Fossil Fuels

Professor Steven Son
Dept. of Mechanical Engineering

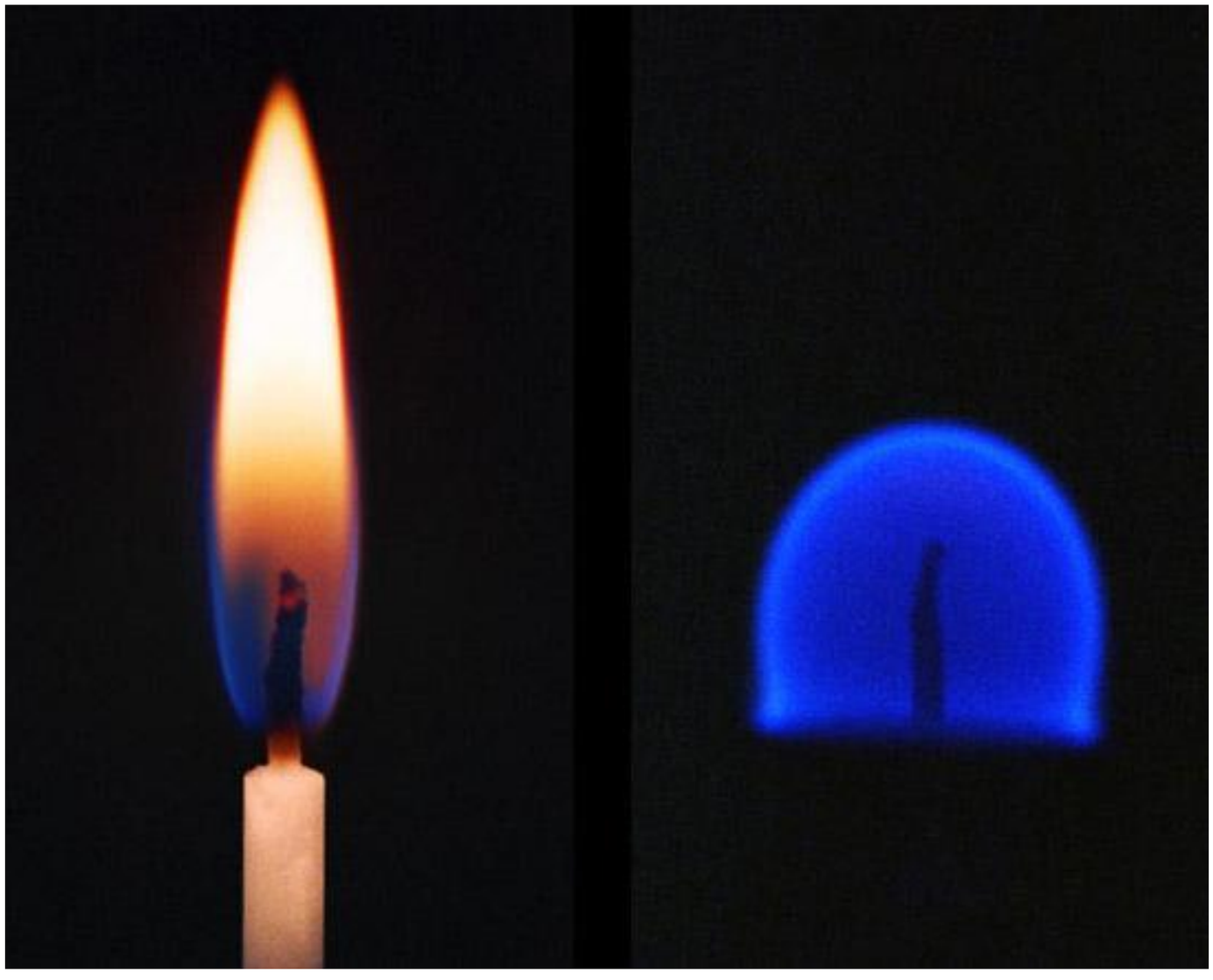
sson@purdue.edu

Purdue Energy Camp 2012

Purdue University

Fossil Fuel Background

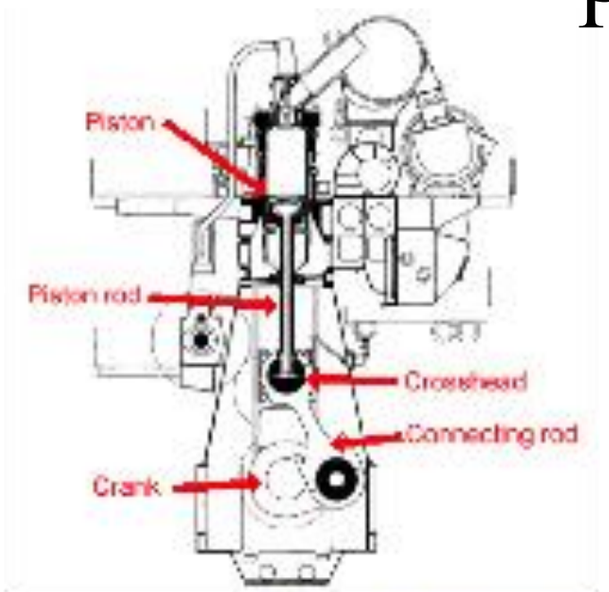
- What fossil fuels?
- What are hydrocarbons?
- How do hydrocarbons affect your life?
- What is combustion?

