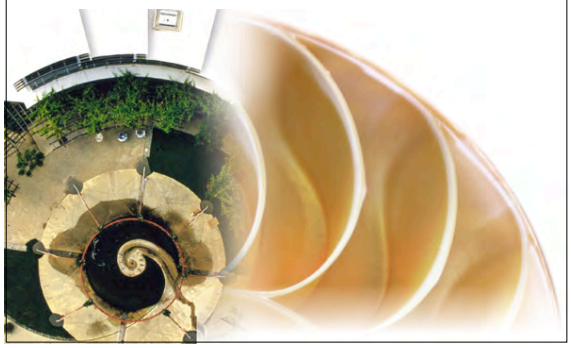
Passive Cooling

ARCH 331/431 Spring 2008
Lecture 16



announcements 5/22/08

Assignment 5: Solar Heating - Direct Gain

DUE NEXT WEEK

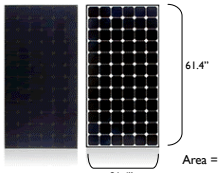
Available on the course website later tonight.

Graduate Section: I will email your assigned location for this exercise;

Quiz 5 Next Tuesday

Sizing a Solar PV System

1. Estimating Size (number of panels and their output, kW)



SUNPOWER
210 Solar Panel

Area = 61.4" x 31.4" = 1929 in^2 = **13.392 ft^2**

DC Rating (output) = **210 Watts**

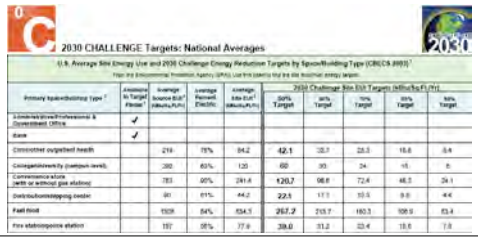
Energy "density" = 210 Watts/ 13.392 ft^2 = **15.68 W/ ft^2**

Determine the number of panels you're willing or able to place on your roof and the resulting output (kW), the panel orientation (azimuth) and their tilt (altitude).

Sizing a Solar PV System (cont.)

2. Estimating Need * 2030 Challenge Targets - National Averages

- Use **Target Table** from **www.architecture2030.org** to find the average **Site Energy Use** for your building type;
- Use the **50% target** for Site **EUI** Targets (Energy Use Intensity);
- Use Average Percent Electric for your building type to estimate electricity demand;
- Convert from kBTU to kWh: 1 kBTU = .293 kWh



Sizing a Solar PV System (cont.)

3. Estimating Output * PV Watts Calculator

- Go to **http://rredc.nrel.gov/solar/codes_algs/PVWATTS/** and use **Version 1** to calculate the electrical output of your PV system for your location;
- Enter the **DC Rating (kW)** of the system you've sized and modify the **Array Tilt** and **Array Azimuth** to match your project's parameter then **calculate**;
- Repeat this process as necessary, changing the DC Rating (kW), tilt or azimuth, until you've either maximized your output or met your building's energy needs.

Building Envelope Integrated PV

Lausanne, Switzerland

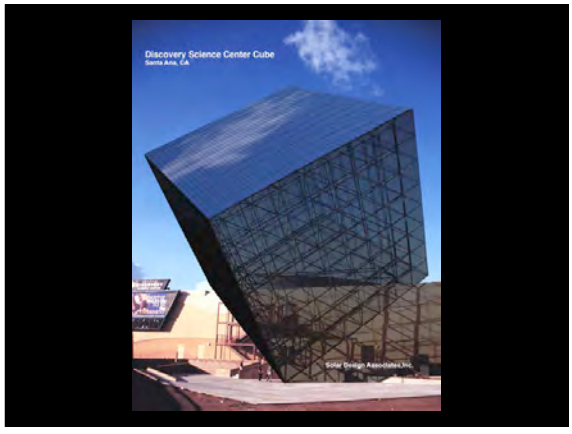
Barcelona, Spain


4 Times Square
Curtainwall application - PV as building envelope


Thoreau Center for Sustainability
Presidio National Park, San Francisco


Building Integrated PV • Monocrystal PV
Integrated into an awning, this systems provides shade while generating electricity


