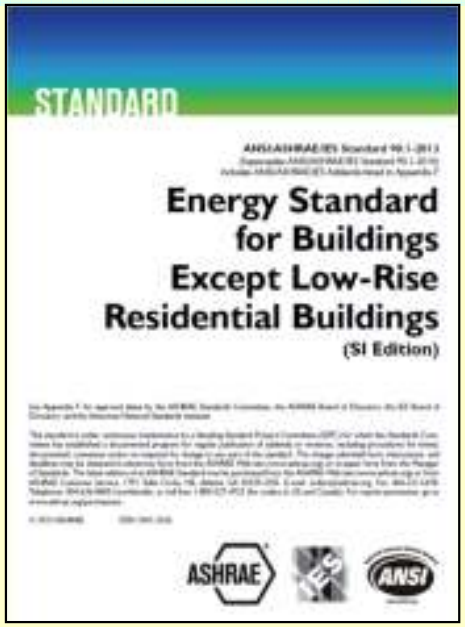
ASHRAE Hong Kong Chapter/ACRA Joint Technical Seminar

24 Mar 2015 (Tue)



ASHRAE Standards 189.1 and 90.1: Green Building and Energy Efficiency

Dr. Sam C. M. Hui

Department of Mechanical Engineering

The University of Hong Kong

E-mail: cmhui@hku.hk

Mar 2015

Contents

- ASHRAE Standard 90.1
- Structure and Scope
- Compliance Options
- Energy Cost Budget Method
- Performance Rating Method
- LEED Rating System
- ASHRAE Standard 189.1

ASHRAE Standard 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 Standard 90.1

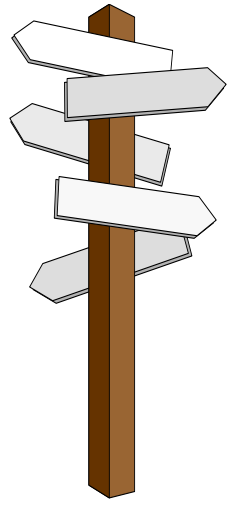
- ASHRAE Standard 90.1 (www.ashrae.org/standard901)
  - Energy Standard for Buildings Except Low-Rise Residential Buildings
    - Include (new) commercial & institutional buildings
  - SSPC 90.1 Standing Standard Project Committee
- Other relevant ASHRAE Standards:
  - 90.2 -- for low-rise residential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

ASHRAE Standard 90.1

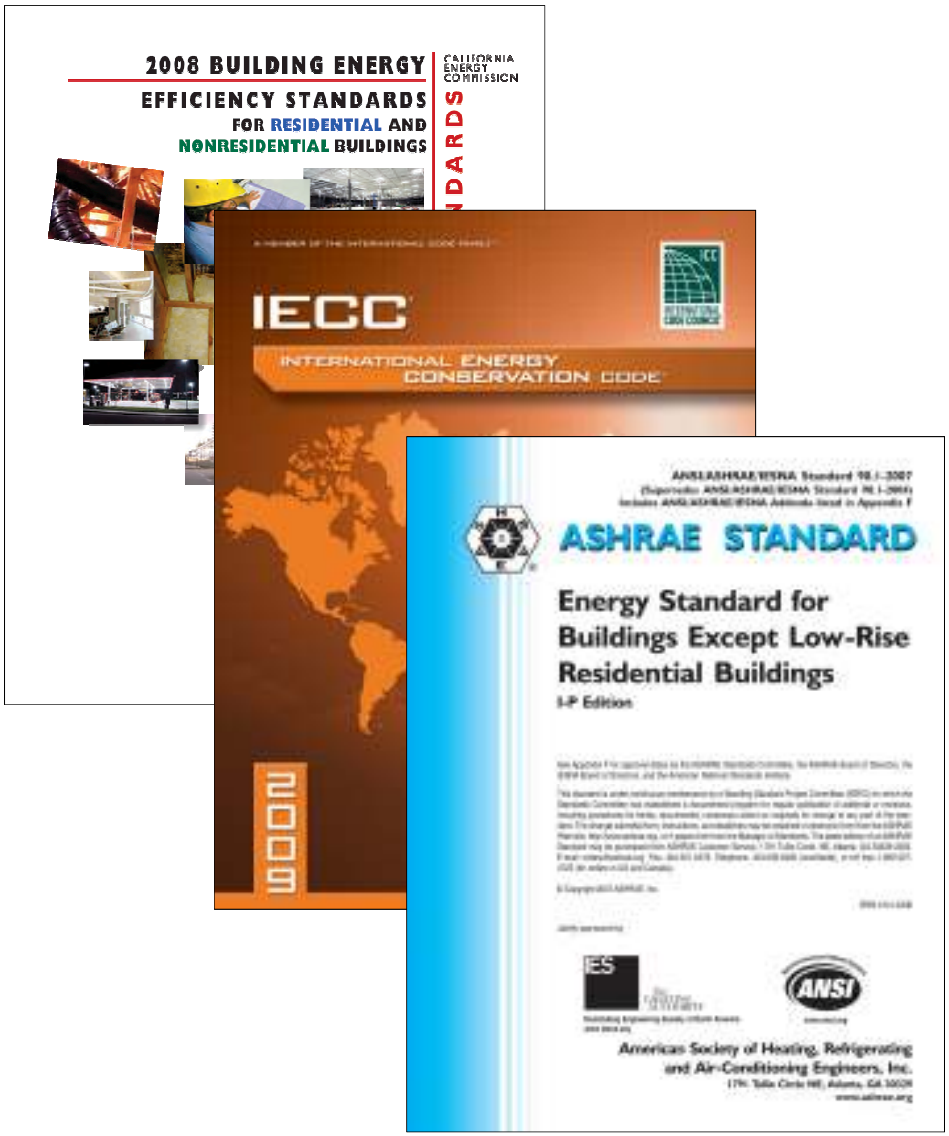
- Why ASHRAE Standards 90.1 is important?
  - It is the reference standard for US Energy Policy Act and many building energy codes in USA
  - It has been adopted in many countries as a model for energy efficiency guidelines and codes
  - It is the professional “standard of care” set by ASHRAE consensus,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

ASHRAE Standard 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)



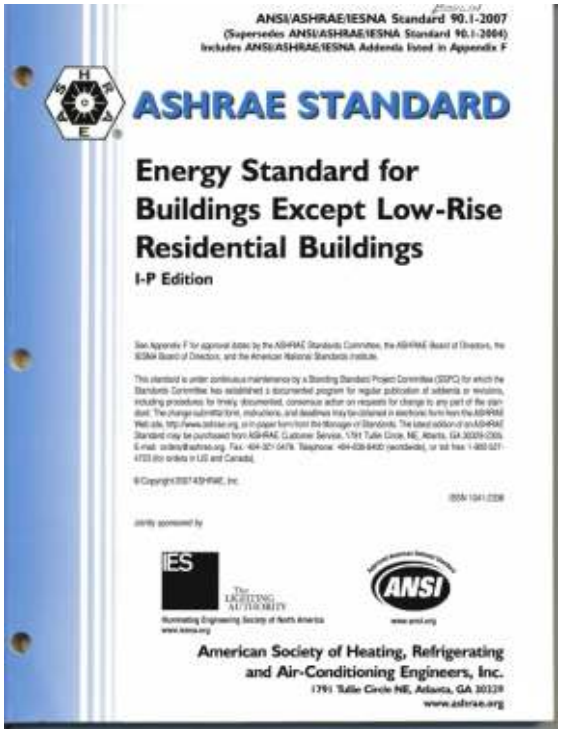
Building Energy Codes, e.g. ASHRAE 90.1, International Energy Conservation Code (IECC), California Title 24



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

ASHRAE Standard 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 Standard 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 Standard 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 Standard 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

