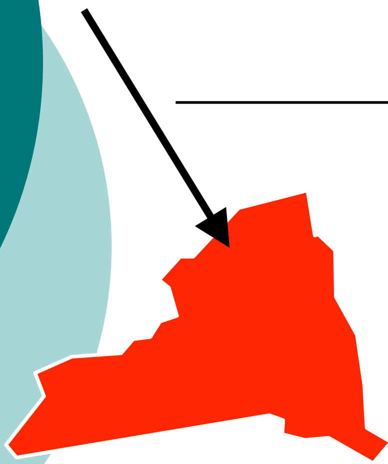
Energy Efficiency:

Preparing middle school students for our energy future



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Project-Based Learning Partnerships

Clarkson

K-12

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ASEE Teachers Workshop

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Powers, S.E., "Energy Efficiency: Preparing middle school students for our energy future." Workshop for teachers presented at the 2010 ASEE Workshop on K-12 Education. Louisville KY, June, 2010.

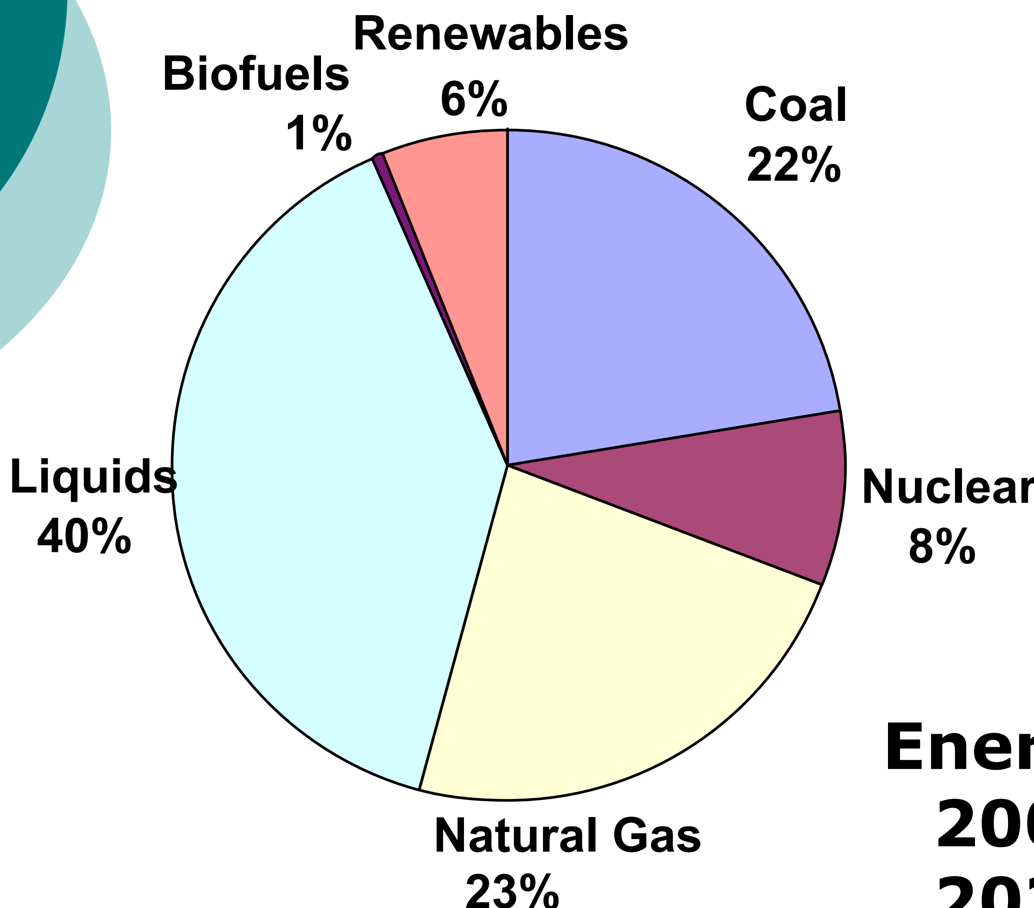
Today

- Brief overview of energy “crisis”
- Need for focus on energy efficiency
- Description of energy curriculum
- Focus on 4 activities
  - Explanation
  - Do activity
  - Report back
- Take home ideas

Key issues in our current energy "crisis"

- Peak Oil – finite supply of fossil fuels
  - World demand for energy is growing
  - Point at which rate of supply decreases imminent
- Climate change
  - Carbon dioxide concentrations in the atmosphere are increasing substantially
  - Temperatures are rising globally
  - Significant consequences
    - Biodiversity
    - Polar ice caps
    - Sea level changes
    - Changes in storm patterns

