Energy 101: Fossil Fuels

or how anaerobic decomposition of buried dead organisms changed the world

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Agenda

- What's new in the world of energy?
- Open Questions

- Coal Basics
- Fossil Fuels
- Externalities

Not from the Greeks!

Coal (from the Old English term *col*, "mineral of fossilized carbon")

Gas (from Flemish: *Chaos* where the *g* in Dutch being pronounced like the English *ch* – In Ancient Greek, *chaos* meant "ultra-rarefied water)

- Petroleum (from Latin: 'petra' (rock) + Latin: *oleum* (oil)

Oil (Latin: *oleum*, Greek "ἔλαιον" (*elaion*), "olive oil“)

Up to 650 million years to create…

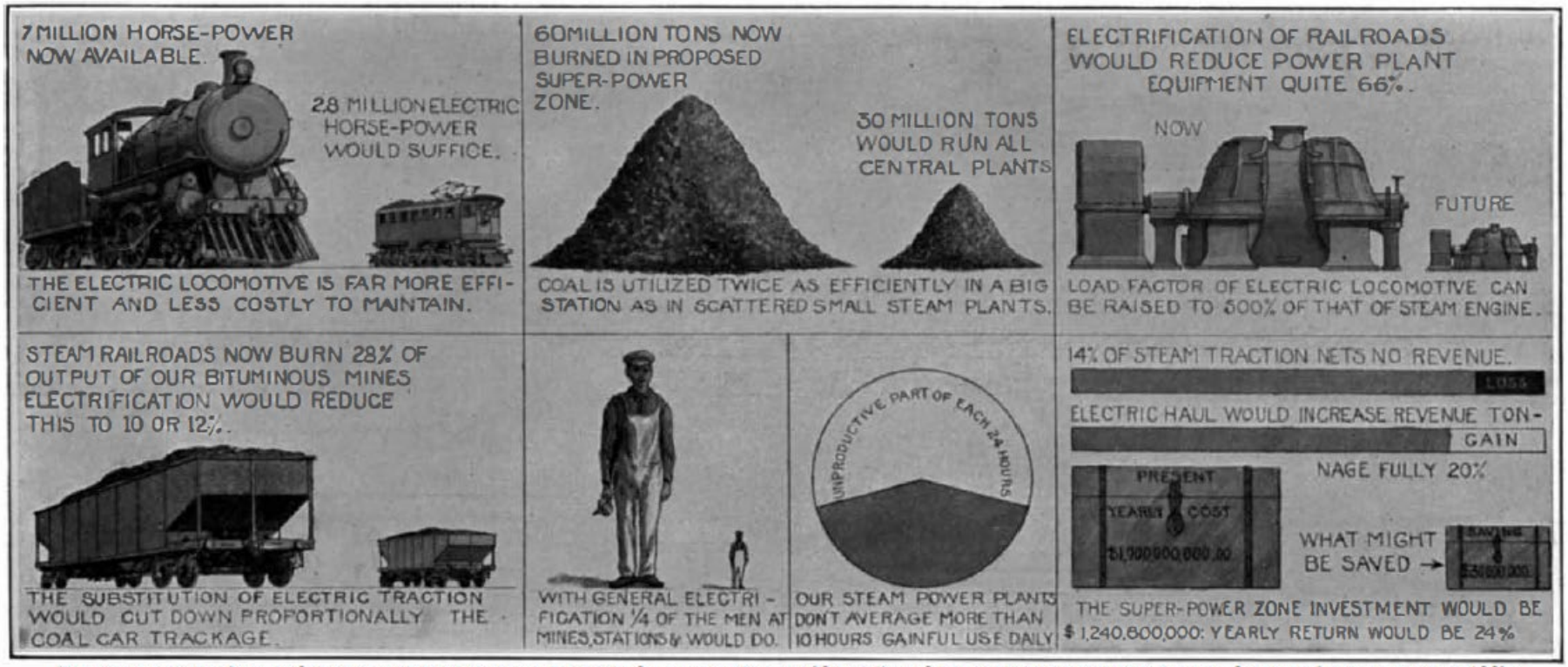
- Combustible, sedimentary, organic rock

- Remains of prehistoric vegetation that accumulated in swamps / peat bogs and then buried and altered over millions of years by pressure and heat

- Formation began 360 to 290 million years ago (Carboniferous Period)

…and a day to consume

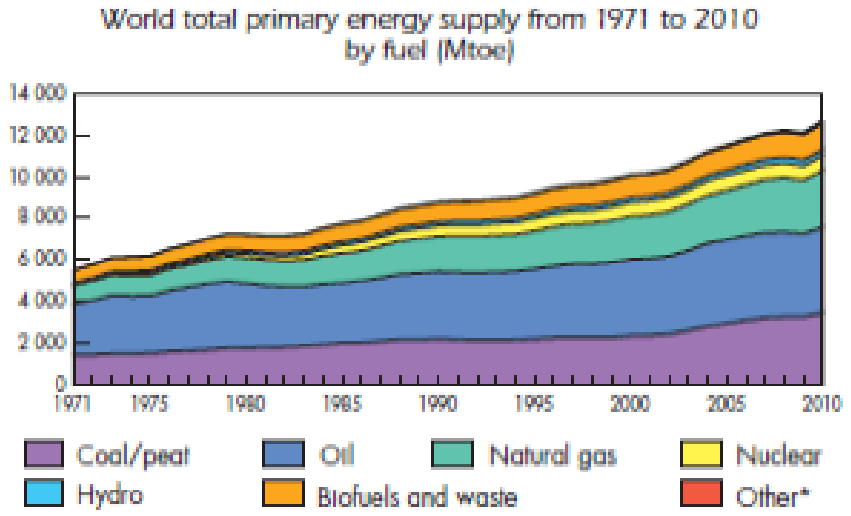
- Coal – 21,000,000 tons per day
- Gas – 10,000,000,000 cubic meters per day
- Petroleum – 87,000,000 barrels per day