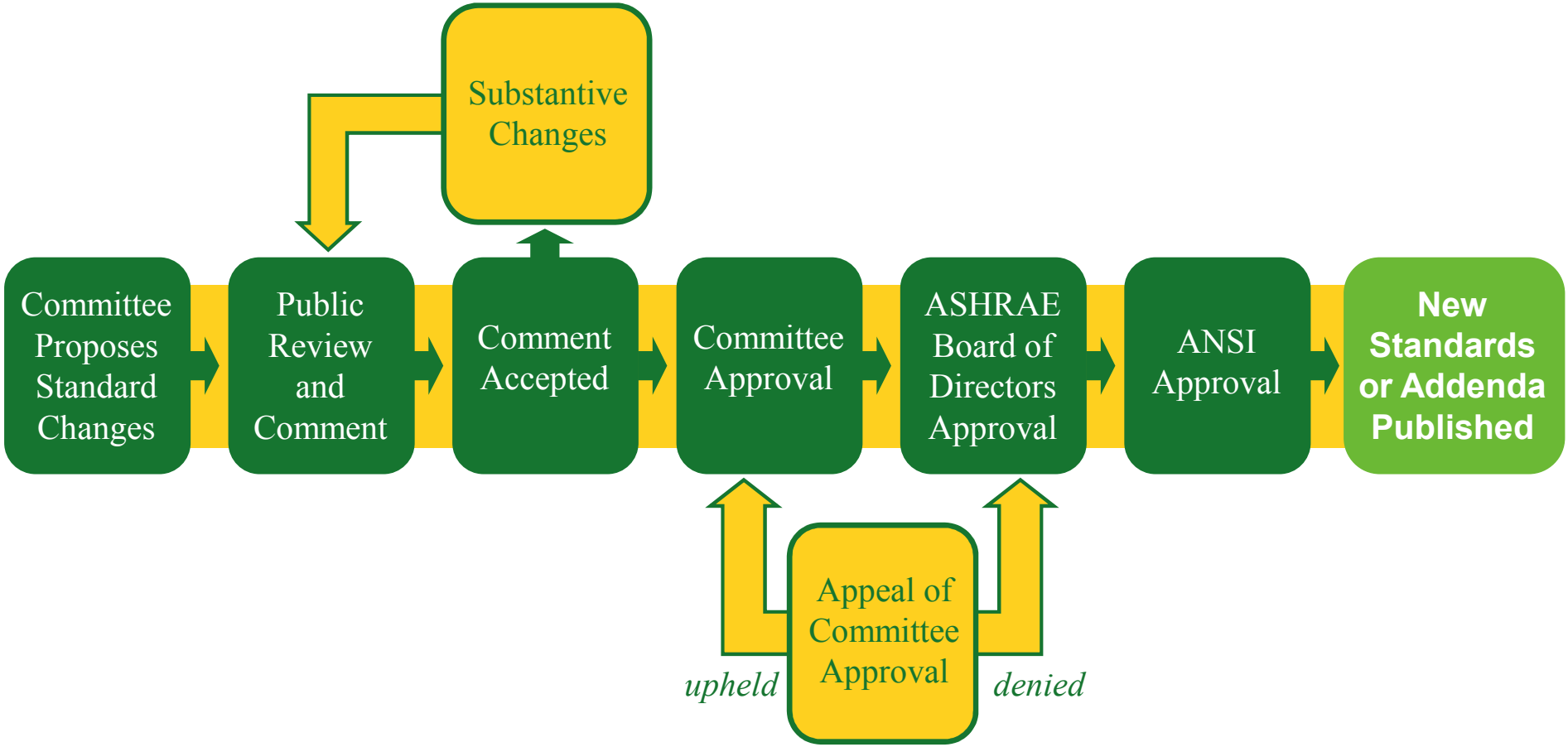
ASHRAE Standard 90.1

- 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 Standard 90.1

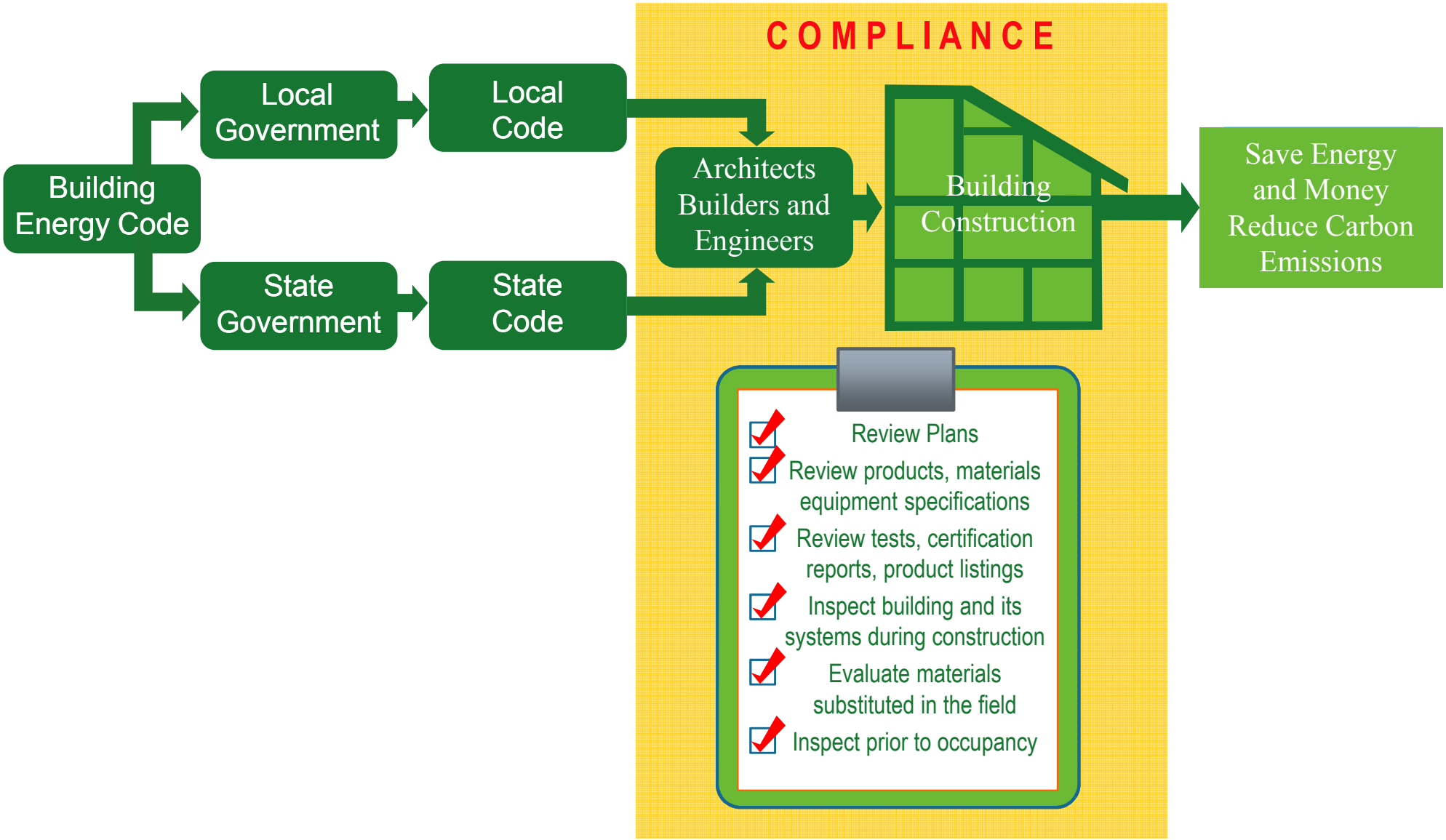
- Related ASHRAE Standards
  - 90.2-2007: for low-rise residential buildings
  - 100-2006: energy conservation in existing buildings
  - 105-2007: standard methods of measuring, expressing and comparing building energy performance
  - 140-2011: evaluation of building energy analysis computer programs
  - 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



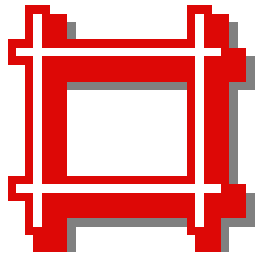
(Source: US Department of Energy)

Code compliance and the building process in USA



(Source: US Department of Energy)

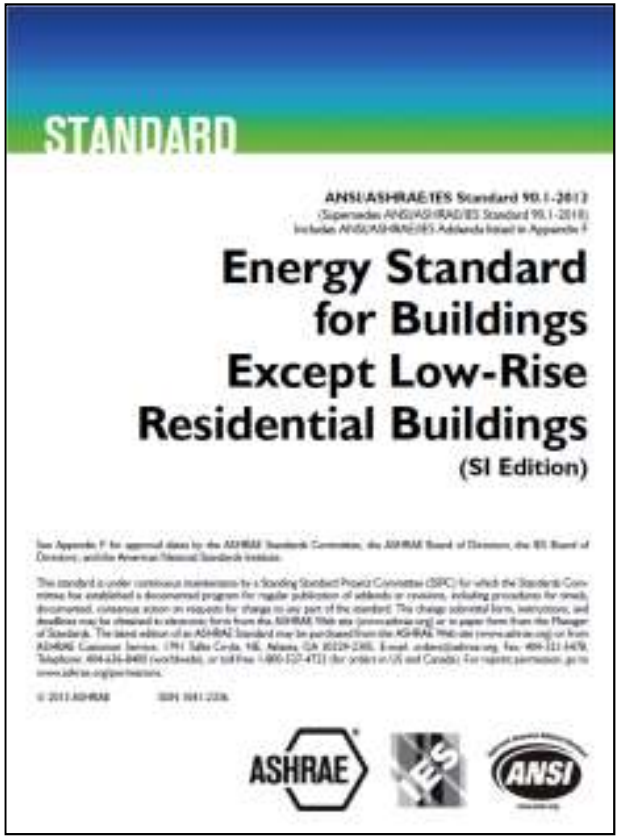
Structure and Scope



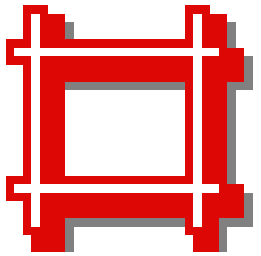
- Structure of Standard 90.1-2013
  - 1. Purpose
  - 2. Scope
  - 3. Definitions, Abbreviations, and Acronyms
  - 4. Administration and Enforcement
  - 5. Building Envelope
  - 6. Heating, Ventilating, and Air Conditioning
  - 7. Service Water Heating

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

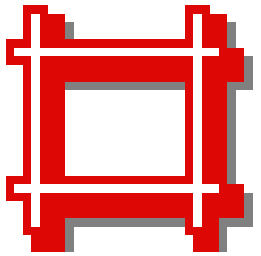


Structure and Scope



- 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

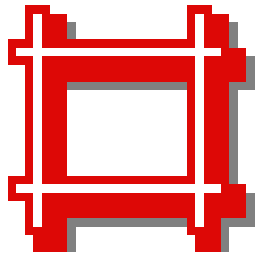
Structure and Scope



- 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

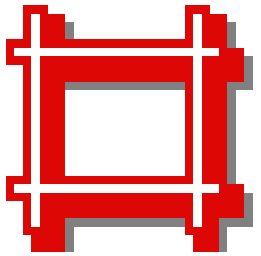
* IESNA = Illuminating Engineering Society of North America (now IES)
ANSI = American National Standards Institute

Structure and Scope



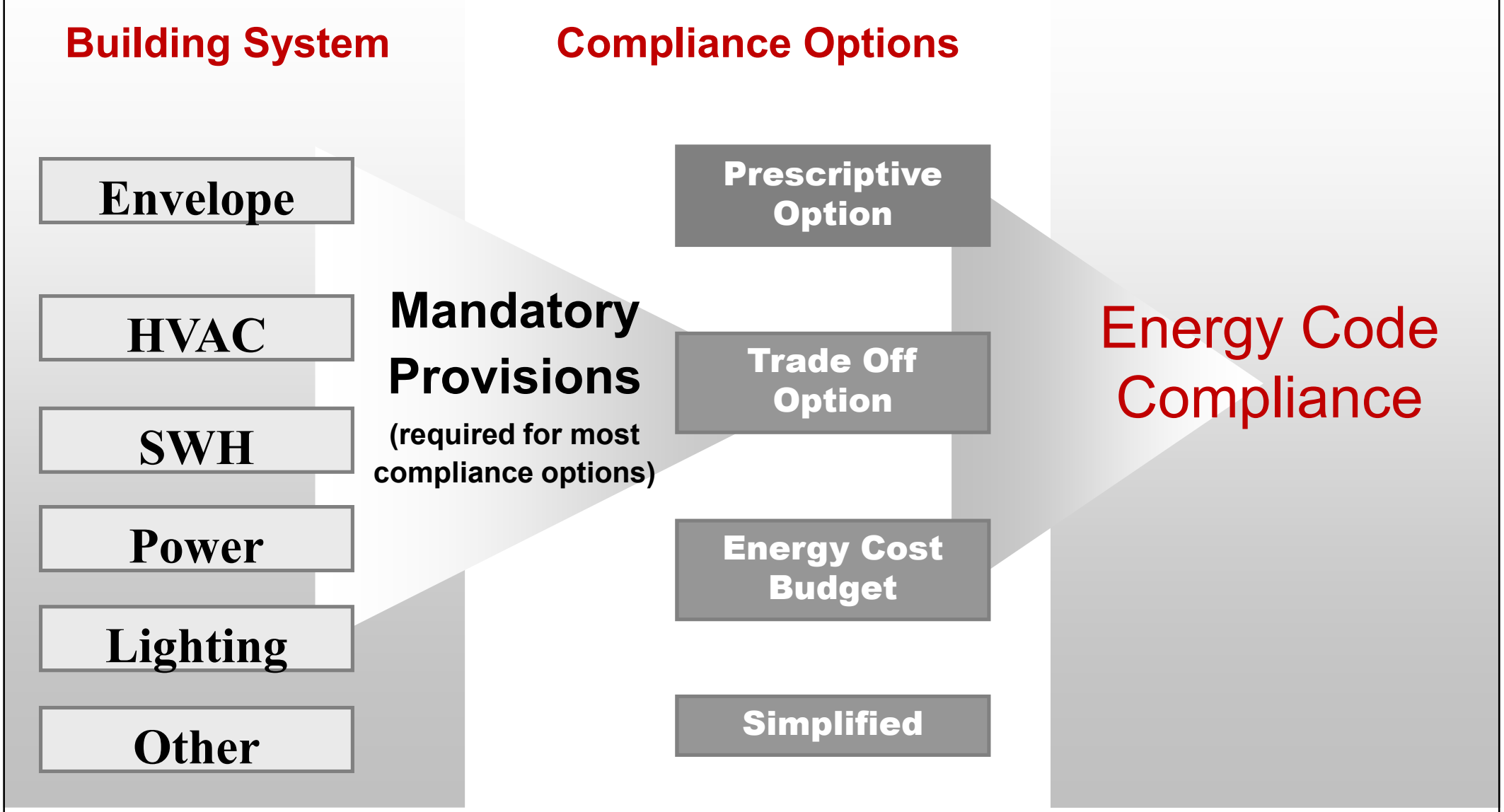
- Scope
  - New buildings and their systems
  - New portions of buildings and their systems (additions)
  - New systems and equipment in existing buildings (alterations), e.g. computer rooms
- Exemptions, such as
  - Equipment and portions of building systems that use energy primarily for industrial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

