Workshop on:

ENERGY EFFICIENT BUILDING DESIGN IN HOT CLIMATES

Sultan Qaboos University, Muscat, Oman

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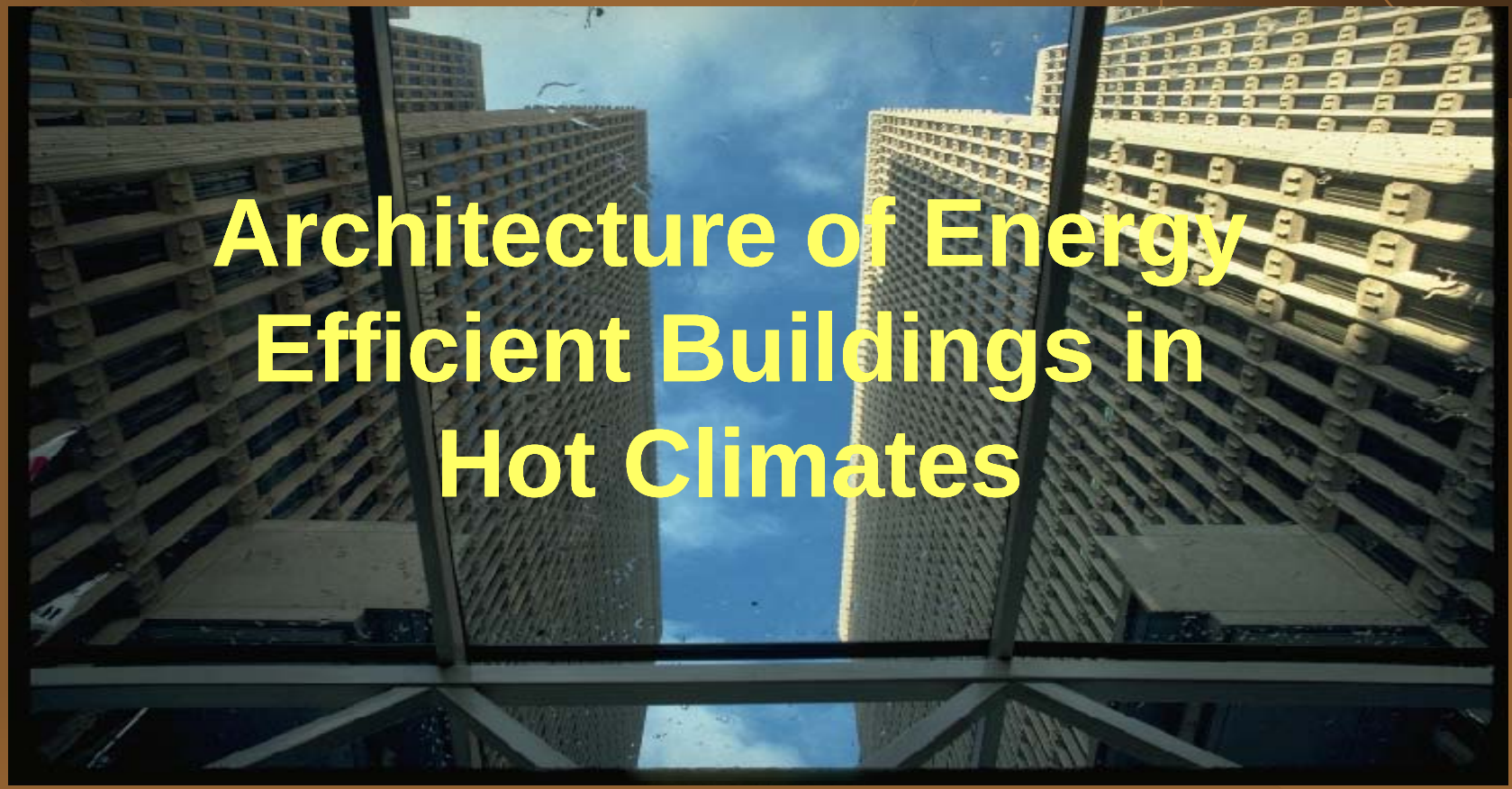

Architecture of Energy Efficient Buildings in Hot Climates

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Architecture of Energy Efficient Buildings in Hot Climates

Energy Efficient Architectural Design

Reasons:

- Buildings are large consumers of energy;
- Buildings are replaced very slowly;
- Early design decisions are the most effective and the least expensive.
- Most buildings cannot be operated without HVAC systems.