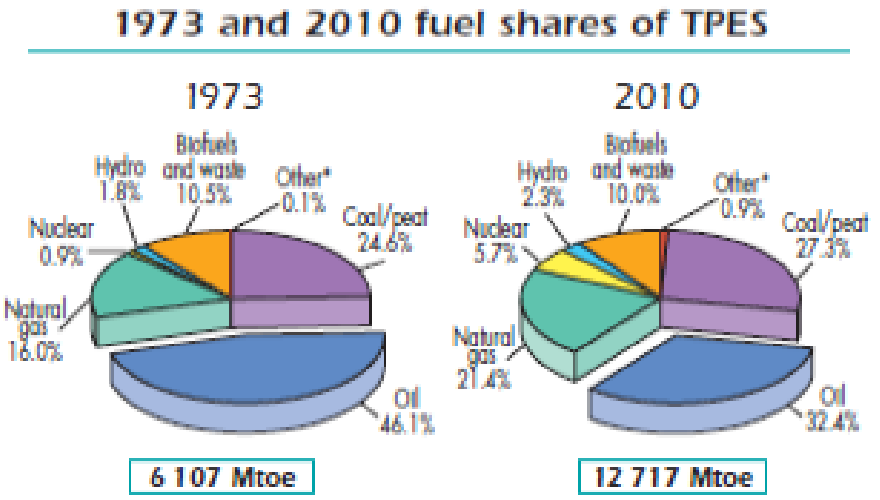


Some comparative facts and figures which go to prove the marked economy that would be effected by gathering the various scattered power plants along the middle Atlantic seaboard into one big operating group, as outlined in the accompanying article

Fossil Fuels - Background

- Coal fuelled the industrial revolution in the 18th and 19th century
- Oil became the dominant fuel in the 20th century
- Fossil fuel contribution to world primary energy supply:
  - 87% in 1973 (5,295 Mtoe)*
  - 81% in 2010 (10,313 Mtoe)*
  - Pretty much doubled over the last ~35 to 40 years
  - Market share movement from oil to natural gas & nuclear





One *toe* (tonne of oil equivalent) equals 42GJ or 11.6MWh

* Source: Key World Energy Statistics. IEA 2012.

Fossil Fuels – More Recently

Fossil fuels have supplied ~85% of new energy growth in the last decade

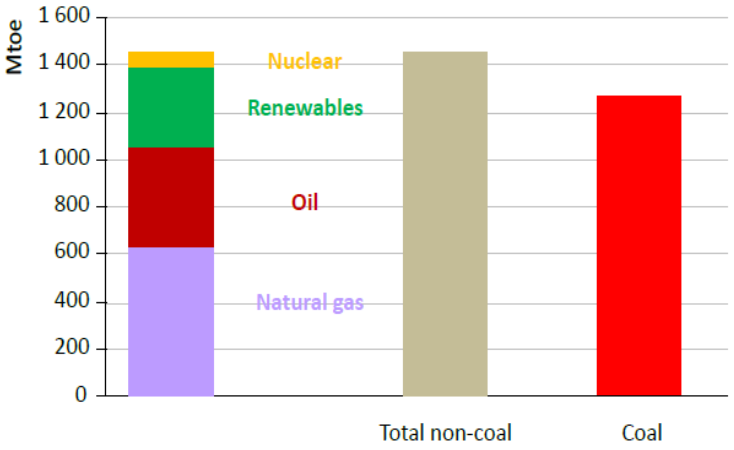
- Coal has done the lions share of the work in catering for recent growth in global energy use

- Why?

Coal won the energy race in the first decade of the 21st century

WORLD ENERGY OUTLOOK 2011

Growth in global energy demand, 2000-2010



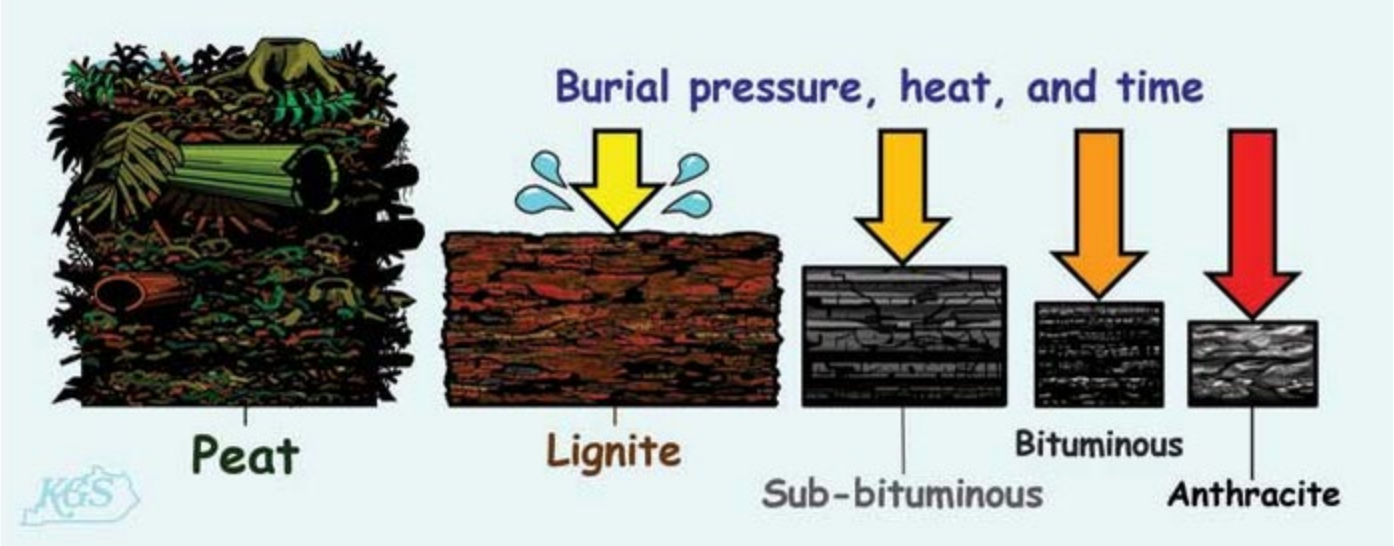
Coal accounted for nearly half of the increase in global energy use over the past decade, with the bulk of the growth coming from the power sector in emerging economies

Source: World Energy Outlook. IEA 2011.

