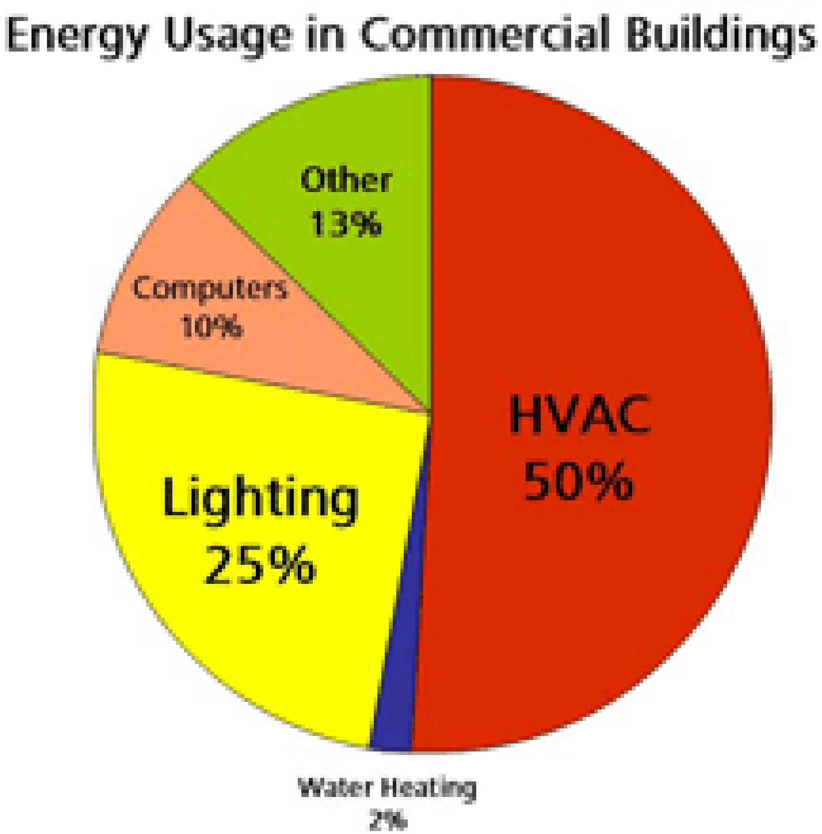
