Design Tools and Strategies to Adapt to Climate Change

Greening in Place: From Policy to Practice

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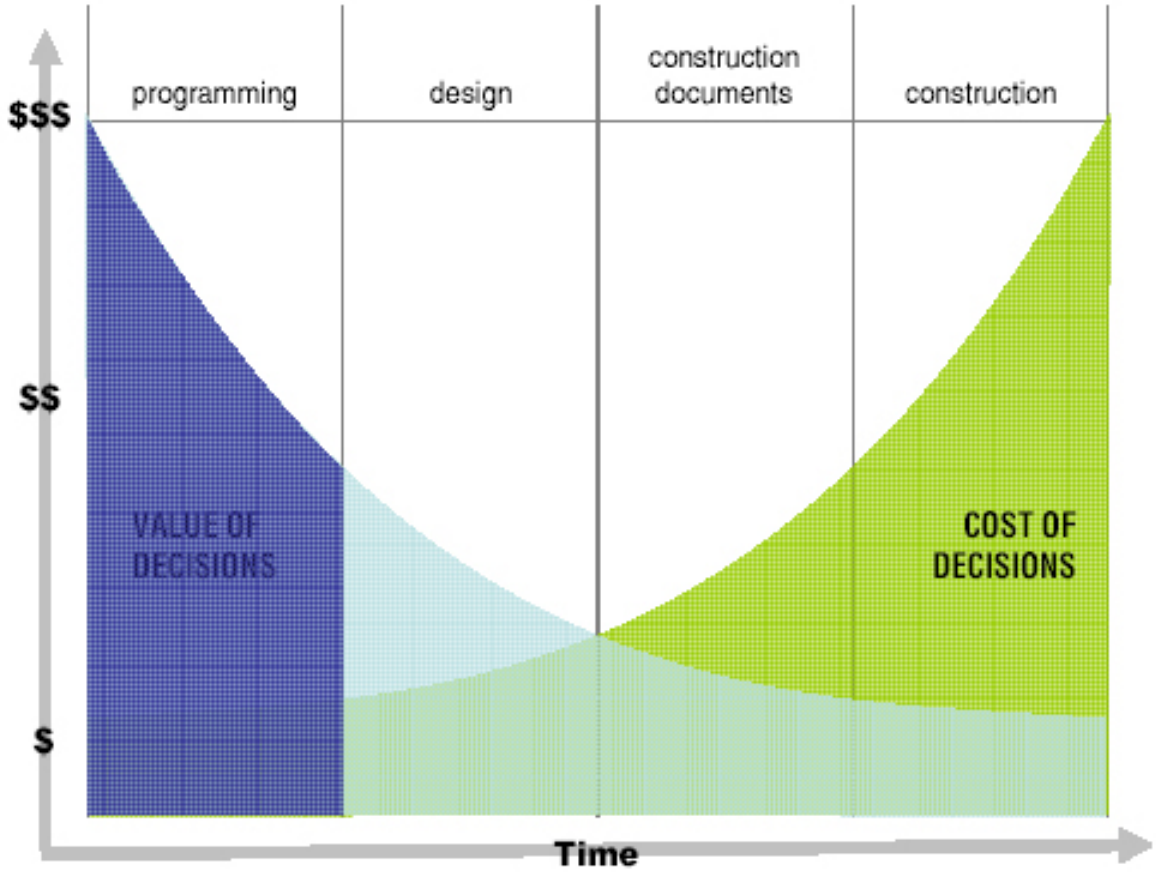
Optimized Building Design Path

- Integrated design process
- Set performance goals at project initiation
- Key steps to an optimized design
- Life cycle cost analysis
- Think beyond the building footprint

Integrated Design Process

- ASHRAE High Performance Building Magazine - "Integrated Design Process" (Three Part Series)