Coal

The degree of change as coal matures from peat to anthracite is known as coalification:

- **has an important bearing on coal's physical and chemical properties (referred to as the 'rank' of the coal)**
- **also largely determines what the coal is used for**



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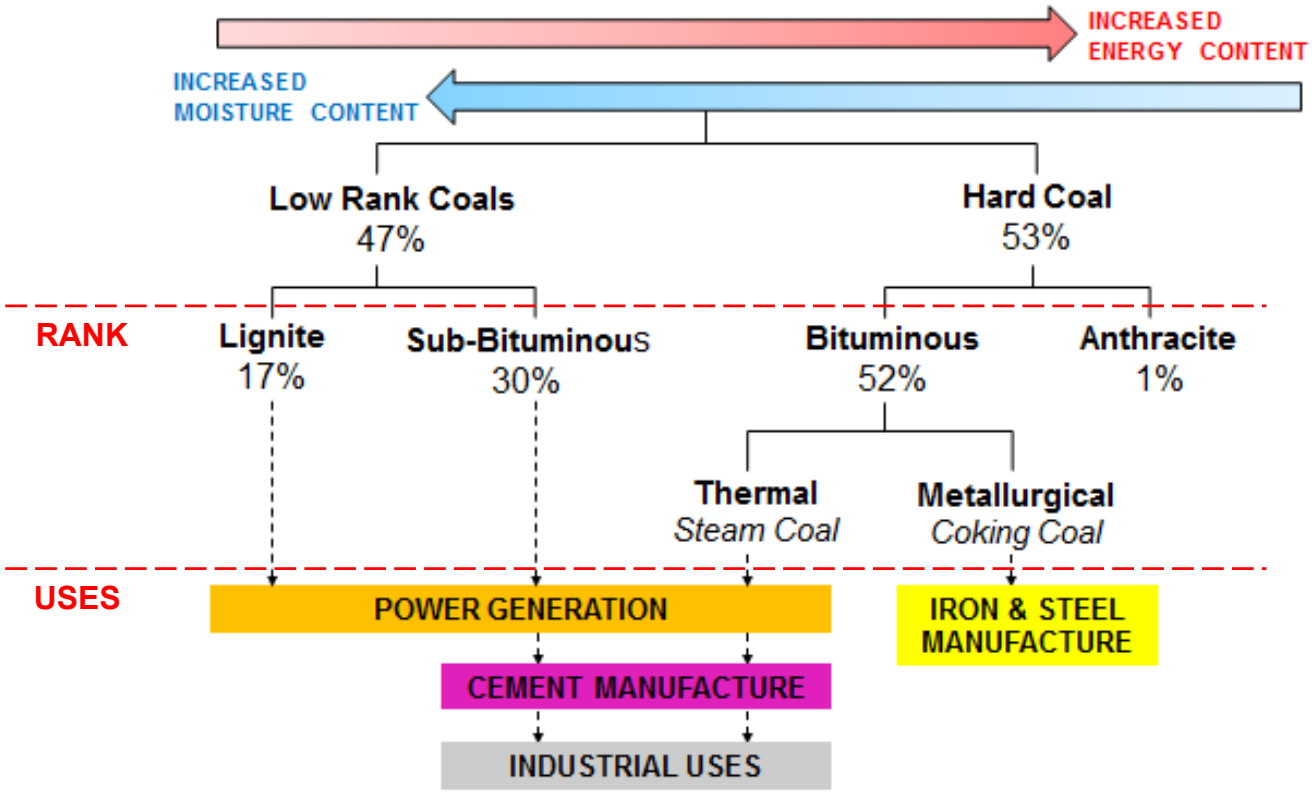


Source: World Coal Institute.

Metallurgical “Coking” Coal

- Crucial for steel production

1. 70% of global steel is produced in Basic Oxygen Furnaces (BOF)

- Coking coal is converted to coke, which is then used to smelt iron ore in a blast furnace. Molten iron is then taken to the BOF to make steel.
- ~770 kg of coal are required to produce 1 tonne of steel (~450 kg for 1 tonne of pig iron) by this method

2. 29% of steel is produced in Electric Arc Furnaces (EAF)

- 90~100% of the steel comes from recycled materials
- ~150 kg of coal are required to produce 1 tonne of steel in EAF’s