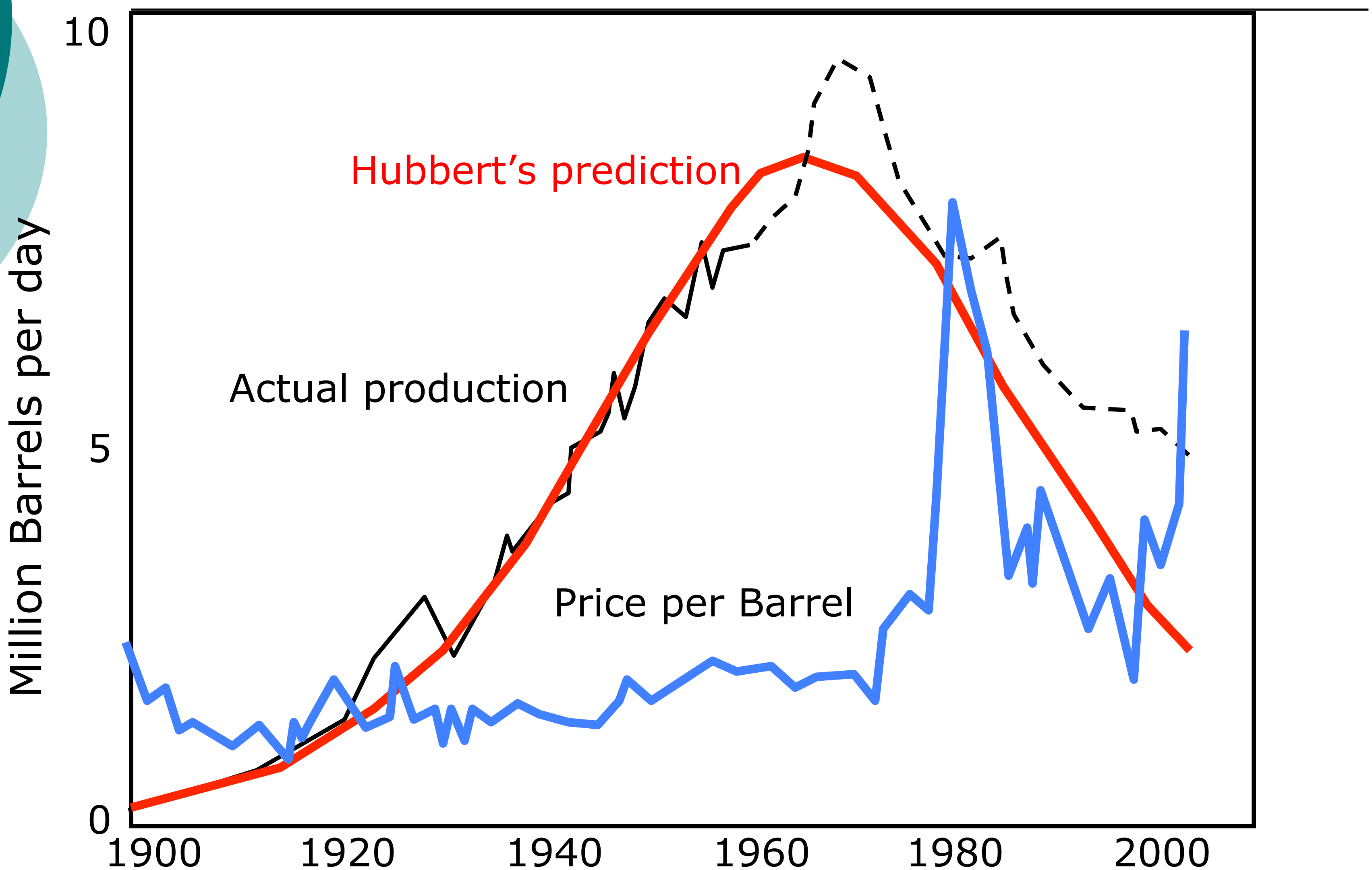
Current Energy Consumption



Energy Consumption
2007 ~100 Quads
2030 ~113 Quads

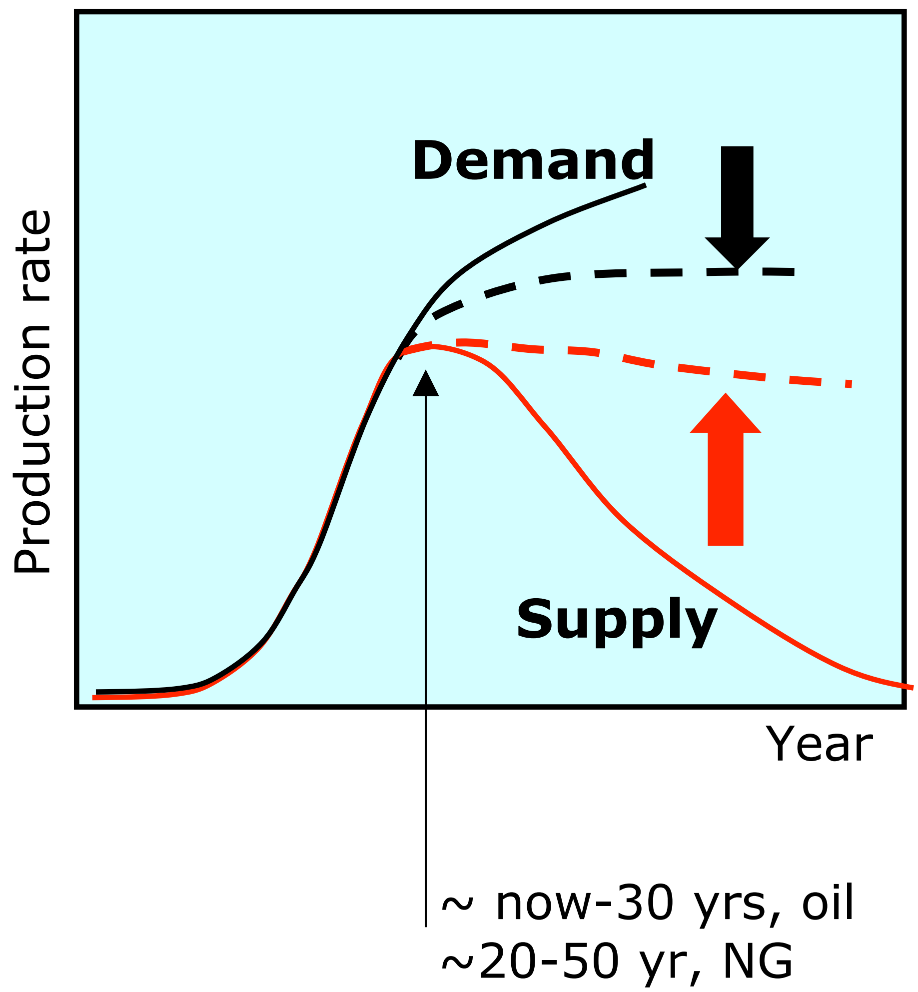
85% non-renewable fossil fuels

Hubbert’s Peak Oil Model
Contiguous USA, 1900 - 2004

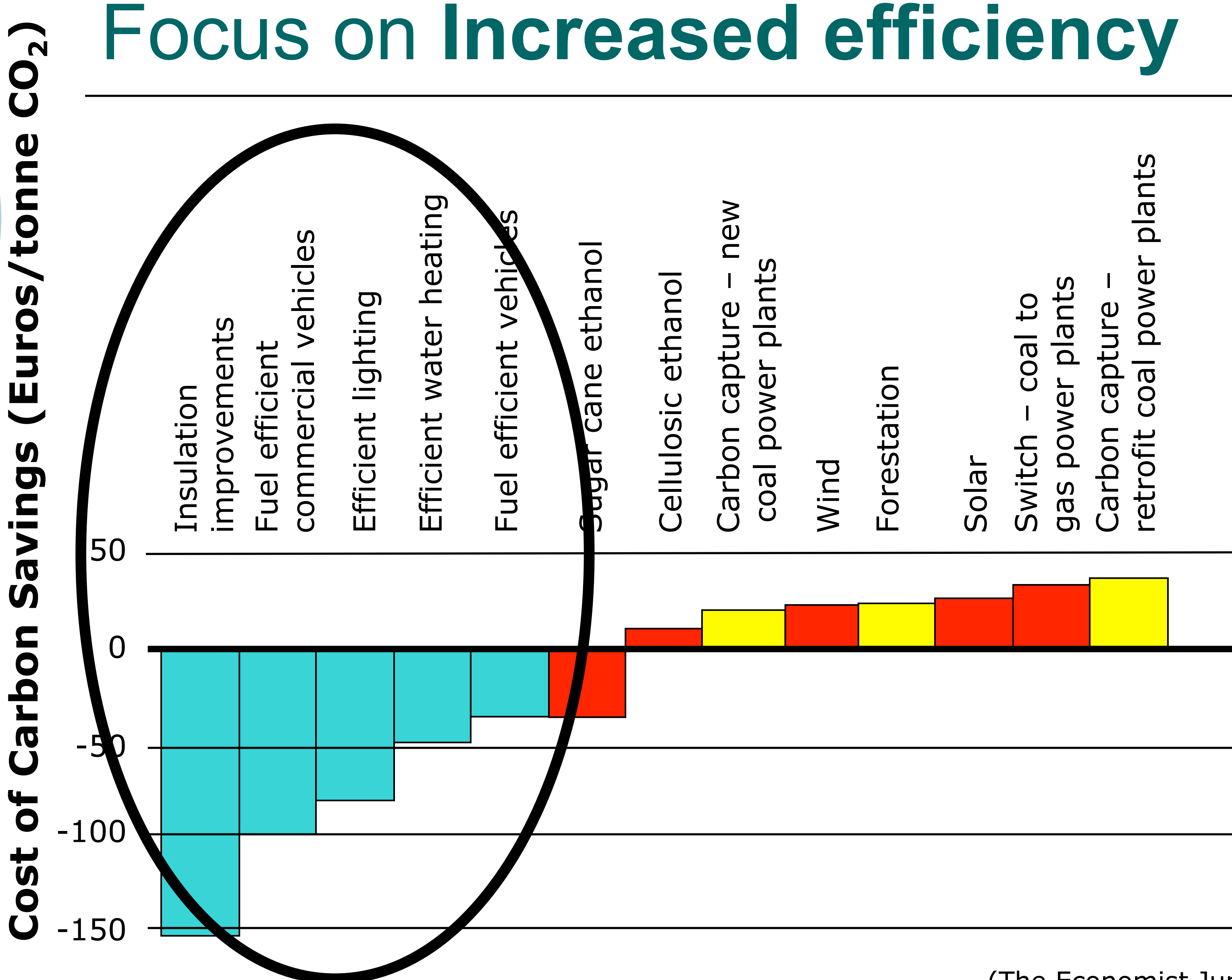


Engineers need to address to Peak Oil