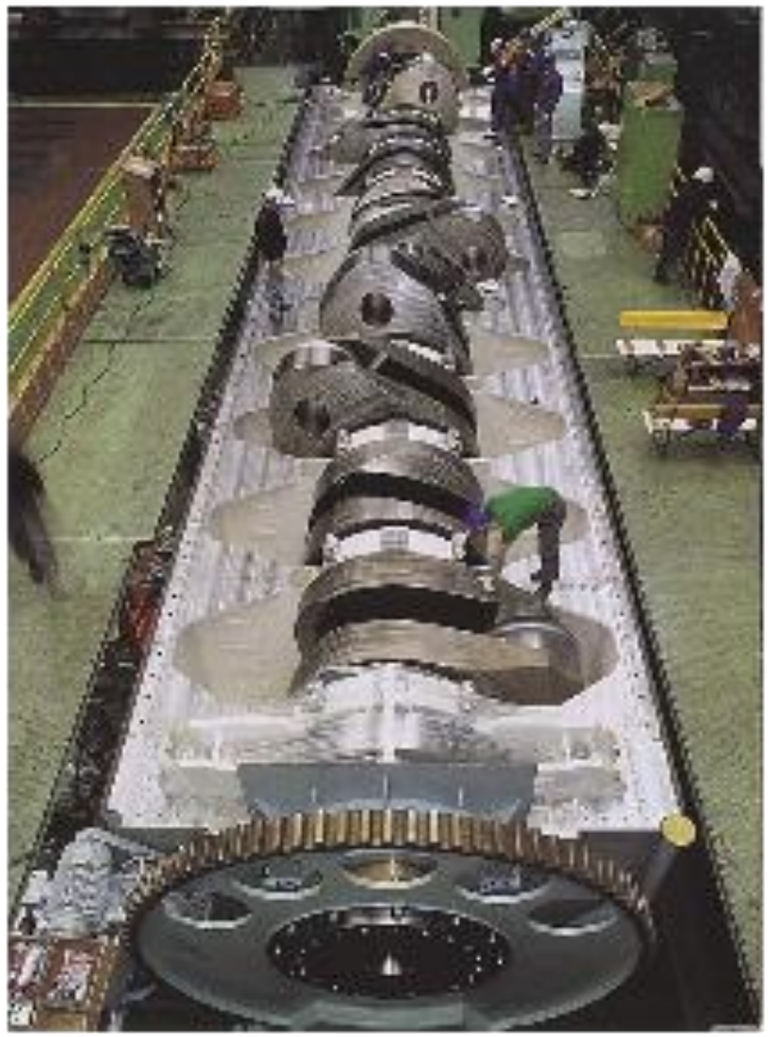


Largest Engine

Wartsila-Sulzer RTA96-C turbocharged two-stroke diesel (application: large container ships). Cylinder bore 38”, stroke 98”; 14 cylinder version: weight 2300 tons; length 89 feet; height 44 feet; max. power 108,920 hp @ 102 rpm; max. torque 5,608,312 ft-lbf @ 102rpm; BMEP 18.5 atm

Paul Ronney (USC)





Smallest

- Application: model airplanes
  Weight: 0.49 oz.
  Bore: 0.237” = 6.02 mm
  Stroke: 0.226” = 5.74 mm
  Displacement: 0.00997 in3 (0.163 cm3)
- RPM: 30,000
- Power: 3 watts
- Ignition: Glow plug
- BMEP: 0.36 atm (low!)
- Typical fuel: castor oil (10 - 20%),
- nitromethane (0 - 50%), balance
- methanol
- Poor performance
- Low efficiency (< 5%)
- Emissions & noise unacceptable for indoor applications

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Why Internal Combustion Engines?

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- Alternatives - electric vehicles
- Why not generate electricity in a large central power plant (≈ 40%), distribute to charge batteries to power electric motors (≈ 80%)?
  - Car battery, lead acid: 100 amp-hours, 12 volts, 20 kg; energy/mass = 100 A * 12 V * 3600 sec / 20 kg = 2×10^5 J/kg
  - Gasoline (and other hydrocarbons): 4.5×10^7 J/kg
- Batteries are heavy ≈ 1000 lbs/gal of gasoline equivalent
- Fuel cell systems better, but still nowhere near gasoline
- "Zero emissions" myth - EVs transfer pollution
  - Environmental cost of battery materials
  - Possible advantage: makes smaller, lighter, more streamlined cars acceptable to consumers

“Zero Emission” Myth

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What about solar?

- Arizona, high noon, mid summer: **solar flux ≈ 1000 W/m^2**
- Gasoline engine, 20 mi/gal, 60 mi/hr, thermal power = (60 mi/hr / 20 mi/gal) x (6 lb/gal) x (kg / 2.2 lb) x (4.5 x 10^7 J/kg) x (hr / 3600 sec) = **102 kW**
- Solar alternative, Need ≈ 100 m^2 collector ≈ **32 ft x 32 ft** - lots of air drag, what about nighttime, bad weather, northern/southern latitudes, etc.?

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Nuclear?

- Nuclear
  - Obviously not directly for transportation
  - Higher energy density:
    - U235 fission: 3.2 x 10^{-11}J/atom * (6.02 x 10^{23} atom / 0.235 kg) = 8.2 x 1013 J/kg ≈ 2 million x hydrocarbons!
  - Still need energy medium (H_2, liquid fuels, etc. and therefore need ICEs
  - Main obstacle is public acceptance

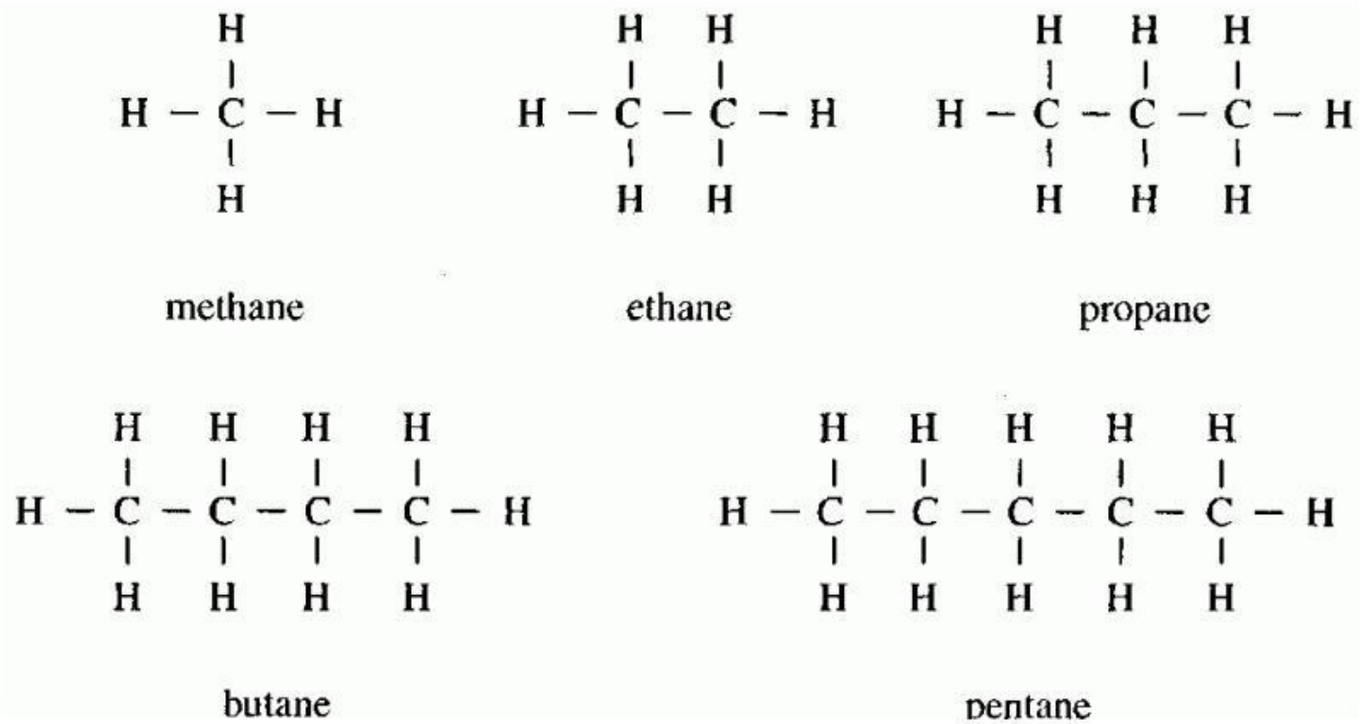
Conclusion

- Moral - **hard to beat liquid-fueled internal combustion engines** for
  - Power/weight & power/volume of engine
  - Energy/weight & energy/volume of liquid hydrocarbon fuels
  - Distribution & handling convenience of liquids
- **Conclusion: IC engines are the worst form of vehicle propulsion, Except all others**
- ***Also, energy from combustion will change forms (clean coal, hydrogen, etc.) but will likely continue for several decades***

