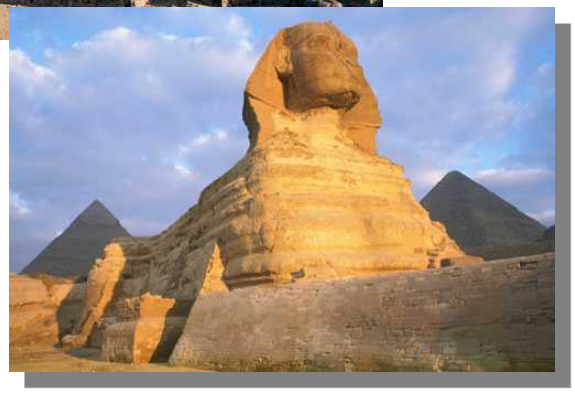
Climate Change, Refrigerants and Building Codes Nexus



Thessaloniki, Greece ,11th May 2019

Prof. Dr. Essam E. Khalil

Professor of Energy Cairo University

ASHRAE Fellow, ASME Fellow and AIAA Fellow

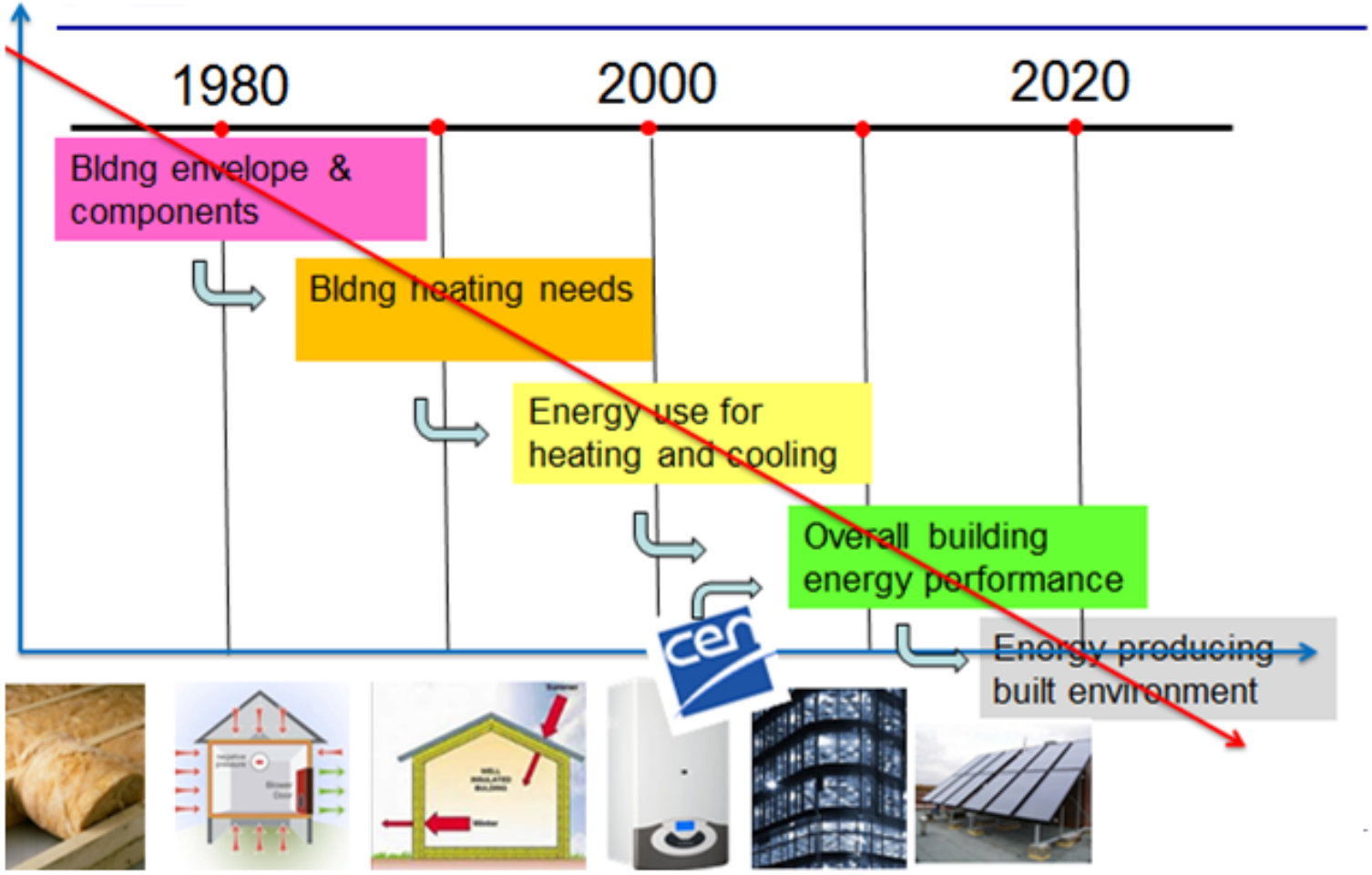
Saturday, 11 May 2019

General

Design standard

- ASHRAE Guide and data books.
- NFPA Codes.
- Uniform Building Codes.
- Applicable local building & mechanical codes.
- Moreover, Adding to the above standards and Norms the HVAC systems will be selected and designed based on the following considerations:
  - The climatic conditions.
  - Computability with architectural layout and aesthetics.
  - Overall economy of construction by establishing standard repetitive components.
  - Desirable interior environmental conditions.
  - Use of local material and equipment.
  - Durability and ease of maintenance.
  - The total cooling capacity will include the proper standby cooling requirement.

Time line


1980
2000
2020
Bldng envelope & components
Bldng heating needs
Energy use for heating and cooling
Overall building energy performance
Energy producing built environment

Definitions

- **Climate change** is any significant long-term **change** in the expected patterns of average weather of a region (or the whole Earth) over a significant period of time.
- **Climate change** is about abnormal variations to the **climate**, and the effects of these variations on other parts of the Earth.
- **Climate change** can also be **caused** by human activities, such as **the** burning of fossil fuels and **the** conversion of land for forestry and agriculture. Since **the** beginning of **the** Industrial Revolution, these human influences on **the climate** system have increased substantially.

Definitions

- **Global warming** is projected to have a number of effects on the oceans. Ongoing effects include rising sea levels due to thermal expansion and melting of glaciers and ice sheets, and **warming** of the ocean surface, leading to **increased** temperature stratification.

- The **greenhouse effect** is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without its atmosphere.

Definitions from IEC-61C-792E

3.8.101
flammable refrigerant
refrigerant with a flammability classification of Class 2L, Class 2 or Class 3 in accordance with ISO 817

Note 1 to entry: For refrigerant blends which have more than one flammability classification, the most unfavourable classification is taken for the purposes of this definition.

3.8.102
qualified person
person having the appropriate technical training and experience necessary to be aware of hazards to which he or she is exposed in performing a task and of measures necessary to minimize the danger to themselves or other persons

GWP

Global warming potential (GWP) is a measure which enables comparisons of the global warming effects of different gases. It compares the amount of heat trapped by a certain mass of a gas to the amount of heat trapped by a similar mass of carbon dioxide over a specific period of time. Carbon dioxide was chosen by the Intergovernmental Panel on Climate Change (IPCC) as the reference gas and its GWP is taken as 1.

Following the 2016 Kigali Amendment, the Montreal Protocol has adopted standard 'reporting values' for GWPs of HFCs[1] and selected HCFCs and CFCs which have been incorporated into the text of the Protocol (in Annexes A, C and F).

GWP values for some common refrigerants

Substance	GWP value
CFC-12	10 900
HCFC-22	1810
HCFC-124	609
HCFC-142b	2310
HFC-143a	4470
HFC-152a	124
HFC-23	14 800
HFC-32	675
HFC-125	3500
HFC-134a	1430
HFC-1234ze(E)	<1
HFC-1234yf	<1
R-290 (Propane)	5

The GWP of blends are therefore calculated as follows:

GWP of Blend	=	Proportion by % mass of component A x GWP of A	+	Proportion by % mass of component B x GWP of B	+	Proportion by % mass of component C x GWP of C

Example: R-401A

R-401A is a blend composed of 53% HCFC-22, 13% HFC-152a and 34% HCFC-124 (mass %). The GWP value for HCFC-22 is 1810, for HFC-152a is 124 and for HCFC-124 is 609.

ODP of Blend (R-401A)	=	Proportion by mass of **HCFC-22** x ODP of **HCFC-22**	+	Proportion by mass of **HFC-152a** x ODP of **HFC-152a**	+	Proportion by mass of **HCFC-124** x ODP of **HCFC-124**
	=	**0.53 (53%)** x 1810	+	**0.13 (13%)** x 124	+	**0.34 (34%)** x 609
	=	959.3	+	16.1	+	207.1
	=	1182.5 (rounded to 1180)				