Energy Efficient Architectural Design

Reasons: (Cont.)

- Conservation is the best approach to use less energy. It:
  - Helps extend the life of existing energy resources;
  - Has less environmental impact;
  - Reduces the cost of production and consumption.

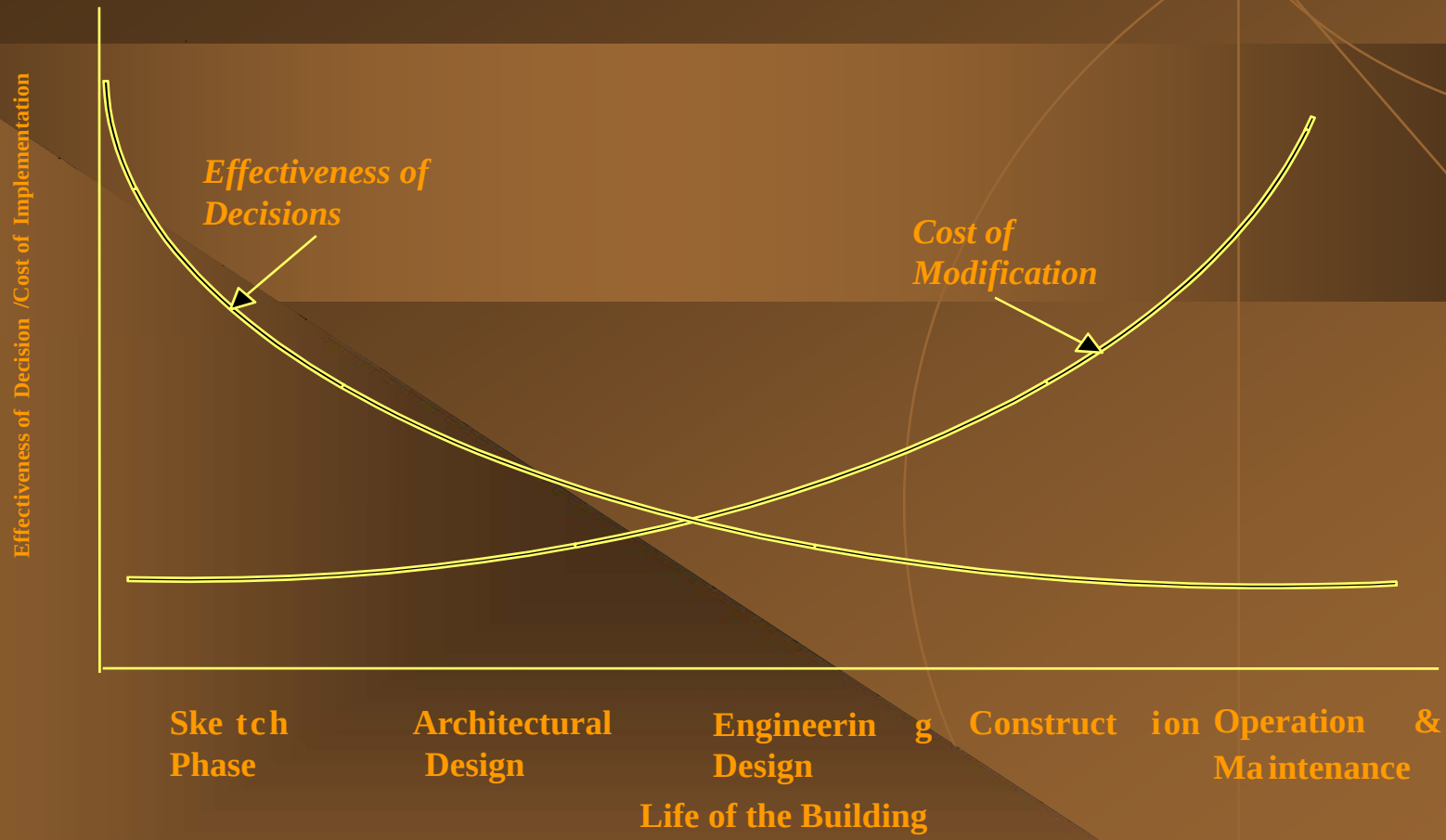
Energy Efficient Architectural Design

Objectives:

- Less thermal loads and, therefore, less equipment size (less HVAC first cost);
- Less operating (energy) cost over the life of the building;
- More thermally comfortable indoor environment especially in between seasons;
- Better looking buildings that interact well with the environment.

