UNIVERSITY OF NORTH CAROLINA CHARLOTTE

Energy Efficiency Strategies for Hotel Design in Hot and Humid Climates

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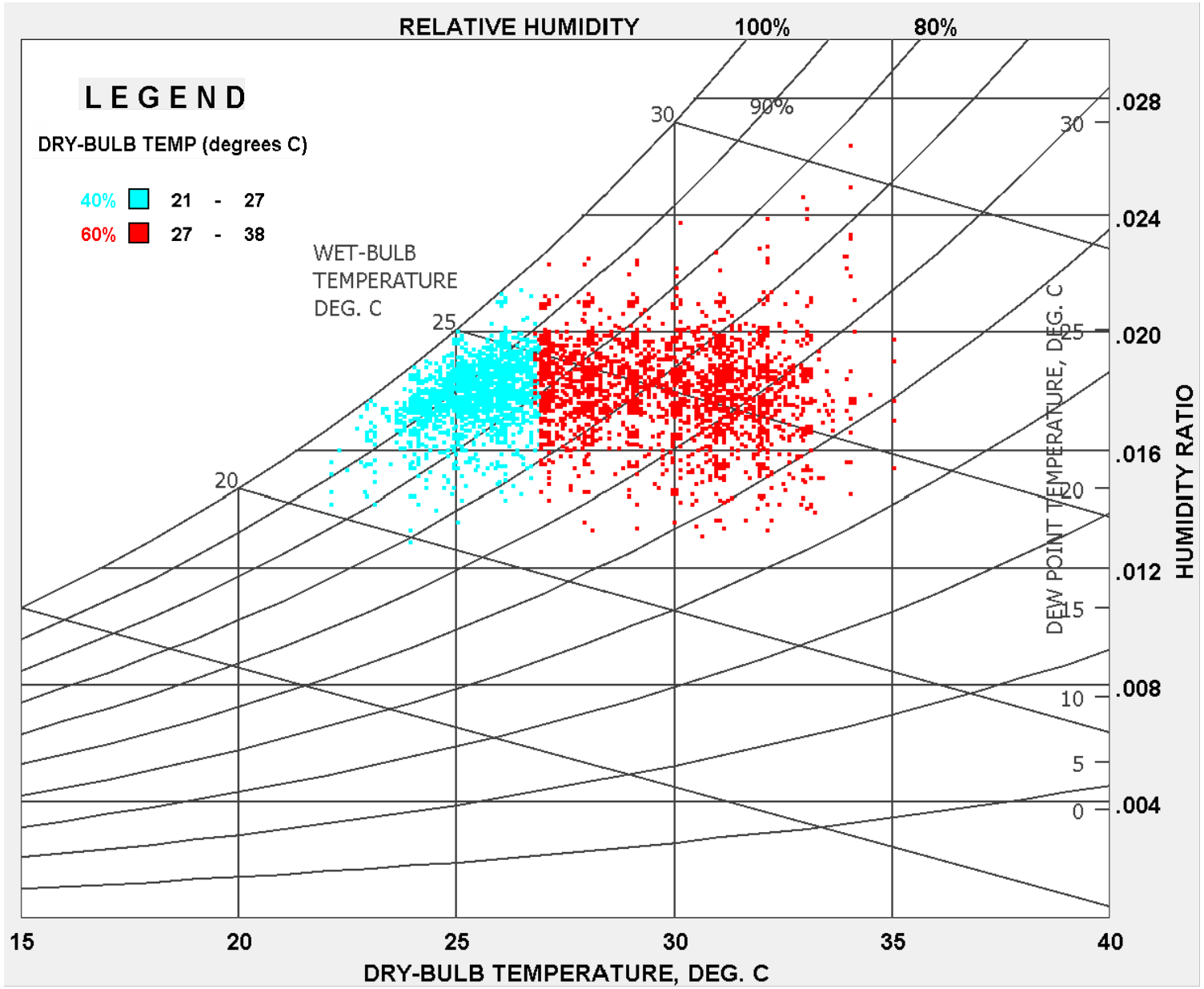
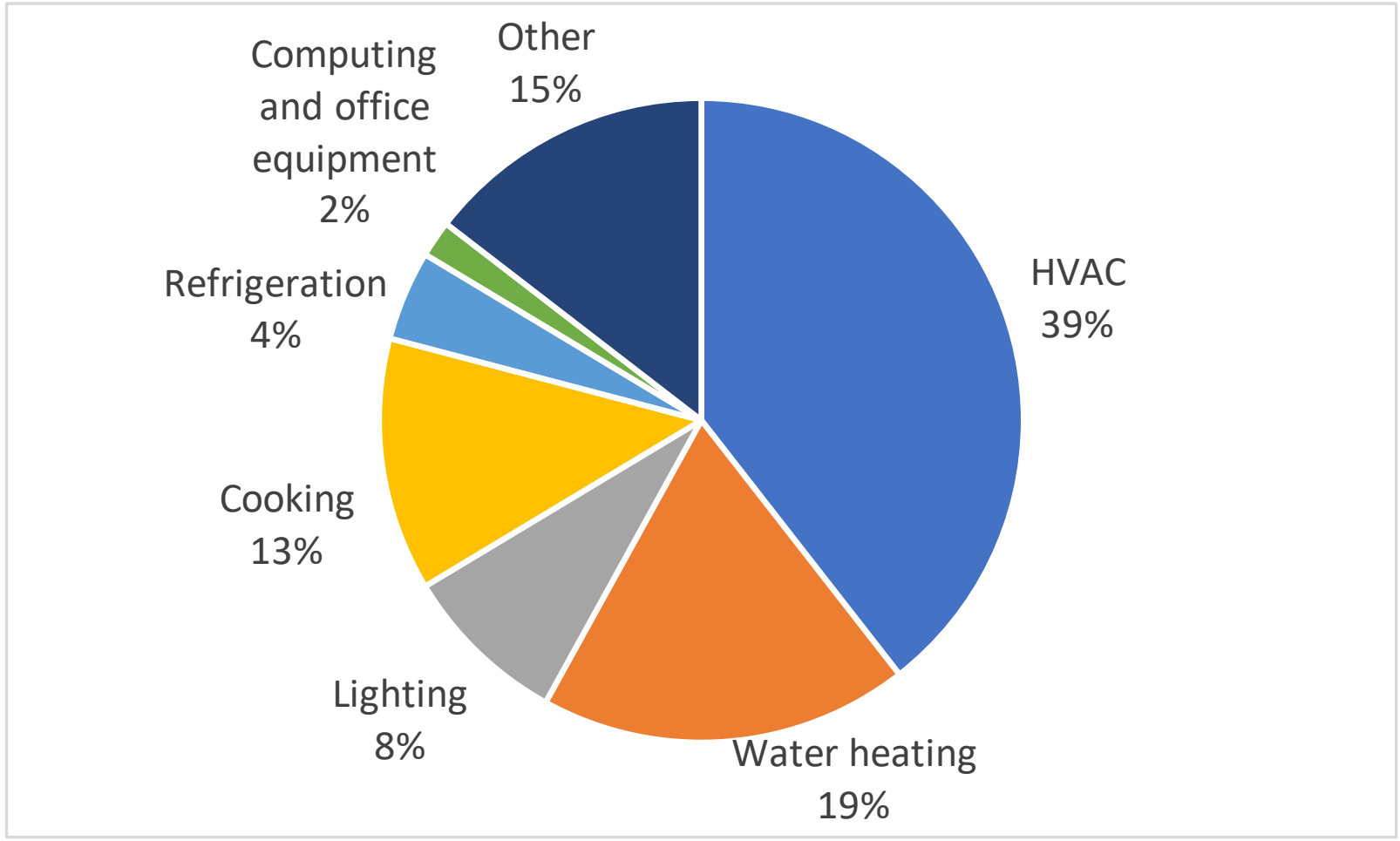
Climate Analysis

