Lecture 6: Monday, February 11, 2008

Guest lecturer:
Professor Amit Lath
Physics and Astronomy

Homework #2 posted, due Wednesday, February 20

Today's topic: the future of fossil fuels

Why Fossil Fuels?

- What's so special about fossil fuels?

  Energy content.

Gasoline: 115,000 BTU/gal = 120 MJoules/gal
Coal: 15,000 BTU/lb = 15 MJoules/lb

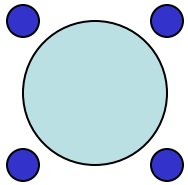
Compare to:

Wood: 7,500 BTU/lb = 7.5 MJoules/lb
A "horse" (working 1 hour) = 2.5 MJoules.
A human … = 0.2 MJoules

Fossil Fuels deliver ***lots*** of energy in a ***small*** volume.

Fossil Fuels are ***transportable***.

How Do Fossil Fuels Work?



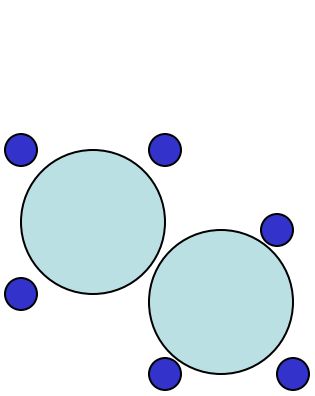
CH_4 Methane, the simplest Hydrocarbon, burns (well, all hydrocarbons burn):

Burning is a process of combining with oxygen.

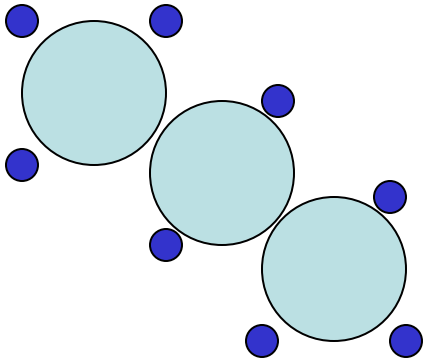
1 Methane + 2 O_2 ➔ 2 H_20 + CO_2 + ***Energy***

