure 6. List of referenced standards

4.4.2.2 Mechanical Systems

Design loads shall be determined in accordance with the procedures described in the ASHRAE/ACCA Standard 183. Alternatively, design loads shall be determined by an approved equivalent computation procedure.

Heating and cooling equipment and systems capacity shall not exceed the loads calculated in accordance with the above-mentioned procedures.

HVAC system performance requirements are specified. The efficiency shall be verified through certification under an approved certification program or if no certification program exists, the equipment efficiency ratings shall be supported by data furnished by the manufacturer.

Each heating and cooling system shall be provided with thermostatic controls. There is a requirement for deadband of at least 2.8^{o}C within which the supply of heating and cooling energy to the zone is capable of being shut off or reduced to a minimum.

Natural or mechanical ventilation shall be provided in accordance with Chapter 4 of the International Mechanical Code.

Duct and pipe insulation and leakage are controlled.

Ductwork shall be constructed and erected in accordance with the International Mechanical Code. All supply and return air ducts shall be insulated with a minimum of R-5 insulation when located in unconditioned spaces and a minimum of R-8 insulation when located outside the building. When located within a building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by a minimum of R-8 insulation.

Service water heating requirements are specified. Service water-heating equipment shall be provided with controls to allow a set point of 43^{o}C for equipment serving dwelling units and 32^{o}C for equipment serving other occupancies. Piping shall be insulated for automatic-circulating hot water systems.

4.4.2.3 Electrical power and lighting systems

Lighting systems shall be provided with controls (e.g interior/exterior lighting controls, light reduction controls, daylight zone control, sleeping unit controls).

Buildings larger than 465 m^2 shall be equipped with an automatic control device to shut off lighting in those areas.

Internally illuminated exit signs shall not exceed 5W per side.

Lighting power is controlled by specifying maximum installed capacity for various indoor and outdoor spaces, generally in terms of W/m2. The interior lighting power is the floor area for each building area type. Table xx shows the interior lighting power allowances.

Table 5. Interior lighting power allowances

LIGHTING POWER DENSITY	
Building Area Type[a]	(W/ft^2)
Automotive Facility	0.9
Convention Center	1.2
Court House	1.2
Dining: Bar Lounge/Leisure	1.3
Dining: Cafeteria/Fast Food	1.4
Dining: Family	1.6
Dormitory	1.0
Exercise Center	1.0
Gymnasium	1.1
Healthcare—clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing Facility	1.3
Motel	1.0
Motion Picture Theater	1.2
Multifamily	0.7
Museum	1.1
Office	1.0
Parking Garage	0.3
Penitentiary	1.0
Performing Arts Theater	1.6
Police/Fire Station	1.0
Post Office	1.1
Religious Building	1.3
Retail[b]	1.5
School/University	1.2
Sports Arena	1.1
Town Hall	1.1

All exterior building grounds luminaires that operate at greater than 100 W shall contain lamps having a minimum efficacy of 60 lumens per watt.
The exterior lighting zones are specified in Table xx.

Table 6.Exterior lighting zones

LIGHTING ZONE	DESCRIPTION
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas
3	All other areas
4	High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority

In buildings having individual dwelling units, the electrical energy consumed by each tenant should be determined by separately metering the individual dwelling units.

4.4.2.4 Total building performance

The following systems and loads shall be included in determining the total building performance: heating systems, cooling systems, service water heating, fan systems, lighting power, receptacle loads and process loads.

The simulated performance alternative applies in the same way as for residential buildings.

Performance analysis tools tested according to ASHRAE Standard 140 shall be permitted.

5 ANSI/ASHRAE/IESNA Standard 90.1-2007

5.1 Introduction

The purpose of this standard is to provide minimum requirements for the energy efficient design of buildings except low-rise residential buildings.

This standard shall not be used to circumvent any safety, health, or environmental requirements. The provisions of this standard shall not be deemed to nullify any provision of local, state, or federal law. Where there is a conflict between a requirement of this standard and such other law affecting construction of the building, precedence shall be determined by the authority having jurisdiction.

5.2 Administrative Provisions

5.2.1 Structure and scope

This standard provides:

(a) Minimum energy efficiency requirements for the design and construction of:

(b)

(1) New buildings and their systems
(2) New portions of buildings and their systems
(3) New systems and equipment in existing buildings

(c) Criteria for determining compliance with these requirements

The provisions of this standard apply to:

(a) The envelope of buildings, provided that the enclosed spaces are:

(1) Heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h.ft2 or
(2) Cooled by a cooling system whose sensible output capacity is greater than or equal to 5 Btu/h.ft2

(b) The following systems and equipment used in conjunction with buildings:

(1) Heating, ventilating, and air conditioning,
(2) Service water heating,
(3) Electric power distribution and metering provisions,
(4) Electric motors and belt drives, and
(5) Lighting

The provisions of this standard do not apply to:

(a) Single-family, multi-family structures of three-stories or fewer above grade, and manufactures houses (mobile homes and modular)
(b) Buildings that do not use either electricity or fossil fuel
(c) Equipment and portions of building systems that use energy primarily to provide for industrial, manufacturing or commercial processes

5.2.2 Compliance methods and tools

Compliance documents shall show all the pertinent data and features of the building, equipment, and systems in sufficient detail to permit a determination of compliance by the building official and to indicate compliance with the requirements of this standard. Supplemental information necessary to verify compliance with this standard, such as calculations, worksheets, compliance forms, vendor literature, or other data, shall be made available when required by the building official.

5.3 Code maintenance and development

The original standard 90 was published in 1975 and revised editions were published in 1980 and 1999 using the ANSI and ASHRAE periodic maintenance procedures. Based upon these procedures, the entire standard was publicly reviewed and published in its entirety each time. As technology and energy prices began changing more rapidly, however, the ASHRAE board of Directors voted in 1999 to place the standard on continuous maintenance, permitting the standard to be updated several times each year through the publication of approved addenda to the standard.

Starting with the 2001 edition, the standard is now published in its entirety in the fall of every third year. This schedule allows the standard to be submitted and proposed by the deadline for inclusion or reference in model building and energy codes. All approved addenda and errata will be included in the new edition every three years. This procedure allows users to have some certainty about when new editions will be published.

5.4 Building envelope

5.4.1 U-factors and Solar Heat Gain Coefficients (SHGC)

U-factors and SHGC for Vertical fenestration and skylights shall not be greater than that specified for all orientations in Tables 5.5-1 through 5.5-8, determined in accordance with National Fenestration Rating Council (NFRC).

Exception for vertical fenestration SHGC values are as below:

(a) For vertical fenestration shaded by opaque permanent projections, the SHGC in the building shall be reduced by using the multipliers in Table 5.5.4.4.1

(b) partial shading - PF shall be reduced by multiplying it by a factor which shall be derived from
Os = (Ai - Oi) + (Af - Of) and then SHGC be reduced by using the multipliers in Table 5.5.4.4.1 for each fenestration product

(c) vertical fenestration that is located on the street side of the street-level story (SLS) only, provided that - (1) the SLS < 20 ft, (2) fenestration has a continuous overhang with a weighted average PF > 0.5, (3) fenestration areas for street side of the SLS < 75 % of gross wall area.

5.4.2 Air leakage

Important areas of the building envelope shall be sealed, caulked, gasketted, or weather-stripped to minimize air leakage. Air leakage shall not exceed 1.0 cfm/ft2 for glazed swinging entrance doors and for revolving doors and 0.4 cmf/ft2 for all other products.

5.4.3 Roofs and skylights

Total vertical fenestration area shall be less than 40 % of gross wall area and total skylight area shall be less than 5 % of the gross roof area.

Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.

For roofs, other than roofs over ventilated attics or roofs over semi-heated spaces or roofs over conditioned spaces that are not cooled spaces, where exterior surface has (a) solar reflectance of 0.70, or (b) solar reflective index of 82. Roof insulation values shall be as specified in Tables 5.5-1 through 5.5-8 of the ASHRAE 90.1-2007.

5.5 HVAC and Domestic hot water

5.5.1 Controls

Controls required for service water-heating equipment, 43 ^{o}C for dwelling units and 32 ^{o}C for other occupancies.

Temperature controls shall be provided that allow for storage temperature adjustment from 120^{o}F or lower to a maximum temperature compatible with the intended use.

5.5.2 Energy recovery

Condenser heat recovery systems shall be installed for heating or preheating of service hot water provided all of the following are true:

(a) Facility operates 24 hours a day
(b) Total installed heat rejection capacity of the water-cooled systems exceeds 6,000,000 Btu/h of heat rejection
(c) The design service water heating load exceeds 1,000,000 Btu/h

5.6 Lighting conditions

5.6.1 Control requirements include:

(a) Each space enclosed by ceiling-height partitions
(b) Interior/ exterior lighting, light reduction, daylight zone, sleeping unit
(c) Display/ accent lighting, case lighting, hotel and motel guest room lighting, task lighting, non-visual lighting and demonstrating lighting
(d) All exterior applications not exempted in generals
(e) Lighting not designated for dusk-to-dawn operation (combination of a photosensor and a time switch or an astronomical time switch)

5.6.2 Interior lighting

The installed interior lighting power for a building shall be calculated in accordance with the 'building area `method' (USA-ASHRAE STD 90.1-2007). An increase in the interior lighting power allowances is permitted in the following cases:

(a) For spaces in which lighting is specified to be installed in addition to the general lighting for the purpose of decorative appearance, such as chandelier-type luminaries or sconces or for highlighting art or exhibits, provided that the additional lighting power shall not exceed 1.0 W/ft2 of such spaces

(b) For lighting equipment installed in sales areas and specifically designed and directed to highlight merchandise

5.6.3 Exterior lighting

Lighting for exterior building grounds luminaires which operate at greater than 100W shall contain lamps having a minimum efficacy of 60 lm/W unless the luminaire is controlled by a motion sensor or exempt under generals. Internally-illuminated exit signs shall not exceed 5W per face.

A minimum of 50% of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps.

The total exterior lighting power allowance for all exterior building applications is the sum of the individual lighting power densities permitted in Table 1.1 for these applications plus an additional unrestricted allowance of 5 % of that sum. Trade-offs are allowed only among exterior lighting applications listed in the Table 1.1 "Tradable surfaces".

5.7 Energy Cost Budget Method (ECBM)

The building ECBM is an alternative to the prerequisite provisions of this standard. It may be employed for evaluating the compliance of all proposed designs except designs with no mechanical system.

5.7.1 Trade-offs limited to Building Permit

When the building permit being sought applies to less than the whole building, only the calculation parameters related to the systems to which the permit applies shall be allowed to vary. Parameters relating to unmodified existing conditions or to future components shall be identical to both the *energy cost budget* and the *design energy cost* calculations. Future building components shall meet the prescriptive requirements detailed in the sections above.

5.7.2 Envelope limitation

Compliance will be achieved if:

(a) The design energy cost, as calculated in Table 7 below, does not exceed the energy cost budget as calculated by the simulation program described in subsection 5.7.3

(b) The energy efficiency level of components specified in the building design meet or exceed the efficiency levels used to calculate the design energy cost

Table 7. Modeling requirements for calculating *design energy cost* and *energy cost budget*

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
1. Design Model		
	a. The simulation model of the *proposed building design* shall be consistent with the design documents, including proper accounting of fenestration and opaque envelope types and area; interior lighting power and controls; HVAC system types, sizes, and controls; and service water heating systems and controls. b. All conditioned spaces in the *proposed building design* shall be simulated as being both heated and cooled even if no cooling or heating system is being installed. c. When the *energy cost budget* method is applied to buildings in which energy-related features have not yet been designed (e.g., a lighting system), those yet-to-be-designed features shall be described in the *proposed building design* so that they minimally comply with applicable mandatory and prescriptive requirements from Sections 5 through 10. Where the space classification for a building is not known, the building shall be categorized as an office building.	The *budget building design* shall be developed by modifying the *proposed design* as described in this table. Except as specifically instructed in this table, all building systems and equipment shall be modeled identically in the *budget building design* and *proposed building design*.
2. Additions and Alterations		
	It is acceptable to demonstrate compliance using building models that exclude parts of the *existing building* provided all of the following conditions are met: a. Work to be performed under the current permit application in excluded parts of the building shall meet the requirements of Sections 5 through 10. b. Excluded parts of the building are served by HVAC systems that are entirely separate from those serving parts of the building that are included in the building model. c. Design space temperature and HVAC system operating setpoints and schedules, on either side of the boundary between included and excluded parts of the building, are identical. d. If a declining block or similar utility rate is being used in the analysis and the excluded and included parts of the building are on the same utility meter, the rate shall reflect the utility block or rate for the building plus the addition.	Same as *proposed building design*

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
3. Space Use Classification		
	The building type or space type classifications shall be chosen in accordance with Section 9.5.1 or 9.6.1. The user or designer shall specify the space use classifications using either the building type or space type categories but shall not combine the two types of categories within a single permit application. More than one building type category may be used for a building if it is a mixed-use facility.	Same as *proposed building design*
4. Schedules		
	The schedule types listed in Section 11.2.1.1(b) shall be required input. The schedules shall be typical of the proposed building type as determined by the designer and approved by the *authority having jurisdiction*. Required schedules shall be identical for the *proposed building design* and *budget building design*.	Same as *proposed building design*
5. Building Envelope		
	All components of the building envelope in the *proposed building design* shall be modeled as shown on architectural drawings or as installed for *existing building* envelopes. **Exceptions:** The following building elements are permitted to differ from architectural drawings. a. Any envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior walls) need not be separately described. If not separately described, the area of an envelope assembly must be added to the area of the adjacent assembly of that same type. b. Exterior surfaces whose azimuth orientation and tilt differ by no more than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers. c. For exterior roofs other than roofs with ventilated attics, the roof surface may be modeled with a reflectance of 0.45 if the reflectance of the proposed design roof is greater than 0.70 and its emittance is greater than 0.75. The reflectance and emittance shall be tested in accordance with the Exception to Section 5.5.3.1. All other roof surfaces shall be modeled with a reflectance of 0.3. d. Manually operated fenestration shading devices such as blinds or shades shall not be modeled. Permanent shading devices such as fins, overhangs, and lightshelves shall be modeled.	The *budget building design* shall have identical *conditioned floor area* and identical exterior dimensions and orientations as the *proposed building design*, except as noted in (a), (b), and (c) in this clause. a. Opaque assemblies such as roof, floors, doors, and walls shall be modeled as having the same *heat capacity* as the *proposed building design* but with the minimum U-factor required in Section 5.5 for new buildings or *additions* and Section 5.1.3 for *alterations*. b. Roof albedo—All roof surfaces shall be modeled with a reflectivity of 0.3. c. Fenestration—No shading projections are to be modeled; fenestration shall be assumed to be flush with the exterior wall or roof. If the fenestration area for new buildings or *additions* exceeds the maximum allowed by Section 5.5.4.2, the area shall be reduced proportionally along each exposure until the limit set in Section 5.5.4.2 is met. Fenestration U-factor shall be the minimum required for the climate, and the SHGC shall be the maximum allowed for the climate and orientation. The fenestration model for envelope *alterations* shall reflect the limitations on area, U-factor, and SHGC as described in Section 5.1.3. **Exception:** When trade-offs are made between an *addition* and an *existing building* as described in the Exception to Section 4.2.1.2, the envelope assumptions for the *existing building* in the *budget building design* shall reflect existing conditions prior to any revisions that are part of this permit.

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
6. Lighting		
	Lighting power in the *proposed building design* shall be determined as follows: a. Where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model. b. Where a lighting system has been designed, lighting power shall be determined in accordance with Sections 9.1.3 and 9.1.4. c. Where no lighting exists or is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building type. d. Lighting system power shall include all lighting system components shown or provided for on plans (including lamps, ballasts, task fixtures, and furniture-mounted fixtures).	Lighting power in the *budget building design* shall be determined using the same categorization procedure (building area or space function) and categories as the *proposed building design* with lighting power set equal to the maximum allowed for the corresponding method and category in either Section 9.5 or 9.6. Power for fixtures not included in the *LPD* calculation shall be modeled identically in the *proposed building design* and *budget building design*. Lighting controls shall be the minimum required.
7. Thermal Blocks—HVAC Zones Designed		
	Where HVAC zones are defined on HVAC design drawings, each HVAC zone shall be modeled as a separate *thermal block*. **Exception:** Different HVAC zones may be combined to create a single *thermal block* or identical *thermal blocks* to which multipliers are applied provided all of the following conditions are met: a. The space use classification is the same throughout the *thermal block*. b. All HVAC zones in the *thermal block* that are adjacent to glazed exterior walls face the same orientation or their orientations are within 45 degrees of each other. c. All of the zones are served by the same HVAC system or by the same kind of HVAC system.	Same as *proposed building design*
8. Thermal Blocks—HVAC Zones Not Designed		
	Where the HVAC zones and systems have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following guidelines: a. Separate *thermal blocks* shall be assumed for interior and perimeter spaces. Interior spaces shall be those located more than 15 ft from an exterior wall. Perimeter spaces shall be those located closer than 15 ft from an exterior wall. b. Separate *thermal blocks* shall be assumed for spaces adjacent to glazed exterior walls; a separate zone shall be provided for each orientation, except orientations that differ by no more than 45 degrees may be considered to be the same orientation. Each zone shall include all floor area that is 15 ft or less from a glazed perimeter wall, except that floor area within 15 ft of glazed perimeter walls having more than one orientation shall be divided proportionately between zones. c. Separate *thermal blocks* shall be assumed for spaces having floors that are in contact with the ground or exposed to ambient conditions from zones that do not share these features. d. Separate *thermal blocks* shall be assumed for spaces having exterior ceiling or roof assemblies from zones that do not share these features.	Same as *proposed building design*
9. Thermal Blocks—Multifamily Residential Buildings		
	Residential spaces shall be modeled using one *thermal block* per space except that those facing the same orientations may be combined into one *thermal block*. Corner units and units with roof or floor loads shall only be combined with units sharing these features.	Same as Proposed Design

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
10. HVAC Systems		
	The HVAC system type and all related performance parameters, such as equipment capacities and efficiencies, in the *proposed building design* shall be determined as follows: a. Where a complete HVAC system exists, the model shall reflect the actual system type using actual component capacities and efficiencies. b. Where an HVAC system has been designed, the HVAC model shall be consistent with design documents. Mechanical equipment efficiencies shall be adjusted from actual design conditions to the standard rating conditions specified in Section 6.4.1, if required by the simulation model. c. Where no heating system exists or no heating system has been specified, the heating system shall be modeled as fossil fuel. The system characteristics shall be identical to the system modeled in the *budget building design*. d. Where no cooling system exists or no cooling system has been specified, the cooling system shall be modeled as an air-cooled single-zone system, one unit per *thermal block*. The system characteristics shall be identical to the system modeled in the *budget building design*.	The HVAC system type and related performance parameters for the *budget building design* shall be determined from Figure 11.3.2, the system descriptions in Table 11.3.2A and accompanying notes, and in accord with rules specified in Section 11.3.2 (a)–(j)
11. Service Hot-Water Systems		
	The service hot-water system type and all related performance parameters, such as equipment capacities and efficiencies, in the *proposed building design* shall be determined as follows: a. Where a complete service hot-water system exists, the model shall reflect the actual system type using actual component capacities and efficiencies. b. Where a service hot-water system has been designed, the service hot-water model shall be consistent with design documents. c. Where no service hot-water system exists or is specified, no service hot-water heating shall be modeled.	The service hot-water system type and related performance in the *budget building design* shall be identical to the *proposed building design*. **Exceptions:** a. Where Section 7.5 applies, the boiler shall be split into a separate space heating boiler and hot-water heater with *efficiency* requirements set to the least efficient allowed. b. For 24-hour-per-day facilities that meet the prescriptive criteria for use of condenser heat recovery systems described in Section 6.5.6.2, a system meeting the requirements of that section shall be included in the *baseline building design* regardless of the exceptions to Section 6.5.6.2. If a condenser heat recovery system meeting the requirements described in Section 6.5.6.2 cannot be modeled, the requirement for including such a system in the actual building shall be met as a prescriptive requirement in accordance with Section 6.5.6.2 and no heat-recovery system shall be included in the *proposed* or *budget building design*.
12. Miscellaneous Loads		
	Receptacle, motor, and process loads shall be modeled and estimated based on the building type or space type category and shall be assumed to be identical in the *proposed* and *budget building designs*. These loads shall be included in simulations of the building and shall be included when calculating the *energy cost budget* and *design energy cost*. All end-use load components within and associated with the building shall be modeled, unless specifically excluded by Sections 13 and 14 of Table 11.3.1: including, but not limited to, exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators and escalators, refrigeration equipment, and cooking equipment.	Receptacle, motor, and process loads shall be modeled and estimated based on the building type or space type category and shall be assumed to be identical in the *proposed* and *budget building designs*. These loads shall be included in simulations of the building and shall be included when calculating the *energy cost budget* and *design energy cost*. All end-use load components within and associated with the building shall be modeled, unless specifically excluded by Sections 13 and 14 of Table 11.3.1: including, but not limited to, exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators and escalators, refrigeration equipment, and cooking equipment.