Photovoltaic Sun Shades


Discovery Science Center Cube
Santa Ana, CA

Palmetto House

Florida Keyes

Jersey Devil

Passive Cooling & *Architectural Sailing*

	MECHANICAL HEATING		MECHANICAL VENTILATION AND COOLING			
OUTSIDE TEMPERATURE	45	55	68	78	85	95
INSIDE TEMPERATURE RANGE						

	CLOSED HEATING		OPEN		CLOSED COOLING	
OUTSIDE TEMPERATURE	45	55	65	75	85	95

Balance Point Temperature

"Change-over" Temperature*

natural ventilation rule-of-thumb assumes interior temperatures are typically 3°F **higher than outside air temperatures when natural ventilation is effective, due to people, lights and equipment.*

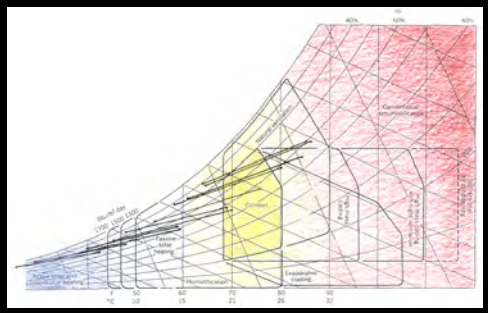
Closed Heating Mode Strategies

MECHANICAL	ARCHITECTURAL
• Active Solar	• Thermal Mass: Heat
• Furnace/Boiler	• Direct Gain: Sun

Closed Cooling Mode Strategies

ARCHITECTURAL	MECHANICAL
• Thermal Mass: "Coolth"	• Ceiling Fans
• Evaporation: Water	• Chillers

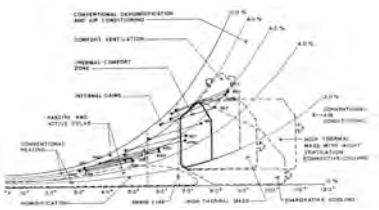
Berea, Kentucky: Average Annual Climate Conditions



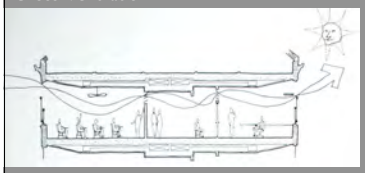
Climate Analysis & Architectural Strategies **Knoxville, Tennessee**

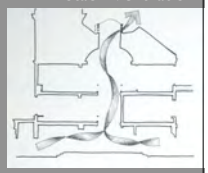
Temperate Climate

- Keep the heat in and cold temperatures out in the winter.
- Use natural ventilation for summer cooling
- Let the winter sun in.
- Protect from the summer sun.
- Protect from the cold winter winds.
- Avoid creating additional humidity during the summer.

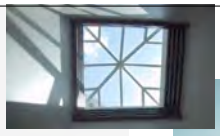


Cross Ventilation Stack Ventilation

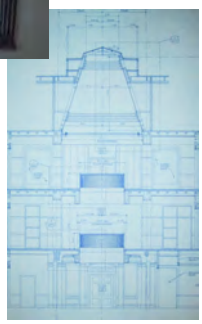




- Double-hung windows
- Transom windows between perimeter rooms and corridors
- Integrated passive and mechanical systems



Atrium



Atrium Concept

Passive Cooling

- *Shading*
- ***Cross Ventilation***
- ***Stack Ventilation***
- *Night Ventilation of Thermal Mass*

Step 1: **Climate Analysis and Architectural Strategies**
Step 2: **Determine Cooling Load**
Step 3: **Use rule-of-thumb charts to predict the effectiveness of window openings**

Passive Cooling

- ***Cross Ventilation***
- ***Stack Ventilation***
- *Night Ventilation of Thermal Mass*

Step 1: Climate Analysis and Architectural Strategies
Step 2: **Determine Cooling Load**
Step 3: Use rule-of-thumb charts to predict the effectiveness of window openings

PART A **Step 2: Determine Cooling Load**
PEOPLE • LIGHTS • **EQUIPMENT**
ENVELOPE • INFILTRATION

F.3 ESTIMATING SUMMER HEAT GAINS **MEEB 10th, pg. 1610**

TABLE F.3 Approximate Summer Heat Gains from Occupants, Equipment, Lighting, and Envelope