Hydrocarbons burn fast.
Hydrocarbon burning releases **water** and **CO_2**

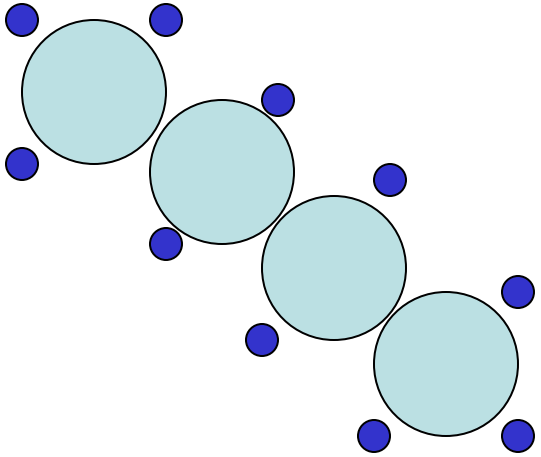
More Hydrocarbons



2 Carbon Atoms
ETHANE



3 Carbon Atoms
PROPANE



4 Carbon Atoms
BUTANE

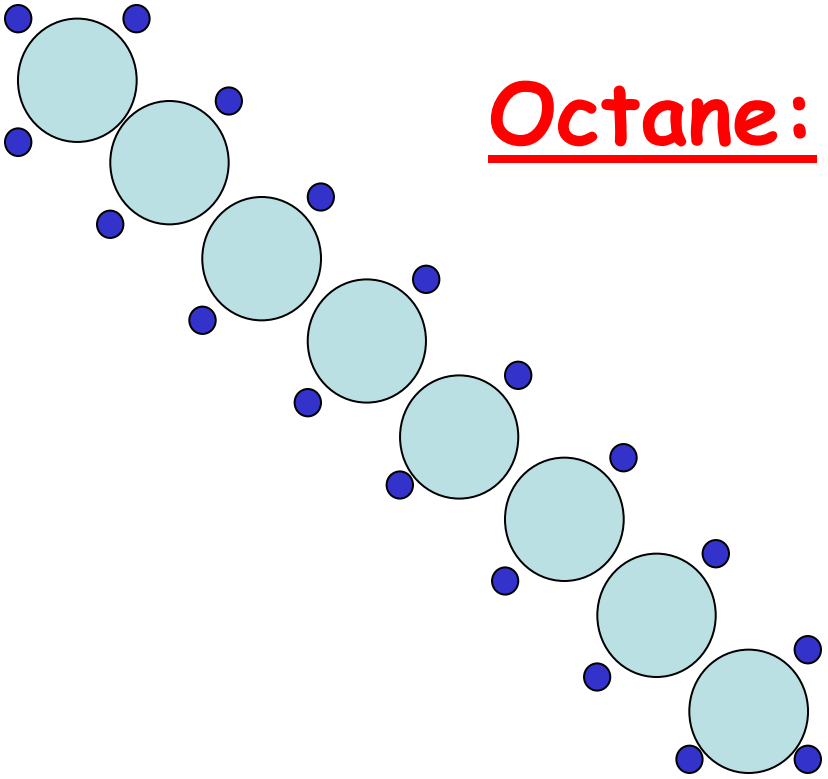
And so on.

Five Carbon Atoms give you PENTANE.

Six Carbon Atoms give you HEXANE.

Seven give you HEPTANE.

The World's Favorite Hydrocarbon



Octane: **Eight** Carbons.
The main ingredient in **gasoline**.

Current consumption rates: oil

- US: about 20 million barrels/day (EIA 2006)
- World: about 83 million barrels/day (EIA 2005)

Cost per primary Btu at $100/barrel*

Cost per end-use Btu at $3/gallon

(we'll come back to natural gas and coal later)

Estimating reserves

- Proven reserves = resources that are well known through geologic exploration and are recoverable at current prices and with current technology (and applicable environmental regulations)
- Other resources: oil that could be recovered from known fields using improved techiques; deposits in known fields but not yet measured, oil fields yet to be discovered

How long before we run out?

- US reserves: 21 billion barrels (EIA 2006)
- World reserves: 1 trillion barrels (uncertain)
- Years' supply:

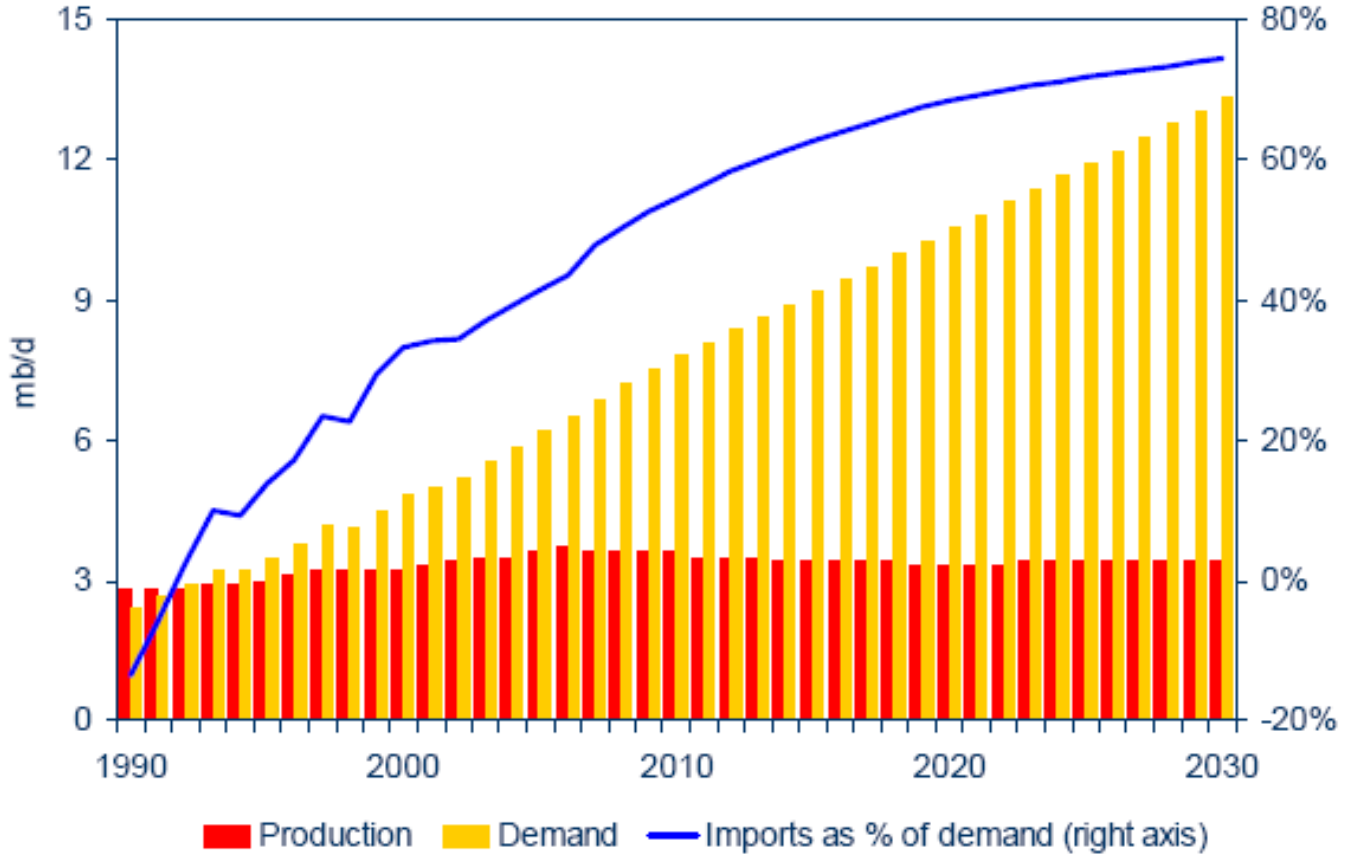
1 trillion barrels / 83 million bpd * 1year/365 days = 33 years

Reminder: demand is increasing! China may double oil demand from 2005 to 2030, from

6 mbpd to 12 mbpd

ARE WE RUNNING OUT OF OIL?

AND IF SO, WHAT ALTERNATIVES EXIST?



