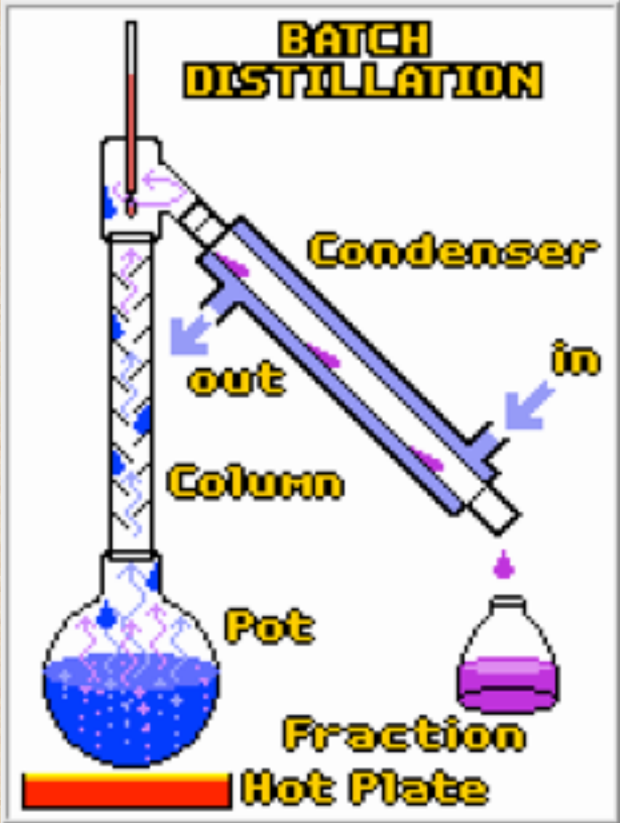
Lecture 5
April 11, 2012

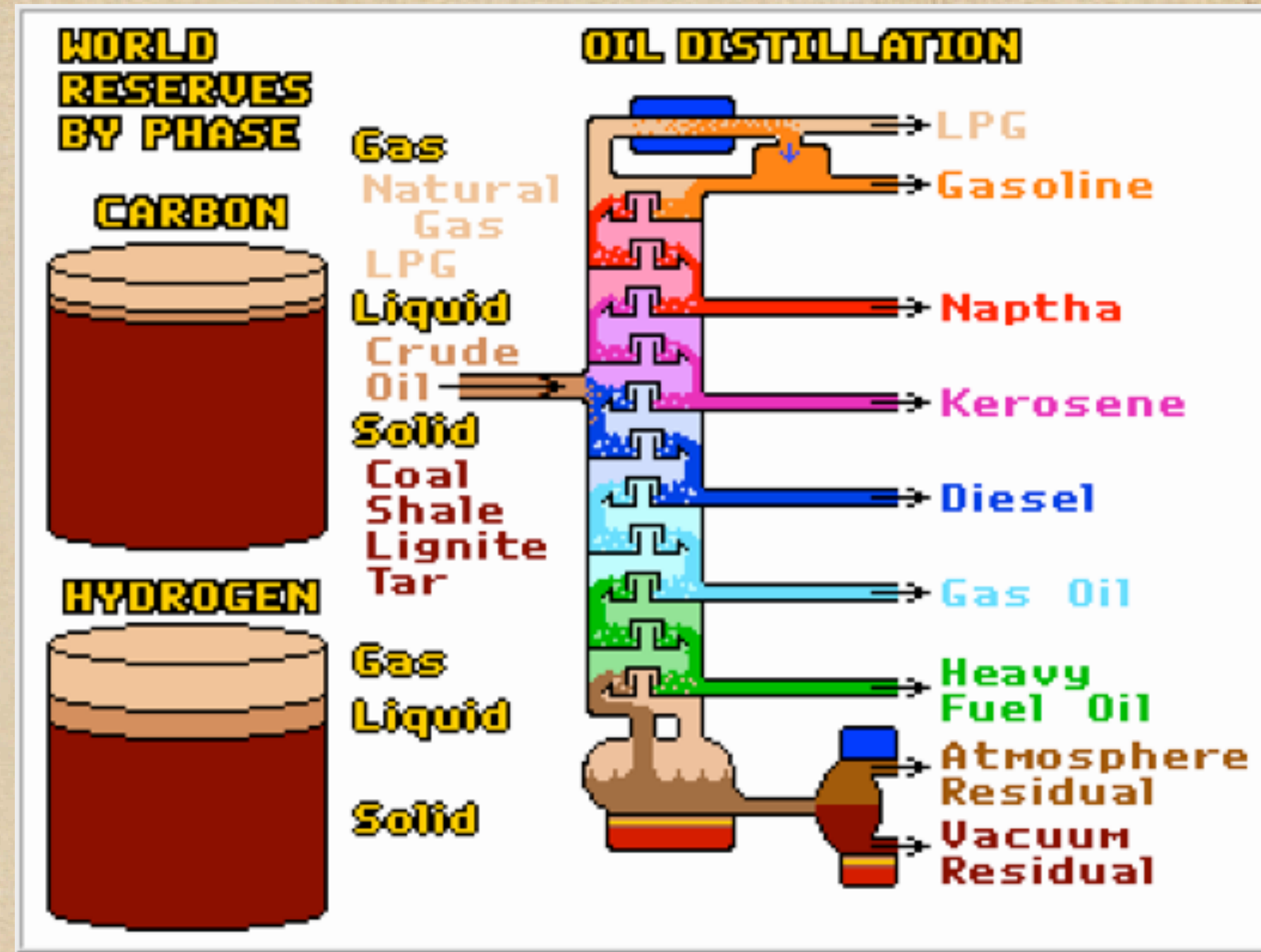
Natural gas

Reasons for Optimism:
1) undiscovered resources exist
2) Methane is now more “tamed” lots of methane in coal beds
3) ~1100 Tcf estimated left (used up 1000Tcf)

- Mostly methane CH_4 or ethane
- Less harmful emissions, CNG is very popular in many parts of the world (SC Metro too)
- Natural gas @ 12.83$/MBtu versus electricity @ 26.08$/MBtu
- Heating efficiency reasonable: Chimney gets most heat though- electric heating is competitive with 100% conversion, but heat pump is best as we will discuss later.

- Resources:
- Q= 1200×10^{12} cft
- Used up 1037×10^{12} cft
- 15% left is one estimate
- Rest Of the World has about 6400×10^{12} cft





Crude Oil Refining

Distillate Fraction	Boiling Point (°C)	Carbon Atoms per Molecule
Gases	below 30	1-4
Gasoline	30-210	5-12
Naphtha	100-200	8-12
Kerosene & Jet Fuel	150-250	11-13
Diesel & Fuel Oil	160-400	13-17
Atmospheric Gas Oil	220-345	
Heavy Fuel Oil	315-540	20-45
Atmospheric Residue	over 450	over 30
Vacuum Residue	over 615	over 60

K R discuss further about

Greases, Paraffin (wax) and Pitch & Tar at tge

bottom of the fraction list.

Examples 2.1 and 2.2: Price of natural gas versus gasoline versus electricity in 2004..

Natural gas sold by gas company at \$13.28/1000ft^3

Electricity cost .089\$ per kWh.

Gasoline sold at 1.85\$/gallon

Compare the three costs per BTU

For electrical consumption we assume 100% efficiency

Energy equivalents data provided:
(page 2 of cover RK)

Gasoline 1 Gallon 1.25x10^5 Btu

