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# **Performance-based Standards for Energy Efficient Buildings**

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# Introduction-Situation and Observations

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- Air conditioning typically contributes about half of the energy consumption of a commercial building
- Building Sector accounts for more than one third of the total electrical consumption in Singapore
- Need for appropriate design guidelines and energy standards to take advantage of advancing technology, ease the compliance process and ensure that commercial buildings are designed and operated to a high standard of comfort and efficiency



# Introduction-Situation and Observations

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- Appropriate engineering tools are required for the design and operation of buildings
- Building services maintenance can lead to improved energy management and energy savings
- Skills training and experience required to act on opportunities and maximise benefits



# Energy Conservation in Buildings- Historical Development

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- 1979: Prescriptive Standards incorporated in the Building Control Regulations
- 1982,1983: Launch of CP 24 Parts 1,2 and 3
- Mid 80s: Development of new OTTV
- 1999: Compliance of CPs 13, 24 and 38
- 2001: Commencement of BCA-funded project on energy efficiency index for non-residential buildings



# Development of Guidelines and Standards

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- Design of Building Envelopes
- Design for Energy Efficiency
- Design Tools



# Design of Building Envelopes

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- Existing OTTV

$$OTTV = \frac{(A_w \times U_w \times TDeq) + (A_f \times U_f \times \Delta T) + (A_f \times SC \times SF)}{A_o}$$



