WHAT IS ENERGY?
THE MASTER RESOURCE

By Vance Ginn

Bradley: Chapters 1, 2, 3

Energy Economics

- Definition:

_____

_____

- The field that studies human utilization of energy resources and energy commodities and includes:
  - Market structures, regulatory structures; distributional, and environmental consequences

Energy

Energy Definition

It is the capacity for doing work,

Examples,

- Lifting

- Accelerating

- Heating

The Master Resource

Some Applications of Energy

- Fuels our nation's economic growth.

- Makes industrial production possible.

- Providing the lifeblood of the information infrastructure.

- Heats and lights our homes.

- Makes the world more accessible.

It is, quite simply, the foundation of the modern economy

Example: Gasoline

DRIVERS OF ENERGY DEMAND

Energy demand is derived from preferences for energy services and depends on properties of conversion technologies and costs.

For example, consumers use gasoline to fuel an automobile or other motorized vehicle, converting gasoline to mechanical energy for motive power. The amount of gasoline used is proportional to the miles the auto is driven and inversely proportionate to the efficiency by which gasoline is converted to useful mechanical energy, measured as miles per gallon of gasoline of the automobile. **Demand for gasoline is thus derived from choices about distances vehicles are driven and their energy conversion efficiencies.**

City

A

CITY

B

Energy & Human Activity

Is Energy an Essential Good?

In economics, an essential good is one for which the demand remains positive no matter how high its price becomes. In the theoretical limit, for prices unboundedly high, consumers would allocate all of their income to purchases of the essential good.

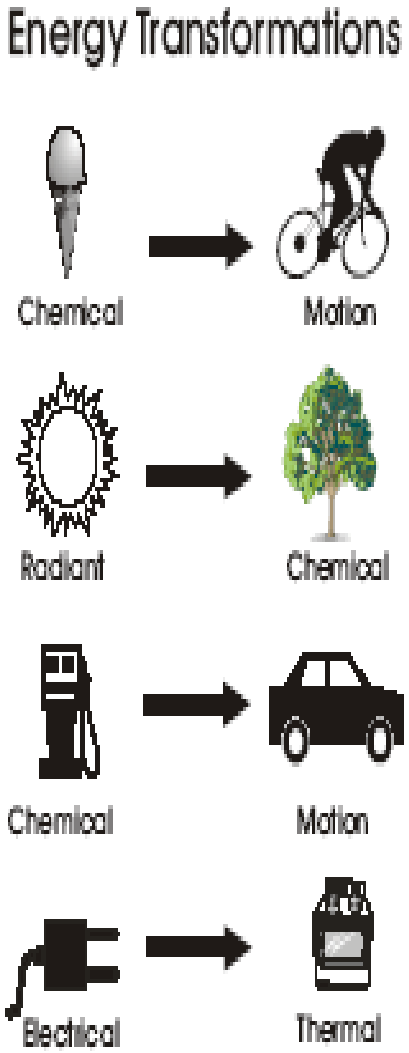
Energy is often described as an essential good because human activity would be impossible absent use of energy: living requires food embodying chemical energy.

Where Does Energy Come From?

- Most of the Earth's energy comes from the Sun! Video
  - _____ –process by plants from sunlight
  - Coal-formed from thick layers of dead plants turning into a substance called _____ that later transformed into coal.
  - Fossil fuels-those fuels (peat, coal, tar, petroleum and natural gas that believed to come from long dead plants and animals

Where Does Energy Come From?

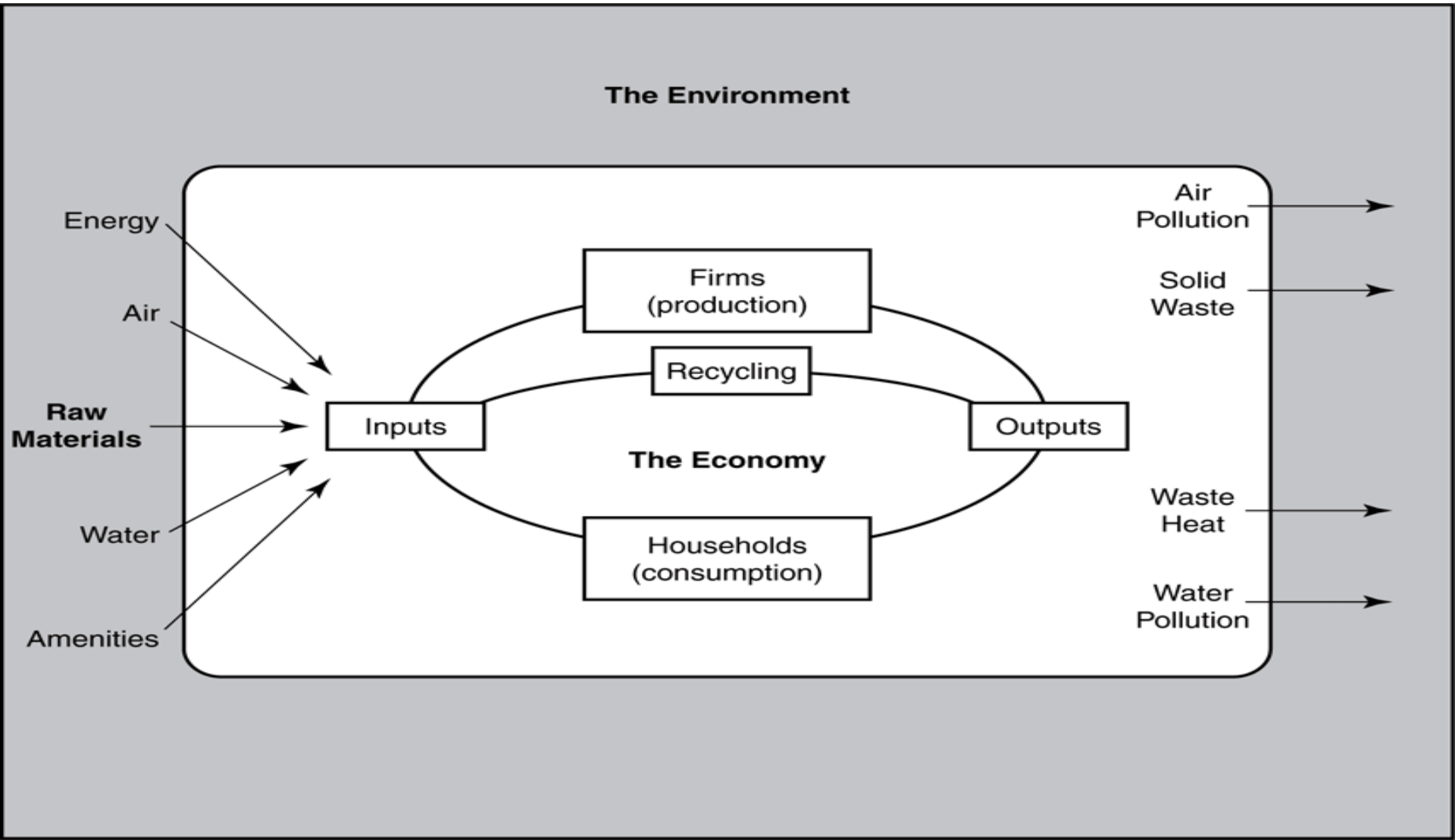
- _____:
  - Tidal energy-from the sun's and the moon's gravitational pull
  - Geothermal energy-produced by radioactive decay deep with the Earth and transmitted by the hot, molten layer of rock beneath the Earth's crust
  - Fission (atomic energy)-released by the splitting of the nuclei of uranium or plutonium atoms
  - Fusion (atomic energy)-released when atoms combine, as occurs in the sun's core
  - Chemical energy-from exothermic reactions
  - Cosmic radiation-from distant stars



