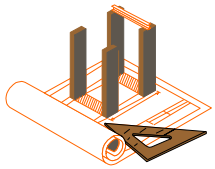
ASHRAE Technical Seminar
Friday, 17 February 2006
STDM Stadium, UM International Library
University of Macau

ASHRAE Standard 90.1 and Its Implications to Worldwide Building Energy Efficiency Codes

Dr. Sam C M Hui *
Department of Mechanical Engineering
The University of Hong Kong
E-mail: cmhui@hku.hk
(* President-Elect, ASHRAE Hong Kong Chapter)

Contents

- Introduction
- Building Energy Codes
- ASHRAE Standard 90.1
- Practical Experience
- Conclusions



(* This presentation file can be downloaded at: http://web.hku.hk/~cmhui/macau.pdf)

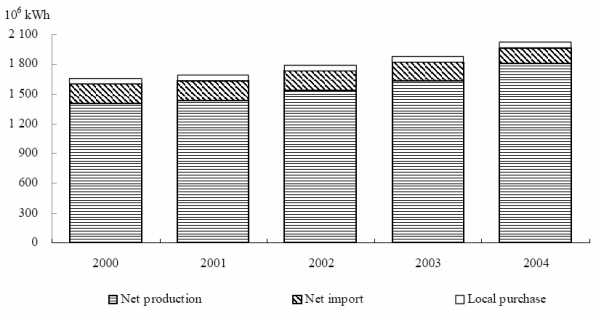
Introduction

Introduction

- **Energy** is important to every society
  - Economic, environmental & social impacts
  - A key issue for sustainable development
- Use energy …
  - Consume finite fossil fuels (oil, coal, natural gas)
  - Cause air pollution & environmental damage
  - Contribute to global warming
  - Cost money

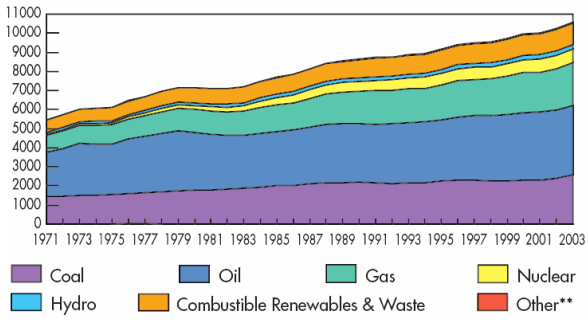
Supply of electricity in Macau

Chart 3 - Variation in composition of gross available supply of electricity

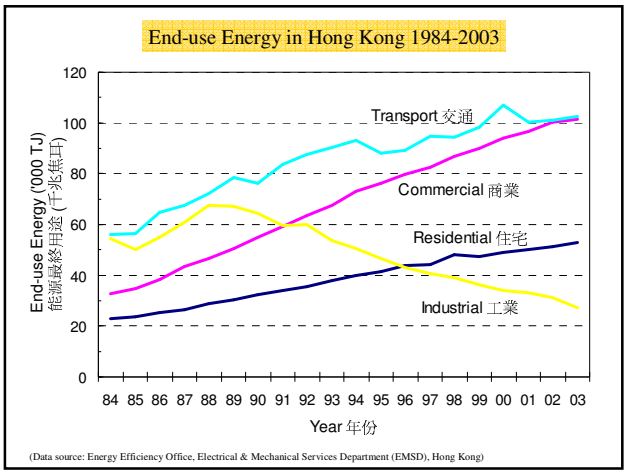


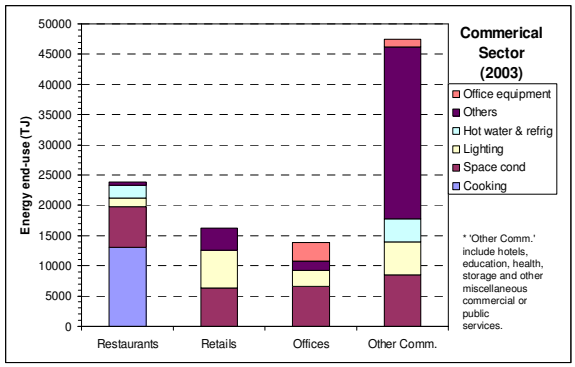
(Source: DSEC, 2005. *Balance of Energy 2004*, Statistics and Census Service (DSEC), Government of Macau SAR, Macau.)