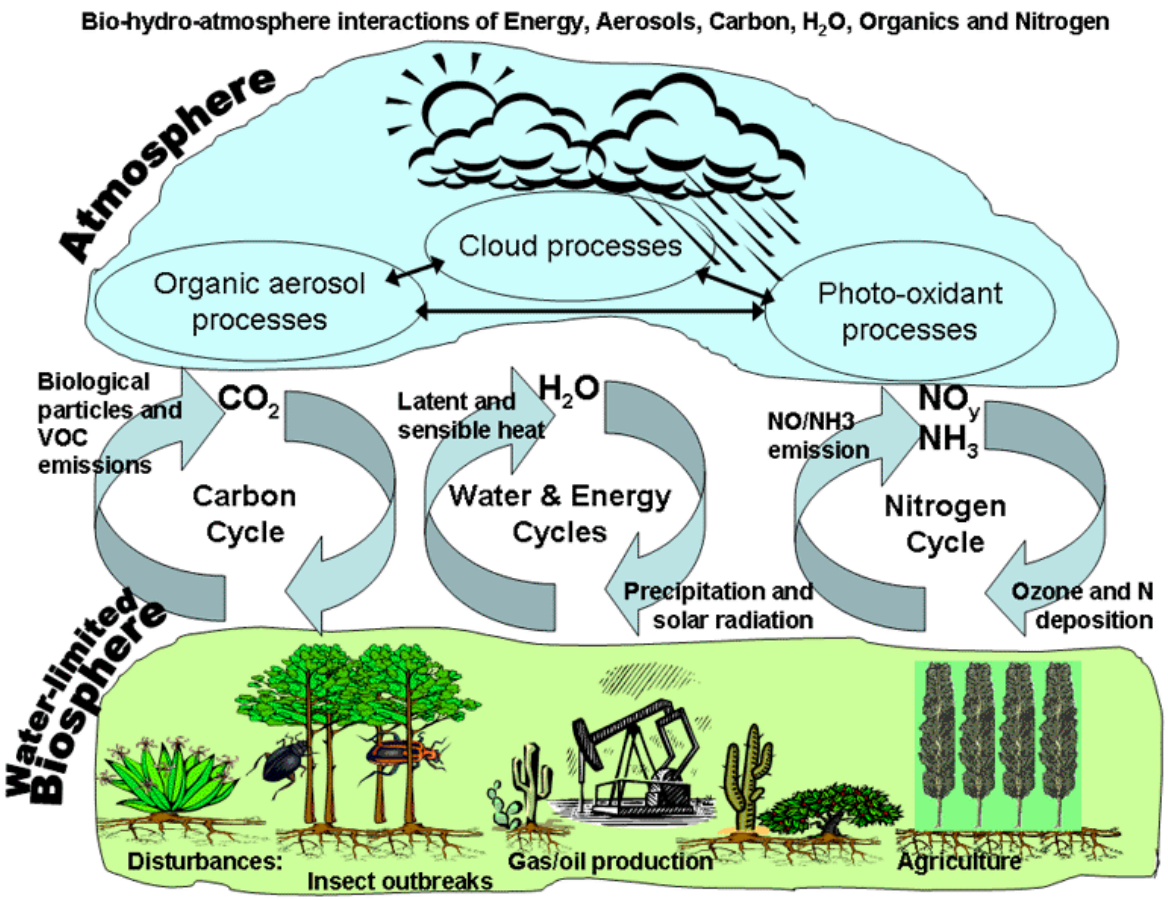
Integrated Design Process



Integrated Design Process

Performance Goals

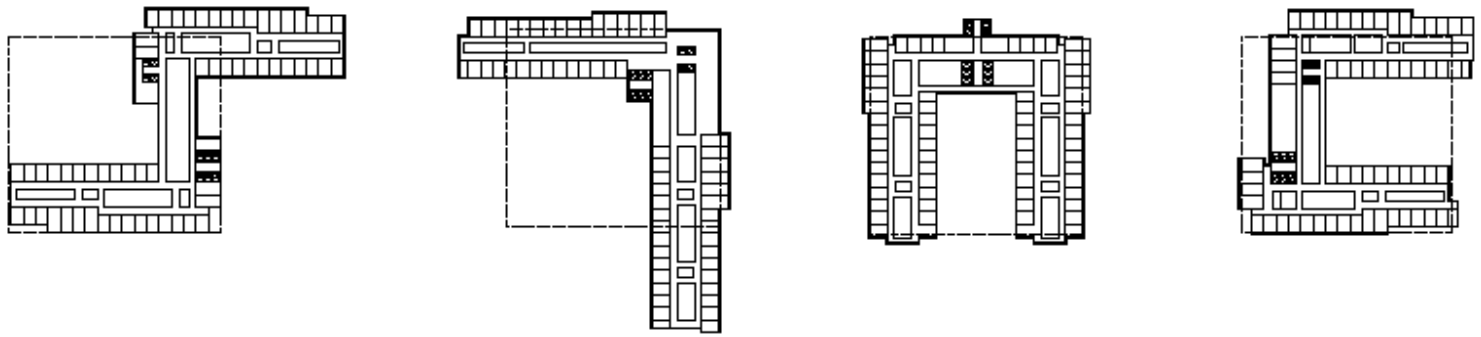
- **Set project performance goals as early as possible**
  - Energy
  - Exergy
  - Carbon emissions
  - Water



Key Steps (in order)

- Step 1 – Site selection
- Step 2 – Building massing & orientation
- Step 3 – Optimize envelope
- Step 4 – Minimize internal loads
- Step 5 – Harvest free energy and water

