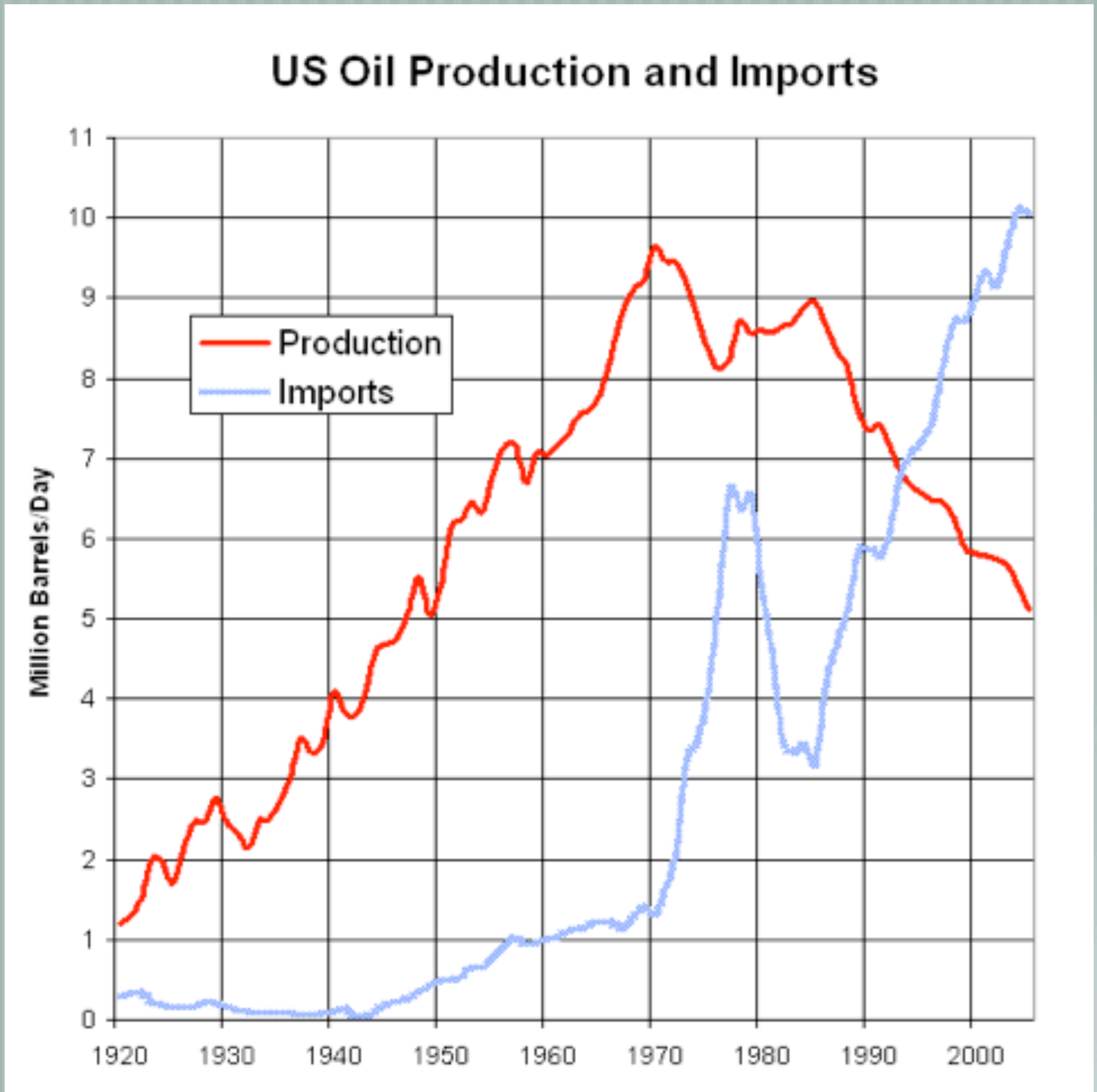
Lecture 4 April 7, 2011
Resource issues: How much do we have left?



M King Hubbert's thesis

Hubbert's estimate for USA in 1955 (ignoring Alaska and off shore)

$$165 \times 10^9 \ barrels$$

More current estimates agree with this and add the Alaska / offshore to give Grand total 324 x 10^9 barrels

Already produced 190 x 10^9 barrels: Left with 134x10^9 barrels

World total $\sim 2500 \times 10^9 \ barrels$

World Future estimate $\sim 1790 \times 10^9 \ barrels$

Time left 60 year!!!!