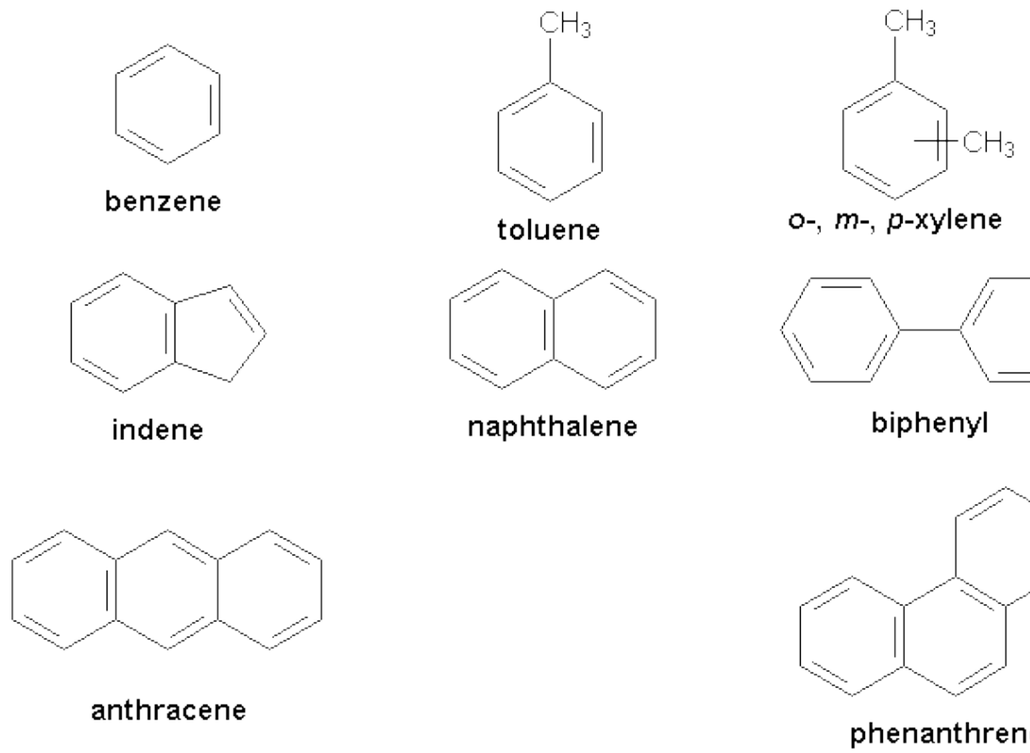
Fossil Fuel Background

- Fossil fuels are hydrocarbon chemicals produced from the decaying matter of plants and animals over geological time periods
- Examples of hydrocarbons:

Aliphatic hydrocarbons



Aromatic hydrocarbons

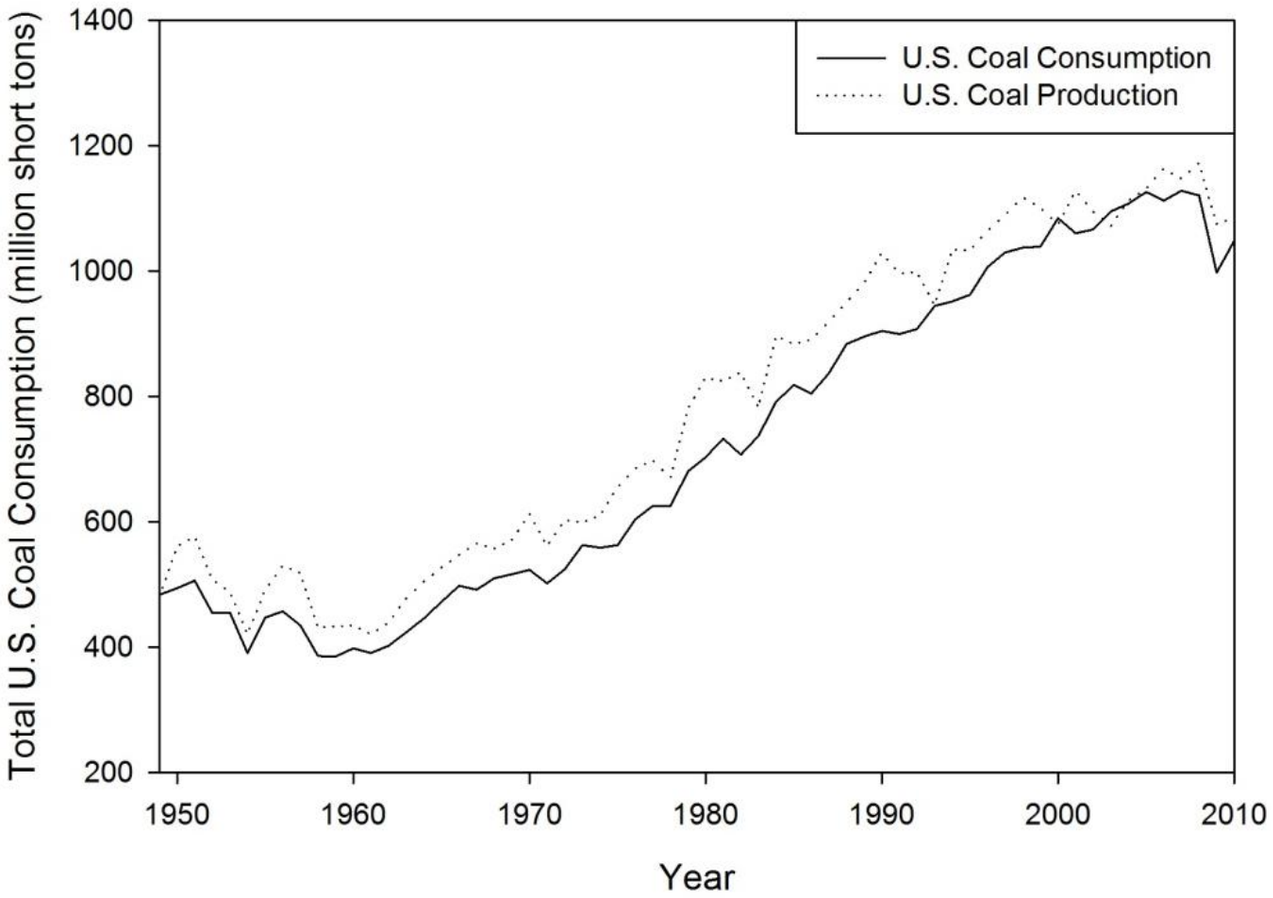


- When hydrocarbons are burned in oxygen (O_2), their atoms separate and rearrange to form more stable products (**what?**), releasing energy as heat and light