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
13.	**Modeling Exceptions**	
	All elements of the *proposed building design* envelope, HVAC, service water heating, lighting, and electrical systems shall be modeled in the *proposed building design* in accordance with the requirements of Sections 1 through 12 of Table 11.3.1. **Exception:** Components and systems in the *proposed building design* may be excluded from the simulation model provided: a. component energy usage does not affect the energy usage of systems and components that are being considered for trade-off; b. the applicable prescriptive requirements of Sections 5.5, 6.5, 7.5, and either 9.5 or 9.6 applying to the excluded components are met.	None
14.	**Modeling Limitations to the Simulation Program**	
	If the simulation program cannot model a component or system included in the *proposed building design*, one of the following methods shall be used with the approval of the *authority having jurisdiction*: a. Ignore the component if the energy impact on the trade-offs being considered is not significant. b. Model the component substituting a thermodynamically similar component model. c. Model the HVAC system components or systems using the *budget building design's* HVAC system in accordance with Section 10 of Table 11.3.1. Whichever method is selected, the component shall be modeled identically for both the *proposed building design* and *budget building design* models.	Same as *proposed building design*

5.7.3 Simulation general requirements

The simulation program shall be a computer-based program for the analysis of energy consumption in buildings (a program such as, but not limited to DOE-2 or BLAST). The simulation program shall include calculation methodologies for the building components being modeled.

The simulation program shall at a minimum have the ability to explicitly model all of the following:

(a) A minimum of 1400 hours per year
(b) Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation, defined separately for each day of the week and holidays
(c) Thermal mass effects
(d) Ten or more thermal zones
(e) Part-load performance curves for mechanical equipment
(f) Capacity and efficiency correction curves for mechanical heating and cooling equipment
(g) Air-side and water-side economizers with integrated control
(h) The *budget building design* characteristics specified in subsection 5.7.6

The simulation program shall have the ability to either:

(a) Directly determine the *design energy cost* and *energy cost budget*, or
(b) Product hourly reports of energy use by energy source suitable for determining the *design energy cost* and *energy cost budget* using a separate calculation engine

In addition the program shall be capable of performing design load calculations to determine required HVAC equipment capacities and, air and water flow rates.

5.7.4 Climatic data

The simulation program shall perform the simulation using hourly values of climatic data, such as temperature and humidity from representative climatic data, for the city in which the *proposed design* is to be located.

5.7.5 Purchased Energy Rates

Annual energy costs shall be determined using rates for purchased energy, such as electricity, gas, oil, propane, steam, and chilled water.

5.7.6 Exceptional calculation methods

Where no simulation program is available that adequately models a design, material or device, the authority having jurisdiction may approve an exceptional calculation method to be used. Applications for approval of an exceptional method to include theoretical and empirical information verifying the method’s accuracy shall include the following documentation to demonstrate that the exceptional calculation method and results,

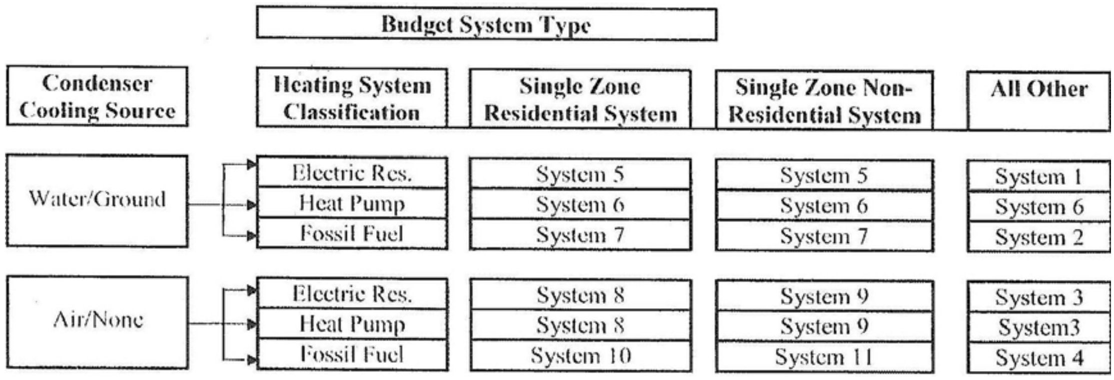
(a) Make no change in any input parameter values specified by this standard and the adopting authority
(b) Provide input and output documentation that facilitates the enforcement agency’s review and meets the formatting and content required by the adopting authority
(c) Are supported with instructions for using the method to demonstrate that the energy cost budget and design energy cost requirements are met

5.7.7 HVAC systems

The HVAC system type and related performance parameters for the budget building design shall be determined from Figure 7, the system descriptions, and the following rules:

(a) All HVAC and service water heating equipment in the budget building shall be modeled at the minimum efficiency levels, both part load and full load
(b) Where efficiency ratings such as EER and COP include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately
(c) Minimum outdoor air ventilation rates shall be the same for both the budget building design and proposed building design.

Figure 7. HVAC systems map



6 United Kingdom Building Regulations – Approved Documents "Part L"

6.1 Introduction

The main way to demonstrate compliance with Building Regulations in England is to follow the guidance set out in the Approved Documents (ADs). These are issued by the Department of Communities and Local Government (CLG) and accompany the UK Building Regulations. "Part L" of the regulations covers energy efficiency. Part L documentation is split into four categories, in four separate documents:

- ADL1A (also referred to as Part L1A) – new dwellings.
- ADL1B (also referred to as Part L1B) – existing dwellings.
- ADL2A (also referred to as Part L2A) – new non-domestic buildings.
- ADL2B (also referred to as Part L2B) – existing non-domestic buildings.

6.2 Administrative Provisions

Being a member of the European Union, the United Kingdom was required to comply with the European Energy Performance of Buildings Directive (EPBD) which was passed in December 2002. The UK implemented the directive in 2005, by requiring all new and existing buildings to meet energy efficiency and CO_2 emissions standards.

Part L was added to the UK National Building Code in 2006, which set goals for reducing carbon energy, and set a goal for all new developments to have zero carbon by 2011.

Every new building is required to have an Energy Performance Certificate (EPC), which provides a diagnostic of the building's general information, energy performance and recommendations for improvement. Energy Performance Certificates are required on construction, sale or lease of all buildings since October 2008. EPC to be displayed in all commercial buildings with a total floor area larger than 250m², that are frequently visited by the public and where an EPC has previously been produced on the sale, rent or construction of that building.

A Display Energy Certificate (DEC) is required for public buildings larger than 1000m^2 which are occupied or part occupied by public authorities or by institutions providing public services and therefore frequently visited by the public.

6.3 Code Development and Maintenance

The UK Building Regulations are attached to the Building Act 1984, and apply in England and Wales. The "Approved Documents" (ADs) accompany the Building Regulations, and consist of 14 'parts'. The "Part L" document deals with the energy efficiency requirements in the Building Regulations.
The Part L document first emerged in 1990, as part of building regulations and was subsequently reviewed and updated in 1995, 2002 and 2006.
The current edition of the Part L regulations is the Approved Document L2, 2006 edition. It came into effect in April 2006.
An updated version of the Part L regulations (edition 2010) will be officially published in October 2010.

6.4 Regulation Method

The energy efficiency requirements are conveyed in Part L of Schedule 1 to the UK Building Regulations (2006) as described below:

Requirement	*Limits on application*
Part L Conservation of fuel and power **L1.** Reasonable provision shall be made for the conservation of fuel and power in buildings by: a. limiting heat gains and losses: i. through thermal elements and other parts of the building fabric; and ii. from pipes, ducts and vessels used for space heating, space cooling and hot water services; b. providing and commissioning energy efficient fixed building services with effective controls; and c. providing to the owner sufficient information about the building, the fixed building services and their maintenance requirements so that the building can be operated in such a manner as to use no more fuel and power than is reasonable in the circumstances.	

Figure 8. Extract from UK Building Regulations (2006)

In order to meet the requirements of the Part L of the UK Building Regulations, buildings are to meet the minimum energy performance requirement specified in the regulations. This minimum energy performance requirement is referred to as the Target CO_2 Emission Rate (TER). It is the mass of CO_2, emitted per year per m^2 of the total useful floor area of the building (kg/m^2/year).

For domestic buildings, the actual emission rate is referred to as the Dwelling Emission Rate (DER) and, for non-domestic buildings, it is referred to as the Building Emission Rate (BER).

The BER or DER of a building must be less than TER in order to comply with the Part L requirements.

As per the regulations, the methodology of calculation of the energy performance of buildings shall be approved by the *Secretary of State*.

In the Secretary of State's view, compliance with Part L and building regulations would be demonstrated by meeting the five separate criteria, as follows:

Criterion 1: the calculated CO_2 emission rate for the building as-constructed (the building emission rate, BER) must not be greater than the target rate (the target emission rate, TER). The TER can be determined by following calculation procedures set out in the Part L document.

Criterion 2: the performance of the building fabric and the heating, hot water and fixed lighting systems should be no worse than the design limits set out in the Part L document; and

Criterion 3: Those parts of the building that are not provided with comfort cooling systems need to have appropriate passive control measures to limit solar gains. Guidance is provided in the Part L document to demonstrate that suitable provisions have been made to control solar gains.

Criterion 4: the performance of the building, as built, should be consistent with the prediction made in the BER. Procedures are described in the Part L document as to show that this criterion has been met.

Criterion 5: The necessary provisions for enabling energy efficient operation of the building need to be put in place. Procedures are described in the Part L document as to show that this criterion has been met.

6.5 Building Lay-out and Design

In new buildings which are not served by air conditioning is not present, the Part L documents state that provision should be made to limit internal temperature rise due to solar gains. This can be achieved through an appropriate combination of window size and orientation, solar protection through shading and other solar control measures, and by using thermal capacity coupled with night ventilation.

For non-domestic buildings, reasonable provision would be to show for every occupied space which is not air conditioned that:

a. when the building is subject to the solar irradiances for July as given in the table of design irradiancies in CIBSE Design Guide A, the combined solar and internal casual gains (people, lighting and equipment) per unit floor area averaged over the period 0630 to 1630 Solar Time (GMT) is **not greater than 35W/m^2** ; or
b. the operative temperature (the temperature index for thermal comfort as used in CIBSE Guide A) in the conditioned space does not exceed a threshold for more than a reasonable number of occupied hours per year when the building is tested against the "CIBSE Design Summer Year" weather data appropriate to the building location; or
c. For school buildings, Building Bulletin 101 specifies overheating criteria and provides guidance on methods to demonstrate that reasonable provision has been made to control excessive solar gains. The performance standards for summertime overheating in compliance with Approved document L2 for teaching and learning areas are:
   a) There should be no more than 120 hours when the air temperature in the classroom rises above 28°C
   b) The average internal to external temperature difference should not exceed 5°C.
   c) The internal air temperature when the space is occupied should not exceed 32°C.

In order to show that the proposed school will not suffer overheating, **two** of these three criteria must be met.

6.6 Building Envelope

6.6.1 General building envelope design and construction

The building fabric should be constructed to a reasonable quality so that:

a. The insulation is reasonably continuous over the whole building envelope; and

b. the air permeability is within reasonable limits.

The building fabric should be constructed so that there are no reasonably avoidable thermal bridges in the insulation layers caused by gaps within the various elements, at the joints between elements and at the edges of elements such as those around window and door openings.

In addition, the builder should have an appropriate system of site inspection in place to give confidence that the construction procedures achieve the required standards of consistency.

6.6.2 U-values

The Part L documents set out the design limits for the building fabric. The limiting U-values for new and existing domestic and non-domestic buildings are as follows:

(i) New non-domestic buildings

Table 4 **Limiting U-value standards (W/m²·K)**

Element	(a) Area-weighted average	(b) For any individual element
Wall	0.35	0.70
Floor	0.25	0.70
Roof	0.25	0.35
Windows[1], roof windows, rooflights[2] and curtain walling	2.2	3.3
Pedestrian doors	2.2	3.0
Vehicle access and similar large doors	1.5	4.0
High usage entrance doors	6.0	6.0
Roof ventilators (inc. smoke vents)	6.0	6.0

Notes:

1 Excluding ***display windows*** and similar glazing. There is no limit on design flexibility for these exclusions but their impact on CO_2 emissions must be taken into account in calculations.

2 The U-values for roof windows and rooflights in this table are based on the U-value having been assessed with the roof window or rooflight in the vertical position. If a particular unit has been assessed in a plane other than the vertical, the standards given in this Approved Document should be modified by making an adjustment that is dependent on the slope of the unit following the guidance given in BR 443.

*Limiting U-values for **new non-domestic** buildings*

(ii) New domestic buildings

Table 2 Limiting U-value standards ($W/m^2 \cdot K$)

Element	a. Area-weighted average U-value	b. Limiting U-value
Wall	0.35	0.70
Floor	0.25	0.70
Roof	0.25	0.35
Windows, roof windows, rooflights and doors[1]	2.2	3.3

Notes:
1. See paragraph 34.

Limiting U-values for ***new domestic*** *buildings*

(iii) Exiting non-domestic buildings

Table 6 Standards for *thermal elements* (W/m²·K)

Element[1]	Standard for new thermal elements	Standard for replacement thermal elements
Wall	0.30	0.35[2]
Pitched roof – insulation at ceiling level	0.16	0.16
Pitched roof – insulation at rafter level	0.20	0.20
Flat roof or roof with integral insulation	0.20	0.25
Floors[3]	0.22[4]	0.25[4]

Notes:
1 'Roof' includes the roof parts of dormer windows and 'wall' includes the wall parts of dormer windows.
2 A lesser provision may be appropriate where meeting such a standard would result in a reduction of more than 5% in the internal floor area of the room bounded by the wall.
3 The U-value of the floor of an extension can be calculated using the exposed perimeter and floor area of the whole enlarged building.
4 A lesser provision may be appropriate where meeting such a standard would create significant problems in relation to adjoining floor levels.

Limiting U-values for newly constructed thermal elements (e.g. in extensions) and new thermal elements to replace thermal elements in existing building

Table 7 Upgrading retained thermal elements

Element[1]	(a) Threshold U-value W/m²·K	(b) Improved U-value W/m²·K
Cavity Wall	0.70	0.35[2]
Other Wall type	0.70	0.35[3]
Pitched roof – insulation at ceiling level	0.35	0.16
Pitched roof – insulation at rafter level	0.35	0.20
Flat roof or roof with integral insulation	0.35	0.25
Floors[4]	0.35	0.25[5]

Notes:
1 'Roof' includes the roof parts of dormer windows and 'wall' includes the wall parts (cheeks) of dormer windows.
2 This only applies in the case of a cavity wall capable of accepting insulation. Where this is not the case it should be treated as for 'other wall type.'
3 A lesser provision may be appropriate where meeting such a standard would result in a reduction of more than 5% in the internal floor area of the room bounded by the wall.
4 The U-value of the floor of an extension can be calculated using the exposed perimeter and floor area of the whole enlarged building
5 A lesser provision may be appropriate where meeting such a standard would create significant problems in relation to adjoining floor levels.

Limiting U-values for retained thermal elements in existing buildings
(Reasonable provision would be to upgrade those thermal elements whose U-value is worse than the threshold value in column (a) of Table 7 to achieve the U-value given in column (b))

Table 5 Standards for controlled fittings (W/m²·K)

Fitting	(a) Standard for new fittings in extensions	(b) Standard for replacement fittings in an existing building
Windows, roof windows and glazed rooflights[1,4]	1.8 for the whole unit OR 1.2 centre pane	2.2 for the whole unit OR 1.2 centre pane
Alternative option for windows in buildings that are essentially domestic in character[2], a window energy rating[3] of	Band D	Band E
Pedestrian doors where the door has more than 50% of its internal face area glazed	2.2	2.2
High usage entrance doors for people	6.0	6.0
Vehicle access and similar large doors	1.5	1.5
Roof ventilators (including smoke extract ventilators)	6.0	6.0

Notes:

1. *Display windows* are not required to meet the standard given in this table.
2. For example, student accommodation, care homes and similar uses where the occupancy levels and internal gains are essentially domestic in character.
3. As defined in 'Windows for new and existing housing', CE66, EST. Controlled fittings.

Limiting U-values for windows and doors in existing non-domestic buildings

(iv) <u>Exiting domestic buildings</u>

Table 4 Standards for thermal elements W/m²·K

Element[1]	(a) Standard for new thermal elements in an extension	(b) Standard for replacement thermal elements in an existing dwelling
Wall	0.30	0.35[2]
Pitched roof – insulation at ceiling level	0.16	0.16
Pitched roof – insulation at rafter level	0.20	0.20
Flat roof or roof with integral insulation	0.20	0.25
Floors	0.22[3]	0.25[3]

Notes:

1. Roof includes the roof parts of dormer windows and wall refers to the wall parts (cheeks) of dormer windows.
2. A lesser provision may be appropriate where meeting such a standard would result in a reduction of more than 5% in the internal floor area of the room bounded by the wall.
3. A lesser provision may be appropriate where meeting such a standard would create significant problems in relation to adjoining floor levels. The U-value of the floor of an extension can be calculated using the exposed perimeter and floor area of the whole enlarged *dwelling*.

Limiting U-values for newly constructed thermal elements (e.g. in extensions) and new thermal elements to replace thermal elements in existing building

Table 5 Upgrading retained thermal elements

Element	(a) Threshold value W/m²·K	(b) Improved value W/m²·K
Cavity wall*	0.70	0.55
Other wall type	0.70	0.35
Floor	0.70	0.25
Pitched roof – insulation at ceiling level	0.35	0.16
Pitched roof – insulation between rafters	0.35	0.20
Flat roof or roof with integral insulation	0.35	0.25

* This only applies in the case of a wall suitable for the installation of cavity insulation. Where this is not the case it should be treated as for 'other wall type.'

Limiting U-values for retained thermal elements in existing buildings

Table 2 Reasonable provision when working on controlled fittings

Fitting	(a) Standard for new fittings in extensions	(b) Standard for replacement fittings in an existing dwelling
Window, roof window and rooflight	U-value = 1.8W/m^2·K or Window energy rating[15] = Band D; or Centre-pane U-value = 1.2W/m^2·K	U-value = 2.0W/m^2·K or Window energy rating = Band E; or Centre-pane U-value = 1.2W/m^2·K
Doors with more than 50% of their internal face area glazed	2.2W/m^2·K or centre-pane U-value = 1.2W/m^2·K	2.2W/m^2·K or centre-pane U-value = 1.2W/m^2·K
Other doors	3.0W/m^2·K	3.0W/m^2·K

Limiting U-values for windows and doors in existing non-domestic buildings

6.6.3 Air Permeability

For new domestic and non-domestic buildings, the Part L documents state that a reasonable limit for the ***design air permeability*** is 10m3/(h.m2) @ 50 Pa.