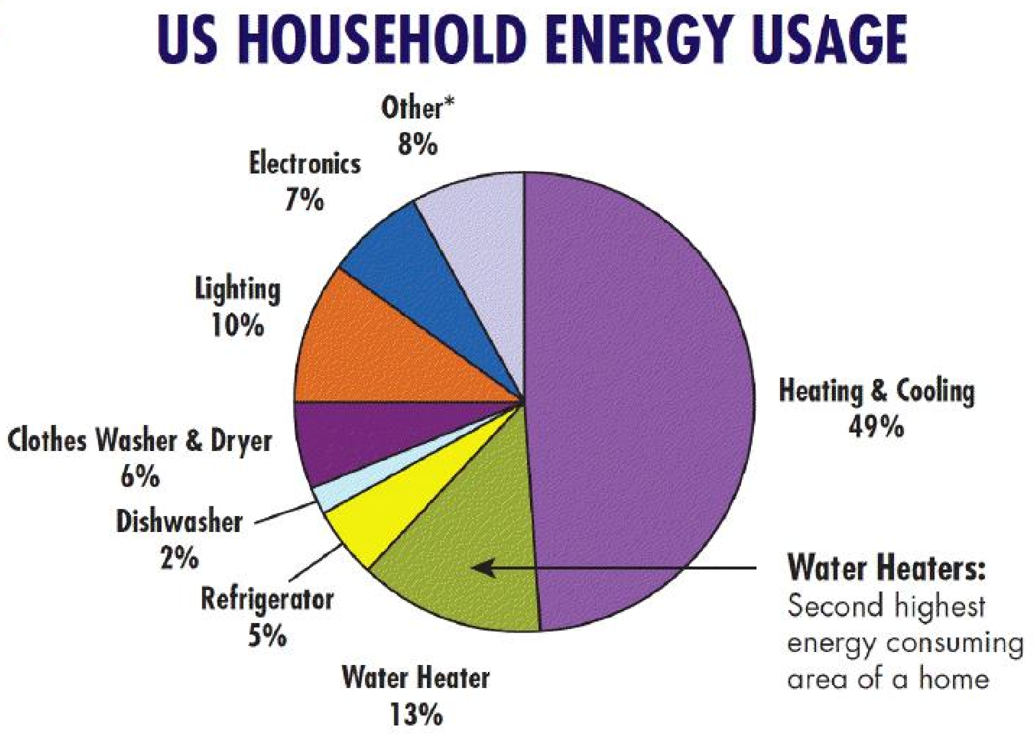
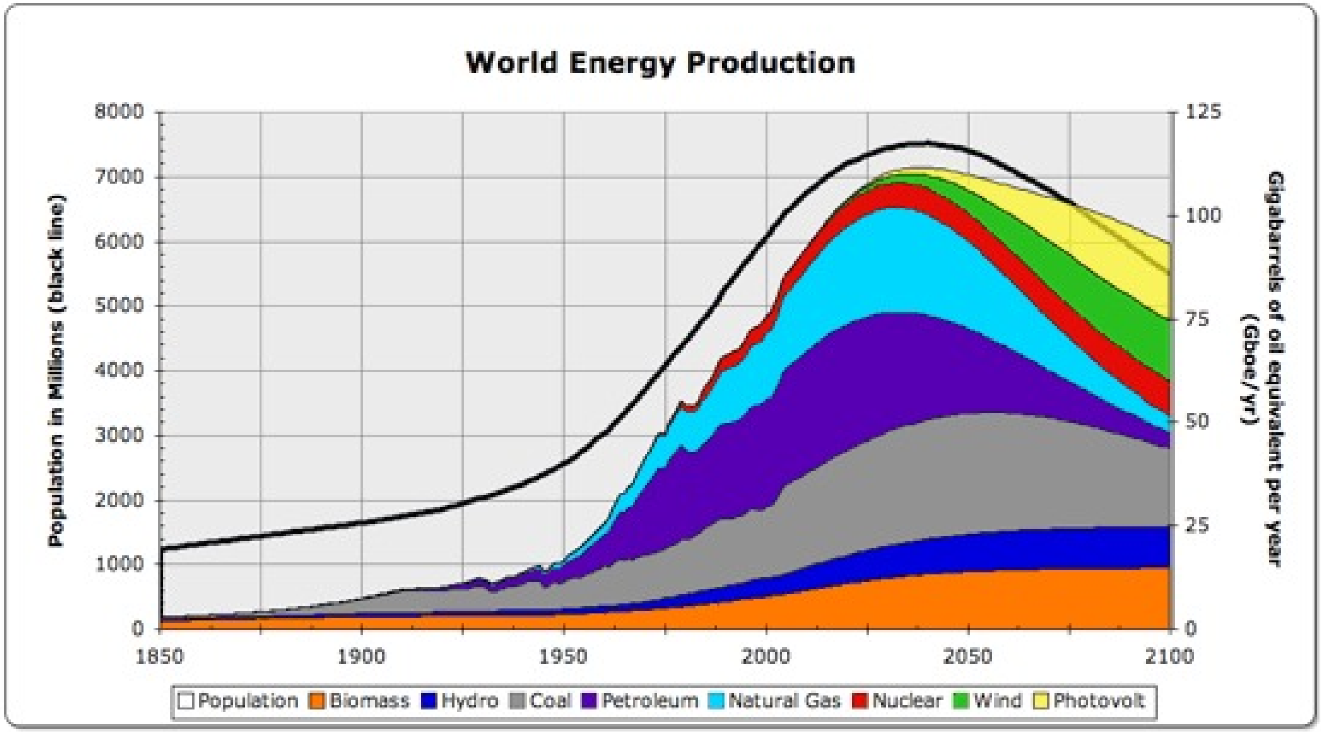