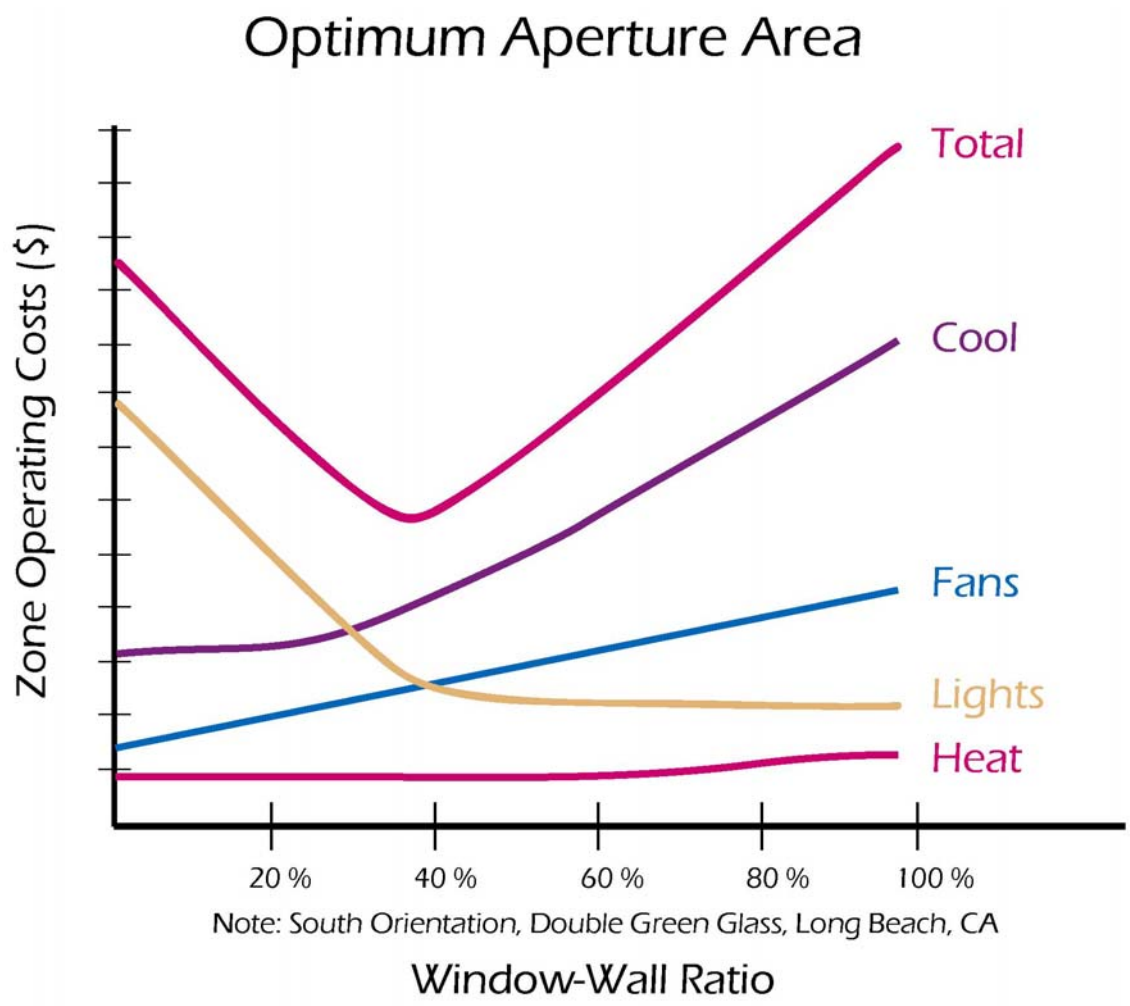
Building Configuration & Orientation



$0 **$160,000** **$130,000** **$60,000**

Energy impacts and related costs

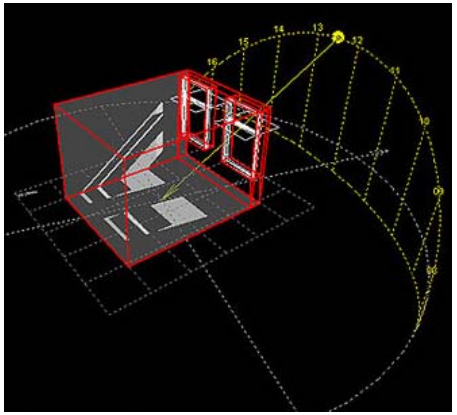
Component Interaction

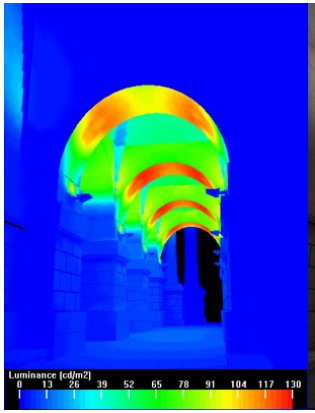


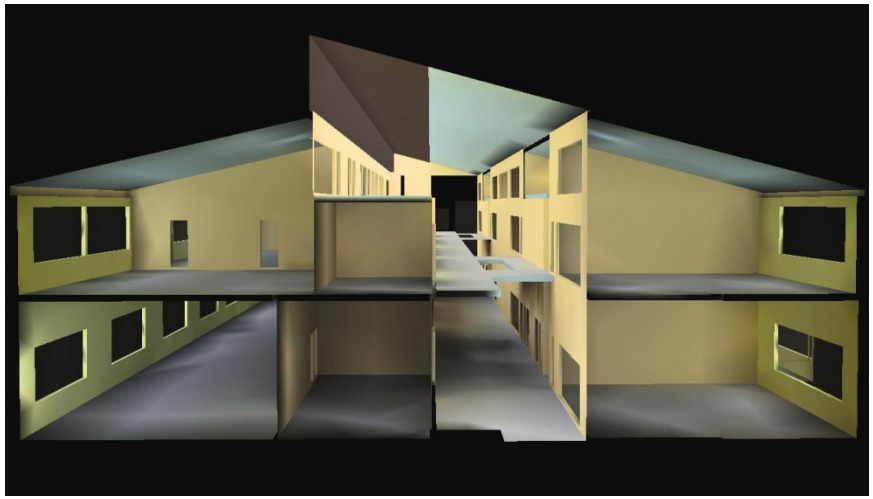
Load Reduction Strategies

- Building Configuration
- Solar Gain
- Envelope and Glazing
- Infiltration
- Lighting
- Equipment Loads

Lighting / Daylighting







Key Steps

- Step 6 – Optimize efficiency of resulting building systems for energy, water and carbon emissions
- Step 7 – Recover and reuse energy and water resources
- Step 8 – Offset part of energy needs with renewable energy sources

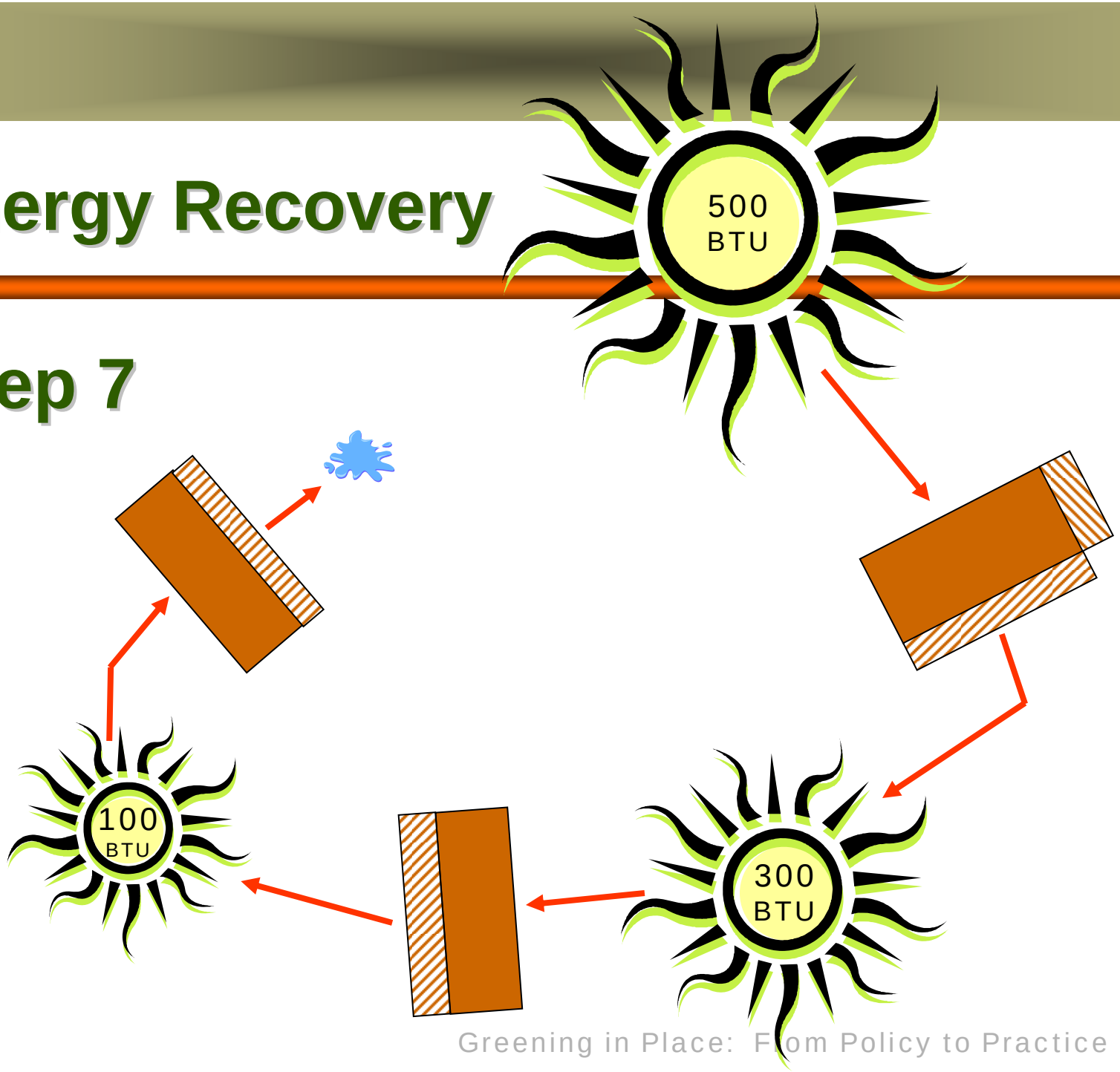
Energy Recovery

- **It's all about delta T (temperature differential)!**

- Look for waste heating & cooling opportunities
- There are some code requirements for energy recovery, but there are many more opportunities within a building