- Location: Jakarta-Soekarno-Hatta Intl. Airport
- Hot humid climate (Climate zone Af based on Koppen-Geiger and Climate zone 0A based on ASHRAE STD 169)
  - Average yearly temperature: 27.8°C
  - Hottest yearly temperature (99%): 33°C
  - Coldest yearly temperature (1%): 23.8°C
  - Dew point temperature seldomly below 18°C



Energy End Uses in Lodging

- A hotel can be divided into three main areas:
  - Guest rooms
  - Public areas (e.g., lobby, restaurants and dining rooms, meeting rooms, stores)
  - Back-of-the-house areas (e.g., kitchens, storage areas, laundry, offices)



Source: Commercial Building Energy Consumption Survey 2018.

Key Design Criteria

- Guest comfort and satisfaction
  - Thermal
  - Indoor air quality
  - Acoustics
  - Privacy
  - Visual

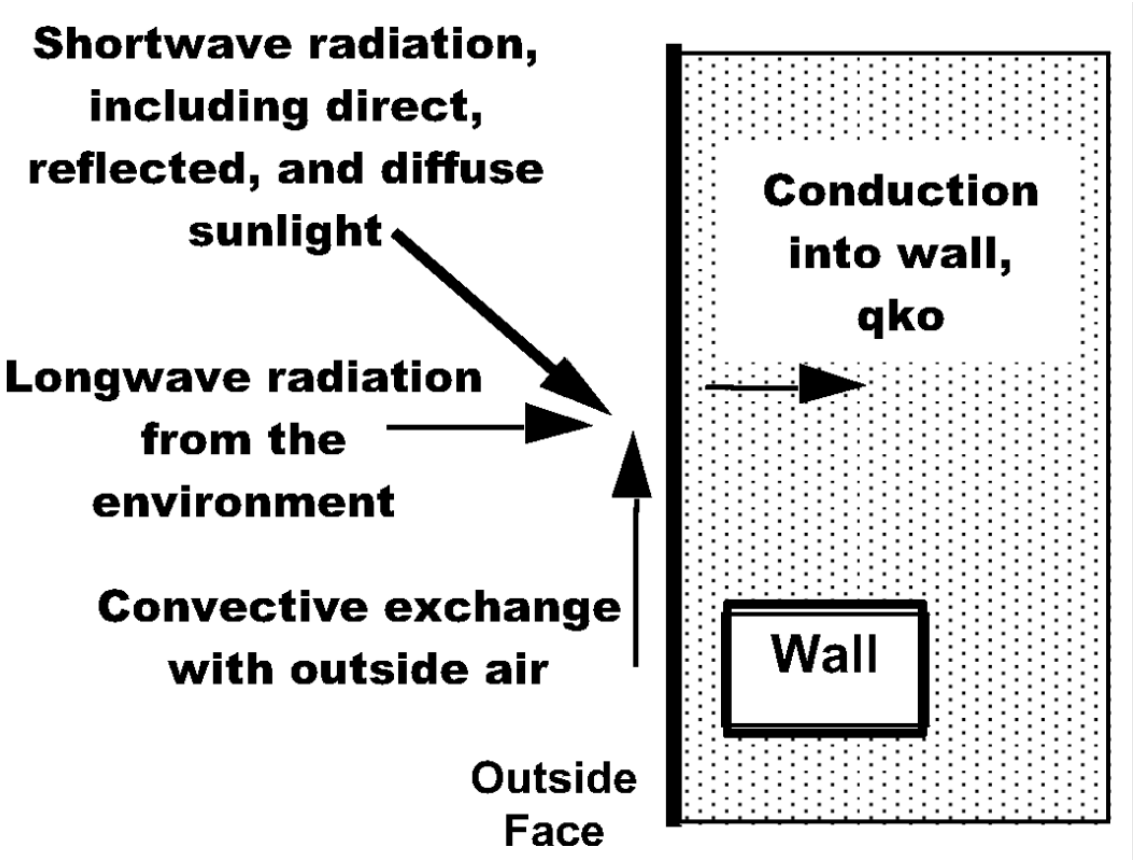
Guest comfort and satisfaction are not in conflict with energy efficiency.

