# Ch. 12 Notes: Energy from Fossil Fuels

STATS FROM GEOHIVE: http://www.geohive.com/charts/

U.S. total energy consumption = ranked first worldwide
U.S. oil consumption = ranked first worldwide
U.S. coal consumption = ranked second worldwide, behind China
U.S. natural gas consumption = ranked first worldwide

"Our country's leaders have three main choices: Taking over someone else's oil fields; carrying on until the lights go out and Americans are freezing in the dark; or changing our life style by deep conservation while heavily investing in alternative energy sources at higher costs."
— Charles T. Maxwell (consultant to oil companies and the U.S. Government on oil policy)

"The *world* is not running out of oil—at least not yet. What our society does face, and soon, is the end of *abundant* and *cheap* oil on which all industrial nations depend." [emphasis added]
— Dr. Colin Campbell and Dr. Jean Laherrere (petroleum geologists)

12.1 Notes

I. Energy Sources and Uses

A. overview timeline of energy sources
additional from http://instituteforenergyresearch.org

1) *fire power*: ~1,000,000-500,000 B.C. – controlled use of fire for cooking, warmth, light, etc.
2) *animal power*: ~6000 B.C. – domestication of cattle; mules used to transport cargo, etc. (~4500 B.C. – invention of the ox-drawn plow in Mesopotamia)
3) *wind power*: ~3500 B.C – Ancient Egyptians invented the sail
4) *solar power* (direct): ~3000 B.C. – Ancient Egyptians, Chinese, Phoenicians, Greeks, and Romans used solar power to evaporate water to obtain salt and to dry crops
5) *coal power*: ~1000 B.C.– coal used in China
6) *water power*: 100 B.C. – water wheels used in what is now Turkey
7) *wind power*: 65 B.C. – windmills used in Greece
8) *Industrial Revolution* (late 1700s, early 1800s… typically 1760-1830) – machinery development; initiated by the invention of *steam engine*
9) Late 1800s: development of the *internal combustion engine, oil-well drilling, and refinement of crude oil*
10) *electric power*: 1879 – Thomas Edison invented electric light bulb
11) *nuclear power*: 1952 –world's first nuclear reactor operational for commercial power (Pennsylvania)
12) *solar power* (indirect): 1954 – first silicon solar collectors constructed (U.S.)
13) *oil power*: 1959 – first drilling in the U.S. for oil (Pennsylvania) by Colonel Edwin Drake

13) other info…

- 1970 – first the major oil find is discovered (U.K. North Sea)
- 1973 – internet developed
- 1980 – first solar-cell power plant is operational (Utah)
- 1989 – World Wide Web established

B. electrical power production

1) **primary energy source**
   a) an energy source *existing on its own*
   b) can contribute to another (the secondary) being produced

c) examples: c*oal, oil natural gas, solar energy, nuclear energy, geothermal energy*

2) **secondary energy source**
   a) an energy source *dependent upon another source* for production
   b) example: *electrical power*
3) *1831 – invention of the generator* by Faraday; a moving magnet will cause a current in a coil of wire (flashlights that you shake for power have this exact setup)
4) **turbine**—a *wheel* made of curves "vanes" on a rotating spindle
5) *generator*—a machine converting mechanical energy to electrical energy
6) **turbogenerator**—a turbine and a generator together
7) *power grids*
   a) three main *power grids* of the continental U.S.
      - Eastern Interconnected System (*Eastern Interconnect*)
      - Western Interconnected System (*Western Interconnect*)
      - Texas Interconnected System (*Texas Interconnect*)
   b) 10 *North American Electric Reliability Council (NERC)* regions within the grid