Structure and Scope



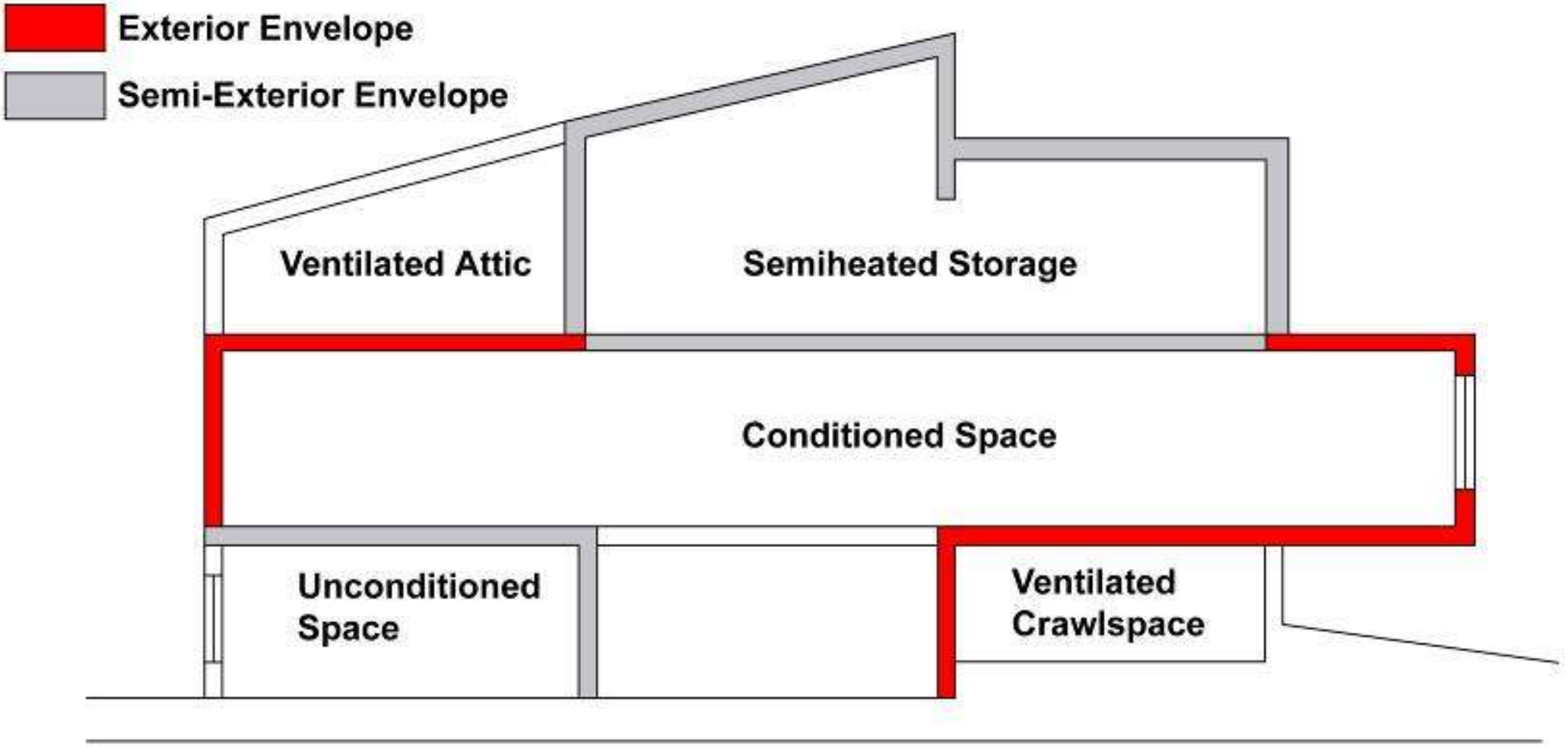
- Main areas of ASHRAE 90.1
  - 1. Building Envelope
    - Roofs, walls, floors, slabs, doors, vertical glazing, skylights
  - 2. HVAC Equipment and System
    - Cooling equipment efficiency, heating equipment efficiency, supply fans, ventilation control, ducts
  - 3. Lighting
    - Interiors electric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

ASHRAE 90.1 compliance approaches

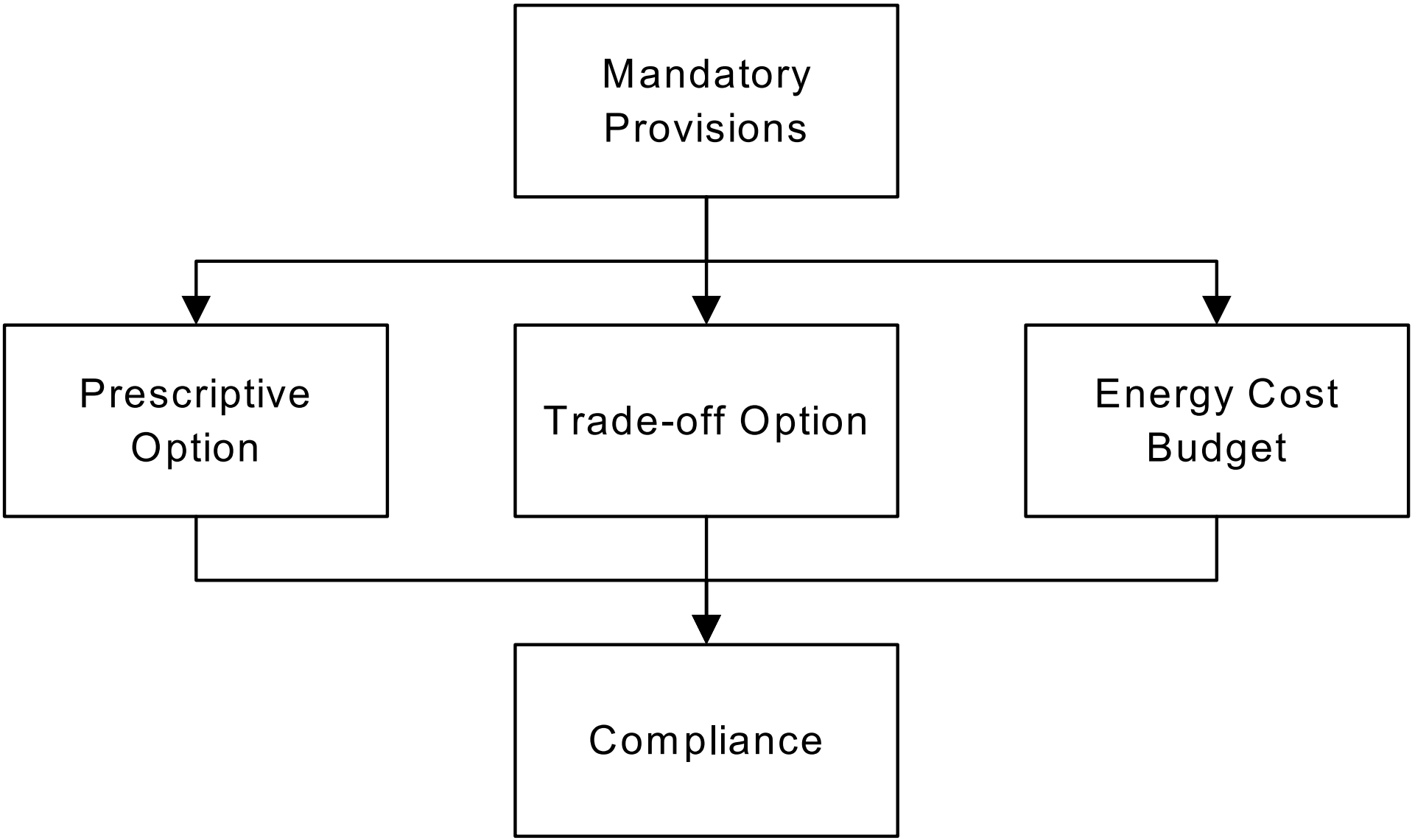


(Source: US Department of Energy)

Exterior envelope and semi-exterior envelope



(Source: US Department of Energy)

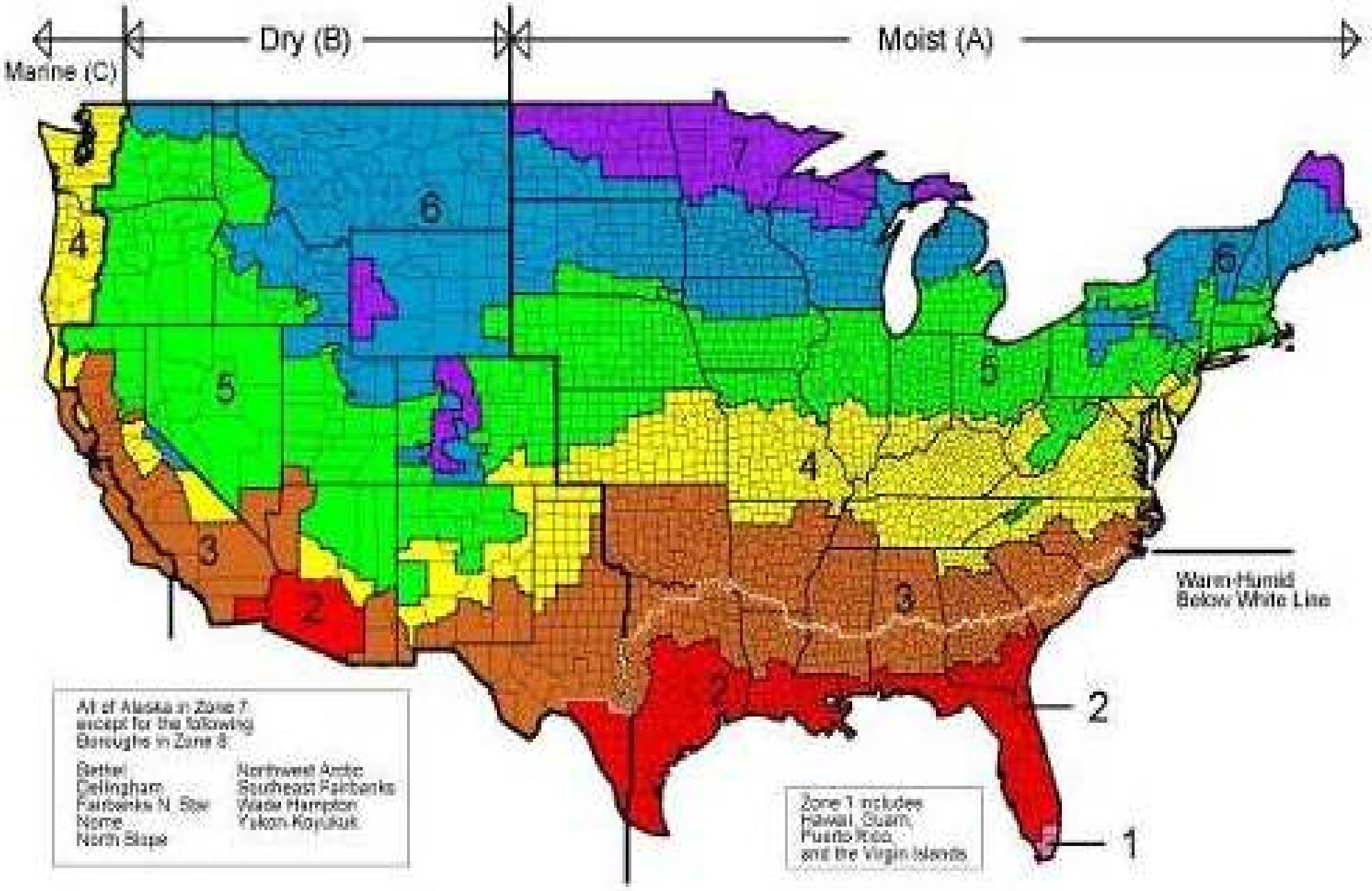


Envelope compliance options in ASHRAE 90.1

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)