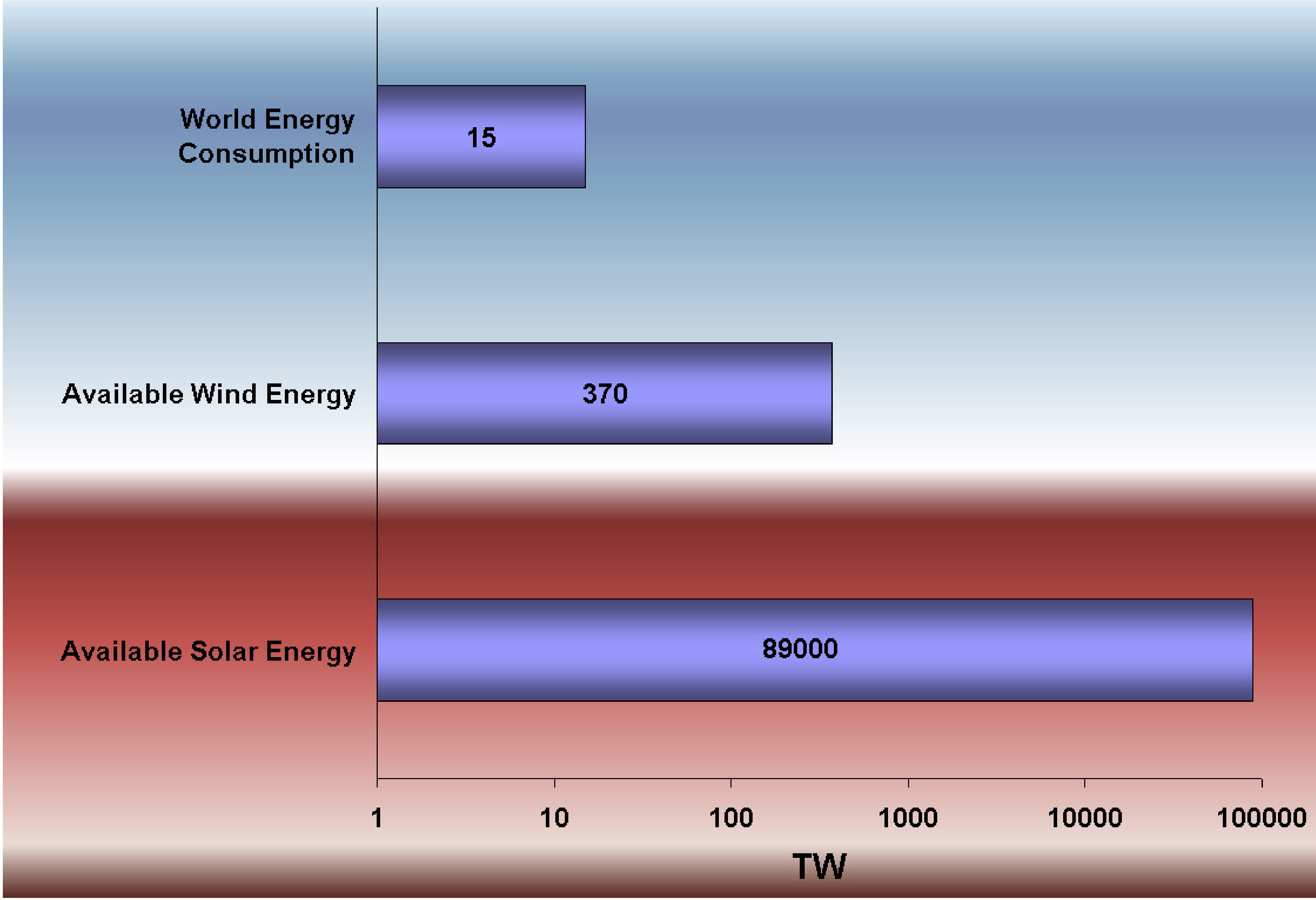


