MEBS6016 Energy Performance of Buildings

http://me.hku.hk/bse/MEBS6016/

Building Energy Standards and Codes

Dr. Sam C. M. Hui

Department of Mechanical Engineering

The University of Hong Kong

E-mail: cmhui@hku.hk

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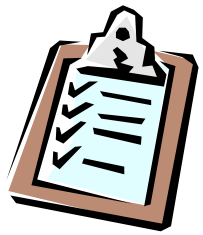
Contents

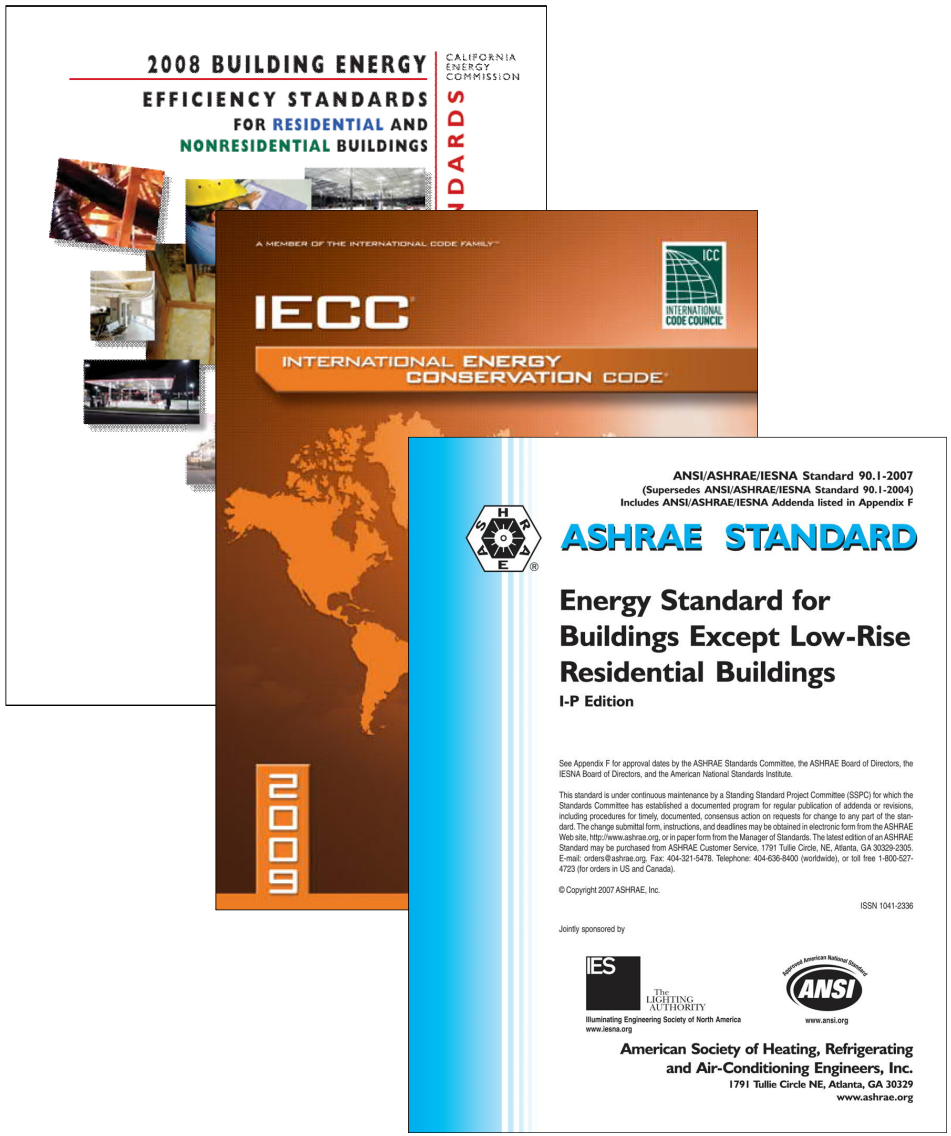


- ASHRAE 90.1
- Structure and Scope
- Compliance Options
- Energy Cost Budget Method
- Performance Rating Method
- Hong Kong BEC

Examples of building energy codes in the world

Australia	Included in the Building Code of Australia
England	Building Regulation Part L: Approved Document L2 – Conservation of fuel and power in buildings other than dwellings
Japan	Design and Construction Guidelines on the Rationalization of Energy Use for Buildings
Korea (South)	Mandatory Building Energy-Saving Standard 2004
New Zealand	Clause H1 of New Zealand Building Code
Singapore	SS 530 – Energy Efficiency Standard for Building Services and Equipment
USA	Codified ASHRAE 90.1 California Title 24 International Energy Conservation Code (IECC)
Mainland China	GB 50189 Design standard for energy efficiency of public buildings《公共建築節能設計標準》
Taiwan	1995 Commercial Building Energy Standard (ENVLOAD)

Building Energy Codes, e.g. ASHRAE 90.1, International Energy Conservation Code (IECC), California Title 24



(Source: Mr. Kent W. Peterson, former ASHRAE President)

ASHRAE 90.1

- ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers
  - Global leader in the arts and sciences of heating, ventilation, air conditioning and refrigeration
  - www.ashrae.org
  - Important ASHRAE Standards:
    - 55: thermal comfort
    - 62.1: indoor air quality
    - 90.1: building energy conservation
    - 135: BACnet (building automation & control)
    - 189.1: high performance green buildings

ASHRAE 90.1

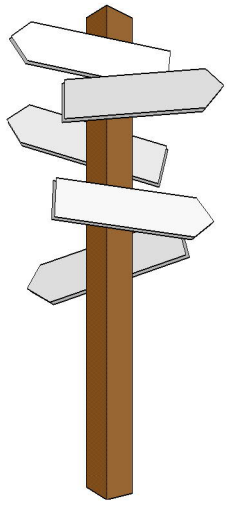
- ASHRAE Standard 90.1 (www.ashrae.org/standard901)
  - Energy Standard for Buildings Except Low-Rise Residential Buildings
    - Include (new) commercial & institutional buildings
  - SSPC 90.1 Standing Standard Project Committee
- Other relevant ASHRAE Standards:
  - 90.2 -- for low-rise residential buildings
  - 90.4 – for data centers (coming soon…)
  - 100 -- for existing buildings

ASHRAE 90.1

- Why ASHRAE Standards 90.1 is important?
  - It is the reference standard for US Energy Policy Act and many building energy codes in USA
  - It has been adopted in many countries as a model for energy efficiency guidelines and codes
  - It is the professional “standard of care” set by ASHRAE consensus, with support from
    - IES (Illuminating Engineering Society) or IESNA
    - ANSI (American National Standards Institute)
  - Required for LEED green building certification

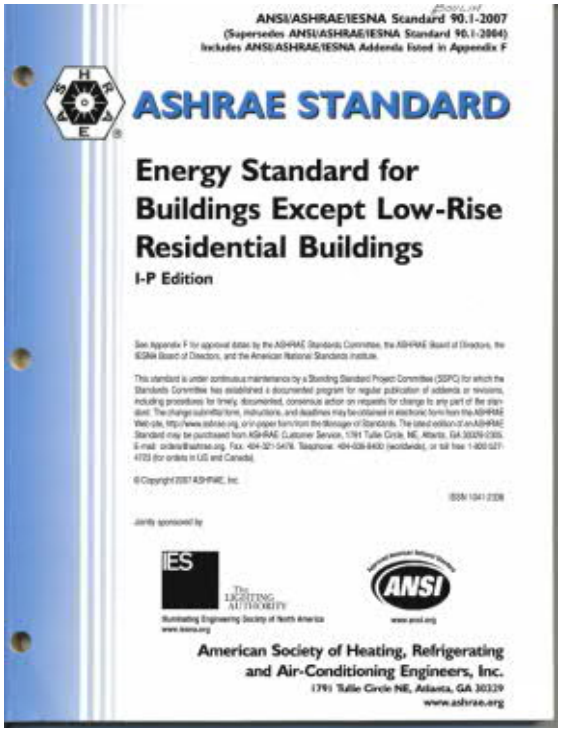
ASHRAE 90.1

- US Energy Policy Act requires State codes to meet or exceed 90.1 (different versions)
  - It becomes law when the States adopt it
- Other codes or standards also refer to it, e.g.
  - International Energy Conservation Code (IECC)
  - NFPA 5000
  - Federal codes
  - State or local specific codes (e.g. California Title24)



ASHRAE 90.1

- ASHRAE 90.1 timeline*:
  - 90-1975: first issued
  - 90A-1980: updated
  - 90.1-1989: updated
  - 90.1-1999: major rewrite
  - 90.1-2001: minor revisions
  - 90.1-2004: updates, reorganization
  - 90.1-2007: updates
  - 90.1-2010: updates
  - 90.1-2013: expanded & updates



(*See also: http://en.wikipedia.org/wiki/ASHRAE_90.1)

ASHRAE 90.1

- Different versions of ASHRAE 90.1
  - 90-1975
    - Earliest version (in response to energy crisis)
  - 90A-1980 (w/ 90B-1975 and 90C-1977)
    - Modified & included lighting procedure from IESNA
  - 90.1-1989 and 1993 codified version of 1989
    - Significant change in envelope compliance
    - Towards a building energy performance standard
    - Upgrades in lighting and HVAC requirements

ASHRAE 90.1

- Different versions of ASHRAE 90.1 (cont'd)
  - 90.1-1999/2001
    - Changes in format and technical content
    - Written in mandatory, enforceable language
    - Expanded climatic data to international locations
    - Both IP and SI units included
  - 90.1-2004
    - Envelope and mechanical requirements expressed using new climate zones
    - Lighting requirements more stringent by about 25%
    - Entire document has been reformatted

ASHRAE 90.1

- Different versions of ASHRAE 90.1 (cont'd)
  - 90.1-2007
    - Incorporate 42 addenda
    - Further reduction in lighting power densities
    - Fan power limitation is based on either nameplate horsepower, or system brake-horsepower
    - Fan pressure drop adjustment & VAV fan control
  - 90.1-2010
    - Incorporate 60+ addenda, elevator was included
  - 90.1-2013 (current)
    - Expand to new areas; holistic building design

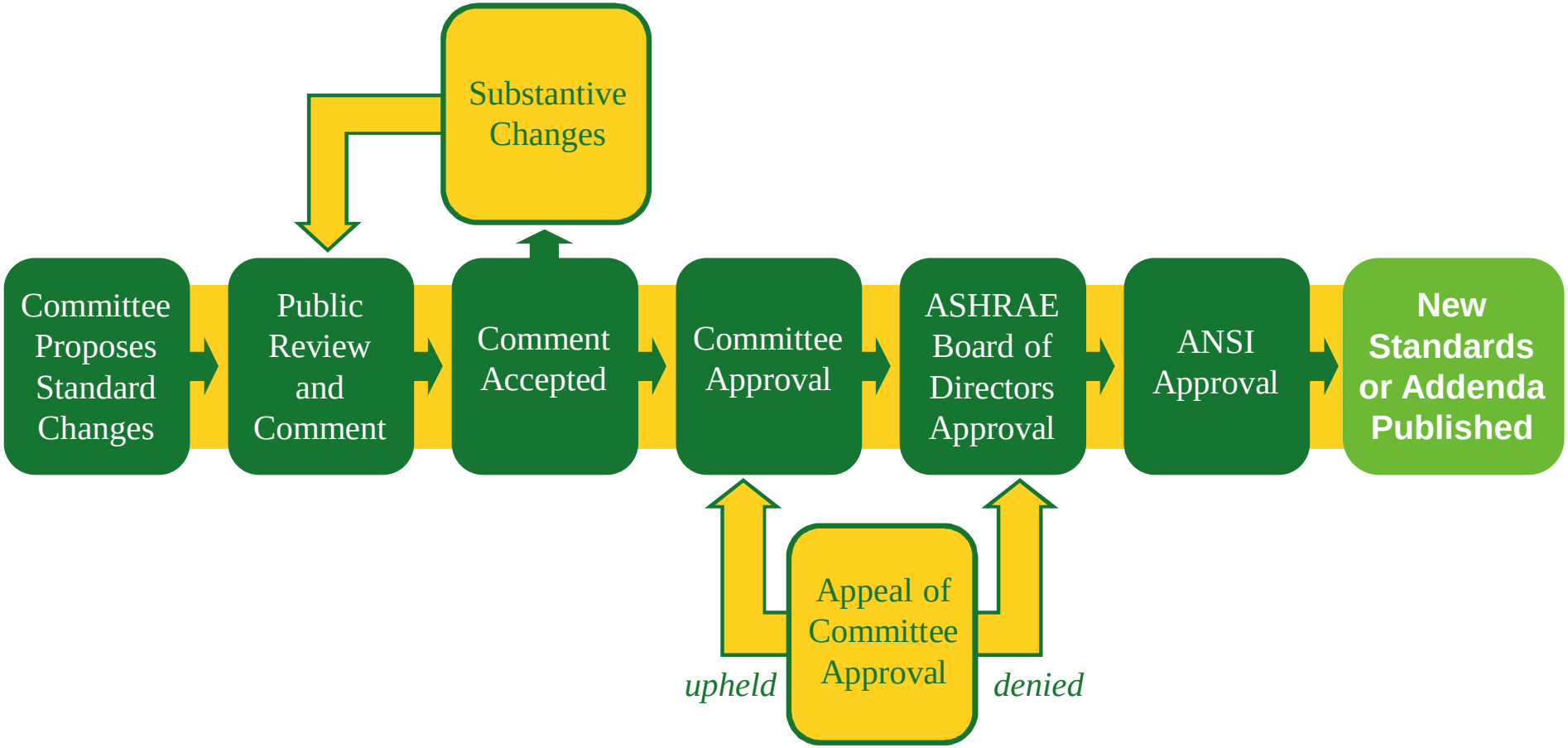
ASHRAE 90.1

- ASHRAE 90.1-2013 (current version)
  - Goal: to achieve 30% energy savings compared to 90.1-2004 (may not be met for all buildings types in all locations)
- Standard 90.1 is on a 3-year cycle under a "continuous maintenance process"
  - Ongoing changes through "addenda"
  - Consensus standard (open ANSI process)
    - Jointly sponsored by IES and ANSI