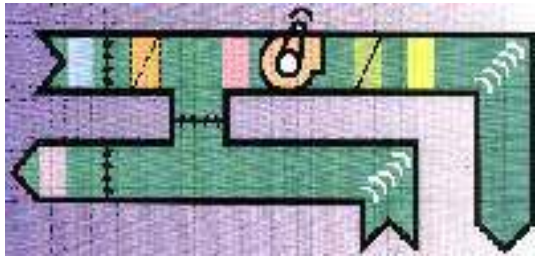
(small buildings only)

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)

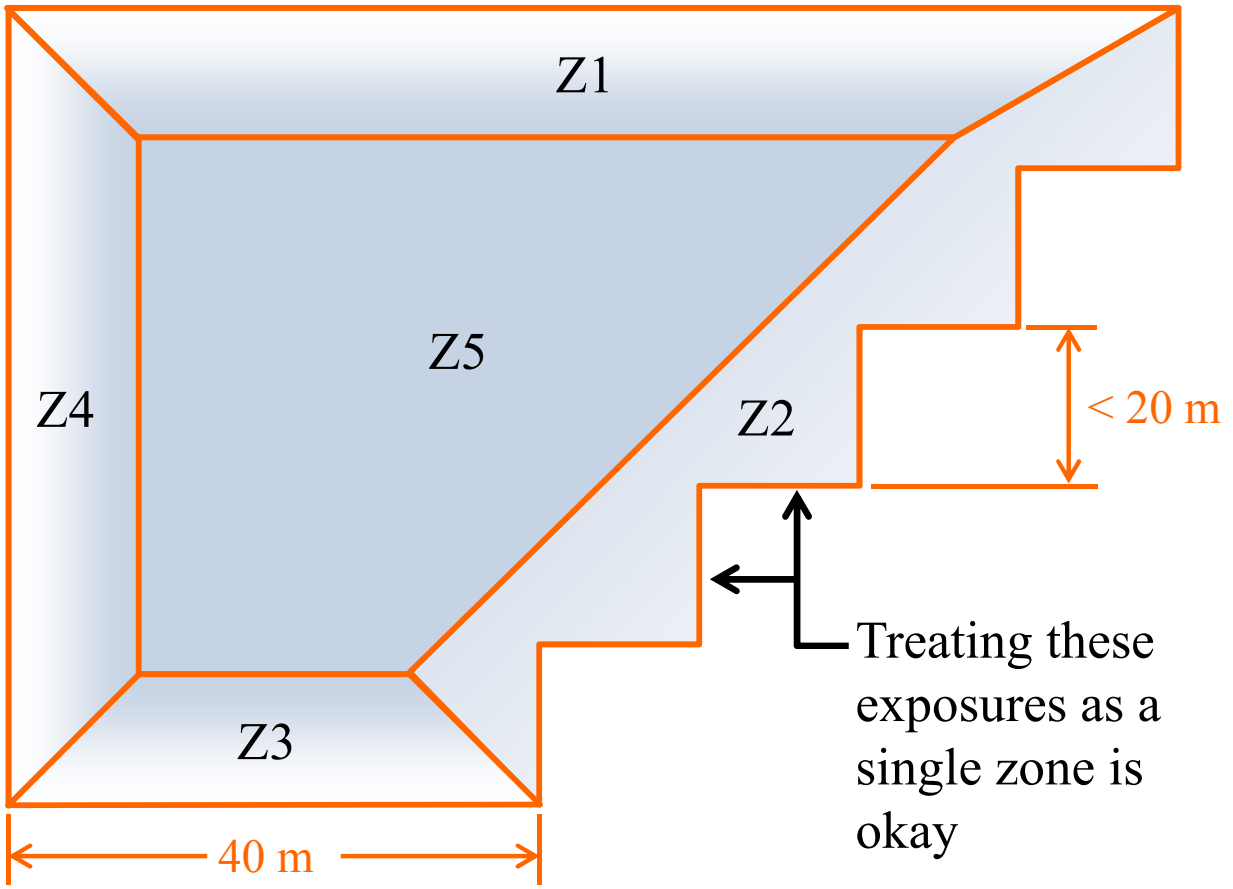
§6.4.1.1: "… Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements …"

(Source: Trane)

Mandatory HVAC provisions:
Zone thermostatic controls: perimeter zones

Core and each long exposure must be zoned separately

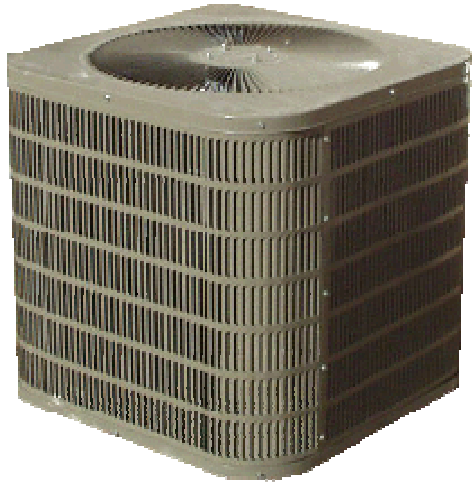
Building plan view: thermal zoning example



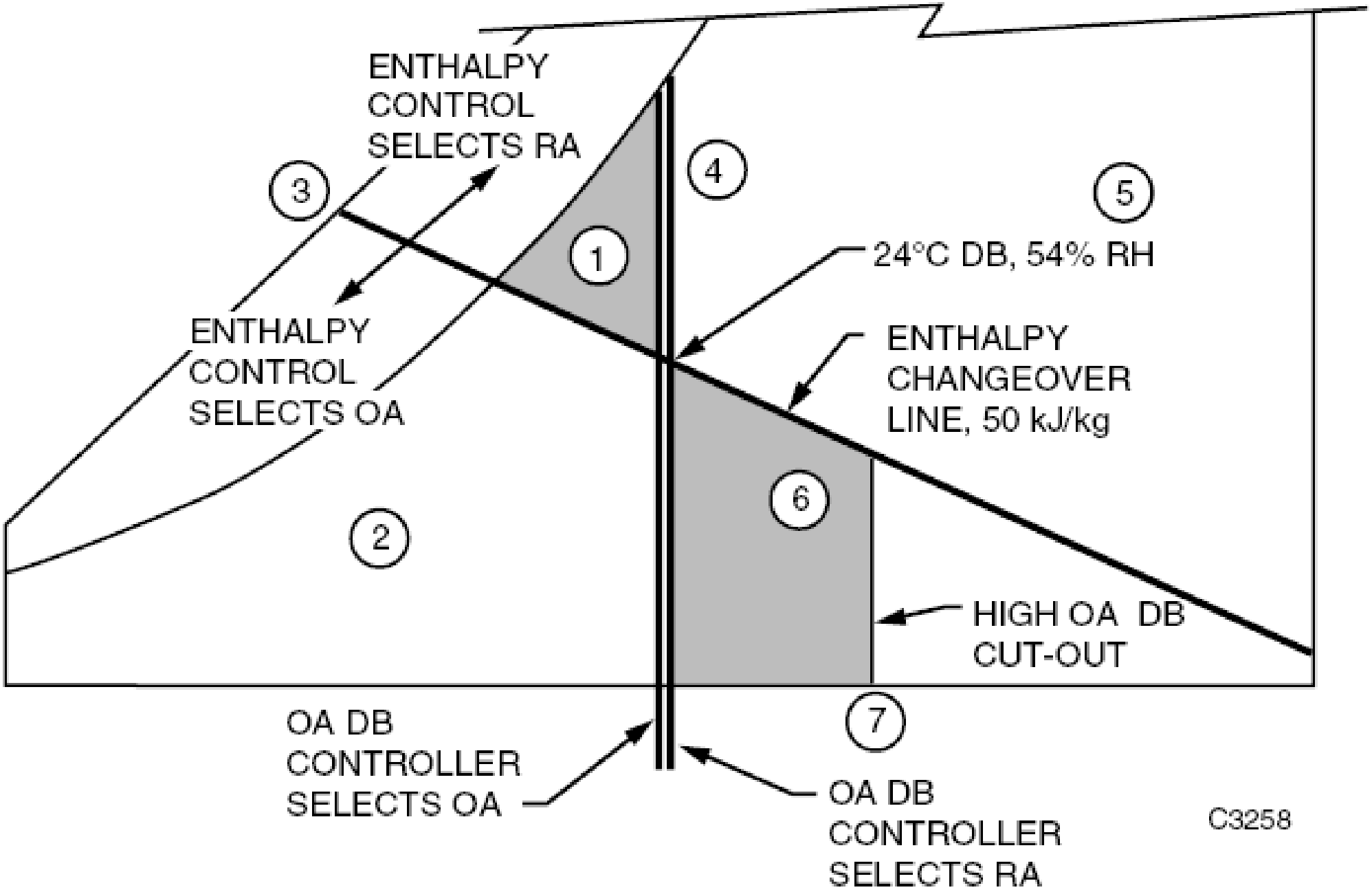
(Source: Trane)