Energy Efficiency Design Strategy Categories

- Building envelope
- HVAC equipment and systems
- Lighting
- Service water heating

Strategies to Minimize Heat Gains Through Opaque Envelope

- Building siting, orientation and shape, see the Bioclimatic Design lecture
- Reduce heat conduction
- Reduce solar heat gains on the exterior surface



Reduce Heat Conduction

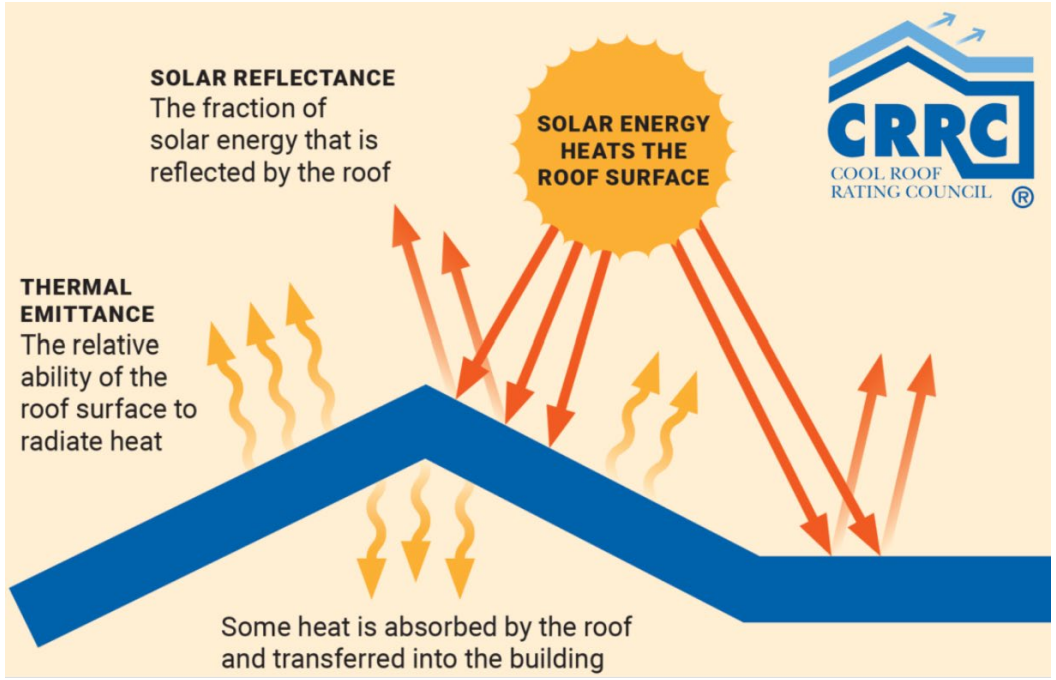
- The table (**IP units**) lists the requirements for Climate Zone 0 by ASHRAE Standard 90.1-2022.
- More stringent requirements exist in other sources such as ASHRAE Standard 189.1

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
			Roofs			
Insulation entirely above deck	U-0.039	R-25 *c.i.*	U-0.032	R-30 *c.i.*	U-0.218	R-3.8 *c.i.*
Metal building [a]	U-0.041	R-10 + R-19 FC	U-0.041	R-10 + R-19 FC	U-0.115	R-10
Attic and other	U-0.027	R-38	U-0.027	R-38	U-0.081	R-13
			Walls, above-Grade			
Mass	U-0.580	NR	U-0.151 [b]	R-5.7 *c.i.* [b]	U-0.580	NR
Metal building	U-0.094	R-0 + R-9.8 *c.i.*	U-0.094	R-0 + R-9.8 *c.i.*	U-0.352	NR
Steel-framed	U-0.124	R-13	U-0.124	R-13	U-0.352	NR
Wood-framed and other	U-0.089	R-13	U-0.089	R-13	U-0.292	NR
			Wall, below-Grade			
Below-grade wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
			Floors			
Mass	U-0.322	NR	U-0.322	NR	U-0.322	NR
Steel joist	U-0.350	NR	U-0.350	NR	U-0.350	NR
Wood-framed and other	U-0.282	NR	U-0.282	NR	U-0.282	NR
			Slab-on-Grade Floors			
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
			Opaque Doors			
Swinging	U-0.370		U-0.370		U-0.700	
Nonswinging	U-0.310		U-0.310		U-1.450	

Source: ASHRAE Standard 90.1-2022

Reduce Solar Heat Gains on the Exterior Surface

- Cool roof
  - ASHRAE Standard 90.1 requires 3-year-aged **solar reflectance** at least 0.55 and 3-year-aged **thermal emittance** at least 0.75
  - Cool roof products rated by CRRC (https://coolroofs.org/directory/roof)
  - Cool roof calculator (https://web.ornl.gov/sci/buildings/tools/cool-roof/)
- Cool exterior wall
  - ASHRAE Standard 90.1 requires that above-grade east-, south-, and west-oriented opaque walls have solar reflectance at least 0.30 and thermal emittance at least 0.75
  - Cool exterior wall products rated by CRRC (https://coolroofs.org/directory/wall)