World Total Primary Energy Supply by Fuel (Mtoe)



(Source: *Key World Energy Statistics from the IEA*, 2005 Edition.)





Energy consumption patterns in commercial buildings
(Data source: Energy Efficiency Office, HK)

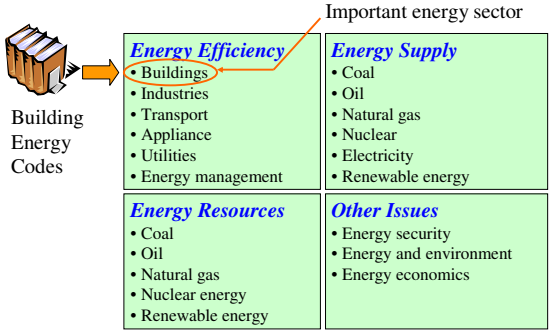
Introduction

- Benefits of energy-efficient buildings
  - Energy saving
  - Greater comfort
  - Better occupant satisfaction
  - More productive
  - Fewer health problems due to indoor air pollutants
  - Reduced greenhouse gas emissions
  - Decreased reliance on imported energy

Building Energy Codes

Building Energy Codes

- Why we need building energy codes (BEC)?
  - Energy efficiency is often discounted in a commercial free market
  - Barriers to energy efficiency
    - Separation of interests between developers & tenants
    - Time & capital constraints of designers/consumers
    - Lack of institutional support & coordination
  - BEC can promote efficiency and ensure good practice is considered & used

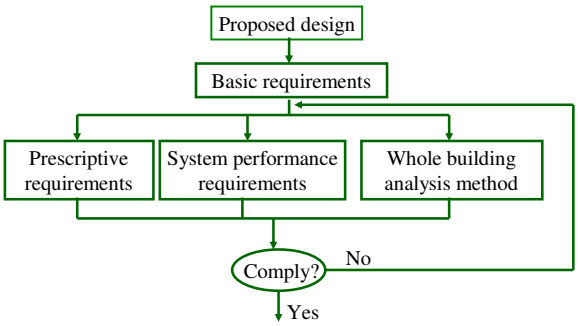


Building energy codes in the national energy policy

Building Energy Codes

- Examples of BEC in the world
  - USA and Canada
    - National model codes and state codes
  - Australia and New Zealand
  - Japan
  - South East Asia, e.g.
    - Singapore, Malaysia, Thailand, Philippines
  - Hong Kong
  - Mainland China

Compliance paths in building energy codes

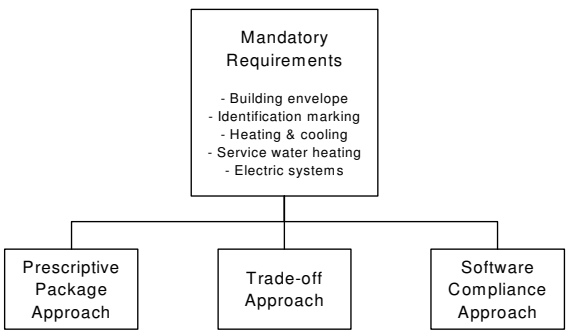


Building Energy Codes

- **Prescriptive** approach
  - Specify minimum requirements for each component e.g. insulation levels & equipment efficiencies
    - For example, maximum U-value for roofs
  - "*This is what you must do*"
  - Simple, easy to follow and enforce
  - Least flexible, does not encourage innovation
  - Restrictive, not deal with the building as a whole

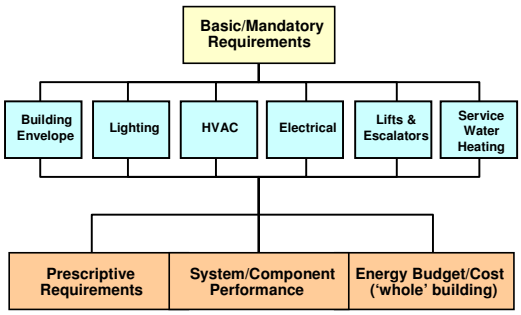
Building Energy Codes

- **Performance** approach
  - Set maximum allowable performance level without specifying the methods, materials and processes to be employed to achieve it
    - For example, custom & fixed energy/cost budgets
  - "*This is what you must achieve*"
  - Consider the end rather than the means
  - Flflexible, allow innovation & alternative solutions
  - More complex, w/ whole building performance