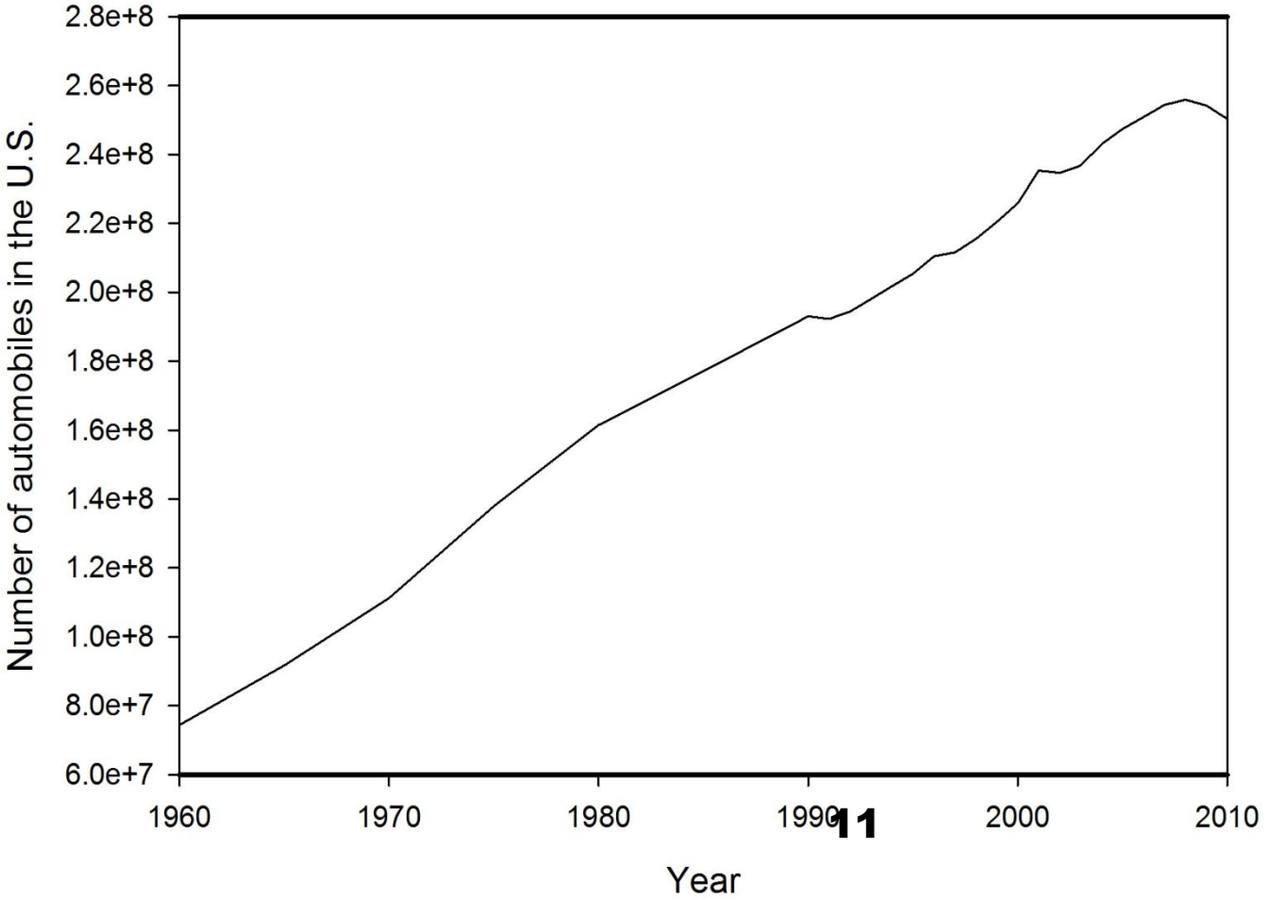
Why should you care?

- Fossil fuels are an important and currently irreplaceable form of energy in modern society
- Fossil fuels provide much of our electricity and nearly all of the power for our transportation systems

In the past 60 years, U.S. coal consumption has more than doubled

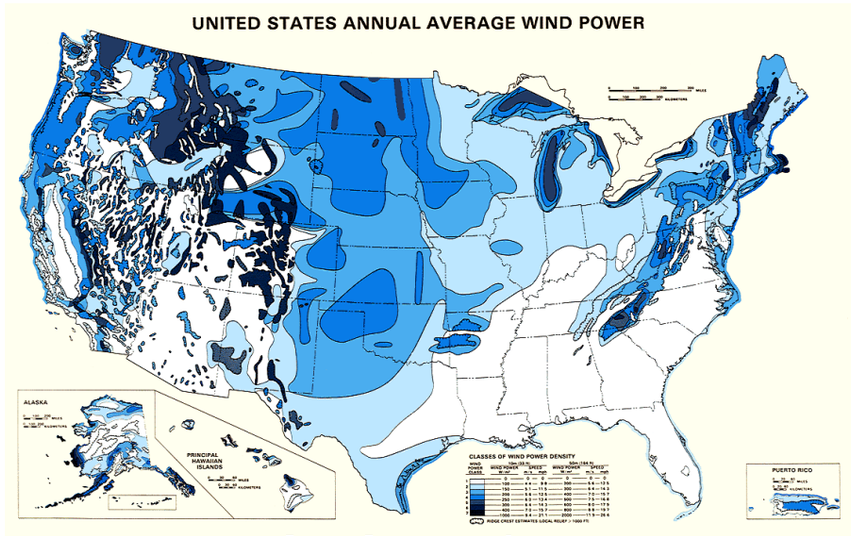


In 2010, there were 250 million automobiles on the road; more than triple the amount in 1970



Why do we use them?