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

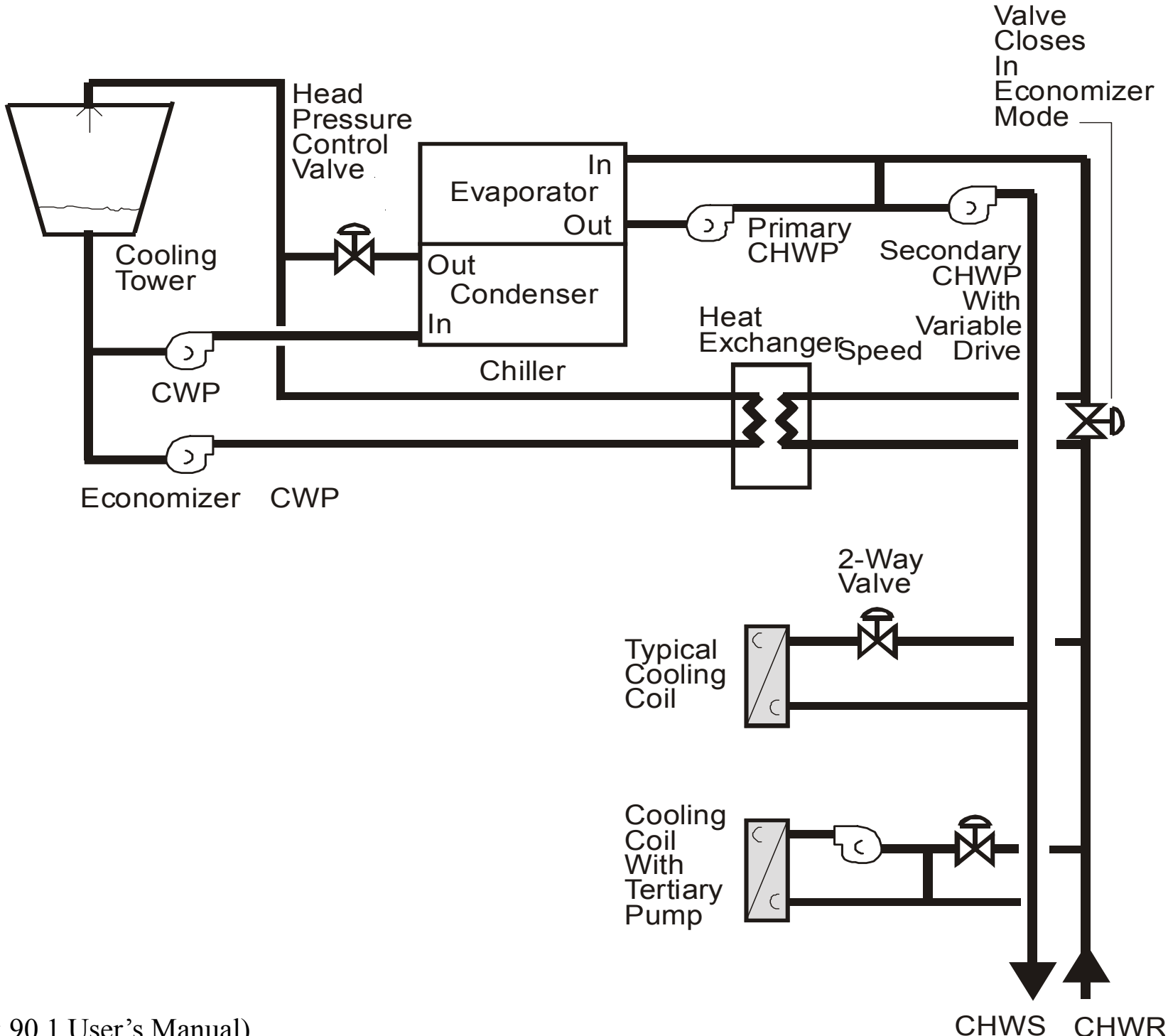


Air-side economizer cycle control (outdoor air enthalpy)



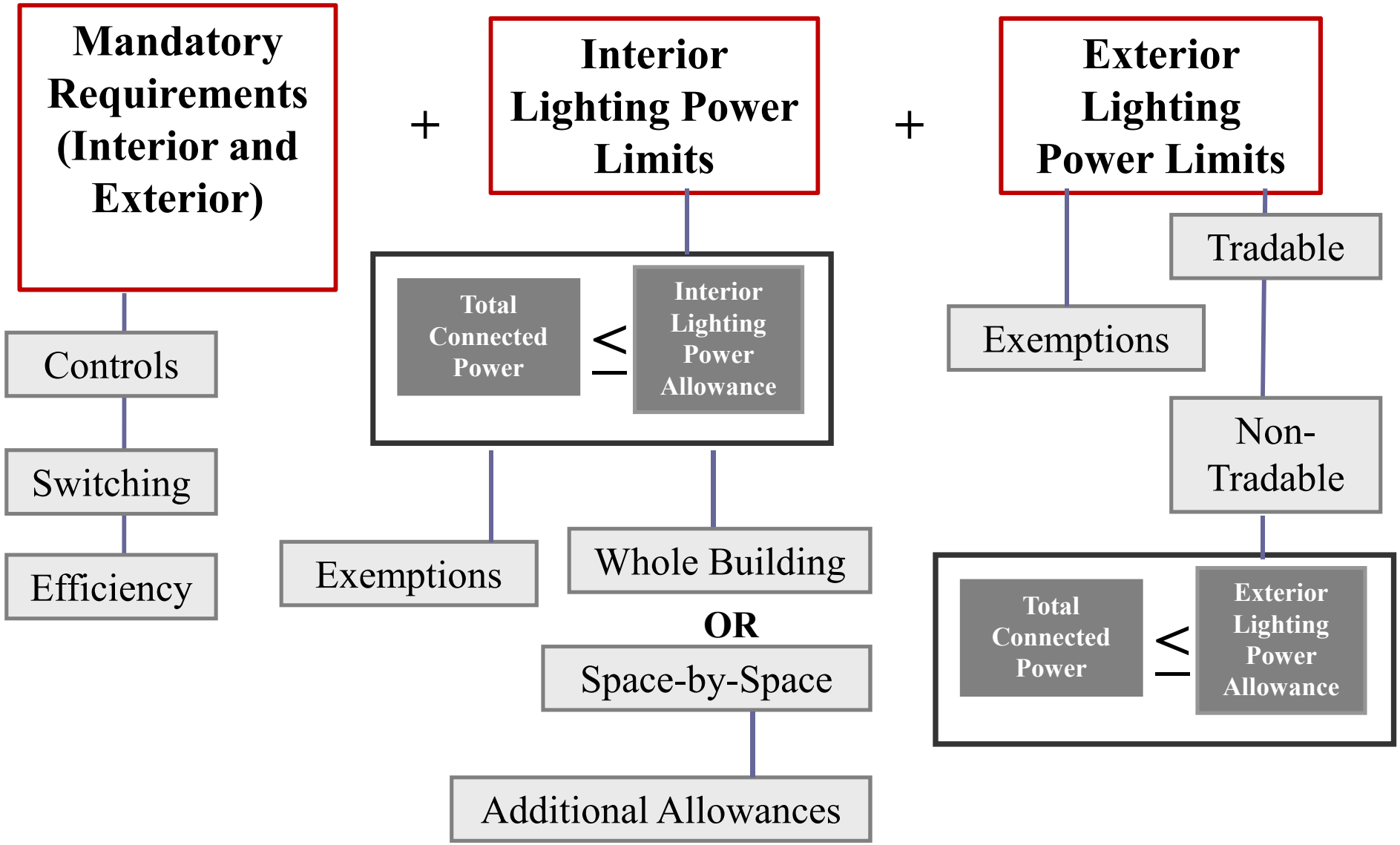
(Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*)

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

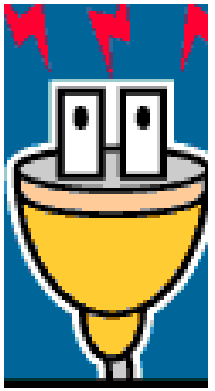
- Exterior lighting power
  - Lamp efficacy
  - Exterior lighting power wattage limits

Compliance Options

- 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

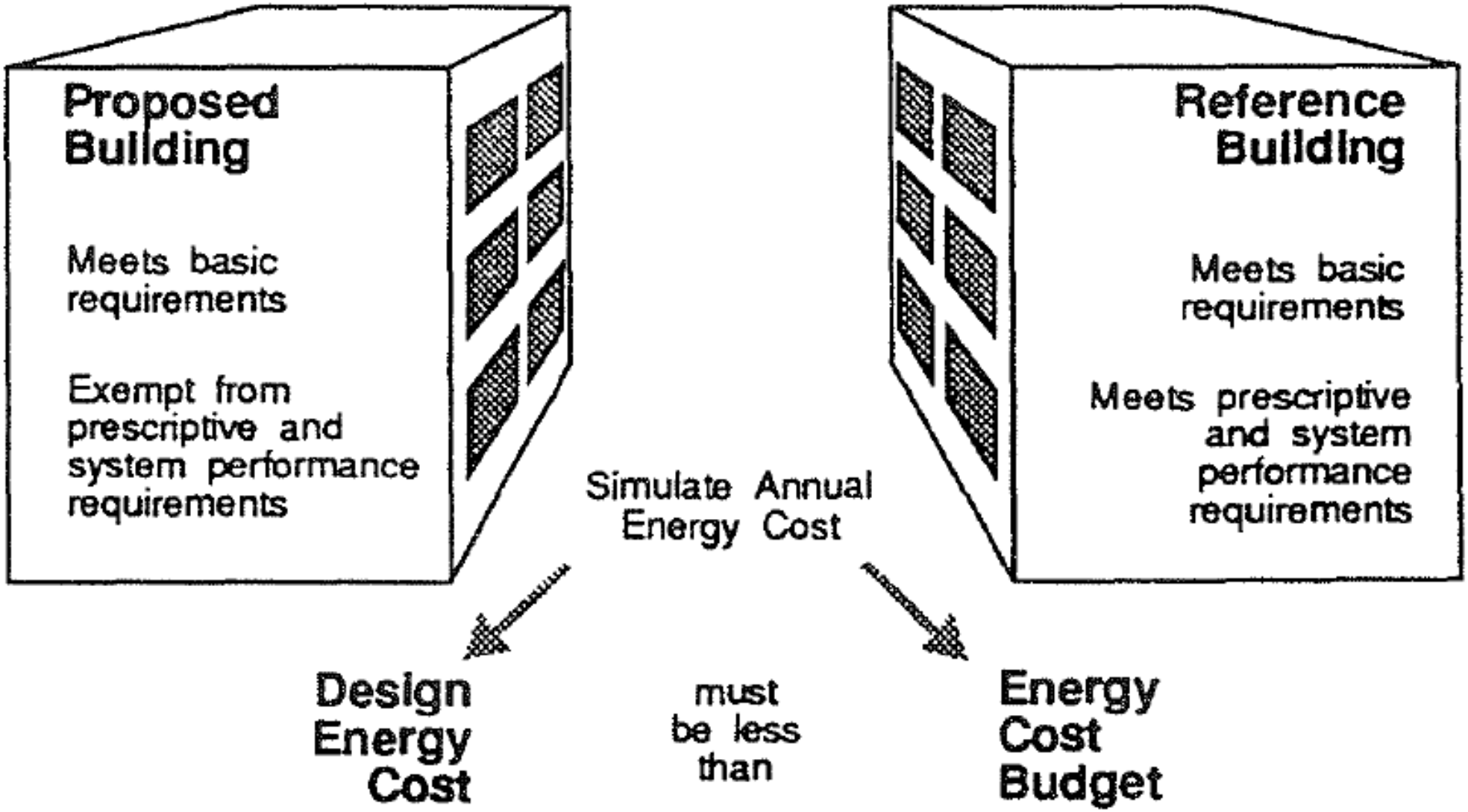
- Power and Other Equipment
  - Max voltage drop allowed at design load
    - Feeder conductors
    - Branch circuit conductors
  - Motor efficiency levels correspond to Energy Policy Act's manufacturing standards
    - Mandatory provisions are for General Purpose Design A and Design B motors only
    - Motors in new buildings, additions to existing buildings, and alterations to existing buildings must comply