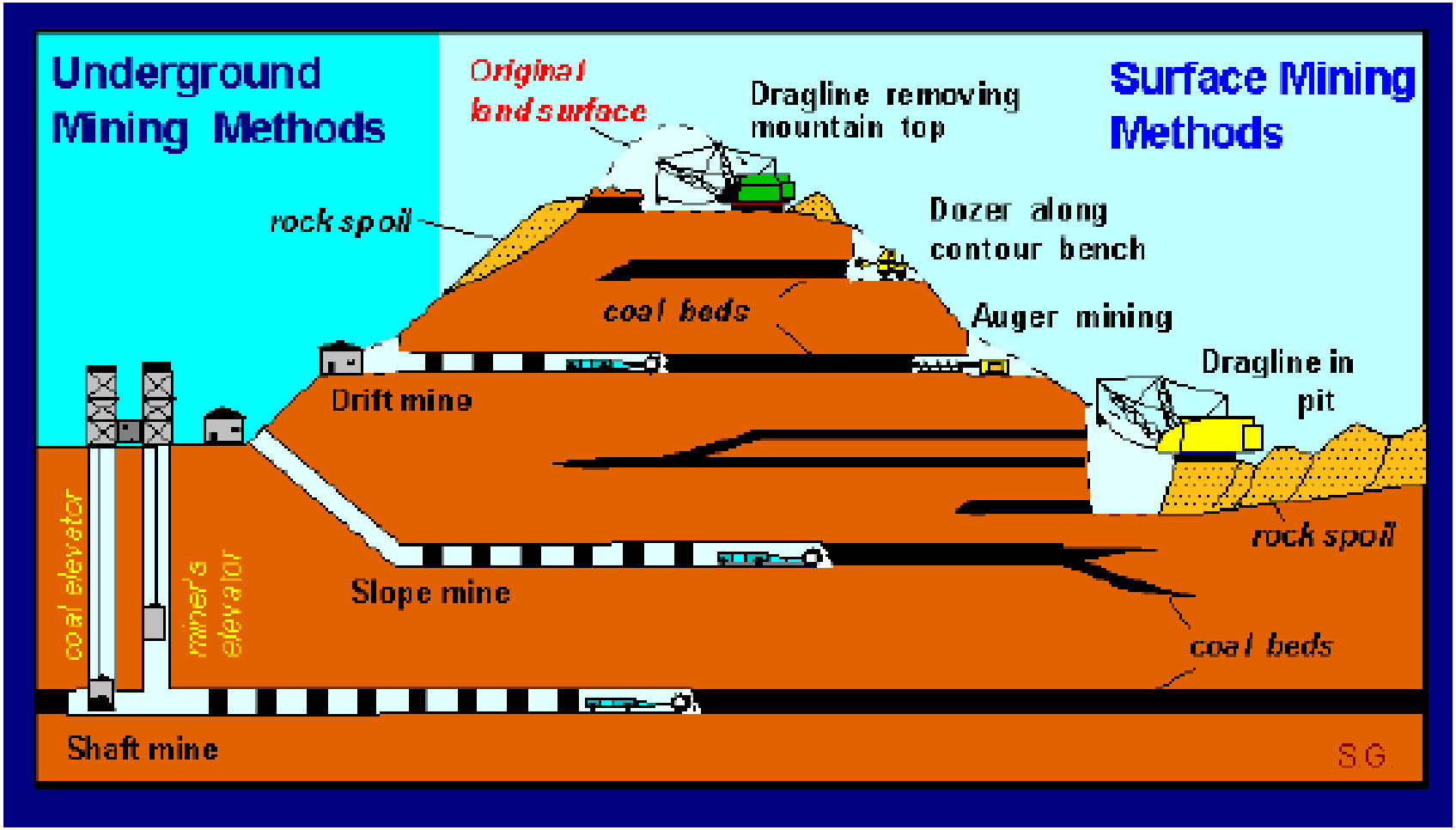
- 70% of total global steel production reliant directly on inputs of coal
- 760Mtpa or about 12% of total hard coal consumption

Source: World Coal Institute. World Steel Institute.

Mining for Coal

- Two Mining Methods

1. Underground Mining
2. Surface Mining



Source: Kentucky University.

Surface Mining

Advantages

- Lower cost for shallow seams
- Resource recovery
- Safety
- Relatively simple
- Productivity

Disadvantages

- Environmental (noise, dust, water)
- Visual disturbance
- Cost prohibitive where seams are too deep

Underground Mining

Advantages

- Significantly smaller surface footprint
- Environmental (reduced dust, noise)
- Resource recovery (at depth)

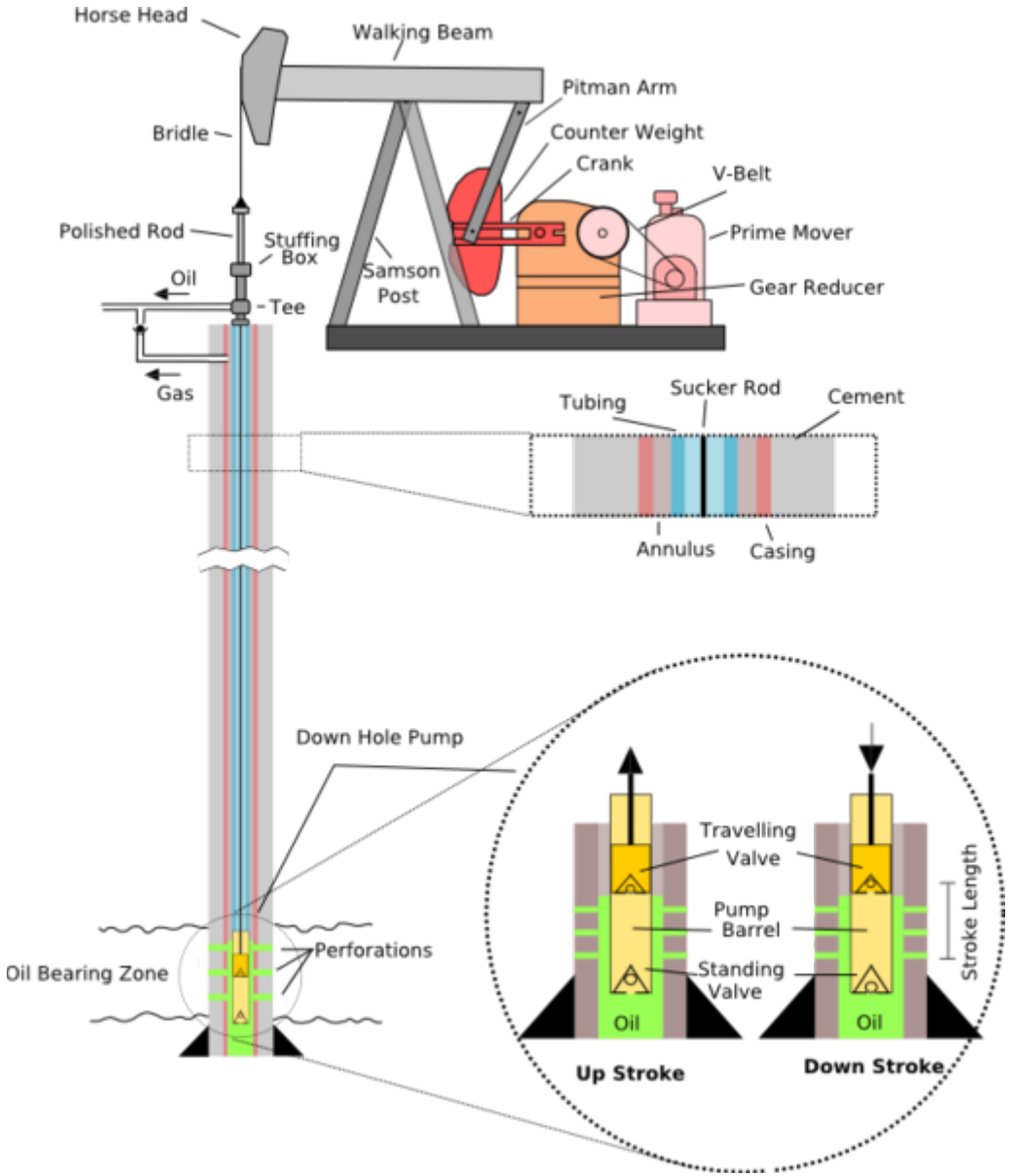
Disadvantages

- Resource recovery (unable to extract all the coal)
- Safety and risk
- Technical issues (gas, ventilation, spontaneous combustion, roof falls)
- Often more capital intensive and greater time to develop a new asset