# Design of Building Envelopes

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- New ETTV

$$ETTV = TDeq(1 - WWR)U_w + \Delta T(WWR)U_f + SF(WWR)(CF)(SC)$$

$$TDeq = 11.9^\circ C$$

$$\Delta T = 3.37^\circ C$$

$$SF = 210.9W / m^2$$



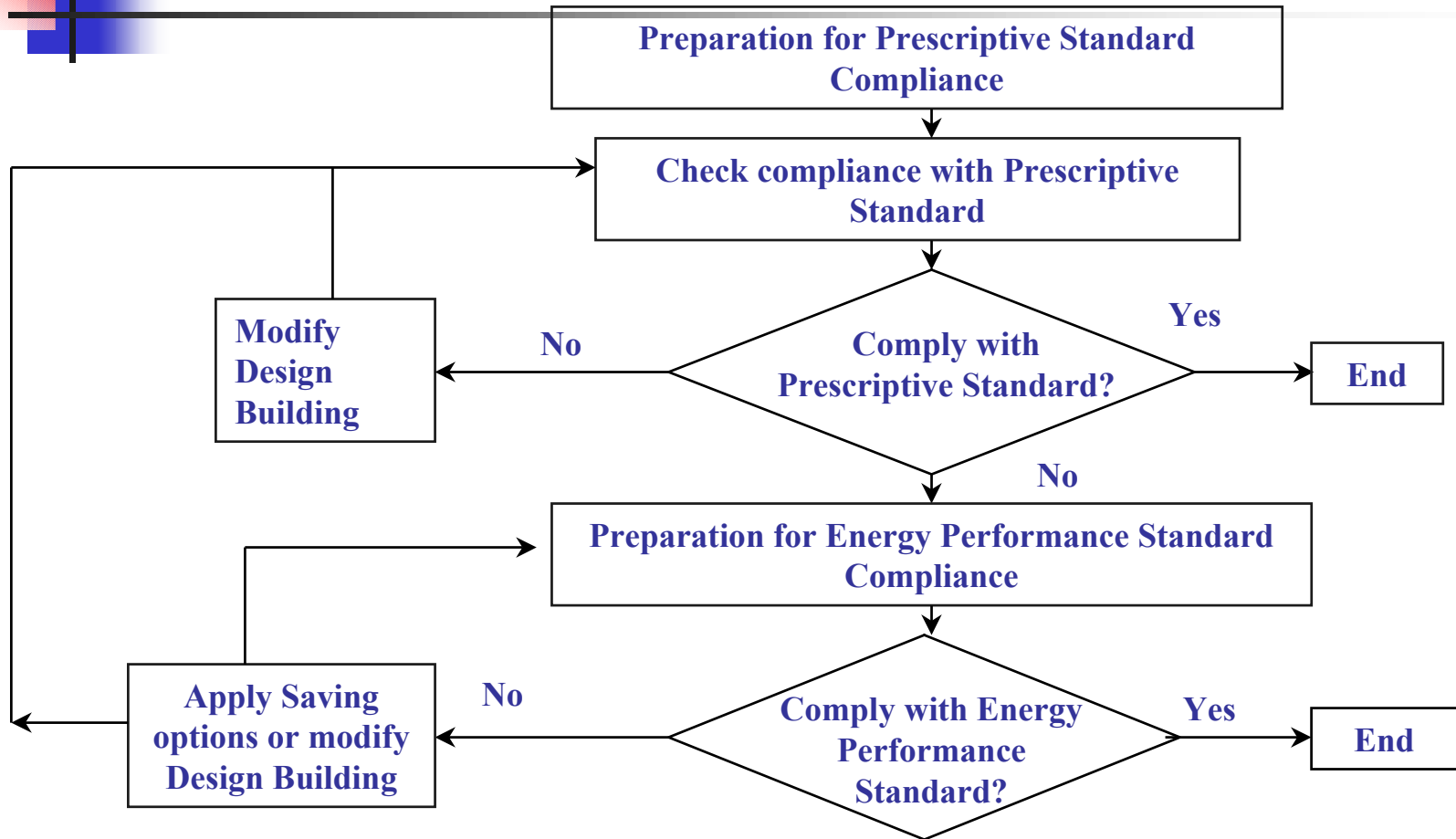
# Design for Energy Efficiency

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- Designing for Energy Performance - The System Analysis Approach
- Energy Efficiency Index (EEI) Bands
- Energy Management

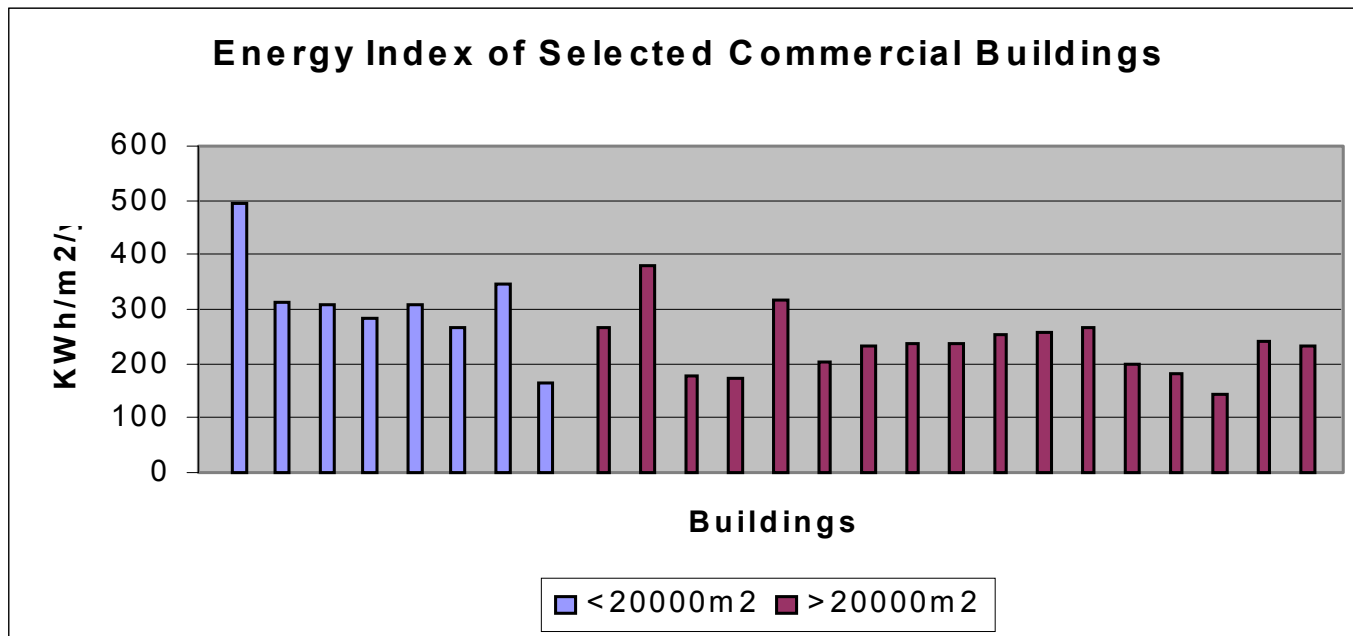


# Designing for Energy Performance- The System Analysis Approach



# Design for Energy Efficiency

- Energy Efficiency Index (EEI) Bands
- Average EEI 293.6kWh/m<sup>2</sup>/year for GFA < 20,000m<sup>2</sup>
- Average EEI 233.6kWh/m<sup>2</sup>/year for GFA > 20,000m<sup>2</sup>