GWP of Different Refrigerants

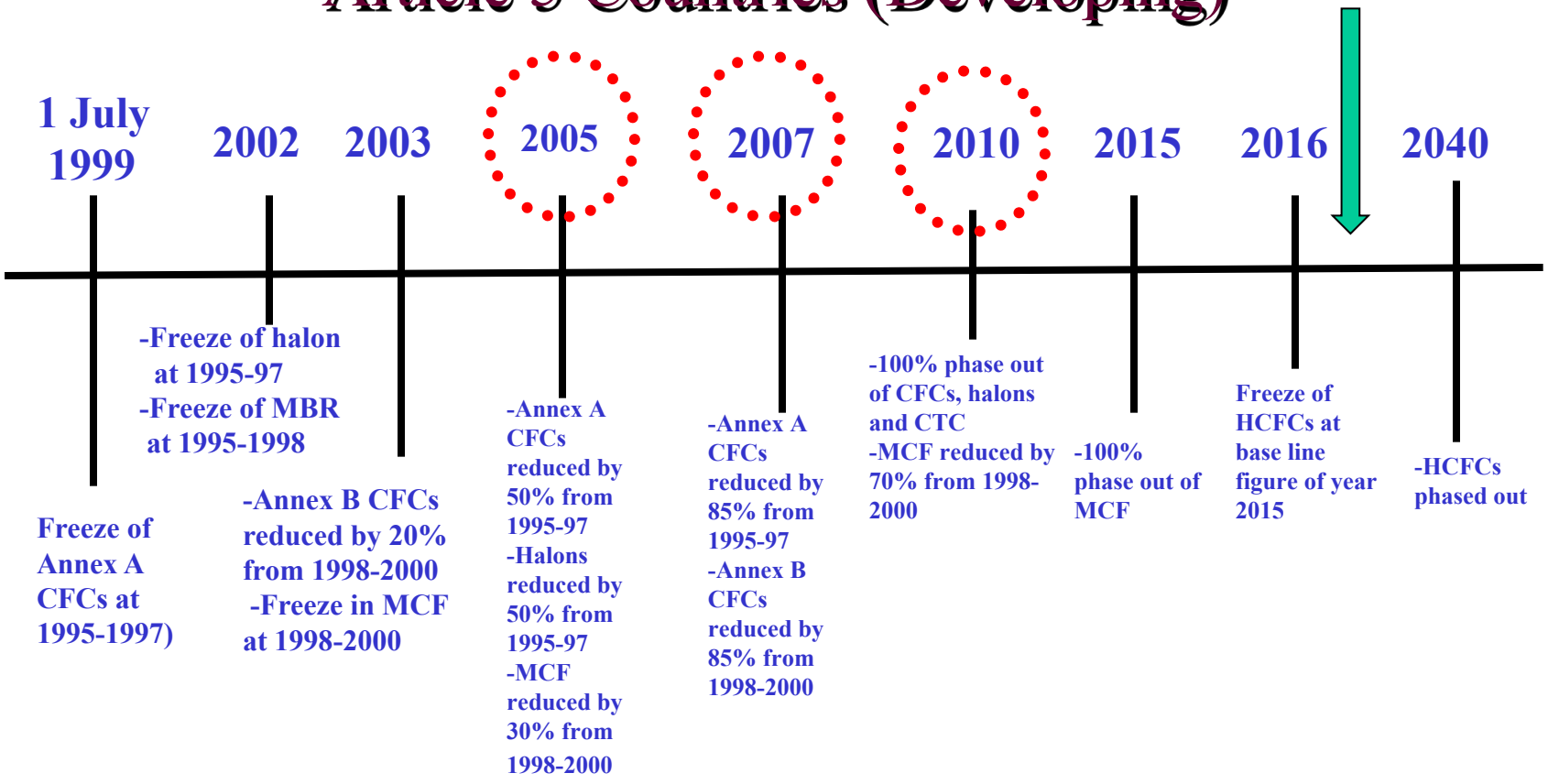
ASHRAE designation	Composition, substances*	Composition (Mass %)	GWP of components†	Blend GWP
Zeotropic Refrigerant Blends				
R-401A	HCFC-22/HFC-152a/HCFC-124	53/13/34	1810/124/609	1180
R-404A	HFC-125/HFC-143a/HFC-134a	44/52/4	3500/4470/1430	3920
R-407A	HFC-32/HFC-125/HFC-134a	20/40/40	675/3500/1430	2110
R-407C	HFC-32/HFC-125/HFC-134a	23/25/52	675/3500/1430	1770
R-407F	HFC-32/HFC-125/HFC-134a	30/30/40	675/3500/1430	1820
R-410A	HFC-32/HFC-125	50/50	675/3500	2090
R-417A	HFC-125/HFC-134a/HC-600	46.6/50/3.4	3500/1430/4	2350
R-444B	HFC-32/HFC-1234ze(E)/HFC-152a	41.5/48.5/10	675/1/124	290
R-446A	HFC-32/HFC-1234ze(E)/HC-600	68/29/3	675/1/4	460
R-449A	HFC-134a/HFC-125/HFC-1234yf/HFC-32	26/25/25/24	1430/3500/1/675	1410
R-452A	HFC-1234yf/HFC-32/HFC-125	30/11/59	1/675/3500	2140
Azeotropic Refrigerant Blends				
R-507A	HFC-125/HFC-143a	50/50	3500/4470	3990
R-513A	HFC-1234yf/HFC-134a	56/44	1/1430	630

* HCFC = hydrochlorofluorocarbon, HFC = hydrofluorocarbon, PFC = perfluorocarbon, HC = hydrocarbon

Montreal Protocol Measures

Phase Out Schedule of ODS

Article 5 Countries (Developing)



Annex C – Group I: HCFCs (consumption)

Non-Article 5(1) Parties: Consumption (Developed Countries)		Article 5(1) Parties: Consumption (Developing Countries)	
Base level:	1989 HCFC consumption + 2.8 per cent of 1989 CFC consumption	Base level:	Average 2009–10
Freeze:	1996	Freeze:	January 1, 2013
35 % reduction	January 1, 2004	10 % reduction	January 1, 2015
75 % reduction	January 1, 2010	35 % reduction	January 1, 2020
90 % reduction	January 1, 2015	67.5 % reduction	January 1, 2025
100 % reduction	January 1, 2020, Allowance of 0.5% of base level consumption untill January 1, 2030 for servicing of refrigeration and air- conditioning equipment existing on 1 January 2020.	100 % reduction	January 1, 2030, Allowance of 2.5% of base level consumption when averaged over ten year 2030-40 untill January 1, 2040 for servicing of refrigeration and air- conditioning equipment existing on 1 January 2030.

Table 2: HCFC phase out schedule and baselines

Source: UNEP

Characteristics of Refrigerants

Pumping Characteristics: The pumping characteristics mean how much refrigerant vapor is pumped per amount of work accomplished. This why water was mainly disqualified as a practical refrigerant for small and medium applications since a very huge compression system is required.

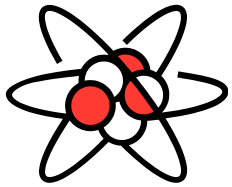
Safety & Design Characteristics

- **Flammability:** Refrigerant flammability is one of the factors affecting refrigerant selection. Some refrigerants are flammable like Hydrocarbons where they are somehow limited in large applications since more safety precautions must be considered.
- **Toxicity:** Toxicity is very important factor for human safety during handling and servicing refrigerants. Toxicity level is measured by ppm (particle per million).
- **Evaporation:** Most of refrigerants evaporate at low temperature, that's why water is considered improper refrigerant (Water boils at 100 C).
- **Heat Capacity:** Heat capacities of a refrigerant are the amount of latent heat the refrigerant could gain or loose during condensation or evaporation processes.
- **Thermal Conductivity:** It is the ability of refrigerant to transmit heat through the vapor or the liquid phases.

Refrigerants History

- Dimethyl ether introduced by Charles Tellier (1828-1913)
- Carbon dioxide (CO_2) introduced by Thaddeus Lowe (1832-1913)
- Tellier (in 1862), first investigated Ammonia (NH3), but it was the American David Boyle (1837-1891) and above all the German Carl von Linde (1842-1934) who were the first to apply it on a broad scale in the industrial field. It is still used
- Sulphur dioxide (SO2) was first implemented by the Swiss physicist Raoul Pierre Pictet (1846-1929) and fell into disuse just before the World War II
- Methyl chloride (CH3Cl) introduced by C. Vincent in 1878, and remained in use for many years: use ceased in the 1960s
- Fluorocarbon refrigerants were developed by an American team at Frigidaire Corporation, headed by Thomas Midgley in 1930. The first CFC, R12 came onto the market in 1931, and was followed by the first HCFC, R22 in 1934, then in 1961, the first Azeotropic mixture R502 (R22/R115) was introduced
- In 1974, two US Nobel prizewinners, S. Rowland and M. Molina, published disturbing findings suspecting that the chlorine released by halogenated hydrocarbons was adversely affecting the ozone layer

Classification of Refrigerants



Refrigerants mainly belong to one of the following groups:

- Hydrocarbons: compounds that contain only the elements hydrogen and carbon.
- Halocarbons: compounds that contain carbon, one or more of the halogens (bromine, chlorine, fluorine) and might contain hydrogen.
- Inorganic: compounds that doesn't contain carbon.
- Blend: compounds that contain two or more of the above single compound
  - Azeotrope Blends
  - Zeotrop Blends

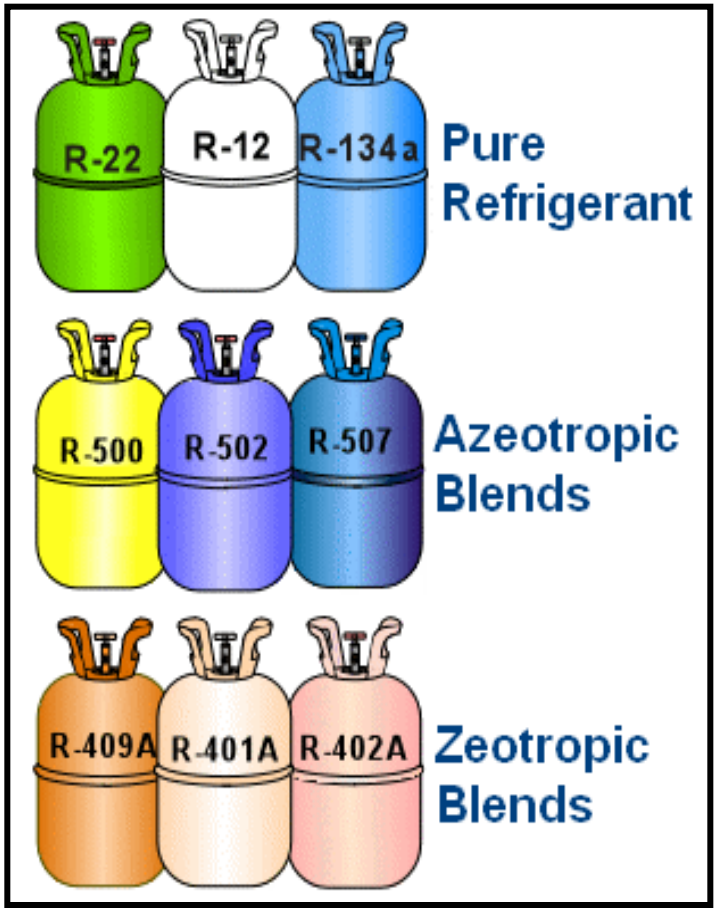
Blend Refrigerants

Blends

- Refrigerant Blends are mixture of two or more refrigerants working together as one refrigerant. Blends are mainly two types:

- Azeotropic Blend: An azeotrope is a mixture of two substances which cannot be separated into its components by distillation. It evaporates and condenses as a single substance and Its properties are completely different from its constituents. For example, Azeotrope R-500 is a mixture composed of 73.8 per cent R-12 and 26.2 per cent R-152.