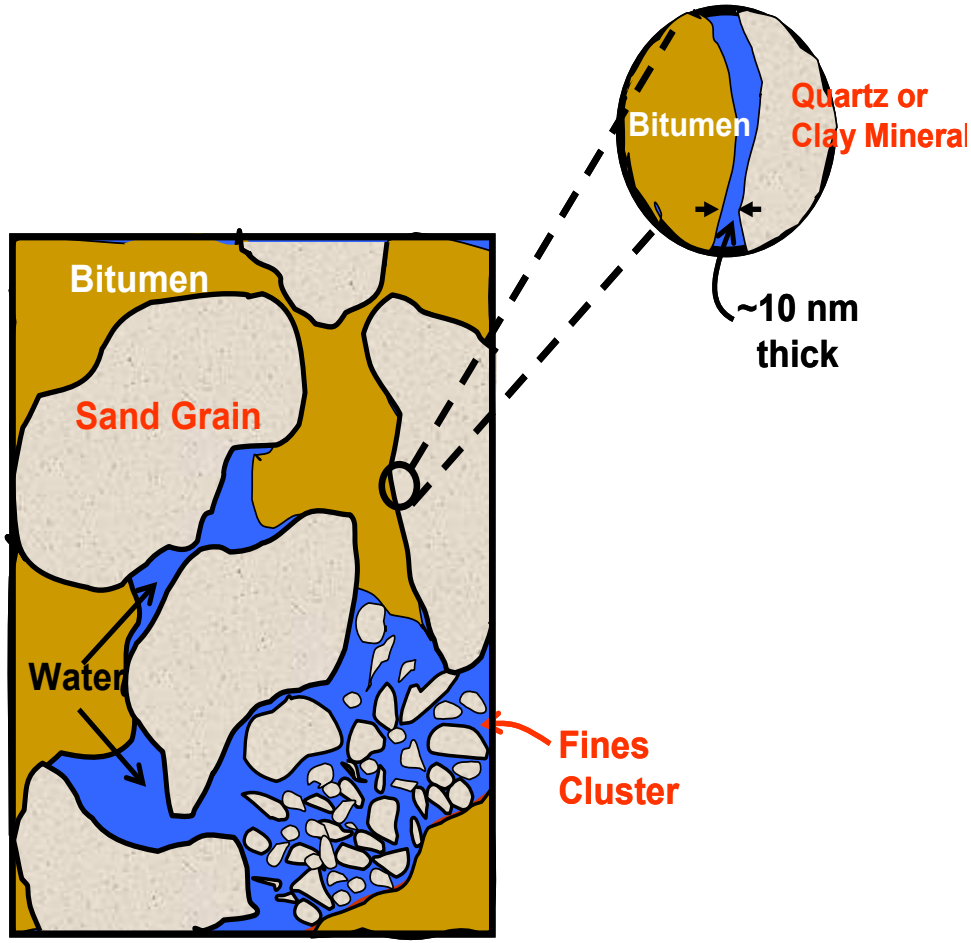
Continuous miner mining an underground roadway