# Design for Energy Efficiency

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- Energy Efficiency Index (EEI) Bands
  - Short Term Targets (< 3 yrs)
    - < 20,000m<sup>2</sup>: 300 to 320kWh/m<sup>2</sup>/year
    - > 20,000m<sup>2</sup>: 240 to 260kWh/m<sup>2</sup>/year
  - Long Term Targets (> 5 yrs)
    - < 20,000m<sup>2</sup>: 260 to 280kWh/m<sup>2</sup>/year
    - > 20,000m<sup>2</sup>: 220 to 240kWh/m<sup>2</sup>/year



# Design for Energy Efficiency

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- Energy Management
  - Energy Auditing
  - Training
  - Maintenance
  - BAS



# Design Tools

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- DOE-2
- Simulation Codes  
(Proprietary and public domain)
- BEST Software

# Computation and Compliance

## – An example by BEST

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- ETTV and RTTV Calculation.
- Annual Energy Consumption Estimation.
- Peak Design Loads Estimation.
- Lighting and Receptacle Power Allowance Calculation.
- Parametric Analyses.
- Energy Saving Options.

# Sample Form (ETTV Input Form)

ETTV

Section	Type	Area	Pitch Angle	Orientation	Solar Corr Factor	Shading Corr Factor
1	Wall #1	334	90	N	0.80000001	1
2	Wall #1	334	90	S	0.82999998	1
3	Wall #1	334	90	E	1.13	1
4	Wall #1	334	90	W	1.23	1
5	Fens #1	200.16	90	N	0.80000001	1
6	Fens #1	200.16	90	E	1.13	1
7	Fens #1	200.16	90	S	0.82999998	1
8	Fens #1	200.16	90	W	1.23	1

ETTV

Design Value 43.36 W/m2

Prescribed Value 70.00 W/m2

OTTV

Design Value 29.86 W/m2

Prescribed Value 45.00 W/m2

ADD DELETE < > UPDATE External Shading Coeff

ETTV

Section	Type	Area	Pitch Angle	Orientation	Solar Corr Factor	External Shading Corr Factor
1	Wall #1	334	90	N	0.80000001	1

# Sample Form (Energy Performance)

Energy Performance
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### Building Data

Gross Floor Area of Building  m<sup>2</sup>

Total Lighted Area in Building  m<sup>2</sup>

Total Conditioned Area in Building  m<sup>2</sup>

Number of Occupants in Design Building  Persons

Number of Occupants in Prototype Building  Persons

### Cooling Plant

Air conditioners, air cooled, split system<19.05

Prototype Setpoint Temperature

◀◀
▶▶
Chiller of Prototype Building
▶▶

°C

Prototype COP

Design COP

Design Outdoor Air [cfm/person]

Design Setpoint Temperature

°C

**Update Results**

### Building Operation

Operating Hours per  Hours

Operating Days per  Day

### Peak Space Load Estimation

Sensible Cooling Load	<b>162.48</b>	kW
Latent Cooling Load	<b>15.02</b>	kW
Total Space Cooling	<b>177.50</b>	kW

### Building Type

Office

Retail

Hotel

### Annual Energy Performance

	<u>Design</u>	<u>Prototype</u>
Cooling Energy	<b>494.79</b>	<b>896.48</b>
Total Energy Consumption	<b>716.87</b>	<b>1,146.82</b>
El,ac	<b>113.09</b>	<b>204.91</b>
El,gross	<b>113.09</b>	<b>204.91</b>



# Sample Form (Shading)

**External Shading Devices**

**Fenestration**

Facade Section:

Orientation:

**Type of Shading Devices**

Continuous horizontal projection

Continuous vertical projection

Egg-crate Louvres

**Shading Coefficient**

Facade:  Shading Coefficient:

**Elevation view**

**INPUT [Horizontal projection]**

P / A:

Horizontal angle of Inclination  $\phi_1$ :

Clear

Update

Edit ETTV

# Sample Form (Summary)

**Results Summary (without savings)**

**Project Description**

Building Description: Generic Office Building  
Building Type: Office

**Prescriptive Standard**

	<u>Design</u>	<u>Prescribed</u>	<u>Status</u>
Lighting Allowance [W/m <sup>2</sup> ]	13.50	10.50	Failed
Receptacle Power Density [W/m <sup>2</sup> ]	3.00	8.10	Passed
ETTV [W/m <sup>2</sup> ]	43.36	70.00	Passed
RTTV [W/m <sup>2</sup> ]	19.88	62.00	Passed

**Energy Performance Standard**

	<u>Design</u>	<u>Prototype</u>	<u>Status</u>
Annual Cooling Energy [MWh]	494.79	896.48	Passed
Annual Total Energy Consumption [MWh] (without savings)	716.87	1,146.82	Passed