Energy Recovery

Step 7



Think Beyond The Building Footprint

Engineering Lesson of the Day:

THERMODYNAMICS

Laws of Thermodynamics

- **First Law**
  - Energy can be neither created nor destroyed (conservation of energy). Power generation processes and energy sources only involve conversion of energy from one form to another.
- **Second Law**
  - The entropy of an isolated system not in equilibrium will tend to increase over time. Entropy is a measure of disorder or chaos.

First Law

What does this mean?

- We are <u>not</u> “running out” of energy!
- The quantity of all the energy in the universe will remain constant no matter what we do to it.

Second Law

Photo credit: Southern California Gas Company

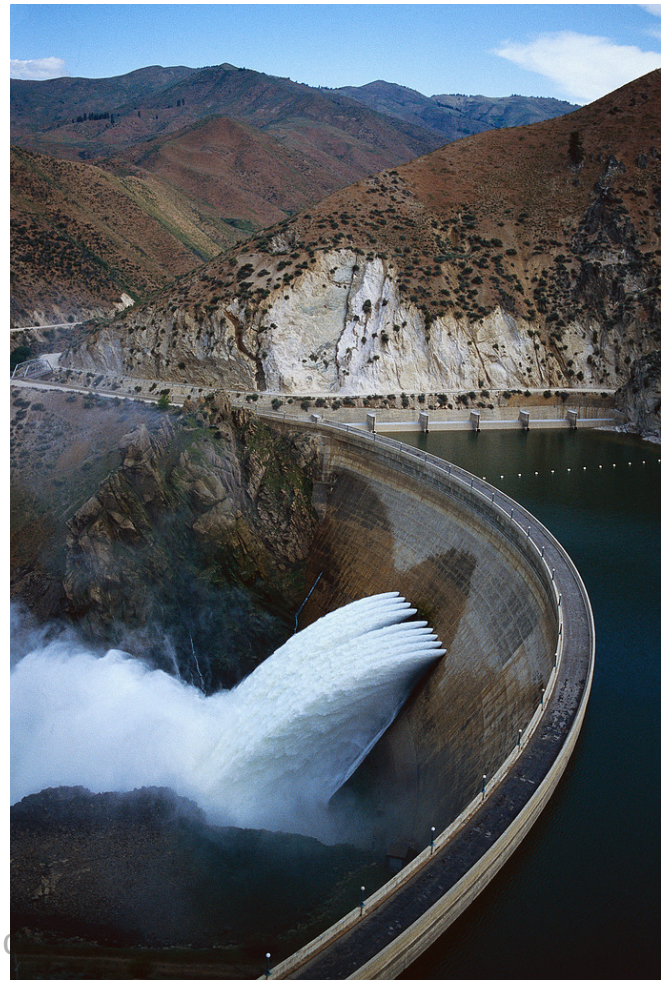
What does this mean?

- We <u>are</u> increasing the entropy of energy forms found in nature that we have figured out how to capture energy from.
- We know how to capture energy from organized forms of matter (matter initially having low entropy).