ASHRAE 90.1

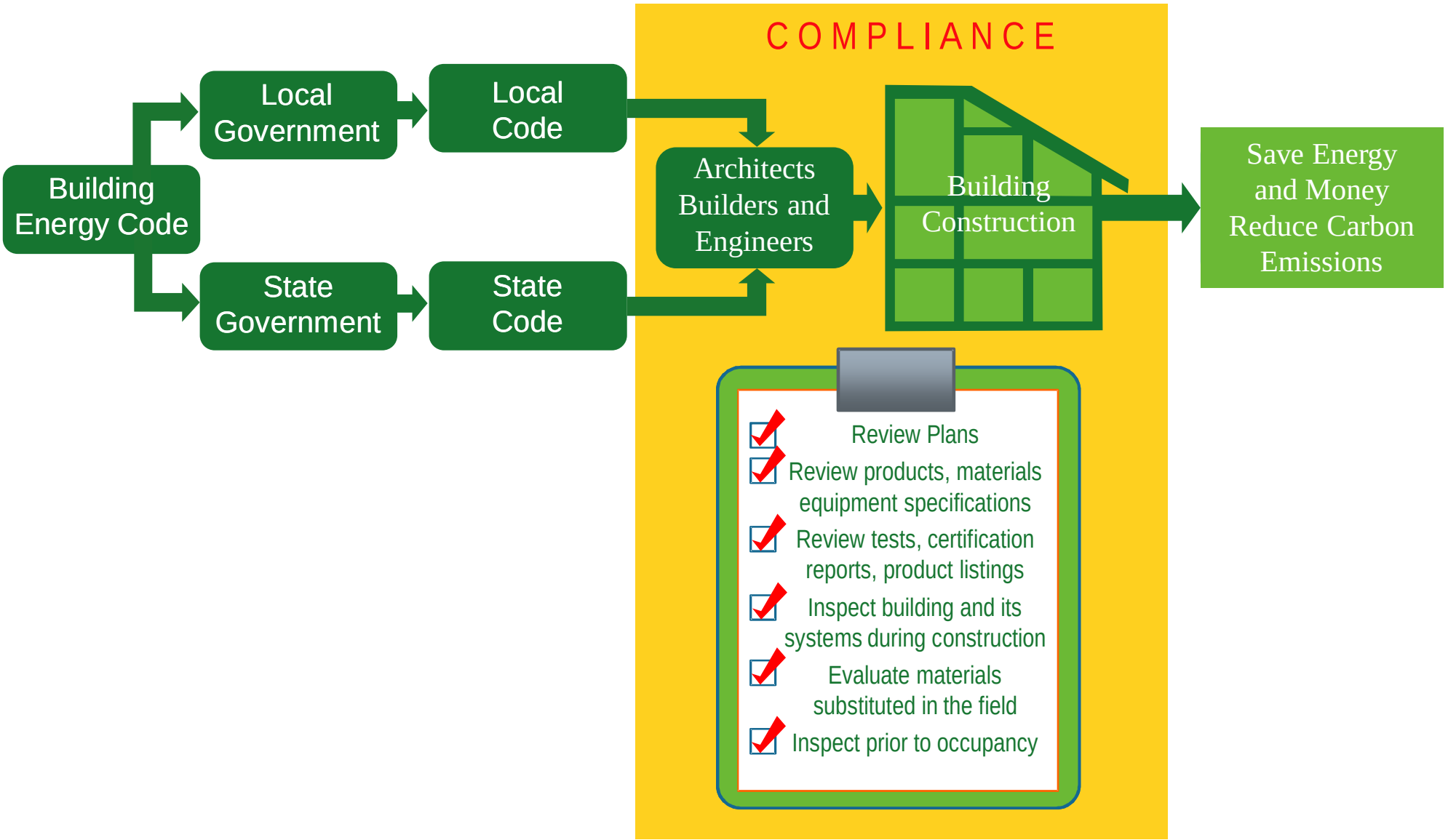
- Related ASHRAE Standards
  - 90.2-2007: for low-rise residential buildings
  - 100-2006: energy conservation in existing buildings
  - 105-2007: standard methods of measuring, expressing and comparing building energy performance
  - 140-2011: evaluation of building energy analysis computer programs
  - 169-2013: weather data for building design standards
  - 55-2013: thermal comfort standard
  - 62.1-2013: ventilation for acceptable indoor air quality
  - 189.1-2011: high performance green buildings

ASHRAE 90.1 development process



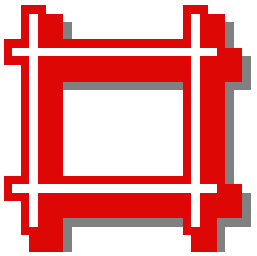
(Source: US Department of Energy)

Code compliance and the building process in USA



(Source: US Department of Energy)

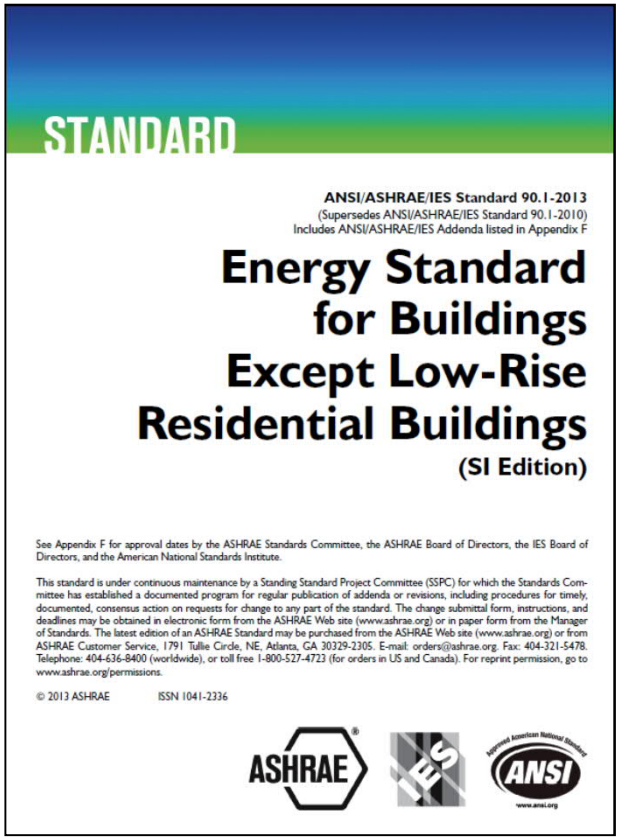
Structure and Scope



- Structure of Standard 90.1-2013
  - 1. Purpose
  - 2. Scope
  - 3. Definitions, Abbreviations, and Acronyms
  - 4. Administration and Enforcement
  - 5. Building Envelope
  - 6. Heating, Ventilating, and Air Conditioning
  - 7. Service Water Heating

Structure and Scope

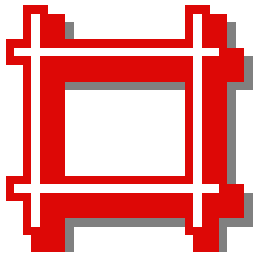
- Structure of Standard 90.1-2013 (cont'd)
  - 8. Power
  - 9. Lighting
  - 10. Other Equipment
  - 11. Energy Cost Budget Method
  - 12. Normative References



Structure and Scope

- Standard 90.1-2013 Normative Appendices
  - Building envelope
    - A – Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations
    - B – Building Envelope Climate Criteria
    - C – Methodology for Building Envelope Trade-Off Option
  - D – Climatic Data
  - E – Informative References
  - F – Addenda Description Information
  - G – Performance Rating Method

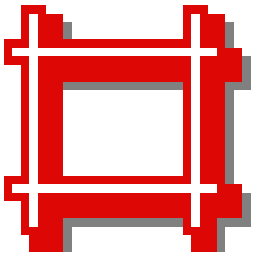
Structure and Scope



- Purpose: provide *minimum* requirements for the energy-efficient design of buildings except low-rise residential buildings
- Not a design or advanced building guide
  - Separate advanced energy design guides were developed by ASHRAE and other related bodies
- Consensus standard (open ANSI process)
  - Jointly sponsored by IESNA and ANSI

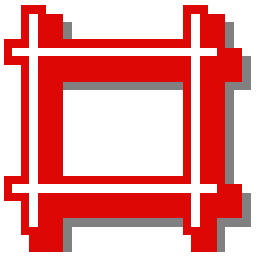
* IESNA = Illuminating Engineering Society of North America (now IES)
ANSI = American National Standards Institute

Structure and Scope



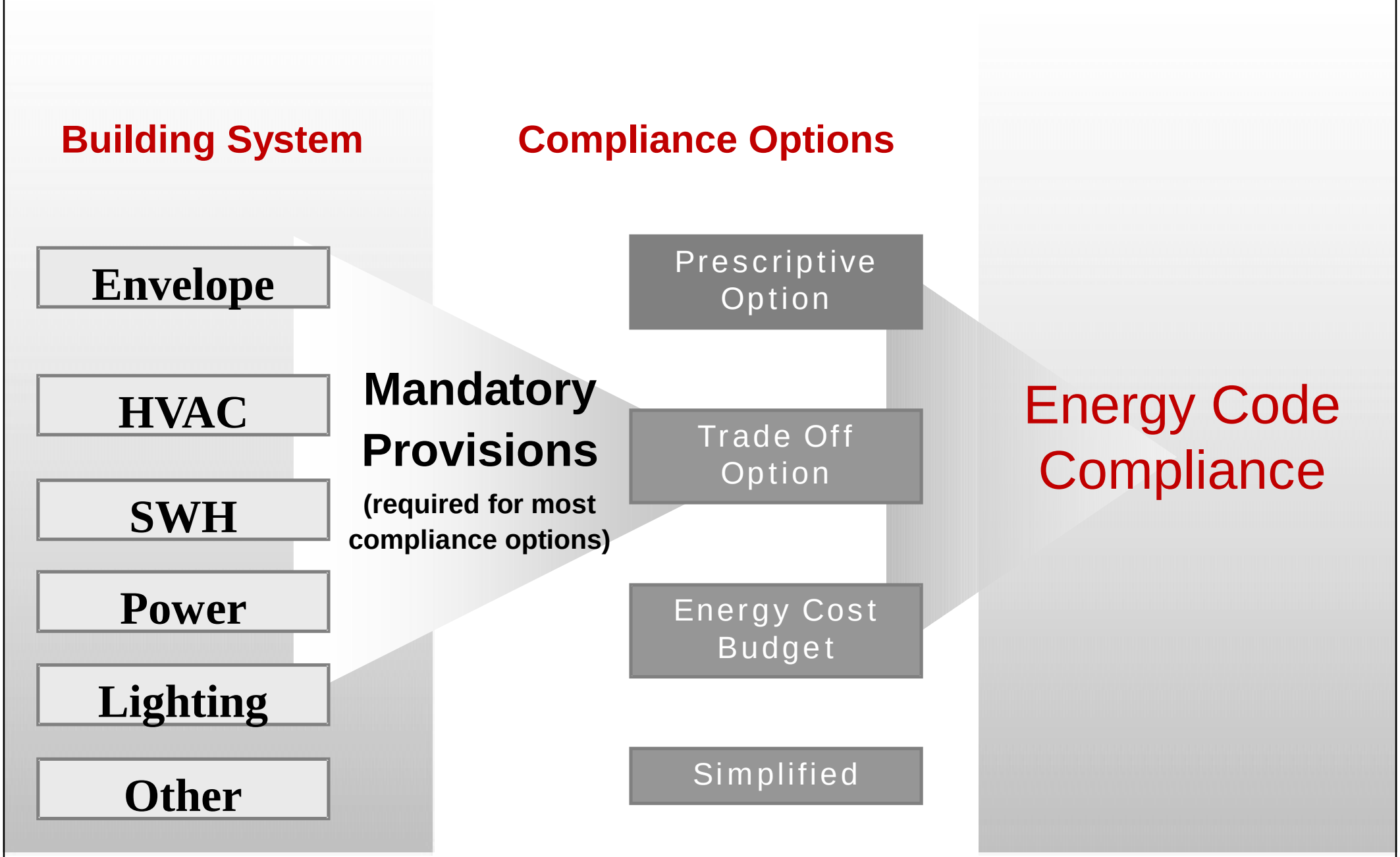
- Scope
  - New buildings and their systems
  - New portions of buildings and their systems (additions)
  - New systems and equipment in existing buildings (alterations), e.g. computer rooms
- Exemptions, such as
  - Equipment and portions of building systems that use energy primarily for industrial or manufacturing purposes