Impact of Design Decisions:

- ***Early design decisions*** are critical and determining factors in the initial and operating costs of buildings.
- ***Early design decisions*** are *easier* to implement at *less* cost with *more* impact on the building performance.
- ***Late decisions*** are *more* difficult to implement, cost *more*, and have *less* impact on the performance of the building.



Cost of decision and its impact on the performance of the building through the various stages over its life.

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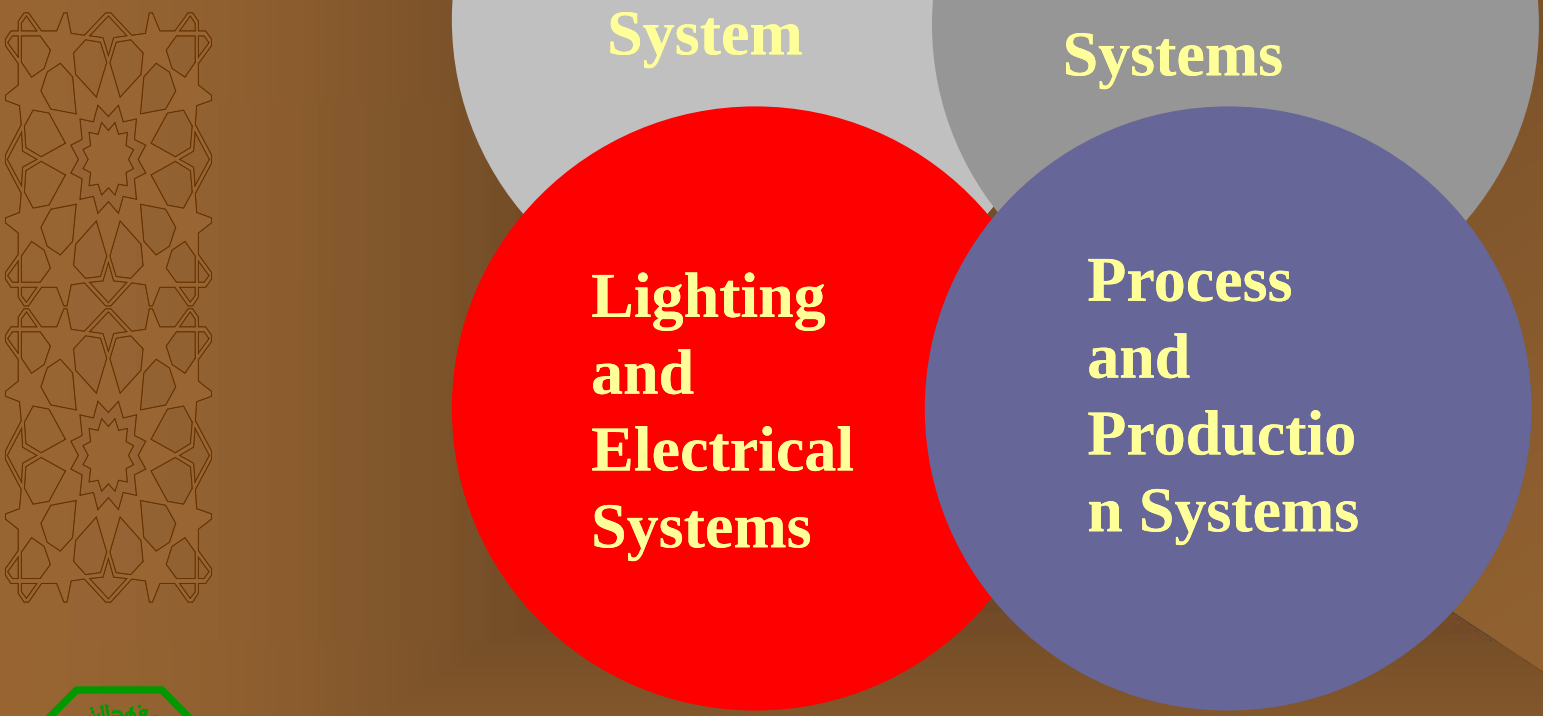

Building Energy Systems Interaction

Architecture of Energy Efficient Buildings in Hot Climates

Energy Efficient Building Design
Basic Requirements:

In order to achieve energy efficient building design, the designer has to understand:

- The influencing climate;
- The building type and characteristics;
- The appropriate energy design strategies;

Climatic Regions

- Every site is unique in its governing constraints and microclimate.
- Subdividing regions into climatic zones is neither an easy nor definite task.
- Climatic regions have no sharp line boundary.