      ECAR - East Central Area Reliability Coordination Agreement
      ERCOT - Electric Reliability Council of Texas
      FRCC - Florida Reliability Coordinating Council
      MAAC - Mid-Atlantic Area Council
      MAIN - Mid-America Interconnected Network
      MAPP - Mid-Continent Area Power Pool
      NPCC - Northeast Power Coordinating Council
      SERC - Southeastern Electric Reliability Council
      SPP - Southwest Power Pool
      WSCC - Western Systems Coordinating Council
8) fluctuations in demand
   a) **baseload**—constant supply of power available
   b) *peak*—highest demand
   c) **reserve capacity**—additional sources of power, drawn upon during peak hours
   d) **brownout**—*reduction* in power
   e) **blackout**—*loss* of power
   f) about the *watt*
      - ***1 W = 1 J/s = 1 Nm/s (N = kgm/s$^2$)***
      - conversions

        1 W ≈ 3.412141630 BTU/h
        1 horsepower ≈ 745.700 W
        1 horsepower (electrical British) = 746 W
        1 horsepower (electrical European) = 736 W
        1 horsepower ("metric") = 735.498 75 W
      - *kilowatt hour (kwh) is the amount of energy expended by a one kilowatt device over the course of one hour* (kw multiplied by hour)
9) Clean energy?
   a) Using electricity creates no new pollution…
   b) but its production has effects on the environment because it has to be produced from using a primary source
   c) *efficiency = useful power output / total power output*

- thermal production of electricity is only *~30% efficient*
- heat is lost in travel from the firebox and in the spent steam (**conversion losses**)
- *cooling towers* are used to condense the steam

C. matching sources to uses

a) *categories of primary energy use*:
- *transportation*
- *industrial*
- *commercial / residential*
- *to generate electric power*

b) how to decrease consumption
- conservation
- efficiency
- demand management

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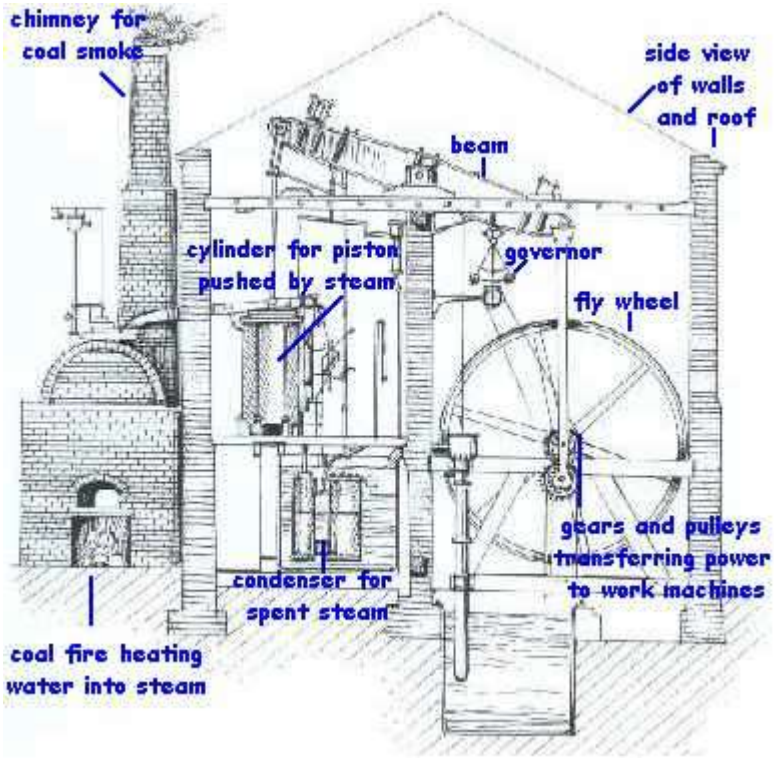
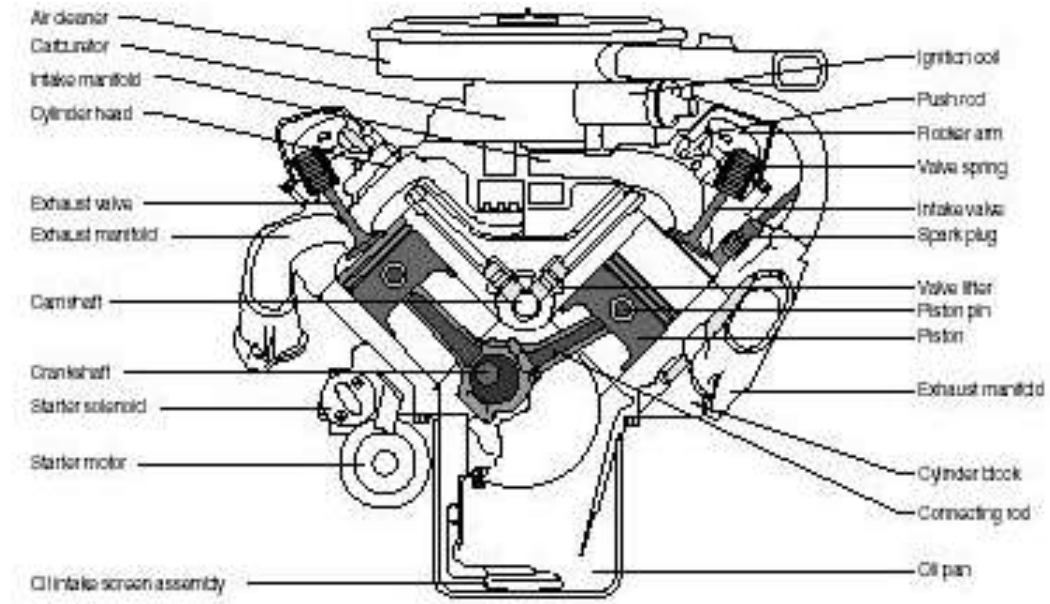
**WATT STEAM ENGINE** from http://csp.edu