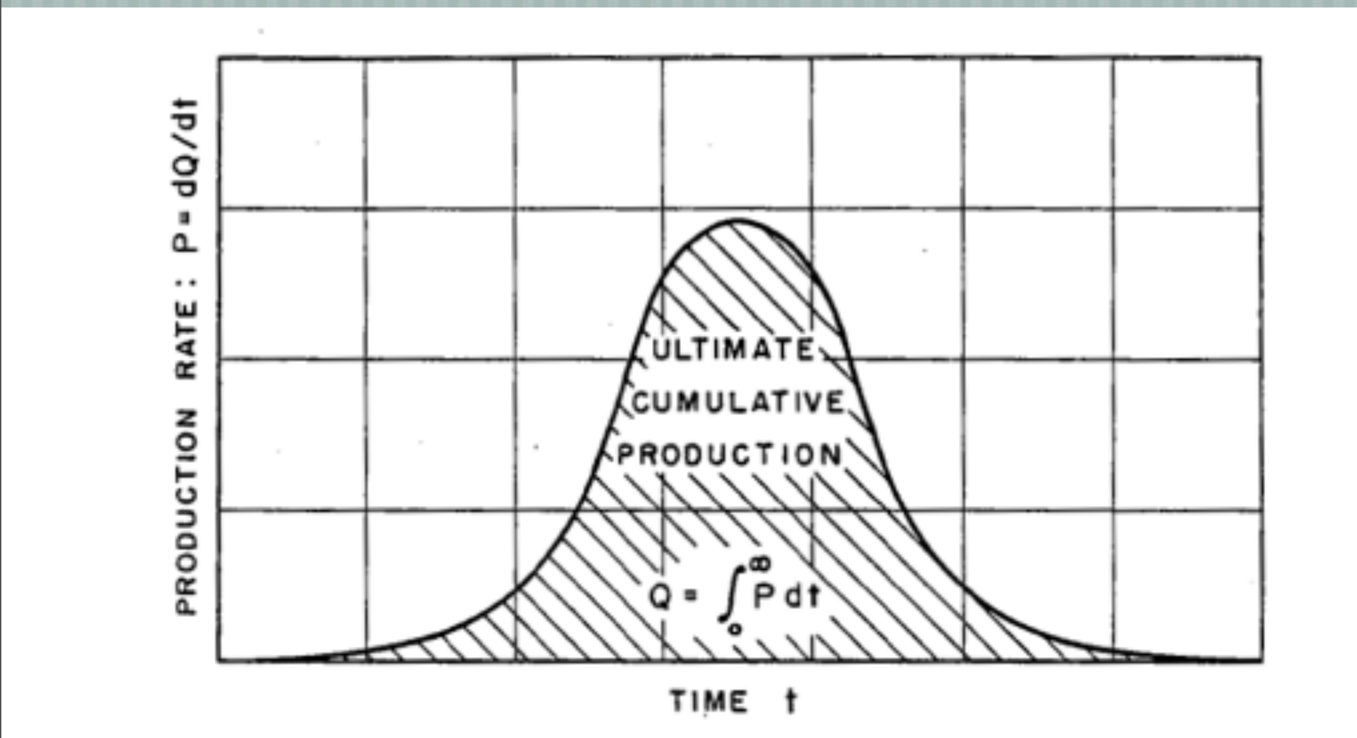
P = production rate

Example a single well may produce 1 Million barrels per day in 1975 changing to .95 in 1976,.... and .75 in 2011.

We will then say that P(t)= 1,.95,..., .75

Actual number

P ~ 5.7 Million barrels per day 2003 (USA) ~9 MB/day Saudi: ~70 MB/day world



For any finite resource we may define

Q(t) is the quantity of the produce upto time "t".

$$Q_\infty = Q(t);\ t \to \infty$$

This represents the grand total of the produce.