6.7 HVAC and Domestic Hot Water

6.7.1 Heating and Hot Water

Reasonable provision for the performance of heating and hot water system(s) would be to follow the guidance in the *Non-domestic Heating, Cooling and Ventilation Compliance Guide (NBS, 2006)* and *Domestic Heating Compliance Guide (NBS, 2006)*, in:

a. the use of an appliance with an efficiency not less than that recommended for its type and;

b. the provision of controls that meet the minimum control requirements for the particular type of appliance and heat distribution system.

Reasonable provision would be demonstrated by insulating pipes, ducts and vessels to standards that are not worse than those set out in the *Non-domestic Heating, Cooling and Ventilation Compliance Guide (NBS, 2006)* and *Domestic Heating Compliance Guide (NBS, 2006).*

6.7.2 Mechanical ventilation

For **non-domestic buildings**, the performance of air handling plant would need to consist of:

a. suitably efficient air handling plant; and

b. effective control systems.

Table 35 of the Non-domestic Heating, Cooling and Ventilation Compliance Guide (NBS, 2006) specifies the following limits to (Specific Fan Power) SFP of mechanical ventilation systems in new buildings:

Table 35 Limiting specific fan powers, W/(litre/s) in new buildings

System type	*SFP*, W/(litre/s)
Central mechanical ventilation including heating, cooling and heat recovery	2.5
Central mechanical ventilation with heating and cooling	2.0
All other central systems	1.8
Local ventilation only units within the local area, such as window/wall/roof units, serving one room or area	0.5
Local ventilation only units remote from the area such as ceiling void or roof mounted units, serving one room or area*	1.2
Other local units, e.g. fan coil units (rating weighted average**)	0.8

Notes:
*This also includes fan assisted terminal VAV units where the primary air and cooling is provided by central plant.
**The rating weighted average is calculated by the following formula

$$\frac{P_{mains,1}.SFP_1 + P_{mains,2}.SFP_2 + P_{mains,3}.SFP_3 + \ldots}{P_{mains,1} + P_{mains,2} + P_{mains,3} + \ldots}$$

For **domestic buildings**, where the work involves the provision of a mechanical ventilation system or part thereof, reasonable provision would be to install systems which also have specific fan powers and heat recovery efficiency not worse than those in the table below:

Table 3 Limits on design flexibility for mechanical ventilation systems

System type	Performance
Specific Fan Power (SFP) for continuous supply only and continuous extract only	0.8 litre/s.W
SFP for balanced systems	2.0 litre/s.W
Heat recovery efficiency	66%

6.7.3 Air-conditioning

For **non-domestic buildings**, the performance of the cooling plant would need to consist of:

a. suitably efficient cooling plant; and

b. effective control systems.

Tables 31 and 32 of the Non-domestic Heating, Cooling and Ventilation Compliance Guide (NBS, 2006) specify the following energy efficiency ratios and controls for cooling plants in new buildings:

Table 31 Minimum Energy Efficiency Ratio (EER) for comfort cooling

Type		Minimum cooling plant full load EER
Packaged air conditioners	Single duct types	1.8
	Other types	2.2
Split and multi-split air conditioners including variable refrigerant flow systems		2.4
Vapour compression cycle chillers, water cooled		3.4
Vapour compression cycle chillers, air cooled		2.25
Water loop heat pump		3.2
Absorption cycle chillers		0.5
Gas engine driven variable refrigerant flow		1.0

Table 32 Minimum controls for comfort cooling in new and existing buildings

	Minimum controls
Cooling plant	• Multiple cooling modules should be provided with controls to provide the most efficient operating modes for the combined plant
Cooling system	• Each terminal unit capable of providing cooling must be capable of time and temperature control either by its own, or remote, controls • In any given zone simultaneous heating and cooling shall be prevented by a suitable interlock

For **domestic** buildings, fixed air conditioners are required to have an energy efficiency classification equal to or better than class C in Schedule 3 of the labelling scheme adopted under the *Energy Information (Household Air Conditioners) (No. 2) Regulations 2005*. The *Energy Information (Household Air Conditioners)* contains energy efficiency classifications for various types of air-conditioning systems (split units, water-cooled, air-cooled, etc.).

6.8 Lighting

Minimum lighting efficacies are required to be met for domestic and non-domestic buildings. For office, industrial and storage areas in all building types, the average initial efficacy should be no less than **45 luminaire-lumens/circuit-Watt**. For any other non-domestic buildings, an average initial (100 hour) lamp plus ballast efficacy of not less than **50 lamp lumens per circuit-Watt** is required.

For domestic buildings, the requirement is to provide lighting fittings (including lamp, control gear and an appropriate housing, reflector, shade or diffuser or other device for controlling the output light) that only take lamps having a luminous efficacy greater than **40 lumens per circuit-Watt**.

Other requirements include the inclusion of **lighting controls** so as to avoid unnecessary lighting during the times when daylight levels are adequate or when spaces are unoccupied.
For domestic buildings, if the lighting efficacy cannot be met for external lit spaces, it is required that Lamp capacity does not exceed 150W per light fitting and the lighting automatically switches off when there is enough daylight and when it is not required at night.

6.9 Elevators and Conveyors

The UK Part L Approved Documents do not specify requirements for the energy efficiency of elevators and conveyors. However, the contribution of elevators and conveyors is taken into consideration when calculating the overall energy consumption.

6.10 Renewable Energy

There is a requirement in Article 5 of the Energy Performance of Buildings Directive (EPBD) to give consideration to the incorporation of low and zero carbon energy supply systems before construction starts.

The contribution of low and zero carbon (LZC) energy systems is taken into account in the calculation of the energy performance of the building.

LZC energy supply systems such as solar hot water, photovoltaic power, bio-fuels (e.g. wood fuels and oil blends), combined heat and power, and heat pumps can make substantial and cost effective contributions to achieving the minimum energy performance.

6.11 Other requirements

Energy metering systems should be installed to enable at least 90% of the estimated annual energy consumption of each fuel used in the building to be assigned to the various end-use categories (heating, lighting etc.). The performance of any LZC system should to be separately monitored; and in buildings with a total useful floor area greater than 1000m^2, automatic meter reading and data collection facilities should be made available.

7 Danish Building Regulation (BR08)

7.1 Introduction

The Danish Building Regulation dated 2008 (BR08) is a national and mandatory regulation that describes the overall functional requirements related to erection of all new buildings, extensions to buildings, conservation of and any other alterations to buildings and any significant change of use of buildings and finally with the demolition of buildings.

The first Building Regulation is dated back to 1961 taken the traditional ways of building houses as its starting point and has since then developed towards more functional requirements based on a higher level of abstraction.

Part 7 in BR08 deals with requirement for energy consumption in buildings in BR08 Part 7 and contains provisions from Directive 2002/91/EC of the European Parliament on the Energy Performance of Buildings.

7.2 Administrative Provisions

7.2.1 Structure and Scope

Requirements for energy consumption are handled and formulated as shown in the figure below, with the specific requirements and compliance method described in BR08 supported by a number of Standards and Guidelines useful for designers and local authorities.

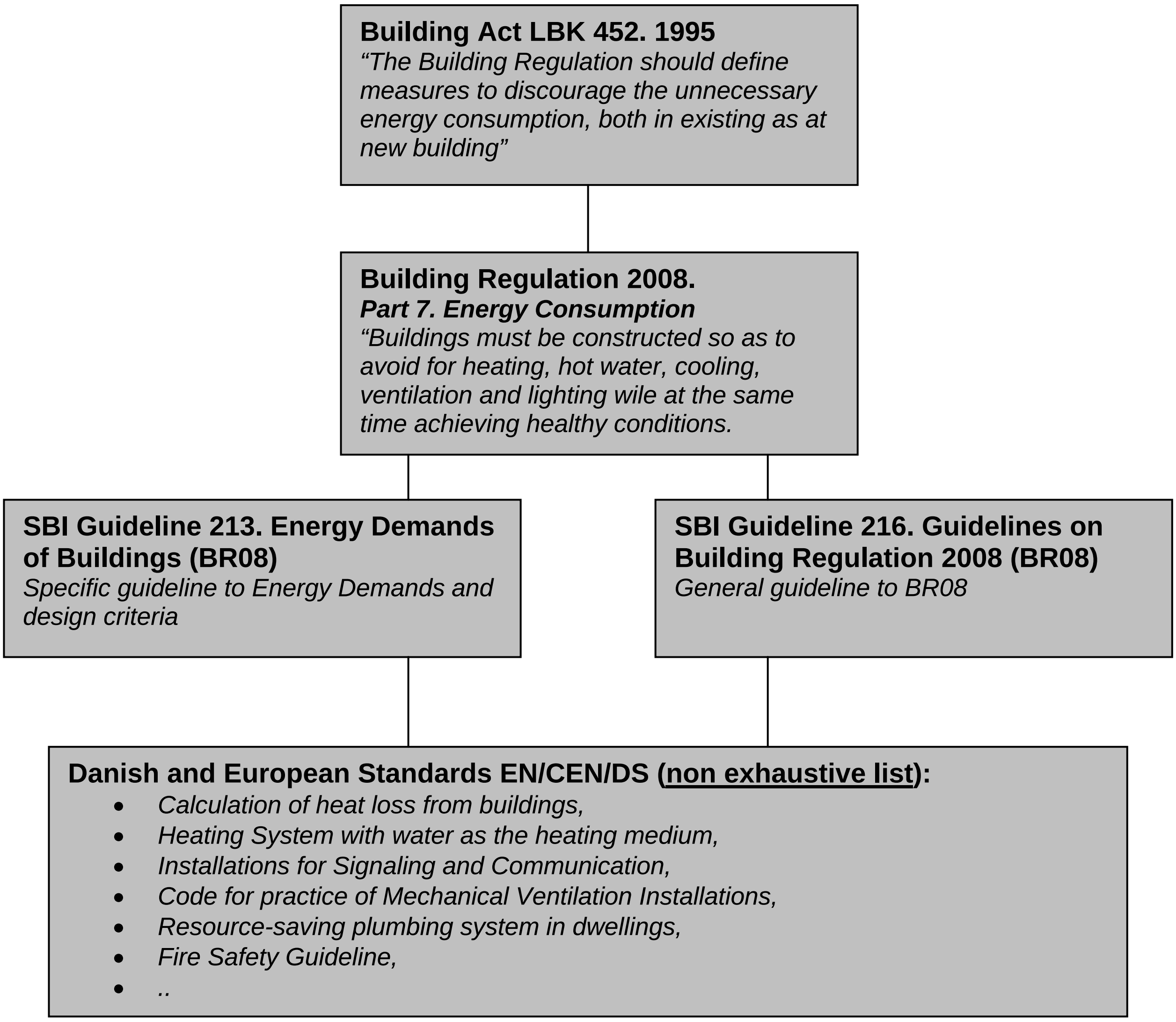


Figure 9. Danish Energy Legislation and Guideline Structure

All buildings heated to above 5^{o}C must comply with the provisions in BR08, part 7 and different requirements are defined for different buildings types. The building types are grouped in:

- New buildings
  - Dwellings, student accommodation, hotels etc
  - Offices, schools, institutions etc
- Changes of use and extensions heated to a minimum 15 ^{o}C
- Conversion and other significant alterations to the building and replacement of boilers etc
- Holiday homes

7.2.2 Enforcement Mechanisms

Any building owner has its own responsibility to meet the legislative requirement set in the Danish Building Act, and any offences will be punished with fine.

7.2.3 Compliance Methods and Tools

Any building permit application much include a calculation of the building energy consumption or a calculation of heat loss depending on building type and heating level. All calculations much be done in accordance to methods set out in *SBI Guideline 213 Energy Demands of Buildings (energy frames)* or *DS 418 Calculation of heat loss from buildings (individual constructions).*

If calculations of the overall energy frame is needed it is mandatory to use the software program BE06 in order to prove that requirements in BR08 part 7 is complied. The software calculates the overall energy balance, total energy requirement and the total energy frame for a specific building. The tool is a compliance tool used by designers to meet requirements, but is normally used by architects and engineers in early stage to indicate if the building design can possible meet energy requirements. The energy performance framework enables large flexibility in the individual building design even though the energy requirements should be met.

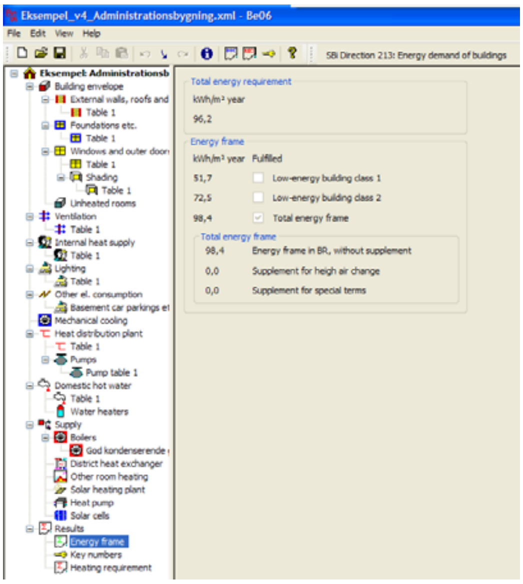


Figure 10. Screen dump - Danish Energy Compliance Tool Be06.

For new buildings compulsory air tightness tests must be carried out and a unique building energy label must be prepared by an independent authority, in order to control that the building meets the energy design. Finally a completion notice and occupancy permit can be issued for the building.

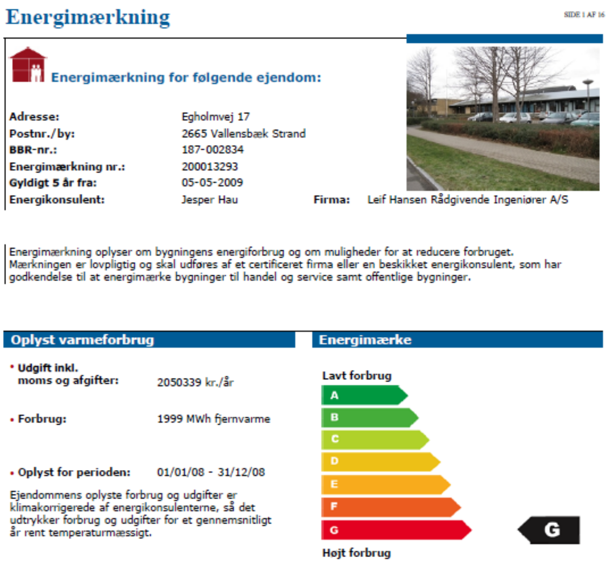


Figure 11. Energy Label example.

According to the Danish Building Act the local Municipal Council may charge for permits, temporary permissions and notices pursuant to the Building Regulation. The Method for calculating and charging fees is determined by the municipal council and varies a lot from one to municipality to another. The building permit lapses, if construction work has not begun within 1 year from the permit date.

7.3 Code Maintenance and Development

Revisions of BR08 occurs regularly, almost every second year a new and updated version is launched, often due to increased energy requirements. Another BR10 is currently in its hearing phase and contains a 25% reduction of existing energy consumption requirement. Further 25% reduction in energy consumption requirements is forecasted for 2012.

7.4 Regulation Method

Buildings heated to a minimum of 15 ^{o}C must be designed such that the energy demand does not exceed the following energy performance frameworks:

Basis:

Dwellings, students accommodations, hotels etc	(70 + 2200/A) kWh/m^2*yr
Offices, schools, institutions etc	(95+2200/A) kWh/m^2*yr

Low Energy Class 1:

Low Energy Dwellings, students accommodation, hotels etc	(35 + 1100/A) kWh/m^2*yr
Low Energy Offices, schools, institutions etc	(50 + 1100/A) kWh/m^2*yr

Low Energy Class 2:

Low Energy Dwellings, students accommodation, hotels etc	(50 + 1600/A) kWh/m^2*yr
Low Energy Offices, schools, institutions etc	(70 + 1100/A) kWh/m^2*yr

(A is the heated floor area).

The energy performance framework covers the total needs of the building for supplied energy for *heating, cooling, domestic hot water and electricity*. Electricity is not included in dwellings.

Even if the energy performance framework has been complied with, the design transmission loss (excluding the loss from windows and doors), may not exceed:

- Single storey buildings 6 W/m^2 of the building envelope
- Two-storey buildings 7 W/m^2 of the building envelope
- Three or more storey's 8 W/m^2 of the building envelope

In Denmark most buildings are provided with at least 2 different types of energy supply. The Danish Energy Authority has decided that when assessing the energy performance framework of buildings a factor of 2.5 applies in respect of combining electricity with gas, oil or district heating as appropriate. This encourages to reduce electricity consumption as much as possible. The 2.5 factor also reflects the price difference between electricity and heating.

7.5 Building Lay-out and Design

Impact on annually cooling and heating demand from building lay-out and design shall be calculated. Data is needs to be feed into the energy performance framework calculation for:

- Orientation, building envelope areas, overhangs, shading from surrounded buildings, heat capacity
- Glazing (type, orientation, internal/external shading) – access of daylight/solar gain

Guiding standard data are available for e.g. shading factors and heat capacity and general recommendations are given:

"Windows must be made, located and, where appropriate, screened such that sunlight through them does not cause overheating in the rooms, and such that nuisance from direct solar heat gain is avoided. In working areas, the daylight can usually be taken to be sufficient if the glazed area of side lights corresponds to a minimum of 10% of the floor area or, in the case of roof lights, no less than 7% of the floor area, assuming that the light transmittance of the glazing is no less than 0.75."

And for mechanical ventilation:

"Where special constructional allowances are in place, for example greater room volumes per person, the use of several extraction options, including cross ventilation options, the requirement for mechanical ventilation may be waived provided that a comfortable, healthy indoor climate is maintained."

7.6 Building Envelope

Insulation of individual building elements in the building envelope must, however, be at least on a par with the values in the table below. To avoid thermal bridges values a set for linear heat loss as well. The minimum insulation requirement is also a means of providing comfort and avoiding risk of condensation.

Table of U-values	**U-value W/m² K**
External walls and basement walls in contact with the soil.	0.20
Partition walls adjoining rooms that are unheated or heated to a temperature more than 8 K lower than the temperature in the room concerned.	0.40
Ground slabs, basement floors in contact with the soil and suspended upper floors above open air or a ventilated crawl space.	0.15
Ground slabs, basement floors in contact with the soil and suspended upper floors above open air or a ventilated crawl space, if underfloor heating is used.	0.12
Ceiling and roof constructions, including jamb walls, flat roofs and sloping walls directly adjoining the roof.	0.15
Windows and external doors, including glass walls and hatches to the outside or to rooms that are unheated or heated to a temperature more than 8 K below the temperature in the rooms concerned (does not apply to ventilation openings below 500 cm²).	1.50
Skylights and rooflights.	1.80

	Linear loss W/m K
Foundations.	0.15
Foundations around floors with underfloor heating.	0.12
Joint between external wall, windows or external doors and hatches.	0.03
Joint between roof construction and windows in the roof or rooflights.	0.10

Figure 12. Table of U-values (K-values) to individual building elements..

Building elements around rooms that are heated to more than 5°C and up to 15 °C must have thermal insulation which corresponds to higher U-values as shown in the table above.

7.7 HVAC and Domestic Hot Water

Ventilation systems and distribution systems for heating, cooling and domestic hot water must be appropriately designed and installed in terms of safety, energy and indoor climate considerations.

Heating and cooling systems must be designed and built for energy-efficient operation, and must be equipped with automatic regulation and temperature control of heat/cooling transfer in individual rooms.

It must be possible to restrict the supply of fresh air during periods when the need for ventilation of the building is reduced, and to adjust the supply of fresh air to suit the loads in rooms with highly variable ventilation needs.

Various requirements for HVAC systems are specified including:

- Ventilation installations must incorporate heat recovery with a temperature efficiency of no less than 65%.
- Power consumption for air movement may not exceed 2,100 J/m³ fresh air (CAV), 2,500 J/m³ fresh air (VAV), 1,000 J/m³ (systems without mechanical fresh air supply), 1,200 J/m³ (CAV in dwellings) for the mode of operation with the maximum pressure drop.
- COP for various equipment types
- Thermal insulation levels for boilers and piping systems (heat losses from technical installation inside and outside building envelope is included in the energy performance framework)
- Efficiency coefficient for boilers (> 91%) and heat recovery in ventilation systems (> 65%) and heating systems (>75%)

The regulation refers to specific standards and code of practice for HVAC systems.