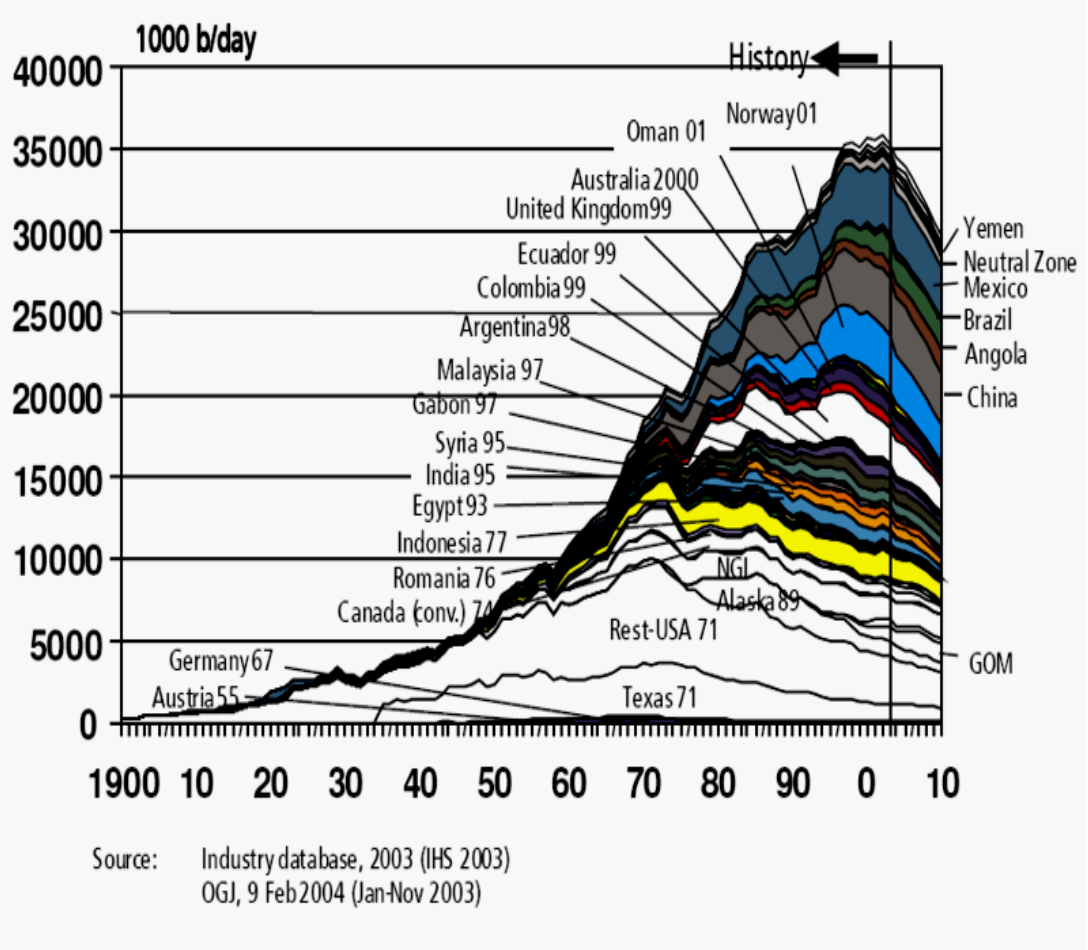
Projections for China oil, from World Energy Outlook 2004

Importance of price

- New technology can bring price of extraction down, increase proven reserves
- Only long-term increases in price lead to increases in production
- Extracting fossil fuels itself costs energy – the idea that it could take as much energy to extract as you obtain in the form of fossil fuel (energy balance)