- Consequences when demand exceeds supply
  - Prices for energy and all other goods and services
  - Conflict
- Solutions
  - Increase supply
    - Renewable energy resources
    - Fossil fuels
  - Reduce demand
    - Conservation
    - **Efficiency**

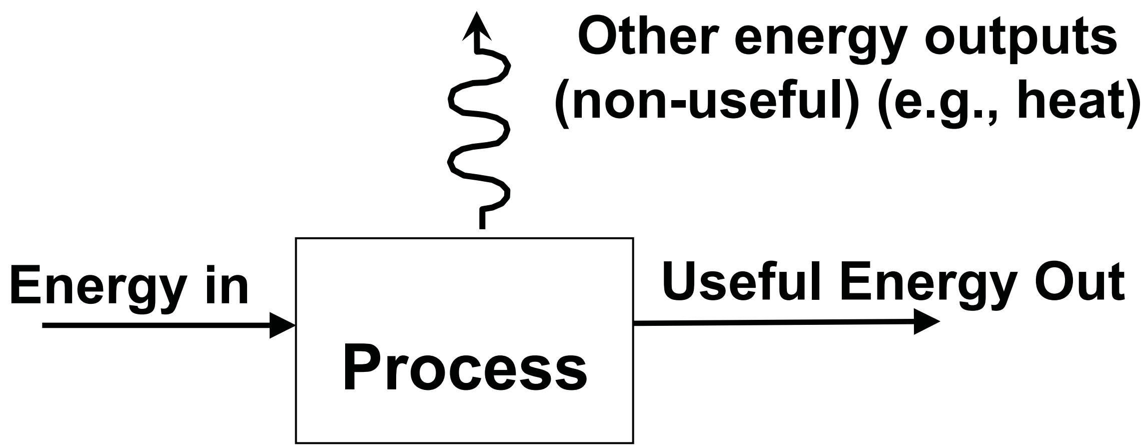


Focus on **Increased efficiency**



(The Economist June 2, 2007)