First & Second Laws of Thermodynamics

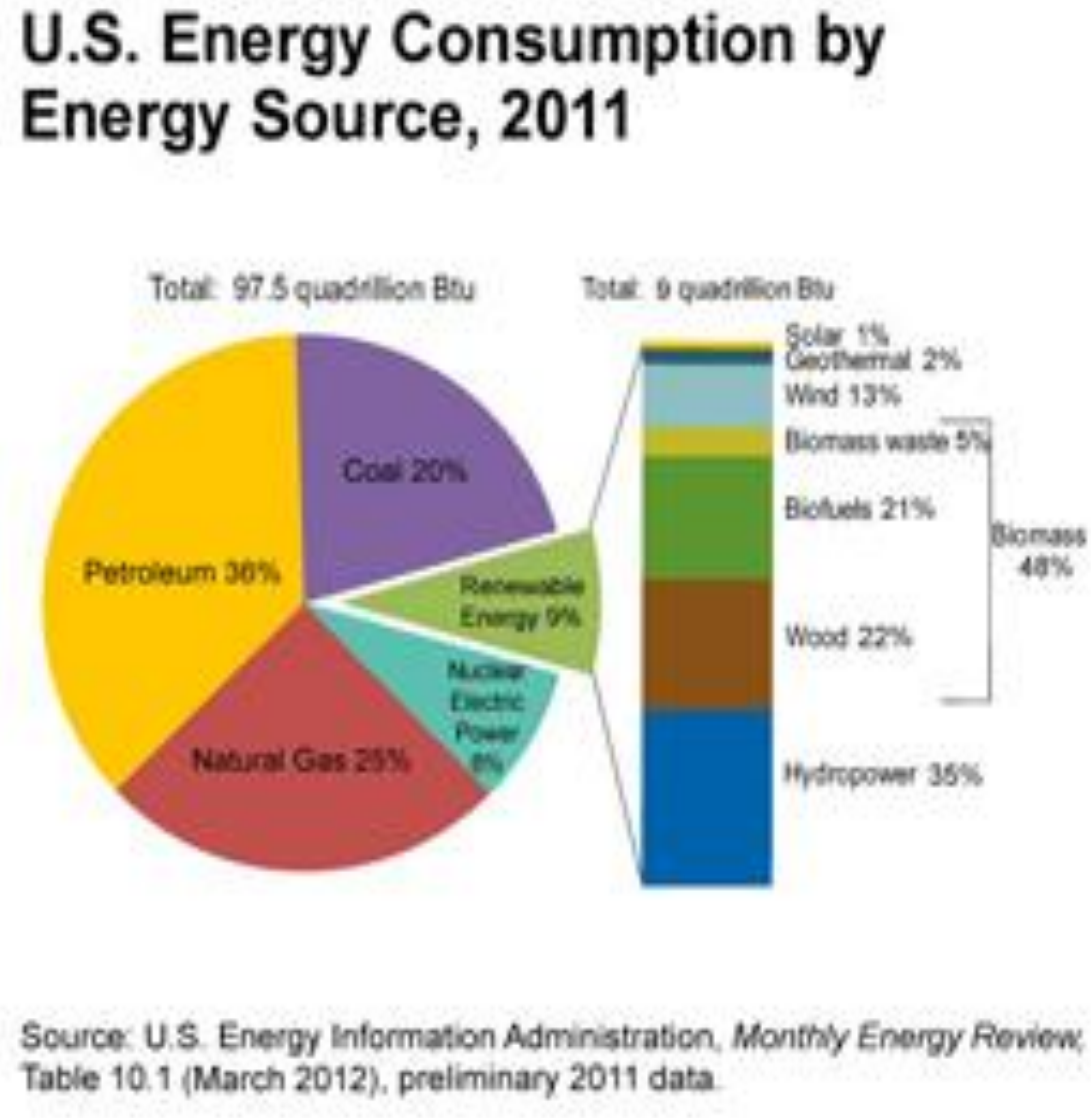
- First Law: Energy is neither created nor destroyed but can be converted among forms:
  - Energy input must equal the total energy output
  - Two basic forms: Video
    - Potential: _____
    - Kinetic: _____
- Second Law: Entropy—energy not available for work—increases as it flows "downhill."

Inputs = Outputs



Primary Energy Sources – link

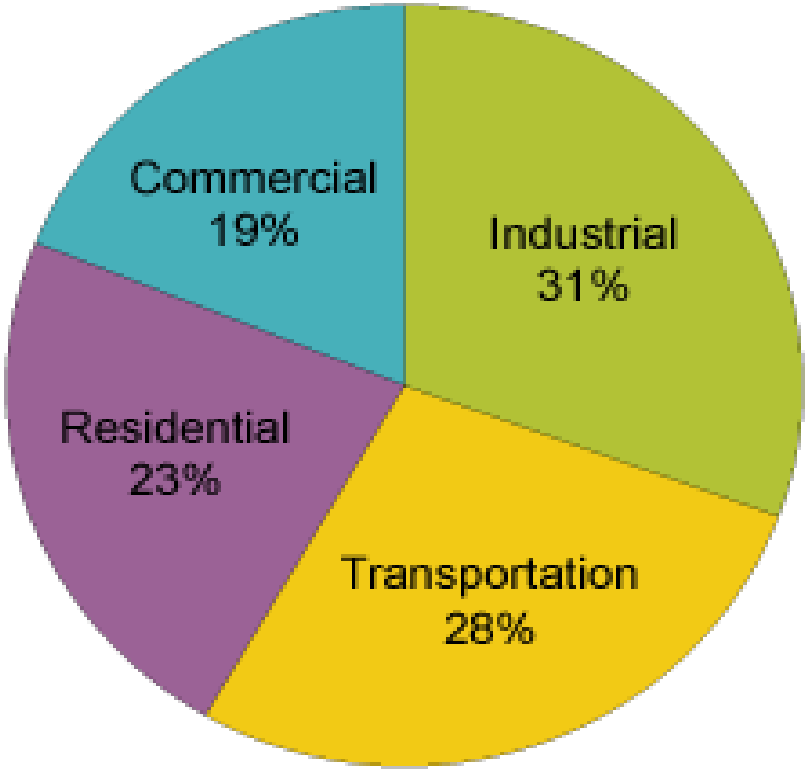
- Nonrenewable Energy:
  - Petroleum–Oil (1st)
  - Coal
  - Nuclear Power
  - Natural Gas
- Renewable Energy:
  - Wind
  - Solar
  - Hydro
  - …more



Use of Energy & Measurements

- We use energy to fuel our economy.
- How is it measured?
  - barrels of oil
  - cubic feet of natural gas
  - tons of coal
  - kilowatt hours of electricity
  - In the United States,
    - British thermal units (Btu), a measure of heat energy
    - In 2011, U.S. primary energy use was about 98 quadrillion ($=10^{15}$, or one thousand trillion) Btu.