Installing rock bolts in the roof

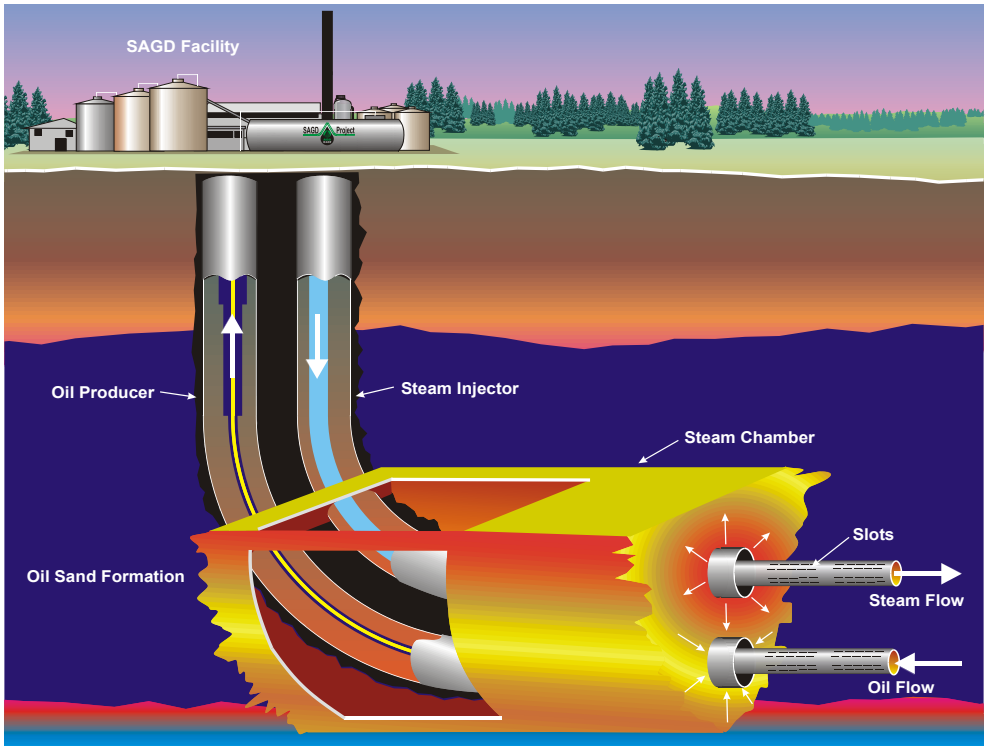
Crude Oil Extraction

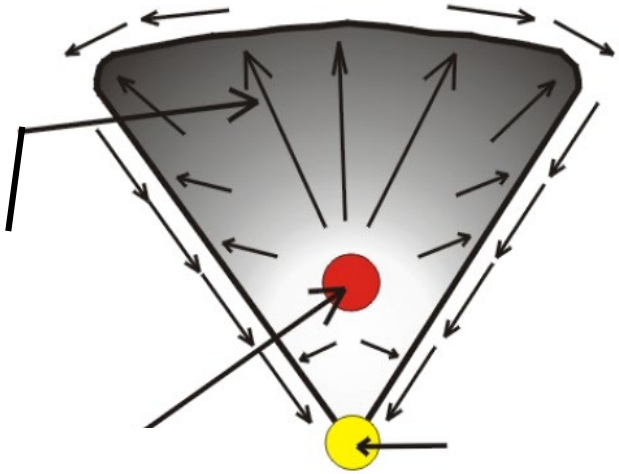


Mining Operations in Shallow Athabasca Deposit



Steam Assisted Gravity Drainage (SAGD) - Schematic for Oil Sands

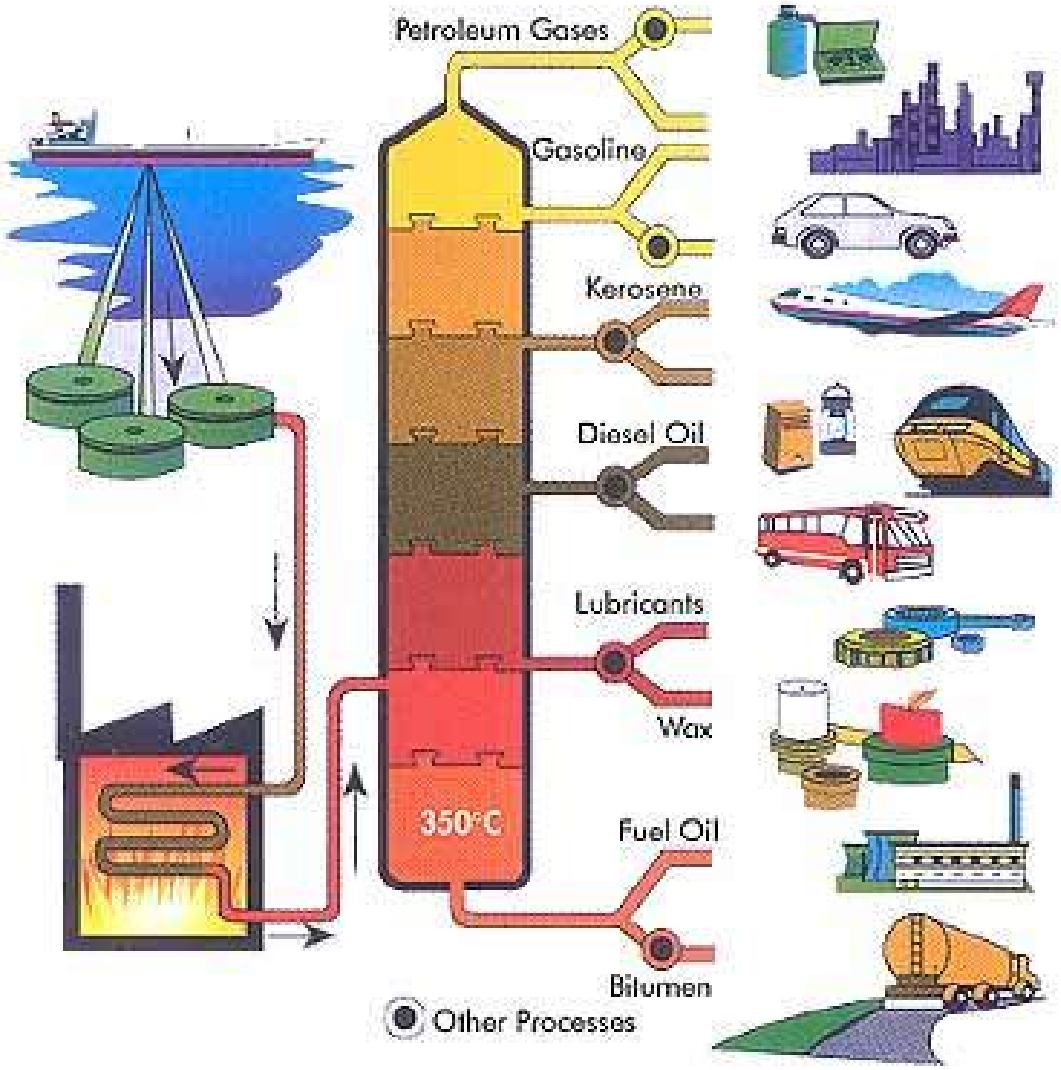




Recovery Mechanisms

- ***Initialization Phase:*** heating between wells, counter-current flow
- ***Growth Phase:*** gravity drainage of hot oil and condensed water