7.8 Light conditions

General recommendations for daylight: *"The requirement for daylight must be viewed in the context of the general health aspects of daylight. The quantity of daylight also affects the artificial lighting requirements."*

Additional guidelines and standards specify recommendations for:

- Lighting quality, - levels, - control and -zoning
- Daylight accessibility, internal surface colors. In some cases daylight access shall be complied with calculations of daylight factor.

7.9 Elevators and Conveyors

No specific energy requirements are set for elevators, lifts, conveyors and minor energy consuming equipment like small pumps and low voltage equipment.

7.10 Renewable Energy

Renewable energy as solar water heating systems, photovoltaic and heat pumps is taken into account when calculating the energy performance framework. The energy demand is decreased accordingly to the energy supply from the RE system. For photovoltaic the energy contribution is multiplied by 2.5 whereas solar water heating and heat pump is multiplies by 1.

8 Passive House Standard

8.1 Introduction

The Passive House is one of the world's leading standard in energy efficient construction with energy saved on heating up to 80% compared to conventional standards of new buildings.
The Passive House concept is in general a comprehensive approach to cost-efficient, high quality, healthy and sustainable construction. Most Passive Houses are located in Germany and Austria, with others in various countries worldwide and the requirements in the standard are mainly set for central European location, but can of course be used in other countries with similar weather conditions. In other words, the standard can not directly be adopted to hot tropical climate conditions; but the standards gives an example on how energy efficiency standards can go even further in order to achieve a close to zero energy demand in buildings.

8.2 Administrative Provisions

8.2.1 Structure and Scope

A Passive House Certificate can be obtained for two different building classes – Buildings for Residential Use and Buildings for Non-Residential use.

8.2.2 Enforcement Mechanisms

Enforcement mechanisms are not relevant as the standard is voluntary, although a Passive House Certificate can be obtained.

8.2.3 Compliance Methods and Tool

It is possible to apply for a *Quality-Assured Passive House* certificate from the Passive House Institute or other accredited representatives.

Verification of energy design for a Passive House must be carried out with the aid of the 'Passive House Planning Package' (PHPP). At the core of the package are worksheets for heating energy balances (annual demand or monthly method), heat distribution and supply, electricity demand and primary energy demand.

A comprehensive checklist defines the minimum criteria for the content of calculations. Furthermore the following documentations shall be delivered together with the application:

- Drawings
- Technical Specifications and data sheet for energy consuming appliances
- Verification of air tightness in the building envelope

8.3 Code Maintenance and Development

PHPP was presented for the first time in 1998 and has since been continuously developed further. New design modules have been added successively, e.g. calculation of window parameters, shading, heating load and summer performance. The PHPP is continuously validated and refined based on measurements and new research results.

8.4 Regulation Method

The definition of a Passive House is:

"A building in which a comfortable indoor climate can be obtained without a traditional heating or cooling system".

This can be done, if a number of conditions for building fabric and installations are fulfilled:

- The building must be designed to have an annual heating demand as calculated with the Passive House Planning Package of not more than 15 kWh/m² per year in heating and 15 kWh/m² per year cooling energy OR to be designed with a peak heat load of 10W/m²
- Total primary energy (source energy for electricity and etc.) consumption (primary energy for heating, hot water and electricity) must not be more than 120 kWh/m² per year
- The building must not leak more air than 0.6 times the house volume per hour ($n_{50} \leq 0.6$ / hour) at 50 Pa (N/m²) as tested by a blower door

A checklist is prepared to make it easier to reach certified passive house standard by listing the most important steps in the process and particularly draw the attention to the quality control process that must accompany the passive house construction process. Extracts from the checklist is listed in the following.

8.5 Building Lay-out and Design

Consider:

- How suitable is the site for a passive house?
- Orientation and shading factors preventing the use of solar gains - any trees with conservation orders?
- Compact buildings
- Orientation of glazing for solar gains and daylight access
- Simple envelope shapes
- Carry out the first iterations of PHPP to see if the ideas add up in passive house terms.

8.6 Building Envelope

Consider:

- Plan wall/foundation/roof construction and insulation thickness.
- Avoid cold bridges: A construction of a passive house is set to be "Thermal Bridge Free" if the maximum bridges are under 0.01 W/mK.
- Ultra-insulated construction elements: External elements - $U \leq 0.15$ W/(m²K)
- Design connection details to eliminate cold bridging - if in doubt calculate and verify.
- Design connection details to assure air tightness.
- Calculate the specific space heating demand using PHPP
- Position of air inlets and exhausts - do not place above heating elements (if present).
- Dimension overflow openings for a pressure drop $\Delta_p \leq 1$ Pa.

8.7 HVAC

Consider:

- Short pipe lengths for cold, hot and waste water, short ventilation ducts - cold air ducts outside the heated envelope, warm ducts inside
- Central ventilation/heat recovery unit, overall efficiency ≥ 75%
- Leakage to surrounding air < 3% of the rated flow volume
- High electrical efficiency, power consumption < 0.45 Wh/m³ air
- Ventilation user controls
- Optionally, consider installing a ground heat exchanger to keep intake air frost free.

8.8 Domestic Hot Water

Consider:

- Short pipes, very well insulated - routed inside the thermal envelope.
- Insulate warm water and heating fittings.
- Use water-saving taps, etc.
- Connect washing machines and dish washers to the hot water supply.

8.9 Passive Houses in Practice

Passive Houses around the world are characterised by having an extreme degree of insulation – which vary with the local climate conditions – very efficient windows and efficient HVAC systems with natural pre-cooling of air. A typical design for a Passive House could cover:

- **Highly insulated.** All the building parts for walls, roofs and floors are insulated with U-values within 0.10 – 0.15 W/m²K.
- **No thermal bridges.**
- **With comfort windows.** Three layers of glass, coating on multiple sides and are filled with gas. They will also have warm edges and special energy efficient frames. Overall, U-values for these windows are 0.70 – 0.85 W/m²K.
- **Very air tight.**
- **Supplied with efficient mechanical ventilation.** To ensure sufficient ventilation passive houses are supplied with mechanical ventilation which will secure a controlled air exchange.
- **Using innovative heating technology.** The heating and cooling of these buildings are typically supplied by innovative systems which include a heat exchanger. Typically this will be combined with a heat pump or a highly efficient small heating system.

9 South African National Standard, Energy Efficiency in Buildings (SANS 204 -1/204-2/204-3:2008)

9.1 Introduction

South Africa's current National Building Code SANS 10400 refers to the National Building Regulations and Building Standards Act, 1977 (Act No. 103 of 1977).

The SABS Technical Committee has yet released amendment to SANS 10400. The document SANS 10400 PART XA: ENERGY USAGE was under review until 20th August 2010.

In October 2008 the SANS 204 was published as a National Standard for "Energy Efficiency in Buildings ". The South African National Standards for Energy Efficiency is currently a voluntary standard including 3 parts, but are expected to become part of the SANS 10400 National Building Code later in 2010, whereupon it will be compulsory for all new buildings to comply with these minimum standards.

In general provisions for building site operations, building design and construction in regulations are deemed-to-satisfy rules, which might be seen as straightforward means of ensuring that the Regulations have been applied. However, deemed-to-satisfy rules are not Regulations and therefore not mandatory.

The coming SANS 10400 XA reads:
1. Buildings shall be designed and constructed so that buildings:
a. are capable of using energy efficiently while fulfilling the user needs in relation to vertical transport, if any, thermal comfort, lighting and hot water; or
b. have features and services which facilitate the efficient use of energy appropriate to their function and use, internal environment and geographical location

2. At least 50% by volume of the annual average hot water heating requirement shall be provided by means other than electrical resistance heating including but not limited to solar heating, pumps, heat recovery from other systems or processes and renewable combustible fuel.

The requirements of sub-regulation 1 shall be deemed to be satisfied when such building is designed and constructed in accordance with the following requirements:

a. Has an orientation, shading, services and building envelope in accordance with SANS 10400 Part XA; or
b. Is the subject of a rational design by a competent person, which demonstrates that the energy usage of such building is equivalent to or better than which would have been achieved by compliance with the requirements of SANS10400 XA, or
c. Has a theoretical energy usage performance determined using certified thermal calculation software, less than or equal to that of a reference building in accordance with SANS 10400 XA.

9.2 Administrative Provisions

9.2.1 Structure and Scope

The SANS 204 specifies the requirements for all new buildings except government subsidized housing.

The SANS 204 includes:

- SANS 204-1 for energy efficiency in buildings with artificial or natural environmental control part 1, general provisions;
- SANS 204-2 for energy efficiency in buildings with artificial or natural environmental control part

2: the application of the general provisions for energy efficiency in buildings with natural environmental control;
- SANS 204-3 for energy efficiency in buildings with artificial or natural environmental control part 2: the application of the general provisions for energy efficiency in buildings with artificial environmental control

9.2.2 Enforcement Mechanisms

Any person who fails to comply with any notice contemplated in the SANS 10400 shall be guilty of an offence.

Failure to comply with requirements in SANS 204 may result in fines or penalties (private sector) or referral to the Auditor-General (public sector).

9.2.3 Compliance Methods and Tools

Part 1 of the SANS 204 is includes compliance methods.

Compliance with the SANS 204 requirement shall be done through a rational design prepared by a competent person (qualified mechanical or electrical engineer), by:

- Demonstrating that requirements for a maximum energy demand depending on building classification and climate zone are met
- Providing a certificate of compliance to the local authority as part of the requirements for obtaining an occupancy certificate.
- For artificially ventilated or air-conditioned buildings the energy rating shall be displayed through annually reports on energy usage.

SANS 204-1:2008
Edition 1

Annex B
(informative)

Pro forma compliance certificate

To (appropriate local authority): ....

Plan submission reference: ....

Name of project: ....

Street address: ....

Erf number: ....

Electricity supply account number: ....

Climatic zone: ....(see figure 1 of SANS 204-1)

Stage (pre- or post-occupancy): ....

Table B.1 — Building occupancies and areas

1	2
Occupancy in accordance with SANS 10400-A	Net floor area m²

It is hereby certified that the building described above has been evaluated (if pre-occupancy) or verified (if post-occupancy) to comply with the requirements of SANS 204-1 and that the performance requirements are evaluated (if pre-occupancy) or verified (if post-occupancy) as indicated in table B.2.

Signed at....................................on this.......................day of ....

....
Signature

Table B.2 — Maximum energy demand and maximum energy consumption

1	2	3	4	5	6
Occupancy in accordance with SANS 10400-A	Maximum energy demand kVA	Maximum energy demand kVA/m²	Maximum annual consumption kWh/a	Other energy sources kWh/a	Maximum energy consumption kWh/(m²·a)

Table B.3 — List of other energy sources and annual kWh equivalent

1	2
Energy source	Annual kWh equivalent

Power factor as verified (entire building) ....

(If pre-occupancy)

The method used to evaluate the building energy requirement:

....

....

....
(For example, program used, details of methodology, any assumptions)

(If post-occupancy)

The evaluation method used:

....

....

....
(For example, electrical billing records, energy monitoring)

Figure 13. Pro Forma Compliance certificate, SANS 204-1:2008

The building service systems should be inspected by a responsible person (building owner/person acting on his behalf) and a certificate should be provided to the local authority.

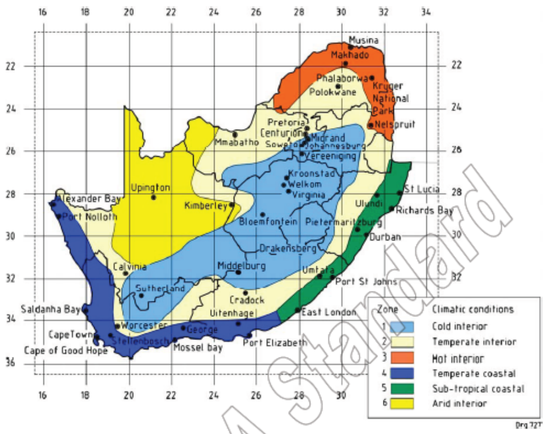
Finally a Building Energy Efficiency Label or Passport should be issued. The standards use the German ENERGIEPASS as an example of an appropriate Energy Labeling Certificate.

9.3 Code Maintenance and Development

It is expected that the SANS 204 will be adopted in the National Building Code SANS 10400 before the end of 2010, and it is planned to be revised at least every fifth year.

9.4 Regulation Method

SANS 204 - Part 1 covers the occupancies of public buildings, offices and hotels. Maximum energy demand and maximum annual energy consumption are determined by the occupancy and climatic zone. See figures below.



Zone	Description	Major centre
1	Cold interior	Johannesburg, Bloemfontein
2	Temperate interior	Pretoria, Polokwane
3	Hot interior	Makhado, Nelspruit
4	Temperate coastal	Cape Town, Port Elizabeth
5	Sub-tropical coastal	East London, Durban, Richards Bay
6	Arid interior	Upington, Kimberley

Figure 1 — Climatic zone map

Table 3 — Maximum energy demand per building classification for each climatic zone

1	2	3	4	5	6	7	8
Classification of occupancy of building	**Description of building**	**Maximum energy demand**[1] VA/m^2					
		Zone					
		1	**2**	**3**	**4**	**5**	**6**
A1	Entertainment and public assembly	85	80	90	80	80	85
A2	Theatrical and indoor sport	85	80	90	80	80	85
A3	Places of instruction	80	75	85	75	75	80
A4	Worship	80	75	85	75	75	80
F1	Large shop (including shopping malls)	90	85	95	85	85	90
G1	Offices	80	75	85	75	75	80
H1	Hotel	90	85	95	85	85	90

[1)] The maximum demand shall be based on the sum of 12 consecutive monthly maximum demand values per area divided by 12 and m^2 – refers to the net floor area

1	2	3	4	5	6	7	8
Classification of occupancy of building	**Description of building**	**Maximum energy consumption** kWh/m^2.a					
		Zone					
		1	**2**	**3**	**4**	**5**	**6**
A1	Entertainment and public assembly	420	400	440	390	400	420
A2	Theatrical and indoor sport	420	400	440	390	400	420
A3	Places of instruction	420	400	440	390	400	420
A4	Worship	120	115	125	110	115	120
F1	Large shop (including shopping malls)	240	245	260	240	260	255
G1	Offices	200	190	210	185	190	200
H1	Hotel	650	600	585	600	620	630

NOTE 1 The annual consumption per meter square shall be based on the sum of 12 months monthly consumption of consecutive months.

NOTE 2 Non-electrical consumption, such as fossil fuels, shall be accounted for on a thermal equivalence basis, i.e. by converting mega joules to Kilowatt hour.

Figure 14. Climatic zone map and Energy Demand and Energy Consumption requirements, SANS 204-1:2008

Other buildings not stipulated in the above tables shall comply with the provisions of SANS 204-2 and 3.

Requirements for R-values should be met for various parts of building envelope.

9.5 Building Lay-out and Design

Town planners shall take cognizance of orientation requirements for energy efficient design when planning lay-outs. Site lay-outs should enable buildings to be orientated towards North and buildings should be oriented to achieve the lowest net energy use in accordance with figures in the standard depending on geographic location.

Glazing must conform to conductance and solar heat gain requirements. Aggregates are calculated for the whole building. In case a building is considered to face north and shading is required, permanent shading features (part of building construction) and external shading devices (blinds, shutters etc) should be prepared in order to restrict at least 60% of the summer solar radiation.

For air conditioned buildings an aggregate air-conditioning value shall be calculated and must not exceed table values.

Data on different glazing types and algorithms for calculating heat transfer though glazing are given in the standard.

9.6 Building Envelope

Depending on climate zone buildings with floor areas of less than 500 m^2 with concrete floor shall have insulation installed around vertical edges of its perimeter, and requirements for insulation thickness and R-value are defined.

For external walls with mass < 300kg/m^2, R–values between 1.9 and 2.2 are required. Walls with mass > 300 kg/m2, for e.g. Zones 1 & 2: R-values between 0.9 and 1.4 are required.

Roofs and ceilings shall achieve the minimum total R-value specified in tables or have a metal deck roof with a thermal break ensuring a R-value of not less than 0,2. Insulation of roofs shall comply with minimum required R-values and reflective insulation shall be installed.

Data on typical insulation products and recommended minimum thickness of products are given in the table below.

Table 8 — Typical deemed-to-satisfy thicknesses of generic insulation products

1	2	3	4	5	6	7	8	9
Description			Climatic zones					
			1	2	3	4	5	6
Generic insulation products	Density kg/m³	Thermal Conductivity W/(m·K)	Recommended minimum thickness of insulation product mm					
Cellulose fibre loose-fill	27,5	0,040	140	120	100	140	100	130
Flexible fibre glass blanket	10 – 18	0,040	140	120	100	140	100	130
Flexible BOQ polyester fibre blanket	24	0,038	130	110	90	130	90	125
Flexible polyester blanket	11,5	0,046	160	140	120	160	110	150
Flexible mineral/rockwool	60 – 120	0,033	115	100	80	115	80	100
Flexible ceramic fibre	84	0,033	115	100	80	115	80	100
Rigid expanded polystyrene (EPS)SD	15	0,035[a]	120	100	90	120	80	115
Rigid extruded polystyrene (XPS)	32	0,028[a]	100	80	70	100	65	90
Rigid fibre glass board	47,5	0,033	115	100	80	115	80	100
Rigid BOQ polyester fibre board	61	0,034	115	100	80	115	80	110
Rigid polyurethane board	32	0,025[a]	85	70	60	85	60	80

NOTE The aforementioned recommended deemed-to-satisfy (DTS) levels of insulation can be achieved by the use of reflective foils, bulk insulation or rigid board insulation or in combination with one another. Maximum efficiency may be achieved at reduced thicknesses taking the aforementioned into account. Rational assessment is always an alternative to DTS provisions.

[a] Thermal efficiencies are dependant on materials thickness, density, age, operating temperature and moisture.

Figure 15. Typical deemed to-satisfy insulation thickness, SANS 204-3:2008

Further general explanatory information and guidelines on building construction characteristics is given in the standard.

Air leakage shall be controlled to specified standards for each part of the building envelope.

9.6 HVAC and Domestic Hot Water

Air-conditioning system shall be best practice using the most efficient technology and distribution of air shall be divided into appropriate zones depending on comfort criteria.

Services requirements include:

- Total fan motor power for air movement may not exceed 1,6 W/l/s of supply air quantity (CAV) and 2,1 1,6 W/l/s of supply air quantity (VAV)
- Fan motor power of at least 5 kW should incorporate control devices
- Pump efficiency for water distribution with minimum efficiency of 70%
- Maximum friction loss of piping systems at 350 Pa/m (noise and erosion control
- Built-in temperature controls in heating and cooling appliances
- Pipe and duct insulation
- Thermostatic controls for set point temperature for thermal comfort
- Humidity and thermal control
- COP for various equipment types
- Ventilation installations must incorporate heat recovery with a temperature efficiency of no less than 75% or covered by site-solar energy source
- Manual operation means shall be incorporated to allow for the adjustment of the indoor environment
- Total Power Factor > 0,95

The standard refers to further specific SANS for HVAC systems.

9.7 Light conditions

Designers are encouraged to use day lighting. Recommended table values for light levels, power and energy usage for artificial lighting can be used when calculating light conditions. General compliance with relevant national legislation is necessary for safety, and minimum lightning levels shall be determined in accordance with SANS 10114-1.

9.8 Elevators and Conveyors

Elevators and lifts fitted into new buildings shall have an energy rating. The energy consumption for these systems shall be calculated and included in the overall energy consumption for the building.

9.10 Renewable Energy

Usage of renewable energy shall be maximized; and if the building energy consumption exceeds specific table values, the amount by which the energy exceeds the requirement may be mitigated by using renewable energy.

All new building shall be fitted with solar water heating systems for domestic hot water, unless it is not proven technically feasible. The system shall cover at least 50% of the energy consumption for hot water.

9.11 Electrical installations and appliances

Appliances fitted into new buildings including office appliances shall have an energy rating.