Part A. Internal Heat Sources—People and Equipment

Function	Area per Person[a] ft²	Area per Person[a] m²	Sensible Heat Gain (Btu/h ft² of Floor Area) People[b]	Sensible Heat Gain (Btu/h ft² of Floor Area) Equipment	Sensible Heat Gain (Btu/h ft² of Floor Area) Total	Sensible Heat Gain (W/m² of Floor Area) People[b]	Sensible Heat Gain (W/m² of Floor Area) Equipment	Sensible Heat Gain (W/m² of Floor Area) Total
Office, U.S.[c]	180–100	16.7–9.3	1.3–2.3	0.6–1.1	1.7–3.4	4.1–7.3	1.2–3.4	5.3–10.7
Office, Europe[c]			1–1.6	2.2–4.2	3.2–5.8	3–5	7–13.1	10–18.1
School, elementary, U.S.	100–20	9.3–1.9	2.3–11.5	0–0.6	2.3–12.1	7.3–36.3	0–2.0	7.3–38.3
School, Europe[c]			3.8–8.0	0–0.8	3.8–8.6	12–25.2	0–2.0	12.0–27.2
School, secondary, college	150–100	13.9–9.3	1.7–2.6	0–0.5	1.7–3.2	5.4–8.2	0–2.0	5.4–10.2
Health care								
Sleeping (hospital)	240	22.3	0.9	0.6[e]	1.5	2.8	2.0[e]	4.8
In-patient (clinic)	120	11.1	1.9	Varies	1.9+	6.0	Varies	6.0+
Assembly: fixed seats	15	1.4	14.0	—	14.0	44.2	—	44.2
standing space, concentrated use	15–7	1.4–0.7	21.0–45.5	0–0.5	21.0–45.5	66.3–142.0	0–1.6	66.3–143.6
Restaurant[f]								
Fast food, dining area	15	1.4	17	3.4	20.4	53.6	10.7	64.3
Kitchen, refrigeration				17.1	17.1		54.0	54.0
Sit-down, dining area	25	2.3	10.2	5.1	15.3	32.2	16.1	48.3
Kitchen, refrigeration				7.2	7.2		22.7	22.7
Mercantile, street floor	50–30	4.7–2.8	6.3–10.5	3.4	9.7–13.9	19.9–33.1	10.7	30.6–43.8
Other sales floors	60–50	5.6–4.7	5.3–6.3	3.4	8.7–9.7	16.7–19.9	10.7	27.4–30.6
Shopping center, Europe[c]			3.2	0.3–1.3	3.5–4.5	10	1.0–4.0	11.0–14.0
Warehouse	1000–300	92.9–27.9	0.8–1.2	—	0.8–1.2	1.3–3.8	—	1.3–3.8
Hotels, nursing homes	300–200	27.9–18.6	0.8–1.2	3.4	4.2–4.6	2.5–3.8	10.7	13.3–14.5
Apartments[g]	300–200	27.9–18.6	0.8–1.2	See note g	See note g	2.5–3.8	See note g	See note g

PART B **Step 2: Determine Cooling Load**
PEOPLE • **LIGHTS** • EQUIPMENT
ENVELOPE • INFILTRATION

MEEB 10th, pg. 1610

Part B. Internal Heat Sources—Electric Lighting

Function	Sensible Heat Gain[a] (Btu/h ft² of Floor Area) DF<1	1<DF<4[b]	DF>4[c]	Sensible Heat Gain[a] (W/m² of Floor Area) DF<1	1<DF<4[b]	DF>4[c]
Office	5.1	2.0	0.5	16.1	6.3	1.6
School, elementary	6.3–6.8	2.5–2.7	0.6–0.7	19.9–21.5	7.9–8.5	1.9–2.2
School, secondary, college	6.3–6.8	2.5–2.7	0.6–0.7	19.9–21.5	7.9–8.5	1.9–2.2
Health care						
Sleeping (hospital)	6.8	2.7	0.7	21.5	8.5	2.2
In-patient (clinic)	6.8	2.7	0.7	21.5	8.5	2.2
Assembly	3.8	1.5	0.4	12.0	4.7	1.3
Restaurants	6.3	2.5	0.6	19.9	7.9	1.9
Mercantile	5.1–6.8	2.0–2.7	0.5–0.7	16.1–21.5	6.3–8.5	1.6–2.2
Warehouse	2.4	1.0	0.2	7.6	3.2	0.6
Hotels, nursing homes	6.8	2.7	0.7	21.5	8.5	2.2
Apartments[d]	Up to 6.8	Up to 2.7	Up to 0.7	Up to 21.5	Up to 8.5	Up to 2.2