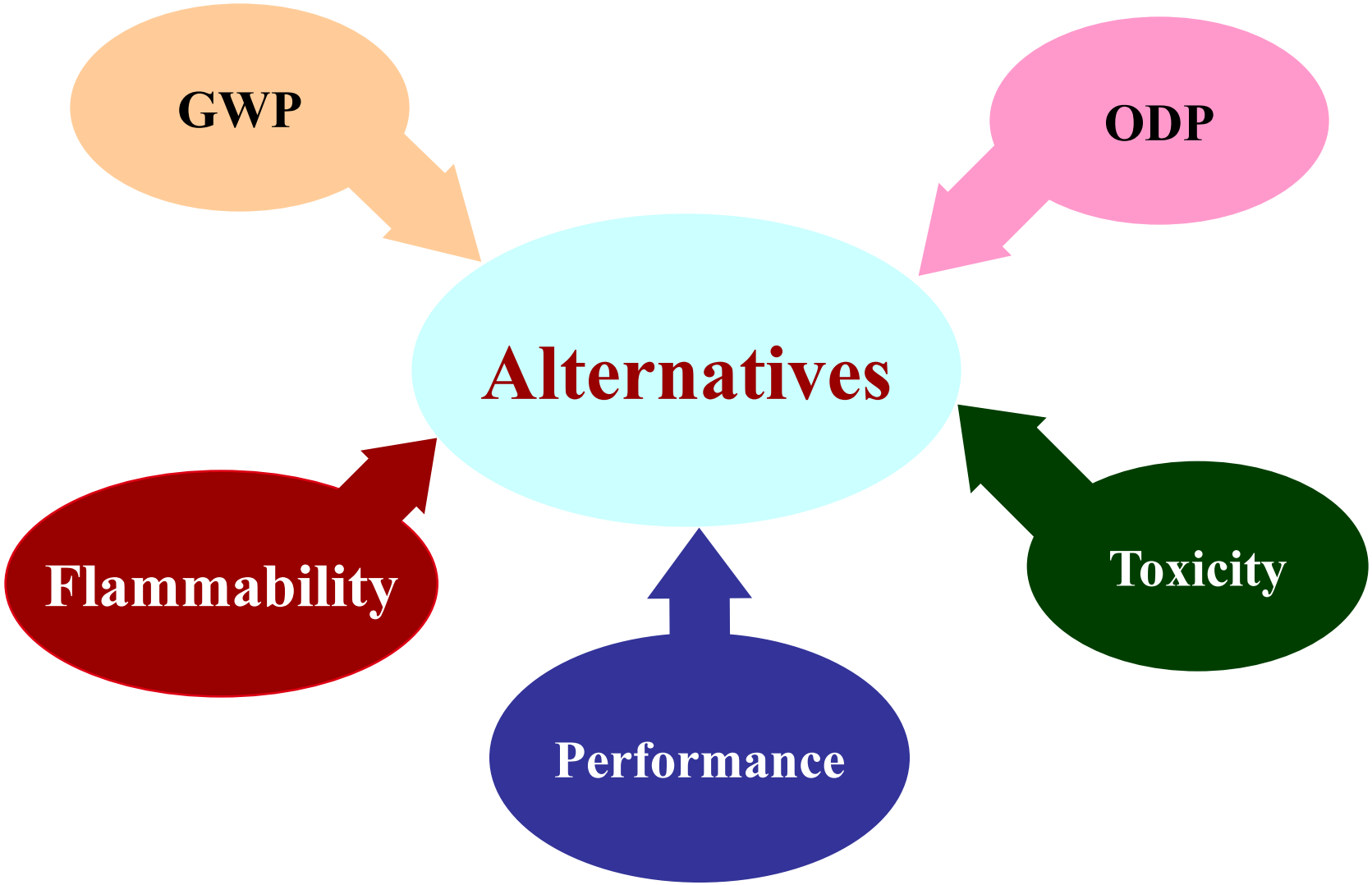
- Zeotropic Blend: mixture of refrigerants that have different values of condensing and evaporating temperature.



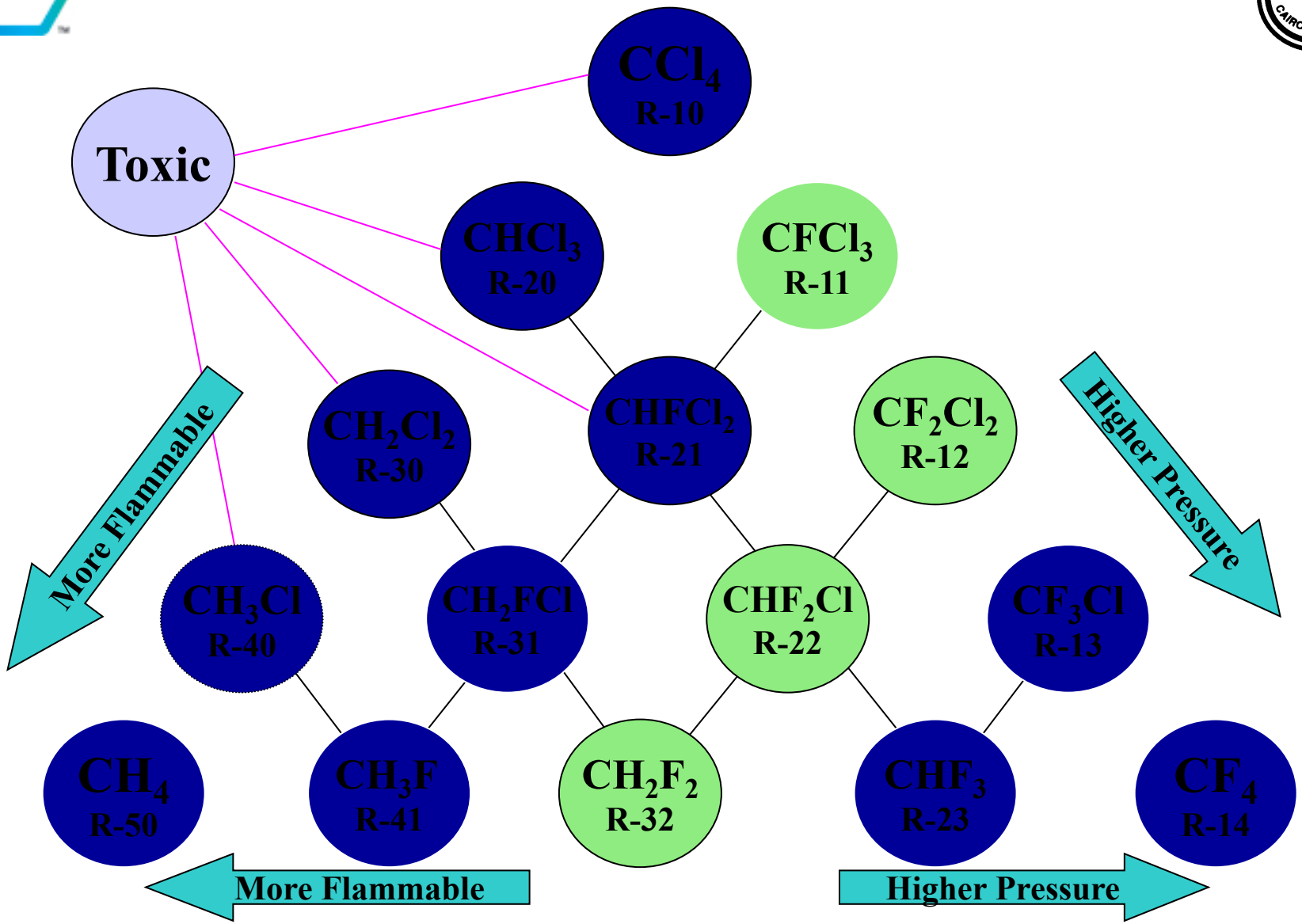
An Ideal refrigerant should:

- Have the desired thermodynamic properties,
- Nontoxic
- Non-flammable
- Compatible with other materials used to fabricate and service refrigeration systems
- Easy to manufacture
- Easy to handle and detect
- System not operating at extreme pressures, either high or low
- No or low Environmental Impact

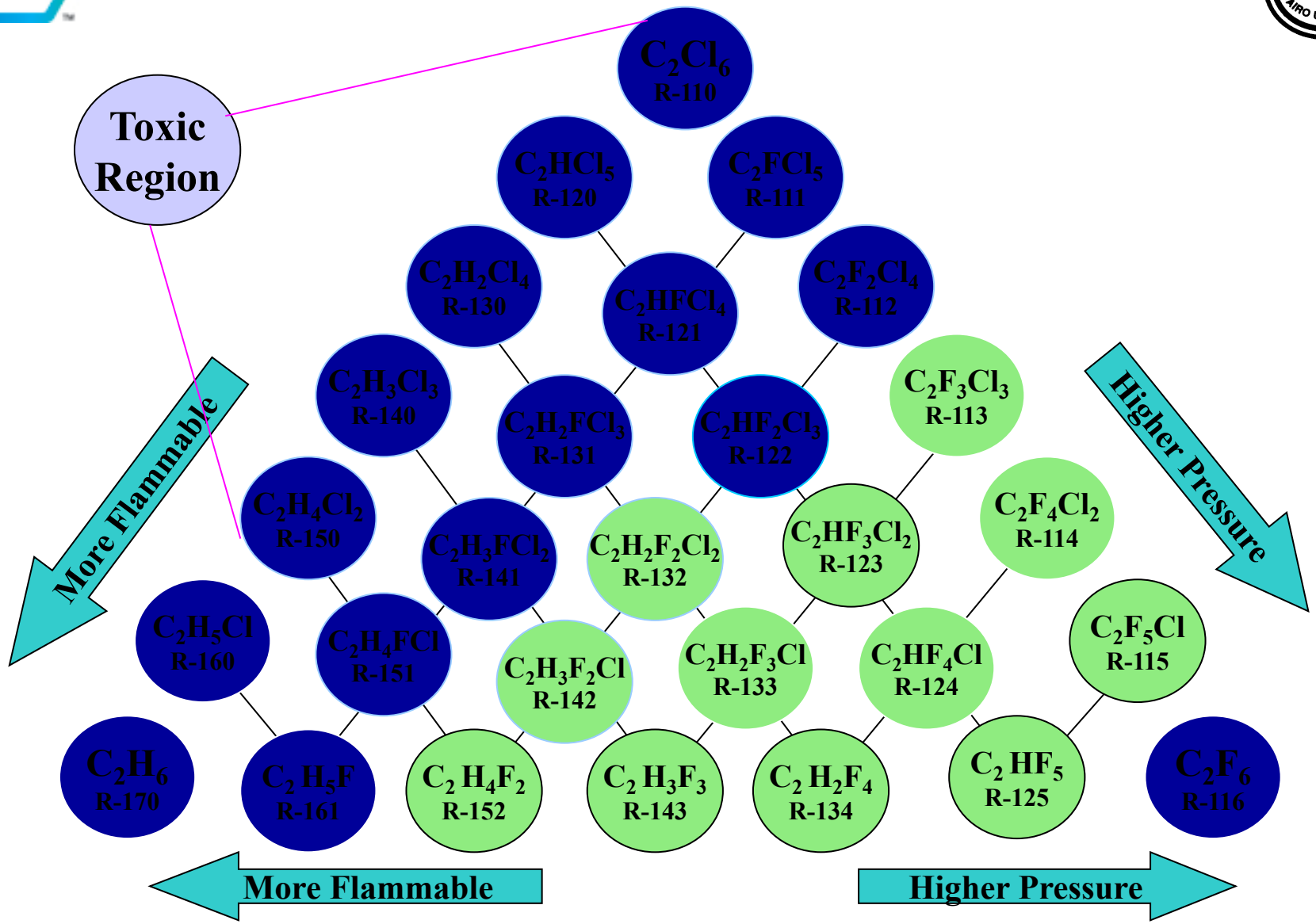
Selection Criteria



Methane Derivatives with Chlorine & Fluorine



Ethane Derivatives with Chlorine and Fluorine



ASHRAE Safety Classification

Occupational Exposure Limit (OEL)

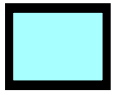
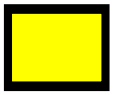
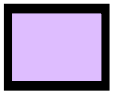
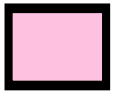
Occupational Exposure Limit (OEL), in parts per million, which reflect the toxicity level of the various refrigerants. In the knowledge of these allowable concentration levels in occupied areas, it is necessary that adequate rates of ventilation be provided in plant rooms and recommended that refrigerant leak detection be installed.