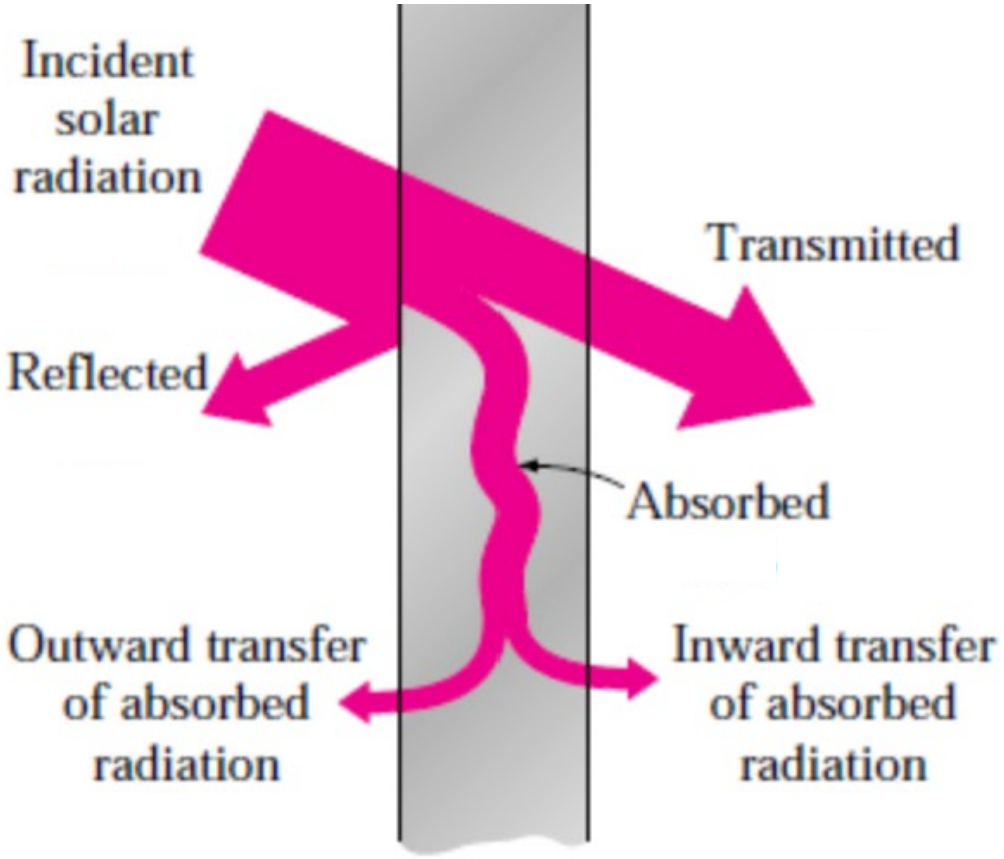
Reduce Solar Heat Gains on the Exterior Surface (Cont'd)

- Vegetative roof/wall
- Ventilated double skin facades

MIA Design Studio Office in Ho Chi Ming City, Vietnam (https://www.archdaily.com/956242/mia-design-studio-office-mia-design-studio)

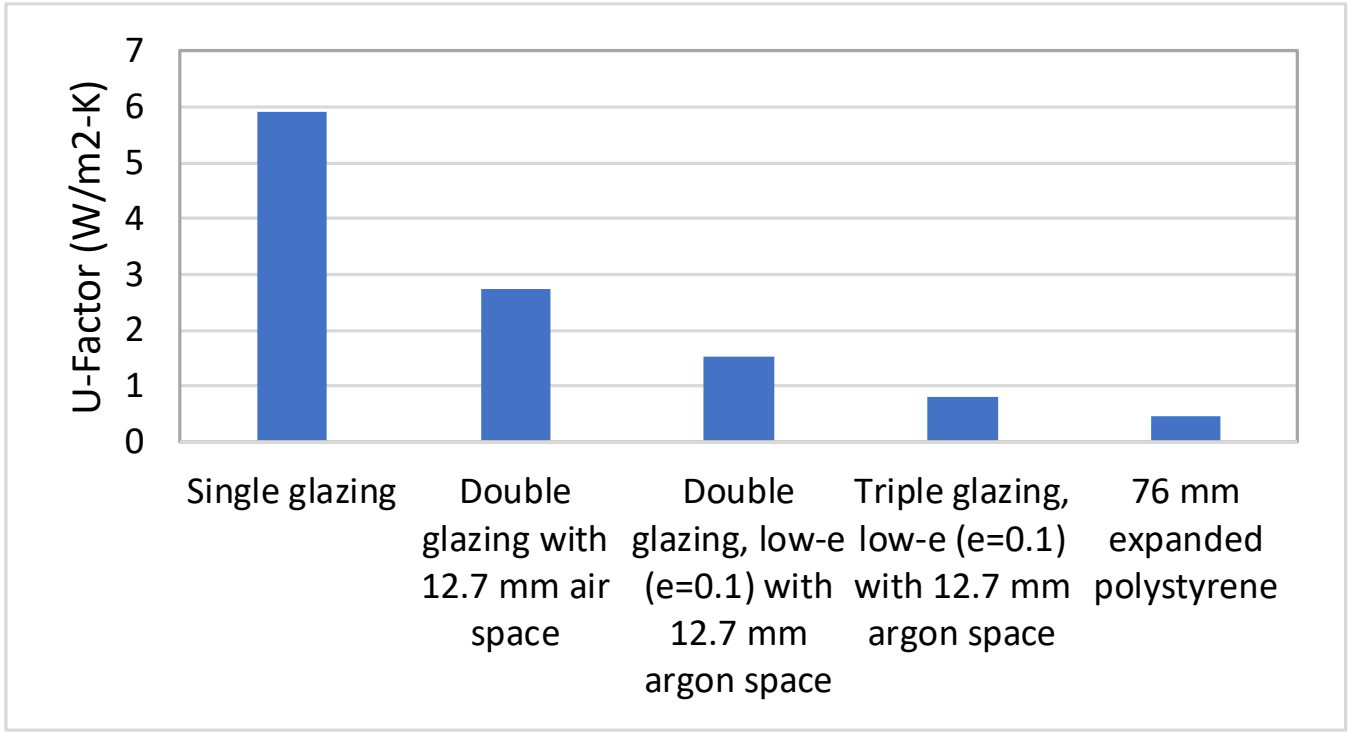
Fenestration Impact on Building Energy Consumption