Share of Energy Consumed by Major Sectors of the Economy, 2010



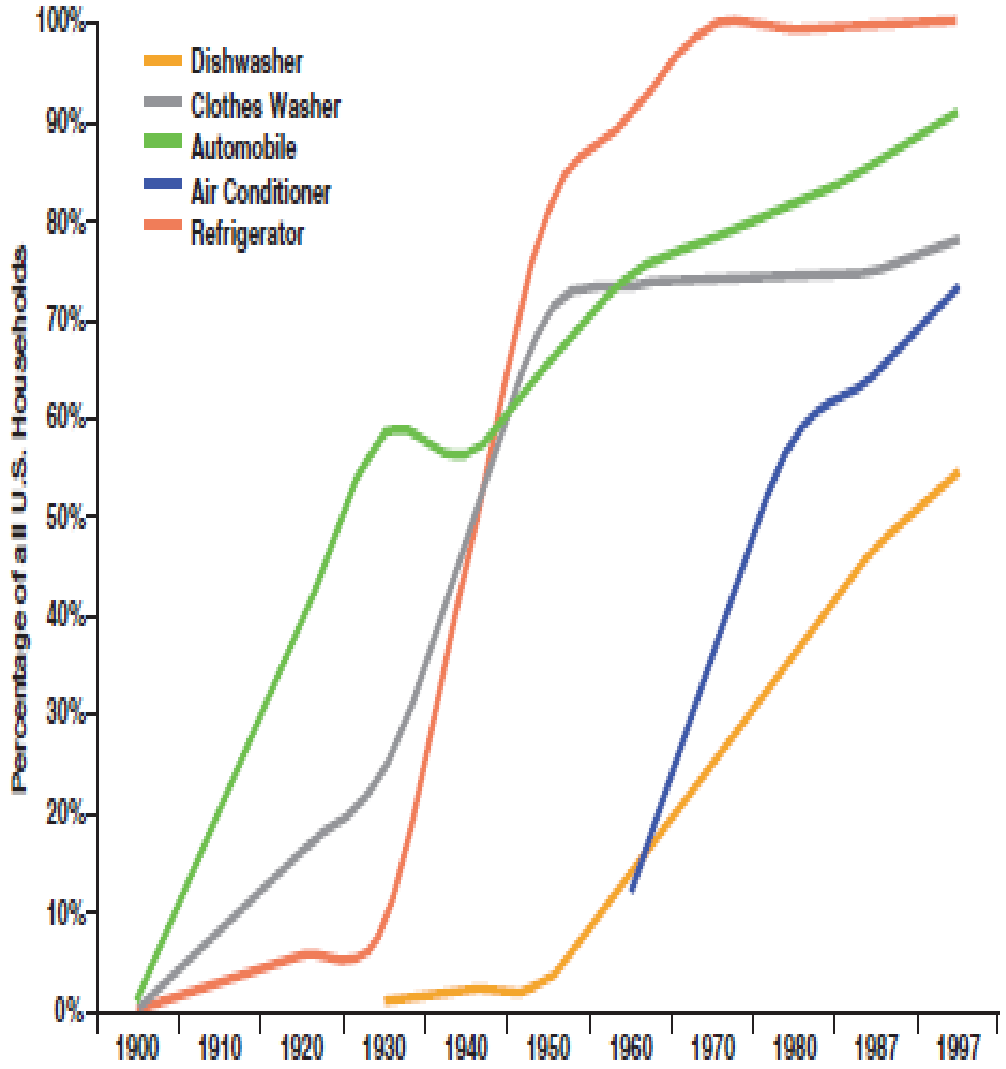
Source: U.S. Energy Information Administration, *Annual Energy Review 2009*, and *Monthly Energy Review (June 2011)*, preliminary 2010 data.

Putting Energy to Work: Electricity (Secondary Source)

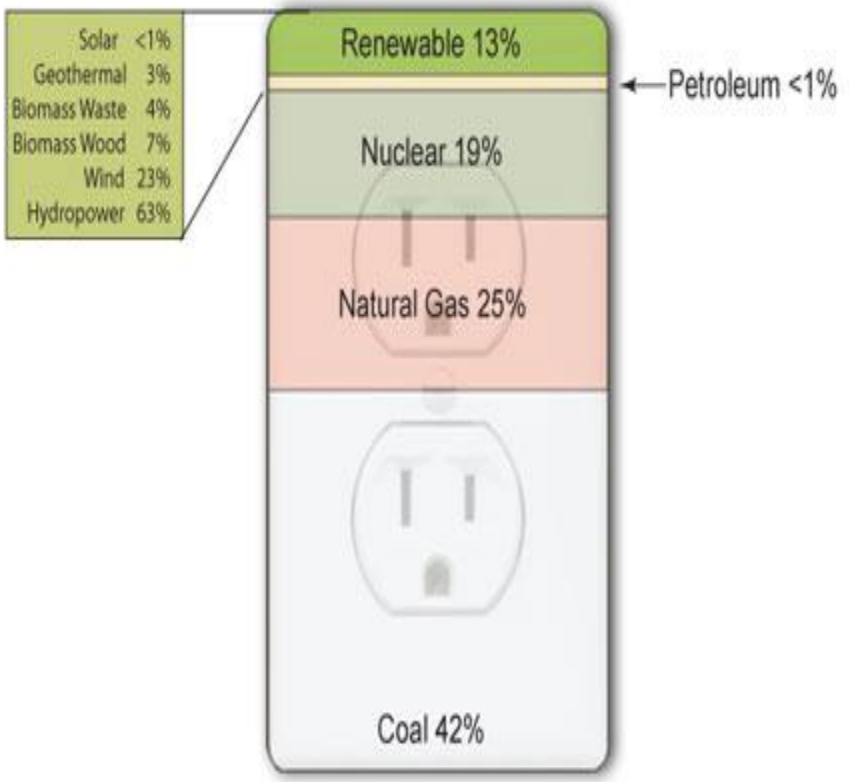
1900s	1910s	1920s	1930s	1940s
• Heater	• Refrigerator	• Air conditioning	• Electric razor	• Electric blanket
• Washing machine	• Electric trains	• Radio	• Can opener	• Dehumidifier
• Vacuum cleaner	• Hair dryer	• Blender	• Garbage disposal	• Electric guitar
• Cloths iron	• Christmas lights			
• Toaster				

1950s	1960s	1970s	1980s	1990s
• Television	• Jacuzzi	• Personal computer	• Dustbuster	• Internet
• TV remote control	• Self-cleaning oven	• VCR	• Rechargeable batteries	• Digital answering
• Dishwasher	• Microwave oven	• Waterbed	• Halogen torchierelamp	• Sony Play Station
	• Security system	• Crockpot	• Cellular telephone	• DVD player
		• Fax machine	• Noise machine	
		• Laser printer		

Electricity Usage & Sources



Sources of Electricity Generation, 2011



Note: Includes utility-scale generation only. Excludes most customer-sited generation, for example, residential and commercial rooftop solar installations

Source: U.S. Energy Information Administration, *Electric Power Monthly* (March 2012). Percentages based on Table 1.1, preliminary 2011 data.