Compliance options of US Model Energy Code

Building systems and compliance options



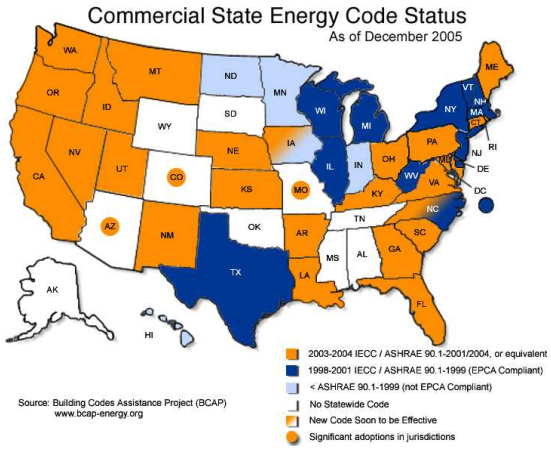
ASHRAE Standard 90.1

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
    - IESNA (Illuminating Engg. Society of North America)
    - ANSI (American National Standards Institute)

ASHRAE Standard 90.1

- US Energy Policy Act requires State codes to meet or exceed 90.1-1999, by July 2004
  - It becomes law when 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



ASHRAE Standard 90.1

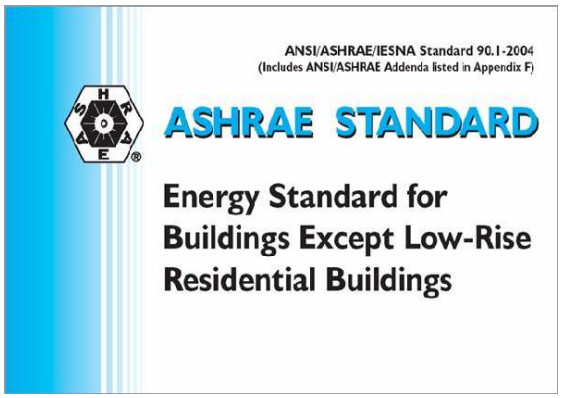
- Different versions of ASHRAE 90.1
  - 90-1975
    - Earliest version (in response to energy crisis)
  - 90A-1980 (w/ 90B-1975 and 90C-1977)
    - Modified & included lighting procedure from IESNA
  - 90.1-1989 and 1993 codified version of 1989
    - Significant change in envelope compliance
    - Towards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

- Related ASHRAE Standards
  - 90.1-2004: for commercial buildings
  - 90.2-2004: for low-rise residential buildings
  - 100-1995: for existing buildings
  - 105-1984: measuring and expressing building energy performance
  - 140-2004: evaluation of building energy analysis computer programs
  - 169P: (draft) weather data for building design
  - 55-2004: thermal comfort
  - 62.1-2004: ventilation for acceptable IAQ



ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (www.ashrae.org)

ASHRAE Standard 90.1

- Section 1 - Purpose
- Section 2 - Scope
- Section 3 - Definitions, Abbreviations, and Acronyms
- Section 4 - Administration and Enforcement
- Section 5 - Building Envelope
- Section 6 - Heating, Ventilating, and Air-Conditioning
- Section 7 - Service Water Heating
- Section 8 - Power
- Section 9 - Lighting
- Section 10 - Other Equipment
- Section 11 - Energy Cost Budget Method
- Section 12 - Normative References

ASHRAE Standard 90.1

- Appendices
  - Appendix A – Rated R-Value of Insulation in Assembly, U-Factor, C-Factor, and F-Factor Determinations
  - Appendix B – Building Envelope Climate Criteria
  - Appendix C – Methodology for Building Envelope Trade-Off Option in Subsection 5.6
  - Appendix D – Climatic Data
  - Appendix E - Informative References
  - Appendix F - Addenda Description Information (Informative)
  - Appendix G - Performance Rating Method (Informative)