Crude Oil also has different uses



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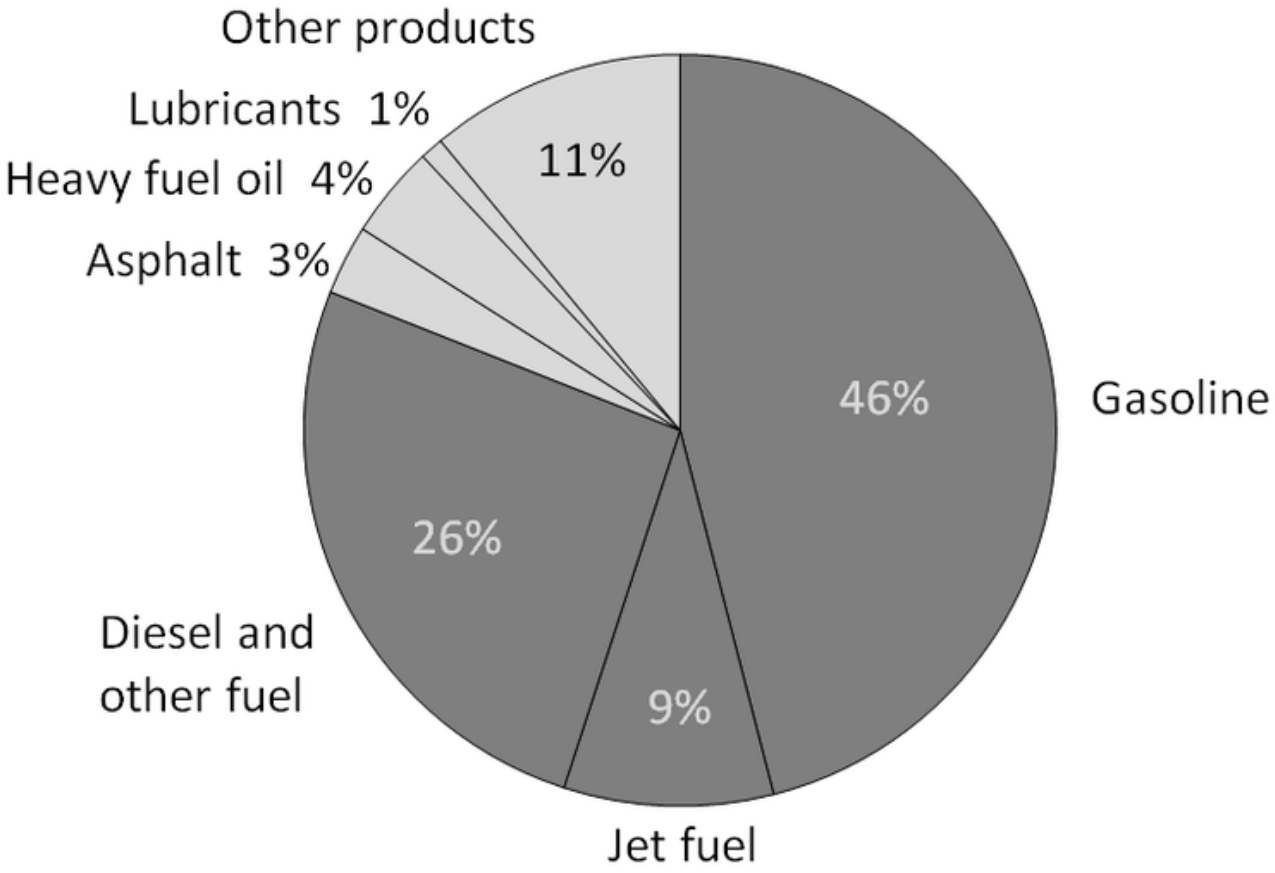
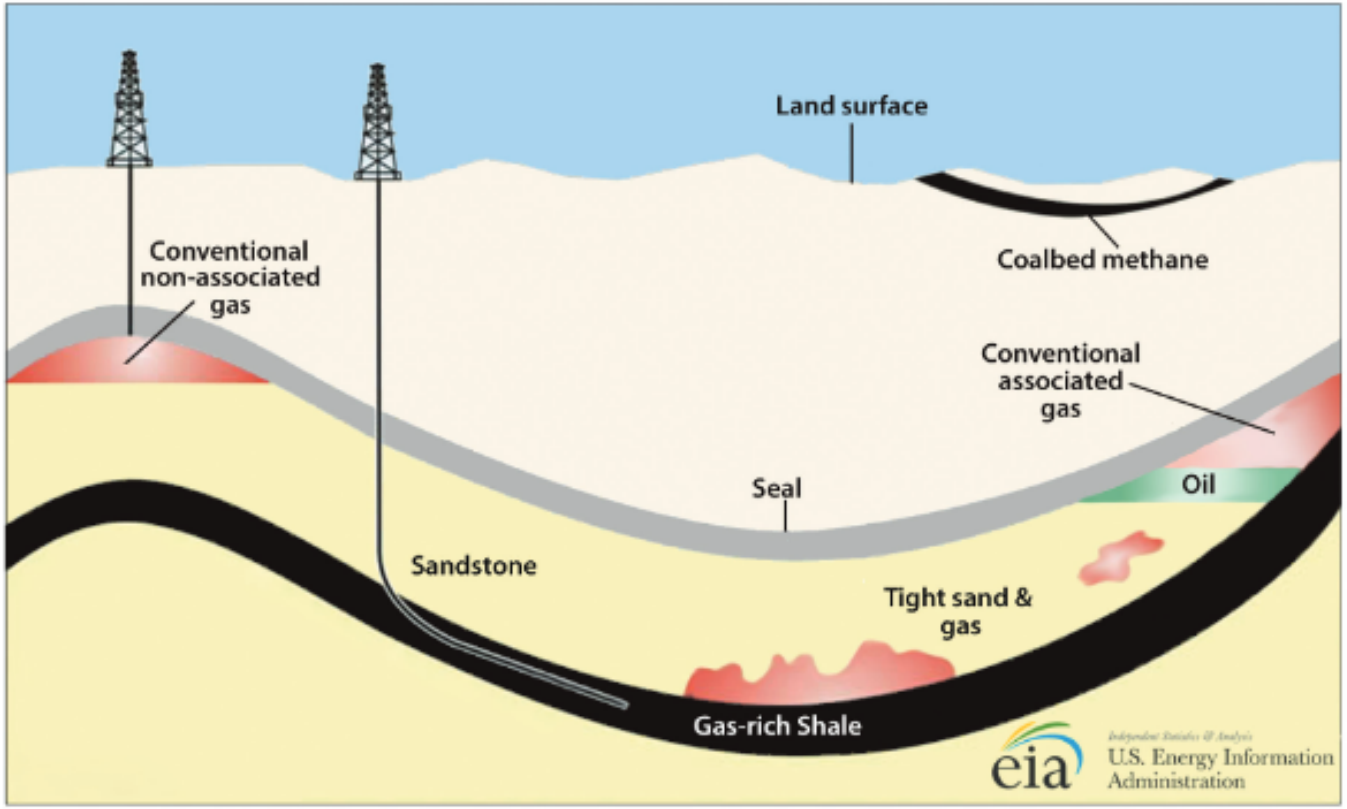