Method of Producing Electricty: Coal (Nonrenewable)

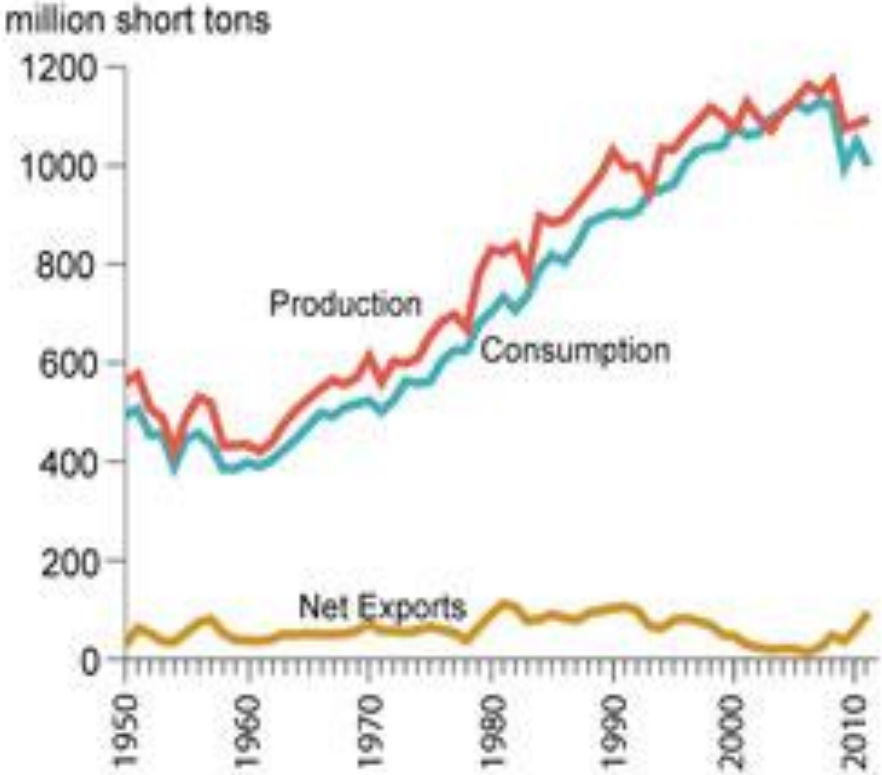
- Coal-fired plant
  - _____
  - Coal is primarily carbon, hydrocarbons, and a minor amount of minerals
  - Four basic forms of coal:

Form of Coal	Energy (BTU/lb)	Typical Sulfur Content (%)	Est. U.S. Reserves (billions of tons)
Anthracite	12,500	0.6	7
Bituminous	11,500	2.2	240
Subbituminous	9,500	0.5	180
Lignite	7,000	0.7	40

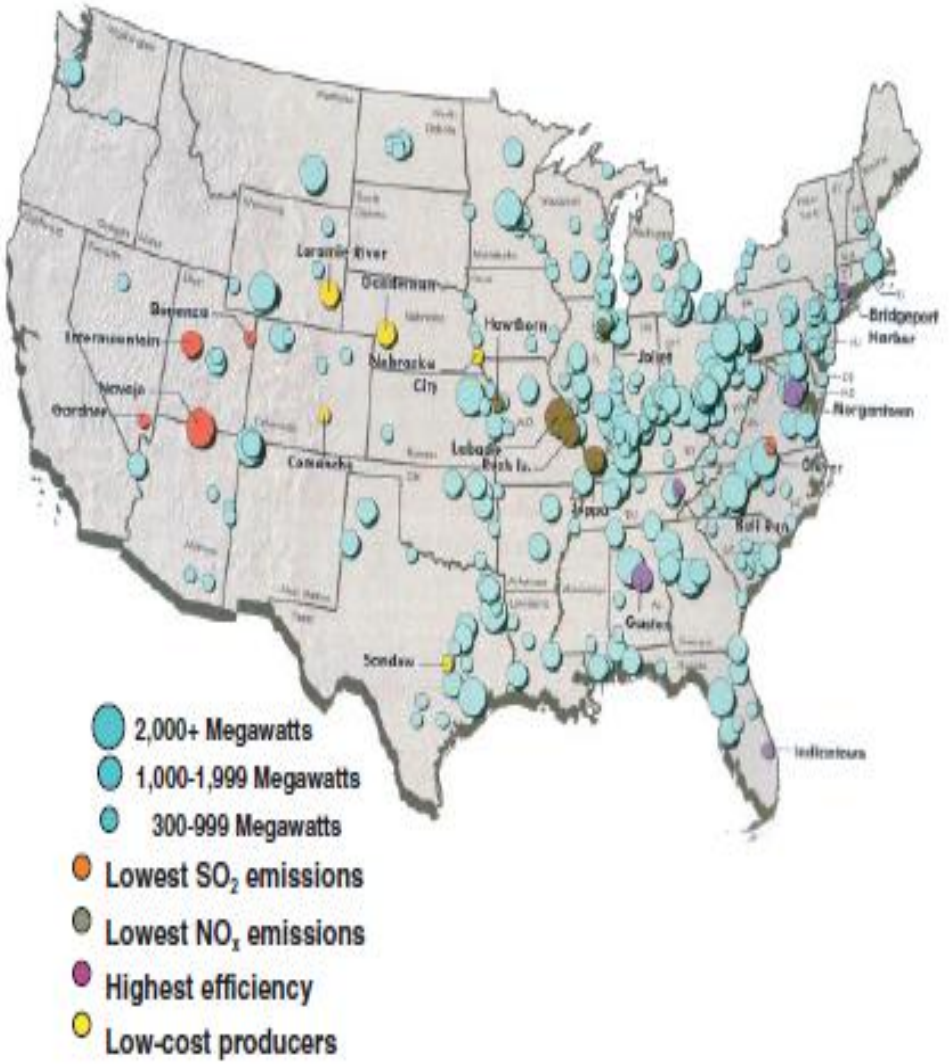
Adapted from Edward Cassedy and Peter Grossman, *Introduction to Energy: Resources, Technology, and Society*, p. 138, Tables 6.1 and 6.2.