10 Energy Efficiency Considerations in the Botswana Building Regulation

10.1 Introduction

As a part of the project "Developing Energy Efficiency and Energy Conversation in the Building Sector, Botswana" a Draft Energy Code for Buildings in Botswana has been prepared in 2007. The code is largely based on The Building Code of Australia (BCA) and the IEEC Energy Code focusing on large scale buildings and is under implementation in the existing Building Regulation.

The code may apply to different building classes, for which reason the following building classification structure is suggested:

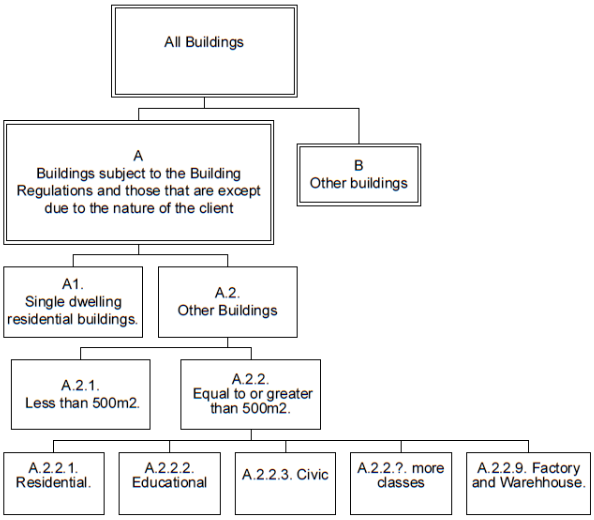


Figure 16. Building Classification for Energy Provisions Codes.

10.2 Administrative Provisions

10.2.1 Structure and Scope

The first draft regulation applies to all buildings with a floor area greater than 500 m^2 other than single dwelling residential buildings (Building class A.2.2).

10.2.2 Enforcement Mechanisms

Enforcement mechanisms are not included in the draft code.

10.2.3 Compliance Methods and Tools

Each Code section includes statements of "Performance Requirements" consisting of conceptual qualitative requirements. In the first version of the code quantitative requirements are avoided since these may vary due to the different climate zones in the country, but can easily be amended in future.

For each performance requirement "deemed-to-satisfy" provision that is approved as meeting the requirements, e.g. maximum U-values for specific building components. Alternative solutions in order to meet the overall performance requirements may be proposed, but shall be supported by an approved assessment method (building simulation programs e.g.). It will enable trade-offs between different elements of the building fabric, e.g. an improved performance of roof insulation will allow for reduced performance of glazing areas and the overall energy balance requirements can still be met. The assessment method by which alternative solutions can be shown to comply with the performance requirements shall be based on computer simulation for both the alternative solutions and the matching deemed-to-satisfy solution.

The code contains a list of approved simulation software, and it is referred to specifications for the procedures in IECC.

Energy simulation program	**URL**
BSim	www.bsim.dk
DesignBuilder	www.designbuilder.co.uk
EnergyPlus	www.energyplus.gov
ESP-r	www.esru.strath.ac.uk/Programs/ESP-r.htm
HAP	www.commercial.carrier.com
IDA ICE	www.equa.se/ice
IES<VE>	www.iesve.com
Tas	www.edsl.net
TRACE 700	www.tranecds.com
TRNSYS	sel.me.wisc.edu/trnsys
VisualDOE 2 or later versions	http://www.archenergy.com/

Figure 17. List of Approved Energy Simulation Programs.

10.3 Code Maintenance and Development

No information available.

10.4 Regulation Method

The overall energy use of the building shall be estimated and indicated with the submission, and the preferred method of estimating the annual energy consumption is by implementing and energy simulation using an approved computer programs.

10.5 Building Lay-out and Design

Two alternative requirements for vertical fenestration are defined:

1) Max. fenestration area of 40% of the total wall area
2) Total annual heat grain and maximum daily heat gain through fenestration simulated with approved computer simulation software shall be less than that for a similar building complying with Alternative 1.

No further requirements or recommendations on building orientation, building shape (area/surface ratio) etc

10.6 Building Envelope

U-values for opaque wall shall be less than 2.5 W/m^{2}K. Recommendation: 220 mm solid brick wall.

Two alternative requirements for roofs are defined:

1) Deemed-to-comply table values for external surface reflectance and U-values
2) Total annual heat gain and maximum daily heat gain shall be less than that for a similar building complying with Alternative 1.

No U-value requirements for other building fabrics available.

10.7 HVAC

Performance requirements for HVAC are defined as:

A building's HVAC systems, including any associated distribution system and components must have features that, to the degree necessary, facilitate the efficient use of energy appropriate to
(a) The building service and its usage; and
(b) The ambient conditions; and
(c) The energy source.

The HVAC systems shall deemed-to-comply with the following sections of IECC:

- Calculation of heating and cooling loads
- Equipment and system sizing
- HVAC equipment performance requirements
- HVAC system controls
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- HVAC system completion
- Simple HVAC systems and equipment (including subsections)
- Complex HVAC systems and equipment

10.8 Light conditions

Performance requirements for HVAC are defined as:

A building's electrical power and lighting systems must have features that, to the degree necessary, facilitate the efficient use of energy appropriate to

(a) The building usage; and
(b) The equipment being supplied; and
(c) Effective use of daylight; and
(d) The ambient conditions.

Electrical power and lighting systems shall comply with IECC Section 505.

In multi-storey buildings with floor area of more than 500 m^2 for any one storey, sub meters for electricity shall be installed at each storey larger than 500 m^2.

For each electrical appliance with a rated power consumption of over 20 kVA sub meters for shall be installed.

10.9 Elevators and Conveyors

No requirements available.

10.10 Renewable Energy

In buildings with a installed water heating capacity more than 10 W/m^2 floor area a minimum of 70% of the water heating capacity shall be provided by solar energy or process waste heat recovery.

11 Energy Code for Reunion – RTAA DOM

11.1 Introduction

As a critical part of this assignment, the new regulations in Reunion - the RTAA DOM (Réglementation Thermique, Acoustique et Aération - Départements d'Outre Mer) - have been analysed and it was attempted to find the success and failures related to the new regulations so far. Reunion is a very relevant candidate in the process of reviewing the regulations and their outcomes/successes/failures since their implementation, as it is an island state in close proximity to Mauritius, with fairly similar climatic conditions (especially in the lower and coastal regions), and exposure to natural hazards such as cyclones and floods.

11.2 Administrative Provisions

The RTAA DOM (Réglementation Thermique, Acoustique et Aération - Départements d'Outre Mer), the new building regulation for the Overseas Departments and Territories of France, was officially published on 17th April 2009. It sets out a number of requirements for *new residential buildings* only.

The RTAA DOM only came in force as of the 1st May 2010 and therefore all applications for a building permit made after this date, need to comply with the requirements of the RTAA DOM.

The RTAA DOM sets requirements for new residential buildings in the Overseas Departments and Territories of France, which include the departments of Guadeloupe, Guyana, Martinique and Reunion Island. The climate and lifestyle of these Overseas Departments make the current French metropolitan regulations unsuitable for thermal, acoustic and ventilation aspects. The regulations in France is mainly applicable for heavy constructions, that are tightly sealed and closed, which make them incompatible with the weather and the local lifestyle in Reunion.

11.3 Code Development and Maintenance

Prior to the RTAA DOM, there were no regulations on the technical aspects of energy efficient design and construction of new domestic buildings in Reunion. This has led to the construction of buildings with diverse levels of performance. The RTAA DOM was created as it was deemed important that there are building regulations in the Overseas Departments, which are adapted to the climatic conditions and which provide a shared set of requirements for the performance of buildings in those countries.

Since the RTAA DOM only came in force recently, it is not yet known when the next update will take place and how frequently updates will be made.

11.4 Regulation Method

The RTAA DOM is in the form of a decree, which amends the "Code de la construction et de l'habitation" (Code of construction and housing) on specific provisions for French Overseas Departments. The RTAA DOM consists of three sets of regulations: *thermal* regulations, regulations for *acoustics* and regulations for *ventilation*. The regulations set out requirements for the minimum level of performance that needs to be achieved for those aspects.

The main objectives of the regulations are:

- To improve the energy performance of buildings.
- To limit the use of air conditioning.
- To ensuring the quality of air inside the housing.
- To protecting the health of occupants.
- To ensuring that minimum comfort levels are maintained (thermal, acoustic and humidity).

11.5 Building Lay-out and Design

Much importance is placed on the protection of the building from solar gains and the location of openings in different orientations to allow for natural cross ventilation.

The requirements for protection of solar gains will be covered in the next section, "Building Envelope". The main aspect which refers to building layout is natural ventilation.

(i) For the purpose of natural ventilation, it is required that there is an uninterrupted flow of air through the living spaces of the building via external openings, by designing the building such that there are openings on different orientations of the building and in internal walls, as shown in the illustration below.

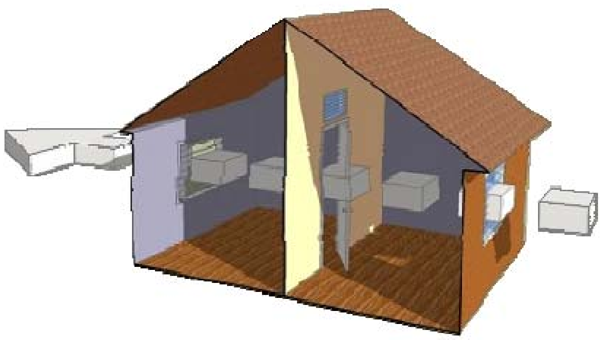


Image source: « RTAA DOM, les nouvelles réglementations » by the Ministry of Ecology, Energy and Sustainable Development, Republic of France

(ii) It is required to have openings in at least two facades in different orientations, and the minimum area of window openings depends on the location of the building. Buildings at an altitude of less than 400m are required to have **at least 20%** opening area on one façade. Buildings at an altitude between 400m and 800m are required to have **at least 15%** opening on one façade. Buildings at an altitude greater than 800m do not have a minimum requirement with regards to window-to-wall ratio.

(iii) Openings are required in interior walls adjacent to any living space and can be parallel or perpendicular. In the case of perpendicular walls, there is a minimum distance which is to be kept between the opening and the angle at which the walls meet. This distance is set to at least half the length of the wall (as shown below) to allow for adequate natural ventilation.

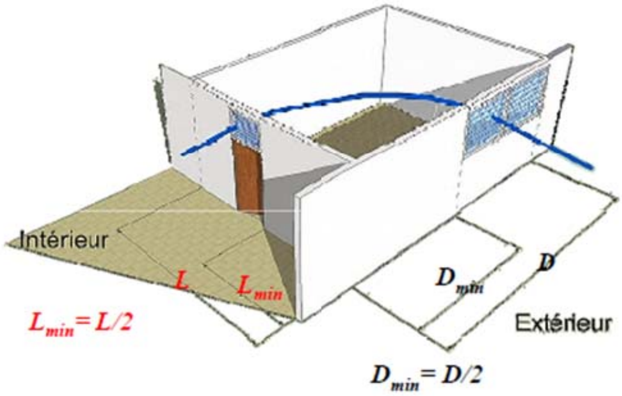


Image source: « RTAA DOM, les nouvelles réglementations » by the Ministry of Ecology, Energy and Sustainable Development, Republic of France

11.6 Building Envelope

Requirements for the performance of the building envelope are specified to reduce the solar gains.

(i) A "solar factor" S is specified for opaque structures, as follows:

Horizontal opaque structure (roofs): S ≤ 0.03
Vertical opaque structure (walls): S ≤ 0.09

where a structure is defined as 'horizontal' if its angle to the horizontal plane as seen from inside the building is less than 60 degrees, and a structure is defined as 'vertical' if its angle to the horizontal plane as seen from inside the building is greater than 60 degrees.

(ii) The solar factor requirement for windows has been set as follows:

Windows adjacent to an air-conditioned space: S ≤ 0.25
Windows adjacent to an un-conditioned space: S ≤ 0.65

(iii) Horizontal structures (roofs) should not to contain any windows or transparent/translucent material, except for buildings which are located at an altitude greater than 800m.

In addition, in the higher zones of Reunion (> 800m), a minimum insulation is required for building, and is defined by the U-value (coefficient of heat transmission). The limiting U-values required for buildings at altitudes greater than 800m are as follows:

Horizontal opaque structure (roofs): U-value ≤ 0.5 W/m².K
Vertical opaque structure (walls): U-value ≤ 2 W/m².K

11.7 HVAC and Hot Water

11.7.1 Heating

With regards to the rare cases where the house is equipped with combustion appliances for heating, it should be ensured that the ventilation system will allow the smooth operation of equipment.

Mechanical ventilation should be sized so as not to reverse the circulation of the flue.

Air intakes should be easily cleanable and the easy maintenance and testing of mechanical systems should be possible.

11.7.2 Domestic Hot Water

According to the RTAA DOM requirements, all new homes must be fitted with a solar hot water system, which should amount to at least 50% of the hot water demand.

11.7.3 Mechanical ventilation

In cases where mechanical ventilation is required due to high external noise levels, the following minimum air extraction rates are specified for different types of houses and for utility spaces (kitchen, toilets, and bathrooms):

	House with 1 bedroom	House with 2 bedrooms	House with 3 or more bedrooms
Kitchen	Air change rate ≥ 20 m^3/h	Air change rate ≥ 30 m^3/h	Air change rate ≥ 45 m^3/h
Bathroom	Air change rate ≥ 15 m^3/h		Air change rate ≥ 30 m^3/h
Toilet	Air change rate ≥ 15 m^3/h		

Table 9. Mechanical ventilation

For living spaces, the following minimum outdoor air exchange rates are required :

- **Bedrooms**: ≥ 20 m^3/h
- **Living room/dining room/lounge**: ≥ 40 m^3/h

In addition, all living spaces should make provision for the later connection of a ceiling fan or have a ceiling fan installed as from the construction of the building.

11.7.4 Air-conditioning

For air-conditioned buildings or rooms with air conditioning, adequate ventilation within these areas is to be provided as per the provisions in section 11.7.2 above.

With the exception of buildings which are insulated and sealed for acoustic reasons, the mechanical ventilation systems mentioned in section 11.7.2 should have the option to be switched off by means of control equipment when air conditioning is not in use.

11.8 Lighting

RTAA DOM does not provide requirements for lighting.

11.9 Elevators and Conveyors

RTAA DOM does not provide requirements for elevators and conveyors.

11.10 Renewable Energy

Except for the requirement of solar hot water for all new residential buildings, the RTAA DOM does not specify any other requirements for renewable energy.

12 Building Code of Australia (BCA)

12.1 Introduction

The Building Code of Australia (BCA) is produced and maintained by the Australian Building Codes Board (ABCB) on behalf of the Australian Government and each State and Territory Government.
The BCA is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia, whilst allowing for variations in climate and geological or geographic conditions.

The “Building Codes of Australia 1990” (BCA-90) were the country's original building codes, which set out the technical requirements for different building types. The Codes have since evolved, and have been developed to become performance-based. The codes were separated into two volumes: volume 1 applies to commercial buildings, and volume 2 applies to domestic buildings. The current version of the Codes is the Building Codes of Australia 2010, which came into effect in all states as from 1st May 2010.

12.2 Administrative Provisions

The development of the first performance-based codes was completed in 1996 (BCA-96), and is essentially a list of mandated, nationwide codes. The system gave builders the option to follow "deemed-to-satisfy provisions", which outlined materials and designs guaranteed to meet designated standards; or use "alternate solutions", which enabled builders to create their own designs, as long as builder's could prove designs met performance requirements set forth by the Australian Building Codes Board (ABCB). The ABCB recommended the latter option, as it allows for greater innovation and technological advances in building and energy efficiency. Since then, greater energy efficient practices in buildings have been incorporated into building codes in Australia.

12.3 Code Development and Maintenance

The Australian Building Codes were periodically updated, and are currently known as the “Building Codes of Australia 2010” (BCA 2010). The latest updates to the Building Codes were carried out in order to meet standards set forth by the Kyoto Protocol. The Council of Australian Governments (COAG) has requested the ABCB to increase the BCA energy efficiency provisions through the creation of the BCA 2009 and subsequently BCA 2010. The provisions of the BCA 2010 require a 6-star energy rating under the Nation House Energy Rating Scheme (or equivalent) for new residential buildings, as well as a significant increase in energy efficiency requirements for commercial buildings. The annual energy consumption calculation method must comply with the ABCB Protocol for Building Energy Analysis Software.

12.4 Regulation Method

Regulatory Legislation

The BCA is given legal effect by building regulatory legislation in each State and Territory. This legislation consists of an Act of Parliament and subordinate legislation which empowers the regulation of certain aspects of buildings and structures, and contains the administrative provisions necessary to give effect to the legislation.

Any provision of the BCA may be overridden by, or subject to, State or Territory legislation and therefore the BCA must be read in conjunction with that legislation.

The goal of the BCA is to enable the achievement of nationally consistent, minimum necessary standards of relevant health, safety (including structural safety and safety from fire), amenity and sustainability objectives efficiently.

This goal is applied so that:

(a) there is a rigorously tested rationale for the regulation; and
(b) the regulation generates benefits to society greater than the costs (that is, net benefits); and
(c) the competitive effects of the regulation have been considered and the regulation is no more restrictive than necessary in the public interest; and
(d) there is no regulatory or non-regulatory alternative that would generate higher net benefits.

A building will comply with the BCA if it satisfies the “Performance Requirements” set out in the Building Code of Australia.

Compliance with the Performance Requirements can only be achieved by:

(a) complying with the *Deemed-to-Satisfy Provisions*; or

(b) formulating an *Alternative Solution* which:

(i) complies with the Performance Requirements; or

(ii) is shown to be at least equivalent to the Deemed-to-Satisfy Provisions; or

(c) a combination of (a) and (b).

Categorisation of Code sections

The BCA is divided into different sections, as follows:

Section A: General Provisions
Section B: Structure
Section C: Fire Resistance
Section D: Access and Egress
Section E: Services and Equipment
Section F: Health and Amenity
Section G: Ancillary Provisions
Section H: Special Use Buildings
Section I: Maintenance
Section J: Energy Efficiency

As a result of the Commonwealth Government's initiative, the Australian Greenhouse Office (AGO) and the Australian Building Codes Board (ABCB) entered into an agreement on 5th January 2001 to develop energy efficiency measures for inclusion in the BCA. In 2003, **energy efficiency provisions** were introduced into the BCA for housing; in 2005, for other residential buildings and in 2006, the provisions were expanded to include all other "classes" of buildings, as well as enhancing the stringency for houses to a target of 5 stars. In the 2010 version, all energy efficiency measures were further strengthened, and are as specified in Section J (Energy Efficiency) of the BCA 2010.

Classification of buildings in the BCA

The BCA covers a large number of building types. These building types are defined in terms of "classes" in the BCA. The Building Code of Australia addresses building "classes" as follows:

Class 1: one or more buildings which in association constitute of:
- a single dwelling;
- a boarding house, guest house, hostel or the like, which is not located above or below another dwelling or another Class of building other than a private garage, where the total area of all floors does not exceed 300 m^2 and in which not more than 12 persons would ordinarily be resident.

Class 2: a building containing two or more sole-occupancy units, each being a separate dwelling.

Class 3: a residential building, other than a building of Class 1 or 2, which is a common place of long term or transient living for a number of unrelated persons.

Class 4: a dwelling in a building that is Class 5, 6, 7, 8 or 9 if it is the only dwelling in the building.

Class 5: an office building used for professional or commercial purposes, excluding buildings of Class 6, 7, 8 or 9.

Class 6: a shop or other building for the sale of goods by retail or the supply of services direct to the public.

Class 7: a building which is a carpark or for storage, or display of goods or produce for sale by wholesale.

Class 8: a laboratory, or a building in which a handicraft or process for the production, assembling, altering, repairing, packing, finishing, or cleaning of goods or produce is carried on for trade, sale, or gain.

Class 9: a building of a public nature (e.g. healthcare building, aged-care building, place of assembly).