ASHRAE

stands for the "American Society for Heating, Refrigeration & Air-conditioning Engineers" ASHRAE classifies working refrigerants with a safety code as an indication for both flammability and toxicity

Lower Toxicity	Higher Toxicity	
A3	B3	Higher Flammability
A2	B2	Lower Flammability
A1	B1	No-Flame Propagation

International Color Codes

R-11:	Orange		**R-717:**	Silver	
R-12:	White		**R-134a:**	Light Blue	
R-500:	Yellow		**R-404A:**	Light Orange	
R-502:	Light Purple		**R-407C:**	Medium Brown	
R-22:	Green		**R410A:**	Rose	
R-123:	Light Grey				

Example of HFCs and HFC Blends

e.g. HFC134a, R404A, R407C, R410A, R507A

☑ **Advantages**

- Zero ODP
- Non-flammable
- Capacity close to CFCs

☒ **Disadvantages**

- High GWP (Regulated under Kyoto Protocol)
- Not all HFCs widely available
- Do not work with Mineral Oil
- Major system changes necessary
- Zeotropic Mixture problems

Code Definition

- A **building code** is a set of rules that specify the standards for constructed objects such as buildings and nonbuilding structures. Buildings must conform to the code to obtain planning permission, usually from a local council. The main purpose of building codes is to protect public health, safety and general welfare as they relate to the construction and occupancy of buildings and structures. The building code becomes law of a particular jurisdiction when formally enacted by the appropriate governmental or private authority.
- **Bases of Design and**
- **Conditions for Execution**

Energy Code General

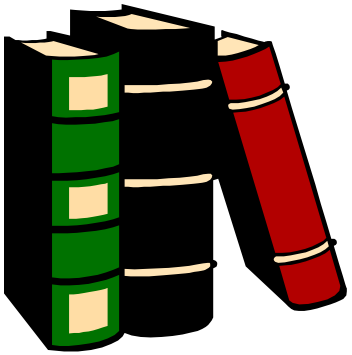
The CODE SCOPE INCLUDES :

- *Building Envelope*
- *Ventilation and Air Conditioning*
- *Lighting*
- *Electric Power and Distribution*
- *Service Water Heating*
- *Building Energy Performance Compliance*
- *Energy Management*

General

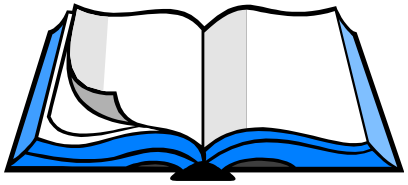
Basic Codes

- NFPA Codes, latest edition
- Uniform Mechanical Code, 2018.
- Uniform Building Code, 2017.
- Uniform Fire Code, 2017.
- National Mechanical code, 2017.
- ASHRAE Handbook Of 2016, 2017, 2018 & 2019



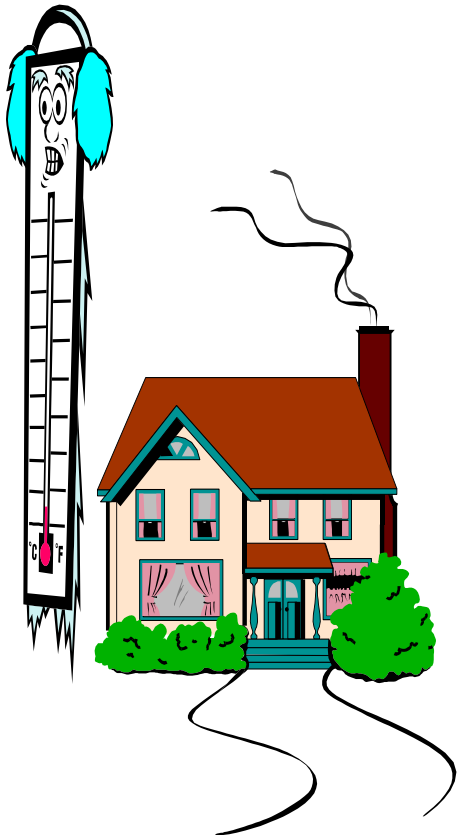
Additional Codes

ADC	Air Diffusion Council.
AGA	American Gas Association.
AMCA	Air moving & Conditioning Association.
ANSI	American National Standards Institute.
ARI	Air-Conditioning & Refrigeration Institute.
ASHRAE	American Society of Heating, Refrigeration & air-conditioning Engineers.
ASME	American Society of Mechanical Engineers.
ASTM	American Society for Testing Materials.
AWS	American Welding Society.
ISO	International Organization for Standardization.
AABC	Associated Air Balance Council.
NFPA	National Fire Protection Association.
SMACNA	Sheet Metal Air Cond. Contractors National Assoc. Inc.
UL	Underwriters' Laboratories.



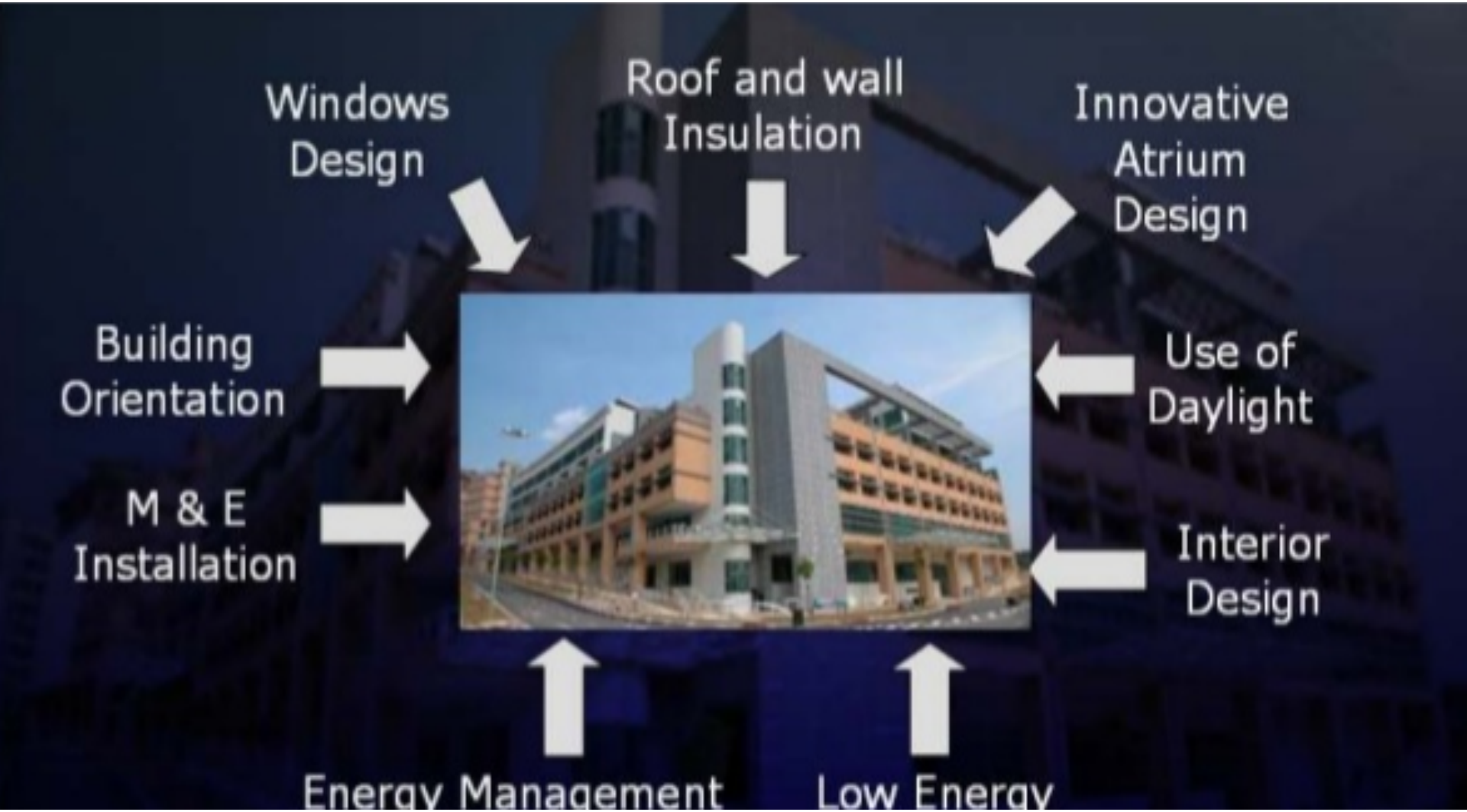
Indoor Design Conditions

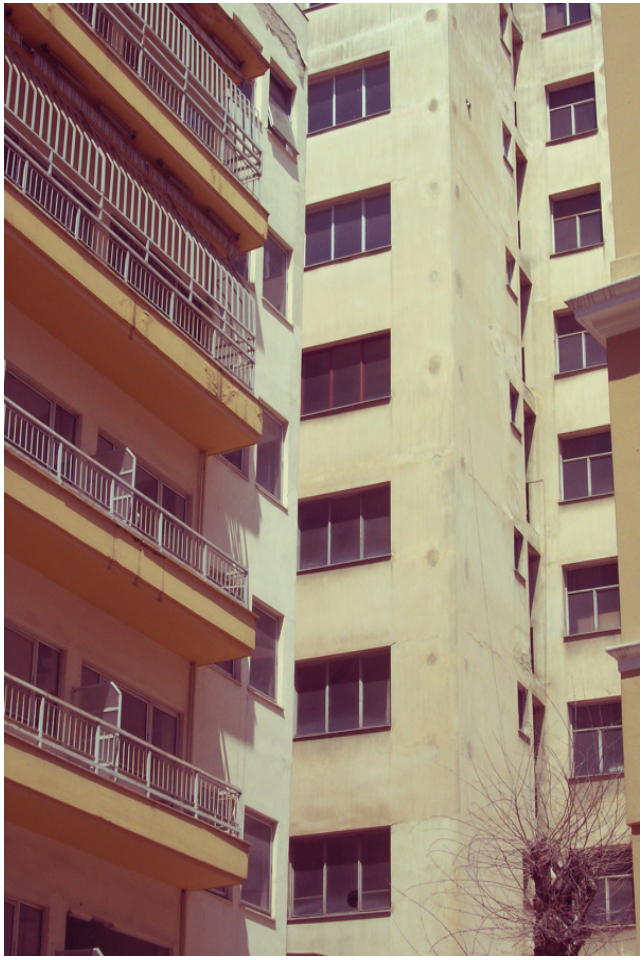
To provide optimum comfort to the occupants, the indoor conditions which shall be maintained are:

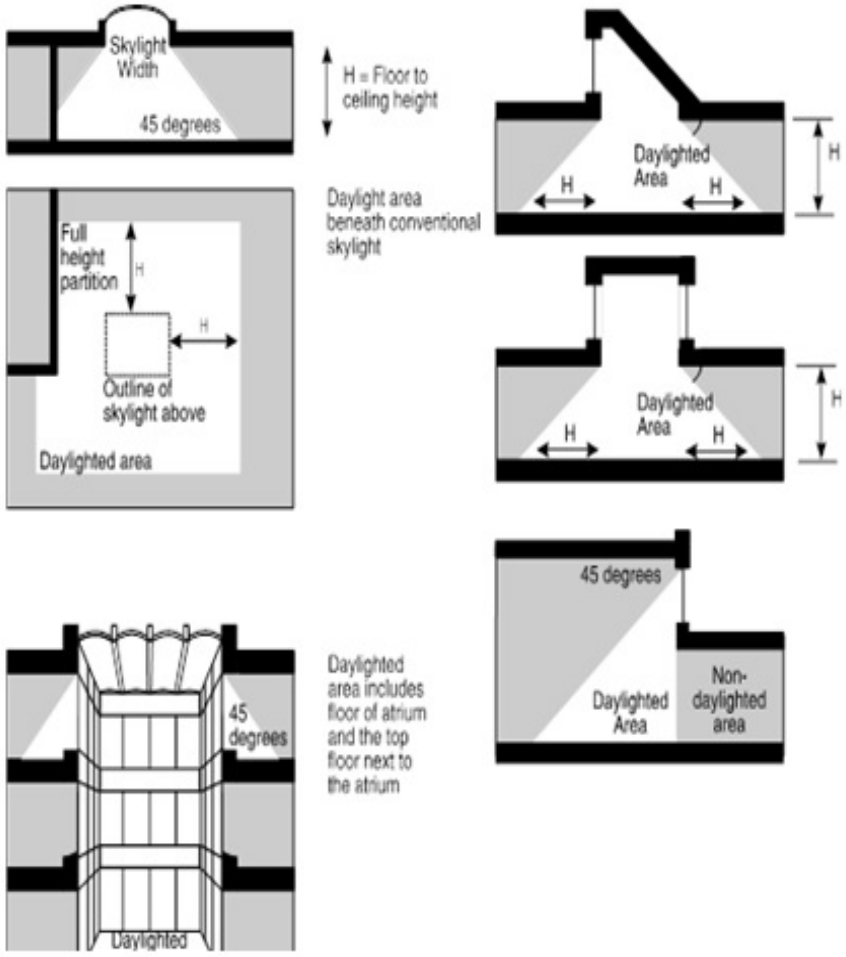


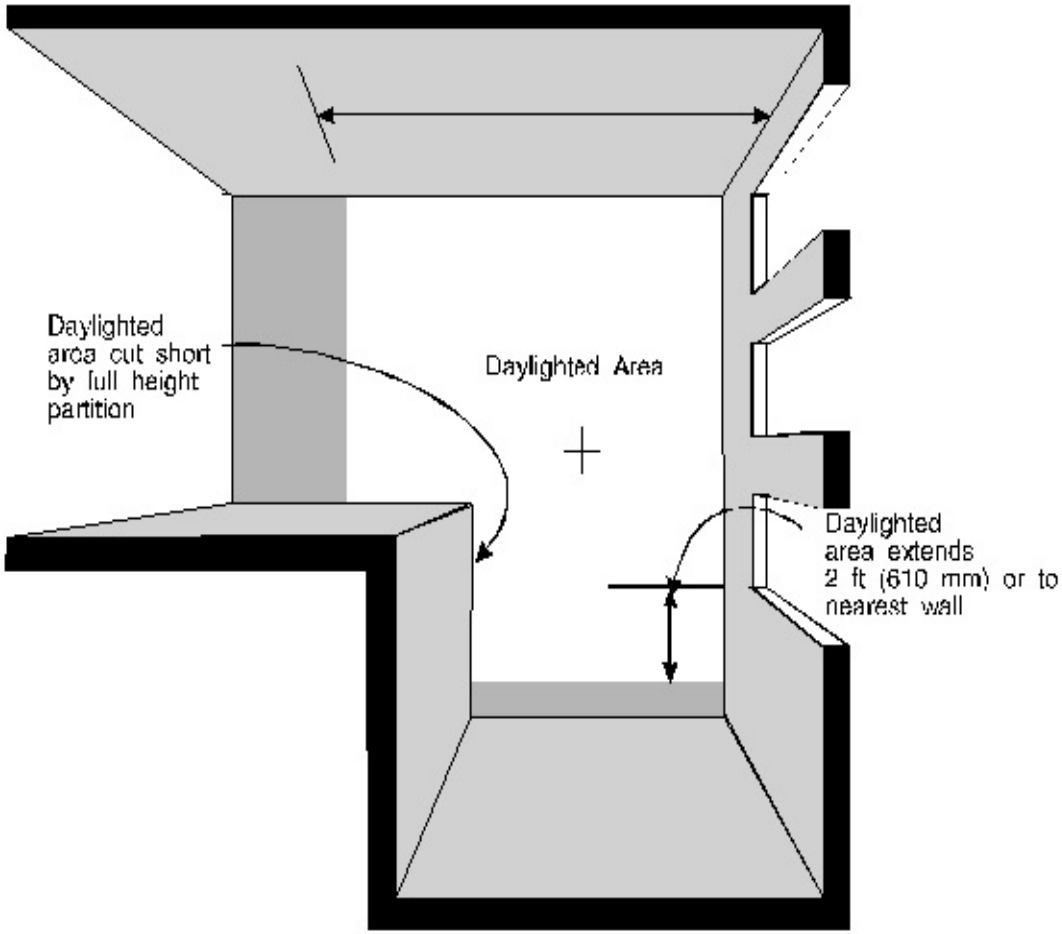
- 22 deg. C dry bulb temperature and 50% relative humidity in guestrooms.
- 23 deg. C dbt and 50% RH to all public air conditioned spaces.

Energy Design Elements

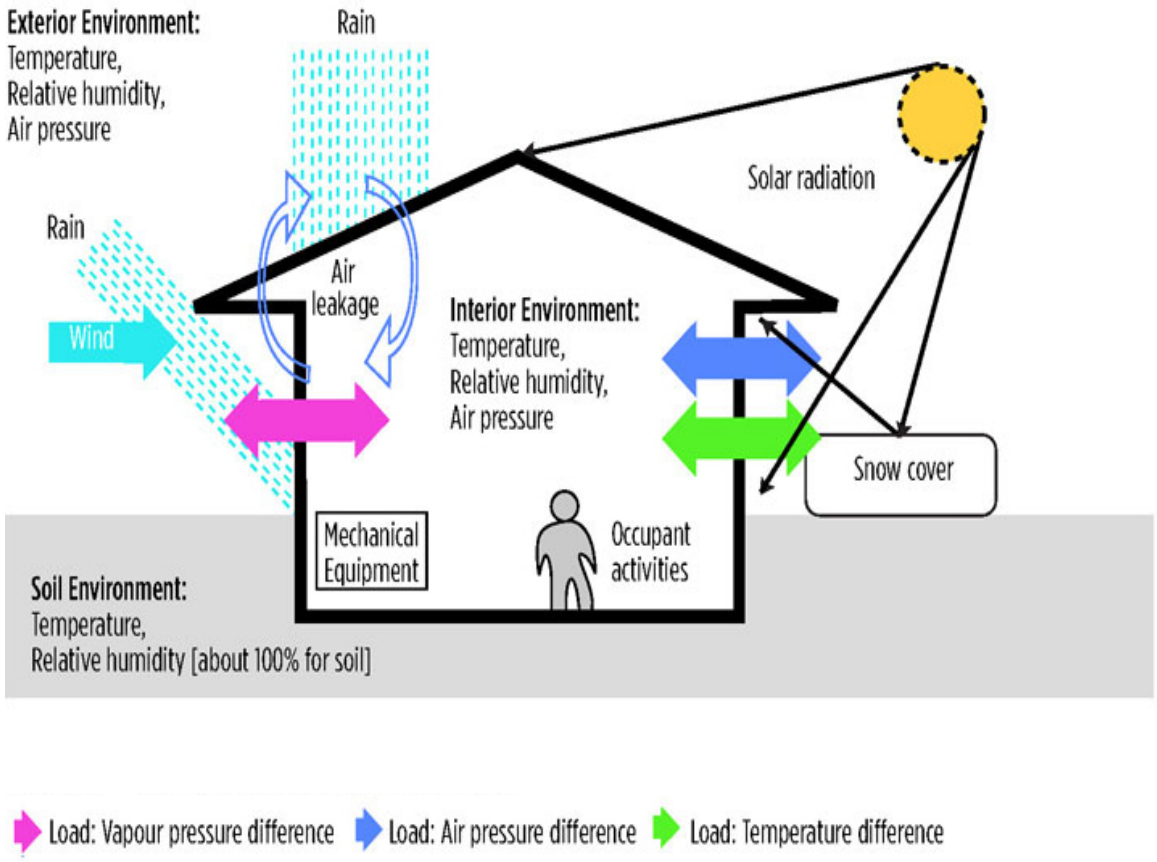




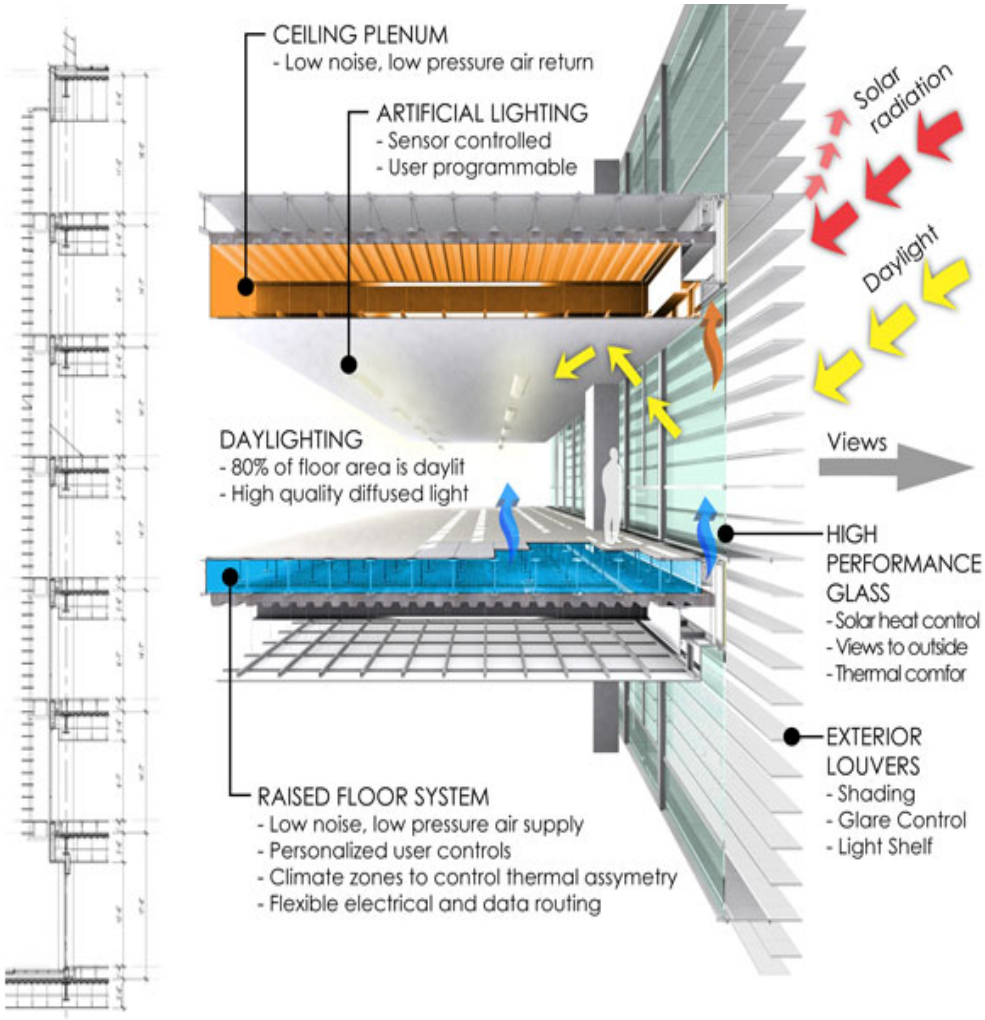

Skylight Width
45 degrees
H = Floor to ceiling height
Daylight area beneath conventional skylight
Full height partition
H
H
Outline of skylight above
Daylighted area
Daylighted Area
H
H
H
Daylighted Area
H
H
45 degrees
Daylighted Area
Non-daylighted area
45 degrees
Daylighted area includes floor of atrium and the top floor next to the atrium
Daylighted