Climatic Regions (Cont.)
Cool Climate:

- Severe cold winter temperatures;
- Short hot summers.

The sun is welcome during winter to supplement heating during this cold period.

Climatic Regions (Cont.)

Temperate Climate:

- Very mild climate;
- Cool winter temperatures with frequent rain;
- Overcast skies.

Varying elevations and distance from the coast cause large microclimate variations that should be considered by designers for specific projects.

Climatic Regions (Cont.)

Hot-arid Climate:

- Extremely hot and dry summers;
- Very large diurnal temperature ranges;
- Moderately cold winters;
- Clear skies most of the year.

The main concern for a designer is summer overheating.

Climatic Regions (Cont.)

Hot-Humid Climate:

- Long hot and humid summers;
- Very small diurnal temperature ranges;
- Short and mild winters.

The main concern for the designer is hot and humid summer conditions.

Building Types

- Building thermal performance is determined by:
  - Outside weather conditions;
  - Building form;
  - Envelope design;
  - Internal loads;
  - Function and zoning;
  - Operating profile.

An understanding of these parameters and their interaction is essential for energy efficient design.

Building Types (Cont.)
Internal-Load Dominated (ILD):

- Dominated by high internal loads basically from lighting, equipment, and occupants.
- Less influenced by outside weather conditions.
- Often require cooling most times of the year.

The main parameters of thermal significance are: internal loads, operating profile, orientation, form and envelope components.

Building Types (Cont.)
Skin-Load Dominated (SLD):

- Thermal behavior significantly influenced by changes in the outside weather conditions.
- Internal loads are less significant to thermal performance compared to ILD buildings.

The main parameters of thermal significance are: envelope components, form and orientation.

Design Strategies
Building Site & Orientation:

- Avoid/minimize building on west slopes:
  - North slopes are best if winter solar heating is not required;
  - South slopes are best if winter solar heating is desirable.
- Elongate the building on the east-west axis;
- Project windows on east and west facades so that they face in a northerly or southerly direction;

Design Strategies (Cont.)

Building Site & Orientation: (Cont.)

- Site and orient the building to capture the prevailing winds;
- Direct and channel winds toward building by means of landscaping and landforms;
- Avoid light-colored ground covers around the building unless daylighting is important;

Design Strategies (Cont.)

Building Site & Orientation: (Cont.)

- Avoid reflections from adjacent structures with reflective surfaces;
- Keep area around the building dry by using proper drainage of land;
- Channel runoff water from the roof and paved areas away from the site;
- Avoid pools and fountains.

Design Strategies (Cont.)

Glazing:

- Use few and small windows to keep heat out;
- Avoid/minimize west windows if at all possible;
- Use only vertical glazing;
- Any horizontal or sloped glazing (skylights) should be shaded on the outside during summer;
- Only skylights on steep northern roofs do not require exterior shading;
- Use double glazing to reduce conduction heat gains;

Design Strategies (Cont.)

Glazing: (Cont.)

- Use glazing for minimum heat gain and maximum visible light (e.g. heat mirror)
- Use exterior shading devices on all windows;
- Use interior shading devices to supplement exterior shading;
- Use movable insulation over windows for un-occupied periods and winter use.

The significance of glazing properties increases with increased amount of glass used.

Design Strategies (Cont.)

Wall & Roof Construction:

- Use ample insulation (low U-values) in the building envelope. The roof and west walls are the most critical;
- Use highly reflective building surfaces, low absorptance (white is best);
- Shade east and especially west walls. In very hot climates also shade the south wall.
- Use earth sheltering in the form of underground or bermed structures.

Design Strategies (Cont.)

Ventilation and Infiltration:

- Do not use evaporative cooling strategies;
- Provide cross-ventilation using large windows on the windward and leeward sides of the building;
- Use a combination of high and low openings to take advantage of the stack effect.
- Use open rather than solid shading devices to prevent trapping hot air next to windows;

Design Strategies (Cont.)
Ventilation and Infiltration:

- Seal cracks and openings around the building envelope for infiltration/exfiltration control;
- Use revolving doors and/or air curtain doors to keep air-conditioned cool air in;
- Use exhaust fans in kitchens, bathrooms, laundry rooms, etc. to remove excess moisture;
- Avoid deep basements that cannot be ventilated well.