- U-Factor
- Solar heat gain coefficient (SHGC)
- Visible transmittance
- Air leakage
- Products certified by the National Fenestration Rating Council (NFRC) (https://search.nfrc.org/search/Searchdefault.aspx)



Strategies to Minimize Solar Heat Gains Through Fenestration

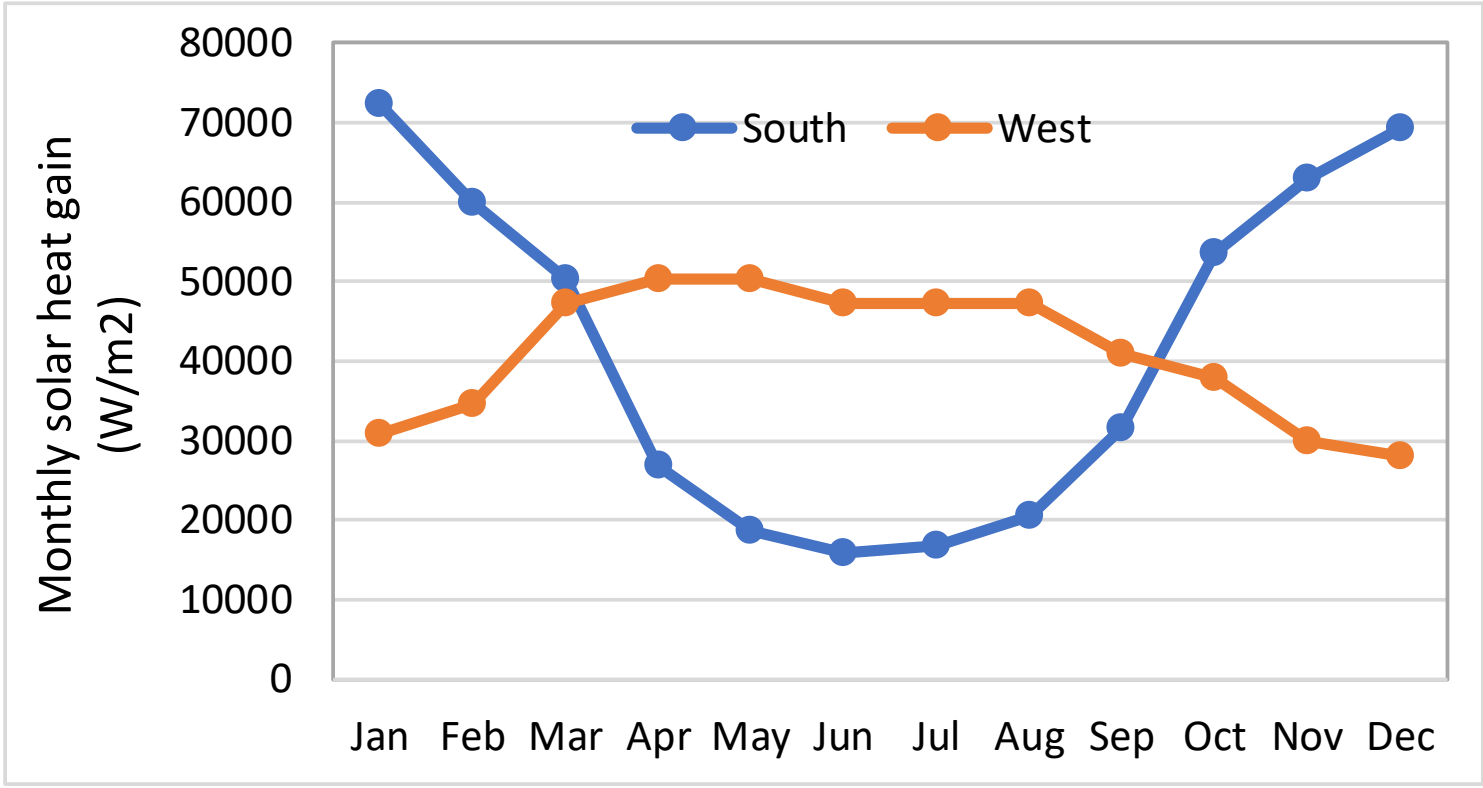
- Less glass is better
  - Even the best glass conducts several times more solar heat than a well-insulated solid wall
  - Potential comfort issues
- Vertical fenestration area is required or recommended to be
  - < 40% (ASHRAE STD 189.1)
  - <30% (The ASHRAE Guide for Buildings in Hot & Humid Climates)