- Fossil fuels are widely used because:
  - They are inexpensive and energy dense **(What does that mean?)**
    - They are highly abundant
    - An estimated 486 billion tons of coal exist in the U.S. (EIA)
    - 272 trillion cubic ft. of proved natural gas reserves in the U.S. (EIA)
  - They are a highly dependable form of energy
    - Unlike wind, hydroelectric, and solar energy, fossil fuel plants are largely unaffected by environmental conditions
  - They do not produce radioactive wastes

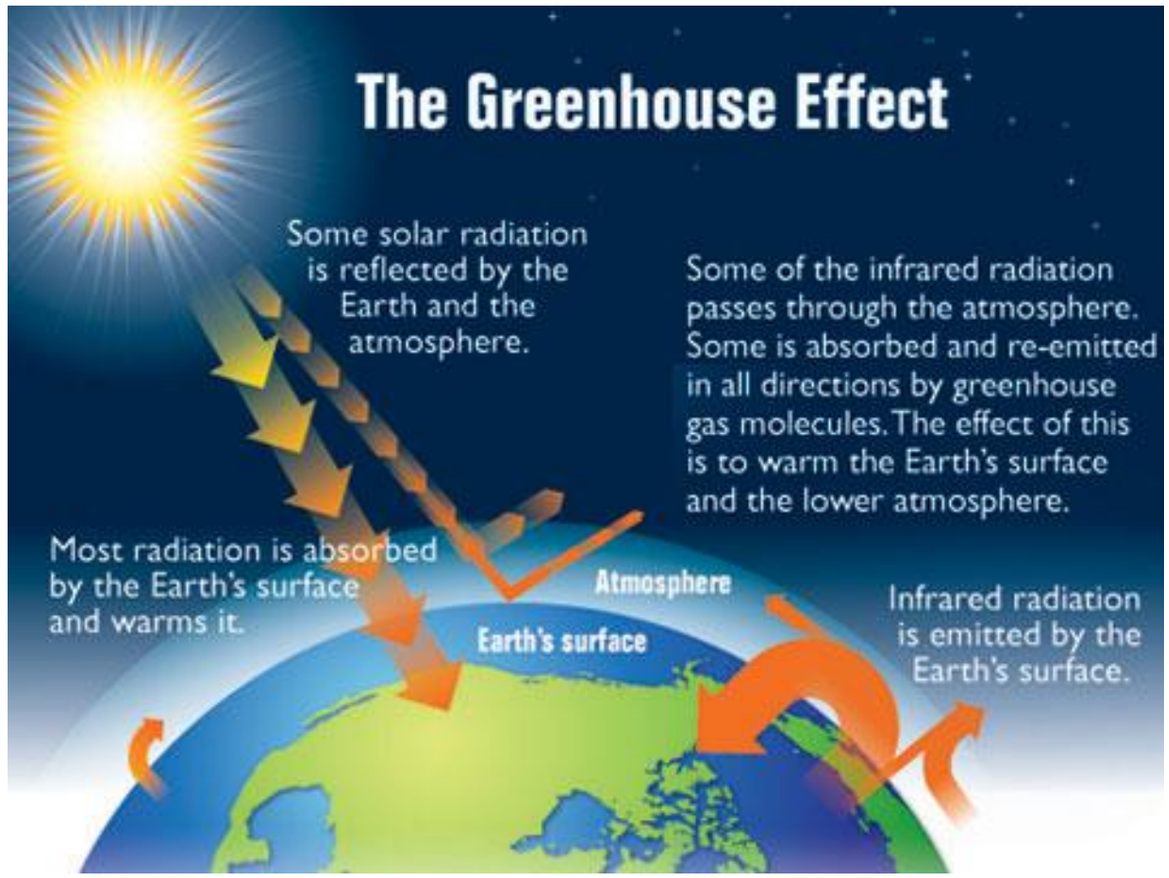


http://www.umt.edu/ethics/imx/climatechange/US_wind_power_map.png

  - Capacity to generate lots of electricity in a single location
    - Wind turbines and solar cells have only a fraction of the generating capacity
  - Plants can be built most anywhere
  - Plants are based on existing technologies

Fossil Fuel Disadvantages

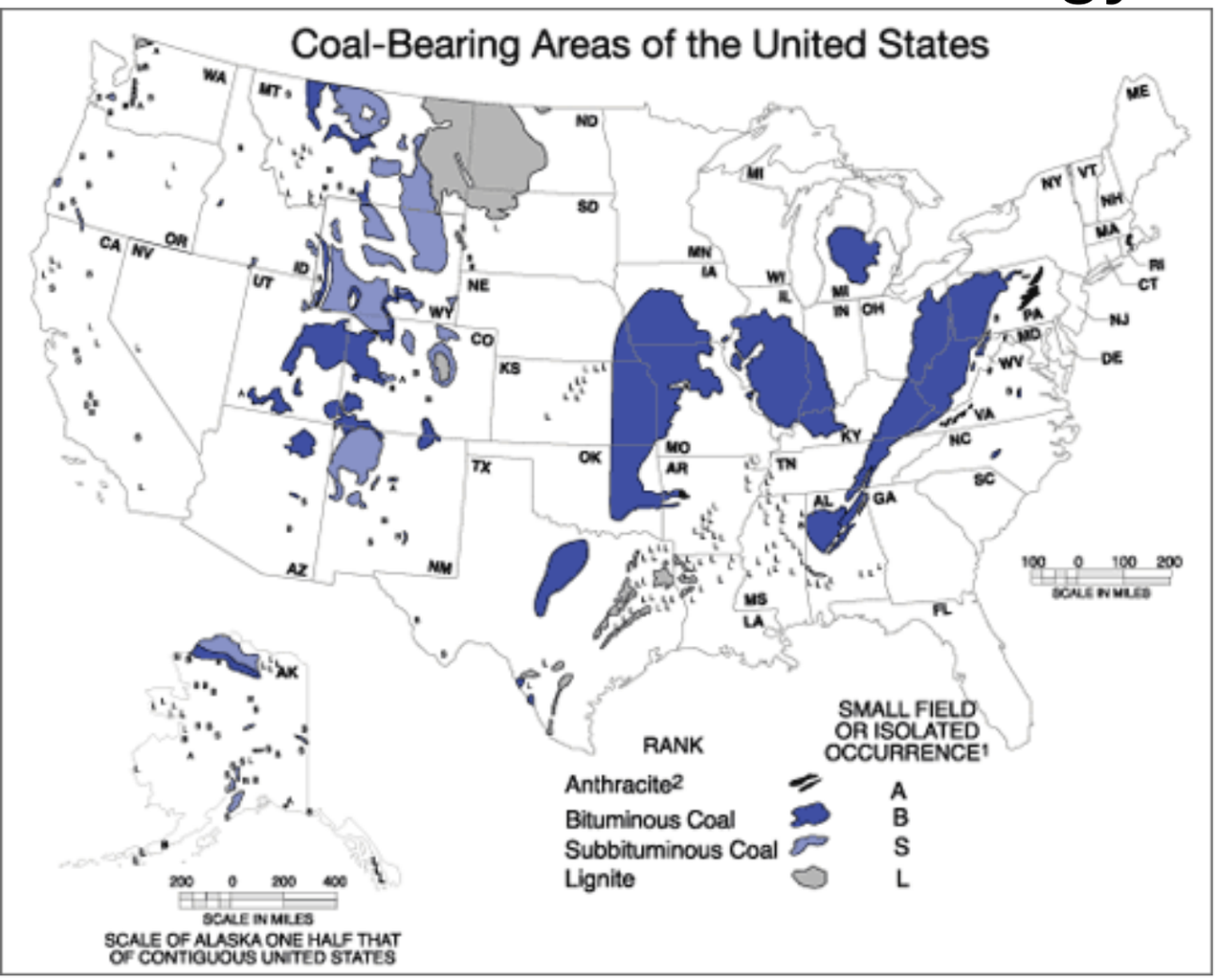
- The combustion of fossil fuels produces CO_2
  - CO_2 is a greenhouse gas
- Other pollutants such as SO_2, NO, and NO_2 can be formed from some fossil fuels
  - These have been greatly reduced
- Prices are highly seasonally and politically dependant
  - The price of gasoline increases during summer months
  - Turmoil in the Middle East can lead to sanctions, embargos, etc.
- Transportation of fuels can be hazardous
  - Oil spills (BP, Exxon Valdez)
  - Natural gas explosions