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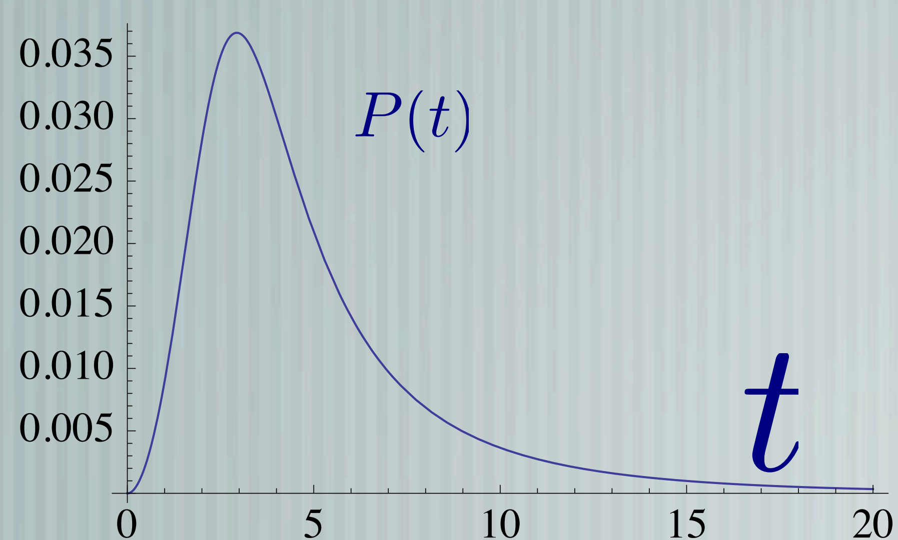

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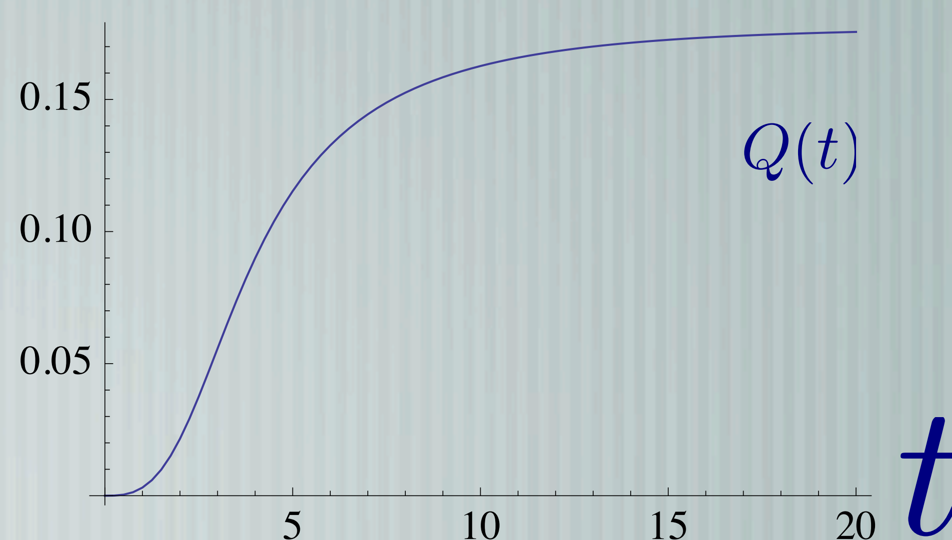