Data Source: ASHRAE Handbook Fundamentals

Strategies to Minimize Solar Heat Gains Through Fenestration (Cont'd)

- Avoid or limit the use of west-oriented windows



Results are generated from the Window Heat Gain Tool (https://www.susdesign.com/windowheatgain/) for Key West, FL (24.6° latitude, North)

Strategies to Minimize Solar Heat Gains Through Fenestration (Cont'd)

- Specify high-performance windows
- The table (**IP units**) below lists the requirements for Climate Zone 0 by ASHRAE Standard 90.1-2022

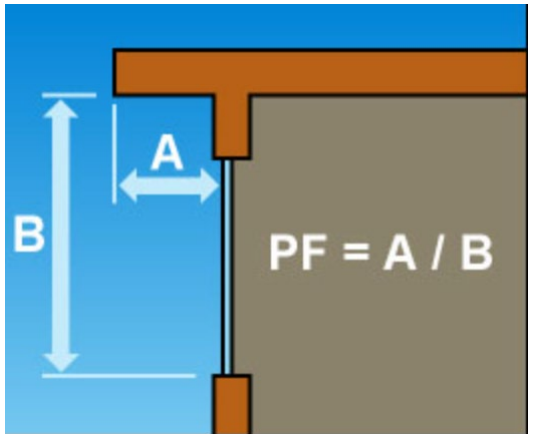
Fenestration	Nonresidential			Residential			Semiheated		
	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC
Vertical Fenestration, 0% to 40% of *Wall*									
Fixed	0.50	0.22	1.10 (for all types)	0.50	0.22	1.10 (for all types)	1.20	NR (for all types)	NR (for all types)
Operable	0.62	0.20		0.62	0.20		1.20		
Entrance door	0.83	0.20		0.83	0.20		1.10		
Skylight, 0% to 3% of *Roof*									
All types	0.70	0.30	NR	0.70	0.30	NR	1.80	NR	NR

Source: ASHRAE Standard 90.1-2022

Strategies to Minimize Solar Heat Gains Through Fenestration (Cont'd)

- Specify shading and fenestration attachments as needed
  - Window overhangs and fins
  - Attachments to the indoor side, between glazings, and the outdoor side
  - Window attachments certified by the Attachments Energy Rating Council (https://aercenergyrating.org/product-search/)

Projection Factor (PF)	SHGC Multiplier (South, East, and West *Orientations*)
0 to 0.10	1.00
>0.10 to 0.20	0.91
>0.20 to 0.30	0.82
>0.30 to 0.40	0.74
>0.40 to 0.50	0.67
>0.50 to 0.60	0.61
>0.60 to 0.70	0.56
>0.70 to 0.80	0.51
>0.80 to 0.90	0.47
>0.90 to 1.00	0.44



Source: ASHRAE Standard 90.1-2022

Impact of Air Infiltration

- Energy consumption
  - Sensible
  - Latent
- Potential indoor air quality problems
  - Mold growth

"A leaky building enclosure is like propping open the door to an EnergyStar™ refrigerator, and then expecting that refrigerator to still meet EnergyStar standards for energy use."

***--From* The ASHRAE Guide for Buildings in Hot & Humid Climates (Harriman and Lstiburek 2009)**

Strategies to Minimize Air Infiltration

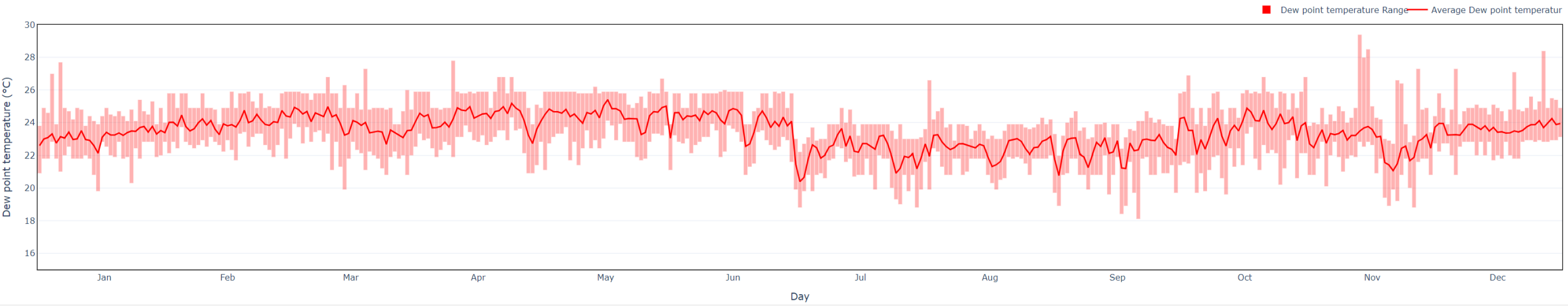
- **Continuous** air barrier design and installation
  - ASHRAE 90.1-2022 requires the measured air leakage rate of building envelope shall not exceed 1.8L/s-m^2 at a pressure differential of 75 Pa.
- Use vestibules at building entrances
- Use air curtains at building entrances

Energy Efficiency Design Strategy Categories

- Building envelope
- HVAC equipment and systems
- Lighting
- Service water heating

The Need for Dehumidification

- ASHRAE Standard 62.1 specifies that indoor humidity shall be limited to a maximum dew point of 15°C (60°F) during both occupied and unoccupied hours whenever the outdoor air dew point is above 15°C (60°F).
- A dew point of 12.8°C (55°F) is recommended as the indoor maximum in The ASHRAE Guide for Buildings in Hot & Humid Climates.