Energy Cost Budget Method

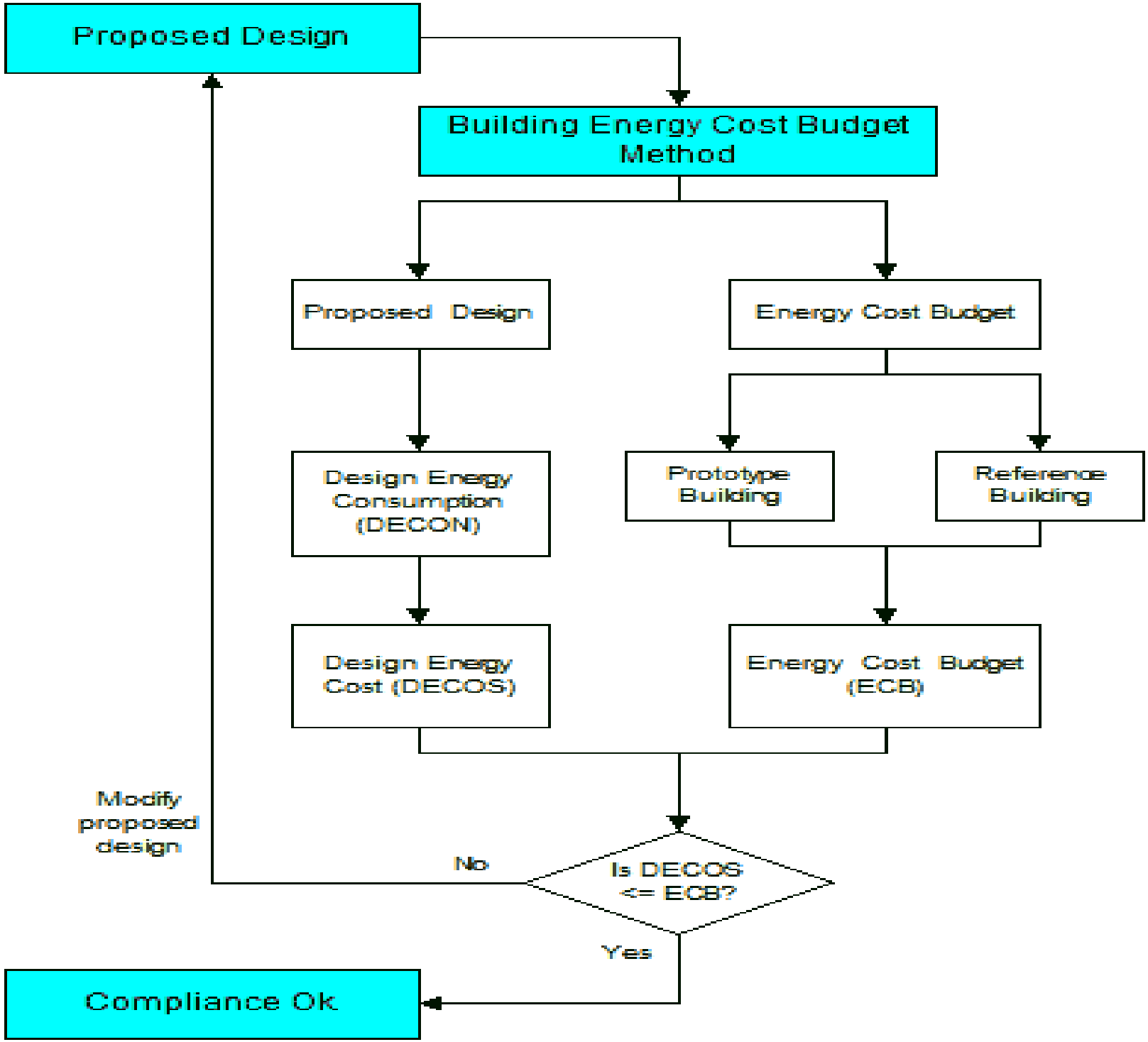
- Energy Cost Budget (ECB) Method
  - The ultimate trade-off method to trade-off across building systems through the use of annual, hourly simulation tools and a baseline building
  - The only real way to deal with unique designs, renewables, high-efficiency equipment, etc.
  - Buildings must still meet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



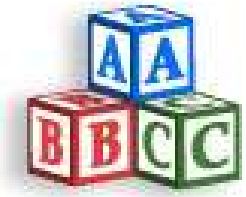
Energy Cost Budget Method

- 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

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

U.S. GREEN BUILDING COUNCIL LEED™ LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

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

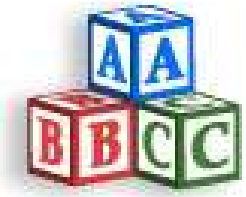
Comparing the simulation requirements for ECB & PR methods

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)

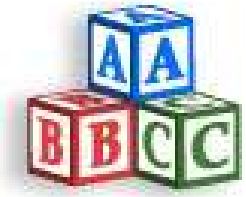
Energy Cost Budget Method (from 90.1 Section 11 for EAp2)	**Performance Rating Method** (from 90.1 Appendix G for EAc1)
Models budget building design characteristics per Section 11.5	Models baseline building design characteristics per Section G3
Calculates design loads	[Same]
Uses hourly weather data, 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

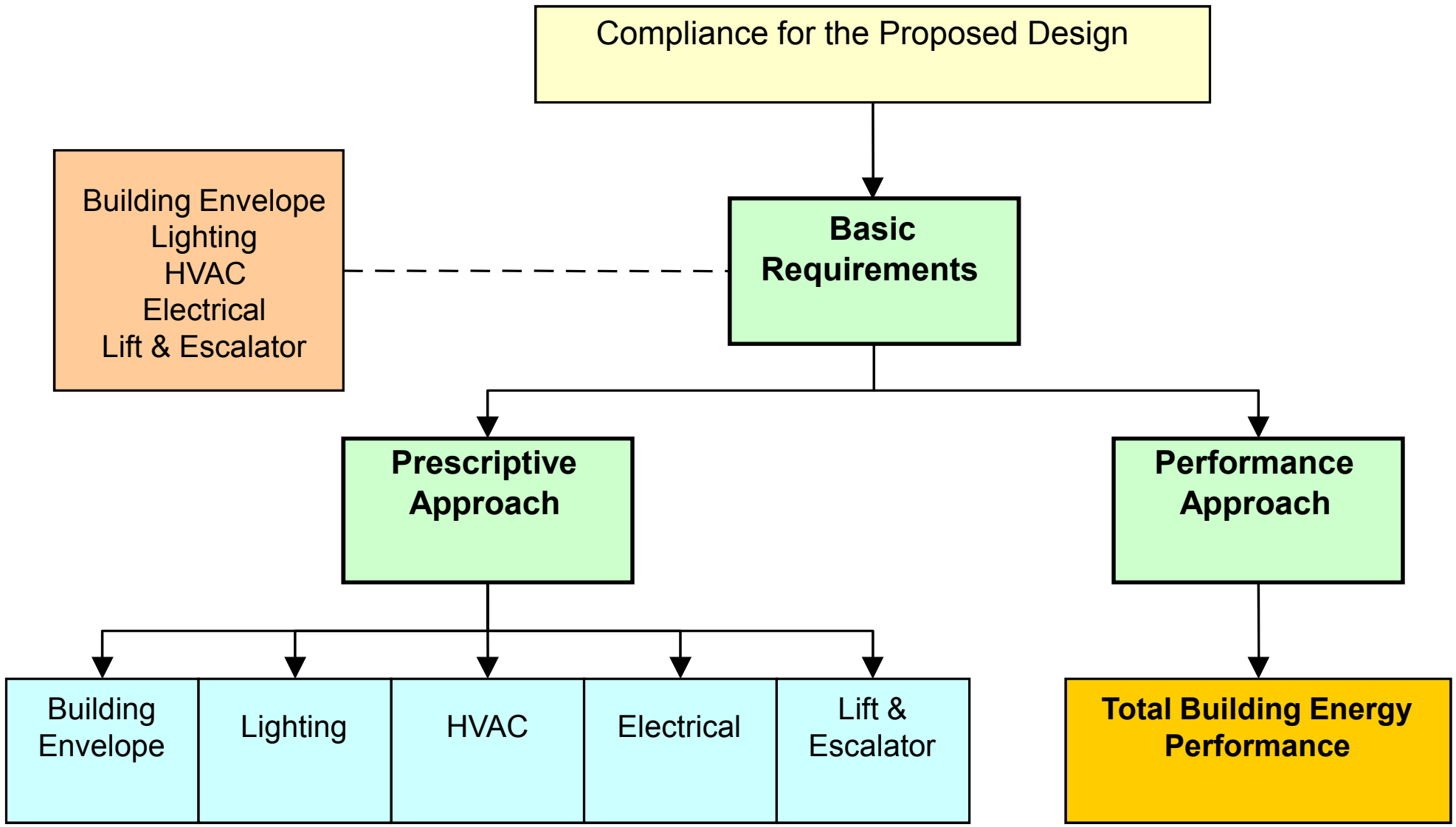


- The proposed building design should model:
  - All end-use loads
  - Any energy-saving strategies (e.g. daylighting and natural ventilation), where applicable
  - Actual lighting power if the lighting system already is designed, or the lighting power allowance in accordance with Section 9 of 90.1
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

(Source: EMSD)

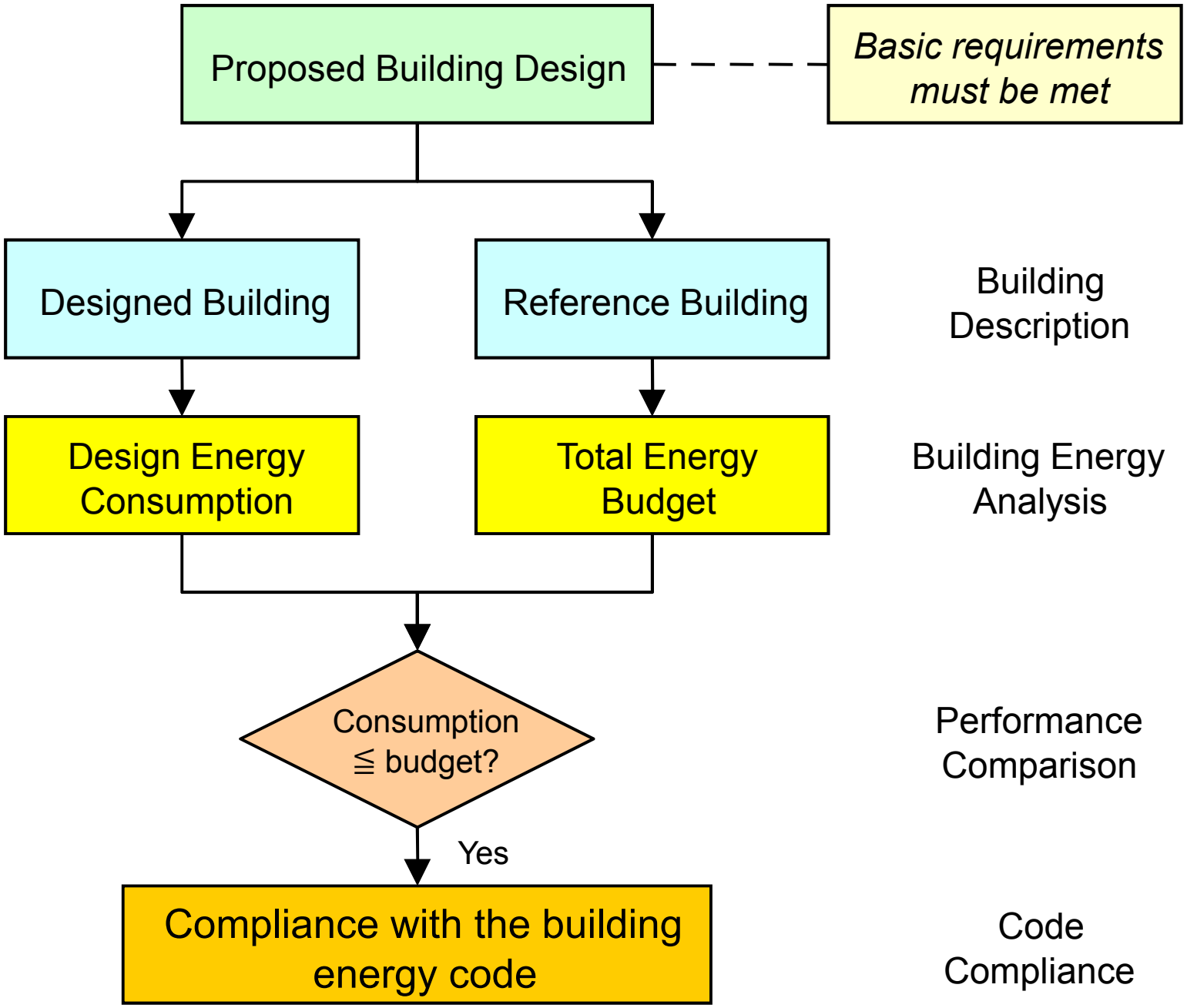
(See http://www.beeo.emsd.gov.hk for details)