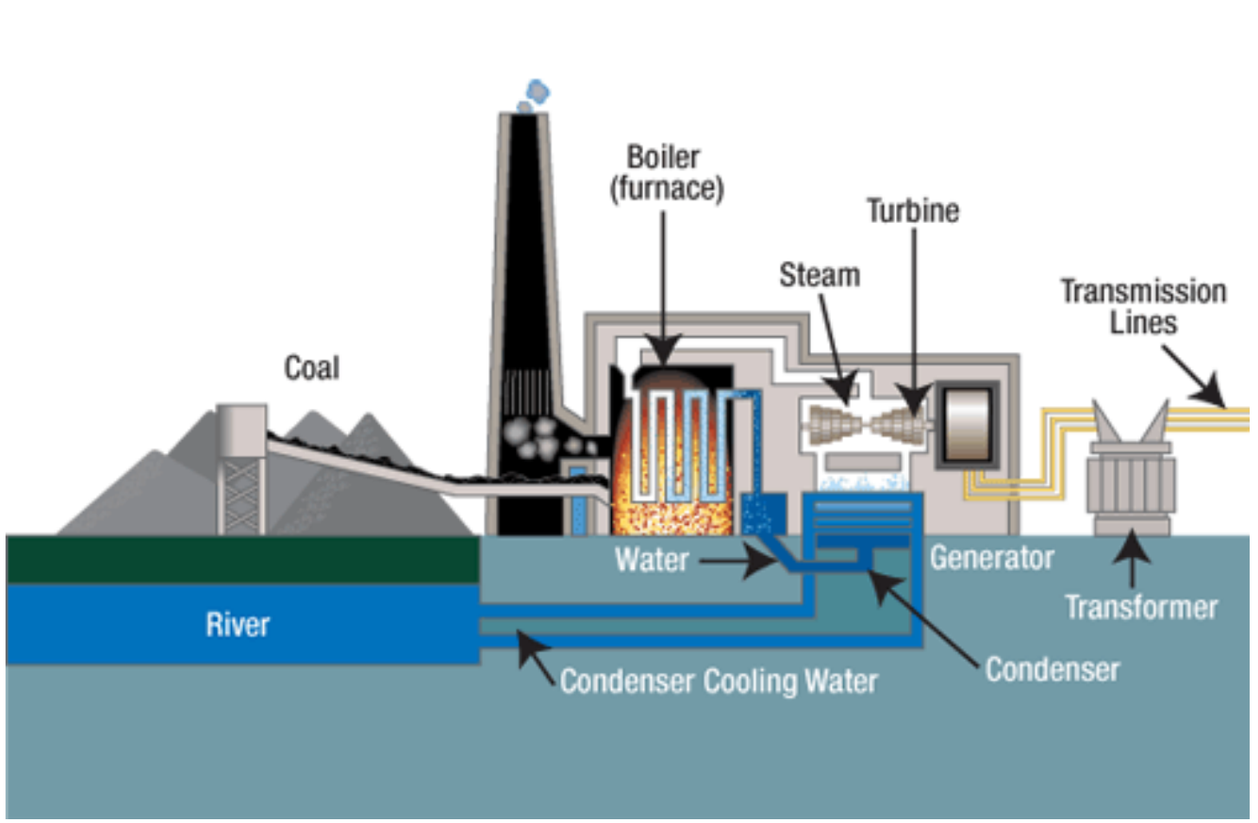
http://www.ghg.psu.edu/images/Climate_Basics.jpg

US is the Saudia Arabia of Coal?

- Coal is one of the most widely used fossil fuels for electricity generation
- The U.S. has vast reserves of coal
  - Hundreds of years at current usage rates
- Source of domestic energy



http://www1.eere.energy.gov/tribalenergy/guide/images/coal_map.gif



http://www.carnotcommunications.com/_Media/coalart.gif

Coal

- There are four main types of coal (rank):
  - **Anthracite:** Highest quality (and oldest) coal, High fixed carbon, low volatile matter, shiny and hard, highest energy density (heating value)
  - **Bituminous:** Lower quality, slightly softer, lower heating value, higher volatile matter
  - **Sub-bituminous:** Slightly lower quality than bituminous, lower heating value
    - Bituminous and sub-bituminous make up the vast majority of U.S. coal
  - **Lignite:** Lowest quality (and youngest) ,Soft, Low fixed carbon, High volatile matter, lowest heating value

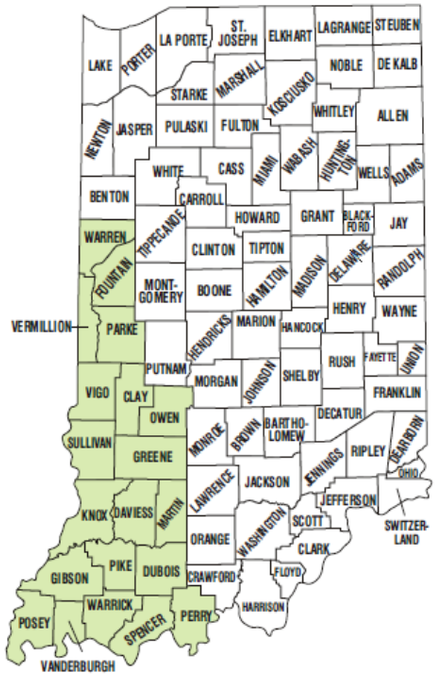
http://www.mii.org/Minerals/Minpics1/CoalAnthracite.jpg