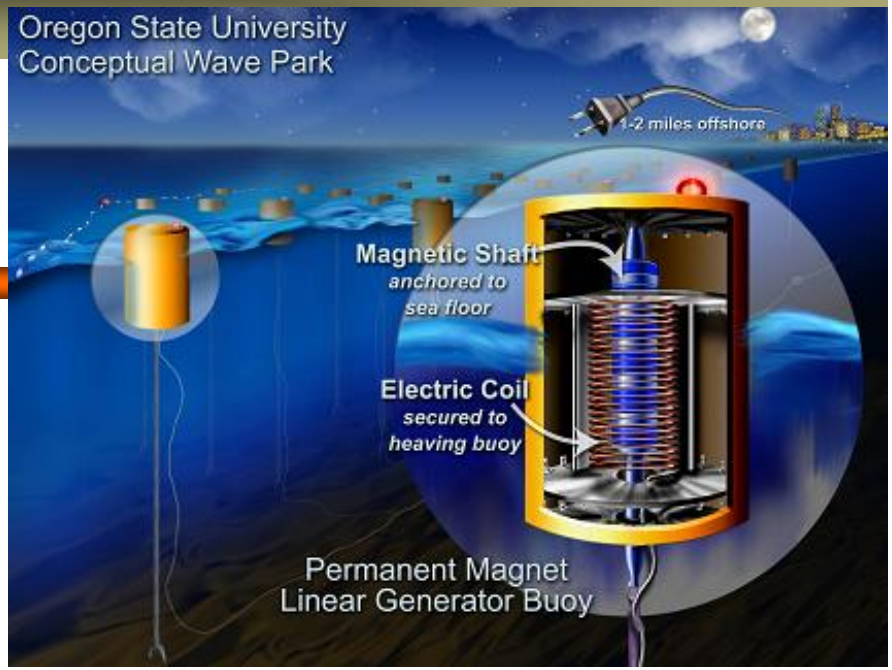
Second Law

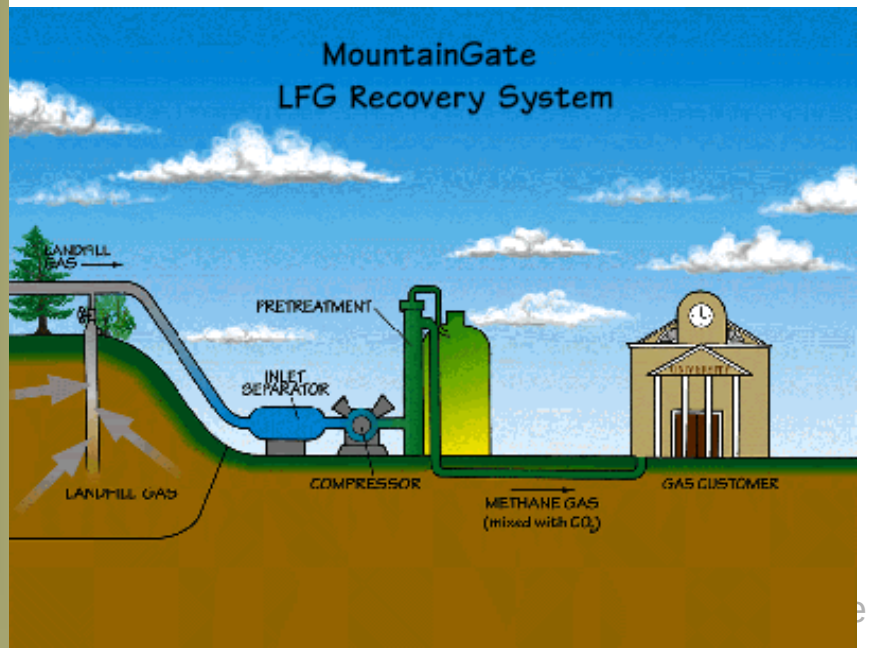
What does this mean?

- We understand how to capture energy from some high entropy forms of matter and are learning how to do this with others.



Second Law

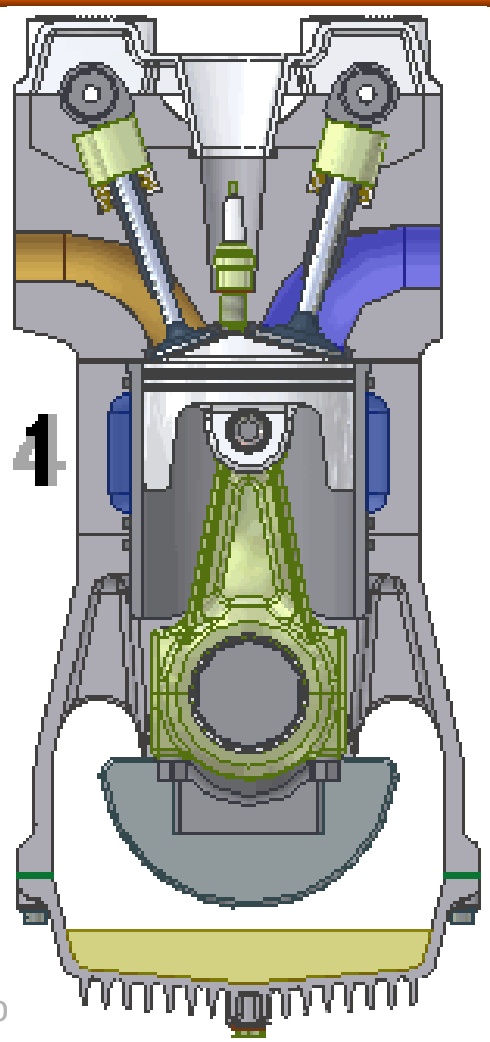

Oregon State University
Conceptual Wave Park
1-2 miles offshore
Magnetic Shaft
anchored to
sea floor
Electric Coil
secured to
heaving buoy
Permanent Magnet
Linear Generator Buoy


MountainGate
LFG Recovery System
LANDFILL GAS
PRETREATMENT
INLET SEPARATOR
COMPRESSOR
METHANE GAS
(mixed with CO_2)
GAS CUSTOMER
LANDFILL GAS

Components of Energy

Energy = Exergy + Anergy

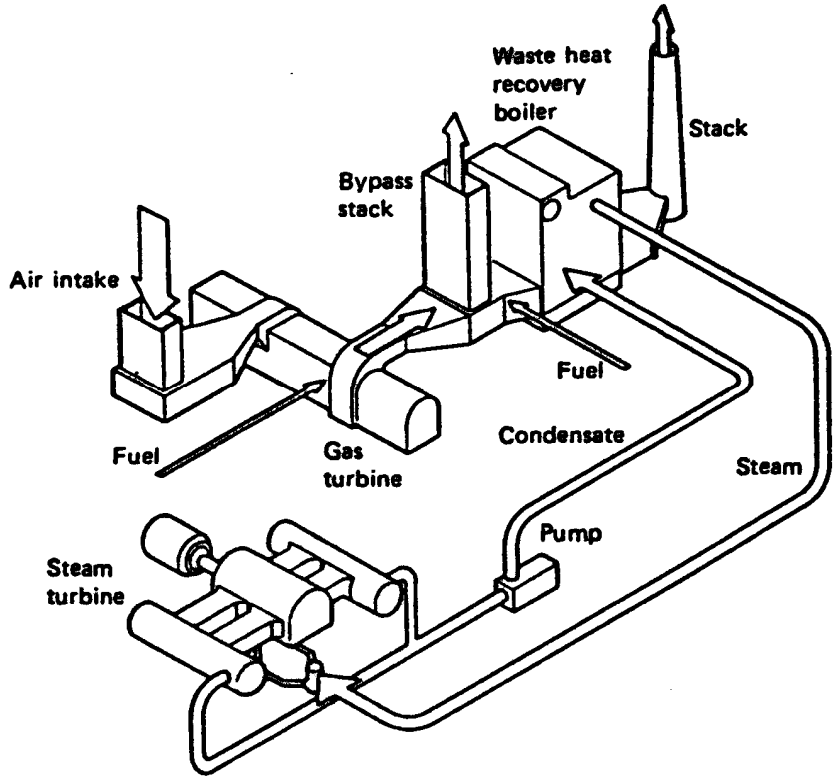
- Exergy is the useful work (power) that may be done by a quantity of energy
- Power is the rate at which work is done: Power = Work / Time
- Anergy is the low value component of this energy
- Heat is a form of anergy