Design Strategies (Cont.)

Building Mass:

- Influenced by the seasonal and daily variations, which determine the need for thermal resistance and mass of the building structure.
- Insulation is more critical in climates with extreme seasonal variations and small daily variations.
- Building thermal mass plays a more significant role in balancing the indoor temperatures in climates with large diurnal ranges.
- Higher internal mass stores excess heat and releases it during unoccupied and cooler periods.

Design Strategies (Cont.)

Building Form:

- Select to allow minimum summer heat gains with the least winter heat losses;
- Use compact designs to minimize surface area-to-volume ratio;
- Square shaped buildings have the least outside surface-to-volume ratio;
- However, for buildings with significant radiation effects from large windows, elongation on the east-west axis is more desirable;

Design Strategies (Cont.)
Building Form: (Cont.)

- High-rise buildings have less outside surface roof exposures compared to low-rise buildings
- Minimize the number of exposed walls using attached buildings or clusters with enough ventilation;
- Have neighboring buildings shade each other;
- Use the form of the building to shade itself (e.g., cantilever floors, balconies, courtyards).

Design Strategies (Cont.)

Building Zoning:

- Zone the building so that space comfort cooling is provided only while occupied;
- Use open floor plan with minimum partitions for maximum airflow;
- Place summer use outdoor courtyards on the north or east sides of the building;
- Use shaded outdoor spaces (e.g. garages) to protect south, east, and especially west facades.

Design Strategies (Cont.)
Daylighting:

- Utilize daylighting to reduce reliance on artificial lighting;
- Benefit from north openings for daylighting;
- Use glazing that allows maximum visible light in with minimum heat gain;
- Use proper lighting control to benefit from daylighting.

Design Strategies (Cont.)

Plantation:

- Use plants for shading;
- Use evergreen trees on the east, west, and north sides of a building;
- Use deciduous plants for shading the southeast, the southwest and the roof;
- Minimize trees, shrubbery, and ground covers to allow air circulation to remove moisture;

Design Strategies (Cont.)

Plantation: (Cont.)

- Use only trees that have a high canopy;
- Use vegetation and shade structures;
- Use underground or drip rather than spray irrigation;
- Minimize plants especially indoors;
- Use plants that add little water to the air by transpiration.

Design Strategies (Cont.)

Other Systems:

- Insure proper HVAC system design/selection;
- Use energy efficient HVAC system/equipment;
- Utilize energy recovery systems when appropriate;
- Use energy efficient lighting system;
- Use Building Energy Management System (BMS);
- Insure proper operation and maintenance.

Alternative Design Strategies
Evaluation:

- Alternative energy design strategies should be proposed and evaluated carefully.
- The best approach for evaluation is through building energy analysis.

Building Energy Analysis
Objectives:

- Evaluation of alternative designs, systems, subsystems, components;
- Allocation of annual energy budgets;
- Compliance with energy standards;
- Economic optimization.

Building Energy Analysis (Cont.)
Levels:

- Simplified energy analysis.
- Detailed energy analysis.

Building Energy Analysis (Cont.)

Methods:

- Degree-Day Method
- Modified Degree-Day Method
- Variable-Base Degree-Day Method
- Modified Bin Method
- Detailed Building Energy and Systems Simulation
- Optimization Techniques

Building Energy Analysis (Cont.)

Selection Criteria:

- Accuracy;
- Sensitivity;
- Speed and cost of learning and use;
- Reproducibility;
- Ease of use and level of detail (i.e. complexity of the input procedure);
- Availability of required data;
- Quality of the output;
- Stage of the project.

Conclusions

- Consider the amount and distribution of glazing over the building exposure carefully;
- West exposures are the least desirable;
- Shading is the first line of defense in hot climates;
- Building orientation with east-west elongation is generally desirable in all climates;

Conclusions (Cont.)

- Avoid square buildings and north-south elongation;
- Use low absorptance (light colors) surfaces;
- Use enough wall and roof insulation;
- Roof insulation is generally more critical than walls;
- Treat cracks and leaks around the building envelope carefully to control infiltration;
- Utilize daylighting effectively;

Conclusions (Cont.)

- Select proper and efficient lighting system;
- Select/design HVAC and other energy systems carefully;
- Utilize energy recovery systems whenever possible;
- Use Building Management Systems (BMS);
- Utilize energy analysis to evaluate design alternatives;
- Insure proper operation & maintenance.

Thank You