Proposed framework of the comprehensive BECs in Hong Kong

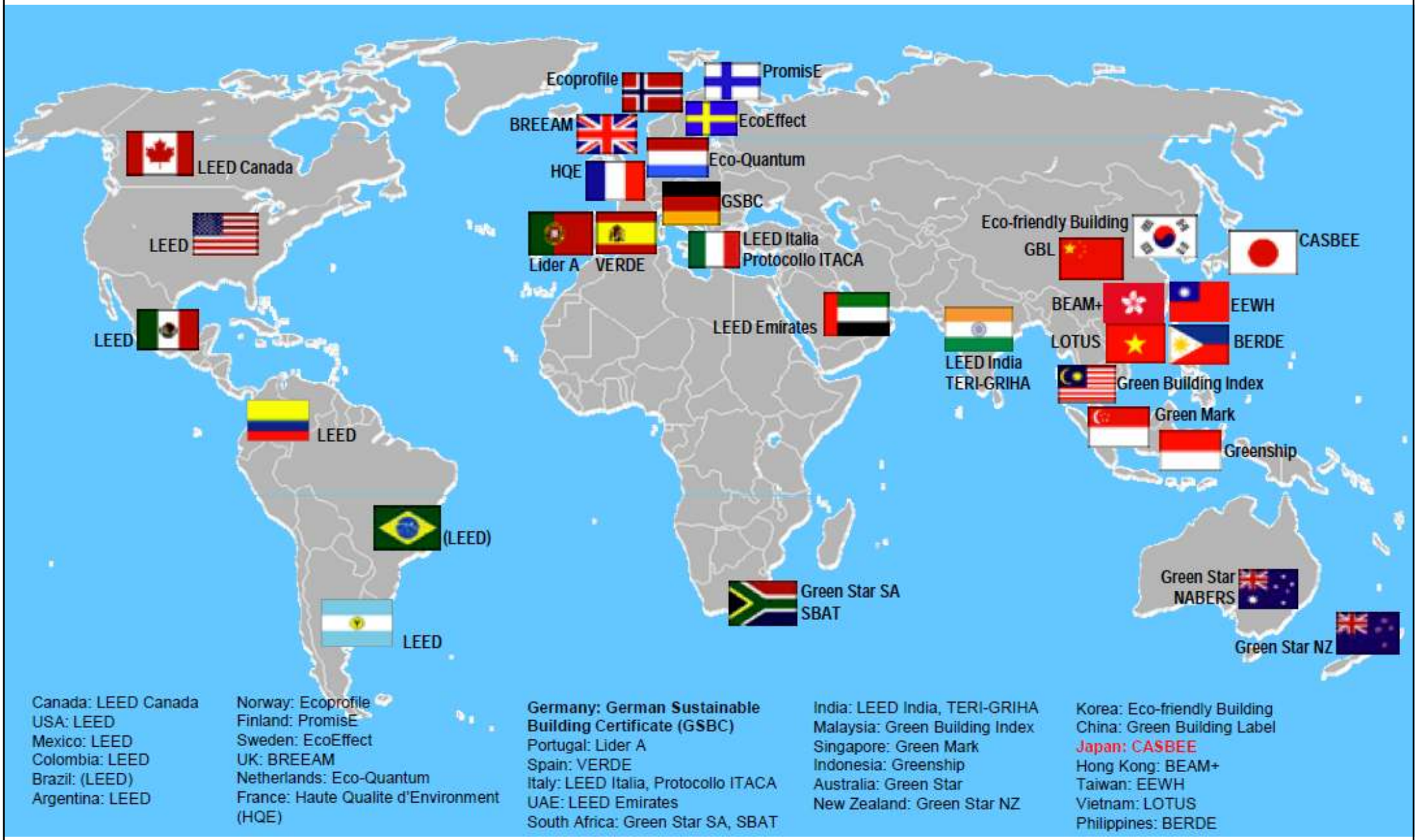


(Source: EMSD)

Performance compliance for building energy code

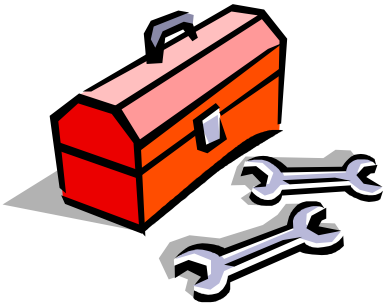


Rating tools of building environmental performances around the world



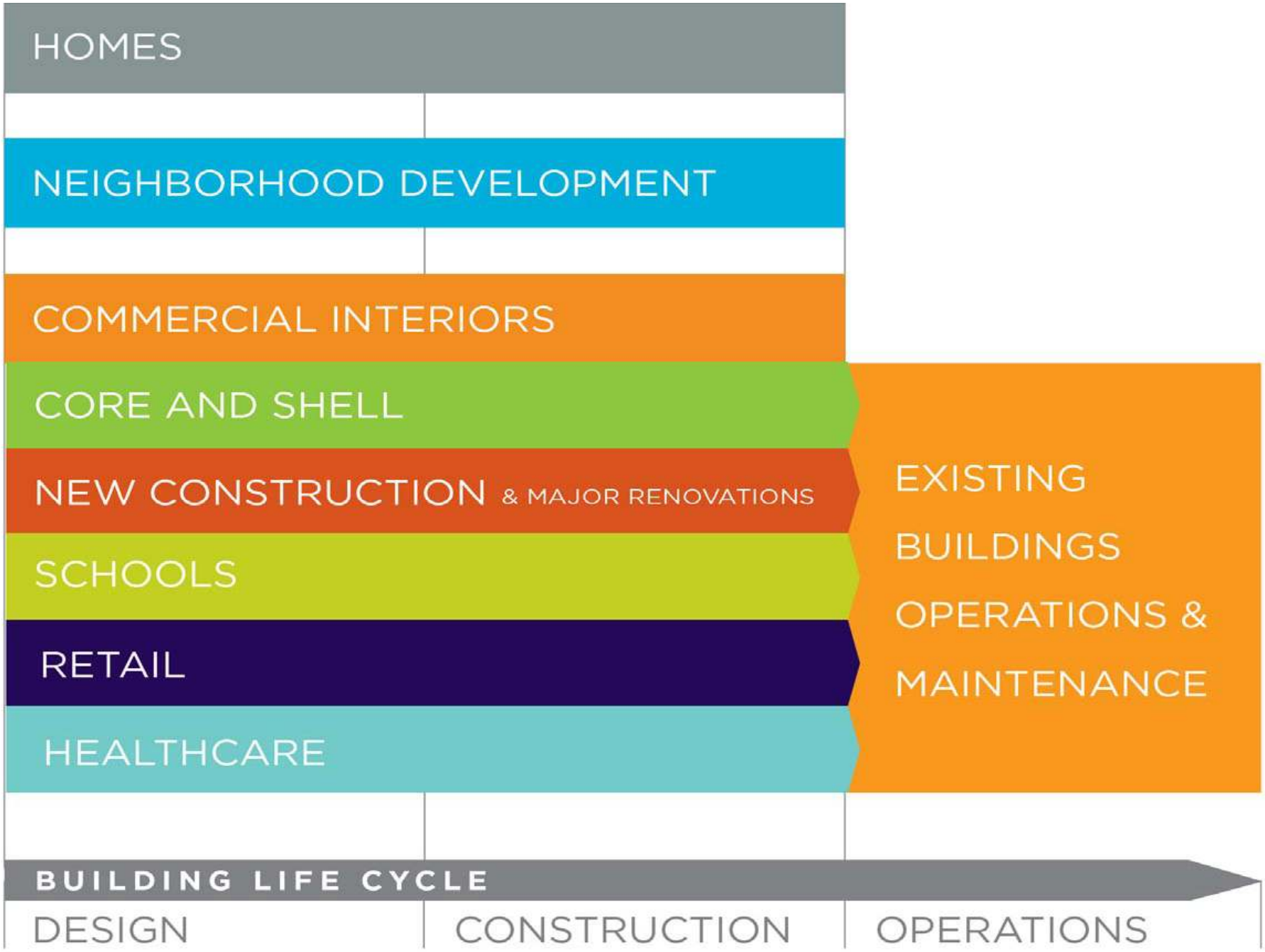
(Adapted from *CASBEE in Progress for Market Transformation in Japan*, by Prof. Kazuo Iwamura, Tokyo City University)

LEED Rating System



- LEED Green Building Rating System
  - **L**eadership in **E**nergy & **E**nvironmental **D**esign
    - By US Green Building Council
  - Current LEED systems:
    - New construction (LEED-NC) or Building design and construction (BD+C)
    - Existing buildings operations & maintenance (LEED-EBOM) (O+M)
    - Commercial interiors (LEED-CI)
    - Core and shell (LEED-CS)
    - Homes, Schools, Healthcare, Retail
    - Neighborhood development (LEED-ND)

LEED Green Building Rating



(Source: USGBC http://www.usgbc.org/leed)

(Source: USGBC)

For LEED version 3

LEED 2009 New Construction Checklist

Energy and Atmosphere		35 Possible Points
☑ 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

Materials and Resources		14 Possible Points
☑ 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)

LEED Rating System

- EAp2: Minimum energy performance
  - **Intent**: Establish the minimum level of energy efficiency for the proposed building and systems
  - **Requirements**: Mandatory provisions of ASHRAE 90.1 **and**
    - Prescriptive requirements of 90.1 **or**
    - Performance requirements of 90.1 Section 11 (Energy Cost Budget Method) **or**
    - The requirements in the local energy code, whichever is more stringent

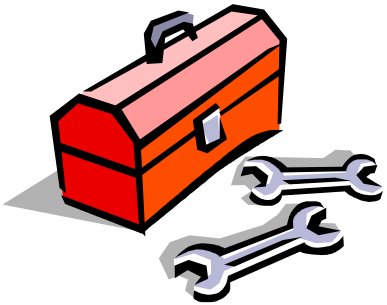
LEED Rating System

- EAc1: Optimize energy performance
  - **Intent**: Achieve increasing levels of energy performance above the baseline in the prerequisite standard to reduce environmental impacts associated with excessive energy use
  - **Requirements**: Awards points for improving performance rating of the design building vs. baseline building as per ASHRAE Standard 90.1 (Appendix G) [1 to 19 points]

EAc1: Optimize energy performance (Up to 19 points)

New Buildings	Existing Building Renovations	Points
12%	8%	1
14%	10%	2
16%	12%	3
18%	14%	4
20%	16%	5
22%	18%	6
24%	20%	7
26%	22%	8
28%	24%	9
30%	26%	10
32%	28%	11
34%	30%	12
36%	32%	13
38%	34%	14
40%	36%	15
42%	38%	16
44%	40%	17
46%	42%	18
48%	44%	19

LEED Rating System



- Standards referenced by LEED, such as
  - ASHRAE Standards
    - 90.1: Building energy conservation
    - 62.1: Indoor air quality
    - 55: Thermal comfort
    - 52: Testing of air-cleaning devices
  - ANSI Standards (e.g. E779-03 for air leakage rate)
  - IESNA (lighting credits for ASHRAE 90.1)
  - ASTM Standards
  - U.S. Code of Federal Regulations (CFR)

(*ASHRAE = American Society of Heating, Refrigerating & Air-conditioning Engineers, Inc.)