Low Exergy

Low exergy building heating

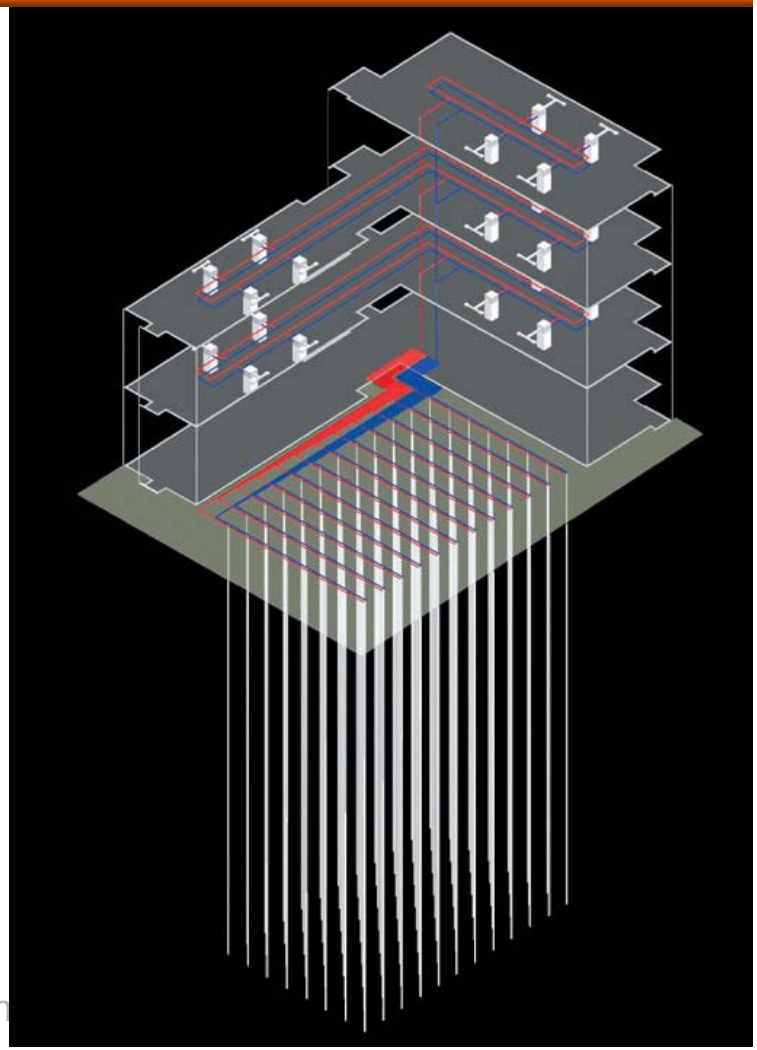
- Passive solar
- Energy recovery
- Waste heat systems from power generation
- Earth energy systems
- Any source of delta T



Low Exergy

Low exergy building cooling

- Economizer (outdoor air cooling)
- Direct/indirect evaporation
- Earth energy systems
- Ground water systems
- Any source of delta T



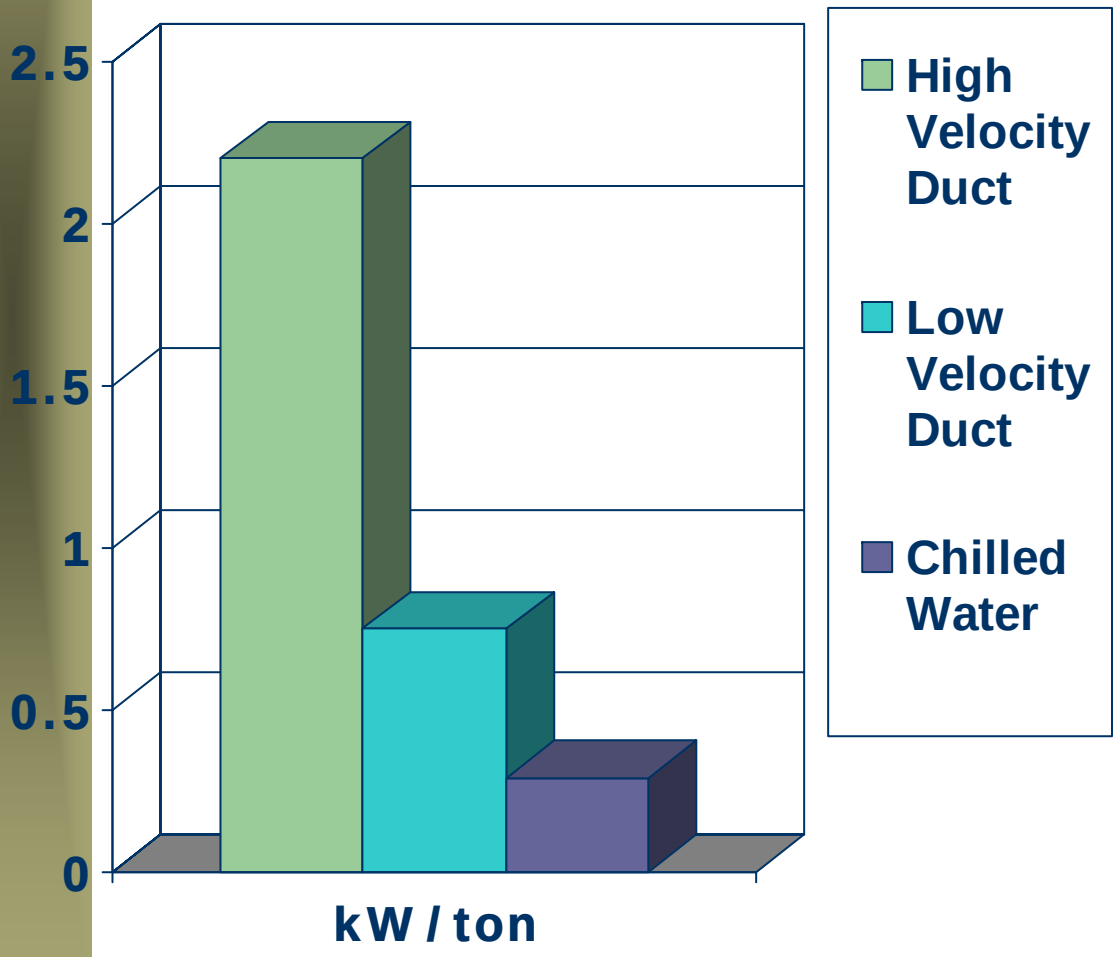
Low Exergy Heating and Cooling

- De-couple ventilation from building load (thermal) management
- Think radiant!