Daylighted
area cut short
by full height
partition
Daylighted Area
Daylighted
area extends
2 ft (610 mm) or to
nearest wall

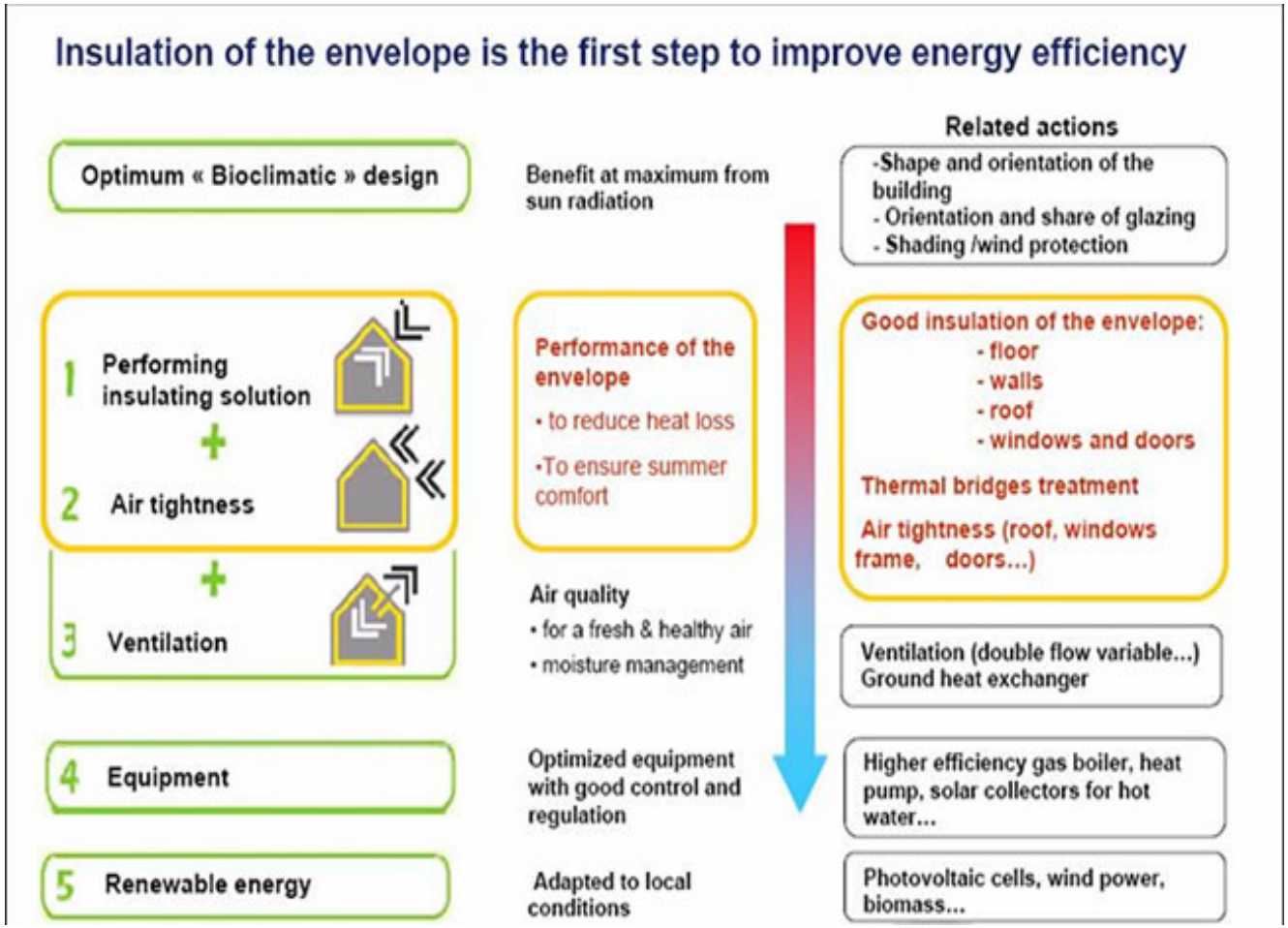
Environmental loads of Envelope

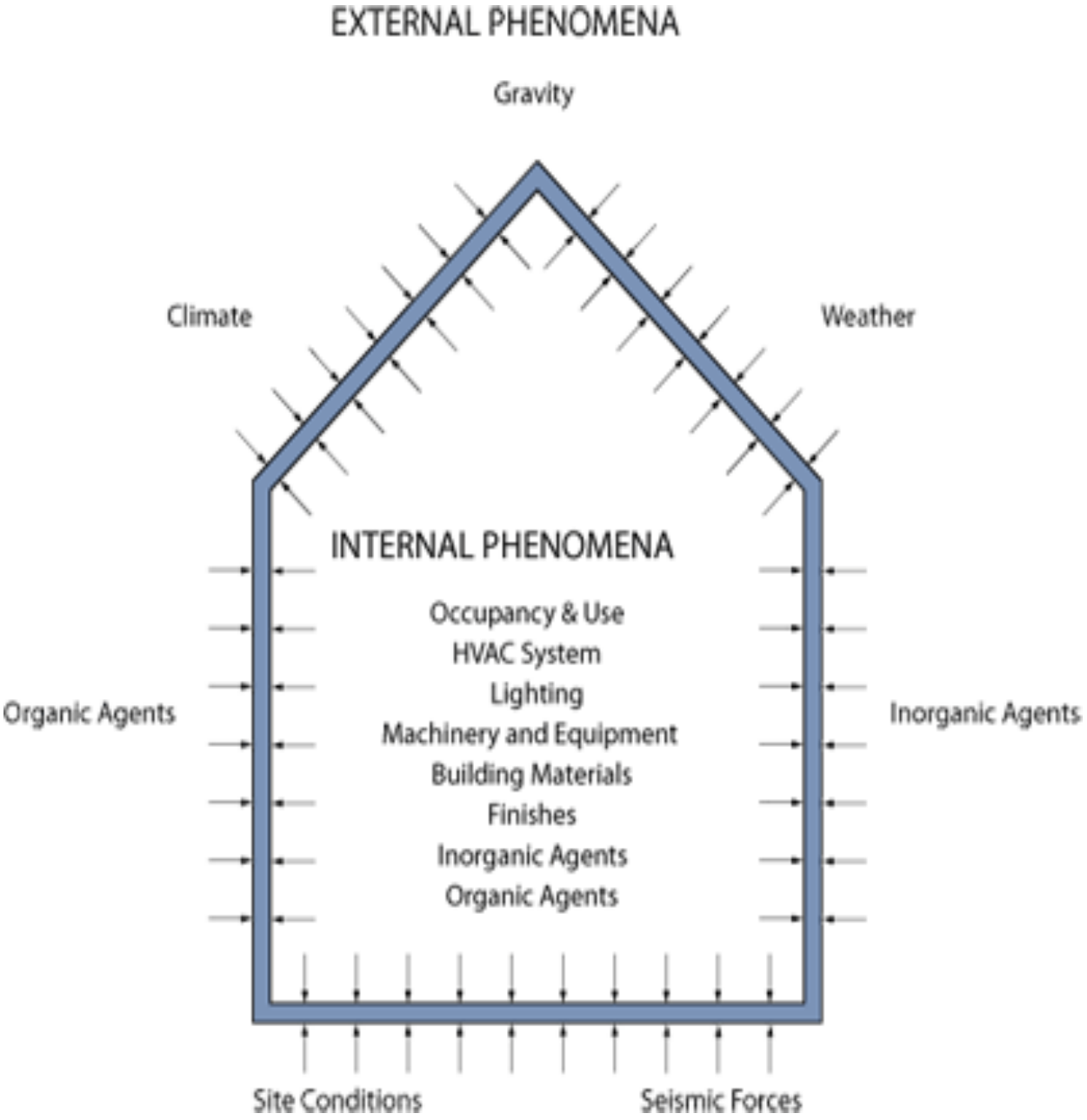


Envelope interactions with exterior

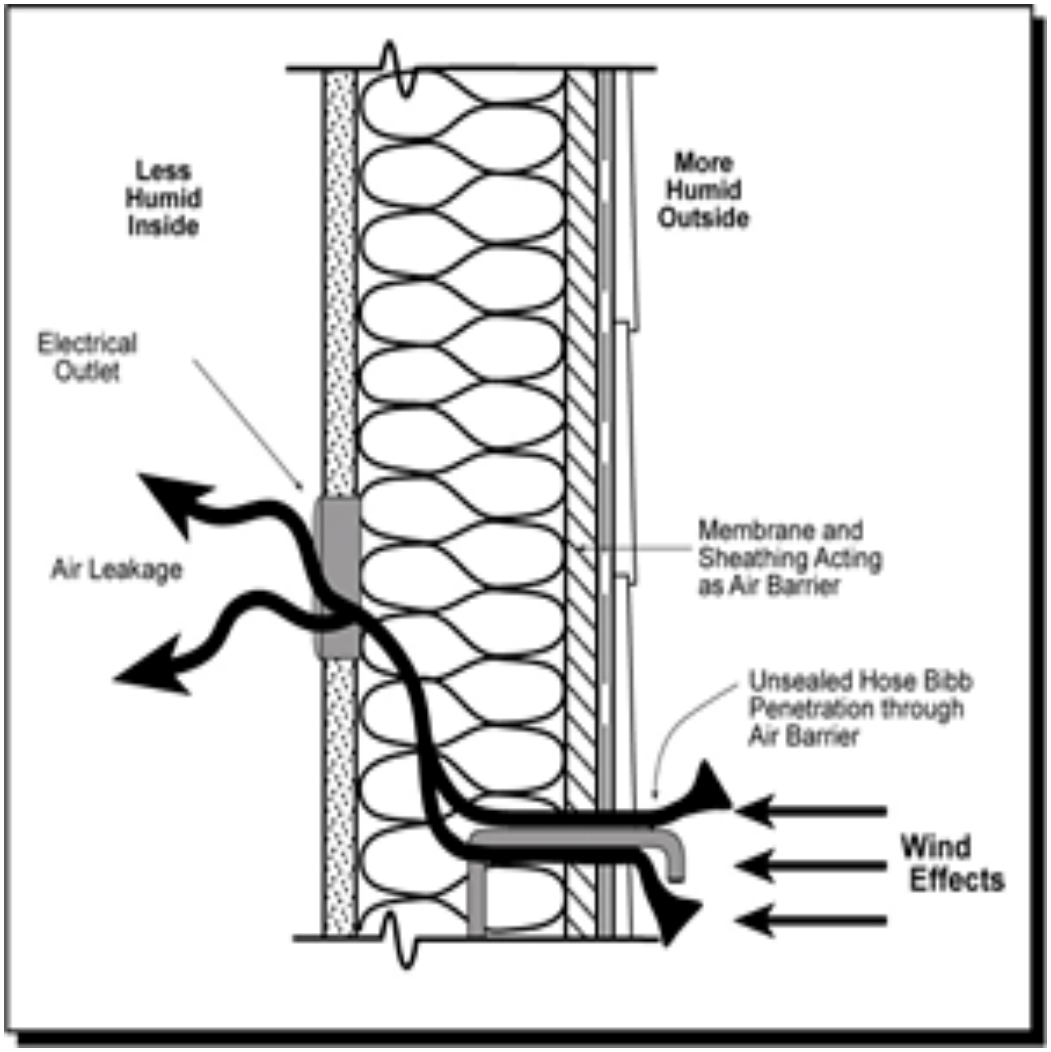


Energy Efficient Envelope




EXTERNAL PHENOMENA
Gravity
Climate
Weather
INTERNAL PHENOMENA
Occupancy & Use
HVAC System
Lighting
Machinery and Equipment
Building Materials
Finishes
Inorganic Agents
Organic Agents
Organic Agents
Inorganic Agents
Site Conditions
Seismic Forces

Moist Air Migration



APPLICATIONS

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight.

- Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs.
- Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun.

Passive Solar

Building facilities

As, perfect air conditioning system is helpful in the prevention of contamination, the construction of air conditioning system for buildings facilities presents many precautions not encountered in the usual comfort air conditioning systems. These precautions are

(1) The need to restrict air movement in and between the various departments;
(2) The specific requirements for ventilation and filtration to dilute and remove contamination in the form of odor, airborne microorganisms , and hazardous substances;
(3) The different temperature and humidity requirements for various areas; and
(4) The design sophistication needed to permit accurate control of environmental conditions.

Building facilities

Air Filters

A number of methods should be used for determining the efficiency of filters in removing particulate from and airstream. All filter efficiencies are based on ASHRAE Standard 52.1.

Installation Guidelines

- All filters should be installed to prevent leakage
- A manometer and/or alarm system should be installed in the filter system to measure and sense the pressure drop across each filter bank.
- During construction, openings in ductwork and diffusers should be sealed to prevent intrusion of dust, dirt and hazardous materials.

Building facilities

Continuity of services and energy concepts Zoning

Zoning-using separate air systems for different departments-may be indicated to
Compensate for exposures due to orientation for other conditions imposed by a particular building configuration,
- Minimize recirculation between departments,
- Provide flexibility of operation,
- Simplify provisions for operation on emergency power, and
- Conserve energy.

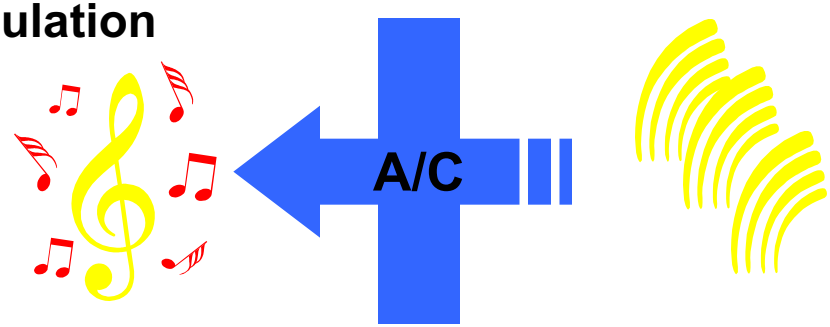
Mechanical Cooling

The source of mechanical cooling for passenger areas in the building should be carefully considered. The preferred method is an indirect refrigerating system using chilled water.

Noise Criteria

Generally, design goals for air conditioning system sound control for indoor areas will be in accordance with ASHRAE system Handbook 2016 as summarized below:

Type of Area	RC or NC Criteria Range
- Halls, corridors, lobbies, service / support areas	40 to 45
- Executive offices	25 to 30
- Conference rooms	25 to 30
- Private area	30 to 35
- Open offices, secretaries,	35 to 40
- Administrative assistant	35 to 40
- Lobbies and circulation	35 to 40
- Computer / business machines.	40 to 45
- Public circulation	40 to 45



Air Conditioning System

- **Acoustic Treatment**

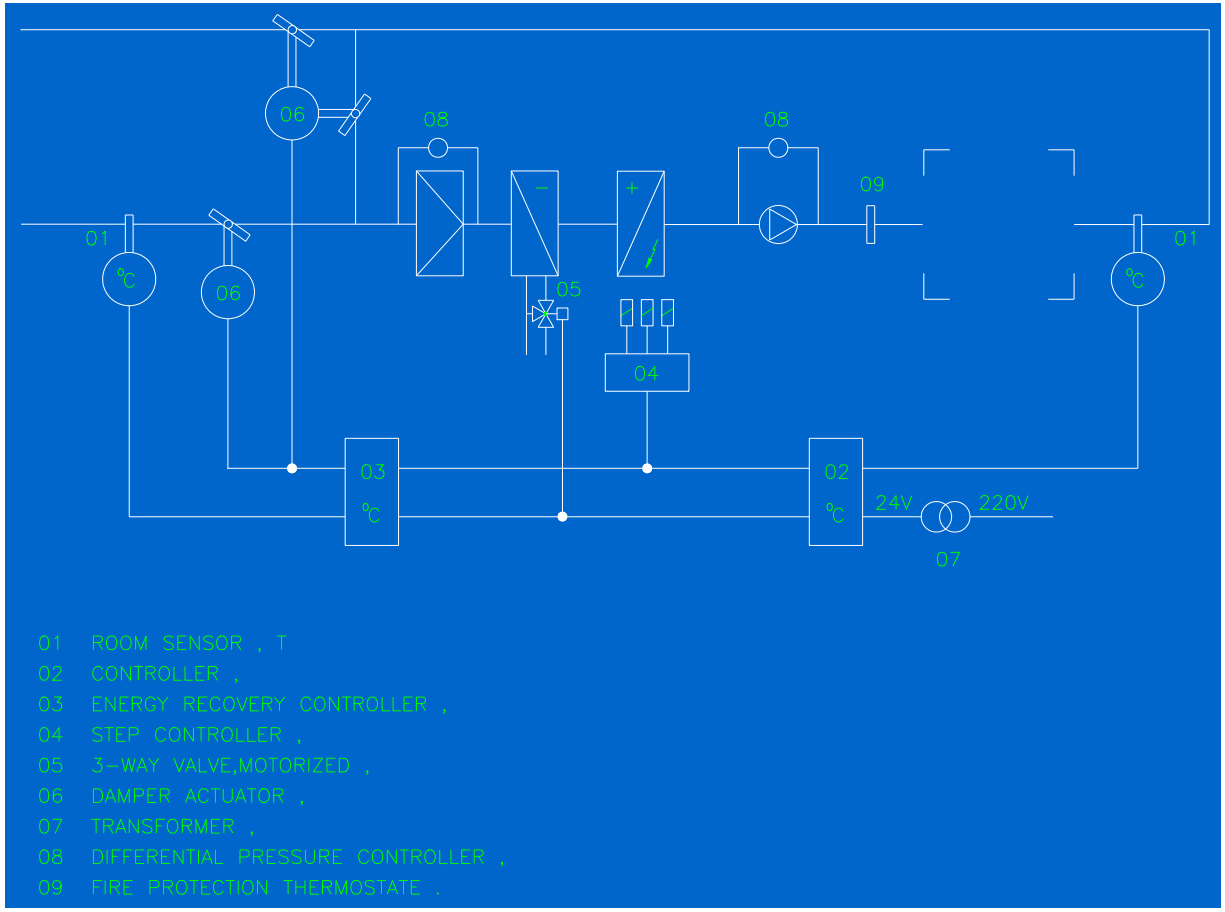
An acoustic analysis based on sound pressure levels at each octave band of selected noise sources (fans etc.) and duct layout shall be conducted to select the most effective means to attenuate the complete spectrum of noise.

- **Vibration**

Vibration isolators will be provided for all equipment and ductwork. Rigid connections between rotating or oscillating equipment and the building will be avoided. Vibration isolators will be selected in accordance with the weight distribution and the manufacturer's recommendations t produce uniform deflection.

System Design and Control

- Control System



Energy Efficiency Codes

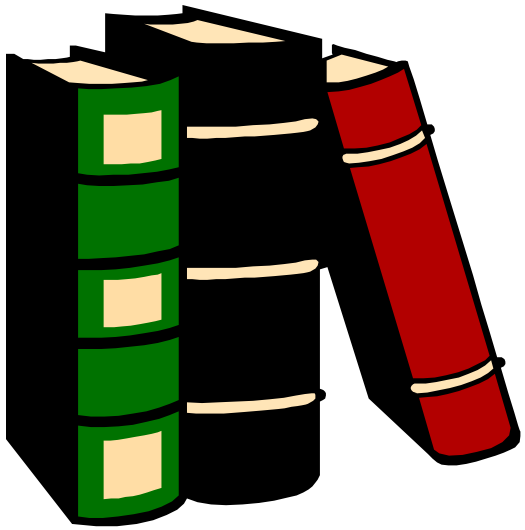
Residential Energy Code Analyses

Country	1	2	3	4	5	6	7	8	9
Srilanka	X	---	X	X	X	X	X	---	---
Kuwait	X	X	X	X	---	X	---	X	---
Canada	X	X	X	X	X	X	X	X	---
China	X	X	X	X	---	X	X	---	---
Malaysia	X	X	X	X	X	X	---	---	X
Hong Kong	X	X	X	X	X	---	---	X	---
Thailand	X	---	X	X	---	---	---	---	---
USA	x	x	x	x	x	x	x	x	x
Egypt	X	X	X	X	X	X	X	X	X

Legend

1. Scope & Definitions
2. General Requirements
3. Building Envelope
4. Ventilation and Air Conditioning
5. Lighting
6. Electric Power and Distribution
7. Service Water Heating
8. Building Energy Performance Com
9. Energy Management

Four different codes were comprehensively selected to be the best that demonstrate the inherent characteristics of the HVAC requirements in Residential Buildings .



These were reviewed by the team for possible consideration and are as follows:

•.The MEC Energy Code MEC

•.ANSI/ASHRAE/IESNA 90.1-2016 Energy Standard for Buildings Except Low-rise Residential Buildings

•.ANSI/ASHRAE 90.2-2018 Energy Efficient Design of New Low-rise Residential Buildings

•.California Title 24 Energy Efficiency Standards for Residential and Non-Residential Buildings

MODEL ENERGY CODE (MEC)

A.1. APPLICAPILITY TO ARAB WORLD:

- MEC assumptions may not apply in ARAB WORLD. Thus, the very foundation of many MEC requirements may need to be re-examined.
- Natural ventilation is not considered. It is suggested that we should develop our own approach to this energy requirement.
- MEC addresses many climates, it is recommended that the requirements initially should address only Major capitals ; further developments may include other climates.
- MEC is too simple in some cases at the cost of lack of flexibility to deal with real variations in building construction conditions.
- The objective of the MEC is energy efficiency no requirements are given to establish minimum thermal comfort conditions when air-conditioning in not installed or installed but not used.

MODEL ENERGY CODE (MEC)

A.2. SUMMARY OF MODEL ENERGY CODE (MEC) (OR IECC 2016)

This is a US national model energy code. It is published and maintained by the International Code Council (ICC) as the "International Energy Conservation Code" (IECC) as of 2016. For residential buildings, this is the national residential model code for the US. The US government requires that each state in the US must either (1) adopt the MEC for residential buildings or (2) must adopt a state-modified version of the MEC that will save at least as much energy as the MEC.In the MEC (IECC 2016), low-rise residential buildings are treated differently from high-rise residential buildings (4 stories or more). The various requirements to assess which would be most appropriate for use at this time should be examined; in particular, section 101.4.3 of IECC 2016 about Mixed Occupancy buildings. There is a WEB Site that includes MEC check compliance software that has been developed by US DOE.