Class 10: a non-habitable building or structure (such as a private garage, carport, shed, or the like) or a structure being a fence, mast, antenna, retaining or free-standing wall, swimming pool, or the like.

12.5 Building Lay-out and Design

The BCA set out requirements for natural daylight and ventilation, which may affect the building's layout and design. The performance requirements with respect to daylight and ventilation entail the following:

- Sufficient openings must be provided and distributed in a building so that natural light, when available, provides a level of illuminance appropriate to the function or use of that part of the building. Natural lighting must be provided either through *windows* or *rooflights*.
  - Windows should have an aggregate light transmitting area (measured exclusive of framing members, glazing bars or other obstructions) of **not less than 10% of the floor area** of the room; and should be open to the sky or face a court or other space open to the sky or an open verandah, carport or the like.
  - Rooflights should have an aggregate light transmitting area (measured exclusive of framing members, glazing bars or other obstructions) of **not less than 3% of the floor area** of the room.
- A space in a building used by occupants must be provided with means of ventilation with outdoor air which will maintain adequate air quality. For adequate natural ventilation, the building must consist of permanent openings, windows, doors or other devices which can be opened with an aggregate opening or openable size not less than **5% of the floor area** of the room required to be ventilated; and should be open to a suitably sized court, or space open to the sky; or an open verandah, carport, or the like; or should "borrow" natural ventilation from an adjoining room.

12.6 Building Envelope

Under the Energy Efficiency section of the Codes (Section J), performance requirements are specified for roofs and ceilings, walls and floors, as follows:

12.6.1 Roof and ceiling construction

A roof or ceiling that is part of the envelope, (other than of a sole-occupancy unit of a Class 2 building or a Class 4 part of a building – as defined under "Classification of buildings" above), must achieve the total R-Value specified in the table below for the direction of heat flow.

Climate zone	1, 2 and 3	4, 5 and 6	7	8
Direction of heat flow	Downwards		Upwards	
Minimum Total R-Value for a roof or ceiling with a roof upper surface solar absorptance value of not more than 0.5	3.2	3.2	3.7	4.8
Minimum Total R-Value for a roof or ceiling with a roof upper surface solar absorptance value of more than 0.5 but not more than 0.6	3.7	3.2	3.7	4.8
Minimum Total R-Value for a roof or ceiling with a roof upper surface solar absorptance value of more than 0.6	4.2	3.2	3.7	4.8

Table 10: Minimum R-values for roof and ceiling constructions

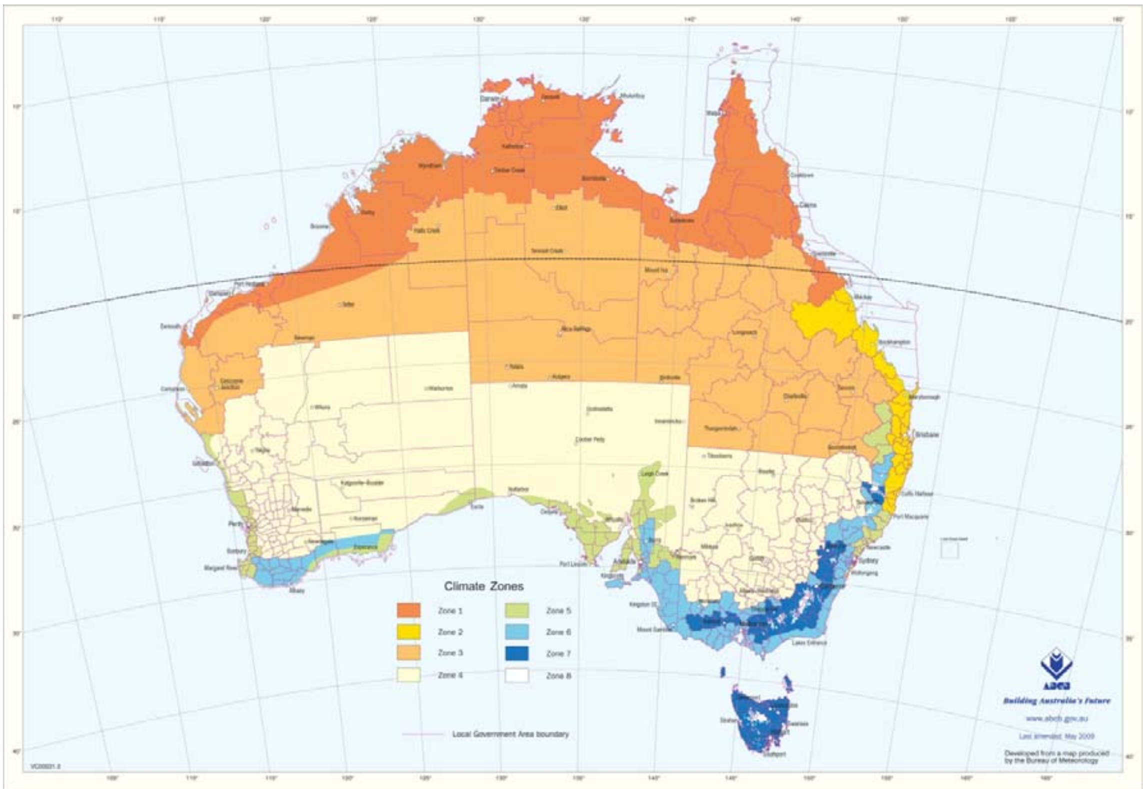


Figure 18. Climate zones defined in BCA

12.6.2 Walls

Each part of an external wall that is part of the building envelope, (other than of a sole-occupancy unit of a Class 2 building or a Class 4 part of a building), must satisfy one of the options in Table xx below, except for:

(i) opaque non-glazed openings in external walls such as doors (including garage doors), vents, penetrations, shutters and the like; and

(ii) glazing; and

(iv) an earth retaining wall or earth-berm, in other than climate zone 8.

Climate zone	**Options**					
1, 2 and 3	(a)	(i)	Achieve a minimum *Total R-Value* of 3.3.			
		(ii)	The minimum *Total R-Value* in (i) is reduced—			
			(A)	for a wall with a surface density of not less than 220 kg/m^2, by 0.5; and		
			(B)	for a wall that is—		
				(aa)	facing the south orientation, by 0.5; or	
				(bb)	shaded with a projection shade angle in accordance with Figure xx below of—	
					(AA)	15 degrees to not more than 45 degrees, by 0.5; or
					(BB)	more than 45 degrees, by 1.0; and
			(C)	if the outer surface solar absorbance value is not more than 0.6, by 0.5.		
	(b)	Where the only space for insulation is provided by a furring channel, top hat section, batten or the like—				
		(i)	achieve a minimum *Total R-Value* of 1.4; and			
		(ii)	satisfy glazing energy index Option B a set out in BCA.			

		(ii)	The minimum *Total R-Value* in (i) is reduced—			
			(A)	for a wall with a surface density of not less than 220 kg/m^2, by 0.5; and		
			(B)	for a wall that is—		
				(aa)	facing the south orientation, by 0.5; or	
				(bb)	shaded with a projection shade angle in accordance with Figure xx below of—	
					(AA)	30 degrees to not more than 60 degrees, by 0.5; or
					(BB)	more than 60 degrees, by 1.0.
	(b)	Where the only space for insulation is provided by a furring channel, top hat section, batten or the like—				
		(i)	achieve a minimum *Total R-Value* of 1.4; and			
		(ii)	satisfy glazing energy index Option B a set out in BCA.			
7	(a)	Achieve a minimum *Total R-Value* of 2.8.				
	(b)	Where the only space for insulation is provided by a furring channel, top hat section, batten or the like—				
		(i)	achieve a minimum *Total R-Value* of 1.4; and			
		(ii)	satisfy glazing energy index Option B a set out in BCA.			
8	(a)	Achieve a minimum *Total R-Value* of 3.8.				

Table 11. Minimum R-values for walls

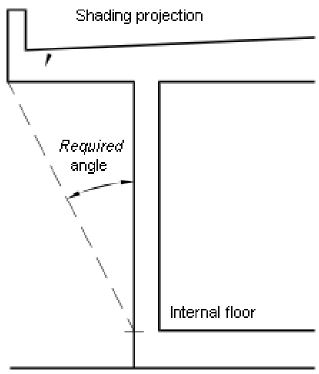


Figure 19. Measurement of projection for wall shading

12.6.3 Floors

(a) A floor that is part of the envelope of a building, other than a sole-occupancy unit of a Class 2 building or a Class 4 part of a building, including a floor above or below a carpark or a plant room -

(i) must achieve the Total R-Value specified in Table XX below; and

(ii) with an in-slab heating or cooling system, must be insulated around the vertical edge of its perimeter with insulation having an R-Value of not less than 1.0.

(b) In climate zones 1 to 6, the minimum Total R-Value required in (a) may be reduced by R0.5 provided R0.75 is added to the Total R-Value required for the roof and ceiling construction.

(c) A concrete slab-on-ground with an in-slab heating or cooling system; or located in climate zone 8, must have insulation installed around the vertical edge of its perimeter.

(d) Insulation required by (c) must have an R-Value of not less than 1.0; and be water resistant; and be continuous from the adjacent finished ground level—

(A) to a depth of not less than 300 mm; or

(B) for the full depth of the vertical edge of the concrete slab-on-ground.

(e) A floor construction is deemed to have the thermal properties listed in the Specifications section of the BCA.

Location			Climate zone							
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
(a)	A slab on ground:									
	(i)	Without an in-slab heating or cooling system	Nil	Nil	Nil	Nil	Nil	Nil	1.0	2.0
	(ii)	With an in-slab heating or cooling system	1.25	1.25	1.25	1.25	1.25	1.25	1.25	2.25
(b)	A suspended floor without an in-slab heating or cooling system where the non- *conditioned space* is—		1.0	1.0	Nil	Nil	1.0	1.0	1.5	2.5
	(i)	enclosed; and								
	(ii)	where mechanically ventilated by not more than 1.5 air changes per hour.								
(c)	A suspended floor with an in-slab heating or cooling system where the non- *conditioned space* is—		1.25	1.25	1.25	1.25	1.25	1.25	1.75	2.75
	(i)	enclosed; and								
	(ii)	where mechanically ventilated by not more than 1.5 air changes per hour								
(d)	For other than (a), (b) or (c)		2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.5

Note:
A sub-floor space with not more than 150% of the required sub-floor ventilation is considered enclosed.

Table 12. Minimum R-values for floors

12.6.4 Glazing

The glazing in each storey, including any mezzanine, of a building must be considered such that the total U-Values and solar heat gain coefficients (SHGCs) are assessed for the combined effect of the glass and frame, with the aim of reducing air-conditioning energy consumption attributable to glazing.

Internal glazing need also be assessed if it is located between an unconditioned and conditioned space.

The assessment of the glazing performance is done by considering the "***aggregate air-conditioning energy value***" which is calculated by adding the air-conditioning energy value through each glazing element in accordance with the following formula:

$$\mathbf{A_1[\,\mathit{SHGC}_1(C_A x S_{H1}+C_B x S_{C1})+C_C x U_1] + A_2[\,\mathit{SHGC}_2(C_A x S_{H2}+C_B x S_{C2})+C_C x U_2] + \ldots}$$

where

$A_{1,\,2,\,etc}$ = the area of each glazing element

$C_{A,\,B\ and\ C}$ = the energy constants A, B and C for the specific orientation (obtainable from the BCA)

$SHGC_{1,\,2,\,etc}$ = the SHGC of each glazing element

$S_{H1,\,2,\,etc}$ = the heating shading multiplier for each glazing element (obtainable from the BCA)

$S_{C1,\,2,\,etc}$ = the cooling shading multiplier for each glazing element (obtainable from the BCA)

$U_{1,\,2,\,etc}$ = the Total U-Value of each glazing element

Note: Where the air-conditioning energy value of a glazing element is calculated to be negative, it must be taken to be zero.

12.7 Heating Ventilation and Air Conditioning (HVAC)

12.7.1 Heating

Heating such as for a conditioned space must, to the degree necessary, obtain energy from

(a) a source that has a **greenhouse gas intensity** that does not exceed 100 g CO_2-e/MJ of thermal energy load; or
(b) a source that is **renewable** on-site such as solar, geothermal or wind; or
(c) another process as **reclaimed energy**.

A heater for heating a space via water, such as a boiler, that is part of an air-conditioning system, must achieve a thermal efficiency complying with Table xx below when tested in accordance with BS 7190; and use reticulated gas where it is available at the allotment boundary.

Fuel type	Rated capacity ($kW_{heating}$)	Minimum gross thermal efficiency (%)
Gas	Not more than 750	80
	More than 750	83
Oil	All capacities	80

Table 13. Minimum thermal efficiency of water heater

For heating a space other than via water, the heating system must be:

(a) a solar heater; or
(b) a gas heater; or
(c) an oil heater if reticulated gas is not available at the allotment boundary; or
(d) a heat pump heater; or
(e) a solid-fuel burning heater; or
(f) a heater using reclaimed heat from another process such as reject heat from refrigeration plant;
(g) or a combination of 2 or more of (a) to (f).

A fixed space heating appliance installed outdoors must be controlled to **automatically turn off** when not needed by an outdoor air temperature sensor, timer, motion detector, or the like.

A **time switch** must be provided to control any heating system of more than 10 $kW_{(heating)}$.

Heating for a **swimming pool** or a **spa pool** must be by:

(i) a solar heater not boosted by electric resistance heating; or
(ii) a heater using reclaimed energy; or
(iii) a gas heater; or
(iv) a heat pump; or
(v) a combination of 2 or more of (i), (ii), (iii) and (iv).

Where some or all of the heating required by the swimming pool or spa pool is by a gas heater or a heat pump, the pool must have:

(i) a **cover** (other than when a swimming pool is located in a conditioned space); and

(ii) a **time switch**, in accordance with specifications stated in the BCA, to control the operation of the heater.

(c) A time switch must be provided, in accordance with specifications in the BCA, to control the operation of a circulation pump.

12.7.2 Mechanical ventilation

A system that provides mechanical ventilation to other than a sole-occupancy unit in a Class 2 building or a Class 4 part of a building, either as part of an air-conditioning system or as a separate ventilation system, must be capable of being **deactivated** when the building or part of the building served by that system is not occupied.

When the mechanical ventilation is provided by means other than an air-conditioning system and the air flow rate is more than 1000 L/s, the system should have a fan power to air flow rate ratio of 0.5 W/(L/s) without filters or 0.75 W/(L/s) with filters for a general mechanical ventilation system.

For carpark exhaust, when serving over 40 vehicles, mechanical ventilation should be controlled by an atmospheric contaminant monitoring system, and should maintain an average minimum air-change rate of 0.5 air changes per hour other than when the carpark is not occupied for a period of more than 2 hours.

The requirements above must not inhibit the smoke hazard management operation of air-conditioning and mechanical ventilation systems and essential ventilation such as for a garbage room, lift motor room, gas meter enclosure or gas regulator enclosure or the like.

Ceiling fans are required as part of compliance and must be permanently installed, have a speed controller and serve the whole room, with the floor area that a single fan serves not exceeding:

(i) 15 m^2 if it has a blade rotation diameter of not less than 900 mm; and

(ii) 25 m^2 if it has a blade rotation diameter of not less than 1200 mm.

12.7.3 Air-conditioning

An air-conditioning unit or system must be capable of being deactivated when the sole-occupancy unit, building or part of the building served is not occupied.

Where the air-conditioning unit or system has motorised outside air and return dampers, the system should be able to close the dampers when the air-conditioning unit or system is deactivated.

When serving a sole-occupancy unit of a Class 3 building, the system should not operate when any external door, including a door opening to a balcony, patio, courtyard or the like is open for more than 1 minute; and should have any supply and return ductwork adequately sealed and insulated in accordance with the specifications of the code.

When serving more than one sole-occupancy unit, air-conditioning zone or area with different heating and cooling needs, the system should:

(a) thermostatically control the temperature of each sole-occupancy unit, zone or area; and

(b) not control the temperature by mixing actively heated air and actively cooled air.

Other than where a packaged air-conditioning unit is used, the system should have a variable speed fan when its supply air quantity is varied.

Where the air-conditioning system provides the required mechanical ventilation, the system should have an outdoor air economy cycle:

(a) in climate zones 2 and 3, when the air-conditioning unit capacity is over 50 kWr; and

(b) in climate zones 4, 5, 6, 7 and 8 when the air-conditioning unit capacity is over 35 kWr;

In a Class 3 building, the system should be capable of controlling the temperature of a sole-occupancy unit at a different temperature during sleeping periods than during other periods.

In general, when the air flow rate is greater than 1000 L/s, the system should be designed so that the total fan power of the fans in the system is in accordance with Table xx below:

Air-conditioning sensible heat load (W/m^2 of the floor area of the conditioned space)		Maximum fan power (W/m^2 of the floor area of the conditioned space)	
		For an air-conditioning system serving not more than 500 m^2	For an air-conditioning system serving more than 500 m^2
Up to 100		4.1	6.4
101 to 150		7.3	10.4
151 to 200		10.5	14.1
201 to 300		17.1	21.5
301 to 400		23.6	28.4
Notes	For more than 400 W/m^2 internal load—		
	(a)	in a building of not more than 500 m^2 floor area, use 0.07 W of fan power for each Watt of internal load; and	
	(b)	in a building of more than 500 m^2 floor area, use 0.09 W of fan power for each Watt of internal load.	

Table 14. Maximum Fan Power

12.8 Lighting

In a sole-occupancy unit of a Class 2 building or a Class 4 part of a building, the lamp power density or illumination power density of artificial lighting must not exceed:

(A) within the building, 5 W/m^2; and

(B) on a verandah or balcony of the building 4 W/m^2.

When designing the lamp power density, the power of the proposed installation must be used rather than nominal allowances for exposed batten holders or luminaires.

Where lamps are used that have a transformer or ballast, the transformer or ballast must be of the **electronic** type.

Halogen lamps must be **separately switched** from fluorescent lamps.

In any *other* building than a sole-occupancy unit of a Class 2 building or a Class 4 part of a building, for artificial lighting, the aggregate design illumination power load must not exceed the sum of the allowances obtained by multiplying the area of each space by the maximum illumination power density in Table J6.2a of the BCA.

The requirements above do *not* apply to the following:

- Emergency lighting in accordance with Part E4 of the BCA.

- Signage and display lighting within cabinets and display cases that are fixed in place.
- Lighting for accommodation within the residential part of a detention centre.
- A heater where the heater also emits light, such as in bathrooms.
- Lighting of a specialist process nature such as in an operating theatre, fume cupboard or clean workstation.
- Lighting of performances such as theatrical or sporting.
- Lighting for the permanent display and preservation of works of art or objects in a museum or gallery other than for retail sale, purchase or auction.

12.9 Domestic Hot Water

The BCA requires that a hot water supply system for food preparation and sanitary purposes, other than a solar hot water supply system in climate zones 1, 2 and 3, must be designed and installed in accordance with Section 8 of Australian Standards AS/NZS 3500.4 (**Plumbing and drainage - Heated water services)**.

12.10 Elevators and Conveyors

The BCA does not specify requirements for the energy efficiency of elevators and conveyors.

12.11 Renewable Energy

The BCA states that, in order to reduce greenhouse gas emissions, to the degree necessary:

(a) a building, including its services, is to be capable of efficiently using energy; and

(b) a building's services for heating are to obtain their energy from:
   (i) a source that has a greenhouse gas intensity that does not exceed 100 g CO_2-e/MJ of thermal energy load; or
   (ii) a source that is renewable on-site such as solar, geothermal or wind; or
   (iii) another process as reclaimed energy.

13 Malaysia Guidelines for Energy Efficiency in Buildings

13.1 Introduction

The Malaysian Standard, MS 1525:2007, is the first revision of MS 1525:2001,*Code of Practice on Energy Efficiency and use of Renewable Energy for Non-residential Building.*

The purposes of this standard are to:

a) encourage the design, construction, operation and maintenance of new and existing buildings in a manner that reduces the use of energy without constraining creativity in design, building function and the comfort or productivity of the occupants; and appropriately dealing with cost considerations

b) provide the criteria and minimum standards for energy efficiency in the design of new buildings, retrofit of existing buildings and methods for determining compliance with these criteria and minimum standards

c) provide guidance for energy efficiency designs that demonstrate good professional judgement to comply with minimum standards

d) encourage the application of renewable energy in new and existing buildings to minimize reliance on non-renewable energy sources, pollution and energy consumption whilst maintaining comfort, health and safety of the occupants.