Energy Usage in Commercial Buildings
Other
13%
Computers
10%
HVAC
50%
Lighting
25%
Water Heating
2%



US HOUSEHOLD ENERGY USAGE
Other*
8%
Electronics
7%
Lighting
10%
Heating & Cooling
49%
Clothes Washer & Dryer
6%
Dishwasher
2%
Refrigerator
5%
Water Heater
13%
Water Heaters:
Second highest
energy consuming
area of a home


World Energy Production
Population in Millions (black line)
8000
7000
6000
5000
4000
3000
2000
1000
0
1850
1900
1950
2000
2050
2100
125
100
75
50
25
0
Gigabarrels of oil equivalent per year (Gboe/yr)
Population
Biomass
Hydro
Coal
Petroleum
Natural Gas
Nuclear
Wind
Photovolt



World Energy Consumption
Available Wind Energy
Available Solar Energy
15
370
89000
1
10
100
1000
10000
100000
TW

HVAC Rules of Thumb

- **Air - 1 CFM/SF**
- **Cooling (office) – 300/400 SF/Ton**
- **Cooling (office) 400 CFM/Ton**
- **Heating 25-35 btuh/sf floor area**
- **Outside Air – 20 CFM/person**
- **Toilet/Jan Closet – 10 air changes/hour**

HVAC Equipment/SF

- **Mechanical Room (Boilers/Chillers/Pumps/Misc) =**
  - **GU College Hall = 2000 SF/186,000 = 1.1%**

- **Mechanical Room (Boilers/Pumps/Misc) =**
  - **RTF (tight) – 300 SF/28,000 SF = 1.1%**
  - **Colbert Elementary – 312 SF/ 40,000 SF = 0.8%**

- **RTU (Gas/Electric/VAV) =**
  - **SEL Office (35’x12’ (2))/95,000 SF**

Building Envelope

* Face House, Kyoto, Japan

Look at me.
Is my face (building envelope) energy efficient?

Main criteria:

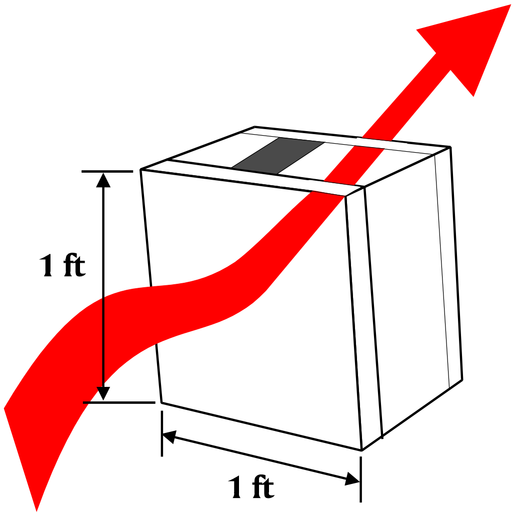
- wall area
- window area
- thermal properties
- orientations
- thermal mass
- shading device

Load Calculations

- Heating and Cooling
- Accuracy *important!*
- Design conditions
- Building shell load
- R, U value
- Internal load
- Ventilation load
- Infiltration
- Occupancy schedules