Coal Facts

U.S. Coal Production, Consumption, and Exports, 1950-2011



Source: U.S. Energy Information Administration, *Annual Energy Review and Quarterly Coal Report (June 2012), preliminary 2011 data.*



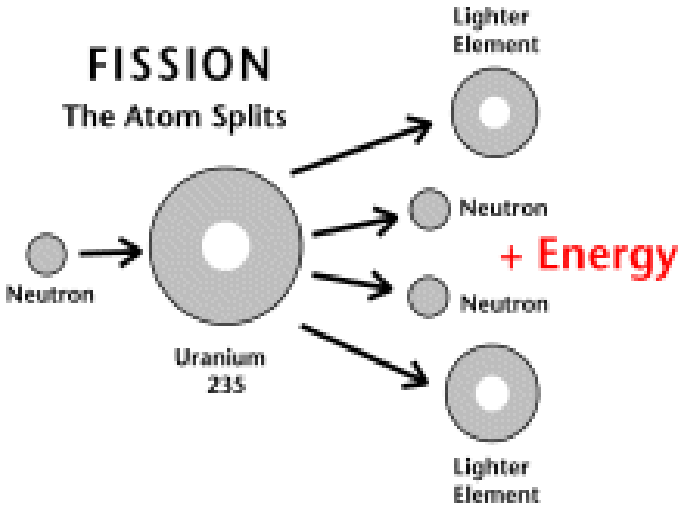
Environmental Impacts of Coal

- Extraction: alters the landscape and pollutes groundwater
- Transportation: railroads transport most of America's coal, but trucks and barges are also commonly used
- Combustion: burning coal produces pollutants and produces more carbon dioxide per BTU of electricity generated than other fossil fuels
- Waste Disposal: unburned ash must be removed
  - Negative externalities: costs to innocent bystanders from another's action (i.e. smoking)

Method of Producing Electricity- Nuclear Fission (Nonrenewable)

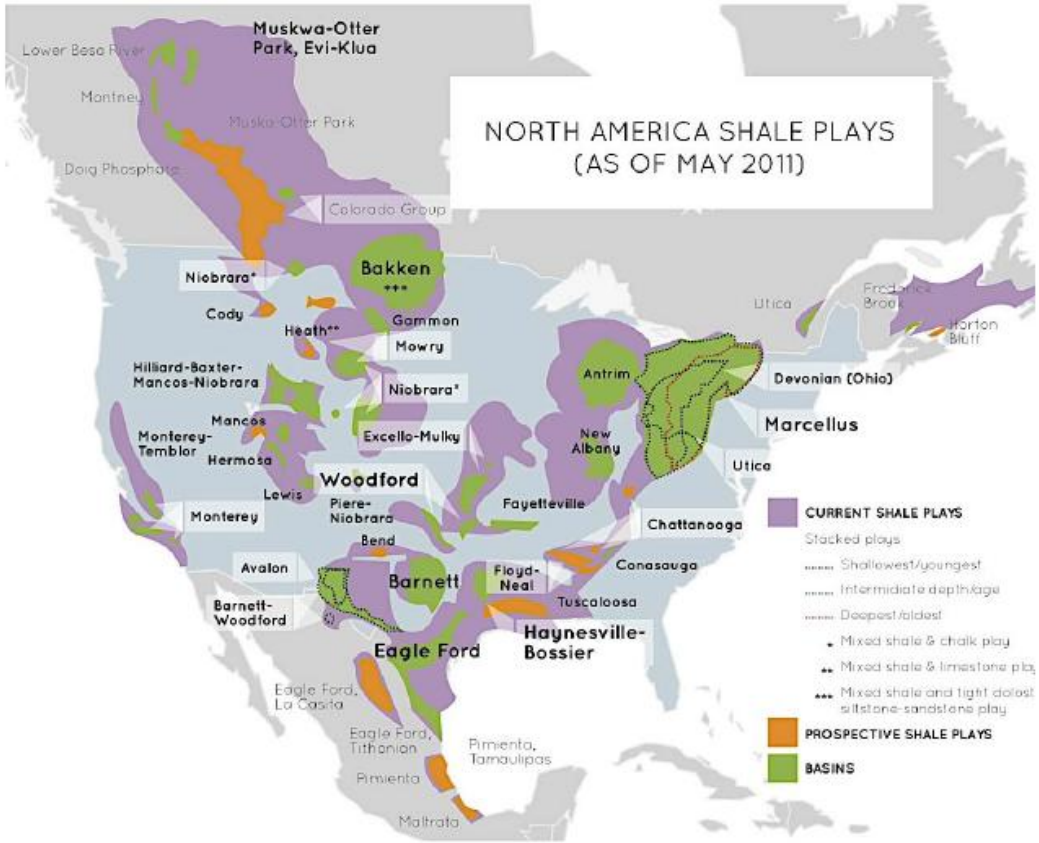
- Produces electricity similar to traditional power plants with the heating of water to produce steam to drive a turbin that spins a generator
- Difference from other power plants?

  - The nuclei of heavy atoms, like uranium, are split into lighter nuclear parts
  - This split causes a chain reaction that creates a self-sustaining chain reaction called a critical mass
  - These plants produce about 18% of the world's electric power
- Storage of nuclear waste is a problem
- Costly to support

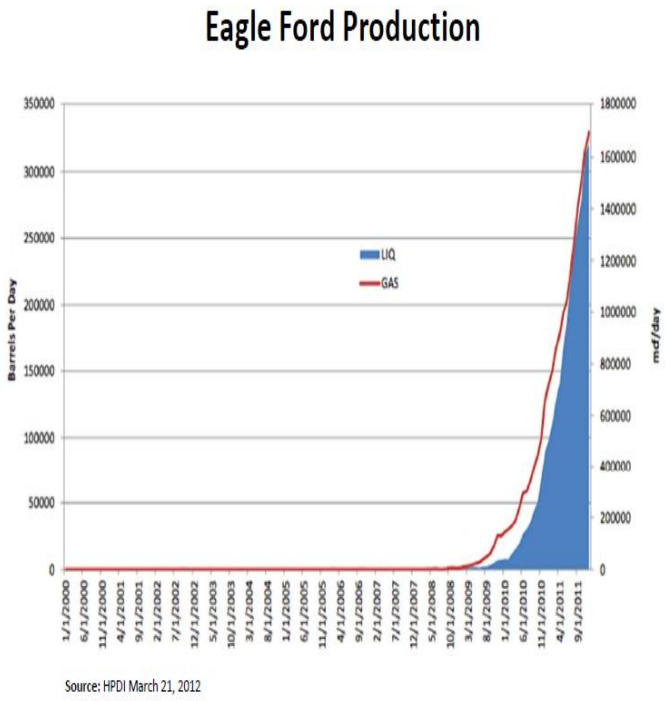


Method of Producing Electricity- Natural Gas Plants (Nonrenewable)