Structure and Scope



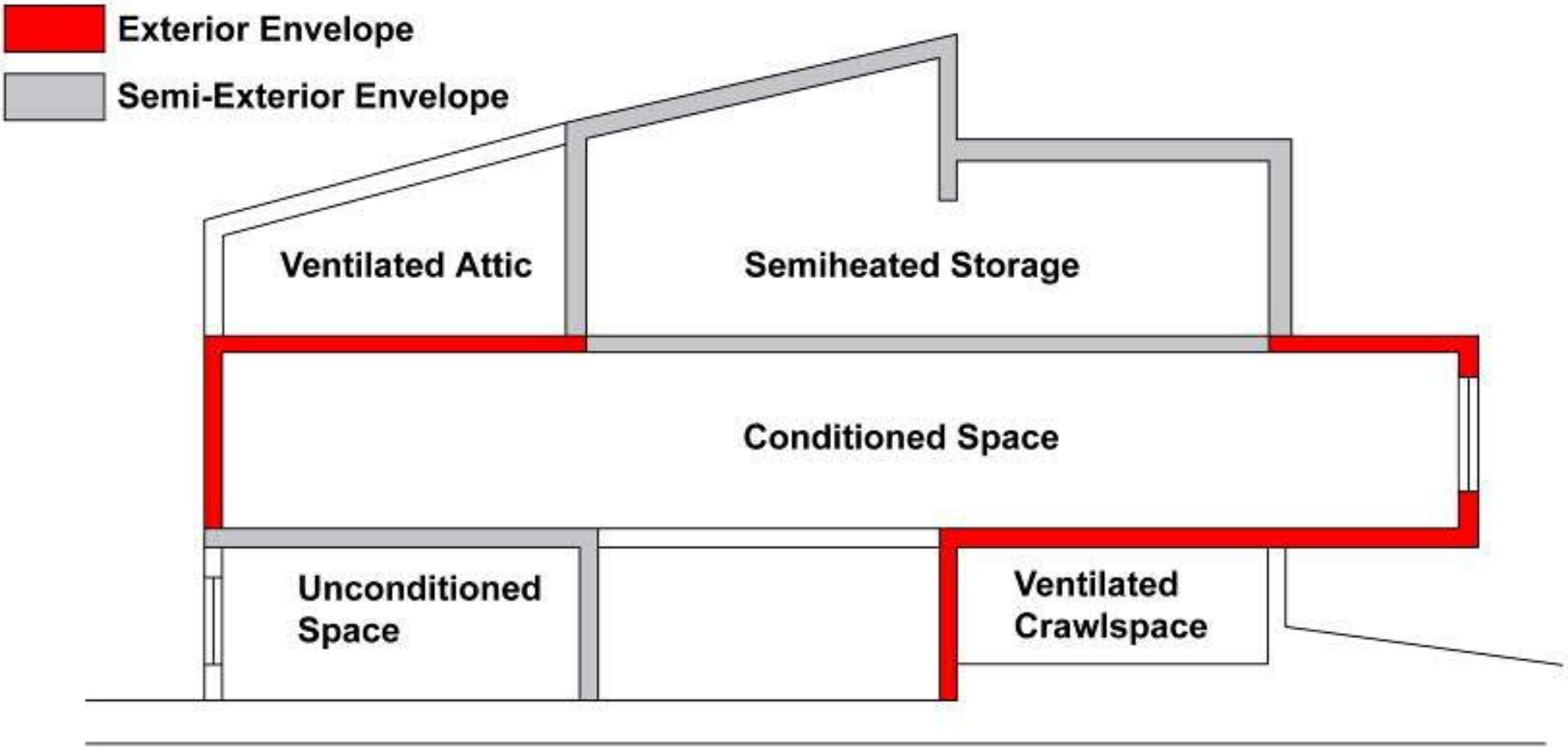
- Main areas of ASHRAE 90.1
  - 1. Building Envelope
    - Roofs, walls, floors, slabs, doors, vertical glazing, skylights
  - 2. HVAC Equipment and System
    - Cooling equipment efficiency, heating equipment efficiency, supply fans, ventilation control, ducts
  - 3. Lighting
    - Interiors electric lighting, controls, daylighting
  - 4. Services Water Heating (SWH)
    - Equipment efficiency, pipe insulation
  - 5. Power and Others
    - Motors, plug loads

ASHRAE 90.1 compliance approaches

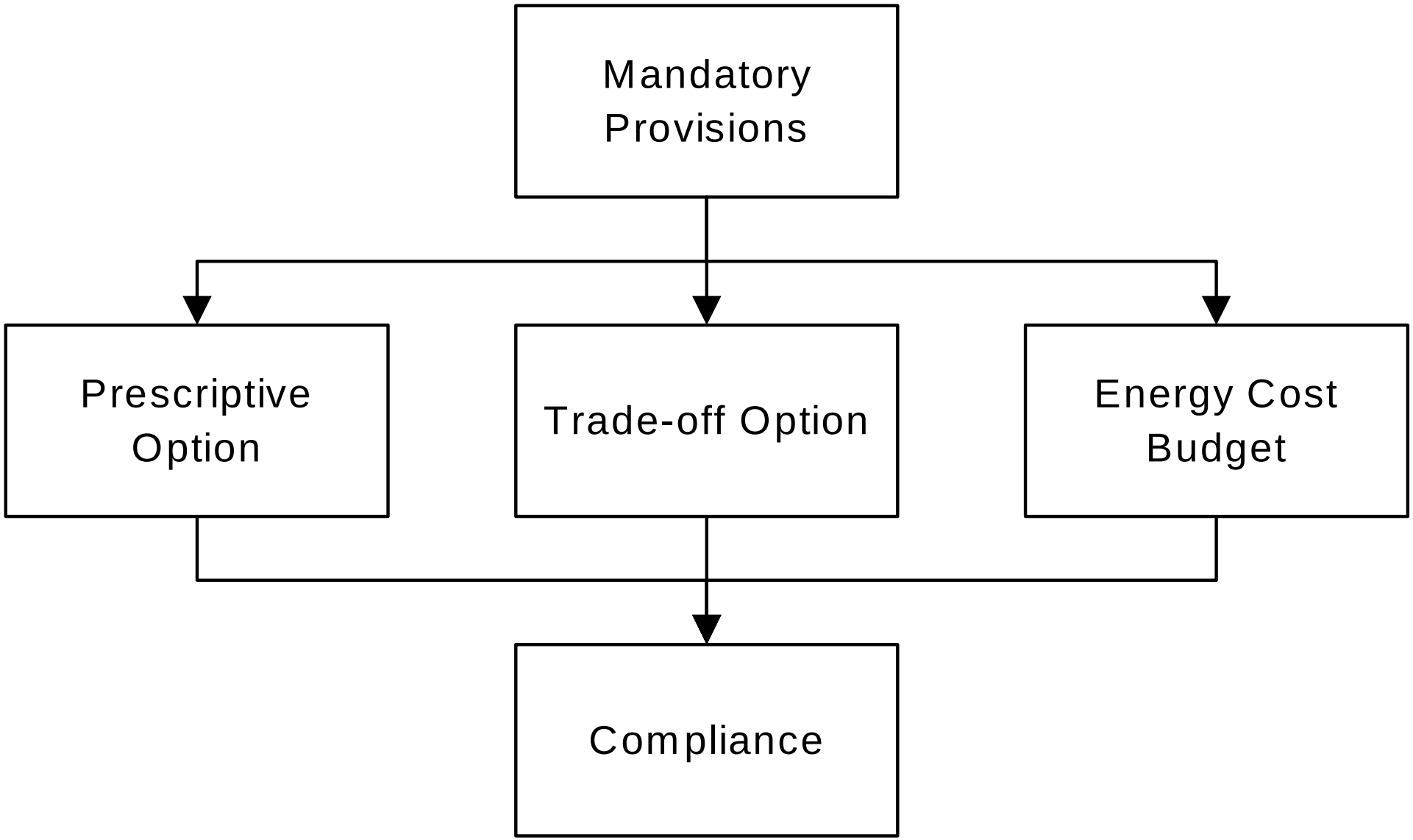


(Source: US Department of Energy)

Exterior envelope and semi-exterior envelope



(Source: US Department of Energy)

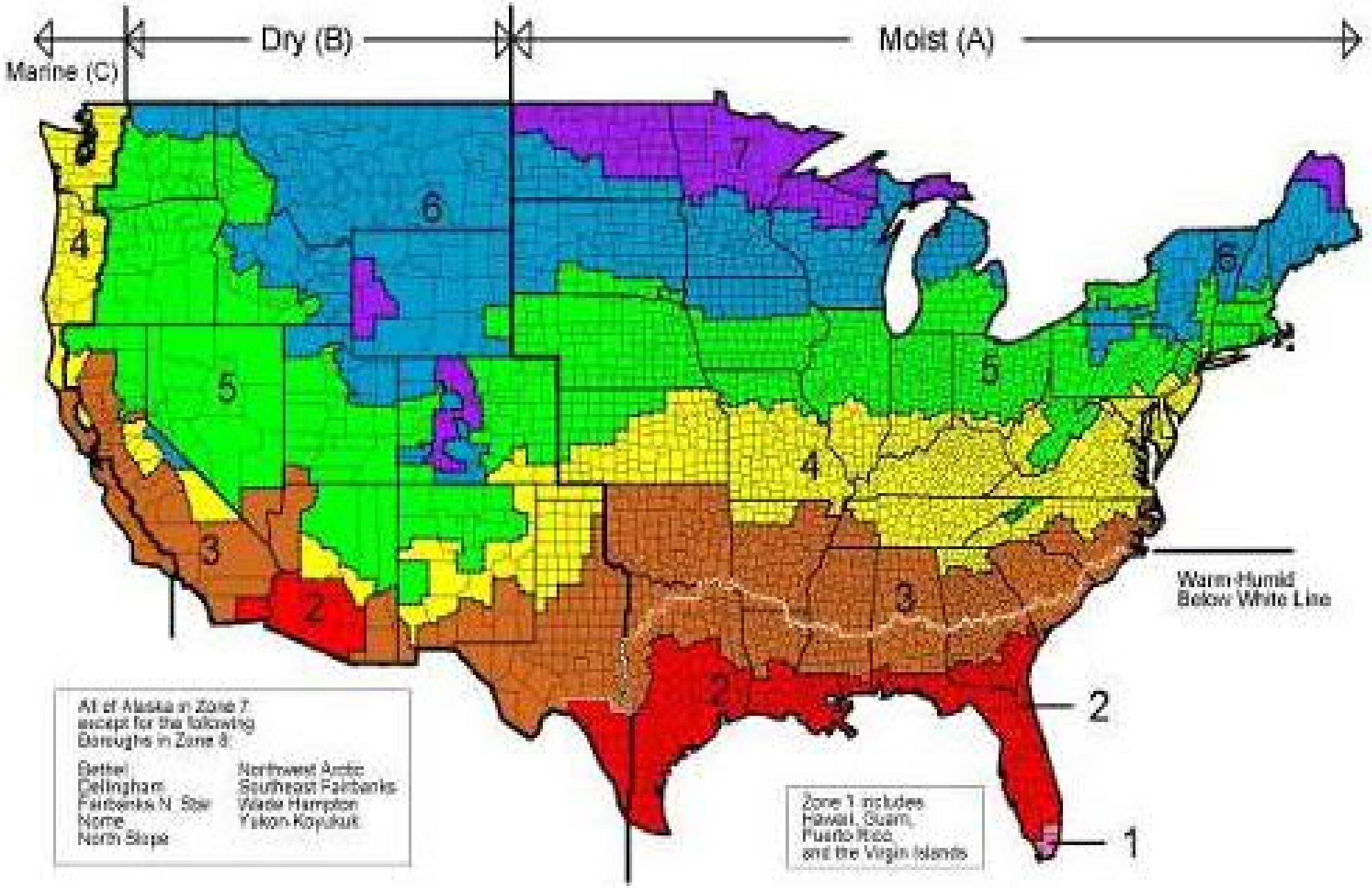


Envelope compliance options in ASHRAE 90.1

Compliance Options

- Building envelope prescriptive option:
  - Window-to-wall ratio (WWR) ≤ 40%, skylight-roof ratio ≤ 5%
  - 8 Criteria sets for different climate types
    - Insulation level, fenestration criteria
- Building envelope trade-off option:
  - Envelope performance factor (EPF) of proposed building ≤ EPF of budget building
    - ENVSTD and ComCheck software

US climate zones for building envelope prescriptive option



(Source: US Department of Energy)

HVAC compliance paths

proposed HVAC design

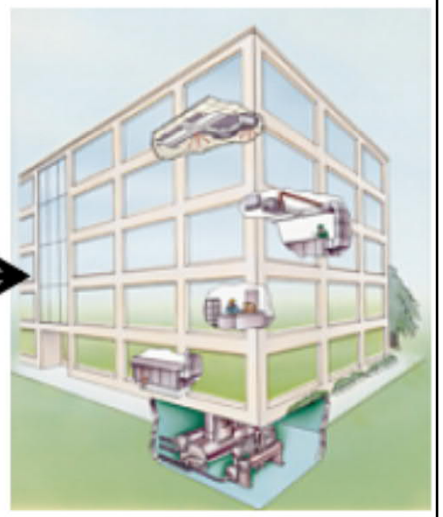
mandatory provisions (§6.4)

prescriptive requirements (§6.5)

Energy Cost Budget Method (ECB, §11)

Simplified Approach Option (§6.3)

(small buildings only)