13.2 Administrative Provisions

13.2.1 Scope

This code of practice gives guidance on the effective use of energy including the application of renewable energy in new and existing non-residential buildings. Buildings or portions thereof, whose peak design rate of electrical energy usage for all purposes is less than 10 W/m^2 (installed) of gross floor area are excluded from this standard.

The recommendations for renewable energy applications are classified under the following areas:

a) maximising the availability of renewable energy resources such as solar heating, solar electricity, solar lighting and solar assisted technologies

b) optimising passive cooling strategies

c) optimising environmental cooling through natural means such as vegetation, site planning, landscaping and shading

d) maximising passive solar design.

The requirements for energy efficiency are classified under the following areas:
a) designing an efficient lighting system (Clause 6)
b) minimising losses in electrical power distribution equipment (Clause 7)

c) designing an efficient air-conditioning and mechanical ventilation system (Clause 8)

d) designing a good energy management system (Clause 9)

13.2.2 Enforcement

The following normative references are indispensable for the application of this standard:

- ASHRAE Handbook: 2000 - HVAC systems and equipment.

- ANSI/SMACNA 006 HVAC Duct Construction Standards Metal and Flexible, SMACNA, second edition, 1995
- HVAC Air Duct Leakage Test Manual, SMACNA, first edition, 1985
- MS IEC 60929: 1995, Specification for a.c. supplied electronic ballasts for tubular fluorescent lamps – Performance requirements.
- MS IEC 60364 : Electrical installations of buildings Uniform Building By Laws, 1984.
- ARI 210-240 Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment
- ANSI/ARI 340/360: Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment
- ARI 550/590 Performance Rating of Water Chilling Packages Using the Vapor Compression Cycle
- ARI 480-2001: Refrigerant-Cooled Liquid Coolers, Remote Type
- ANSI/ASHRAE 140-2004: Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs

13.3 Building layout and design

The Code includes a section on design strategies for achieving energy efficiency including the following aspects:

- building orientation and configuration (geometry and layout)
- effective room depth
- floor to ceiling height
- location of cores
- building façade
- internal layout
- fenestrations
- building materials
- natural ventilation
- roof design and colour
- landscaping and shading.

For climatic zones near the equator, the best orientation for buildings is with the long directional axis of buildings facing North-South, minimising the East-West orientation.

Designing with emphasis on natural daylighting should begin at the preliminary design stage. The daylight distribution is as shown in Table xx.

Table 15. Daylight factors and distribution

Zone	DF (%)	Distribution
Very Bright	> 6	Very large with thermal and glare problems
Bright	3 – 6	Good
Average	1 – 3	Fair
Dark	0 – 1	Poor
NOTE. The figures are average daylight factors for windows without glazing		

Correct choice of building materials for façade design can help minimise solar heat gain.

Creating cooler microclimate around the building may involve strategic landscaping techniques through maximising softscape and implementation of aquascape.

13.4 Building envelope

13.4.1 Overall Thermal Transfer Value (OTTV)

A design criterion for building envelope known as the overall thermal transfer value (OTTV) has been adopted. It has units of Watts per metre square (W/m2).

The OTTV aims at achieving the design of building envelope to cut down external heat gain and hence reduce the cooling load of the air-conditioning system.

The OTTV requirement applies only to air-conditioned buildings.

The OTTV of the building envelope for a building, having a total air-conditioned area exceeding 4000 m^2 and above should not exceed 50 W/m^2.

13.4.2 Roofs and skylights

The roof of a conditioned space shall not have a U-value greater than that tabulated in Table xx.

Table 16. Maximum U-value for roof (W/m^2K)

Roof Weight Group	Maximum U-Value (W/m^2K)
Light (Under 50 kg/m^2)	0.4
Heavy (Above 50 kg/m^2)	0.6

For roofs that do have skylights, a Roof Thermal Transfer Value (RTTV) is defined that combines the various thermal transfer values for the roof surfaces and skylights into one value. It has units of Watts per metre square (W/m^2). For roofs with skylight, the maximum recommended RTTV is 25 W/m^2.

Skylights for which daylight credit is taken may be excluded both from the U-value calculation and the calculation of the RTTV provided certain conditions are met.

All electric lighting fixtures within the skylight areas shall be controlled by automatic daylighting controls.

13.4.3 Air leakage

Air leakage should be controlled.

Any duct providing a connection between conditioned space to outside air should have a damper in between to prevent air leakages into conditioned space when the duct is not in operation.

It is recommended that a door that separates conditioned space from the exterior is protected by an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices.

13.5 HVAC

Cooling system design loads for the purpose of sizing systems and equipment should be determined in accordance with the procedures described in ASHRAE Handbook.

Room comfort condition should consider the following 3 main factors:

- dry bulb temperature
- relative humidity
- air movement (air velocity)

The indoor design conditions of an air-conditioned space for comfort cooling should be as follows:

a) Recommended design dry bulb temperature : 23 º C – 26 °C
b) Minimum dry bulb temperature: 22 ° C
c) Recommended design relative humidity: 55 % – 70 %
d) Recommended air movement: 0.15 m/s – 0.50 m/s
e) Maximum air movement: 0.7 m/s

In addition, the recommended outdoor design conditions should be as follows:

a) Dry bulb temperature 33.3 °C
b) Wet bulb temperature 27.2 °C

Outdoor air-ventilation rates should comply with Third Schedule (By Law 41) Article 12(1) of Uniform Building by Laws, 1984.

Zones which are expected to operate non-simultaneously for more than 750 hours per year and zones with special process temperature and/or humidity requirements should be served by separate air distribution systems.

Each system should be provided with at least one thermostat for the regulation of temperature. Each system should be equipped with automatic controls capable of accomplishing a reduction of energy use.

Each mechanical ventilation system (supply and/or exhaust) should be equipped with a readily accessible switch or other means for shut-off or volume reduction when ventilation is not required. Examples of such devices would include timer switch control, thermostat control, duty cycle programming and CO/CO_2 sensor control.

All piping installed to serve buildings and within buildings should be adequately insulated to prevent excessive energy losses. Similarly, all ducts, plenums and enclosures installed in or on buildings should be insulated.

Requirements for the coefficient of performance (COP) for various equipment types are specified.

13.6 Lighting

Recommended average illuminance levels for various activities are specified in Table xx.

Table 17. Recommended average illuminance levels

Task	Illuminance (Lux)	Example of Applications
Lighting for infrequently used area	20	Minimum service illuminance
	100	Interior walkway and car-park
	100	Hotel bedroom
	100	Lift interior
	100	Corridor, passageways, stairs
	150	Escalator, travellator
	100	Entrance and exit
	100	Staff changing room, locker and cleaner room, cloak room, lavatories, stores.
	100	Entrance hall, lobbies, waiting room
	300	Inquiry desk
	200	Gate house
Lighting for working interiors	200	Infrequent reading and writing
	300 – 400	General offices, shops and stores, reading and writing
	300 – 400	Drawing office
	150	Restroom
	200	Restaurant, Canteen, Cafeteria
	150 – 300	Kitchen
	150	Lounge
	150	Bathroom
	100	Toilet
	100	Bedroom
	300 – 500	Class room, Library
	200 – 750	Shop / Supermarket/Department store
	300	Museum and gallery
Localised lighting for exacting task	500	Proof reading
	1000	Exacting drawing
	2000	Detailed and precise work

The maximum allowable power for illumination systems are also specified (Table xx).

Table 18. Unit lighting power (including ballast loss) allowance

Type of Usage	Max. lighting power W/m^2
Restaurants	15
Offices	15
Classrooms/ Lecture Theatres	15
Auditoriums/ Concert Halls	15
Hotel/ Motel Guest Rooms	15
Lobbies/ Atriums/ Concourse	20
Supermarkets/ Department Stores/ Shops	25
Stores/ Warehouses/ Stairs/ Corridors/ Lavatories	10
Car Parks	5

All lighting systems except those required for emergency or exit lighting should be provided with manual, automatic or programmable controls. For lighting loads exceeding 100 kW automatic control should be provided.

The minimum number of lighting control for daylight energy savings scheme are also taken into consideration. All lighting controls should be located at an accessible place.

13.7 Electric power and distribution

The energy efficiency requirements of electric motors, transformers and distribution systems of buildings except those required for emergency purposes are described. These include limits to the sizing of motors, minimum motor and transformer efficiencies and power factor correction.

Electrical energy meters should be installed at strategic load centres to identify consumption by functional use.

13.8 Energy management control system (EMS)

It should be considered for buildings having area greater than 4 000 m2 of air-conditioned space.

The building EMS has 3 functions:
- control of equipment
- monitoring of equipment
- integration of equipment sub-systems

The EMS should placed special emphasis on the air conditioning and mechanical ventilation system and lighting systems.

Buildings provided with EMS should be equipped with data logging facilities for the collation of data for energy auditing.

13.9 Building Energy Simulation Method

The building energy simulation should be performed twice. The first simulation should be for a building as per the architectural design, referred to as the design building. The second stimulation is for a reference building referred to as the base building.

The simulation program used should be a computer-based program for the analysis of energy consumption in buildings

14 India Energy Conservation Building Code

14.1 Introduction

The Energy Conservation Building Code &ECBC) 2007, revised in May 2008 has been developed by the Energy Efficiency Bureau to be used as a national standard of which some measures are mandatory and others only prescriptive. The purpose of this code is to provide minimum requirements for the energy-efficient design and construction of buildings.

Where this code is found to conflict with safety, health, or environmental codes, the safety, health, or environmental codes shall take precedence.

National Building Code 2005 is the reference document/ standard for lighting levels, HVAC, comfort levels, natural ventilation, pump and motor efficiencies, transformer efficiencies and any other building materials and system performance criteria.

14.2 Administrative Provisions

14.2.1 Structure and scope

The code is applicable to buildings or building complexes that have a connected load of 500 kW or greater or a contract demand of 600 kVA or greater. Generally buildings or complexes having conditioned area of 1,000 m2 or more will fall under this category.

The provisions of this code apply to:

(a) Building envelopes, except for unconditioned storage spaces or warehouses
(b) Mechanical systems and equipment, including heating, ventilating, and air conditioning
(c) Service hot water heating
(d) Interior and exterior lighting
(e) Electrical power and motors,

With exemptions to:

(a) Buildings that do not use either electricity or fossil fuel
(b) Equipment and portions of building systems that use energy primarily for manufacturing processes

14.2.2 Enforcement mechanisms

Administrative requirements relating to permit requirements, enforcement, interpretations, claims of exemption, approved calculation methods, and rights of appeal are specified by the authority having jurisdiction.

14.2.3 Compliance methods and tools

The building shall comply with the mandatory provisions and either of the following:

(a) Prescriptive Method, except the envelope trade-off option may be used in place of the prescriptive criteria
(b) Whole Building Performance Method (Appendix B §10)

Plans and specifications shall show all pertinent data and features of the building, equipment, and systems in sufficient detail to permit the authority having jurisdiction to verify that the building complies with the requirements of this code. Details shall include, but are not limited to:

(a) Building Envelope: insulation materials and their R-values; fenestration U-factors, solar heat gain coefficients (SHGC), visible light transmittance (if the trade-off procedure is used), and air leakage; overhangs and sidefins, building envelope sealing details
(b) Heating, Ventilation, and Air Conditioning: system and equipment types, sizes, efficiencies, and controls; economizers; variable speed drives; piping insulation; duct sealing, insulation and location; requirement for balance report
(c) Service Hot Water and Pumping: solar water heating system
(d) Lighting: lighting schedule showing type, number, and wattage of lamps and ballasts; automatic lighting shutoff, occupancy sensors, and other lighting controls; lamp efficacy for exterior lamps
(e) Electrical Power: electric schedule showing transformer losses, motor efficiencies, and power factor correction devices; electric check metering and monitoring system

14.3 Building envelope

14.3.1 U-factors and Solar Heat Gain Coefficients (SHGC)

U-factors and Solar Heat Gain Coefficient shall in general be in accordance with ISO-15099 as in Appendix C §11 or determined from ASHRAE fundamentals 2005. For roofs either the maximum assembly U-factor or the minimum insulation R-value in Table 19 should be complied with. Roofs with slopes less than 20 degrees shall have an initial solar reflectance (ASTM E903-96) of no less than 0.70 and an initial emittance (ASTM E408-71: RA 1996) no less than 0.75.

Table 19. Roof assembly U-factor and Insulation R-value Requirements

Climate Zone	**24-Hour use buildings Hospitals, Hotels, Call Centers etc.**		**Daytime use buildings Other Building Types**	
	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2-°C/W)	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2-°C/W)
Composite	U-0.261	R-3.5	U-0.409	R-2.1
Hot and Dry	U-0.261	R-3.5	U-0.409	R-2.1

Warm and Humid	U-0.261	R-3.5	U-0.409	R-2.1
Moderate	U-0.409	R-2.1	U-0.409	R-2.1
Cold	U-0.261	R-3.5	U-0.409	R-2.1

Opaque doors shall comply with either the maximum assembly U-factor or the minimum insulation R-value in Table 20.

Table 20. Opaque Wall Assembly U-factor and Insulation R-value Requirements				
Climate Zone	**Hospitals, Hotels, Call Centers (24Hour)**		**Other Building Types (Daytime)**	
	Maximum U-factor of the overall assembly (W/m2-°C)	Minimum R-value of insulation alone (m2-°C/W)	Maximum U-factor of the overall assembly (W/m2-°C)	Minimum R-value of insulation alone (m2-°C/W)
Composite	U-0.440	R-2.10	U-0.440	R-2.10
Hot and Dry	U-0.440	R-2.10	U-0.440	R-2.10
Warm and Humid	U-0.440	R-2.10	U-0.440	R-2.10
Moderate	U-0.440	R-2.10	U-0.440	R-2.10
Cold	U-0.369	R-2.20	U-0.352	R-2.35

14.3.2 Fenestration and skylight

Vertical fenestration shall comply with the maximum area weighted U-factor and maximum area weighted SHGC requirements of Table 21.

Table 21. Vertical Fenestration U-factor and SHGC Requirements (U-factor in W/m2-°C)			
		WWR≤40%	**40% <WWR≤60%**
Climate	**Maximum U-factor**	**Maximum SHGC**	**Maximum SHGC**
Composite	3.30	0.25	0.20
Hot and Dry	3.30	0.25	0.20
Warm and Humid	3.30	0.25	0.20
Moderate	6.90	0.40	0.30
Cold	3.30	0.51	0.51
See Appendix C §11.2.1 for Defaults values of Unrated Fenestration			

Vertical Fenestration areas located more than 2.2 m (7 ft) above the level of the floor are exempt from the SHGC requirement in Table 21 if the following conditions are complied with:

(a) Total Effective Aperture: The total Effective Aperture for the elevation is less than 0.25, including all fenestration areas greater than 1.0 m (3 ft) above the floor level

(b) An interior light shelf is provided at the bottom of this fenestration area, with an interior projection factor not less than:

(i) 1.0 for E-W, SE, SW, NE, and NW orientations
(ii) 0.5 for S orientation, and
(iii) 0.35 for N orientation when latitude is < 23 degrees

Vertical fenestration area and skylight area are limited to a maximum of 60% of the gross wall area and 5% of the gross roof area respectively, in the prescriptive requirement.

Vertical fenestration product shall have the minimum Visual Light Transmittance (VLT), defined as function of Window Wall Ratio (WWR), where Effective Aperture > 0.1, equal to or greater than the Minimum VLT requirements of Table 22.

Table 22. Minimum VLT Requirements

Window Wall Ratio	Minimum VLT
0 -0.3	0.27
0.31-0.4	0.20
0.41-0.5	0.16
0.51-0.6	0.13

Provisions for skylight area have been made in the standard in accordance with Table 23 below.

Table 23. Skylight U-factor and SHGC Requirements (U-factor in W/m2-°C)

Maximum U-factor	Maximum SHGC			
Climate	With Curb	w/o Curb	0-2% SRR	2.1-5% SRR
Composite	11.24	7.71	0.40	0.25
Hot and Dry	11.24	7.71	0.40	0.25
Warm and Humid	11.24	7.71	0.40	0.25
Moderate	11.24	7.71	0.61	0.4
Cold	11.24	7.71	0.61	0.4

SRR = Skylight roof ratio which is the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof. See §11.2.2 for typical complying skylight constructions.

14.3.3 Air leakage

Air leakage for glazed swinging entrance doors and revolving doors shall not exceed 5.0 l/sm2. Air leakage for other fenestration and doors shall not exceed 2.0 l/s-m2.

14.4 HVAC

14.4.1 Natural ventilation

Natural ventilation should comply with the design guidelines provided for natural ventilation in the National Building Code of India 2005.

14.4.2 Heating and cooling equipment

Cooling equipment shall meet or exceed the minimum efficiency requirements presented in Table 1.0. Heating and cooling equipment not listed here shall comply with ASHRAE 90.1- 2004 §6.4.1.

All heating and cooling equipment shall be temperature controlled. Where a unit provides both heating and cooling, controls shall be capable of providing a temperature dead band of 3^{o}C. All mechanical cooling and heating systems shall be controlled by a timeclock that can start and stop the system under different schedules for 3 different day-types per week.

14.4.3 Piping and ducts

Piping for heating systems with a design operating temperature of 60°C or greater shall have at least R-0.70 (R-4) insulation. Piping for heating systems with a design operating temperature less than 60°C but greater than 40°C, piping for cooling systems with a design operating temperature less than 15°C and refrigerant suction piping on split systems shall have at least R-2 insulation.

14.4.4 Hot water

Solar water heaters or heat recovery systems must be provided to supply at least 20% of design capacity for residential facilities, hotels and hospitals. Heated pools are required to have a cover, unless solar heated.

14.5 Lighting conditions

14.5.1 Controls

Control requirements include:

(a) Occupancy sensors in buildings >500m2 for offices <30m2, meeting rooms, classrooms and storage spaces.
(b) Luminaire in dalighted areas >25sqm
(c) All space enclosed by ceiling-height partitions
(d) Display/accent lighting, case lighting, hotel and motel guest room lighting, task lighting, non-visual lighting and demonstration lighting

14.5.2 Interior lighting

Two alternative methods are provided for determining the max. interior lighting power:

(a) The Building Area Method is calculated based on maximum lighting power density for different building area types.
(b) The Space Function Method is similar, but specifieds the maximum lighting power density for various functions.

14.5.3 Exterior lighting

Lighting for exterior building grounds luminaires which operate at greater than 100W shall contain lamps having a minimum efficacy of 60 lm/W unless the luminaire is controlled by a motion sensor or exempt under generals. Internally-illuminated exit signs shall not exceed 5W per face.

14.6 Domestic hot water

Residential facilities, hotels and hospitals with a centralized system shall have solar water heating for at least 1/5 of the design capacity, except systems that use heat recovery for at least 1/5 of the design capacity.

Service water heating equipment shall meet or exceed the performance and minimum efficiency requirements presented in available Indian Standards (IS):

(a) Solar water heater shall meet the performance/ minimum efficiency level mentioned in IS 13129 Part (1&2)

(b) Gas Instantaneous Water heaters shall meet the performance/minimum efficiency level mentioned in IS 15558 with above 80% thermal efficiency

(c) Electric water heater shall meet the performance / minimum efficiency level mentioned in IS 2082

Vertical pipe risers serving storage water heaters and storage tanks not having integral heat traps and serving a non-recirculating system shall have heat traps on both the inlet and outlet piping as close as practical to the storage tank.