**INTERNAL COMBUSTION ENGINE** from www.scienceclarified.com




13.2 Notes

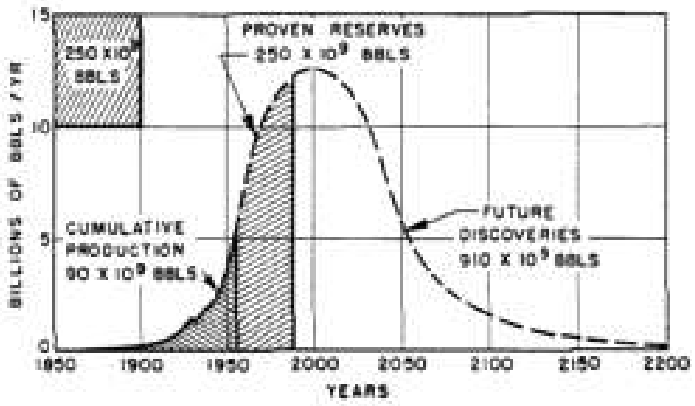
II. Exploiting Crude Oil

A. how fossil fuels are formed
   1) decreased detritus formation in ocean depths (lack of $O_2$)
   2) *compaction of dead organic matter* below layers of sediment
   3) conversion by heat and pressure to *fossil fuels: coal, oil, and natural gas*
   4) fossil fuels can still form but are considered *nonrenewable resources* because the replacement rate cannot keep up with demand

B. crude oil reserves vs. production
   1) *oil resources*—total amount of crude oil remaining
   2) **estimated reserves**—amount of crude oil *expected* to exist
   3) *exploratory drilling*—a method of finding crude oil deposits
   4) **oil field**—underground area containing oil deposits
   5) **proven reserves**—an estimate of *how much oil can be extracted in an economically feasible way* from an oil field
      *a) 1 barrel of oil = 42 gal*
      b) proven reserves listed as *probabilities* (P*x*), like P50
   6) **production**—"harvesting" the oil or natural gas form the field by *extraction*
      a) *nonconstant extraction rate from pore spaces in sedimentary rock*
      b) *gusher*—quick flow from an oil well; not lasting
      c) **primary recovery**—*conventional* pumping
      d) **secondary / tertiary recovery**—*forcing* the oil up into the wells by injection of steam or brine into the reservoir