ASHRAE Standard 90.1

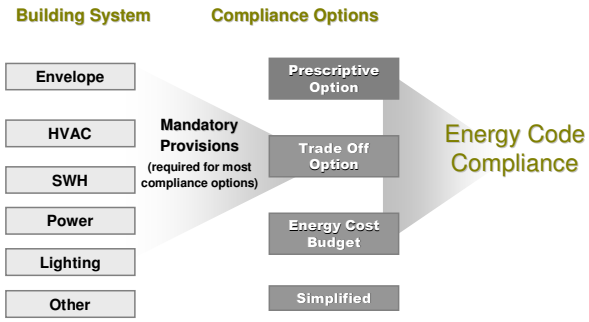
- Purpose: provide *minimum* requirements for the energy-efficient design of buildings except low-rise residential buildings
- Not a design or advanced building guide
  - Separate advanced energy design guides were developed by ASHRAE and other related bodies
- Consensus standard (open ANSI process)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

ASHRAE Standard 90.1

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

ASHRAE Standard 90.1

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

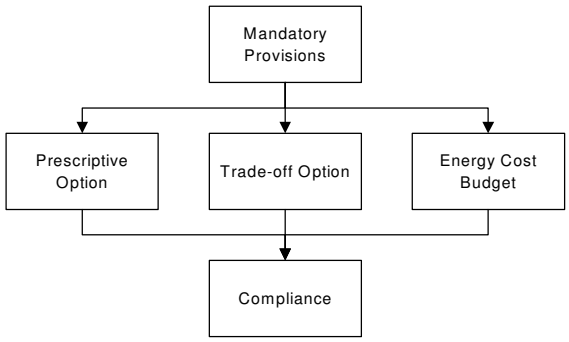


Compliance options in ASHRAE 90.1-2004

(Source: www.energycodes.gov)

ASHRAE Standard 90.1

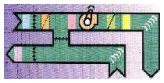
- Building Envelope
  - Mandatory Provisions (Section 5.4)
    - Insulation, fenestration and doors, air leakage
  - Prescriptive building envelope option (Section 5.5)
    - Opaque Areas
    - Fenestration
  - Building envelope trade-off options (Section 5.6)
    - Envelope performance factor (EPF)
  - Product information and insulation requirements (Section 5.8)

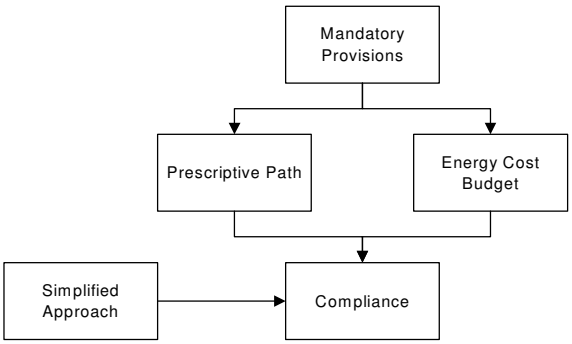


Envelope compliance options in ASHRAE 90.1-2004

ASHRAE Standard 90.1

- HVAC Systems
  - Mandatory provisions
    - Minimum equipment efficiency (Section 6.4.1)
      - Such as coefficient of performance (COP), energy efficiency ratio (EER) and integrated part load value (IPLV)
    - Load calculations (Section 6.4.2)
    - Controls (Section 6.4.3)
    - HVAC system construction and insulation (Section 6.4.4)
    - Completion requirements (e.g. O&M, commissioning)
  - Prescriptive
  - Simplified (for small building, simple system)
  - Energy cost budget





HVAC compliance options in ASHRAE 90.1-2004

ASHRAE Standard 90.1

- HVAC equipment covered
  - Package air conditioners and condensing units
  - Heat pumps (air, water, and ground source)
  - Packaged terminal and room air conditioners
  - Chillers including absorption chillers
  - Furnaces and unit heaters
  - Boilers
  - Heat rejection equipment

ASHRAE Standard 90.1

- Lighting
  - Mandatory provisions (Section 9.4)
    - Lighting control, Tandem wiring, exit signs
    - Exterior building grounds lighting
      - Lamp efficacy (> 60 lm/W)
      - Power density limits
  - Building area method compliance path (Section 9.5)
    - Installed interior power must not exceed wattage allowances (with some exceptions/allowances)
      - Based on set of specified whole building or space type Lighting Power Densities (LPD)
  - Alternative compliance path: space-by-space method (Section 9.6)