ASHRAE Standard 189.1

- New ASHRAE Standard 189.1: Design of High-Performance Green Buildings
  - Developed by ASHRAE, USGBC and IESNA
  - A total building sustainability package
  - The first code-intended commercial green building standard in USA
  - It covers key topic areas similar to LEED
  - Further information:
    - www.ashrae.org/greenstandard

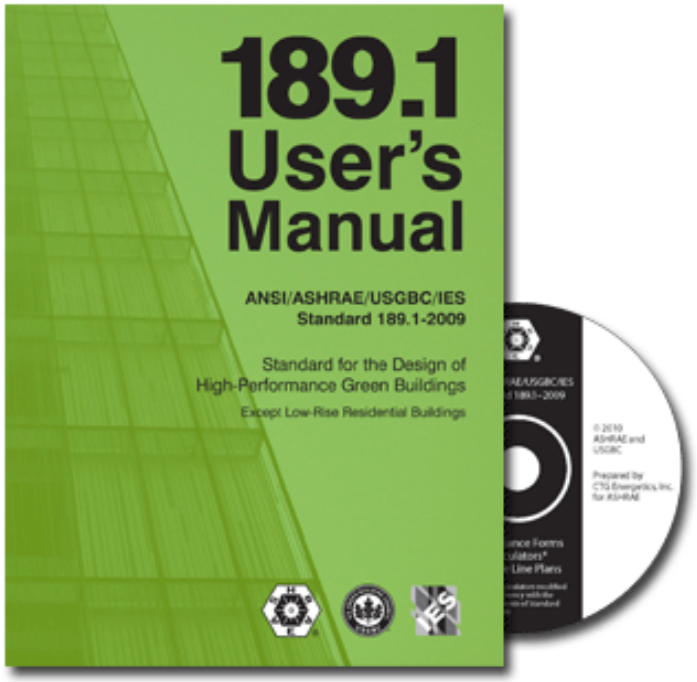
ASHRAE Standard 189.1

- What is Standard 189.1?
  - A standard developed in model code language
  - Provides minimum requirements for high-performance, green buildings
  - Applies to all buildings except low-rise residential buildings (same as ASHRAE Standard 90.1)
  - Optional compliance path to the International Green Construction Code (IgCC)
  - Not a design guide, not a rating system

ASHRAE Standard 189.1 Preview

www.ashrae.org/greenstandard

Knowledge is power.
Understanding is power^2.



(Image source: ASHRAE)

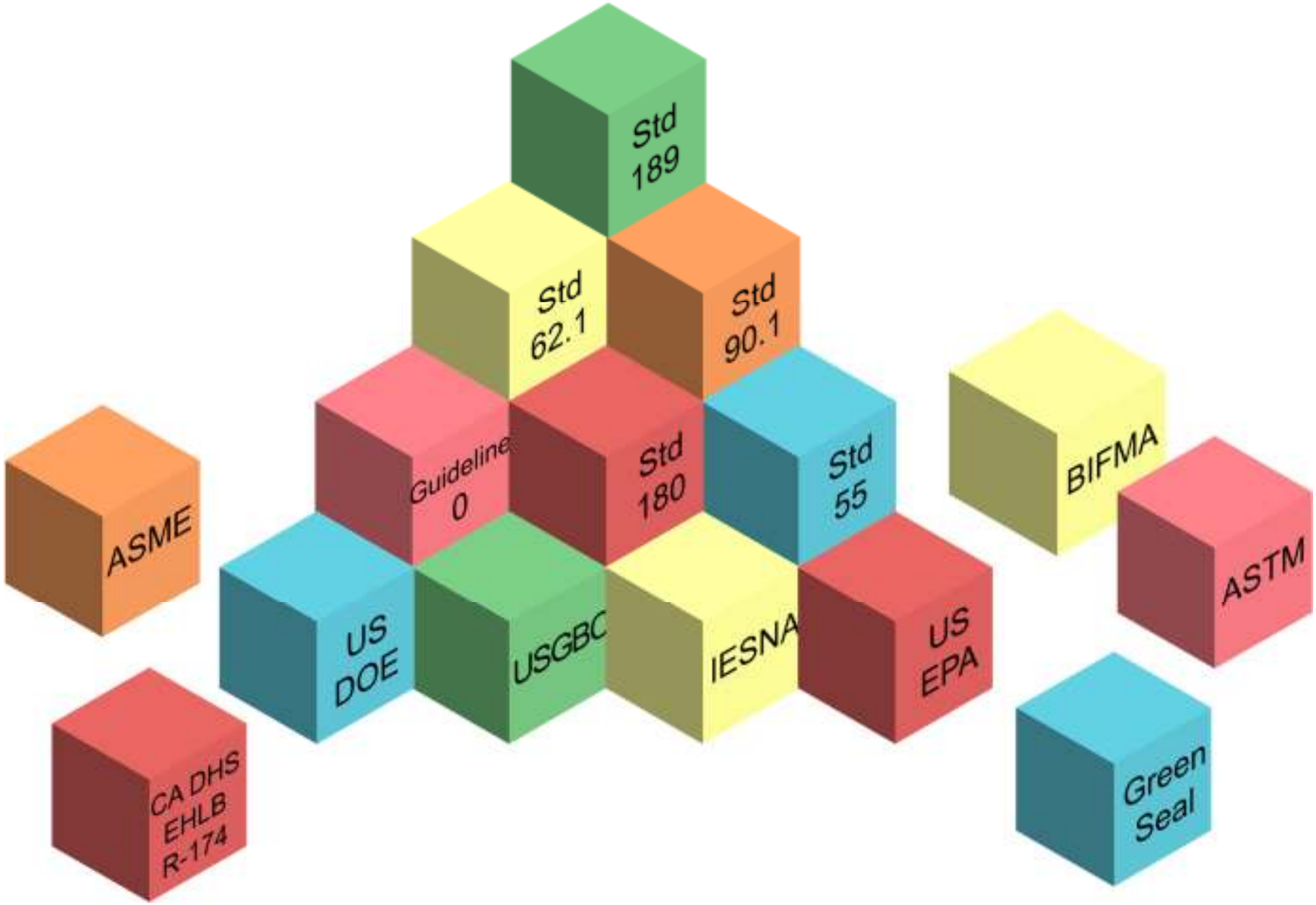
ASHRAE Standard 189.1

- It is jointly developed by:
  - ASHRAE (American Society of Heating,
  - Refrigerating and Air-Conditioning Engineers)
  - USGBC (U.S. Green Building Council)
  - IESNA (Illuminating Engineering Society of North America)
- It is also approved by American National Standards Institute (ANSI)

ASHRAE Standard 189.1

- Goals for Standard 189.1
  - Establish mandatory criteria in all topic areas
    - One “challenge” is existing green building rating systems contain few mandatory provisions
  - Provide simple prescriptive compliance options
  - Provide flexible performance compliance options
  - Complement green building rating programs
    - Standard is not intended to compete with green building rating programs (e.g. LEED)

Standard 189.1 building blocks



(Source: Mr. Kent W. Peterson)

Compliance paths of Standard 189.1

(simple option, very few calculations)

(more options, but more effort)

(Source: Mr. Kent W. Peterson)

ASHRAE Standard 189.1

- Standard 189.1 topic areas:
  - SS Sustainable Sites
  - WE Water Use Efficiency
  - EE Energy Efficiency
  - IEQ Indoor Environmental Quality
  - MR Building's Impact on the Atmosphere, Materials & Resources
  - CO Construction and Operations Plans

ASHRAE Standard 189.1

- Sustainable Sites Highlights

SS

  - Site selection
    - Allowable sites (e.g. brownfield)
    - Prohibited development activity
  - Reduce heat island effect
    - Site hardscape
    - Wall and roof
  - Reduce light pollution
    - Outdoor lighting
    - Light trepass limits

ASHRAE Standard 189.1

- Water Use Efficiency Highlights

WE

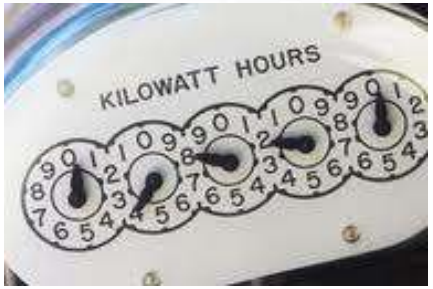
  - Site water use
    - Bio-diverse plantings, hydrozoning, and smart irrigation controllers
  - Building water use
    - Plumbing fixtures & fittings, appliances, HVAC systems & equipment
    - Cooling tower maximum cycles of concentration
  - HVAC Systems, equipment
  - Water consumption management

ASHRAE Standard 189.1

- Energy Efficiency Highlights

EE

  - More stringent than Standard 90.1-2007
    - Equipment efficiency compliance
  - Includes plug/process loads
  - Electric peak load reduction
  - Renewable energy provisions
    - On-site renewable energy systems
  - Energy measurement for verification
    - Remote or automatic reading meters



ASHRAE Standard 189.1

- Indoor Environmental Quality Highlights

IEQ

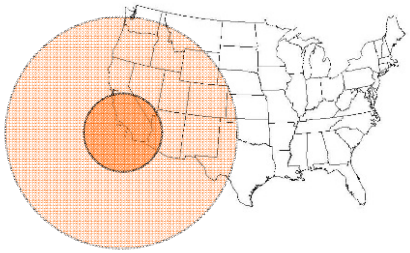
  - Indoor air quality
    - Ventilation rates per ASHRAE Standard 62.1
    - Outdoor air flow rate monitoring of min. outside air
    - MERV 8 filter (MERV 13 in PM2.5 non-attainment areas)
    - No smoking inside building
    - Source contaminant control
  - Daylighting
  - Acoustical control

ASHRAE Standard 189.1

- The Building's Impact on the Atmosphere

MR Highlights

  - Construction waste management
  - Reduced impact materials
  - Wood products
  - Refrigerants (no CFC)
  - Storage and collection of recyclables and discarded goods



ASHRAE Standard 189.1

- Construction and Operation Highlights
  - Acceptance testing / commissioning
  - IAQ construction management plan
  - Plans for Operation
    - High-performance building operation
    - Maintenance
    - Service life
    - Transportation management