C. declining U.S. reserves and increasing imports
   1) in *1970*, new exploratory drilling began to turn up *no new oil deposits*
   2) shift from oil independent status to being dependent on imported oil
   3) **Hubbert's curve**
      a) *bell curve* named for geologist M.K. Hubbert

b) based on his prediction, U.S. oil production would peak around 1965-1970




D. oil crisis of the 1970s

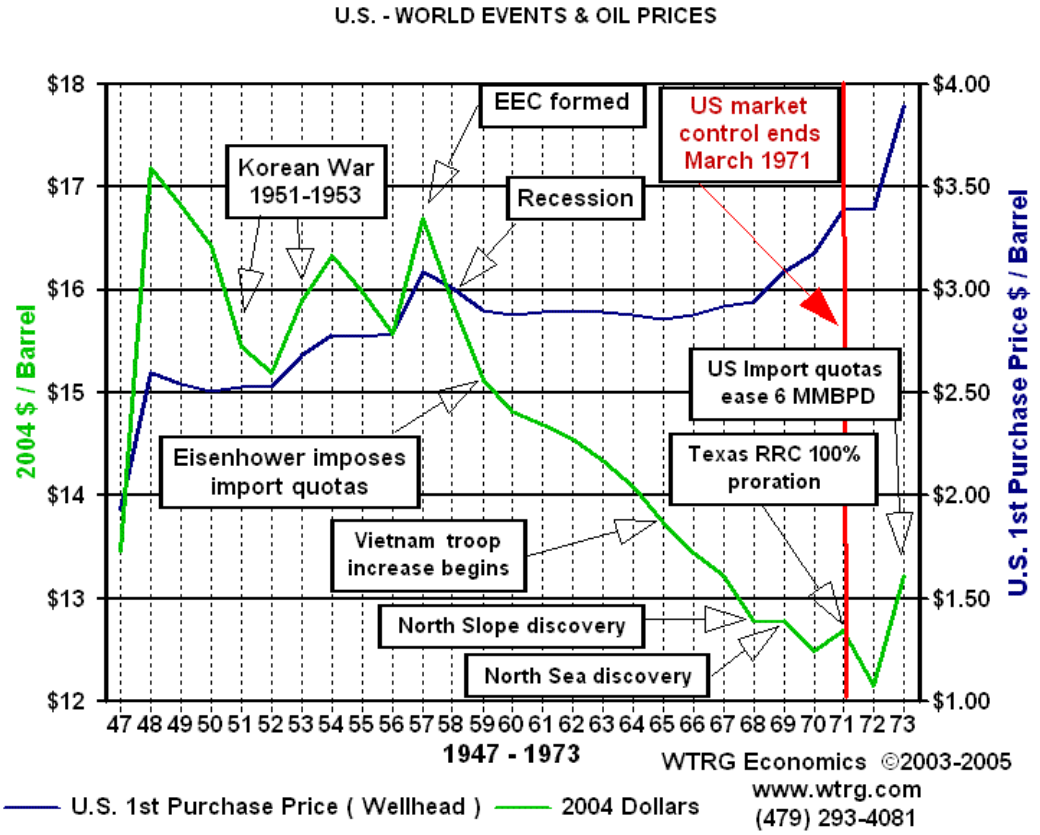
1) **OPEC**—*Organization of Petroleum Exporting Countries*

