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

<table>
<thead>
<tr>
<th>Year</th>
<th>Net production (GWh)</th>
<th>Net import (GWh)</th>
<th>Total (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1,200</td>
<td>800</td>
<td>2,000</td>
</tr>
<tr>
<td>2001</td>
<td>1,500</td>
<td>700</td>
<td>2,200</td>
</tr>
<tr>
<td>2002</td>
<td>1,800</td>
<td>600</td>
<td>2,400</td>
</tr>
<tr>
<td>2003</td>
<td>2,000</td>
<td>500</td>
<td>2,500</td>
</tr>
<tr>
<td>2004</td>
<td>2,200</td>
<td>400</td>
<td>2,600</td>
</tr>
</tbody>
</table>


World Total Primary Energy Supply by Fuel (Mtoe)

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

- 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

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

Building energy codes in the national energy policy

![Diagram showing energy consumption patterns in commercial buildings](image-url)

![Building Energy Codes](image-url)
**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**

- Proposed design
  - Basic requirements
  - Prescriptive requirements
  - System performance requirements
  - Whole building analysis method
  - Comply?
    - No
    - Yes

**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
  - Flexible, allow innovation & alternative solutions
  - More complex, w/ whole building performance

**Compliance options of US Model Energy Code**

**Building systems and compliance options**

- Basic/Mandatory Requirements
  - Building envelope
  - Identification marking
  - Heating & cooling
  - Service water heating
  - Electric systems

- Prescriptive Requirements
  - System/Component Performance
  - Energy Budget/Cost ('whole' building)
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)

  - 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

- 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 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

- 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

- 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

• 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

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)

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

Compliance options in ASHRAE 90.1-2004
Dr. Sam C M Hui (cmhui@hku.hk)

**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)
  - 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 luminaire 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
    - 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
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

Experience in Southeast Asia

- Building energy codes in Southeast Asia
  - Singapore (1979 – mandatory; revised 2004)
  - Malaysia (1989 – voluntary)
  - Philippines (1994 – mandatory, not enforced)
  - Indonesia (1994 – voluntary)
- Models/Documents used for reference
  - In fact, the ASHARE standards are also influenced by the California’s building energy codes
Dr. Sam C M Hui (cmhui@hku.hk)

Experience in Southeast Asia

- Major control requirements
  - Building envelope
    - Overall Thermal Transfer Value (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

Energy efficiency measures in Southeast Asia countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Building codes</th>
<th>Appliance standards</th>
<th>Energy audits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>Mandatory</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Voluntary</td>
<td>Voluntary</td>
<td>Voluntary</td>
</tr>
<tr>
<td>Philippines</td>
<td>Mandatory</td>
<td>Mandatory</td>
<td>Voluntary</td>
</tr>
<tr>
<td>Singapore</td>
<td>Mandatory</td>
<td>Voluntary</td>
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</tr>
<tr>
<td>Vietnam</td>
<td>Voluntary</td>
<td>Voluntary</td>
<td>Mandatory</td>
</tr>
</tbody>
</table>

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 codes
      - Using total-energy-budget approach
  - Energy efficiency registration scheme for buildings (voluntary)
Building energy codes in Hong Kong *

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

(* 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

Comparison of solar factors for different OTTV methods
Experience in Mainland China

- Building energy codes in Mainland China
  - GB 50189-2004, Design Standard for Energy Efficiency of Public Buildings

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/