Radiant Heating and Cooling

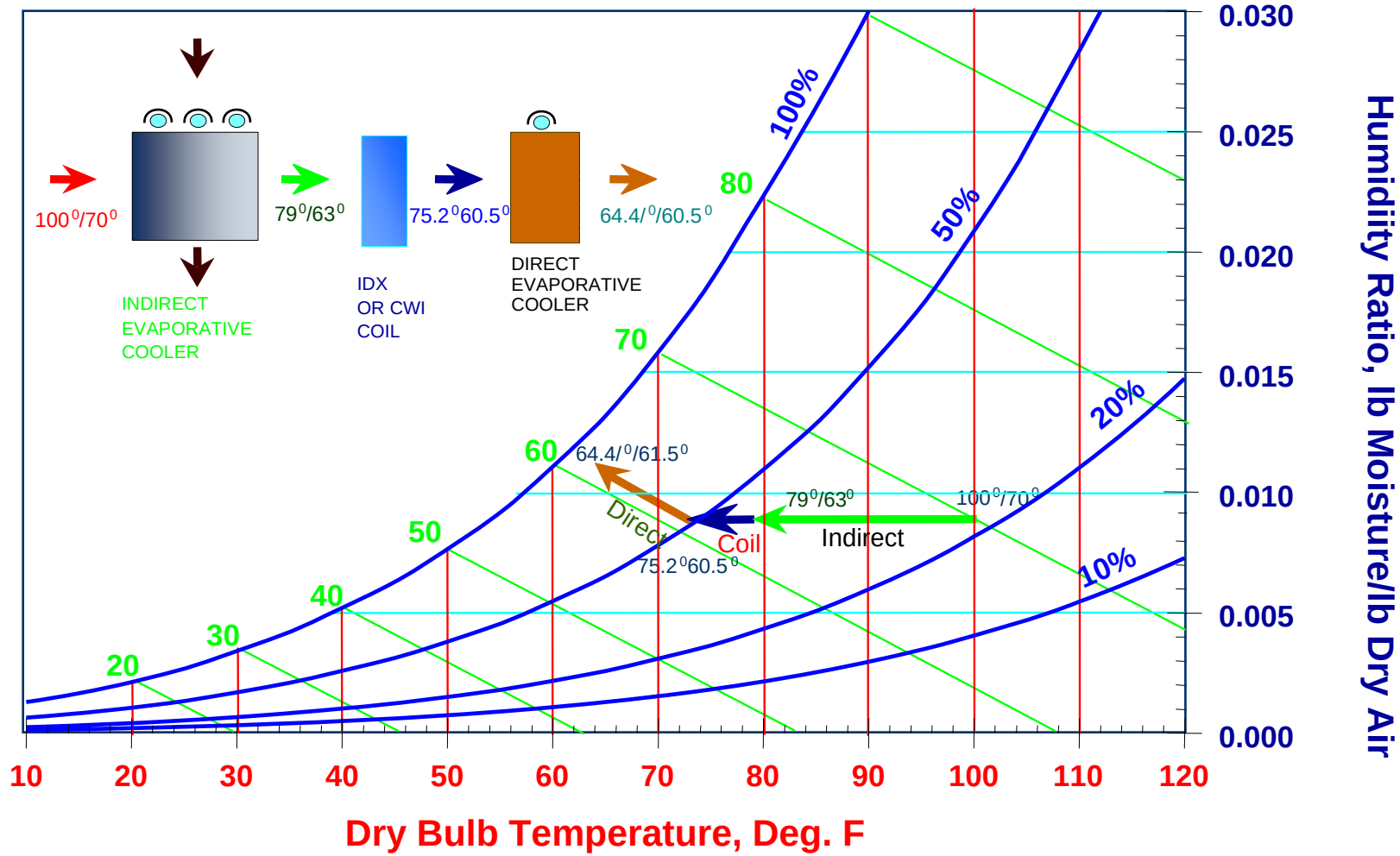
Photos Courtesy of Viega North America

Distribution Efficiency

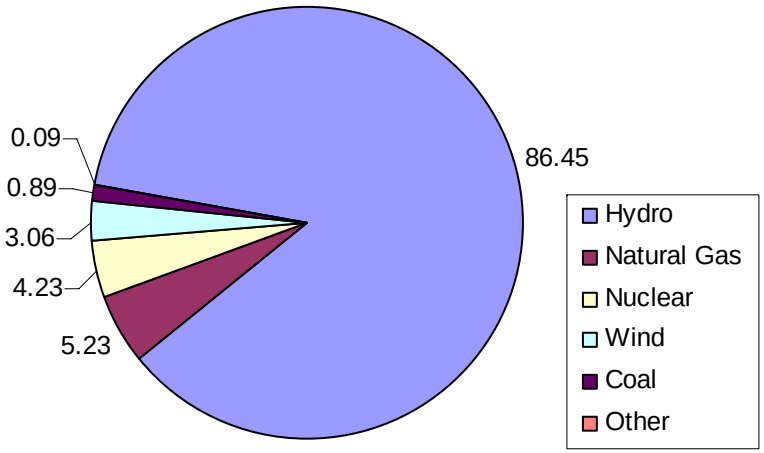


Low Exergy

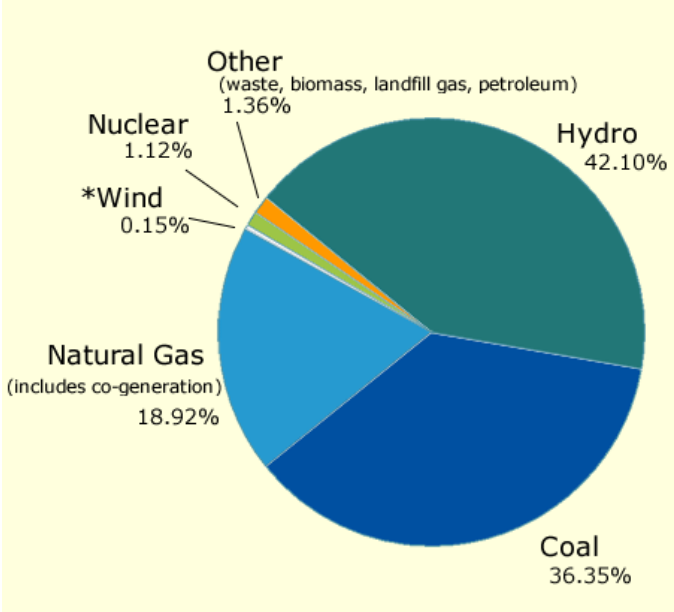
INDIRECT - DIRECT EVAPORATIVE COOLING WITH CHILLED WATER ASSIST



Utility Power Supply Profiles



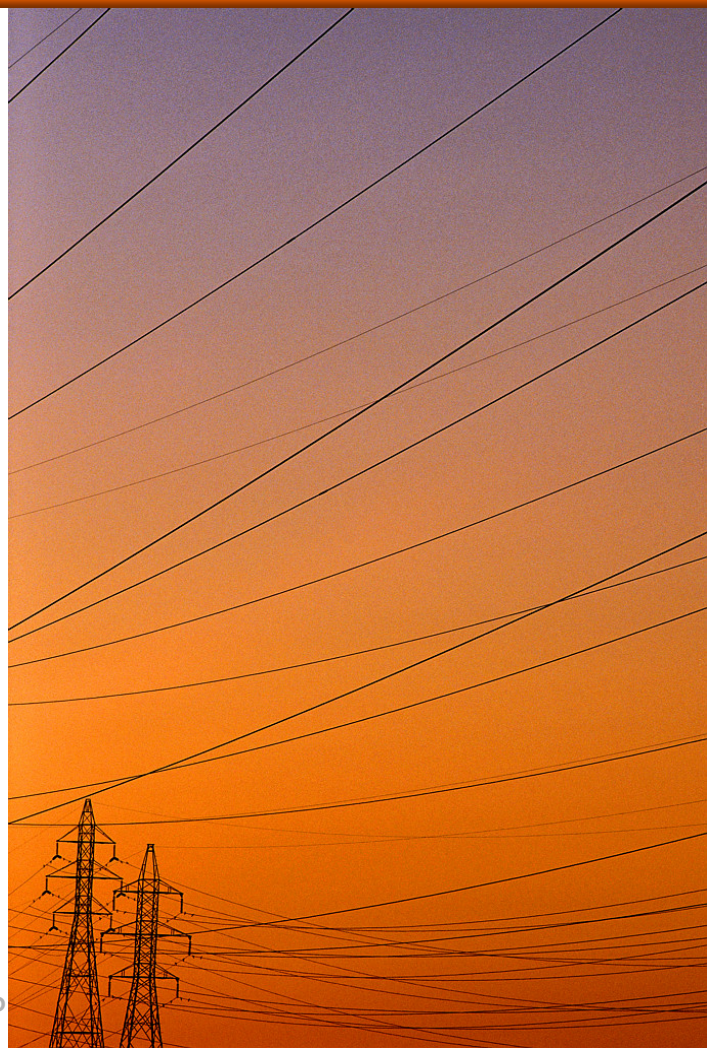
Seattle City Light



Puget Sound Energy

Utility System Losses

- **Production**
  - Energy losses
  - Greenhouse gas emissions
  - Solid by-products
- **Transmission & distribution**
  - Energy losses



Utility System Losses

- **Energy source efficiencies**
  - Coal to power = 35-45% electric efficiency and 50-60% waste heat
  - Natural gas to power = 45-60% electric efficiency and 35-50% waste heat
  - Hydro to power = 85-90% electric efficiency
  - Combined heat and power = 90%
- **Transmission & distribution losses**
  - Power plant to building user = 7% average
  - Natural gas well to building user = 3% average

Utility System Losses

- **Carbon emissions**
  - Coal to power = 0.00086 metric tons/kWh (1.9 lbs)
  - Natural gas to power = 0.000372 metric tons/kWh (0.82 lbs)
  - Washington Utilities Average = 0.0005 metric tons/kWh (1.1 lbs)
  - Natural gas direct to boiler = 0.000186 metric tons/kWh (0.41 lbs)

Energy Efficiency Calculations

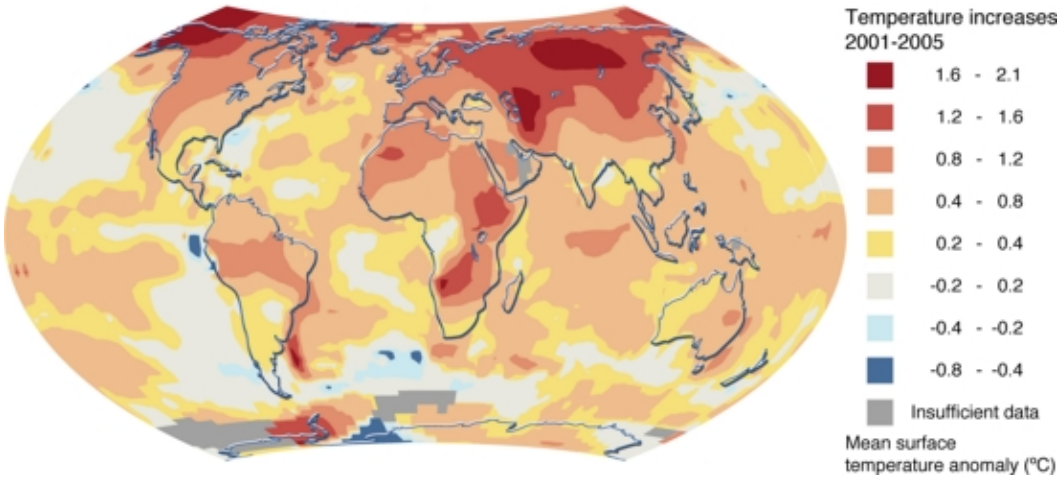
- **Electric heating system**
  - **Average power supply profile**