- Natural gas is the _____
  - Used in gas turbine and steam generating plants



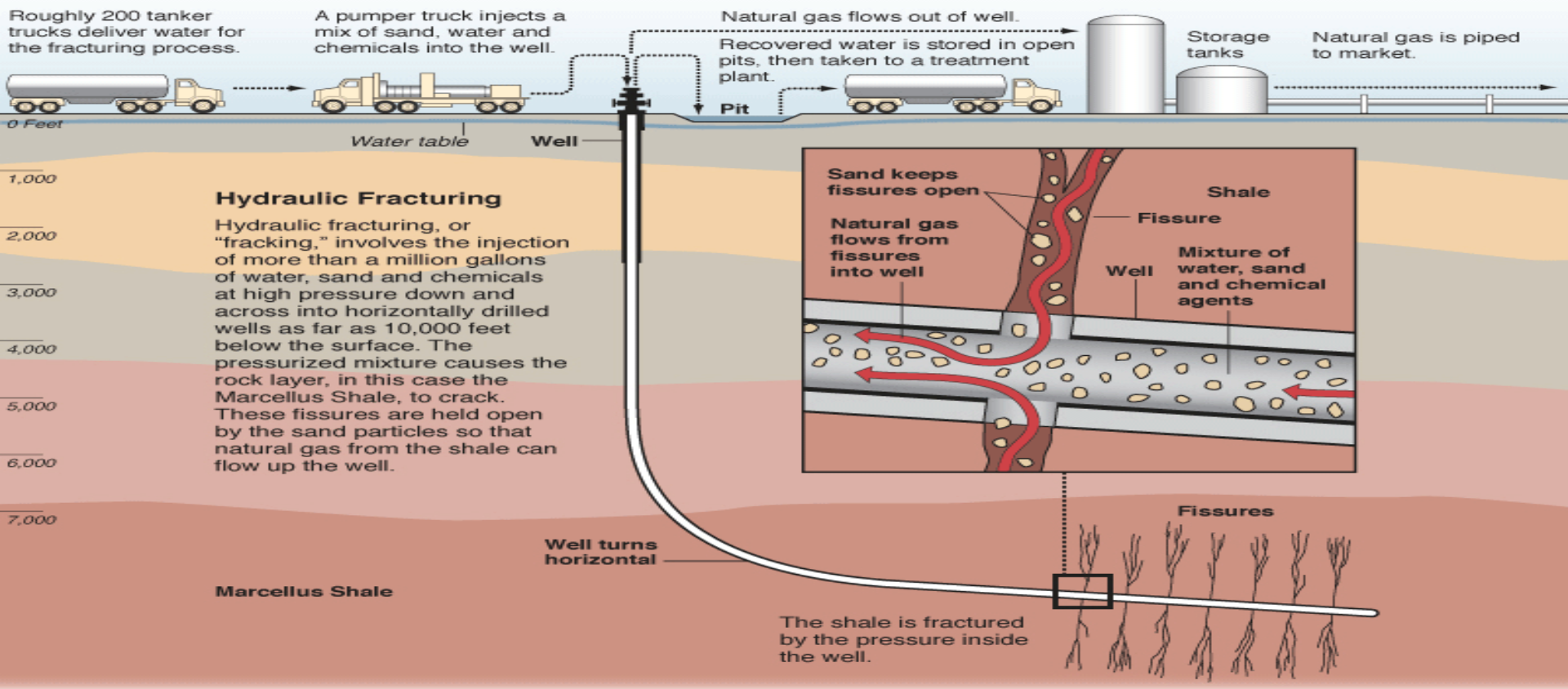
Source: U.S. Energy Information Administration Based on Data From Various Published Studies. Canada and Mexico Plays From ARI. Last Updated: May 9,



Source: HPDI March 21, 2012

Method of Producing Electricity: Natural Gas Plants/Natural Gas Boom/Fracking

- Truthland Movie (34 minutes)- Is hydraulic fracturing –one of many key processes used to produce America's enormous reserves of natural gas—as unsafe and environmentally ruinous as some have said?

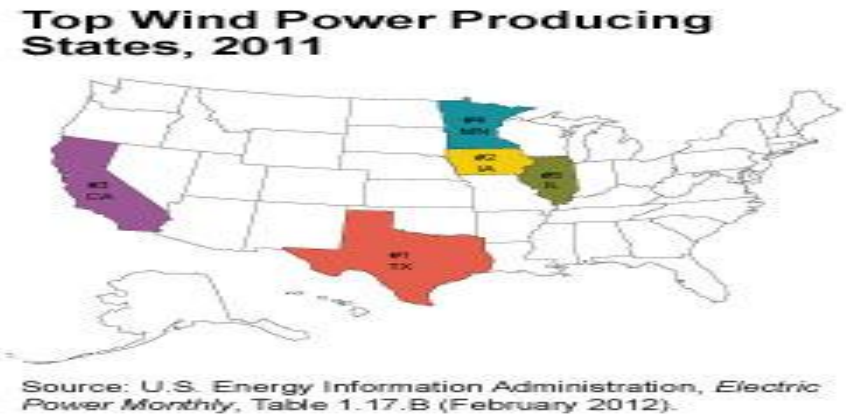


Graphic by Al Granberg

Method of Producing Electricity: Wind (Renewable)

- Windmills have little impact on the environment
- There are problems that exist:
  - Location
  - Unrealiabiliy
  - Land Use
  - Aesthetics

- Harm to Wildlife
- Noise
- Safety
- Placing windmills offshore could overcome these problems



Method of Producing Electricity: Solar Power (Renewable)

- The main benefits of solar energy are:
  - Solar energy systems do not produce air _____
  - When located on buildings, they have minimal impact on the environment
- Because solar cells only work when the sun shines, they must either be used together with storage devices or as supplements to conventional facilities.
- Currently, _____ _____

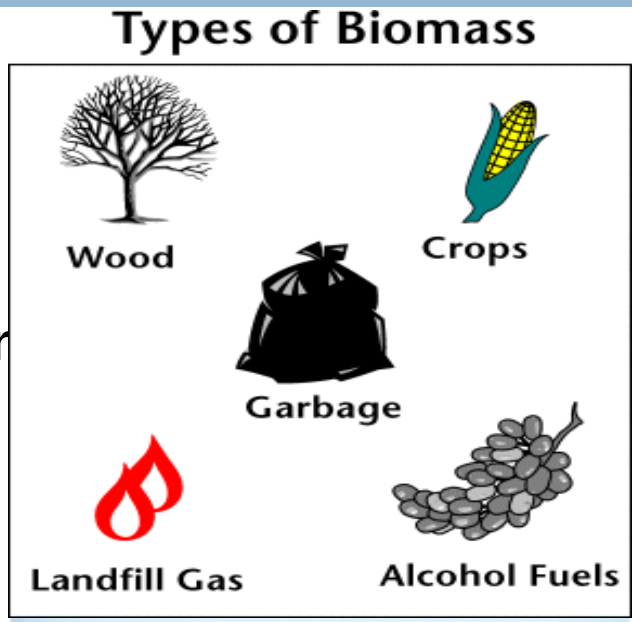
Method of Producing Electricity: Biomass (Renewable)