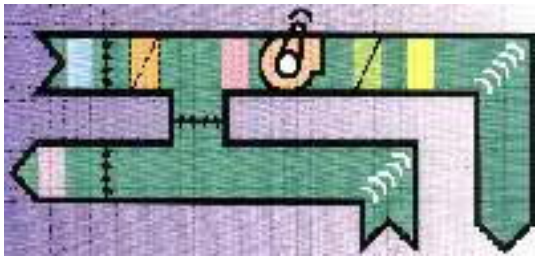


90.1-compliant HVAC system

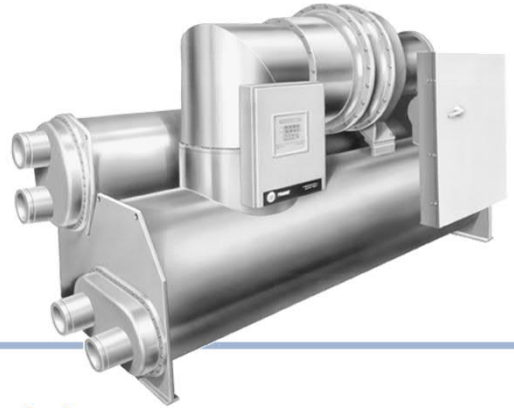
(Source: US Department of Energy)

Compliance Options

- HVAC simplified approach option:
  - Limited to small buildings (< 2,500 sq.m)
- HVAC mandatory provisions:
  - Minimum equipment efficiency
  - Load calculations
  - Controls
  - HVAC system construction and insulation
  - Completion requirements



Examples of HVAC equipment efficiencies



Equipment type	Minimum efficiency
Self-contained, water-cooled w/electric resistance heat (20–100 tons)	11.0 EER 10.3 IPLV
Water-source heat pump (1.5–5.25 tons)	12.0 EER (cooling) 4.2 COP (heating)
Centrifugal chiller, water-cooled (≥ 300 tons)	6.10 COP 0.576 kW/ton 6.40 IPLV 0.549 IPLV (at ARI rating conditions)

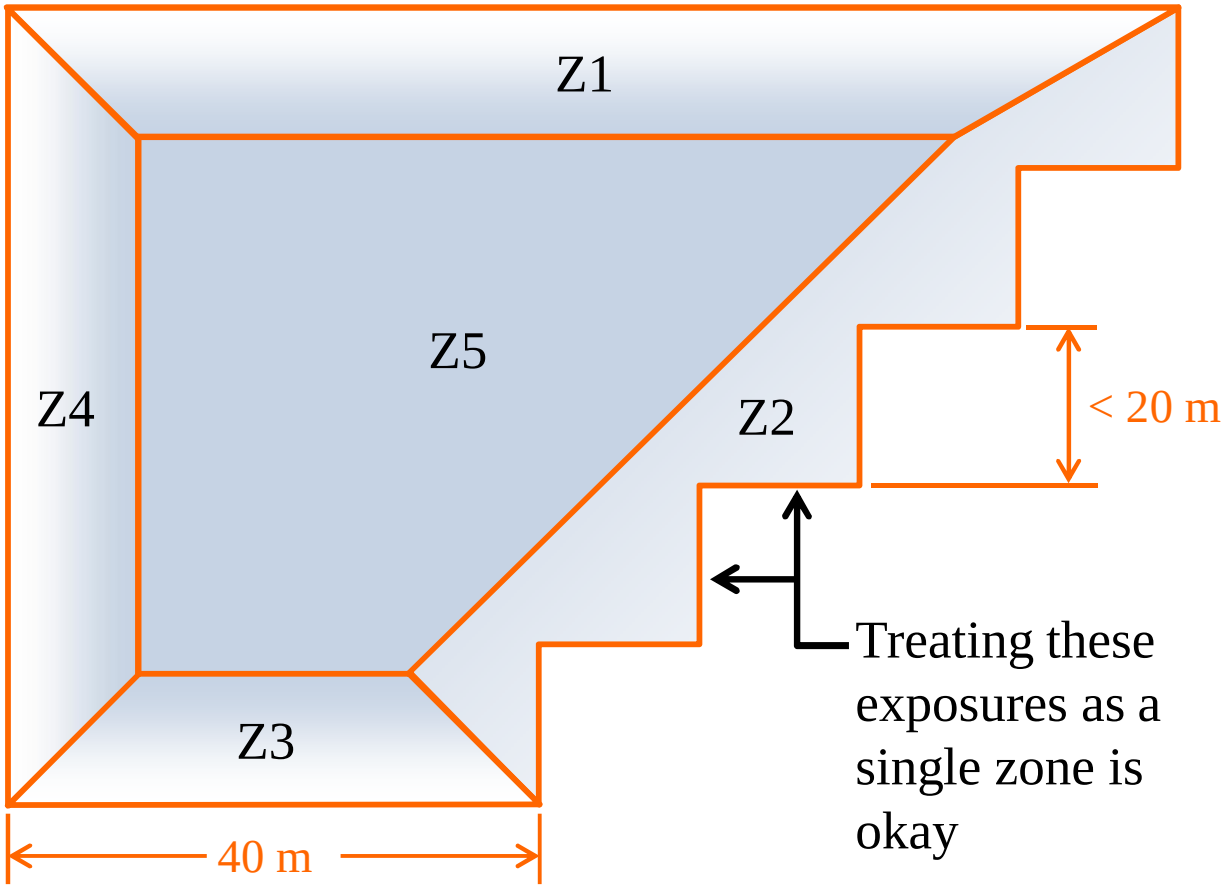
§6.4.1.1: "… Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements …"

(Source: Trane)

Mandatory HVAC provisions:
Zone thermostatic controls: perimeter zones

Core and each long exposure must be zoned separately

Building plan view: thermal zoning example

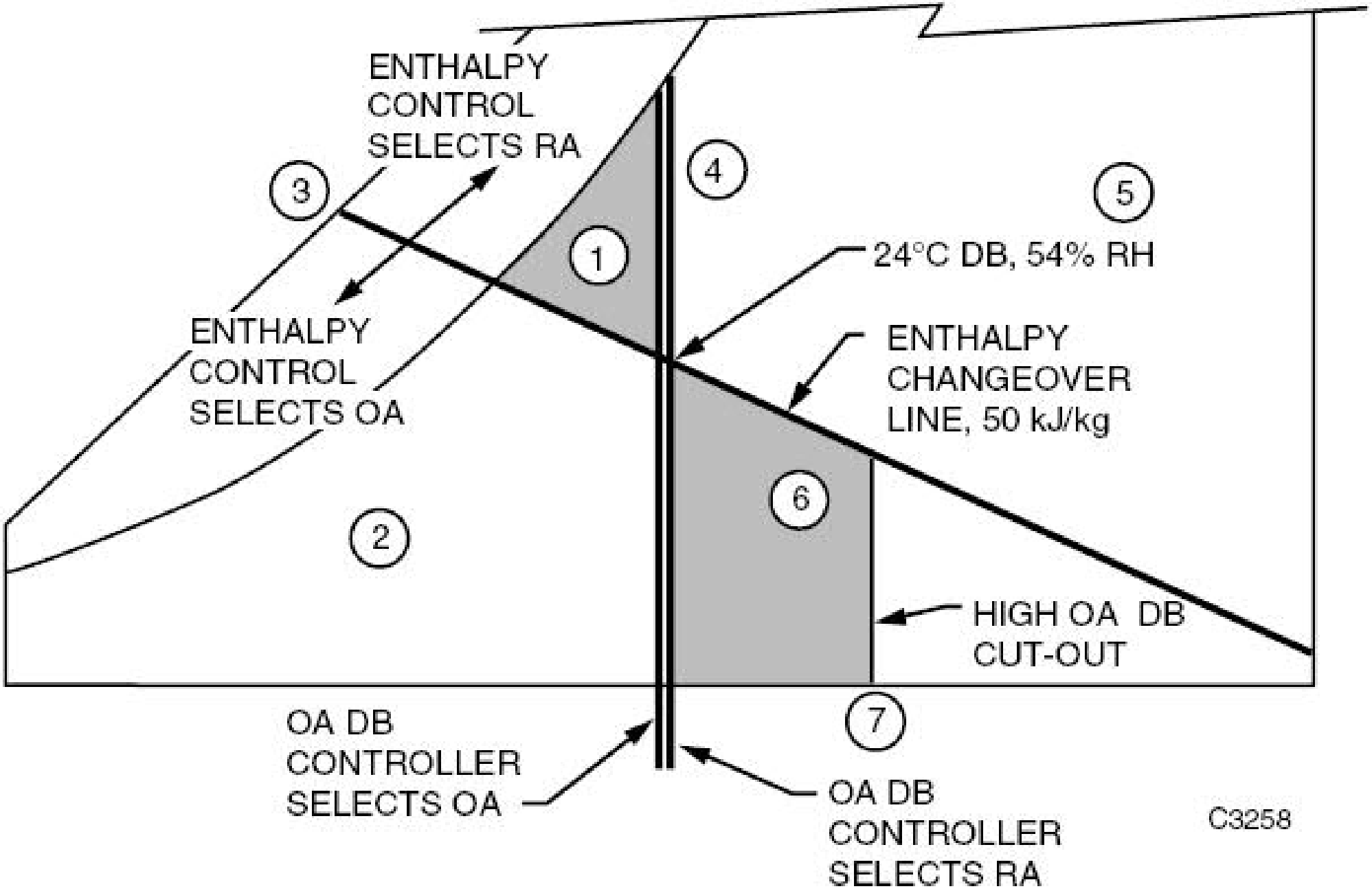


(Source: Trane)

Compliance Options

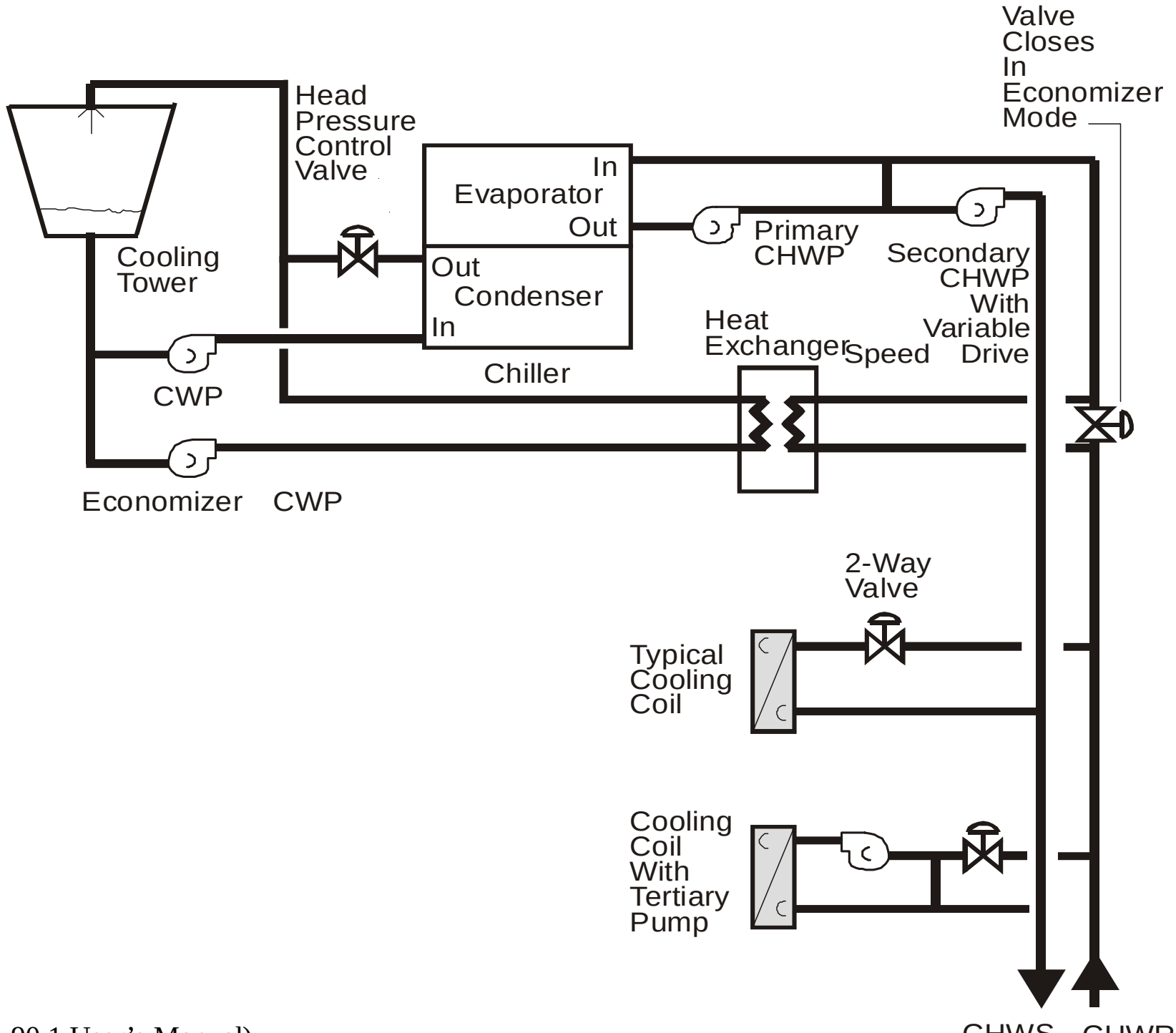
- HVAC prescriptive path:
  - Economizers
  - Simultaneous heating and cooling limitation
  - Air system design and control
  - Hydronic system design and control
  - Heat rejection equipment
  - Energy recovery
  - Exhaust hoods, radiant heating systems
  - Hot gas bypass limitation