Heat Transfer

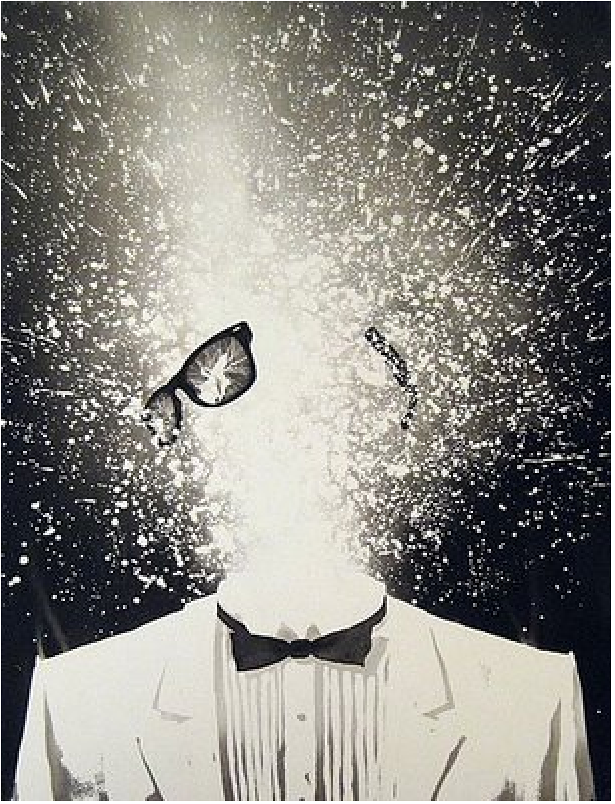
- Conduction
- Convection
- Radiation
- Resistance (R-Value)
- $U = 1 / R$
- $Q = U \times A \times \Delta T$



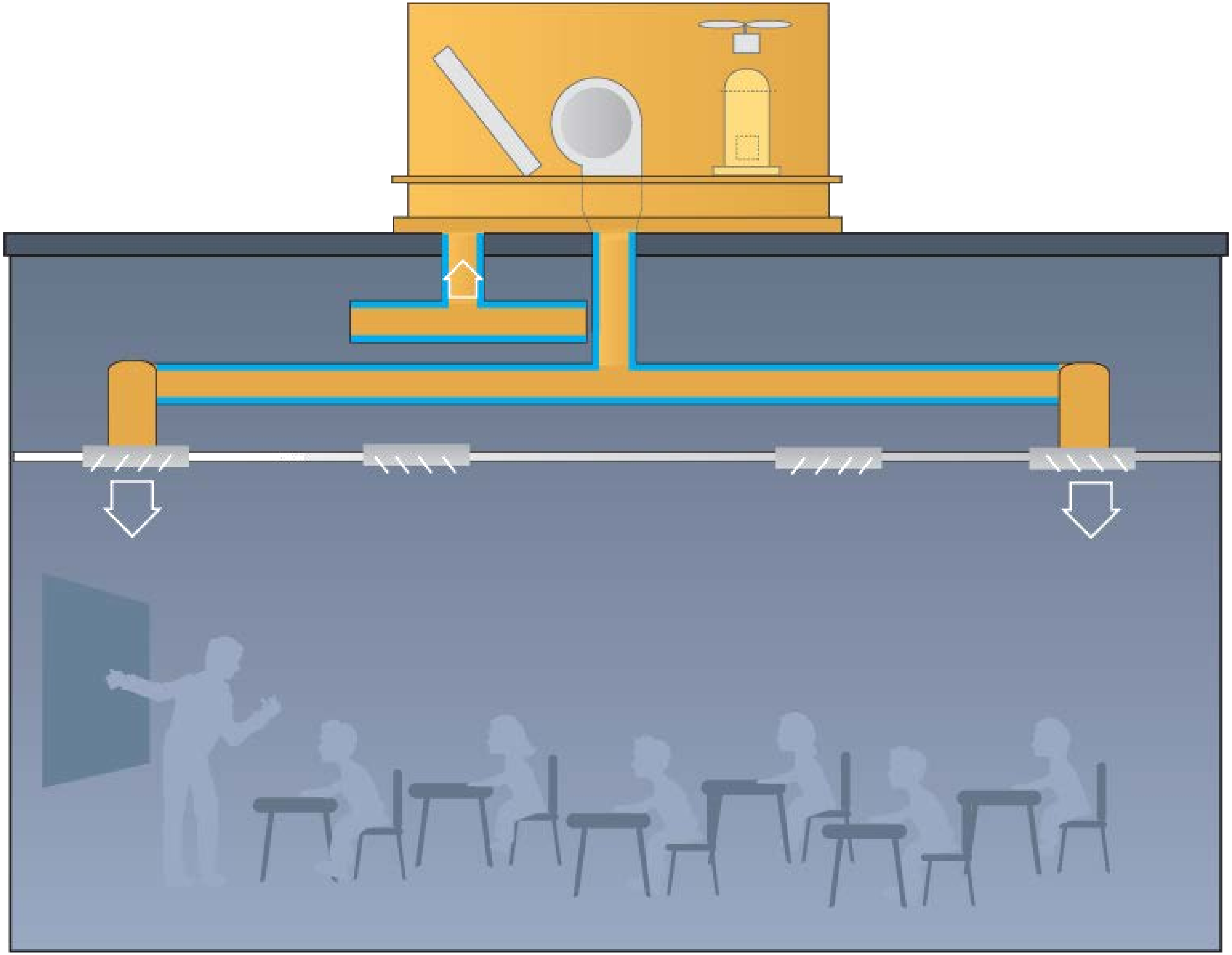
U-Value is the rate of heat flow in Btu/h through a one ft^2 area when one side is 1^oF warmer