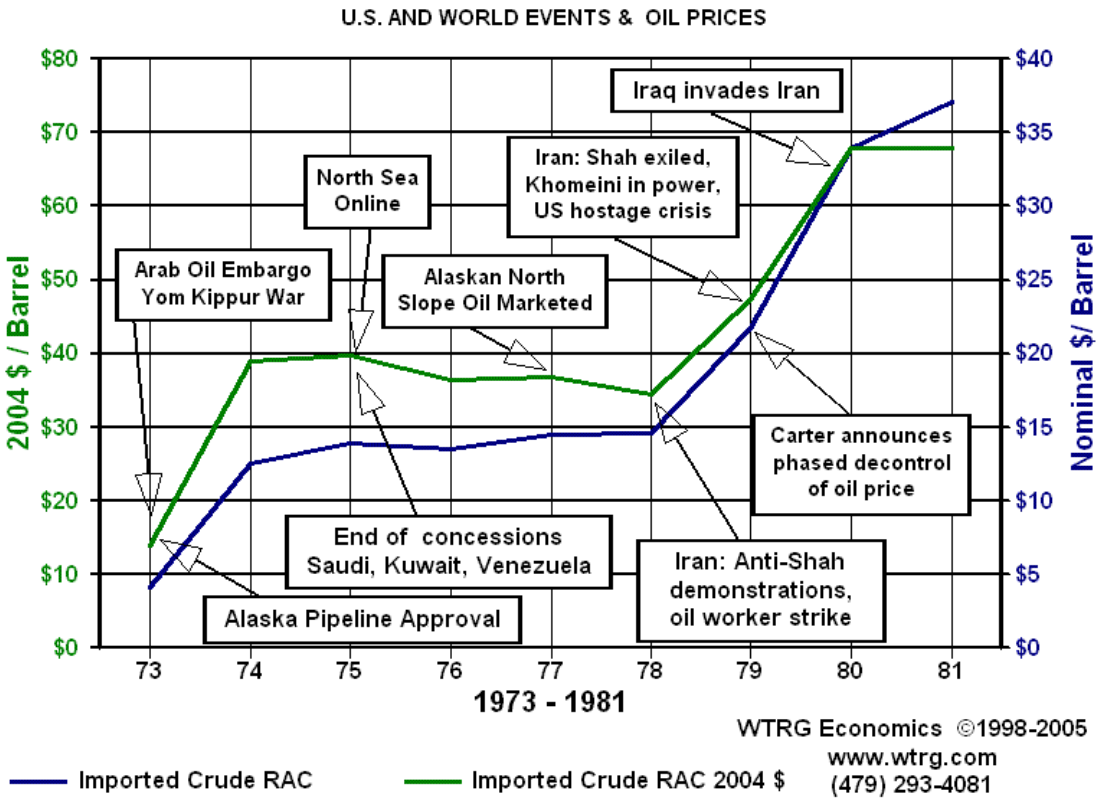
a) *11 member countries*:

Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela

2) OPEC formed a *cartel*, working together to raise prices

From http://www.wtrg.com/prices.htm - world events and oil prices, 1947-1973






E. adjusting to higher prices
   1) increase domestic production of oil
   2) *decrease consumption*
      a) *increasing fuel efficiency standards* for vehicles and appliances
      b) improving building *insulation*
      c) development of *alternative energy sources*
   3) protect against another OPEC boycott by a massing a *strategic oil reserve*

F. consequences
   1) exploration is expensive; older oil fields were shut down
   2) conservation incentives and efforts decreased; related tax incentives stopped
   3) conservation mindset was not a priority

G. problems of growing U.S. dependency on foreign oil
   1) costs of purchase
   2) risk of supply disruption
      a) Middle East conflicts
      b) Persian Gulf War, Desert Shield/Storm, Iraq War
   3) resource limitations
      a) the U.S. is basically "tapped out"
      b) geologists are still searching using computer mapping
      c) global usage: *900 BB (billions of barrels)* used, most in 20th century
      d) proven reserves:

http://www.eia.doe.gov/emeu/international/reserves.html

H. solutions
1) use coal and natural gas instead of crude oil
2) reduce demand through *conservation and energy efficiency*
3) develop and use *alternative energy sources*

12.3 Notes

III. Other Fossil Fuels

A. natural gas (some info from www.naturalgas.org)
1) primary uses: heating and cooking
2) gas used in homes is almost all *methane ($CH_4$)*
3) most gas is inaccessible; need pipelines
4) *"clean burning" fuel*
5) **liquefied natural gas (LNG)**
a) a synthetic oil made from *cooling natural gas* to -260° F to liquefy it
b) used in transporting natural gas, since it takes up 1/600 of the gas volume
c) U.S. gets most of its LNG from Trinidad and Tobago, Qatar, and Algeria, and also receives shipments from Nigeria, Oman, Australia, Indonesia, and the United Arab Emirates