Air-side economizer cycle control (outdoor air enthalpy)



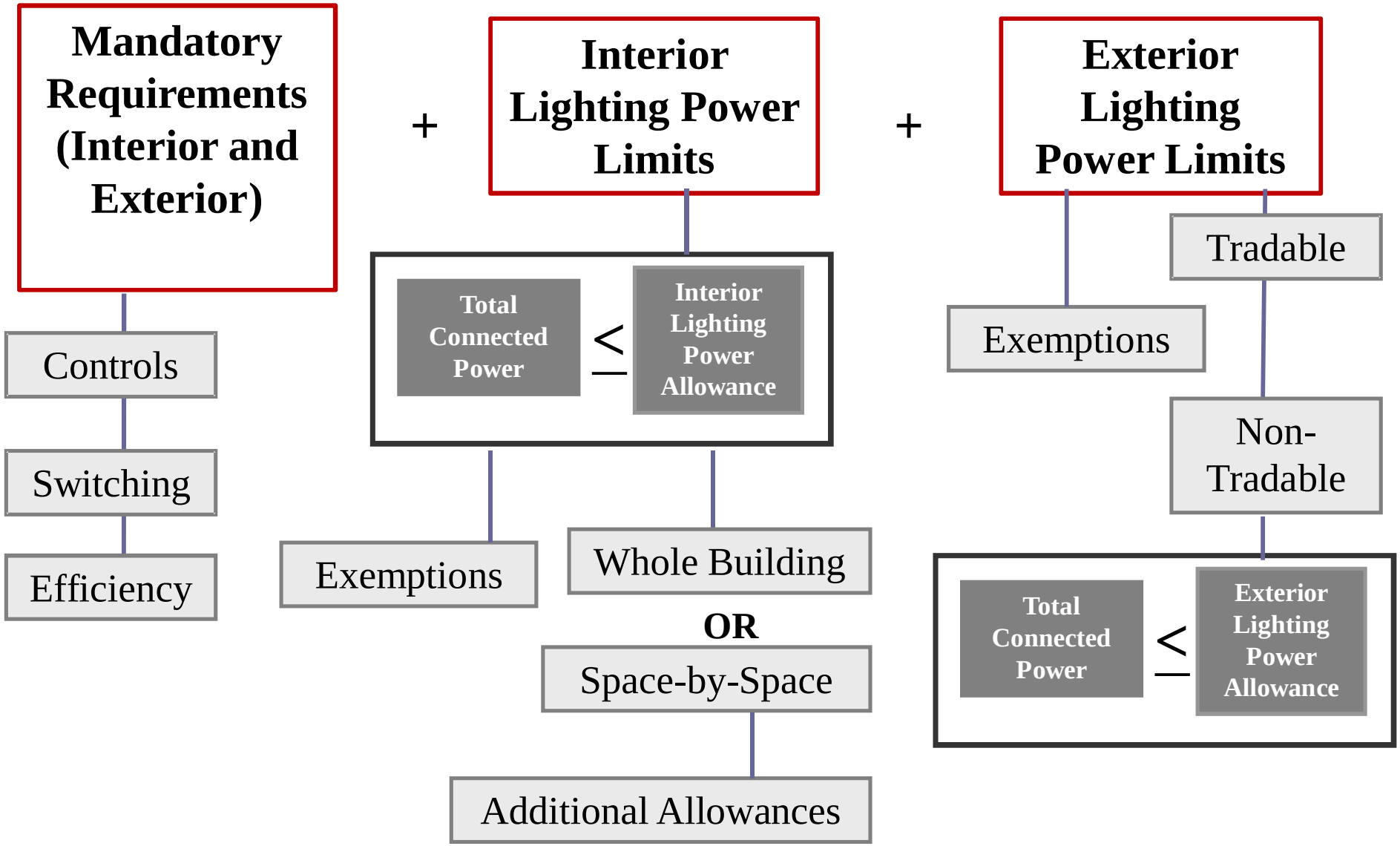
(Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*)

Water-side economizer (free refrigeration)



(Source: 90.1 User's Manual)

Lighting compliance requirements



(Source: US Department of Energy)

Compliance Options

- Interior lighting power
  - Two methods to determine the interior lighting power allowance (ILPA):
  - 1) Building area method
    - For whole building, grossed lighted area is multiplied by allowance (more restrictive)
  - 2) Space-by-space method
    - For projects with well-defined space types
  - Exemptions, e.g. video production, medical

Compliance Options

- Interior lighting power (cont'd)
  - 1) Building area method
    - One lighting power density per major building function (e.g. office / parking garage /retail)
    - Average lighting power density (LPD) across entire building function modeled for both baseline and proposed case
    - No additional lighting power allowed

Compliance Options

- Interior lighting power (cont'd)
  - 2) Space-by-space method
    - One LPD per space function
    - Separate LPD modeled for each space or space function in both Baseline and Proposed cases
      - Total wattage allowance = sum of individual space allowances
      - Individual space allowance = space area x LPD allowance
    - Trade-offs are allowed
    - Additional lighting power are allowed

Compliance Options

- The ILPA is to be determined for:
  - The entire building OR
  - Separately metered or permitted portions of the building
    - Tradeoffs between portions are NOT allowed if they use different methods of calculation

- Exterior lighting power
  - Lamp efficacy
  - Exterior lighting power wattage limits

Compliance Options

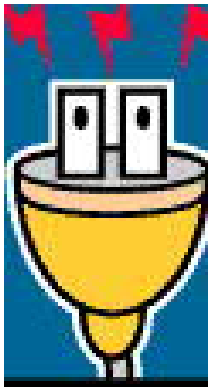
- How were the Lighting Power Densities (LPD) developed?
  - Basis: A space type lighting design modeling that applies:
    - Current lighting product performance data
    - Current lamp/ballast efficacy and light loss factors
    - Latest IESNA recommended light levels
    - Professional consensus of quality lighted environments
  - Combine these elements into building space models to calculate lighting power densities
  - Apply space type LPDs to real building data to generate whole building LPDs

Compliance Options

- Service Water Heating
  - Prescriptive and energy cost budget
  - Mandatory provisions (Section 7.4)
    - Load calculations
    - Equipment efficiency
    - Service hot water piping insulation
    - System controls
    - Pools
    - Heat traps
  - Prescriptive path (Section 7.5)
    - Space heating and water heating
    - Service water heating equipment

Compliance Options

- Power and Other Equipment
  - Max voltage drop allowed at design load
    - Feeder conductors
    - Branch circuit conductors

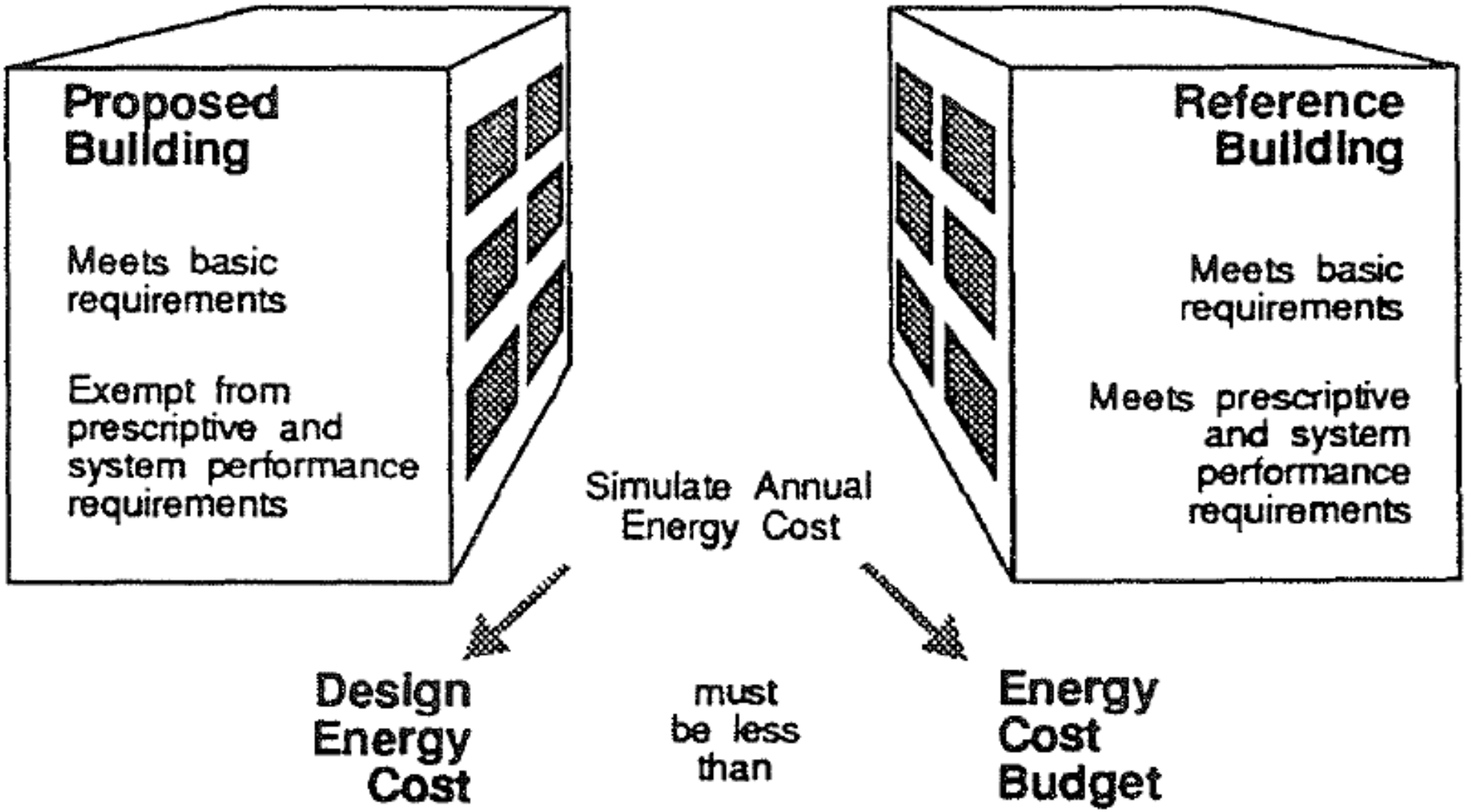


  - Motor efficiency levels correspond to Energy Policy Act's manufacturing standards
    - Mandatory provisions are for General Purpose Design A and Design B motors only
    - Motors in new buildings, additions to existing buildings, and alterations to existing buildings must comply

Energy Cost Budget Method

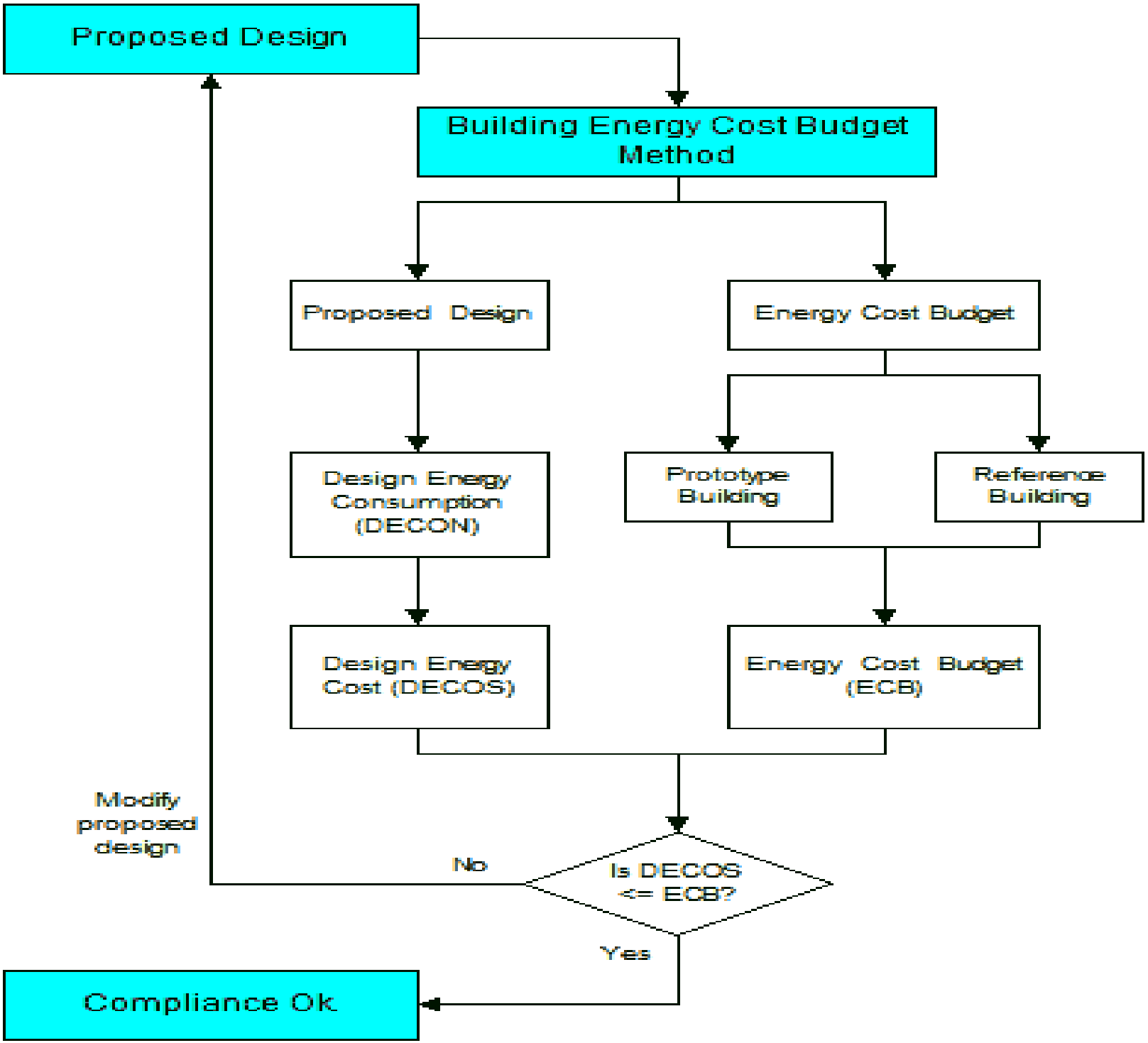
- Energy Cost Budget (ECB) Method
  - The ultimate trade-off method to trade-off across building systems through the use of annual, hourly simulation tools and a baseline building
  - The only real way to deal with unique designs, renewables, high-efficiency equipment, etc.
  - Buildings must still meet all mandatory requirements
  - Basis of *performance-based* codes