15 Code Relevance to Mauritius

15.1 IEEC

The International Energy Conservation Code (IECC) 2009 is a model code that regulates minimum energy conservation requirements for new buildings. The code addresses energy conservation requirements for all aspects of energy uses in both commercial and residential buildings. It is relevant to the United States but it can be used as a template for energy efficiency internationally and thus adopted in Mauritius. Its use within a governmental jurisdiction can be accomplished through adoption by reference in accordance with proceedings establishing the jurisdiction's laws.

Energy efficiency in residential and commercial buildings has been addressed separately. There is a section on climatic zones whereby 3 classes of climate have been defined in relation to precipitation/moisture and these are Marine, Moist and Dry. The determination of climate zones outside the United States has been tackled and thus it can be easily applied in Mauritius.

For residential energy efficiency, aspects such as building envelope, mechanical systems and building energy simulation analysis for heating, cooling and service water heating energy have been described. Each cooling and heating system should be provided with a control. In addition to the above-mentioned aspects, electrical power and lighting systems have been covered under the code for commercial energy efficiency.

Referenced standards such as ASHRAE, ANSI and the International Mechanical Code have been taken into account for issues such as air leakage, design loads for mechanical systems and ventilation. Efficiency of an HVAC system should be verified through certification under an approved certification program or if no certification program exists, the equipment efficiency ratings shall be supported by data furnished by the manufacturer and there should be provisions for thermostatic controls for each heating and cooling system.

Lighting systems also shall be provided with controls (e.g. interior/exterior lighting controls, light reduction controls, daylight zone control, sleeping unit controls). Lighting power is controlled by specifying maximum installed capacity for various indoor and outdoor spaces.

The following systems and loads shall be included in determining the total building performance: heating systems, cooling systems, service water heating, fan systems, lighting power, receptacle loads and process loads. The simulated performance alternative applies in the same way as for residential buildings. Performance analysis tools tested according to ASHRAE Standard 140 shall be permitted.

15.2 ASHRAE

This American National Standard (ANS) is a national voluntary consensus standard developed under the auspices of the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). It provides minimum energy efficiency requirements for the design and construction of new buildings, additions to buildings and existing buildings. The standard is structured in terms of building envelope; heating, ventilating, and air conditioning; service water heating; power; lighting; other equipment; energy cost budget method.

Requirements related to building envelope takes into account insulation, fenestration and doors, and air leakage, which are applicable to Mauritius although all spaces are considered to be conditioned in the standard.

Conditions that need to be met with for HVAC requirements in the standard are that building is two stories or fewer in height, gross floor area is less than 25,000 ft2, and that each HVAC system in the building complies with some other requirements in the clause.

Service water heating part deals with sizing of systems and equipment, equipment efficiency, piping insulation, system controls, pools and heat traps. These are all relevant to Mauritius as to any other country.

Power, lighting and other equipment requirements all have their importance in the Mauritian context. The simulation part of the energy cost budget method might however, not be readily accessible.

Furthermore, the standard does not apply to single-family houses, multi-family structures of three stories or fewer above grade, manufactured houses (mobile homes and modular), and to equipment and portion of building systems that use energy primarily to provide for industrial, manufacturing or commercial processes.

15.3 UK

The UK Approved Documents "Part L" provide a prescriptive method for compliance with the Building Regulations with regards to Energy Efficiency. The design standards are clearly set out in different sections, such as design limits to building envelope and building services, controls, etc. The standards are divided in either new or existing domestic and non-domestic buildings. Additionally, there is no "climatic zoning" within the UK Approved Documents.

These aspects can be seen as positive in the context of the development of new codes for Mauritius. The number of climatic zones usually depends on the balance between accuracy and simplicity. Mauritius being a small island, the need for climatic zoning will need to be assessed and it may be found that the use of one climate zone like in the UK is most appropriate and will not considerably affect accuracy.

Although the UK is predominantly prone to colder climate, there are also standards and criteria to prevent overheating in buildings which are not air-conditioned and to limit the effect the solar gains in summer. The design standards which apply are either to show that the sum of solar and internal gains does not go above a certain limit, or that the internal temperature does not exceed a threshold for more than a reasonable number of occupied hours per year. This approach could successfully be applied to Mauritius, where the design needs to be predominantly geared towards minimisation of overheating.

In the Part L documents, no specifications are given as to minimum daylight factors, due to the possible contradictory effect on solar heat gains. Daylighting is however an important issue which needs to be tackled in the design of buildings in Mauritius, due to high natural daylight availability and long sunshine hours. Increasing access to daylight can result in higher solar heat gains; therefore the right "balance" should be found, based on the local context.

The use of lighting controls and efficiency of building services equipment is also highly stressed in the Part L documents. Limits to Specific Fan Power are specified for mechanical ventilation and Energy Efficiency Ratios for air conditioning systems. Building services account for a large part of the operative energy of a building, and the energy codes for Mauritius should certainly contain specifications for controls and equipment efficiency, bearing in mind that the proposed limitations for equipment should take into account access to highly efficient equipment.

15.4 Danish Building Regulation

The Danish Building Regulation energy provisions relevance to Mauritius is mainly related to the compliance methods and tools used for verification of energy requirements.

Functional requirements for overall energy performance enables flexibility for building designers, but the flexibility can on the other hand cause some uncertainty on how to comply with the functional requirements. There is a need for comprehensive guidelines and recommendations on how requirements can be possible complied with. It should be considered if the building sector in Mauritius is mature enough to adopt functional requirements at the level in the Danish Building Regulation. The energy provisions in the Danish Building Regulation have a long history and the implementation in the building sector has been done over decades.

The overall energy performance includes all energy used for building operation (heating, cooling, electricity and lighting) without compromising safety, noise and indoor climate aspects. This approach based on the total energy balance elaborated with specific prescriptive requirements is found suitable for adoption in energy provisions in Mauritius.

BE06 is very manageable as compliance software for calculating and verifying overall energy performance in buildings; algorithms and program structure may be useful for the development of algorithm for the Mauritian energy code.

Finally the content and approach for building energy labeling is a useful reference for the feasibility study on an energy labeling approach for Mauritius.

15.5 Passive House Standard

The Passive House Standard will need to be modified to be adopted in Mauritius due to fact that in Mauritius there is a cooling demand rather than a heating demand. However, the standard gives some useful guidelines on the design approach and what to be considers in different phases of a building design and construction.

In a tropical climate, it could be helpful for ideal internal conditions to use Energy Recovery Ventilation instead of Heat Recovery Ventilation to remove the excess humidity into the drains and excess heat into the hot water tank. Passive cooling, solar air conditioning, and other solutions in passive solar building design need to be studied to adapt the Passive house concept for use in tropical and hot regions as Mauritius.

For future development of Energy Efficiency Codes for Mauritius the Passive House Standard and similar low energy standards can be used as inspiration for tighten up the requirements.

The first certified Passive House in hot and humid climate is actually just completed in Lafayette, Louisiana, USA. The house is well insulated and the cooling system is based on an air-con split unit with high efficient (95%) Energy Recovery Ventilator (ERV). A large BIPV (Building Integrated Photovoltaic System) supplies the house with electricity. The Lafayette home will serve as a cost effective urban prototype that demonstrates a remarkable 90% reduction in energy usage over traditional homes built to current codes.

15.6 South African National Standard (SANS 204)

There is some connection between building design in South Africa and in Mauritius which can make the South African Standard helpful when developing the new Energy Efficiency Codes for Mauritius.

It should be considered whether the structure of the South African Standard with one standard for natural ventilated buildings and one for artificial ventilated buildings is appropriate for Mauritius.

Both countries has huge annual solar radiation and the mandatory usage of solar water heating systems in South Africa in all new buildings can be found appropriate for Mauritius as well.

The Standard prescribes that a Building Energy Efficiency Label or Passport should be issued which is very much in line with the strategy in Mauritius.

It is considered that the South African Standard can be helpful in formulating the code for Mauritius.

15.7 Energy Efficiency Considerations in the Botswana Building Regulation

The draft code gives an example of how flexible provisions for energy performance and prescriptive requirements can be combined. Alternative solutions for overall energy performance requirements may be proposed, but shall be supported by an approved computer simulation of the building energy balance. Designers can hereby be motivated and encouraged to develop alternative building designs as long as the overall energy performance is complied.

The list of Approved Energy Simulation Programs is useful for further development of a possible similar list for the Mauritian Codes.

Requirements for installation of energy sub meters in multi-storey buildings with floor area more than 500 m2 and for electrical appliances with a rated power consumption of over 20 kVA is a very suitable initiative for subsequent energy management in larger buildings, and corresponds with the energy audit concept in Mauritius.

The draft code is essentially and application of the IEEC adopted and elaborated to a specific country, and it should be considered if this approach is appropriate for Mauritius.

15.8 Reunion

Having come into force only recently, the RTAA DOM is fairly concise as compared to other energy codes and standards around the world. The regulations are especially important due to the proximity of Reunion to Mauritius, the similar socio-economic characteristics and fairly climatic conditions.

During the review of the RTAA DOM, questions were asked to professionals such as architects, engineers and trainers, regarding the positive and negative aspects of the regulations. It was generally noted that the responses were fairly critical, however it should be kept in mind that the RTAA DOM has only recently come into force, and the full extent of the benefits and disadvantages attained due to its implementation may only be known in the future.

Some of the key points found during the review are highlighted below:

- The requirement for all new homes to be fitted with a solar hot water system, which should amount to at least 50% of the hot water demand, can be seen as positive and should be considered for Mauritius, where solar energy is abundant throughout the year. RTAA DOM currently covers domestic buildings. However, the new regulations in Mauritius will cover different building types. Therefore, a distinction should be made between building types, as some buildings may not require consequent amounts of domestic hot water (e.g. offices, schools). Instead, for these types of buildings, the opportunity for rainwater recycling or greywater recycling could be investigated for use in one of the main water usages, toilet flushing.
- the amount of openings required in the building façades for natural ventilation (**at least** 20% of wall areas as openings) is found to be demanding and expensive to implement in residential buildings. Also, large areas of openings can also increase solar heat loads, therefore prescribing a lower limit for the area of openings can cause buildings to overheat. Instead, a balance should be found between the area of openings to allow for adequate natural ventilation and daylight, whilst limiting overheating risks.
- A Solar Factor is prescribed for walls and windows, regardless of whether they are shaded, i.e. regardless of which orientation the walls face or if overhangs or other shading features protect windows adequately. Therefore this can be an unnecessary additional cost for solar protection where it is not required.
- The RTAA DOM favours natural ventilation over mechanical ventilation, however the requirements for location of openings seem to consider cross ventilation only. Other methods of natural ventilation such as stack effect, or night cooling is not considered, and could be successfully introduced in the Mauritian context, where night-time air temperatures can be positively used for “free-cooling” buildings.
- It is required that all houses have a ceiling fan or have provision for one to be installed in the future. This can be seen as positive a positive aspect, which could also be considered for Mauritius, especially in areas where wind velocities are low. However, the frequency of usage needs to be discussed, so that it does not highly affect the operational costs of the house. The fans could be used predominantly at night, to aid in the removal of internal heat gains.

Other general views of the RTAA Dom are that it is fairly simple and easy to understand, and does not cover as many issues as other energy codes and standards around the world do. As it is the first regulation introduced in Reunion regarding energy efficiency, it can be seen as positive in that it does not set very high standards initially, and can give developers a chance to find the best ways to implement the energy efficiency issues, and the future updates to the regulations can then tighten and raise the standards and requirements. This strategy could also be used in Mauritius, where enforcing high standards of energy efficiency in the first energy codes can be daunting to developers and may not be welcomed favourably.

15.9 Building Code of Australia

The BCA contains a large amount of information, and covers different climatic zones of Australia (eight zones in total). The types of buildings covered are divided into 10 classes, ranging from single dwellings, to communal residential buildings, to offices, laboratories and car parks.

One of the negative aspects of the code is that it can be seen as too comprehensive, covering very detailed information, especially with regards to requirement of controls. Equipment efficiency and controls should definitely be covered in the Mauritian code, as building services are big energy consumers; however the detail to which these requirements are set need to be carefully assessed, so as not to create requirements which are unlikely to be feasible in practice, due to costs or even accessibility to certain equipment and controls.

One of the positive aspects of the BCA is the fact that it allows for some level of flexibility. For instance, the limitation of the roof insulation prescribed can be made more flexible, depending on what the solar absorbance of the upper surface of the roof is. For walls, flexibility is given by allowing a less strict insulation requirement for walls which face South and walls which are adequately shaded by an overhang. This would allow developers to either chose a less costly option of designing the building to be adequately shaded or to have recourse to more expensive measures for insulation.

Restrictions are set for the illumination power density of artificial lighting. This can be a useful strategy in encouraging developers to consider enhancement of daylighting in their building. Requirements should however be set on the amount of solar gains that enter through windows, by specifying adequate solar protection for glazing.

Another positive aspect is that the openings required for natural ventilation is given in terms of % of the floor area of the space to be ventilated. This can be more useful in providing adequate ventilation than openings based on façade area. A deep room with a small external façade will not be adequately ventilation with a small opening which is based on the façade area.

Overall, the BCA is a very broad and comprehensive code, and contains numerous requirements for energy efficiency in various building types. However, it also tends to allow some flexibility, such as in the example for lesser insulation, and also through the compliance methods, which allow both *deemed-to-satisfy* provisions to be followed or *alternative* solutions to be proposed. This flexibility can be a positive aspect, especially in the early stages of development of energy codes in Mauritius.

15.10 Malaysia Guidelines for Energy Efficiency in Buildings

The Malaysian Standard energy provisions relevance to Mauritius is related to the sustainable approach towards design and passive design strategies, the contribution of daylight factors and the implementation of an Energy Management Control System (EMS) and the recommendations for renewable energy applications.

A sustainable approach towards design and passive design strategies are specified in the standard. To achieve energy efficiency in a building, some building aspects such as orientation and geometry, arrangement of windows, sunpath diagram, façade design, natural ventilation and strategic landscaping should be considered. Daylighting is an important issue in the building design in Mauritius and thus designing with emphasis on natural daylighting should begin at the preliminary design stage.

The use of lighting controls and the energy efficiency requirements of electric motors, transformers and distribution systems of buildings have been described. Installation of electrical energy meters has been stated. It is an important aspect that should be considered in building design in Mauritius.

Emphasis should be laid on the implementation of an EMS for air conditioning and mechanical ventilation system and lighting systems. Buildings provided with EMS should be equipped with data logging facilities for the collation of data for energy auditing. Building energy simulation analysis should be encouraged.

15.11 India Energy Efficiency Conversation Building Code

The Code defines norms and standards of energy consumption expressed in terms of per square meter of the area wherein energy is used and includes the location of the building. The Bureau of Energy Efficiency is mandated to take suitable steps to prescribe guidelines for ECBC. In addition, the Central Government including the State Governments can amend the ECBC to suit regional and local climatic conditions as well as direct every owner or occupier of the building or building complex, being designated consumer to comply with the provisions of the ECBC for efficient use of energy and its conservation

This code covers building aesthetics, building envelope, mechanical systems and equipment, including heating, ventilating, and air conditioning (HVAC) system, interior and exterior lighting system, service hot water, electrical power and motors including thermal comfort in non-centrally air conditioned/heated buildings. The ECBC ensures the construction of energy efficient buildings with a concomitant reduction in electrical demand.

National Building Code 2005 is the reference document/ standard for lighting levels, HVAC, comfort levels, natural ventilation, pump and motor efficiencies, transformer efficiencies and any other building materials and system performance criteria.

Since the climate zones criteria is quite relevant to our country, the code requirements are well adapted to Mauritian context.

16 Code Implementation Barriers

Many barriers unfortunately hamper energy efficiency in buildings, for which reason there is a strong request for implementation of Energy Efficiency Codes in Building Regulations. To support a successful development and implementation of energy aspects in the New Building Control Bill in Mauritius it is important to be aware of potential barriers.

From meetings with stakeholders and discussions at the inception workshop some very fruitful inputs on potential barriers are highlighted. Additionally, this current review of Energy Efficiency Building Codes practices and their strengths and weaknesses has identified possible key barriers and how they possibly might be overcome:

- ***Lack of awareness and tools –*** Very often a lack of awareness among many stakeholders in the building industry of the opportunities and how to save energy in buildings is seen. Needs for additional information and training programmes before and when new regulations and codes are executed.
- ***Absorptive capacity*** – Adequate capacity for intake of new material can be a barrier for the uptake of the regulation and code by stakeholders. This will require an additional support programme.
- ***Climatic Conditions*** – International Energy Efficiency Codes and Methods can be utilized, but necessary adjustment according to local climate conditions is essential.
- ***Energy efficient equipment, materials and technologies -*** Highly energy efficient equipment, technologies or appropriate building materials is often not available in the local market, and is mostly imported for larger projects.

Over and above, the lack of skills, knowledge and support on the use of technologies, it is noted that there is a learning phase with all new technologies.

- ***Lack of equipment testing/certification for local products*** – The lack of testing and certification programs for local products is a serious barrier to effectively enforcing energy efficiency regulations and codes. This might favour the use of imported products in lieu of local products.
- ***Lack of Life Cycle Costs Analysis*** – Life Cycle Costs analysis is needed to illustrate that increased incremental costs caused by energy efficient building design can lower running costs and make investments feasible.
- ***Compliance procedures*** – Improved procedures and new compliance tools imply allocation of skilled resources for verification and site inspection.
- ***Consumer behaviour*** – Several factors can lead to a large number of non-compliants, and eventually lead to market failure. They are:
  1. the lack of awareness and information on energy consumption and costs,
  2. the low priority of energy efficient investments,
  3. the high upfront costs and,
  4. the low or volatile energy prices

  Furthermore, the effect will be the difficulty for enforcement and there will be a need for additional resources.
- ***Potential threat of regulatory system abuses*** – There is a potential threat of abuses of the regulatory system by officials for economic self-interest.

17 Recommendations

The recommendation to this report is as follows:

- Climate definition: The UK and Danish model have one climatic zone, compared to distinctions made for larger countries such as Australia and USA, where they have use geographical regions as climatic zones. Although Mauritius has micro climates, it is recommended to determine and define one climatic zone for Mauritius, since this model has worked successfully for smaller countries.
- Categories of buildings: Buildings are categorized differently under different codes. The recommended categorization of the buildings under review is “Residential” and “Commercial”. This can be further separated into “Existing” and “New”. This is similar to most of the codes. It is noted that codes for India and Malaysia only have one category, with further exemption clauses for buildings in the said category. It is pointed out that Australia distinguish 10 different classes of buildings
- Building systems to be included in code: Generally similar building systems are treated in the codes. The systems to be included are at a minimum:
  - Building Envelope
  - Heating, Ventilation, Air Conditioning (HVAC)
  - Service hot water heating
  - Interior and Exterior lighting
  - Electrical power and motors

- Evaluation criteria in the code: It is recommended to evaluate the different building elements and systems rather than the overall building energy performance. From the background of some codes, initially the overall building performance is not included, but only the prescriptive requirements such as U-values, lighting etc. The logic behind this, is that there is no sufficient data for creation of baselines. A simple trade-off model is recommended for some building parts e.g. building envelope. The trade-off provided more freedom and flexibility for designers. Furthermore such calculation is complex. We recommend that overall building performance is evaluated, and is included at a later stage as a revision to the code. It is understood that part of the project within “Removal to Barriers to Energy Efficiency”, there is a programme for Energy audits. The information gathered will form the database and will help in the creation of baselines. It is further recommended that simple tools are developed for verification of the prescriptive requirements.
- Inclusion of renewable energy: Mauritius has very high potential with regards to solar energy. Due to high costs of PVs, it is proposed to consider solar hot water systems, as the latter are already fairly popular in residential homes in Mauritius, and are available through various manufacturers or re-sellers already. It is therefore proposed to consider specifying solar hot water installations as a mandatory requirement, but for certain types of buildings only. For instance, it should be proposed for buildings which would have the highest usage of hot water, for example, residential buildings, restaurants, hotels, hospitals, care homes, etc. Other buildings such as offices and schools, which do not generally require high usage of hot water, may possible be excluded from this requirement.
- Guide to the code: For several codes, there are guidebooks written. It is recommended that a similar document is developed for Mauritius.

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