**Typical Composition of Natural Gas** (from www.naturalgas.org)

| | |
|---|---|
| Methane $CH_4$ | 70-90% |
| Ethane $C_2H_6$, Propane $C_3H_8$, Butane $C_4H_{10}$ | 0-20% |
| Carbon Dioxide $CO_2$ | 0-8% |
| Oxygen $O_2$ | 0-0.2% |
| Nitrogen $N_2$ | 0-5% |
| Hydrogen sulfide $H_2S$ | 0-5% |
| He, Ne, Xe | trace |

B. Coal (some info from www.coal.org)
1) types of coal
a) *hard coals*
- **anthracite***:* metallic luster, 90% C, least plentiful, "smokeless"
- **bituminous***:* soft, black, 20-% moisture, most common U.S. coal, thermal/steam coal

b) *low rank coals*
- **lignite** ("brown coal")*:* brown-black, higher moisture, lower C, used to generate electricity
- **subbituminous***:* dull black, 20-30% moisture, used to generate electricity and for space heating

2) types of mining
a) *surface (strip) mining*
b) *underground mining*

C. oil shales and oil sands
1) **oil shale**
a) *sedimentary* rock containing *kerogen* (solid waxy hydrocarbons)
b) when heated, the rock releases vapor that can be recondensed into a crude oil-like product
c) impractical: too small of a yield (1/2 barrel oil impractical—too small of a yield (1/2 barrel oil ton of rock)

2) **oil sands** (sometimes called tar sands)
   a) containins *bitumin* (tar-like hydrocarbon)
   b) when heated, the bitumen "melts;" can be collected and refined into a crude oil-like product
   c) Alberta, Canada – world's largest oil sand deposits

from www.oilsandsdiscovery.com :
"An estimated 1.7 to 2.5 trillion barrels of oil are trapped in a complex mixture of sand, water and clay. The most prominent theory of how this vast resource was formed suggests that light crude oil from southern Alberta migrated north and east with the same pressures that formed the Rocky Mountains. Over time, the actions of water and bacteria transformed the light crude into bitumen, a much heavier, carbon rich, and extremely viscous oil. The percentage of bitumen in oil sand can range from 1% -20%."

   d) U.S.— limited oil sand deposits in Utah

12.4 Notes

IV. Fossil Fuels and Energy Security

A. Report by the *Union of Concerned Scientists* (UCS; www.ucsusa.org):
*Energy Security: Solutions to Protect America's Power Supply and Reduce Oil Dependence*

**Our national energy supply is vulnerable:**

1) *oil supply*
   a) market beyond our control
   b) dependence on OPEC and Middle Eastern countries
   c) continued involvement in volatile situations
2) *energy infrastructure* contains possible targets for terrorist attack: nuclear power plants, power grids, dams, pipelines, etc.

From http://www.ucsusa.org :
" According to Energy Security: Solutions to Protect America's Power Supply and Reduce Oil Dependence, the nation's energy infrastructure is highly exposed and makes an easy target for a well-placed attack. A disruption at a key power plant, refinery, transmission hub, or pipeline can break the flow of power or fuel to millions of customers and create costly energy price spikes. A major accident at a nuclear power plant could kill tens of thousands and contaminate an area the size of Pennsylvania…

Energy sources like wind, solar, biomass, geothermal, and landfill gas are geographically dispersed, burn no volatile fuels, produce no radioactive fallout in the event of an attack, and require less of the infrastructure that delivers fuel and transmits electricity that makes our current system so vulnerable. *Through efficiency and clean energy, we could, between now and 2020, avoid building 975 new power plants, retire 180 coal plants, and close 14 nuclear plants.* Hundreds of thousands of miles of new gas pipelines would not be necessary. Independent studies show that renewable energy delivers more jobs per dollar than investments in fossil fuel plants. The Department of Energy estimates that harnessing just 5 percent of our energy from wind by 2020 would create 80,000 new jobs.