PART C **Step 2: Determine Cooling Load**
PEOPLE • LIGHTS • EQUIPMENT
ENVELOPE • INFILTRATION

MEEB 10th, pg. 1610

Part C. Heat Gain through Envelope[a]

	(Btu/h ft² of Floor Area) Outdoor Design Temperature 90°F	100°F	(W/m² of Floor Area) Outdoor Design Temperature 32°C	38°C
I. Gains through externally shaded windows[b]				
Find ratio, $\frac{\text{total window area}}{\text{total floor area}}$, then multiply by	16	21	50	66
II. Gains through opaque walls:				
Find ratio, $\frac{\text{total opaque wall area}}{\text{total floor area}} \times (U_{wall})$, then multiply by	15	25	8	14
III. Gains through roofs:				
Find ratio, $\frac{\text{total opaque roof area}}{\text{total floor area}} \times (U_{roof})$, then multiply by	35	45	19	25

PART D **Step 2: Determine Cooling Load**
OPEN vs. CLOSED
mode

MEEB 10th, pg. 1611

Part D. Summary Gains

I. Passive cooling systems for (thermally) "open" buildings
Cross-ventilation
Stack ventilation
Nighttime or "open" hours of thermal mass/night ventilation
Total gains: Add Parts A, B, and C to obtain cooling load, in Btu/h ft² (W/m²), of floor area.

II. Passive cooling systems for (thermally) "closed" buildings
Roof ponds
Evaporative cooling
Daytime or "closed" hours of thermal mass/night ventilation
Total gains: Add Parts A, B, C, and E to obtain cooling load, in Btu/h ft² (W/m²), of floor area.

PART E **Step 2: Determine Cooling Load**
PEOPLE • LIGHTS • EQUIPMENT
ENVELOPE • **INFILTRATION**

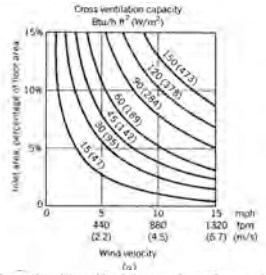
CLOSED mode

MEEB 10th, pg. 1611
Part E. Gains from Infiltration/Ventilation of "Closed" Buildings

	Outdoor Design Temperature		Outdoor Design Temperature	
	90°F	100°F	32°C	38°C
Infiltration:				
Find ratio, $\frac{\text{total window + opaque wall area}}{\text{total floor area}}$, then multiply by	1.0	1.9	3.2	6.0
Ventilation:				
Find known $\frac{\text{total cfm of outdoor air}}{\text{total floor area, ft}^2}$, then multiply by	16	27	—	—
Find known $\frac{\text{total L/s of outdoor air}}{\text{total floor area, m}^2}$, then multiply by	—	—	9.9	16.8

Step 3. Passive Cooling Rules-of-Thumb
CROSS VENTILATION • STACK VENTILATION

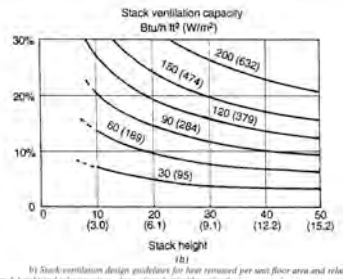
MEEB FIG. 8.14 (a), pg. 237



(a) Cross-ventilation design guidelines for heat removed per unit floor area and relationship of inlet openings and wind speed. Total inlet opening area is expressed as a percent of total floor area served by cross ventilation. Note: Outlet areas must also be at least equal to inlet areas. This graph is based on an internal temperature 3°F (1.7°C) above the exterior temperature, and assuming that the wind is not quite perpendicular to the window openings, for a wind effectiveness factor of 0.4 (see Section 5.14).