Comfort

- Comfort is primary intent of HVAC systems.
- Productivity
- Building Durability
- Health
- *Mold*



COP,EER,SEER

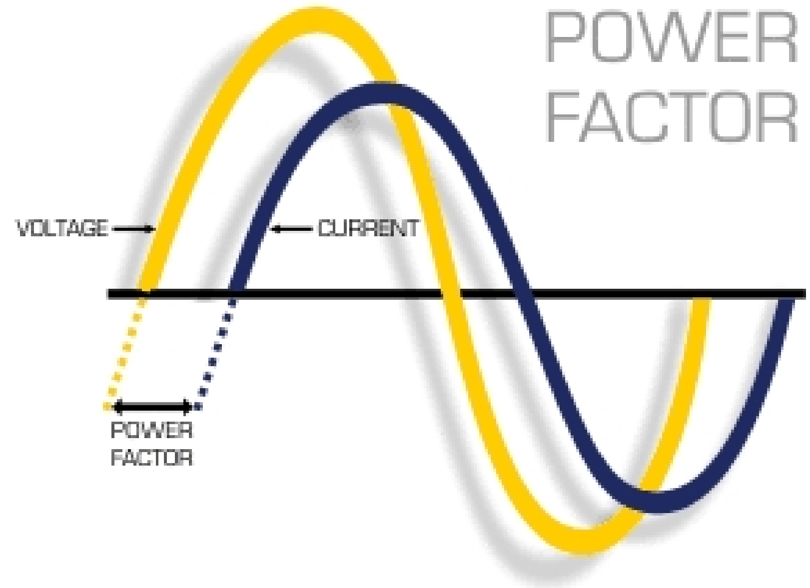


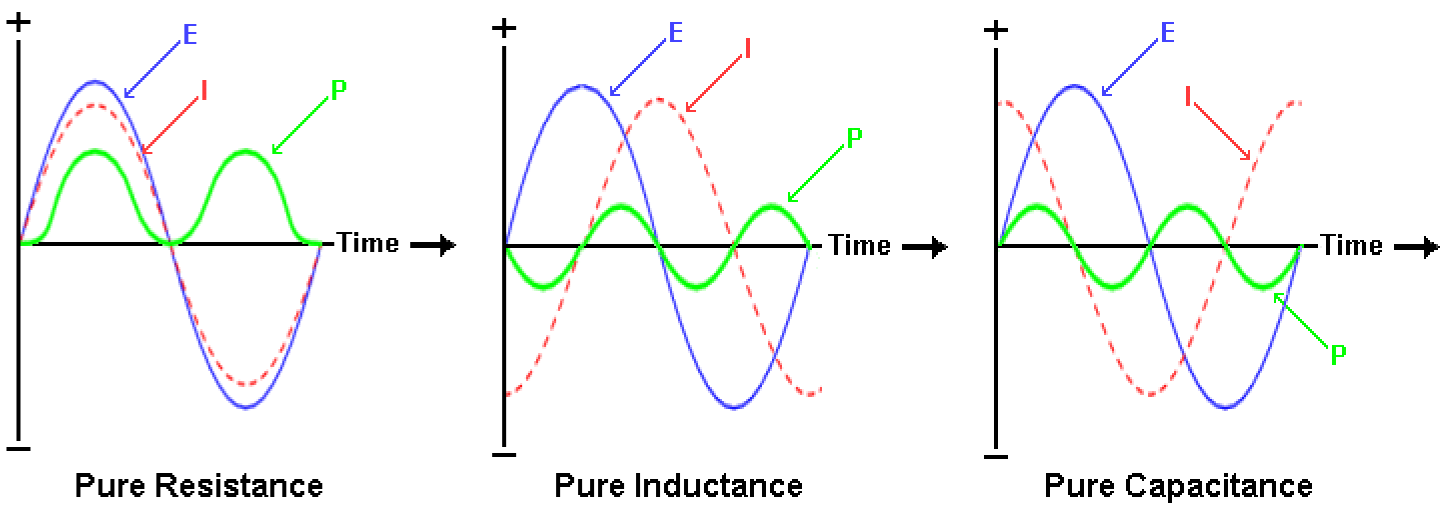
EER

- BTU = British Thermal Unit: a unit measurement of heat.
  It takes 1 btu to increase the temperature of 1 lb. of water 1 degree Fahrenheit.
- EER = Energy Efficiency Ratio - Formula: EER = Btu's / Watts
- The higher the EER the more efficient the system

Watts Calculation

- Watts Formulas
  - Single Phase =watt = *PF* × amp × volt
  - 3 Phase=W = V avg. x A avg x p.f. x 1.732
    - V_{avg} = average voltage of the three separate phases (volts)
      A_{avg} = average current of the three separate phases current (amps)
      p.f. = average power factor or the three separate phases
      - For resistive loads: p.f. = 1.0
        For inductive/Capacitive Loads: p.f. < 1.0 (.8 -.9)
    - 1.732 = a constant necessary with 3 phase.


POWER
FACTOR
VOLTAGE
CURRENT
POWER
FACTOR


E
I
P
Time
Pure Resistance
E
I
P
Time
Pure Inductance
E
I
P
Time
Pure Capacitance

EER Example

- $\frac{36{,}000 \text{ BTU/HR}}{4000 \text{ Watts}}$ = EER of 9
- $\frac{36{,}000 \text{ BTU/HR}}{3600 \text{ Watts}}$ = EER of 10

Go Backwards

EER of 10

Example 36,000/10= 3600 Watts

SEER
Seasonal Energy Efficiency Ratio