MODEL ENERGY CODE (MEC)

A.3. RESUME OF THE MODEL ENERGY CODE

The MEC was originally developed jointly (under the auspices of the Council of American Building Officials, CABO) by

- Building Officials and Code Administrators International, Inc. (BOCA),
- International Conference of Building Officials (ICBO),
- National Conference of States on Building Codes and Standards
- NCSBCS), and Southern Building Code Congress International (SBCCI), under a contract funded by the U.S. Department of Energy.

MODEL ENERGY CODE (MEC)

A.4. MEC CODE ANALYSES:

The code was reviewed and analyzed in terms of the suitability to ARAB WORLD Conditions as follows:

- **The code contains the general requirements as outlined in a general requirement Guide**
- **The code contains Prescriptive Packages User's Guide of 73 pages on PDF format. It contains additions, Default U-Factors and SHGS Values, Building Envelope, Forms and Climate Zones and finally the definitions.**
- **Trade-off Worksheet User's Guide follows this. This contains the introduction, instructions for using the Trade-off Approach, Quick compliance and compliance example. Appendix C defined what is a building envelope while appendix D gave the various necessary forms.**

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- **Compliance Requirements**
  - **Prescriptive**
  - **Trade-off**
  - **Plan and building envelop**

- **.Detailed requirements of the forced ventilation, HVAC, hot water, building material are indicated.**

REVIEW

ANSI/ASHRAE/IESNA 90.1-2016

The code was reviewed and analyzed in terms of the suitability to ARAB WORLD Conditions as follows:

- Scope and definitions are clearly indicated in the text of ASHRAE and in the appendix
- The code contains the general requirements as outlined in a general requirement Guide
- The code contains compliance forms in PDF format. It contains Insulation, Fenestration and Doors, Air Leakage, Default U-Factors and SHGS Values, Building Envelope, Forms and Climate Zones and finally the definitions.
- It defined what is a building envelope and gave the various necessary forms.
- Compliance Requirements
  - Prescriptive
  - Trade-off
  - Plan and building envelop
- Detailed requirements of the forced ventilation, HVAC, hot water, building material, lighting is indicated. The code however does not address the electrical power requirements in adequate depth.

REVIEW

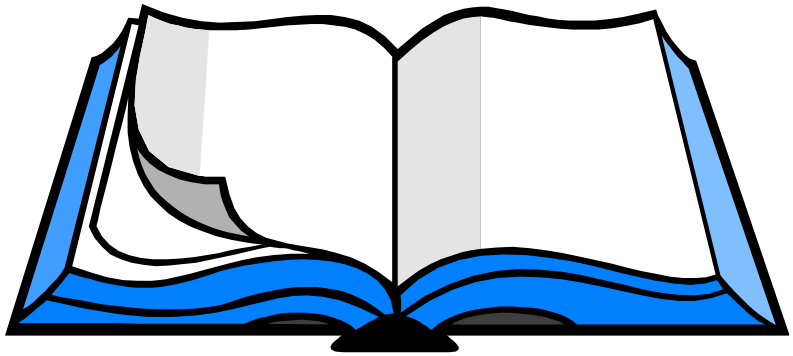
ANSI/ASHRAE 90.2-2018

The ASHRAE standards – 90.2 – are consensus standards that together specify requirements for residential buildings. ASHRAE 90.2 specifies energy requirements for low-rise residences of 3 stories or less.
Low-rise Residential. This standard covers only 1- and 2-family dwellings (villas) and low-rise multifamily residences up to 3 stories above grade. The latest published version of this document is in 2018.

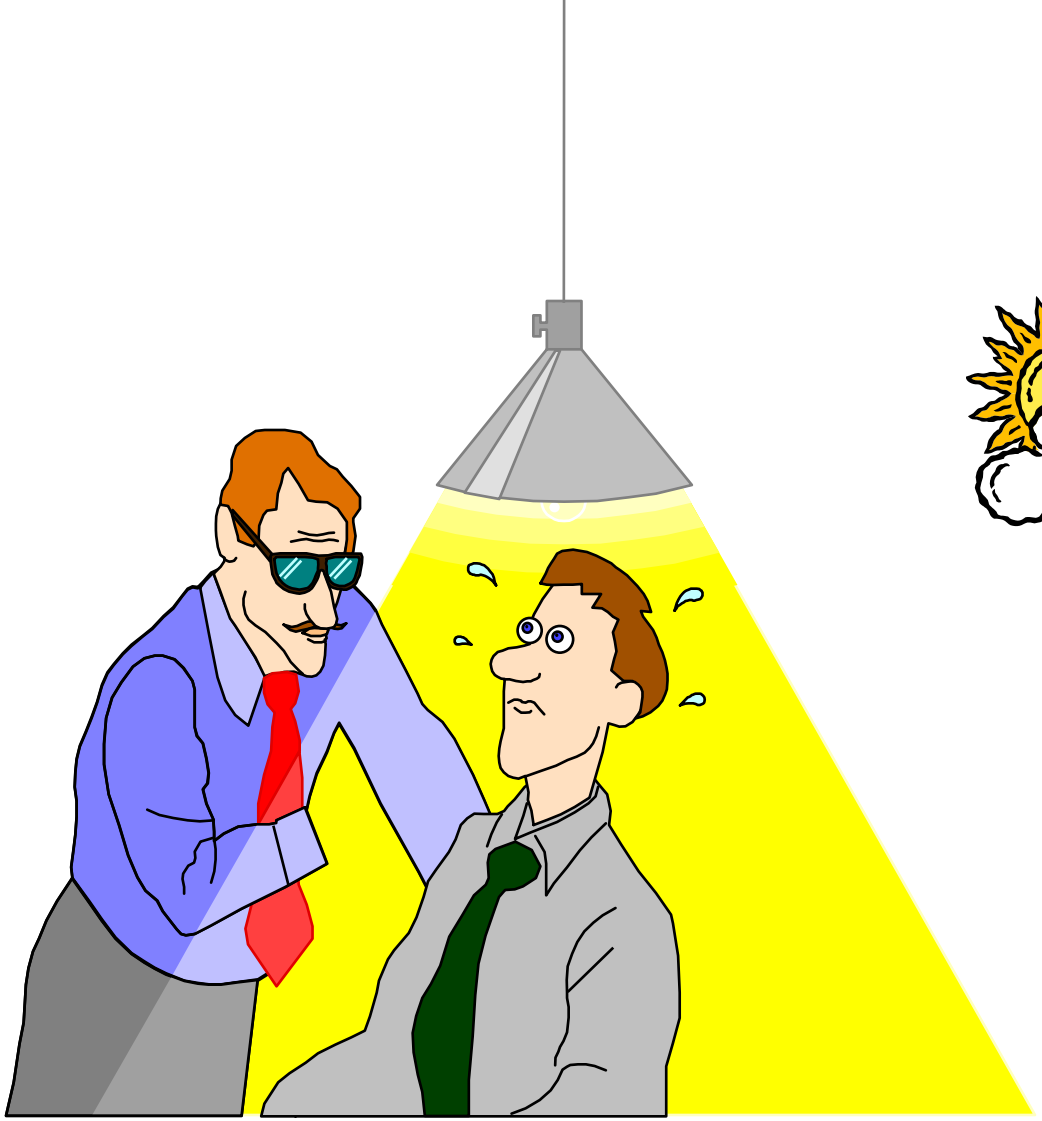
Recent changes. Because the MEC has been designated as the basis for a "national" US code for residential buildings, there has been less focus on ASHRAE 90.2. For this reason, ASHRAE 90.2 for low-rise residential buildings has not been officially updated since 2018. However, since 1993 the ASHRAE 90.2 committee has been developing a number of proposed addenda, or changes, to the 2018 version. While these possible addenda have been developed, they have not yet been distributed for formal public review in preparation for publication. Draft Addenda Contained on CD.

California Title 24

The California Title 24 energy code is technically one of the most advanced and most stringent in the world, but also has a complicated compliance and administration. The latest version, AB970, January 2016, has just been developed. There is also compliance supplement for the new 2016 revisions.



It is very gratifying to find some one that silently appreciates your efforts

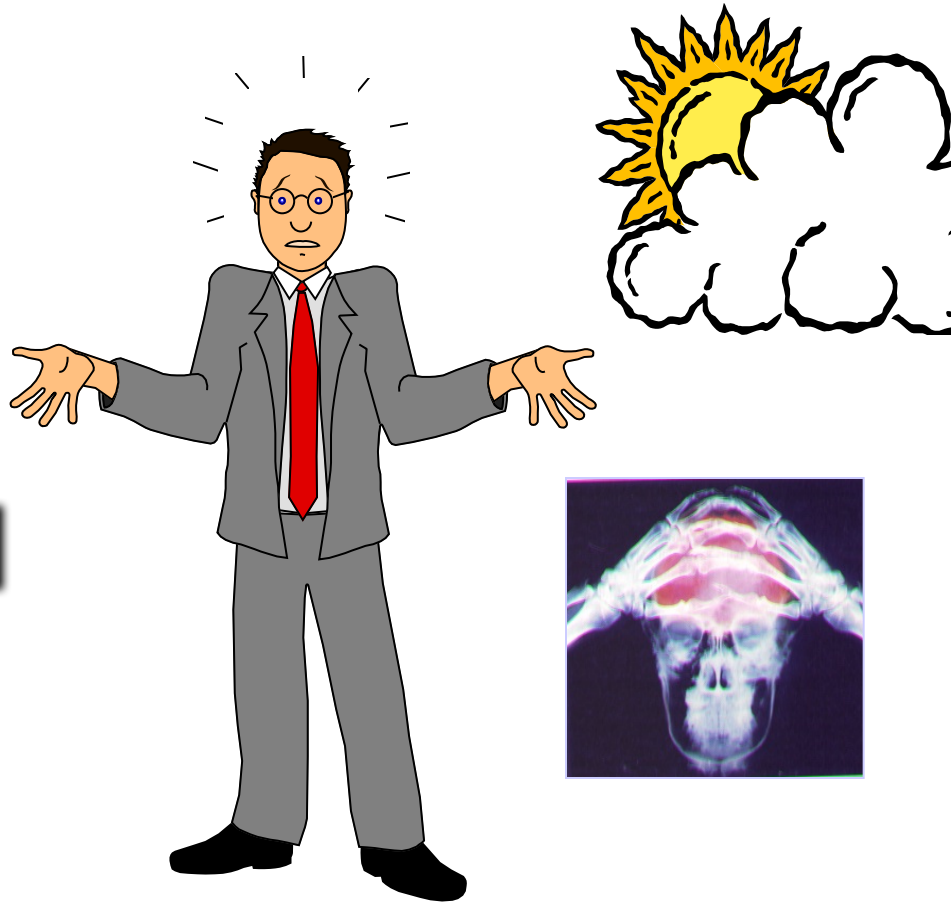


QUESTIONS !!

I REST MY CASE YOUR HONOURS

The End

Thank You



Yes ……. I have two hands