- Biomass energy is derived from

  _____

  _____

  - Energy Crops-crops grown specifically for energy purposes (corn ethanol)
  - Opportunity Crops-residue or waste materials for energy purposes (animal waste)
- Main uses of biomass:
  - Electric power generation
  - Heating
  - Ethanol fuel



Costs of Electricity & Subsidies

REAL LEVELIZED COSTS OF ELECTRICITY

GENERATING TECHNOLOGIES	PRICE (CENTS PER kWh)
CONVENTIONAL COAL	3.79
"CLEAN COAL" (IGCC)	4.37
NATURAL GAS	5.61
NUCLEAR	5.94
BIOMASS	5.95
WIND	6.64
SOLAR THERMAL	18.82
SOLAR PHOTOVOLTAIC	37.39

SOURCE: GILBERT METCALF, FEDERAL TAX POLICY TOWARD ENERGY, P. 22 (OCT. 2007) HTTP://WEB.MIT.EDU/GLOBALCHANGE/WWW/MITJPSPGC_RPT142.PDF

Total Federal Subsidies MWh, FY 2007

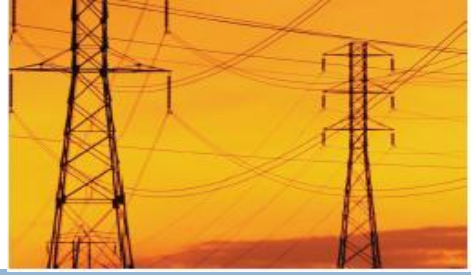
Solar	$24.34
Wind	$23.37
Nuclear	$1.59
Hydro	$0.67
Coal	$0.44
Natural Gas	$0.25

*FY 2010 – With Some Stimulus Additions

Solar	$775.64
Wind	$56.29

Source: Energy Information Administration, Direct Federal Financial Interventions and Subsidies in Energy in Fiscal Year 2010, July 2011

Transportation of Electricity



- Electrical power is carried from generation plants over high-voltage wires and reduced for homes by a _____
- Grids connect _____(10 separate grids)

Transportation: 28% of Energy Consumption

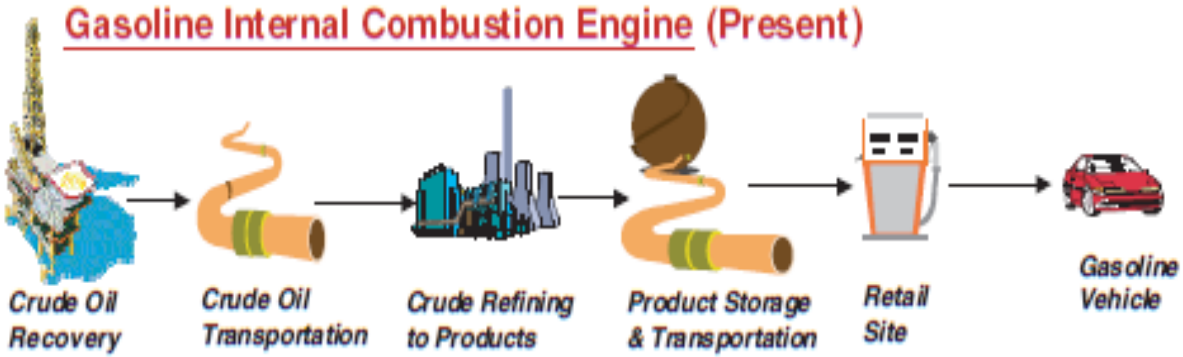
- Horses and Oxen powered most vehicles during the early 20th century.

  - Opportunity Costs
    - Loss of natural habitat
    - Filthy streets
    - Disposal of animals
      - "A big city had to clear 10,000 to 15,000 horse carcasses from the streets every year."
- Early autos (video) were not efficient, but kept the street clean

Transportation

- Internal Combustion Engine-powerful, efficient, cleaner than their ancestors.
- Primary fuels to power these vehicles
  - _____-19 gallons of gas are refined out of every 42-gallon barrel of oil (Close price relationship)
    - Americans used about 360 million gallons per day in 254 million vehicles in 2011
  - Diesel-10 gallons of diesel are refined out of every 42-gallon barrel of oil
  - Ethanol-alcohol produced from the _____
    - In the US, it is primarily made from corn. (ex. 90% ethanol)
    - Renewable supply, non-toxic, lower carbon dioxide emissions

Fuel Costs



- Gasoline
  - Highly flammable, toxic, produces carbon dioxide emissions
- Diesel
  - Diesel fuel produces many harmful emissions when it is burned, and diesel fueled vehicles are major sources of harmful pollutants such as ground level ozone and particulate matter.
- Ethanol
  - Renewable supply, non-toxic, lower carbon dioxide emissions
  - However,
    - About 20% less BTU content by volume, so less efficient
    - Cannot be transported through existing pipelines, mostly by trucks
    - More expensive to produce (tractors, water, etc.)
    - Creating ethanol may consume more energy than what is in it

Environmental Economics-Policy?

- Definition: a subfield of economics concerned with environmental issues.
- Environmental economists determine how environmental policies affect the economy.
- For example, an environmental economist may study the economic costs and benefits of alternative policies for issues such as water quality or managing waste.

The EPA-website

- Environmental Protection Agency (EPA)
- Mission: _____
- Budget: $8.5 billion; 17,500 employees
- History – timeline
  - "Born in the wake of elevated concern about environmental pollution, EPA was established on December 2, 1970 to consolidate in one agency a variety of federal research, monitoring, standard-setting and enforcement activities to ensure environmental protection."
  - EPA received $7 billion from ARRA in 2009 for projects and programs.

Dept. of Energy - website

- The mission of the Department of Energy is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions.
- Budget:$27 billion

The EIA – website (Documentary)

- Energy Information Administration (EIA)
- The Department of Energy Organization Act of 1977 established EIA as the primary federal government authority on energy statistics and analysis.
- Budget: _____
- EIA collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment.

How to Calculate Efficiency

- Efficiency = the ratio between the usable work that comes out of the machine to the energy that went in.
- Loss = _____
- System efficiency = multiples of each energy device
  - Example: Power plant = Boiler X Steam Turbine X Generator
    - _____

Energy Conversion Device	Energy Conversion	Efficiency (%)
Electric heater	Electricity/Thermal	100
Electric generator	Mechanical/Electrical	95
Electric motor (large)	Electricity/Mechanical	90
Battery (dry cell)	Chemical/Electrical	90
Steam boiler (power plant)	Chemical/Thermal	85
Home gas furnace	Chemical/Thermal	85
Home oil furnace	Chemical/Thermal	65
Electric motor (small)	Electrical/Mechanical	65
Natural gas combined cycle	Chemical/Mechanical	60
Home coal furnace	Chemical/Thermal	55
Steam turbine	Thermal/Mechanical	45
Diesel engine[80]	Chemical/Mechanical	43
Gas turbine (aircraft)	Chemical/Mechanical	35
Gas turbine (industrial)	Chemical/Mechanical	30
Automobile engine	Chemical/Mechanical	25
Fluorescent lamp	Electrical/Light	20
Human[81]	Chemical/Mechanical	18
Silicon solar cell	Solar/Electrical	15
Steam locomotive	Chemical/Mechanical	10
Horse[82]	Chemical/Mechanical	10
Incandescent light (light bulb)	Electrical/Light	5

Source: Pennsylvania State University's Earth and Mineral Sciences web site: www.ems.psu.edu/~radovic/fundamentals4.html, unless otherwise noted.