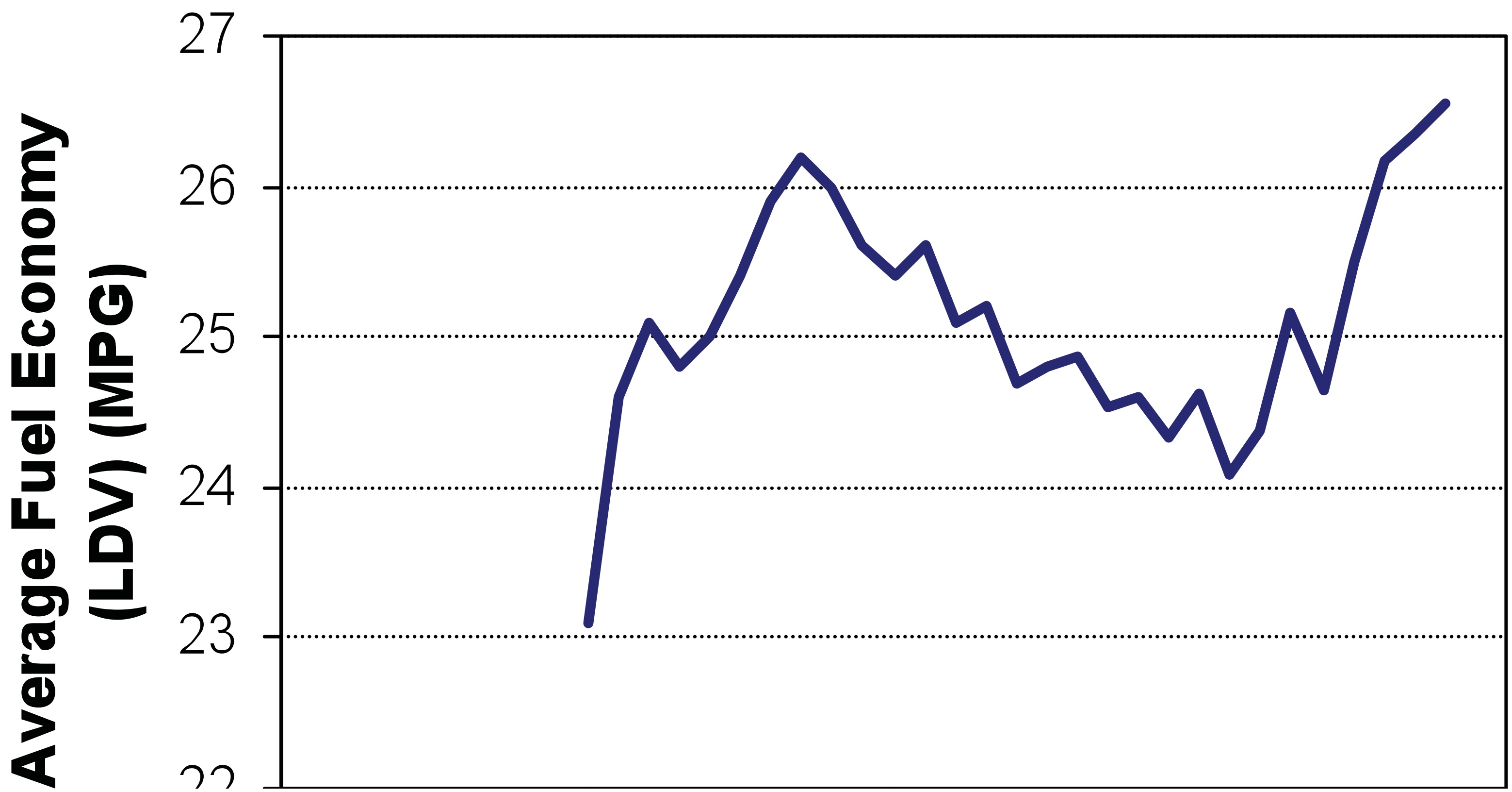
Focus on Efficiency



- Less than 1/4 energy used in stove reaches food
- Waste heat from US power plants could power the Japanese economy
- 15% of energy in gas reaches wheels of a car
- 2.7 mpg increase in light vehicle fleet would displace Persian Gulf imports

(Amory Lovins)

Fuel Economy (Light vehicles only)

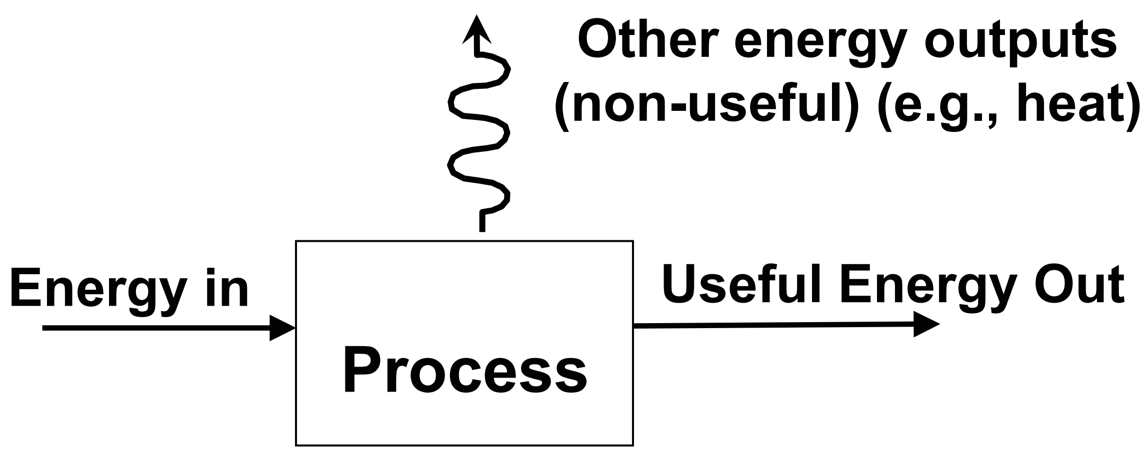


May 2009 – New fuel efficiency standards set for 2016

Current	27.5 mpg for cars	23.1 mpg for light trucks/SUVs
Proposed	39 mpg	30 mpg

Energy Systems - Popcorn Efficiency

- Illustrative example to illustrate
  - Energy “losses”
  - Basic efficiency calculations for a system



$$Efficiency = \frac{useful\ energy\ out}{energy\ in}$$

Popcorn Efficiency - Summary

1. Measure how much “energy” you start with
2. Define an energy conversion process
3. Measure useful “energy” output
4. Calculate efficiency
5. Try a more complicated system

Education and Energy Literacy Critical

Our students will be affected by energy in their lives

Students will learn more and become more interested in math, science and engineering if they:

- understand the ***relevance*** of what they are learning
- are ***actively involved*** with the learning process
- understand that these subjects will help them ***solve problems*** that are import to their community
- work with MST ***mentors*** from local Universities

→ **Project-Based Learning**

A systems-based approach

- Energy in our lives
- Energy sources
- Energy systems
- Design and Communication

Understanding the Energy Problem

Introduction-The Energy Problem	Energy Intelligence Agency **Energy Choices Board game** Graphing – Energy facts and statistics
Problem Solving Approaches	Egg drop demo Example problem solving

Energy Background

Energy Basics	Human Power experiment
Forms, States and Conversions	Forms and conversions – everyday items
Sources and Systems	Renew-a-Bean Energy Sources Research Energy System Diagrams
Efficiency	Efficiency of an Electro-mechanical System **Efficiency of Water Heating Systems**

Solving the Problem

Household Conservation and Efficiency	Using a watt meter – **Holiday Lights** Home energy audit **Light vs. Heat bulb experiment**
Final project	Final project

Energy in our Lives: The Energy Problem

"Energy Choices"

Patterned after game "Life"

House and car defined

Pay gasoline and home energy bills

Choices made along way, e.g.,

- Add insulation
- Buy air conditioner
- Trade in car

Two-door hybrid

(Two Seater) Automatic Transmission

Small hybrids offers great mileage and aids in reducing pollution and global warming by switching between a gas engine and electric motor.