ASHRAE Standard 90.1

- 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

ASHRAE Standard 90.1

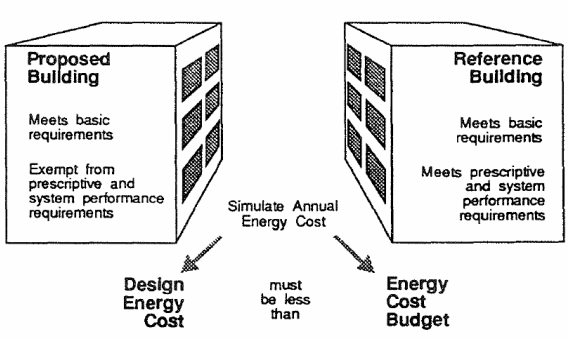
- Service Water Heating
  - Prescriptive and energy cost budget
  - Mandatory provisions (Section 7.4)
    - Load calculations
    - Equipment efficiency
    - Service hot water piping insulation
    - System controls
    - Pools
    - Heat traps
  - Prescriptive path (Section 7.5)
    - Space heating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

ASHRAE Standard 90.1

- Power and Other Equipment
  - Max voltage drop allowed at design load
    - Feeder conductors
    - Branch circuit conductors
  - Motor efficiency levels correspond to Energy Policy Act of 1992 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

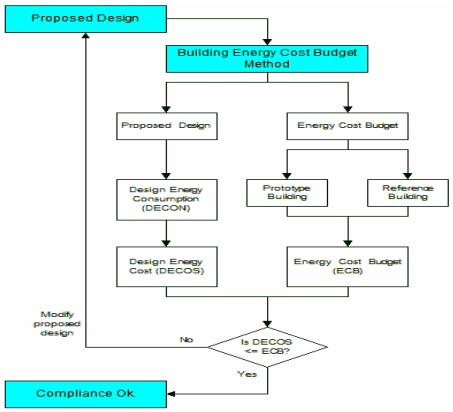
ASHRAE Standard 90.1

- 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

ASHRAE Standard 90.1

- Energy Cost Budget (ECB) Method
  - 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

ASHRAE Standard 90.1

- Building Performance Rating Method (App. G)
  - Instructions for using the ASHRAE Standard 90.1-2004 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

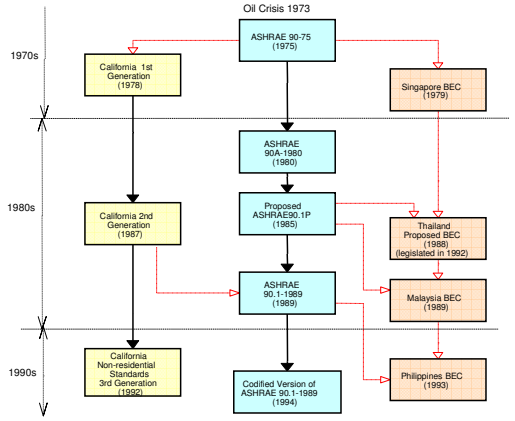
LEED

Practical Experience

Experience in Southeast Asia

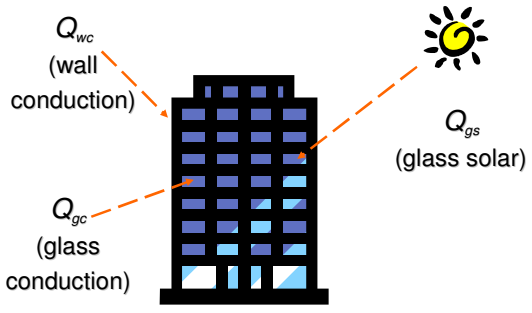
- Building energy codes in Southeast Asia
  - Singapore (1979 – mandatory; revised 2004)
  - Malaysia (1989 – voluntary)
  - Thailand (1992 – mandatory; updated 2005)
  - Philippines (1994 – mandatory, not enforced)
  - Indonesia (1994 – voluntary)
- Models/Documents used for reference
  - ASHRAE 90-75, 90A-1980, 90.1P, 90.1-1989
    - In fact, the ASHARE standards are also influenced by the California's building energy codes