http://www.geography.hunter.cuny.ed

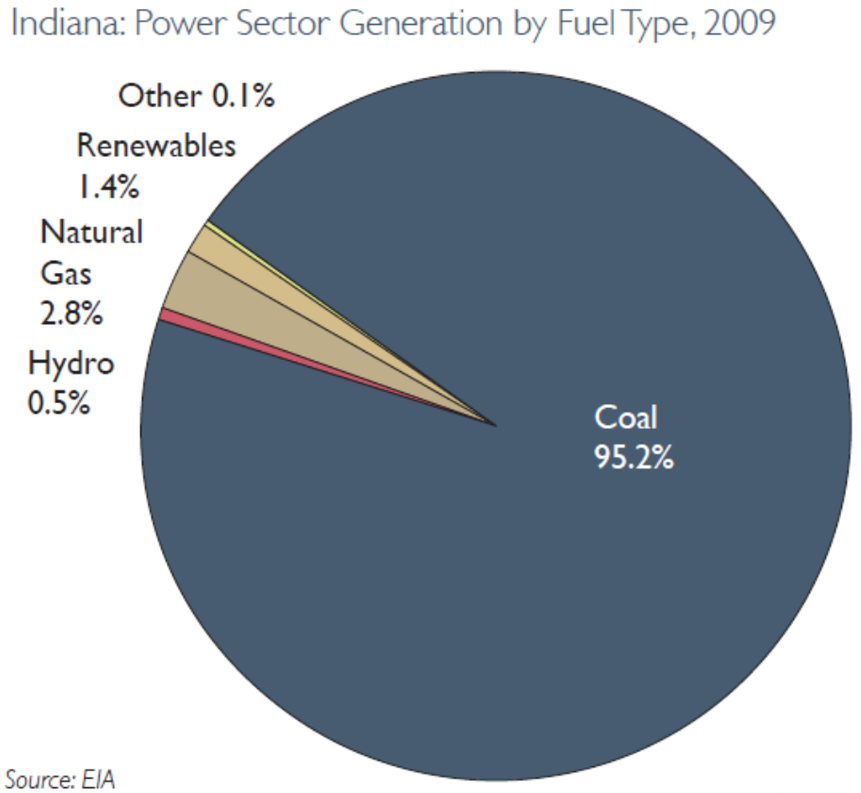
http://geology.com/rocks/pictures/coal-lignite-380.jpg

Coal in Indiana

- Indiana relies **extremely** heavily on coal combustion
  - 95% of Indiana's electricity



http://www.indianacoal.com/doc/Coal%20in%20Indiana.pdf

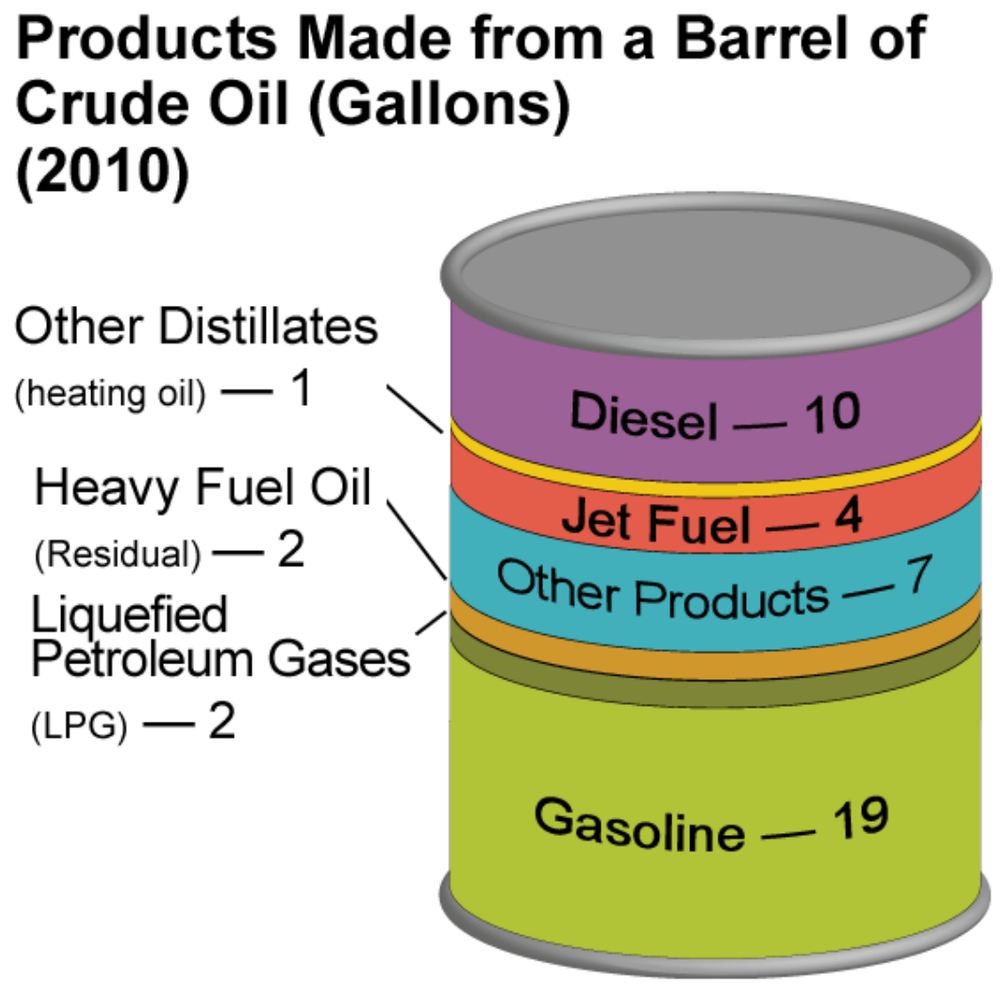


http://www.nma.org/pdf/americas_power_states/in.pdf

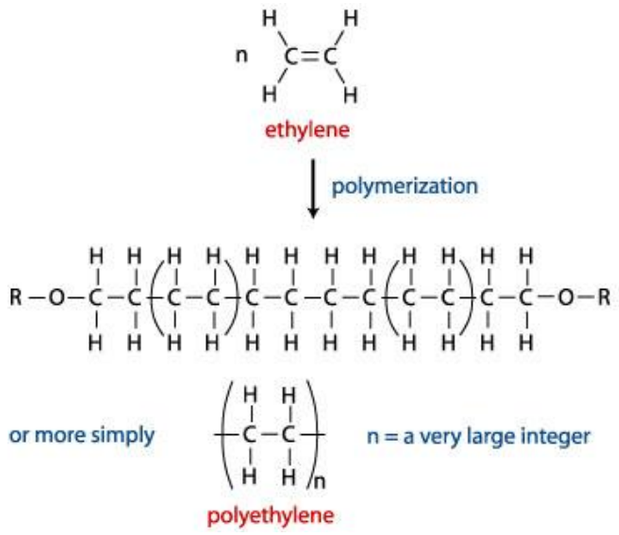
- Southern Indiana produces significant amounts of high-volatile, medium/high sulfur bituminous coal
  - ~36 million tons in 2011
- Purdue's Wade Utility plant burns 100% Indiana coal
  - Produces steam to heat/cool buildings and co-generates electricity

What is petroleum?