The new report says US security is further threatened by our dependence on oil. *The US sends more than $200,000 overseas each minute to buy oil.* Even if we imported far less and drilled more, the US economy would still be susceptible to Persian Gulf instability and OPEC market power because the price we pay for oil - whether domestic or foreign - is tied to the world market. The estimated costs of oil dependence to the US economy are $7 trillion over the last three decades…

Not only do efficient technologies and clean power supplies create a safer energy future, they save consumers money. In less than twenty years, the annual consumer savings from efficiency and renewable energy would reach $150 billion per year, $500 annually for a typical family.

*To deliver a safer, cheaper, and cleaner future, UCS calls on Congress and the administration to: raise fuel economy standards for cars and light truck; create incentives for next-generation vehicles, like high-efficiency hybrids and fuel cells; strengthen energy efficiency standards for appliances, buildings, and industry, while increasing funding for efficiency programs; adopt a renewable portfolio standard requiring*

*20 percent of our electricity to come from renewable energy sources by 2020, along with appropriate incentives; and update and enforce safety standards at our nuclear facilities."*

B. *Supply-side policies*

National Energy Policy Report, 2001
Complete report: http://wtrg.com/EnergyReport/National-Energy-Policy.pdf

1) open **ANWR** (**Arctic National Wildlife Refuge**) and similar areas to oil/gas exploration
2) add more coal-fired power plants
3) extend Alaska gas pipeline to the lower 48 states

from http://www.alyeska-pipe.com/default.asp

"The 800-mile-long Trans Alaska Pipeline System (TAPS) is one of the largest pipeline systems in the world. It stretches from Prudhoe Bay on Alaska's North Slope, through rugged and beautiful terrain, to Valdez, the northernmost ice-free port in North America. Since pipeline startup in 1977, Alyeska Pipeline Service Company, the operator of TAPS, has successfully transported over 15 billion barrels of oil."

4) monetary assistance to other countries' oil/gas development…

$CO_2$ emissions are a result in combustion (burning) of fossil fuels, increasing Greenhouse gases

Natural gas produces equal amounts of $CO_2$ per unit energy (100%)
Gasoline produces 134% $CO_2$ per unit energy
Crude Oil produces 138% $CO_2$ per unit energy
Coal produces 178% $CO_2$ per unit energy

C. *Demand-side policies: sustainable energy options*

1) conservation through *improving vehicles*
   a) PNGV

*PNGV = Partnership for a New Generation of Vehicles* (www.fuelecomony.gov)

"The PNGV Challenge: 'Build a car with up to 80 miles per gallon at the level of performance, utility and cost of ownership that today's consumers demand.'"

   b) other vehicular options: carpooling; using mass transit; walking or riding a bicycle

2) conservation through **combined heat and power (CHP)** or **cogeneration**

from http://www.energy.rochester.edu/cogen/chpguide.htm :

"Cogeneration… is an enormous and growing market… The common feature in all cogeneration systems is the *prime mover*, which will either convert waste heat into power or generate heat and power from a single energy input. Prime movers can either be reciprocating engines (such as an automobile engine, which produces both power and heat) or a turbine. Turbines can be powered by steam, hot air, and occasionally other media. Combustion turbines have a compressor, combustor, and hot air turbine in a single unit. Prime movers can be combined in a variety of ways to increase energy utilization. One common method is to use the waste heat from an engine or combustion turbine to generate steam, which is then used to power a steam turbine. A simple cycle plant has a single prime mover, and a combined cycle plant will have two in series."

- *combined-cycle natural gas unit*—two turbines: the first (gas turbine) fueling the second (steam turbine)

3) conservation through state-adopted *deregulation*—the process by which governments remove restrictions on business in order to (in theory) encourage the efficient operation of markets
4) conservation through *improvements in appliances* and *light bulbs*: increased energy efficiency and lower energy costs (may cost more to buy)
5) conservation through *new building codes*—improved insulation, windows…
6) conservation through the *internet*: emails, telecommuting, online shopping…

D. non-fossil fuel energy sources: *nuclear power, solar power, geothermal energy, hydroelectric, wind* …