Natural gas 1000ft3 1.035x10^6 Btu

Electricity 1kWh 3413 Btu

We will calculate the cost of 10^5 Btu energy by the three means electrical, gas and gasoline

Gasoline: 1.85/1.25 = 1.48 \$ for 10^5 Btu energy

Natural Gas: 13.28/10.35 = 1.28 \$ for 10^5 Btu

Electricity: .089/kWh x 1kWh/3413 Btu x 10^5 Btu = 2.61 \$ for 10^5 Btu

Ratios NG:G:E = 1:(1.15):(2.03)

Coal

- Origin is in plants that died 350 Million years ago by anaerobic decay of organic matter (without oxygen).
- Big role in the past development. (Steam age = Coal age)
- Enormous reserve left but severe environmental problems and efficiency issues
- US has about 25% of world's reserves, Russia about 23%, China, ...
- If we use at the current rate, good for another 260 years!!!!

Shale oil

- USA has huge deposit of oil shale in Green river formation in Wyoming/Utah/Colorado
- Oil shale is a solid hydrocarbon, like wax contains Kerogen
- Q is between 600 to 2000 Billion barrels compared to Q=324 B Barrels of petroleum.
- Very low energy density: 3 to 5 million Btu/ton compared to 27 for coal.

Tar Sand

- Canada special
- Viscous crude Bitumen
- Energy density is again very low- but vast deposits exist

Sun: INSOLATION

"May we attain that excellent glory of Savitar the (Sun) god:
So may he stimulate our prayers."
—The Hymns of the Rigveda (2000 BC Anonymous)

तत् सवितुर्वरेण्यं ।
भर्गो देवस्य धीमहि ।
धियो यो नः प्रचोदयात् ॥

Similarly Egypt + Mayans.....

Solar Constant ≈ 2 cal/min/ cm^2 (averaged over the 24 hr day)

Solar energy reaching upper atmosphere in direct line of sight of Sun.
Averaging over seasons reduces this.