Mileage (City/Hwy): 57/56

# of Gas Cards: 1

Big, luxury vehicle

Automatic Transmission

This sleek black sedan is a great car if you like fast and beauty. However it requires Premium gasoline which is expensive and it needs a lot of it.

Mileage (City/Hwy): 19/27

# of Gas Cards: 5

System B: On-Grid Electric

Large Size (3,000 sq. ft)

This home's electricity comes from the national electric grid. Heating which comes from natural gas, is included in the energy bill.

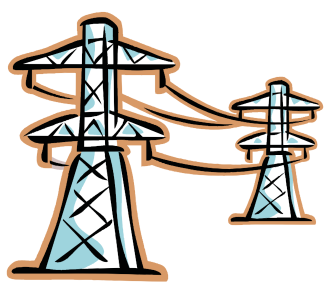
Minimal Insulation (1)

Central Air Conditioning

Set-Up Cost: $0

Annual Energy Bill: 2,900 zaps

Carbon Tax: $2,500



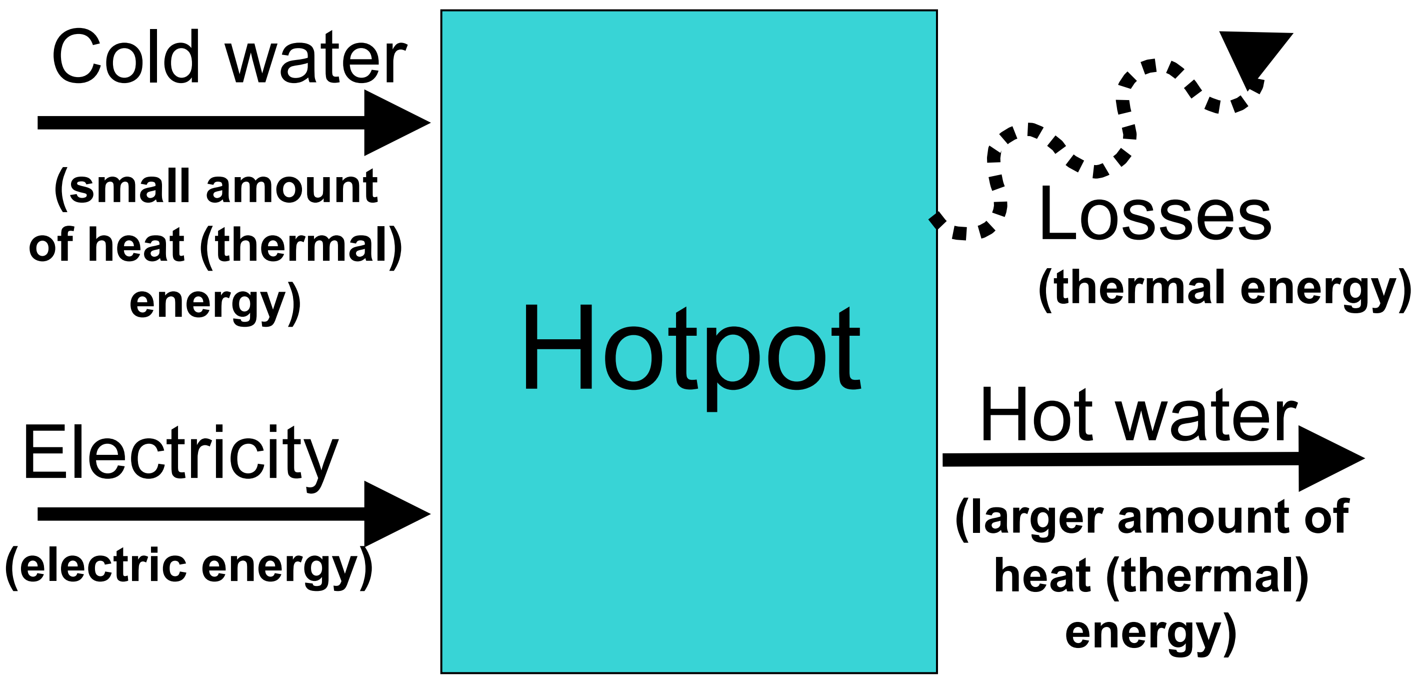
Situation:

Heat Wave strikes!

All players pay:

if Air Conditioning pay	$200
if Fans pay	$50
if Insulating Window Shades pay	$0

Efficiency of Heating Water



$$Efficiency = \frac{energy\ out}{energy\ in} \sim \frac{m\ C_p\ \Delta T}{power \times time}$$

Efficiency of Heating Water

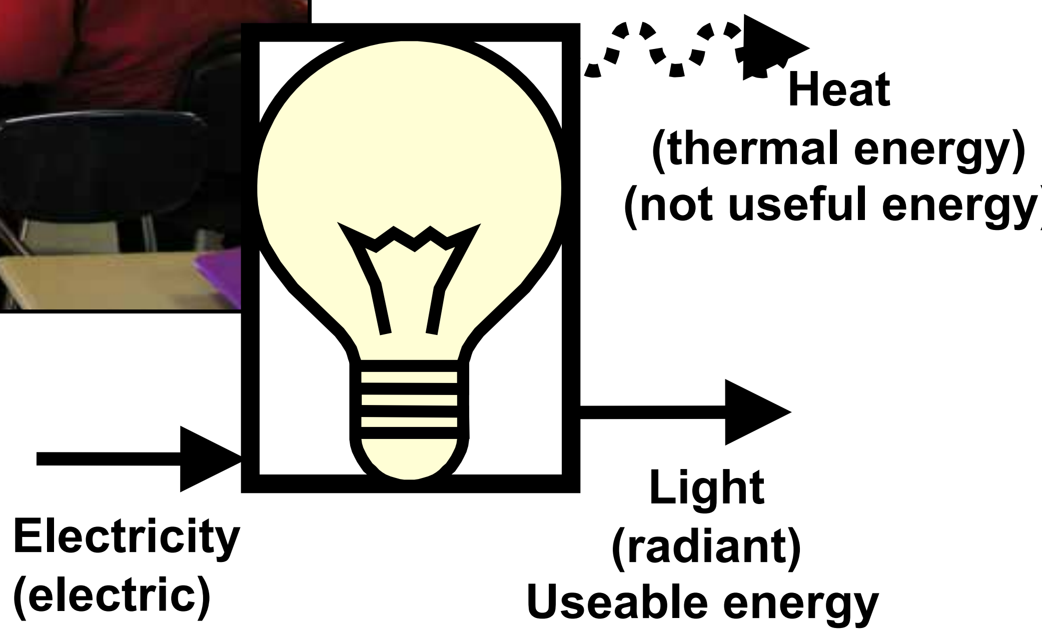
- Energy change in water (Q):
  - *Q* is the energy required (joules, J);

$$Q = m\,C_p\,\Delta T$$

  - *m* is the mass of the substance (g);
  - *Cp* is the specific heat (J/g/°C) = 4.186 J/g/°C
  - ΔT is the change in temperature (°C)
- Electrical energy input
  - Energy = power (W) X time (s)
  - Measured with watt meter and stop watch

Light bulb efficiency

Which light bulb generates the most useful energy (light) for the least amount of electrical energy input?