M King Hubbert and FF reserves

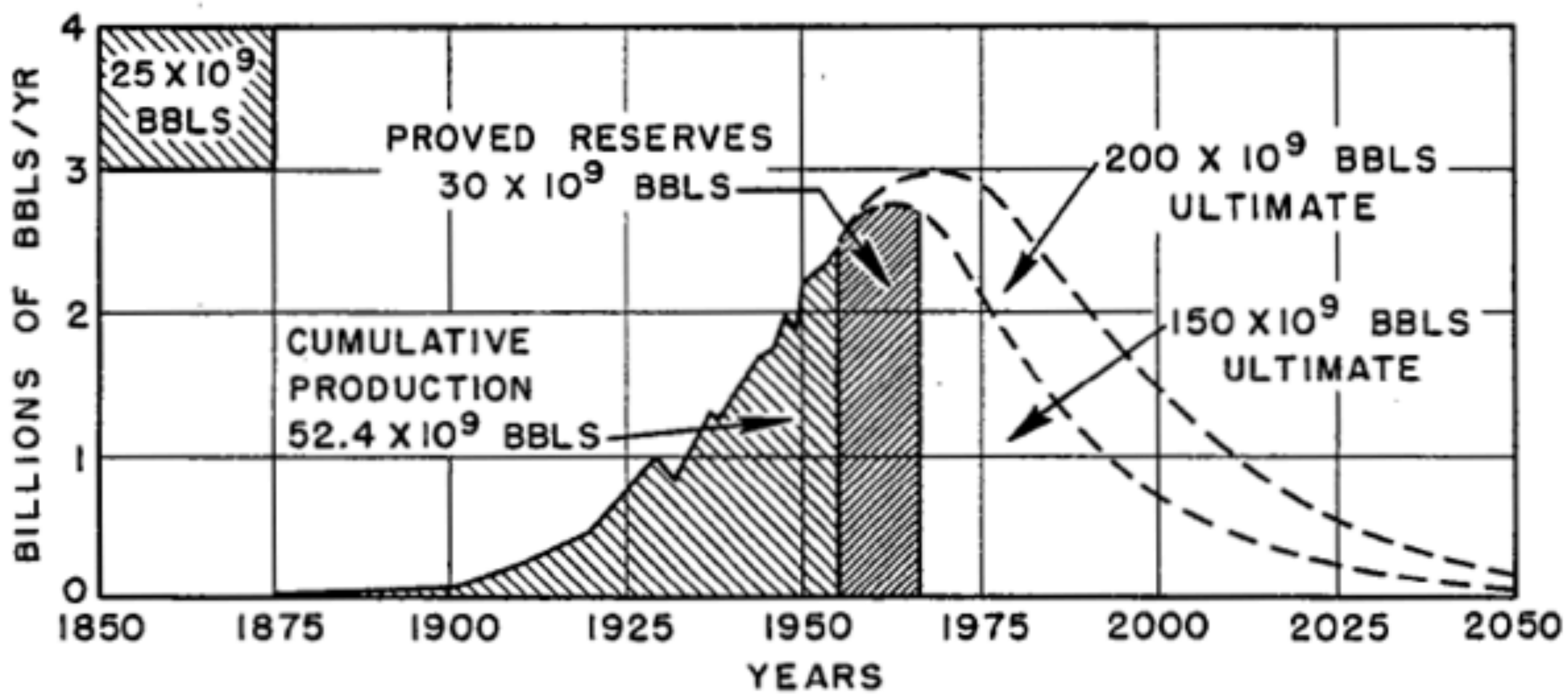


Figure 21 – Ultimate United States crude-oil production based on assumed initial reserves of 150 and 200 billion barrels.

Hubbert also predicted the time lag between discovery of wells and the production peak by about 11 years.