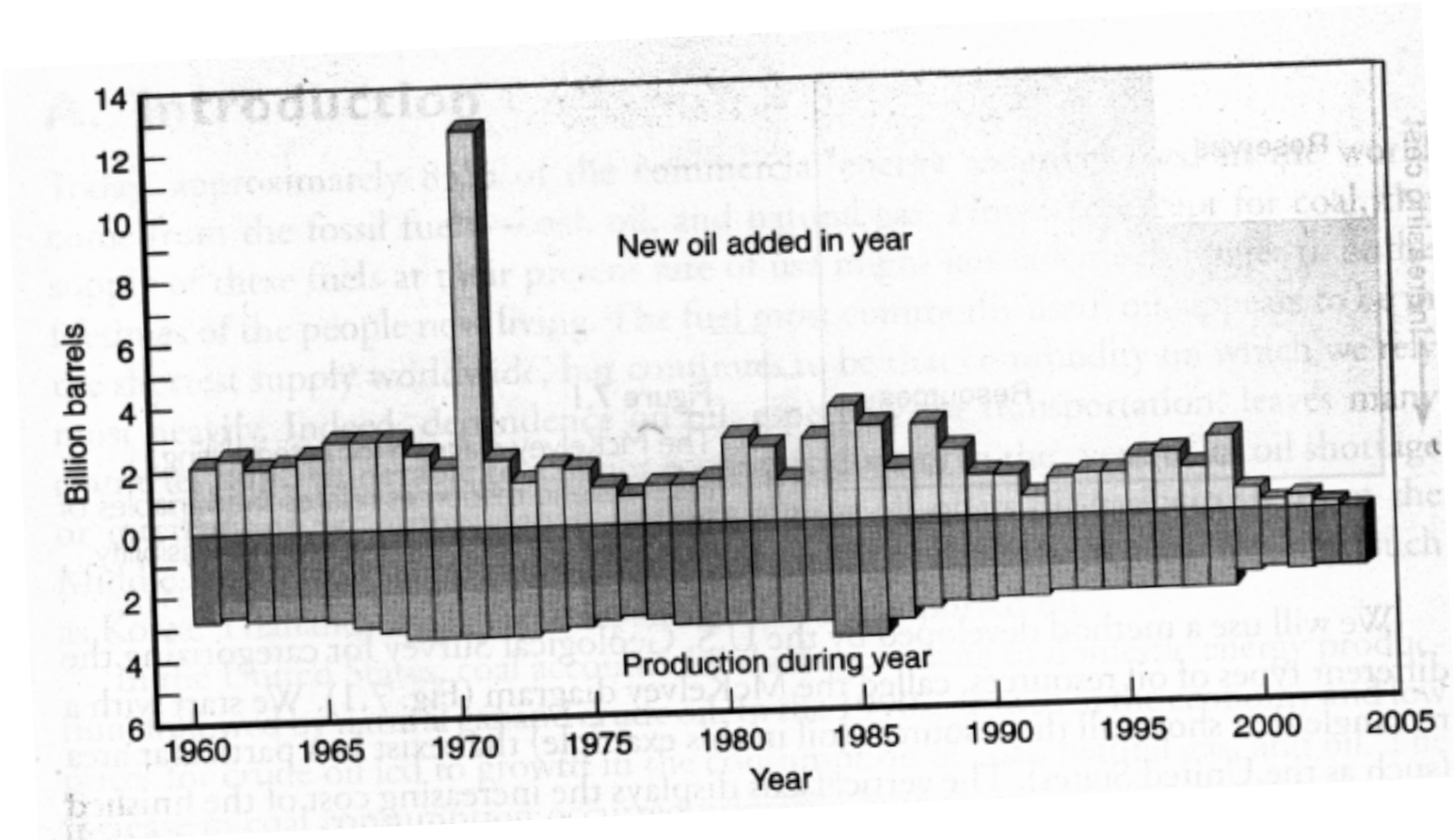
Oil production

- Hubbert's peak
  - At peak, ½ of all oil that will ever be extracted has been.
- New Technology
  - Drill sideways
  - Drill in deeper ocean
  - Find hidden pockets.
- But at some point, peak will be reached. Only question is when.



Annual addition of reserves

production outpaces added reserves



US reserves: ANWR


Miles 100
MISSISSIPPI
ALABAMA
GEORGIA
TEXAS
LOUISIANA
FLORIDA
New Orleans
Houston
Gulf of Mexico
Water depth: about 1,000 feet
Tampa
About 5,000 feet
Jack No. 2 well
About 10,000 feet

Two US reserves – how big?

- ANWR

Estimate up to 10 billion barrels

How long would this last?