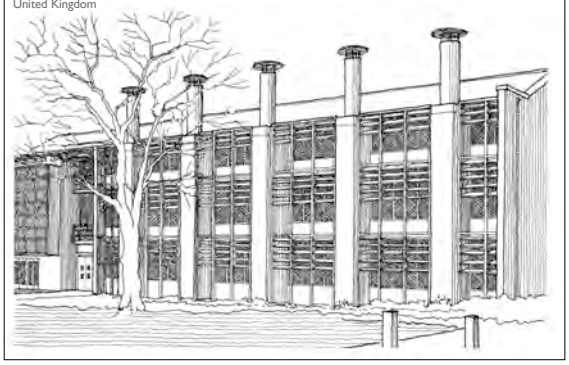
Step 3. Passive Cooling Rules-of-Thumb
CROSS VENTILATION • **STACK VENTILATION**

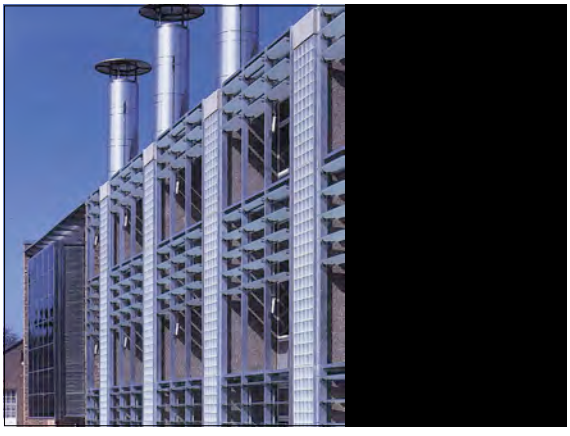
MEEB FIG. 8.14 (b), pg. 237



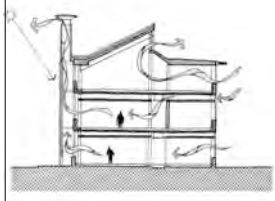
(b) Stack-ventilation design guidelines for heat removed per unit floor area and relationship of stack height and inlet openings. Area of stack inlet/throat/outlet is expressed as a percentage of total floor area served by stack ventilation. Note: Outlet areas and stack throat area must also be at least equal to inlet areas. This graph is based on an internal temperature of 83°F, exterior temperature 80°F, for a 3°F differential (28.3°C internal, 26.7°C internal, for a 1.6°C differential).

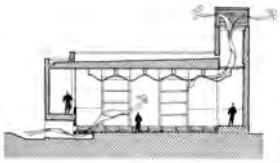
The Environmental Building
BRE: Building Research Establishment
Feilden Clegg Architects
United Kingdom



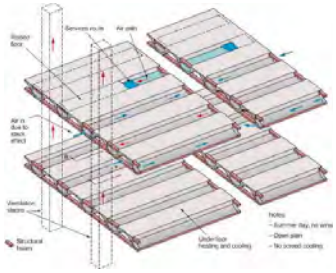


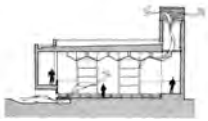
Stack Ventilation



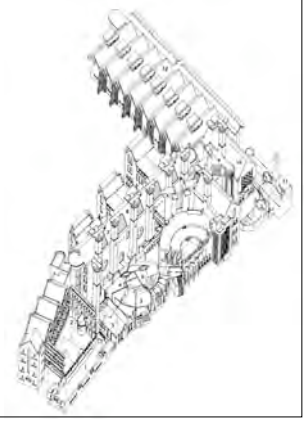


Night Ventilation of Thermal Mass

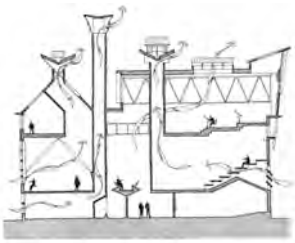




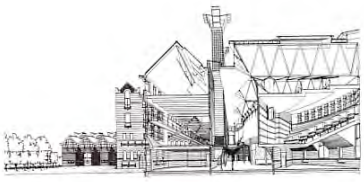
School of Engineering and Manufacture
Queens Building, de Montfort University
Short Ford & Associates Architects
United Kingdom



Stack Ventilation



Night Ventilation of Thermal Mass

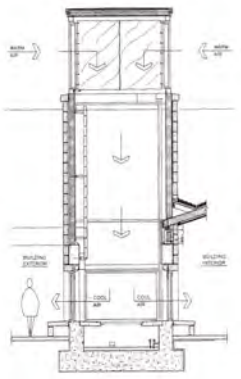


Zion National Park
Visitor Center
NPS/Denver Service Center
Utah, United States

Stack Ventilation

+

Evaporative Cooling



Cross Ventilation & Shading