Regroup

- Energy efficiency is an essential component of our energy future
- Energy efficiency and education -
  - Basics of energy efficiency and calculations fit well in middle school curriculum
  - Students and consumers need to understand efficiency concepts
- All activities and lesson plans available on the web
  - www.clarkson.edu/k12
  - www.teachengineering.org

- Questions?

For more information…

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How much do we know?

In the period between 1990 and 2000, the average miles per gallon of gasoline used by vehicles in the U.S. …

a) increased
b) remained the same
c) went down, or
d) has not been tracked?

- In 2001 - 17% of 1500 American adults chose correct answer regarding gasoline mileage (National Environmental Education and Training Foundation
- Only 12% considered to have a passing knowledge about energy

Meeting the increased demand

Changes for 2030 relative to 2007

Changes in Supply (%)	
Coal	17
Nuclear	13
Natural Gas	6
Oil	-4
Biofuels	444
Renewables	76

Reduction in demand (%) due to increased efficiency	
Commercial Sector	18
Residential	29
Transportation (LDV)	51

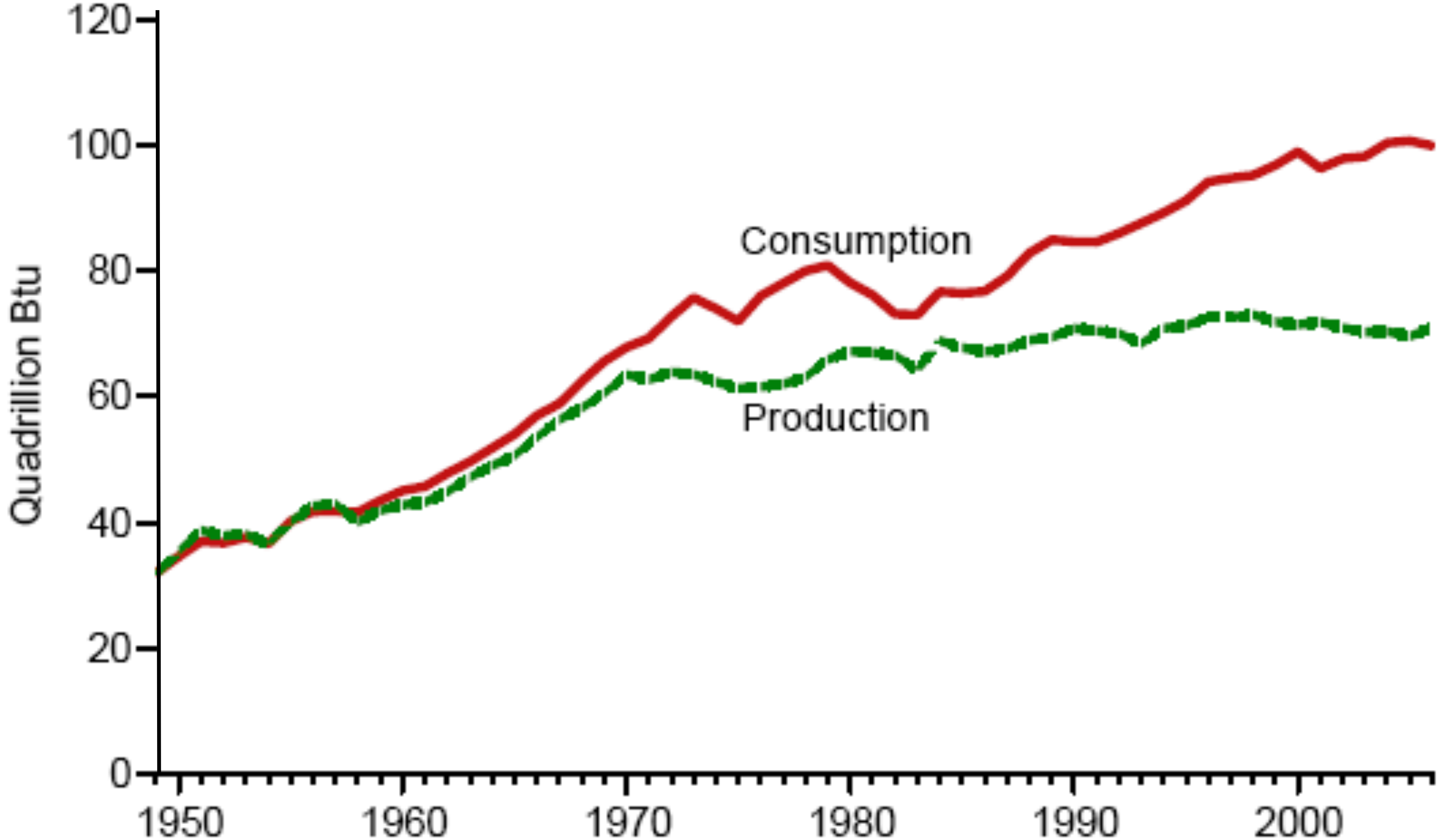
Lesson Plan: Efficient Energy Use

- **Concepts**
  - Energy conservation can be defined as the protection, preservation, management, or restoration of our energy resources.
  - Conservation is one of the ways we can reduce energy use, thus reducing … the negative effects of the burning fuels.
  - Conservation methods include modifications to our daily behaviors
  - **Efficiency measures include choosing energy conscious products.**