Energy Economics

- We will study markets in the next chapter
  - William Stanley Jevons founded energy economics in 1865
- These markets determine the prices of different energy sources and help allocate those sources to their most efficient use.
  - "A mechanism for communicating information."~F.A. Hayek
- This will be decided by supply and demand
  - In a free market, prices tend, over time, to reflect the explicit and implicit costs of producing a commodity.
  - Property rights (video) & rule of law are essential in a free market
    - Precondition for trade, ownership, etc.

Petroleum Market

Governments in poor countries do both too much and too little. South American economist Hernando de Soto and his team of researchers worked for 289 days to get all the certifications needed to open a small garment workshop on the outskirts of Lima, Peru. "The cost of legal registration was $1,231—thirty-nine times the monthly minimum wage."[99] Some 26 months of effort were needed for a taxi driver to get approval for a route. Obtaining permission to build a house on state-owned land took nearly seven years and 207 administrative steps by 52 government offices. De Soto's team found similar levels of red tape in Egypt and Haiti.[100]

At the same time that these governments have erected monumental roadblocks to individual initiative and productivity, they have failed to create the legal structure essential to any modern society. What developing nations need most are legal systems that document and uphold property rights, enabling people to easily transfer, trade, and borrow against their property.[101]

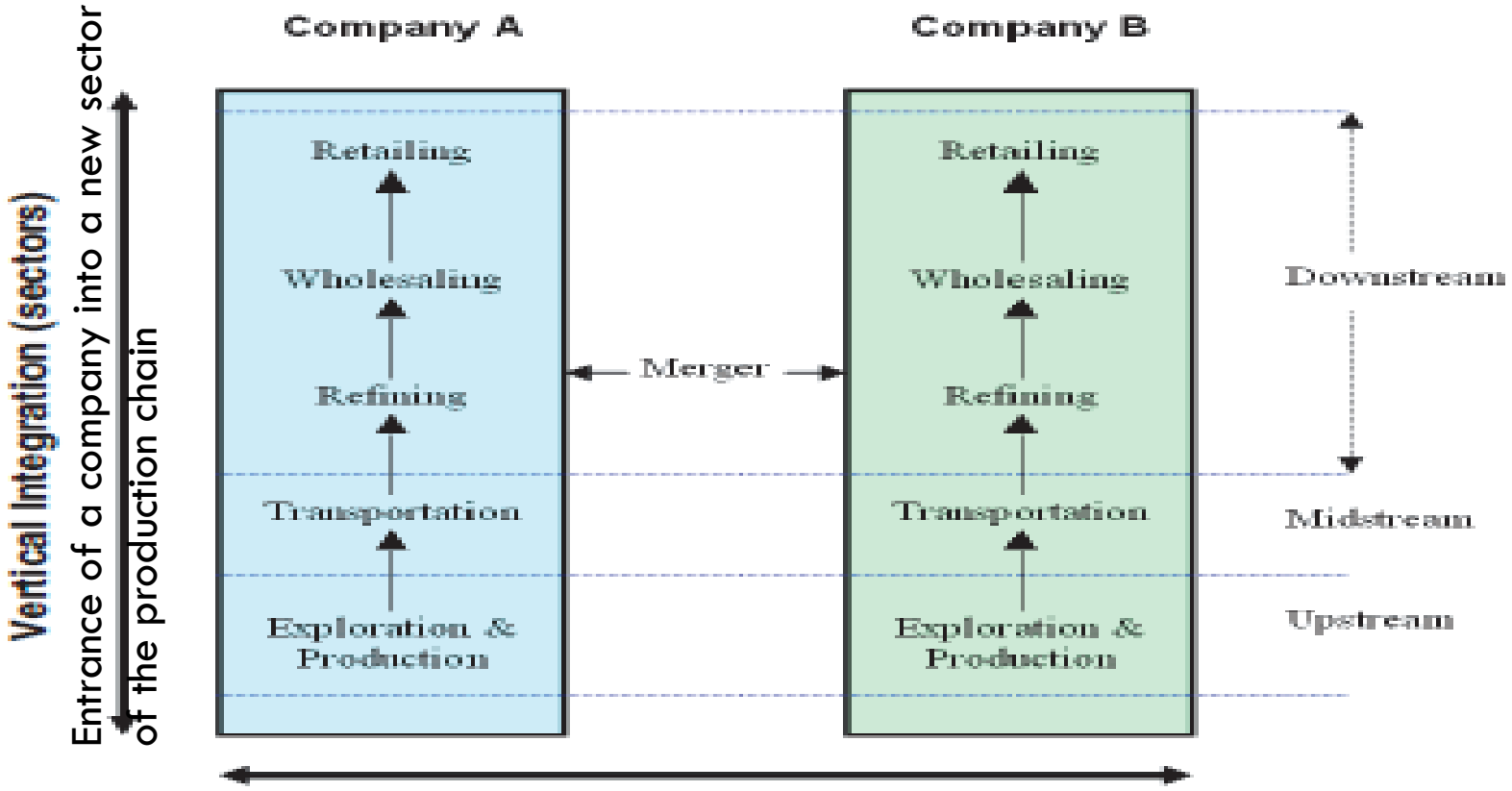
Oil becomes increasingly valuable as it moves downstream. Yet the supply of, and consumer demand for, the final product determine the value of the entire chain of activities, not the other way around. Crude oil's value is governed by the prices consumers pay for gasoline, fuel oil, and other end products, rather than what crude oil costs to find, produce, and refine.

Over time, however, costs and prices tend to approach each other. In order to stay in business, a company must charge enough for its product to cover its costs. On the other hand, if a firm charges substantially more than its costs, competitors will move in and win customers by offering lower prices.

Petroleum Industry

OIL INDUSTRY SEGMENTATION

The petroleum industry is divided into five general sectors from the production of crude oil to the final sale of petroleum products. Each of these divisions has associated service industries such as drilling contractors for exploration and production and pipeline construction companies for transporters.



Size & Structure of Firms

- _____: falling costs from larger output (larger firms typically have lower average costs)
- _____: falling costs from performing more than one function (oil production and refining)
- Capitalistic firms: privately-owned
  - Exxon-Mobil, Shell, Chevron, etc.
- Socialistic firms: government-owned
  - Petroleos Mexicanos (PEMEX)-legal monopoly over all oil and gas-related functions in Mexico.

Drivers of Energy Industry

- Intellectual capital: Collective knowledge (whether or not documented) of the individuals in an organization or society
- Entrepreneurs (video): someone able to identify and provide for an unmet need.
- Creative destruction (Joseph Schumpeter): a process in which new techniques and technologies render existing modes of operation obsolete