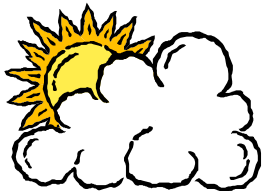
Basic concept of Energy Cost Budget (ECB) Method



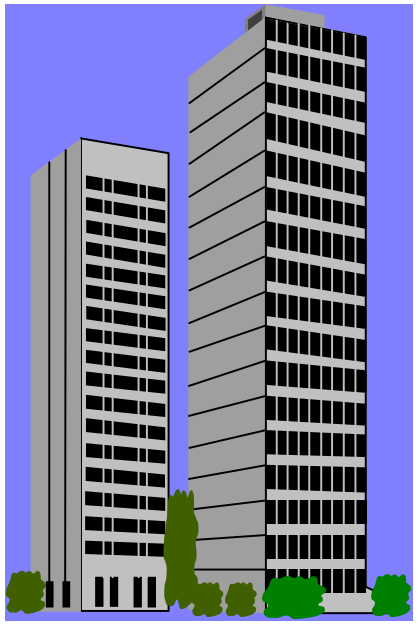
(Source: Hawaii building energy code)

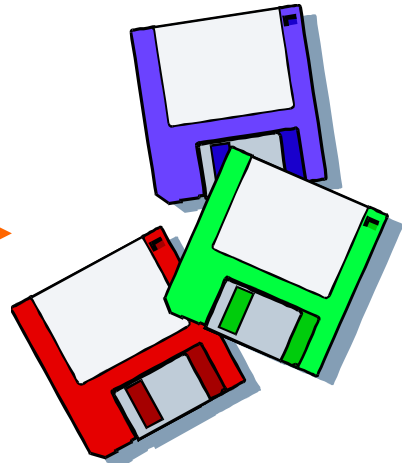
Energy Cost Budget (ECB) Method in ASHRAE 90.1





Weather data





Building description

- physical data
- design parameters

Simulation tool (computer program)

Simulation outputs

- energy consumption (MWh)
- energy demands (kW)
- environmental conditions

Energy Cost Budget Method

- ECB method's Pros and Cons
  - User sophistication
  - Enforcement sophistication
  - Better buildings
  - Aging of the standard
  - Gamesmanship
  - Cheating
  - Innovation

Energy Cost Budget Method

- Step 1: Verify compliance with the mandatory provisions of Standard 90.1
- Step 2: Determine which prescriptive requirements to implement
- Step 3: Model the proposed design in accordance with Section 11.3 of Standard 90.1
- Step 4: Model the budget design to determine the annual energy cost budget
- Step 5: Compare the annual energy costs of the two models

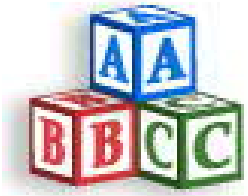
Energy Cost Budget Method

- Budget design (reference building)
  - Based on the proposed design, but changes all Standard 90.1-governed design details to represent minimum compliance, e.g.
    - Building envelope characteristics
    - Lighting power densities
    - Economizer type (if required)
    - Heat-recovery type (if required)
    - HVAC system type
    - Fan energy, cooling & heating equipment

Energy Cost Budget Method

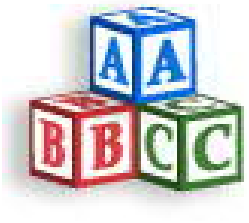
- Typical requirements by authorities
  - Must document all the info in great detail
  - Must use a good and approved simulation program
  - Must use appropriate and approved climate data
  - Must use appropriate and approved purchased energy rates
  - All details not covered by the 90.1 must be identical in both models
- ECB method compliance forms

Performance Rating Method



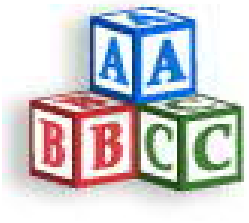
- Performance Rating (PR) Method
  - Appendix G of Standard 90.1
  - Instructions for using the ASHRAE Standard 90.1 Energy Cost Budget Method in conjunction with the LEED program
    - LEED = **L**eadership in **E**nergy and **E**nvironmental **D**esign (developed by US Green Building Council)
  - ECB forms the basis of the energy portion of the LEED rating

Performance Rating Method



- From 90.1-2010, Appendix G becomes a normative section (previously informative)
  - It incorporates Appendix G fully into the standard making it subject to the same rigorous public review process the rest of the standard undergoes
- Using 90.1 as baseline for energy efficient and green building programmes
  - Use performance rating method to calculate energy savings; give credits to advanced design strategies, more flexible than ECB method

Performance Rating Method



- Understand the intent and limitations
  - Intended for rating only; not for code compliance
  - Provide a baseline for comparison & rating
  - Not to accurately predict actual energy use/costs
- Factors affecting absolute accuracy:
  - Variations in occupancy
  - Variations in control and maintenance
  - Variations in weather
  - Changes in energy rates
  - Precision of the simulation software

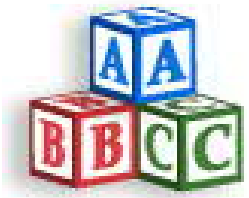
Comparing the simulation requirements for ECB & PR methods

Energy Cost Budget Method (from 90.1 Section 11 for EAp2)	**Performance Rating Method** (from 90.1 Appendix G for EAc1)
Calculates at least 1,400 hours of building operation to simulate annual energy use	Calculates 8,760 hours of building operation to simulate annual energy use
Accounts for hourly variations (defined separately for each day of the week and holidays) in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC operation	[Same]
Accounts for thermal mass effects	[Same]
Models 10 or more thermal zones	[Same]
Accounts for part-load performance of mechanical equipment	[Same]
Includes capacity and efficiency corrections for mechanical cooling & heating equipment	[Same]
Models airside and waterside economizers with integrated control	Models airside economizers with integrated control

Comparing the simulation requirements for ECB & PR methods (cont'd)

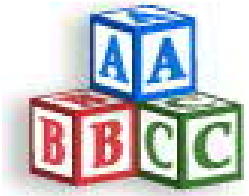
Energy Cost Budget Method (from 90.1 Section 11 for EAp2)	**Performance Rating Method** (from 90.1 Appendix G for EAc1)
Models budget building design characteristics per Section 11.5	Models baseline building design characteristics per Section G3
Calculates design loads	[Same]
Uses hourly weather data, such as temperature and humidity, for the climate that best represents the location of the proposed design	[Same]
Calculates annual energy costs using rates for purchased energy approved by the adopting authority; or, exports hourly reports of energy use to a program that can	Calculates annual energy costs using either actual rates for purchased energy or state average energy prices published by DOE's Energy Information Administration, http://www.eia.doe.gov/; or exports hourly reports of energy use to a program that can
Tested in accordance with ASHRAE Std 140-2007, Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs	Includes calculation methodologies for the building components being modeled

Performance Rating Method



- Trade-off limits
  - Does not allow energy savings based on promises about the future or measures made in the past
  - Savings must be based on “real time” conditions
- Documentation requirements
  - Project summary & project overview
  - Energy efficiency features
  - Mandatory features
  - Prescriptive tradeoffs
  - Energy results

Performance Rating Method



- Documentation requirements (cont'd)
  - Exterior shading
  - Floor plans and elevations
  - Thermal blocks
  - Modeling assumptions
  - Back-up calculations
  - Input and output reports
  - Energy rates
  - Explanation of error messages
  - Exceptional calculation methods

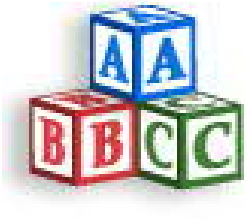
LEED 2009 New Construction Checklist

☑	Prerequisite 1	Fundamental Commissioning of Building Energy Systems	Required
☑	Prerequisite 2	Minimum Energy Performance	Required
☑	Prerequisite 3	Fundamental Refrigerant Management	Required
☐	Credit 1	Optimize Energy Performance	1–19
☐	Credit 2	On-site Renewable Energy	1–7
☐	Credit 3	Enhanced Commissioning	2
☐	Credit 4	Enhanced Refrigerant Management	2
☐	Credit 5	Measurement and Verification	3
☐	Credit 6	Green Power	2

☑	Prerequisite 1	Storage and Collection of Recyclables	Required
☐	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors and Roof	1-3
☐	Credit 1.2	Building Reuse—Maintain Existing Interior Nonstructural Elements	1
☐	Credit 2	Construction Waste Management	1-2
☐	Credit 3	Materials Reuse	1-2
☐	Credit 4	Recycled Content	1-2
☐	Credit 5	Regional Materials	1-2
☐	Credit 6	Rapidly Renewable Materials	1
☐	Credit 7	Certified Wood	1

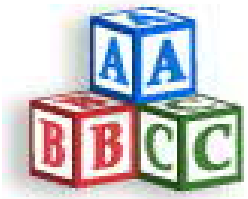
(Source: USGBC)

Performance Rating Method



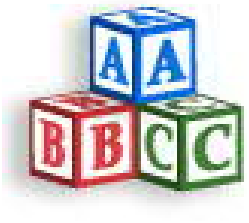
- EAp2: Minimum energy performance
  - Option 1: performance compliance path
    - Mandatory provision (5.4, 6.4, 7.4, 8.4, 9.4, and 10.4)
    - Baseline building complies with Appendix G Building Performance Rating Method
    - 10% better than 90.1-2007 for new construction, 5% better for existing building

Performance Rating Method



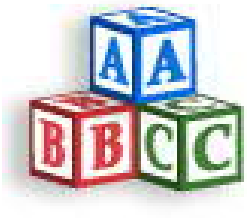
- EAp2: Minimum energy performance (cont'd)
  - Option 2: prescriptive compliance path
    - ASHRAE Advanced Energy Design Guides (AEDG)
      - Small office buildings 2004
      - Small retail buildings 2006
      - Small warehouses and self-storage buildings 2008
      - K-12 school buildings 2010
  - Option 3: prescriptive compliance path
    - Advanced Buildings "Core Performance" Guide by New Building Institute

Performance Rating Method



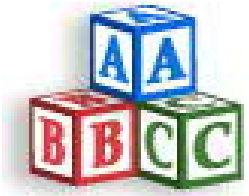
- Use the PR Method to quantify energy savings
  - Like the ECB Method, the PR Method relies on computer modeling to simulate the energy performance of two designs:
    - Proposed Building vs Baseline (Reference) Building
  - Slight modifications as compared to ECB model:
    - Includes receptacle and process energy consumption
    - Takes credit for automatic lighting controls in the proposed design, either in accordance with Table G3.2 or via modified lighting schedules

Performance Rating Method



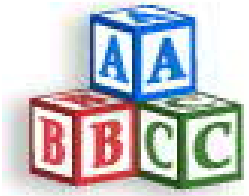
- Use the PR Method to quantify energy savings
  - Slight modifications vs ECB model (cont'd):
    - Averages the performance of the baseline building at its actual orientation and when rotated 90°, 180°, and 270°. For each of the rotated simulations, the cooling and heating equipment are resized to 1.15 and 1.25 times the design capacity, respectively
    - Uses lightweight assembly types for opaque assemblies, and U-factors, F-factors, and C-factors corresponding to weather/location-dependent values in Tables 5.5-1 through 5.5-8 of the standard

Performance Rating Method



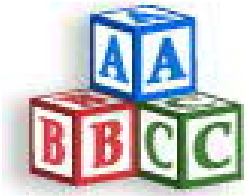
- Use the PR Method to quantify energy savings
  - Slight modifications vs ECB model (cont'd):
    - Models vertical fenestrations as evenly distributed bands of glass on all building orientations and limits them to not more than 40% of the above-grade wall area
    - Calculates fan and pump energy in accordance with the equations in Appendix G
    - Uses the appropriate HVAC system type (cooling, heating, and fan control types) from Tables G.3.1.1A and G.3.1.1B

Performance Rating Method



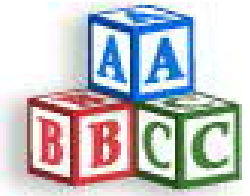
- The PR Method can be used for:
  - New construction and major renovations
  - Alterations or additions to existing buildings
- Points to note:
  - Systems that aren't yet designed or that already exist and are unmodified must be modeled identically for the proposed and baseline buildings
  - If the proposed design includes future building components, then the components must be modeled as conforming to the minimum prescriptive requirements of 90.1