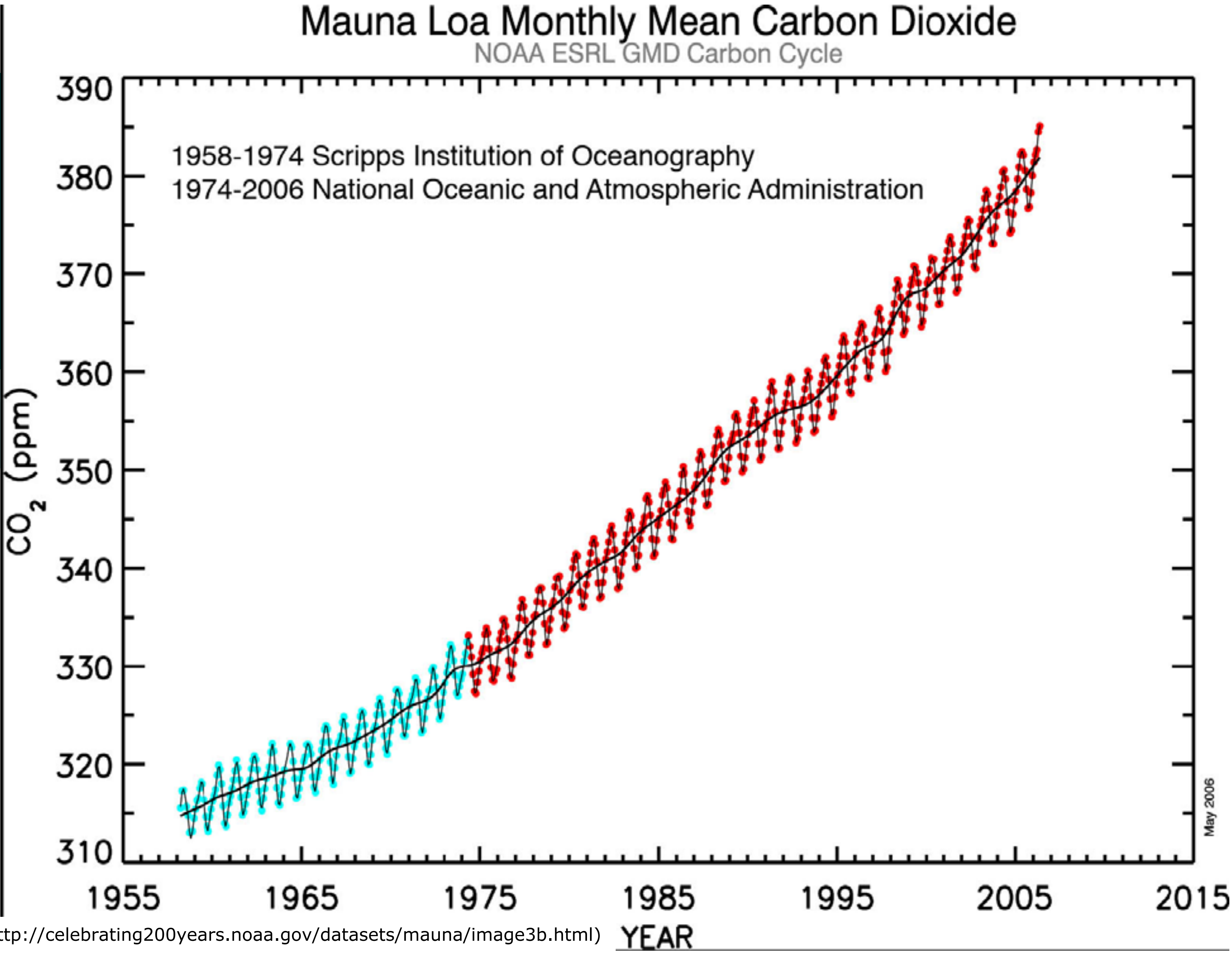
Lesson Plan: Thermodynamic Efficiency

- Concepts
  - The efficiency of a system is defined as the ratio of the output energy (or power) to the input energy (or power). These can be measured and calculated.
  - The second law of thermodynamics can describe the energy that cannot be captured and used by humans.
  - The efficiency of a system will decrease as the number of energy conversions increases.
  - A goal of technology is to increase efficiency both directly and indirectly.

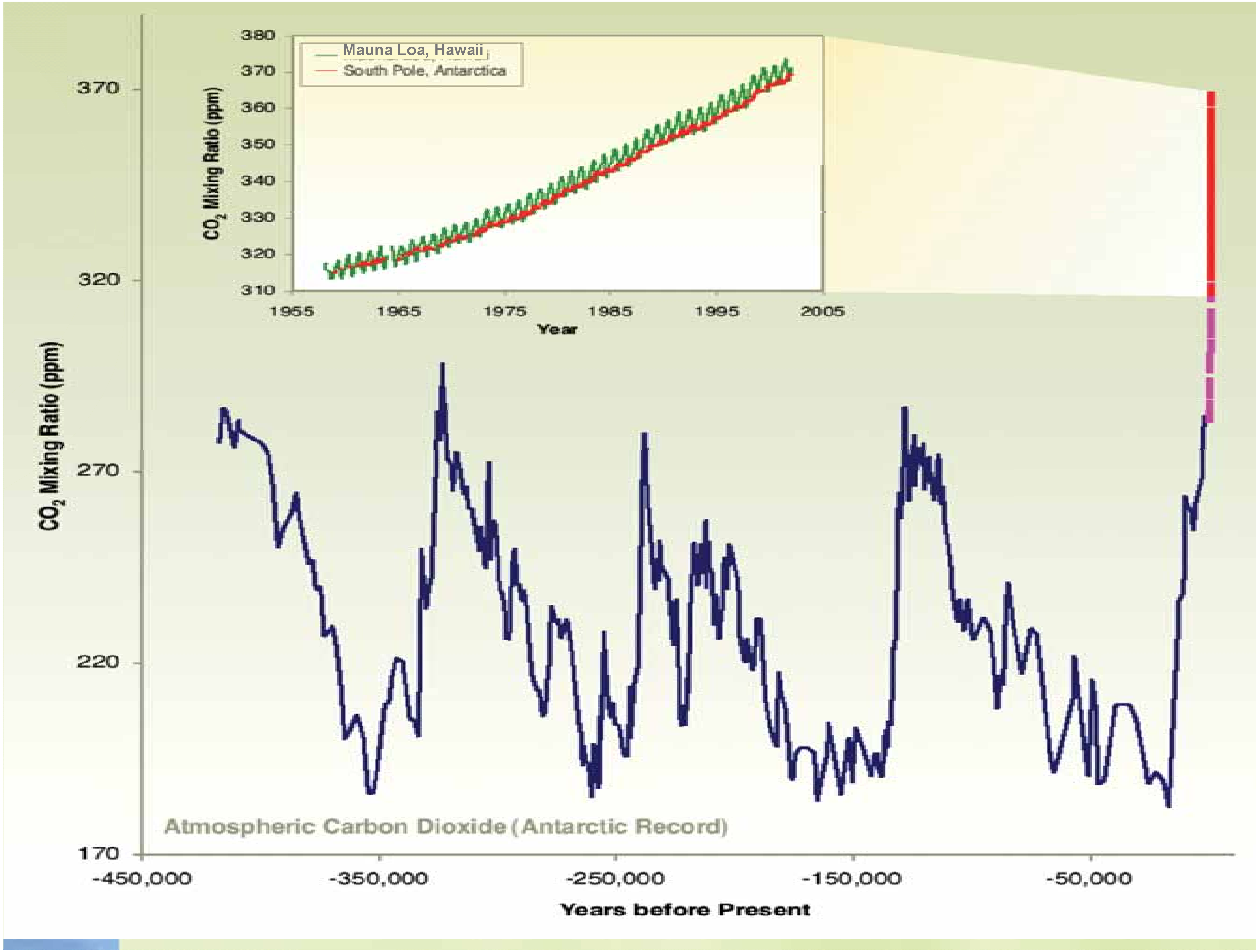
Production and Consumption, 1949-2006 - USA