Effective Solar Constant ≈ 0.5 cal/min/ cm^2

Losses in atmosphere due to absorption amount to 53% so we get about 47% of that

For an 8 hour day @ noon

$$600\ W/m^2 \sim 190 \frac{Btu}{ft^2\ hr}$$

$$\text{Insolation} \equiv Energy\ in\ 8\ hr\ day \sim 1520 \frac{Btu}{ft^2} \sim 4.5kWhr$$

Total energy supplied to USA per year by the Sun

Insolation x number of days per year x total area

1520 Btu/ sqft x 365 x 3.6
x10^6 miles^2 x $(5280)^2$

1 mile = 1760 yds = 5280 ft

$$E_{total} = 5.6 \times 10^{19}\ Btu/year$$

$$E_{total-Used} = 98 \times 10^{15}\ Btu/year$$

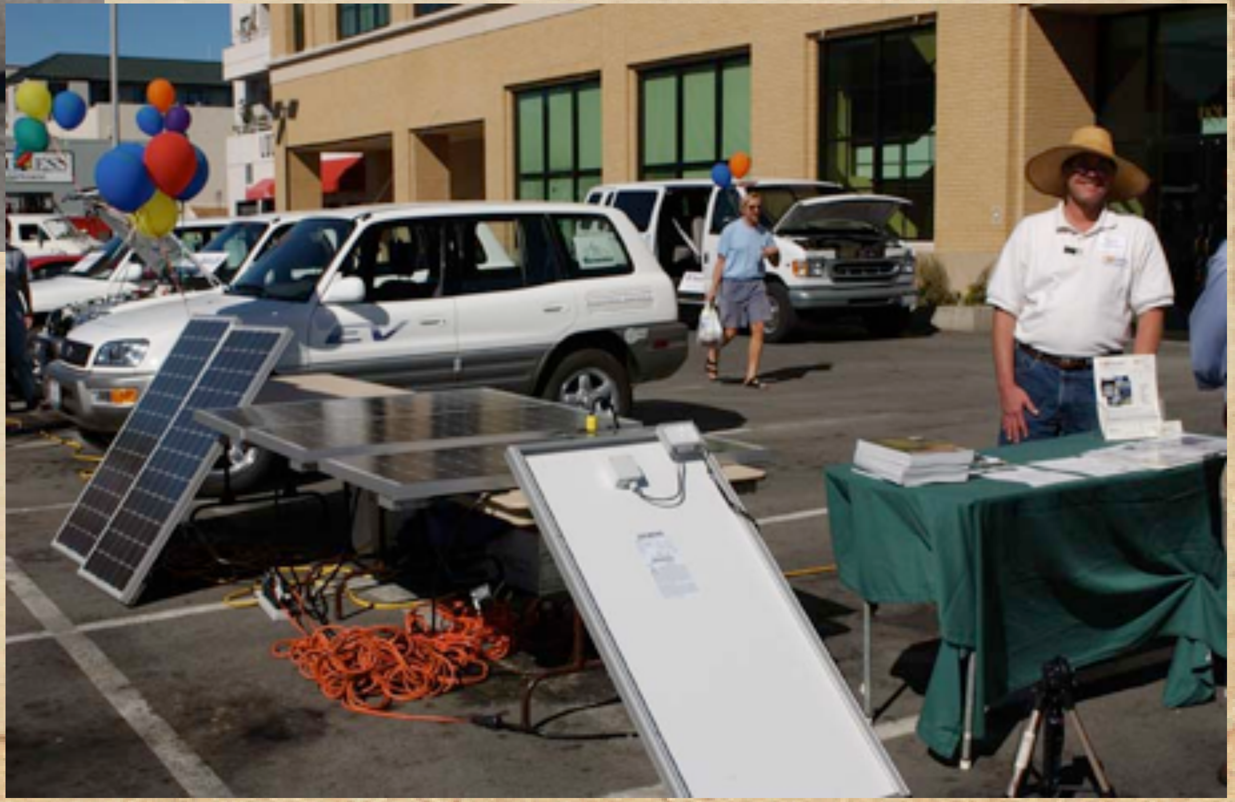
A mere 0.16% !!!!

We will study in details several Sun related issues
Sun is at 5800^0 K.
How do we know that?
Origin of solar energy? Thermonuclear processes.

http://www.solarwarrior.com/

Adelmans' photovoltaic system. Santa Cruz CA!!! Our system has a 2,880 square foot array with a theoretical output of 30.5kW.

Clean Air Fair Santa Cruz.



Heat Engines
Thermodynamics
and
Efficiency

Energy equivalents:
1 Gallon gas= 1.25×10^5 Btu
1 Btu=$.8 \times 10^{-5}$ Gallon gas = 1 match stick
= 778 ft-pounds (lift up 1 pound by 778 ft! That is a lot)

But:

Useful energy content is much less: Carnot efficiency limits us in converting heat into energy. Entropic loss.

For this and next lecture you might
refer to other books than RK
e.g. Joseph Priest's
Energy:Principles, Problems, Alternatives
Addision Wesley

Concepts:

Temperature T, Heat ΔQ, Specific heat C, Latent heat L, Pressure

Laws of Thermodynamics 0,1,2,3

Mixtures and resulting temperatures

Carnot Cycle for efficiency

Quality of Heat and 2nd law efficiencies