Outdoor air dew point profile for Jakarta

Dehumidification Loads and Design Conditions

- Loads
  - Ventilation
  - Air infiltration
  - Internal sources (e.g., occupants)
- Dehumidification loads and sensible cooling loads do not coincide with each other.

Cooling		Dehumidification	
0.40%	**1%**	**0.40%**	**1%**
DB/MCWB (°C)	DB/MCWB (°C)	DP/MCDB (°C)	DP/MCDB (°C)
33.8/25.7	33.1/25.8	27.0/33.4	26.2/29.5

Data Source: ASHRAE Handbook Fundamentals

The Strategy to Decouple Sensible Cooling from Dehumidification and Ventilation

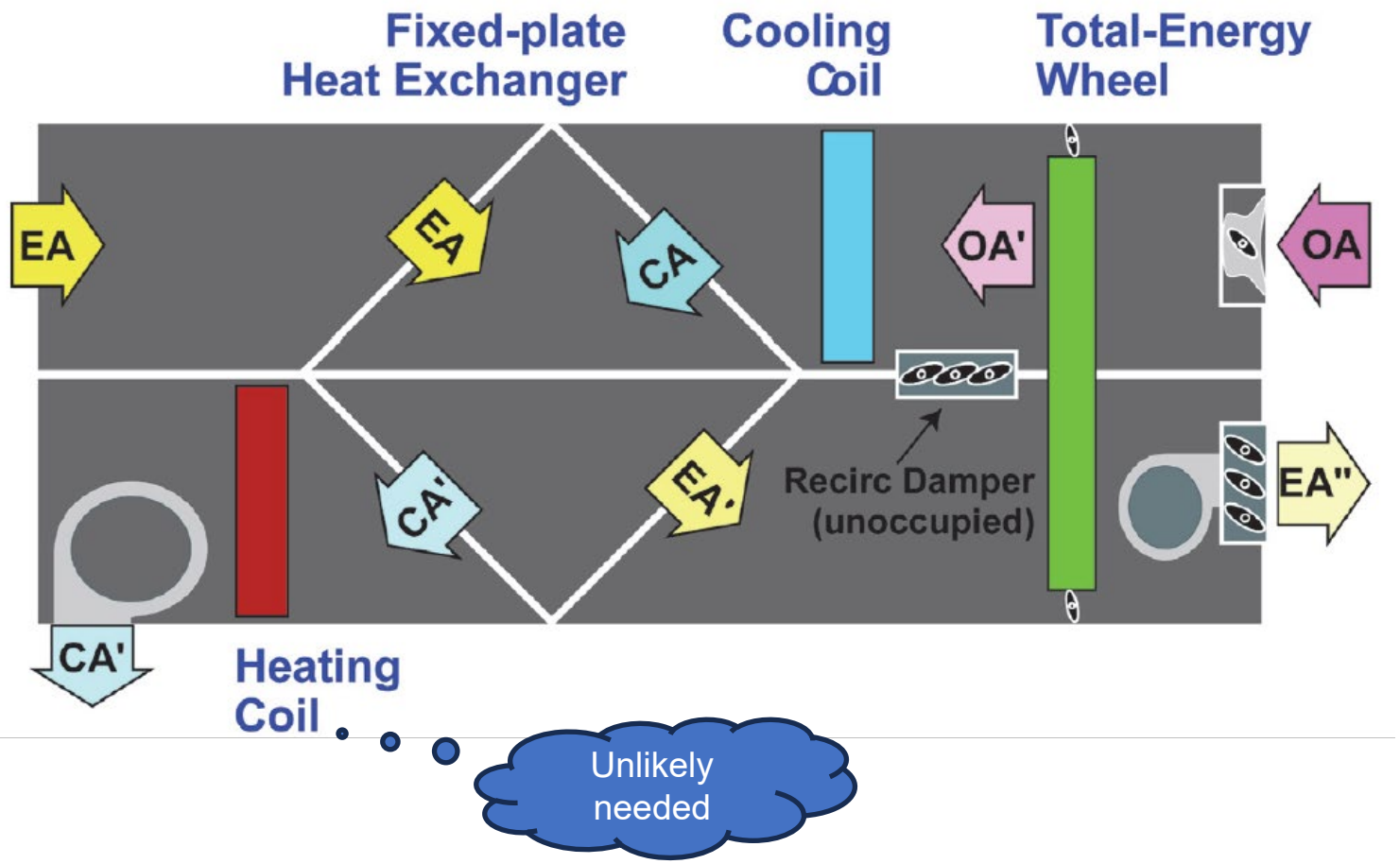
- Dedicated Outdoor Air System (DOAS), see another lecture
  - Ventilation
  - Dehumidification
- Terminal Units
  - Sensible cooling
  - Many options such as
    - Fan-coil units
    - Water-source heat pumps
    - VRF terminals
    - Chilled beams
    - Ceiling radiant panels

Occupancy Category	People Outdoor Air Rate R_p cfm/person	People Outdoor Air Rate R_p L/s·person	Area Outdoor Air Rate R_a cfm/ft^2	Area Outdoor Air Rate R_a L/s·m^2
Hotels, Motels, Resorts, Dormitories				
Barracks sleeping areas	5	2.5	0.06	0.3
Bedroom/living room	5	2.5	0.06	0.3
Laundry rooms, central	5	2.5	0.12	0.6
Laundry rooms within dwelling units	5	2.5	0.12	0.6
Lobbies/prefunction	7.5	3.8	0.06	0.3
Multipurpose assembly	5	2.5	0.06	0.3