Data from www.eia.doe.gov; included in 8th grade graphing activity – www.clarkson.edu/k12

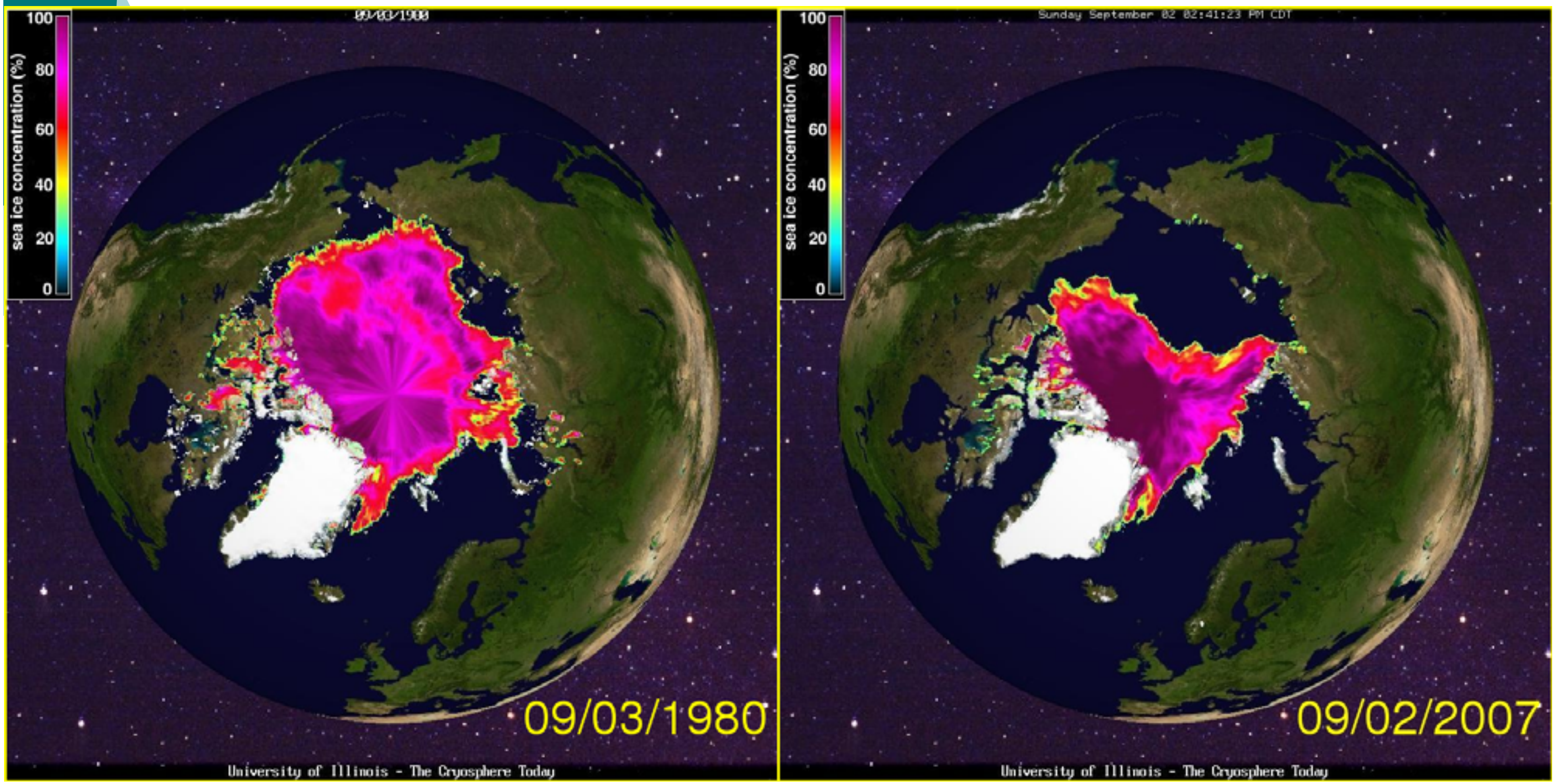


(http://celebrating200years.noaa.gov/datasets/mauna/image3b.html)



Mauna Loa, Hawaii
South Pole, Antarctica
CO_2 Mixing Ratio (ppm)
Year
Atmospheric Carbon Dioxide (Antarctic Record)
Years before Present

Decline in Sea Ice Coverage



(http://arctic.atmos.uiuc.edu/cryosphere/ - great site)

Electro-Mechanical Efficiency

- Generator (L) – Motor (R) system
- 100% efficiency → both washers would rise to the same height
- define the "useful" energy output as the work done to lift the right washer
- energy input estimated from the work to raise the left washer

$$energy\ in = work\ to\ move\ left\ washer =$$

$$force \times distance = mass_{washer}\, g\, height_{L\ washer\ moved}$$

- the efficiency defined by energy out/ energy in:

$$efficiency(\%) = 100\% \times \frac{mass_{washer}\, g\, height_{R\ washer\ moved}}{mass_{washer}\, g\, height_{L\ washer\ moved}} = 100\% \times \frac{height_{R\ washer\ moved}}{height_{L\ washer\ moved}}$$