- Higher the Number the More Efficient the equipment.
- SEER = ((BTU / h) ÷ W)
  - For example

A 5000 BTU/h air-conditioning unit, with a SEER of 10, would consume 5000/10 = 500 Watts of power on average. The electrical energy consumed per year can be calculated as the average power multiplied by the annual operating time:

SEER

- 500 W × 1000 h = 500,000 W•h = 500 kWh
- Assuming 1000 hours of operation during a typical cooling season (i.e., 8 hours per day for 125 days per year).

COP

The higher the COP the more efficient the system

- COP = Coefficient of Performance –
- COP=Power output/Power input
- Example:
  - 36,000 BTU/HR output (AC capacity)
  - 3,600 Watts of power used
  - Convert BTU/HR to watts 0.293071
    - 36,000 X 0.293071 = 10,551 watts
  - COP = 10551/3600= 2.93
    - **So for every 2.93 units of heat removed the system uses on unit of energy.**
- Conversion Formula: COP = EER x 0.293
- The COP represents the cooling effect in btu's or watts of a refrigerant cycle, compared to the btu or watts equivalent of the electrical energy put into the system during the cycle.

Formulas

- *KW/ton = 12 / EER*
- *KW/ton = 12 / (COP x 3.412)*
- *COP = EER / 3.412*
- *COP = 12 / (KW/ton) / 3.412*
- *EER = 12 / KW/ton*
- *EER = COP x 3.412*
- If a chillers efficiency is rated at *1 KW/ton,*
- *COP = 3.5*
- *EER = 12*