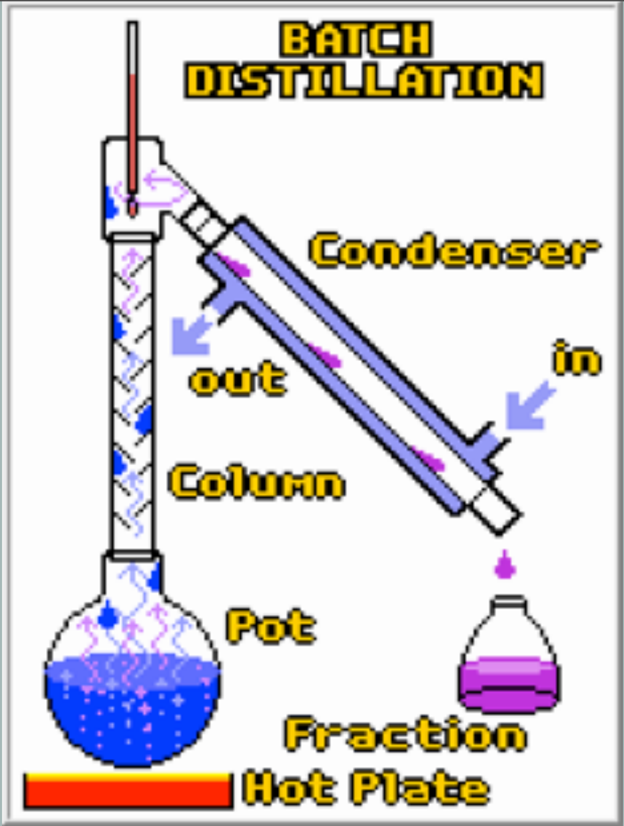
NUCLEAR ENERGY AND THE FOSSIL FUELS

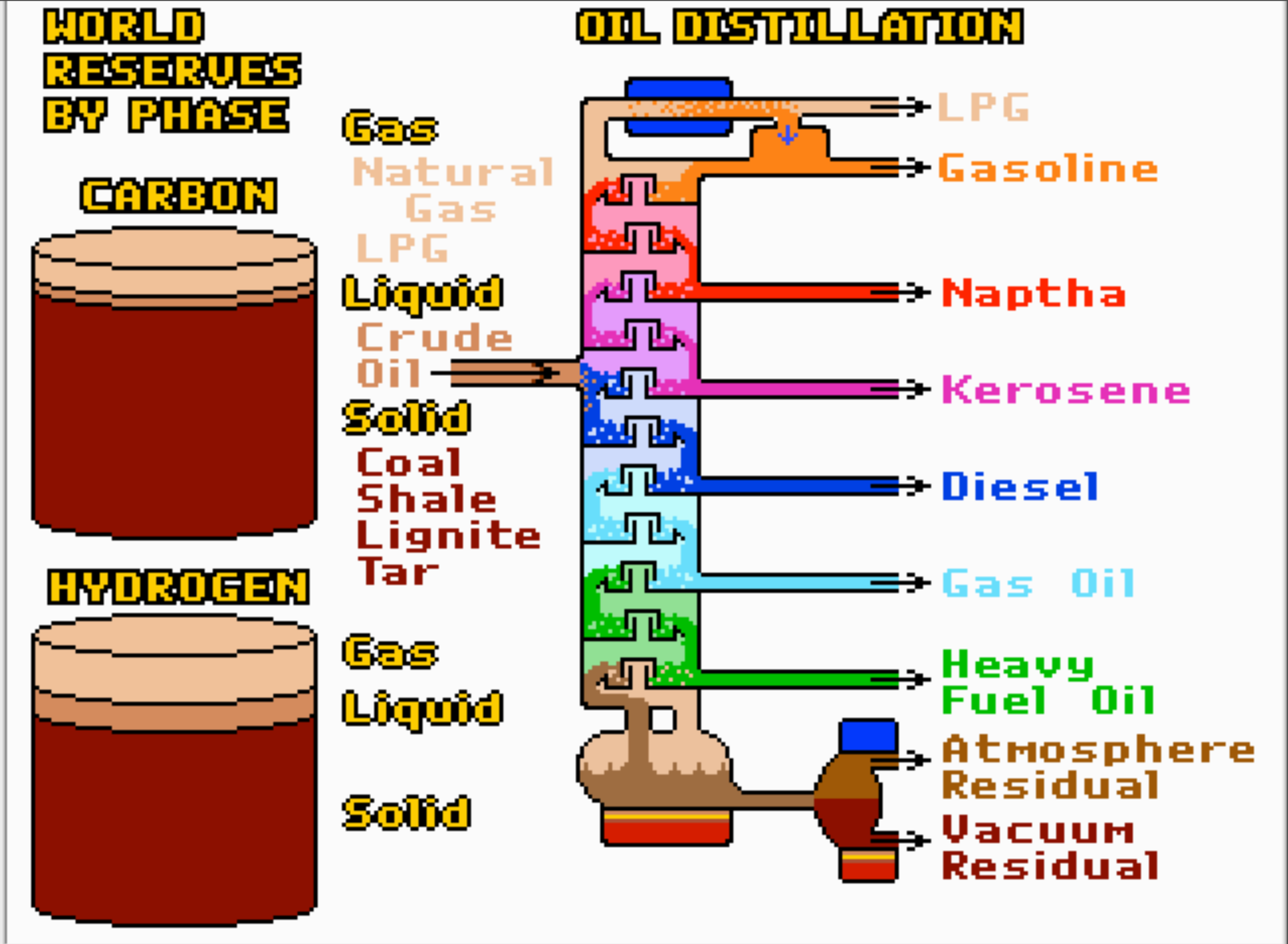
BY

M. KING HUBBERT

CHIEF CONSULTANT (GENERAL GEOLOGY)

Presented before the
Spring Meeting of the Southern District
Division of Production
American Petroleum Institute
Plaza Hotel, San Antonio, Texas
March 7-8-9, 1956





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.

Natural gas

- 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

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

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

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

Gasoline	1 Gallon	1.25×10^5 Btu
Natural gas	1000ft3	1.035×10^6 Btu
Electricity	1kWh	3413 Btu

For electrical consumption we assume 100% efficiency

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:

"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

$$164\ W/m^2\ (24\ hour\ day)$$

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

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

Total energy supplied to USA per year by the Sun

Insolation x number of days per year x total area

1520 Btu/ ft2 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% !!!!

Sun is at 5800° 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.

Problem:

You are going to visit a friend and pack a 25 lb suitcase. How many kilograms is that? What is the force, in Newtons, required to pick it up? Your friend lives on the 3rd floor of an apartment building. When you arrive you must carry your suitcase up 2 flights of stairs, each with a vertical distance of 10 ft. How much work is done against gravity, in joules, during this process? If it takes you 2.5 minutes, how much horse power was that?

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Concepts tested here:

- Relationship between lbs and kgs (look up table)
- Relationship between force and weight or mass (F= MxA)
- Relationship between work done and force (W= FxL)
- Relationship between power and work done (P = W/t)
- Finally we need to convert Watts into horsepower- again look up table.
- General Rule: as far as possible calculate in MKS units, these are clearer in many ways.

Finally convert to whatever units are needed.