Performance Rating Method



- The proposed building design should model:
  - All end-use loads
  - Any energy-saving strategies (e.g. daylighting and natural ventilation), where applicable
  - Actual lighting power if the lighting system already is designed, or the lighting power allowance in accordance with Section 9 of 90.1
  - Energy-saving architectural features, e.g. light shelves, overhangs, and other shading devices
  - Any undesigned systems as identical to the baseline building design

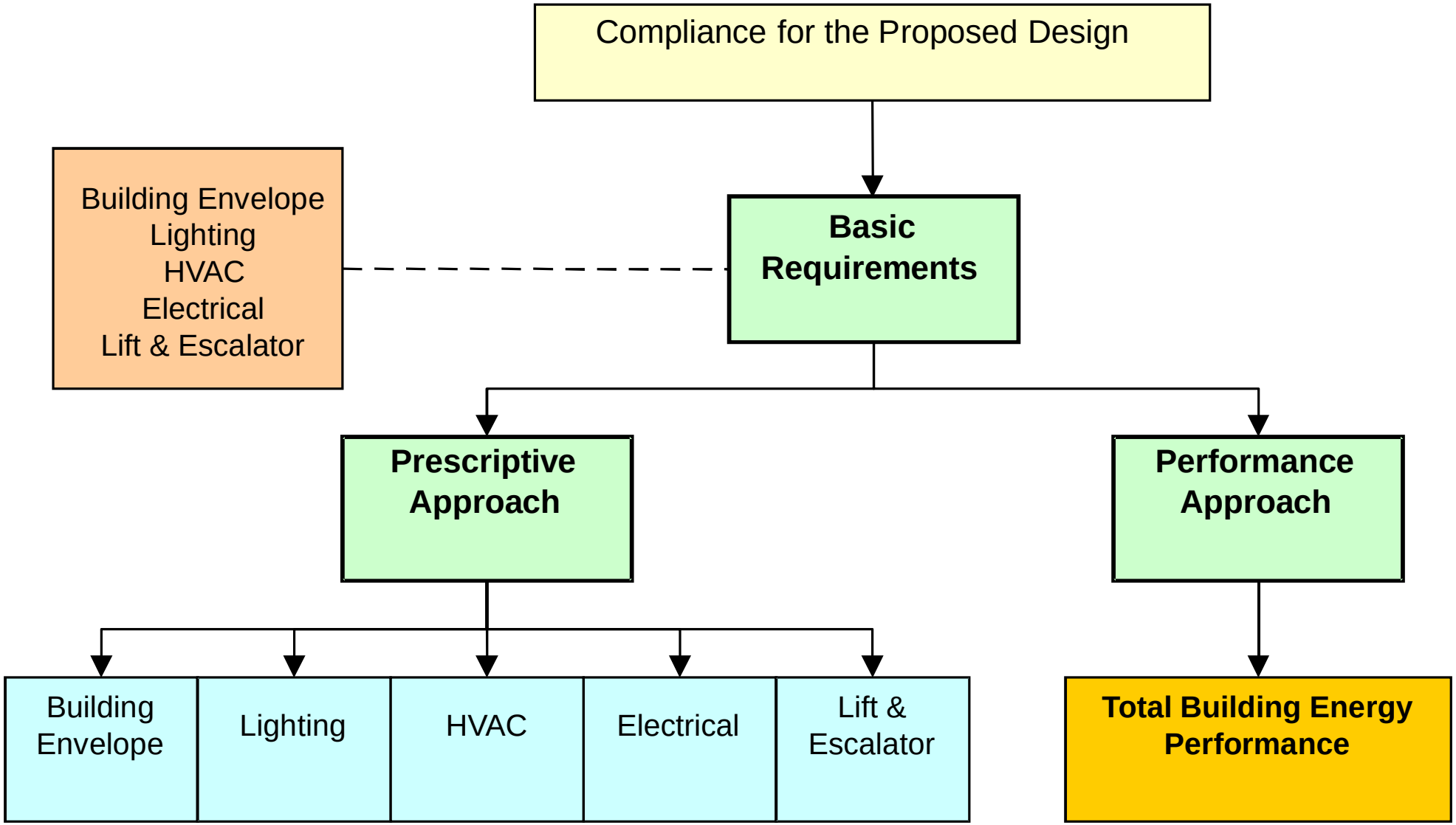
Performance Rating Method



- The performance of both building models must be calculated using
  - The same weather data
  - The same energy rates
  - The same simulation software

- Performance rating method compliance forms
  - Project name and information
  - Advisory messages
  - Performance rating result
  - Energy use and energy cost summary

Proposed framework of the comprehensive BECs in Hong Kong



(Source: EMSD)

Hong Kong BEC

- Buildings Energy Efficiency Ordinance (BEEO), Cap 610: Prescribed buildings
  - Building Energy Code (BEC):
    - Commercial building
    - Common areas of industrial building & residential building, composite building – common area & portion not for residential or industrial use
    - Hotel & guesthouse, educational building, community building, municipal services, medical & health, government building, airport passenger building, railway station

Hong Kong BEC

- "Newly constructed" building
  - Building having obtained the consent to the commencement of building works for superstructure construction from Building Authority after 21 Sep 2012 (21 Sep not inclusive) after BEEO comes into full operation
- "Existing" building
  - Building that is not "Newly constructed": having obtained the consent on or before 21 Sep 2012

Hong Kong BEC

- Major retrofitting works
  - Works area
    - Addition/replacement of BS installation – conducted at one or more places in a unit or a common area
    - A total floor area covered by the works under the same series of works within 12 months ≥ 500 sq.m
  - Central BS installation
    - Addition/replacement of a main component –
      - A complete electrical circuit at rating ≥ 400A, or a chiller or a unitary airconditioner at rating ≥ 350kW capacity (cooling or heating), or motor drive + mechanical drive of a lift, escalator or passenger conveyor
    - Central BS Installation – not solely serves a unit eg serving common area

Overall Thermal Transfer Value (OTTV)

OTTV requirement in Hong Kong

•The OTTV code was subsequently amended (for all buildings except residential buildings) in 1995 as follows: (revised 2010)

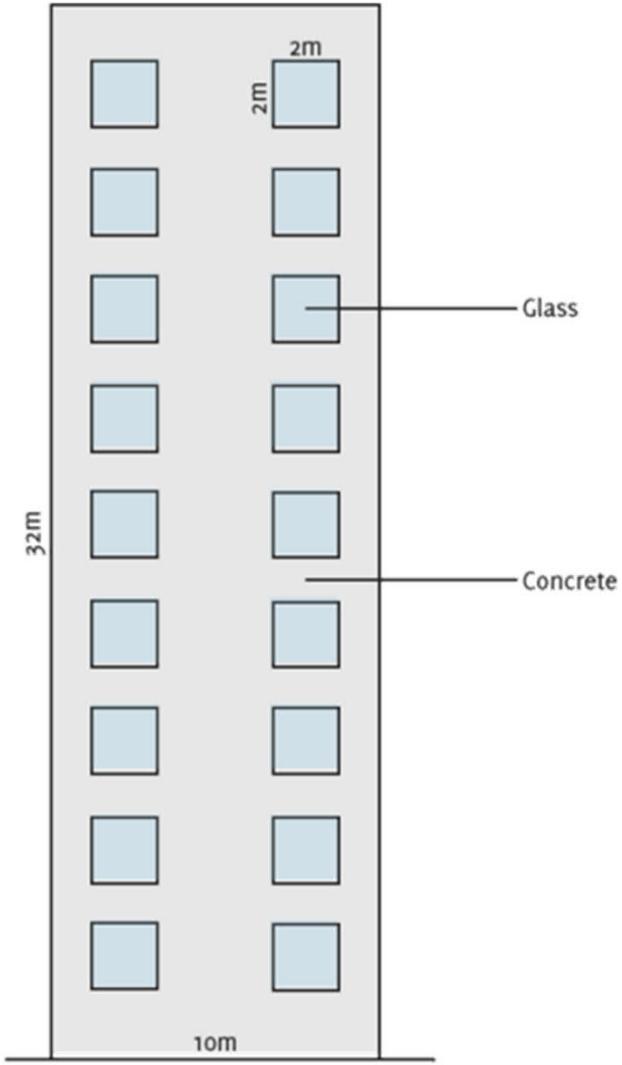
- In the case of a building tower, the OTTV should not exceed 24W/m²
- In the case of a podium, the OTTV should not exceed 56W/m²
- open-front shops or the like on ground level may be exempted from the OTTV calculations upon applications

(Source: Calculation and Application of OTTV and U-value (Science Teaching Kit for Senior Secondary Curriculum))

Overall Thermal Transfer Value (OTTV)

Exercise 1

Study the drawing and figures below and calculate the OTTV of this building. Assume that the four elevations of the building are identical. Calculate the OTTV of the building. Determine if this building follows the OTTV code in Hong Kong (24W/m²).



U-value of a wall Uw = 1.9 W/m²K
Outdoor temperature = 28.4ºC
Indoor temperature = 27ºC
Solar absorptivity of wall α = 0.58
External shading multiplier ESM= 1
Shading coefficient of window glass SC= 0.4
Solar factor SF = 191W/m²

(Source: Calculation and Application of OTTV and U-value (Science Teaching Kit for Senior Secondary Curriculum))

Overall Thermal Transfer Value (OTTV)

Reference answer

Considering the tower part of the building:

Total area of all windows on one façade A_f = 2m x 2m x 18 = 72m^2

Area of the wall Aw = (32m x 10m)-72m2= 248m^2

Equivalent temperature difference TD_{eq} = 28.4°C-27°C = 1.4°C

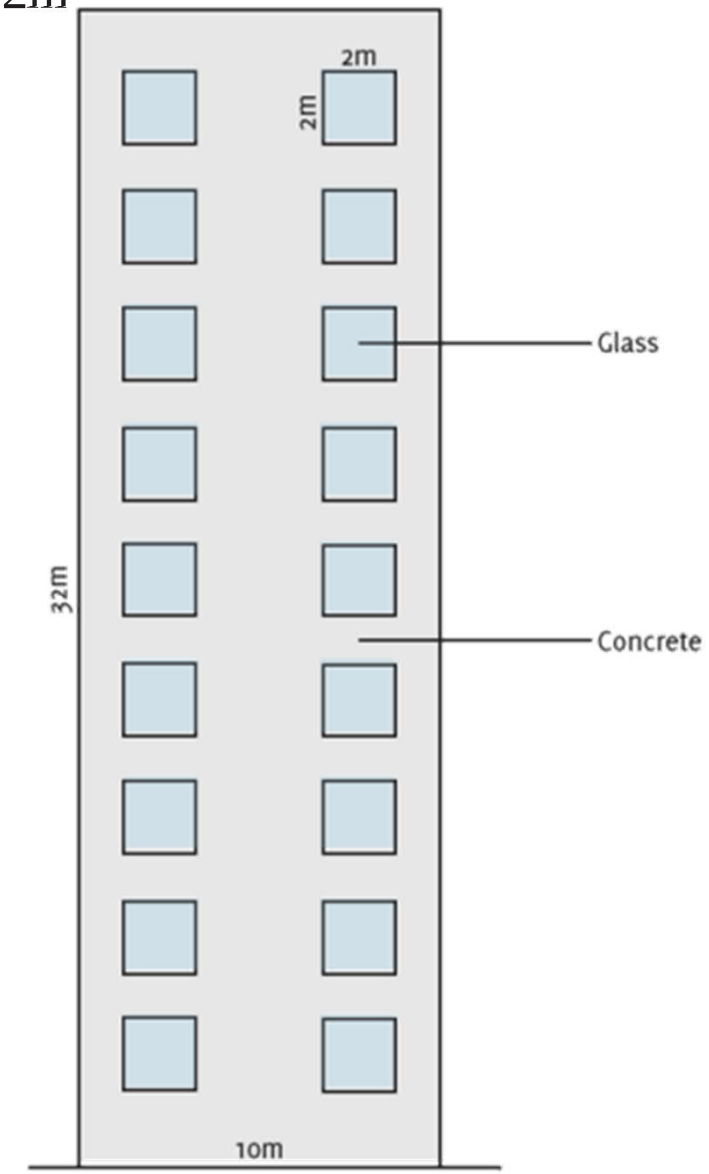
$$OTTV = \frac{Q_{wc} + Q_{gs}}{\Sigma A}$$

$$= \frac{(A_w \times U_w \times \alpha \times TD_{eq}) + (A_f \times SC \times ESM \times SF)}{A_w + A_f}$$

$$= \frac{(248 \times 1.9 \times 0.58 \times 1.4) + (72 \times 0.4 \times 1 \times 191)}{248 + 72}$$

$$= \frac{382.6 + 5500}{320}$$

$$= 18.39\ \mathrm{W/m^2}\ (< 24\ \mathrm{W/m^2})$$



(Source: Calculation and Application of OTTV and U-value (Science Teaching Kit for Senior Secondary Curriculum))

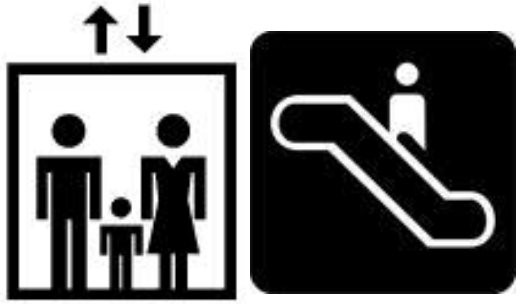
Hong Kong BEC

- Lighting installation
  - Lighting power density
  - Lighting control points
- Air conditioning installation
  - Equipment coefficient of performance (COP)
  - Fan power per volume air flow
  - Pipe frictional loss
  - Thermal insulation
  - Air-conditioning control
  - Energy metering