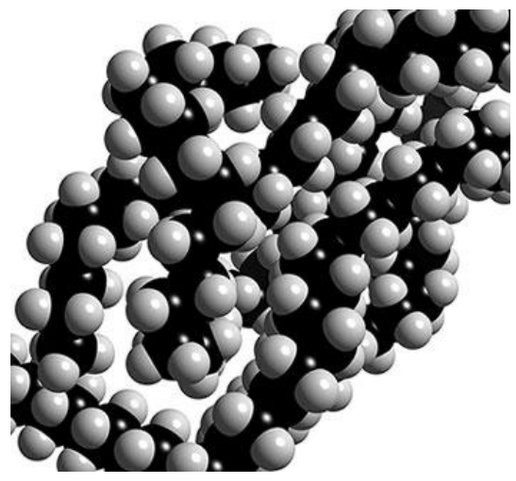
- Crude oil produces a wide variety of products
  - Gasoline, diesel, jet fuel, rocket fuel, lubricants, plastics, cosmetics
- Gasoline is made from a variety of crude oil distillates
- Most consumer plastics are produced from petroleum
  - Plastics are long hydrocarbons strung together



http://www.eia.gov/energyexplained/images/charts/products_from_barrel_crude_oil-large.gif

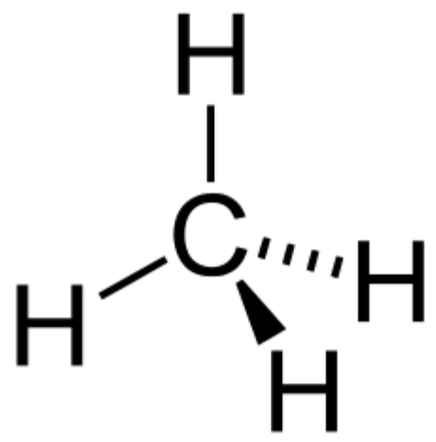


http://www.mpcfaculty.net/mark_bishop/polyethylene_formation_complete.jpg



http://www.3dchem.com/imagesofmolecules/Polyethylene.jpg

What is natural gas?

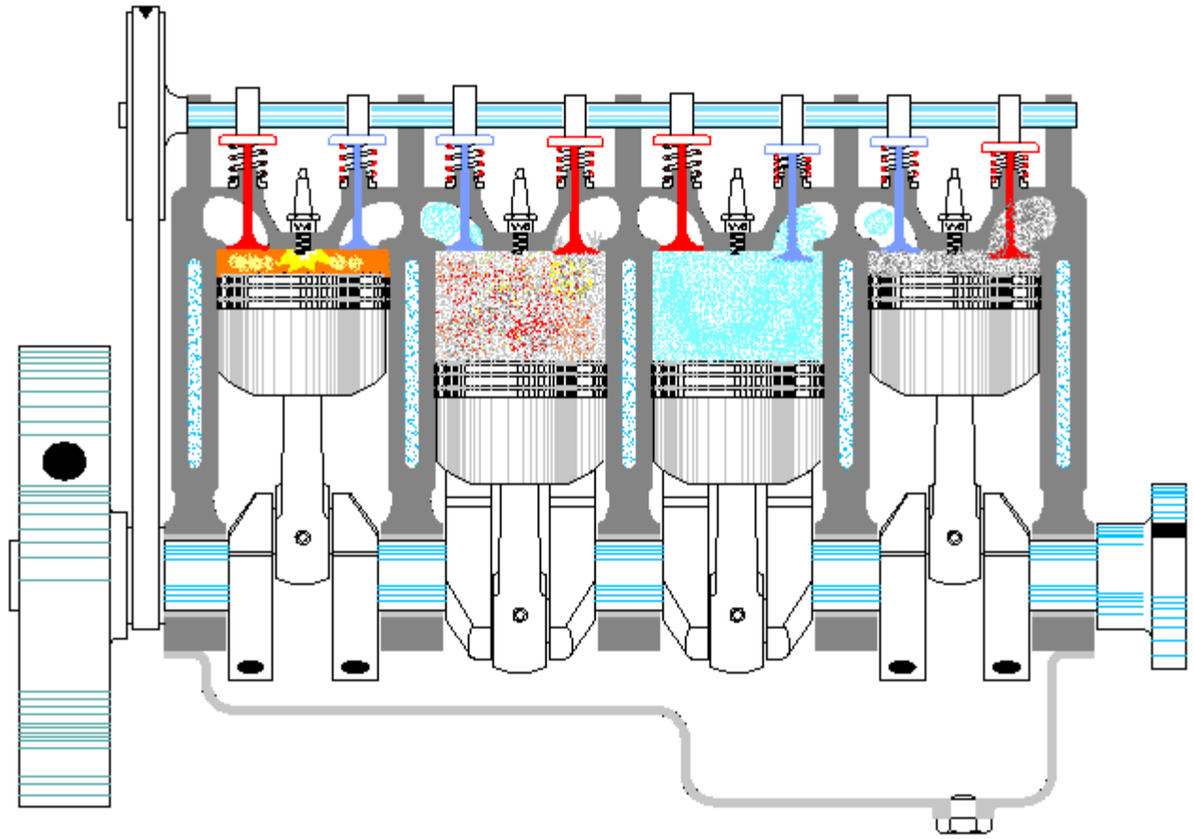


- Natural gas is a flammable gas composed of approximately 90% methane
- Methane is an odorless and colorless hydrocarbon gas
  - T-butyl mercaptan added to give smell
- N.G. is commonly mined by fracturing ("fracing") underground shale deposits and collecting the escaping gases
- Recent developments in the Marcellus Shale indicate massive reserves under PA,WV,NY,VA, and OH
  - Enough gas to supply the country's N.G. demand for 20 years
- N.G. combustion is relatively clean (lower CO_2 and no SO_x) – **Why lower CO_2?**

http://oilshalegas.com/sitebuildercontent/sitebuilderpictures/mar.JPG

Current Fossil Fuel Research

- Significant research is devoted toward the following fossil fuel topics:
  - Improving internal combustion engine efficiency



  - Reducing emissions from coal-fired power plants (Clean coal technology) – i.e. oxyfuels and bio/coal
  - Coal-to-liquids
  - Coal cleaning (removing pollutants from fuel)

Fossil Fuels in the Future

- U.S. population is projected to reach 439 million (an increase of 42%) by 2050
- Coal will continue to provide abundant, affordable energy to U.S. population
- With large deposits, N.G. could see an increase in automobile usage

Fossil fuels are an integral part of our society. Continued research and commercial efforts should (and will) be devoted toward the efficient, safe, ecologically-responsible, and economical use of these fuels!

QUESTIONS?