    - 45% Hydro at 90% electric efficiency
    - 35% Coal at 45% electric efficiency
    - 20% Natural Gas at 60% electric efficiency
  - **Power generation efficiency**
    - (0.45)(0.90) + (0.35)(0.45) + (0.20)(0.60) = 0.683 = 68.3% efficient

Energy Efficiency Calculation

- **Electric heating system**
  - **Say we need 10 therms (290 kWh)…**
  - Building electric distribution efficiency –
    - (1,000,000 btu) / (98%) = 1,020,408 btu
  - Electric utility distribution system efficiency –
    - (1,020,408 btu) / (93%) = 1,097,213 btu
  - Electric utility power generation efficiency –
    - (1,097,213 btu) / (68.3%) = 1,606,461 btu
  - Total system efficiency –
    - (1,000,000 btu) / (1,606,461 btu) = 0.622 = 62.2% efficient
    - 1,606,461 btu = 465.9 kWh

Energy Efficiency Calculations

- **Natural gas heating system**
  - Hydronic system efficiency –
    - (1,000,000 btu) / (93%) = 1,075,269 btu
  - Boiler efficiency –
    - (1,075,269 btu) / (80%) = 1,344,086 btu
  - Natural gas utility distribution system efficiency –
    - (1,344,086 btu) / (97%) = 1,385,656 btu
  - Total system efficiency –
    - (1,000,000 btu) / (1,385,656 btu) = 0.722 = 72.2% efficient
    - 1,385,656 btu = 401.8 kWh

Carbon Emissions Calculations

- **Electric heating system –**
  - **(1.1 lbs per kWh) * (465.9 kWh) = 512.5 lbs**
- **Natural gas heating system –**
  - **(0.41 lbs per kWh) * (401.8 kWh) = 164.7 lbs**