Hong Kong BEC

- Electrical installation
  - Motor efficiencies
  - Power distribution loss
  - Power quality
  - Metering devices

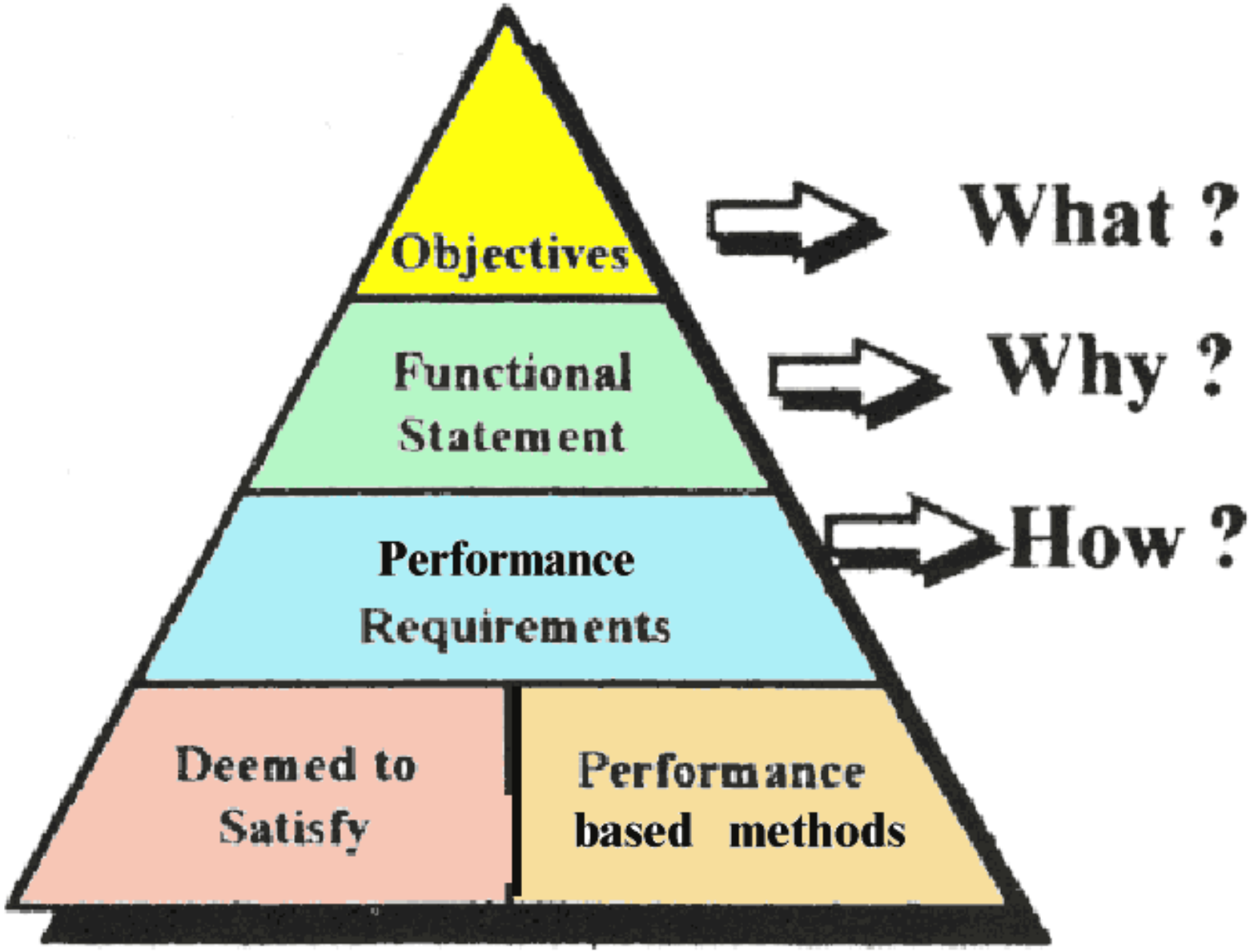
- Lift and escalator installation
  - Power demand of lifts/escalators
  - Power quality
  - Metering devices
  - Lift decoration load
  - Parking mode



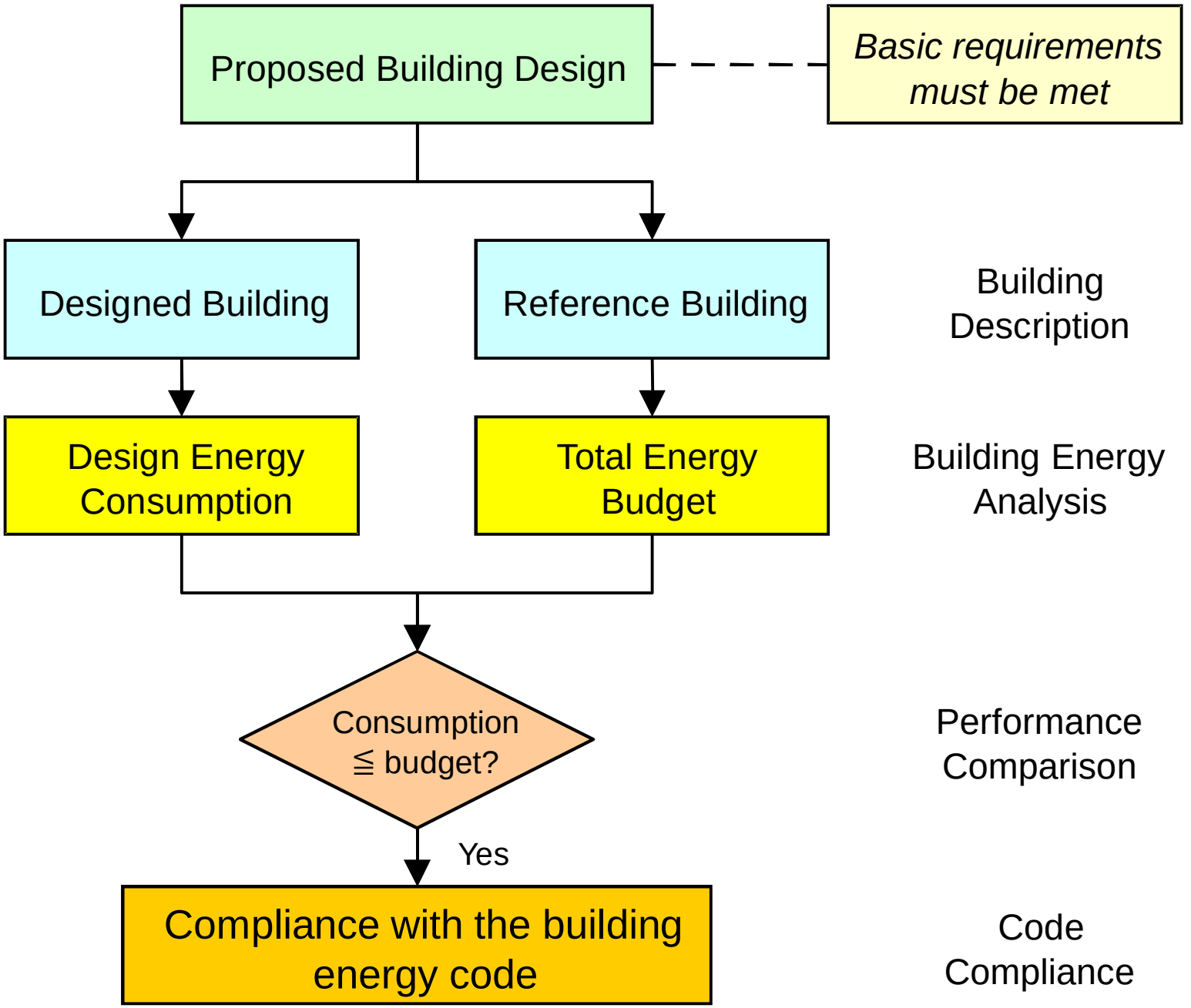
Hong Kong BEC

- Performance-based building energy code
  - As an alternative route to comply with BEC
    - Allow trade-off among components
  - Total energy budget approach
    - Building energy analysis
    - Actual design vs reference design
  - Encourage use of
    - Energy efficient equipment
    - Innovative building design & systems
    - Renewable energy

The triangle of performance-based approach



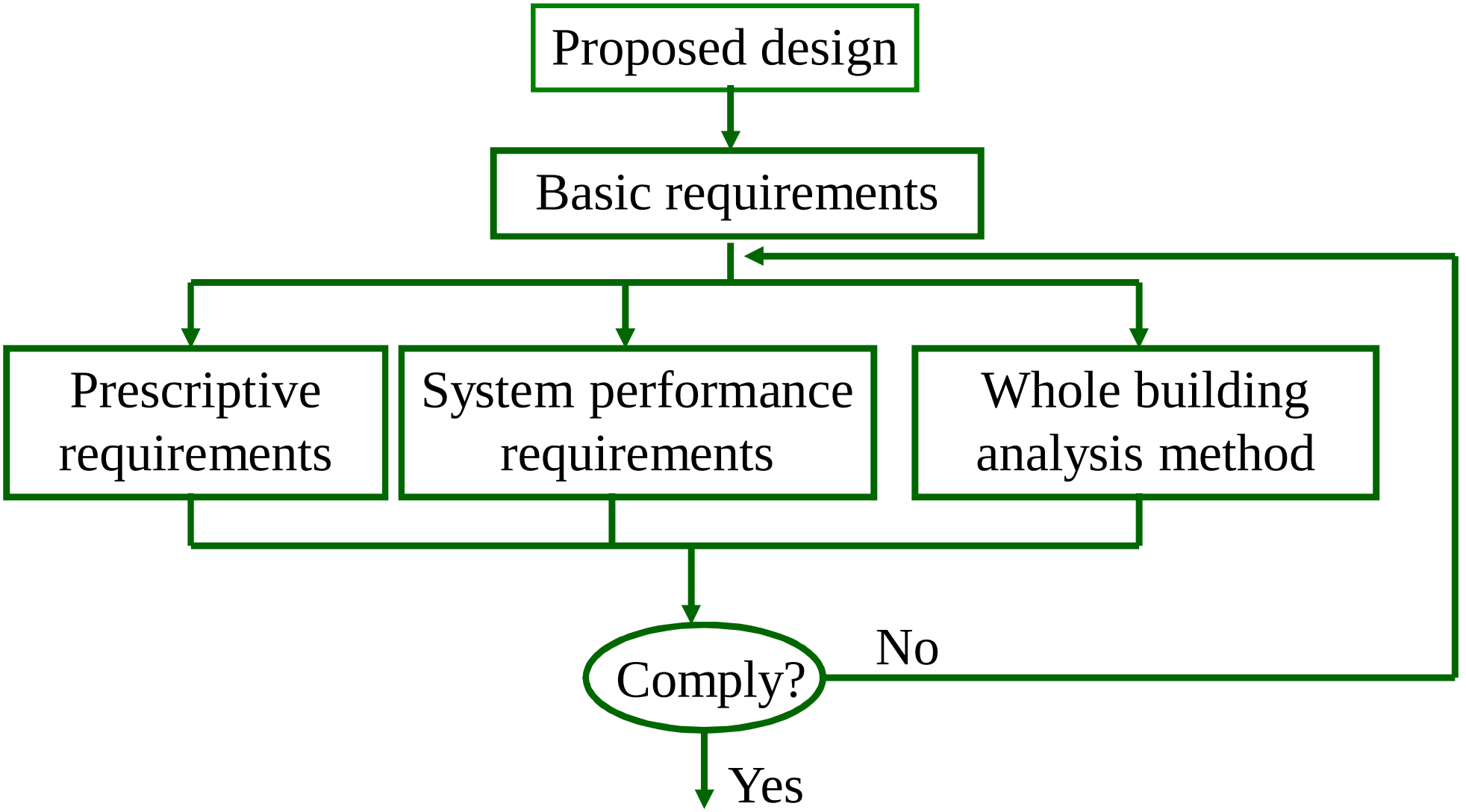
Performance compliance for building energy code



Hong Kong BEC

- Performance-based building energy code
  - Basic requirements (no trade off)
    - Building envelope
    - Lighting
    - HVAC
    - Electrical
    - Lift & escalator
  - Total energy budget approach
    - Design building vs reference building

Compliance paths in building energy codes



Further Reading

- Calculation and Application of OTTV and U-value
  - http://minisite.proj.hkedcity.net/hkiakit/eng/Science/lesson_6.html
- Introduction to OTTV and Building Energy Simulation
  - http://www.arch.hku.hk/~cmhui/teach/65256-X.htm
- Introduction to Buildings Energy Efficiency Ordinance (Cap. 610), Building Energy Code (BEC) and Energy Audit Code (EAC) [By EEO, EMSD]
  - http://www.aiib.net/files/2012-08-02%20Technical%20Training%20Course/1.%20Ir%20David%20Li%20BEEO&BEC&EAC.pdf
- Public CPD Lecture – Building Energy Codes Workshop
  - http://www.bse.polyu.edu.hk/cpd/2010/20100326-Building_Energy_Codes_Workshop.pdf