10 billion / 20 million/day*1 year/365 days

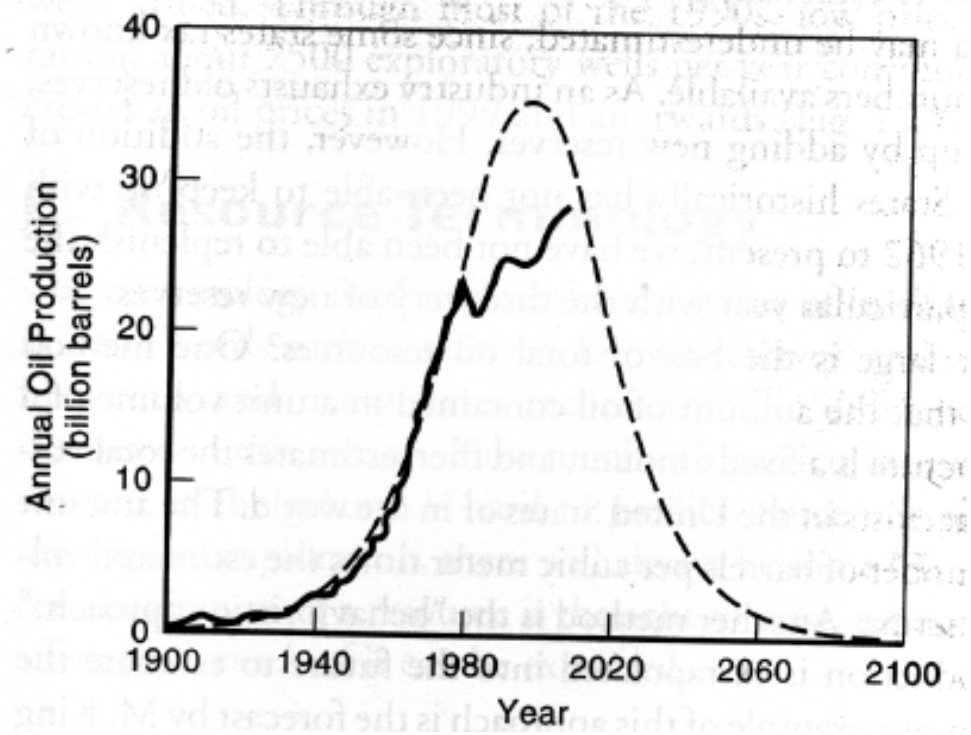
Answer: 1.3 years

- Gulf of Mexico

Estimate up to 40 billion barrels → 5.5 years

Off-shore drilling is expensive

Hubbert's peak -- world



Natural gas

- Consumption rates US: 22 trillion cubic ft/yr
- World: 105 trillion cubic ft/yr
- Estimated reserves US: 204 trillion cubic ft
- World 6,300 trillion cubic ft
- How long will it last? (US: 9.2 years, WORLD: 60 yrs)
  - Gas is harder to ship than oil.
- Cost per end-use Btu (residential) $13.75/thousand cf*

Coal

- US consumption: 1,100 million tons/year
- World consumption: 6,500 million tons/yr
- Estimated US reserves: 270 billion tons
- Estimate world reserves: 1 trillion tons
- Years available: (US:245 yrs, World 154 yrs)
- Primary cost per Btu at $25/ton (compare with cost per Btu for residential electricity at average $0.10/kWh)*

Problems with coal

- Dirty to burn
- Danger and environmental impact of mining
- Limited use: conversion via electricity generation (which is only 35% efficient) increases cost per end-use Btu
- CO2 emission and climate change
- COAL RESERVES WILL LAST “FOREVER”

Coal Power

Mohave Generating Station, a 1,580 MW coal power plant near Laughlin, Nevada

Future-Gen?

- Gasification: allows removal of impurities
- Coal → gas/fuel: Fischer-Tropsch process.
  - Used by Axis in WW2.
- Benefits:
  - Integrated Gasification Combined Cycle (IGCC) produces electricity at 50% eff, with much lower pollution.
  - Fuel for cars?
- Problems:
  - Expensive. Will need subsidies.
  - Hinder CO2 eventual fossil-fuel free solutions.

Building of coal-fired plants continues

- Estimate rate: 1000 MW/plant

16,000 billion kWh/year current world consumption

Doubles in 30 years?

- where in the world?
- A problem because these plants will operate for the next 50 years
- TXU deal →

TXU Deal

Within TXU, the plan to build a raft of coal plants had become so damaging to the company's stock price that its board had been privately weighing a plan to scrap part of its coal plant development project…

The two coal-burning units at TXU's Big Brown facility in Fairfield, Texas.
(Misty Keasler for The New York Times)

The group worked out a "10-point plan" that included a commitment by the investors to return the carbon-dioxide emissions by TXU to 1990 levels by 2020 and support a $400 million energy efficiency program.

Summary

- We have a few decades of oil left.
  - Price of gasoline will increase unless large new deposits are found/exploited. (ANWR, etc not large on this scale).
- More natural gas left, but it is a more local market (harder to ship).
- All countries have essentially unlimited (> 100 yrs) reserves of COAL.
  - Coal can be turned into gas/liquid fuels.
  - Gasification,synfuels could have devastating greenhouse consequences