Source: ASHRAE Standard 62.1-2022

The Strategy of Exhaust Air Energy Recovery (DOAS Example)

- The total energy wheel: precool and dehumidify the outdoor air
- The fixed-plate heat exchanger: rehear the cold and dehumidified air
- The fixed-plate heat exchanger may not be needed and can be bypassed
- The heating coil is unlikely needed for hotels in Climate zone 0



The Strategy of Demand-Controlled Ventilation

- Reduce the amount of ventilation air during unoccupied periods or partial occupancy
- Needs variable-speed fans, both the supply fan and the exhaust fan
- Needs air flow control and measurement at each zone

Other HVAC Strategies

- Recover waste energy from the condenser heat
  - In hot and humid climates, there is nearly always some cooling equipment in operation. That cooling equipment is constantly releasing heat to the outdoors. Consider making productive reuse of this large and constant generation of waste heat.
- Use well-sealed ducts instead of building cavities for air supply and return.
- Specify the use of high-efficiency HVAC equipment. Refer to ASHRAE Standard 90.1 for the minimum efficiency requirement for different HVAC equipment.
- Specify advanced HVAC system controls. Refer to ASHRAE Guideline 36: High-performance sequences of operation for HVAC systems.
- **Perform HVAC system commissioning by a professional third-party entity.**

Energy Efficiency Design Strategy Categories

- Building envelope
- HVAC equipment and systems
- Lighting
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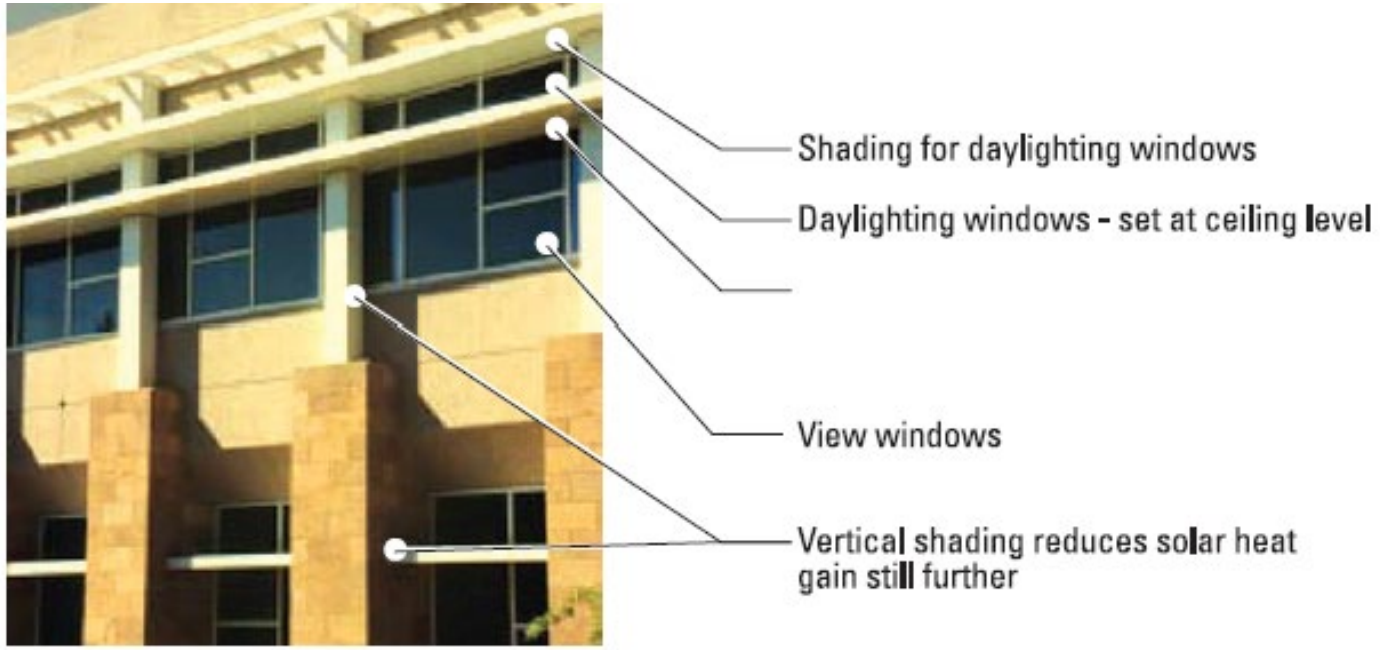
The Strategy of Daylighting

- Daylighting windows placed high, near the ceiling
- Use glazing with high VT (0.6 or higher) in daylighting windows
- Use light shelves to increase daylight penetration
- Use light-colored, diffusively-reflective ceilings and walls



From The ASHRAE Guide for Buildings in Hot & Humid Climates (Harriman and Lstiburek 2009)

The Strategy of Efficient Electric Lighting and Controls

- Use LED lamps, both indoor and outdoor
- Use master switch for guest rooms
- Use occupancy sensor controls on lights in corridors, stairs, offices, conference rooms, laundry, and storage rooms.
- Provide controllable bathroom night lights

Energy Efficiency Design Strategy Categories

- Building envelope
- HVAC equipment and systems
- Lighting
- Service water heating

Strategies for Energy Efficient Water Heating

- Less water = Less energy
  - Specify low-flow showerheads (less than 5.7 liter/min) and touchless bathroom faucets (less than 1.9 liter/min)
  - Specify the use of high-performance laundry equipment (e.g., ozone laundry systems)
- Consider the use of tankless water heater systems
- For storage hot water systems, consider the use of heat pump water heaters
- Consider solar water heating

Thank You!

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