Development of codes in California, ASHRAE and Southeast Asia



Experience in Southeast Asia

- Major control requirements
  - Building envelope
    - **O**verall **T**hermal **T**ransfer **V**alue (OTTV)
      - First introduced in ASHRAE Standard 90-1975 (* it was removed later, starting from 1989 version)
      - Adapted for the warm climates in Southeast Asia
      - Emphasis on the impact of solar heat
  - Building services systems
    - Lighting, air conditioning, power
    - Follows ASHRAE 90.1's recommendations, but with local adaptation



$$OTTV_i = \frac{Q_{wc} + Q_{gc} + Q_{gs}}{A_i}$$

$$= \frac{(A_w \cdot U_w \cdot TD_{eq}) + (A_f \cdot U_f \cdot DT) + (A_f \cdot SC \cdot SF)}{A_i}$$

Energy efficiency measures in Southeast Asia countries

Country	Building codes		Appliance standards		Energy audits	
	Comm.	Resident.	Comm.	Resident.	Comm.	Resident.
Indonesia	Mandatory	---	---	---	Voluntary	---
Malaysia	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary	---
Philippines	Mandatory	---	Mandatory	Mandatory	Voluntary	---
Singapore	Mandatory	Mandatory	Voluntary	Voluntary	Voluntary	---
Thailand	Partly Mand.	Partly Mand.	Partly Mand.	Partly Mand.	Voluntary	---
Vietnam	Voluntary	Voluntary	Voluntary	Voluntary	Mandatory	Mandatory

Note: The information is extracted from Balce and Zamora (2000).

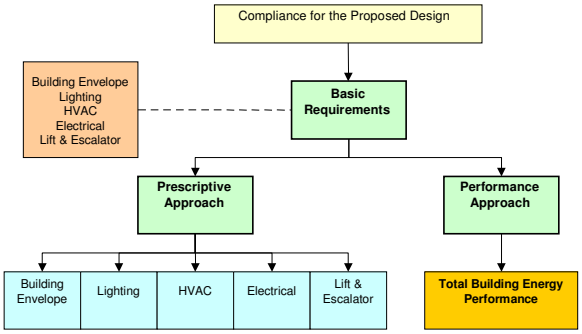
Experience in Hong Kong

- Hong Kong
  - Mandatory OTTV code since July 1995
  - Voluntary codes of practices
    - Lighting
    - Air-conditioning
    - Electrical
    - Lifts & escalators
    - Performance-based building energy code
      - Using total-energy-budget approach
  - Energy efficiency registration scheme for buildings (voluntary)

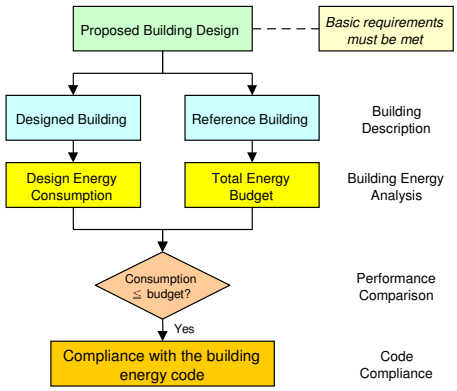
Building energy codes in Hong Kong *

Code	Year implemented	Status	Scope
OTTV (building envelope)	1995	Mandatory	Commercial buildings and hotels
Lighting	1998	Voluntary	All buildings except domestic, industrial and medical ones
Air-conditioning	1998	Voluntary	All buildings except domestic, industrial and medical ones
Electrical services	1999	Voluntary	All buildings except special industrial process
Lifts and escalators	2000	Voluntary	All buildings except special industrial process
Performance-based building energy code	2003	Voluntary	Commercial buildings and hotels

(* Codes and guidelines can be downloaded from http://www.emsd.gov.hk)



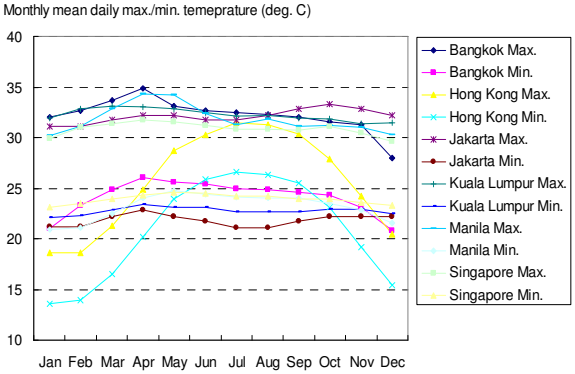
Framework of the building energy codes in Hong Kong

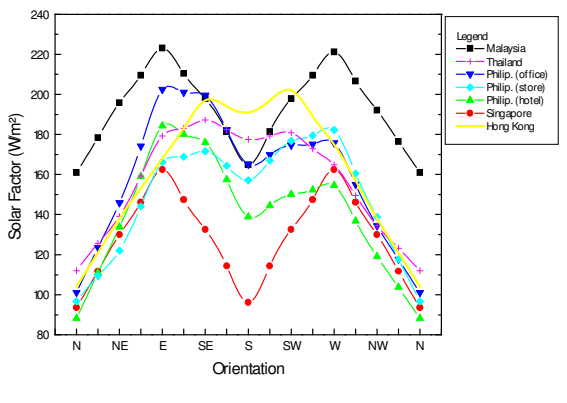


Performance compliance for building energy code

Comparison of OTTV standards in Southeast Asia

	Singapore	Malaysia	Indonesia	Thailand	Philippines	Hong Kong
Latitude (North)	1°20′ Singapore	3°7′ Kuala Lumpur	6°11′ Jakarta	13°41′ Bangkok	14°35′ Manila	22°18′ Hong Kong
Year adopted	1979	1989	1994	1992	1993	1995 (updated 2000)
Current Status	Mandatory	Voluntary	Proposed	Mandatory	Voluntary	Mandatory
Applied to	new bldgs. for comm. use	new & exist ing bldgs. for comm. use	N/A	new & existing bldgs. for comm. use	new bldgs. for comm. use	new comm. bldgs. & hotels
OTTV limits for walls (W/sq.m)	45	45	45	45 (new) 55 (extg.)	48	Tower : 30, podium: 70 (average for walls & roof)
OTTV limits for roof (W/m)	45 (max. U-value if no skylights)	25 (max. U-value if no skylights)	N/A	25 (max. U-value if no skylights)	Max. U-value if no skylights	

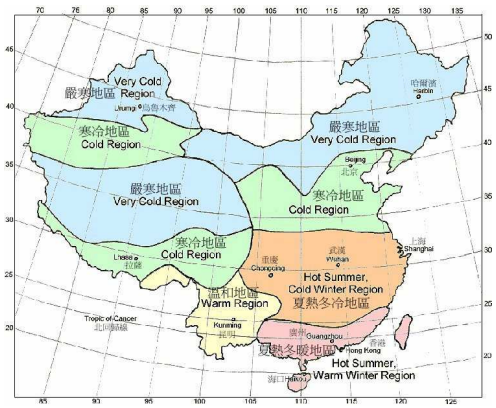




Experience in Mainland China

- Building energy codes in Mainland China
  - JGJ 26-1995, Energy Conservation Design Standard for New Heating Residential Buildings
  - JGJ 134-2001, Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone
  - JGJ 75-2003, Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter Zone
  - GB 50189-2004, Design Standard for Energy Efficiency of Public Buildings

Make reference to ASHRAE 90.1



Climatic zones for building design in mainland China

Conclusions

Conclusions

- Building energy codes are very important for promoting energy efficiency
  - Can help establish a benchmark for assessing building energy performance
- ASHRAE Standard 90.1 sets a reference model for building energy codes
  - Different versions have been adopted in the world
- More codes & their upgrades are expected to come up

Further Information

- Online preview of the standards (go to www.ashrae.org and click "Technology & Standards" sector)
  - ASHRAE 90.1-2004
  - ASHRAE 90.2-2004
- Standard 90.1 User's Manual (from ASHRAE bookstore)
- US-DOE's Building Energy Codes Program
  - http://www.energycodes.gov/

Thank You

ASHRAE
Engineering for Sustainability