Natural Gas

FIGURE 2: Geological Formations Bearing Natural Gas



Source: Energy Information Agency, "Schematic Geology of Natural Gas Resources," January 2010. Available at: http://www.eia.gov/oil_gas/natural_gas/special/ngresources/ngresources.html

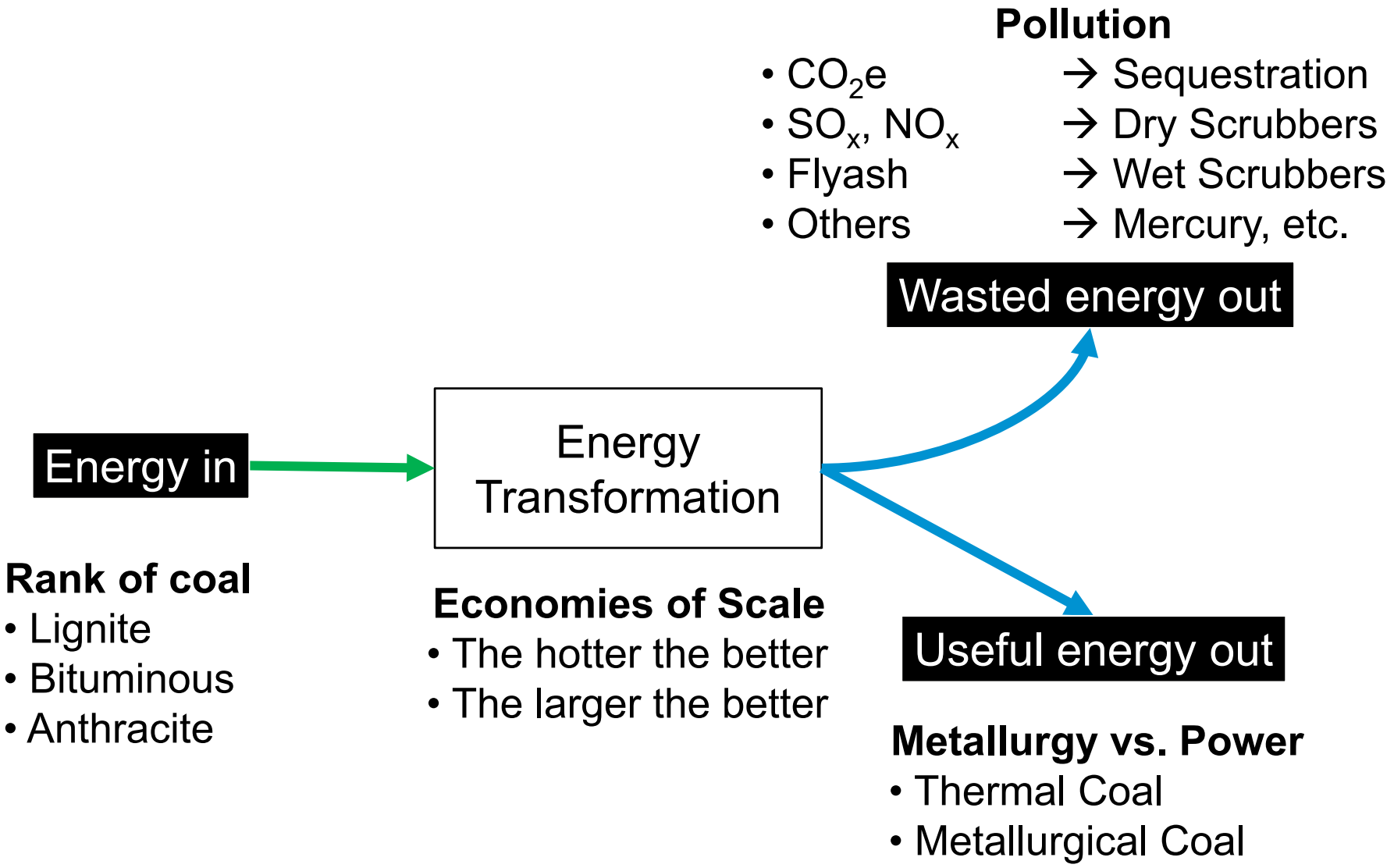
Notes: Gas-rich shale is the source rock for many natural gas resources, but, until now, has not been a focus for production. Horizontal drilling and hydraulic fracturing have made shale gas an economically viable alternative to conventional gas resources.

Conventional gas accumulations occur when gas migrates from gas rich shale into an overlying sandstone formation, and then becomes trapped by an overlying impermeable formation, called the seal. Associated gas accumulates in conjunction with oil, while non-associated gas does not accumulate with oil.

Break

- http://www.youtube.com/watch?v=HI0x0KYChq4

The Energy Equation



Emissions of fossil fuels

- What is CO_2e ? A normalized metric on Global Warming Potential

?

CO_2 is defined as 1 for any timescale

Atmospheric lifetime and GWP relative to CO_2 at different time horizon for various greenhouse gases.

Gas name	Chemical formula	Lifetime (years)	Global warming potential (GWP) for given time horizon		
			20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See above	1	1	1
Methane	CH_4	12	72	25	7.6
Nitrous oxide	N_2O	114	289	298	153
CFC-12	CCl_2F_2	100	11 000	10 900	5 200
HCFC-22	$CHClF_2$	12	5 160	1 810	549
Tetrafluoromethane	CF_4	50 000	5 210	7 390	11 200
Hexafluoroethane	C_2F_6	10 000	8 630	12 200	18 200
Sulfur hexafluoride	SF_6	3 200	16 300	22 800	32 600
Nitrogen trifluoride	NF_3	740	12 300	17 200	20 700

Other pollutants as well!

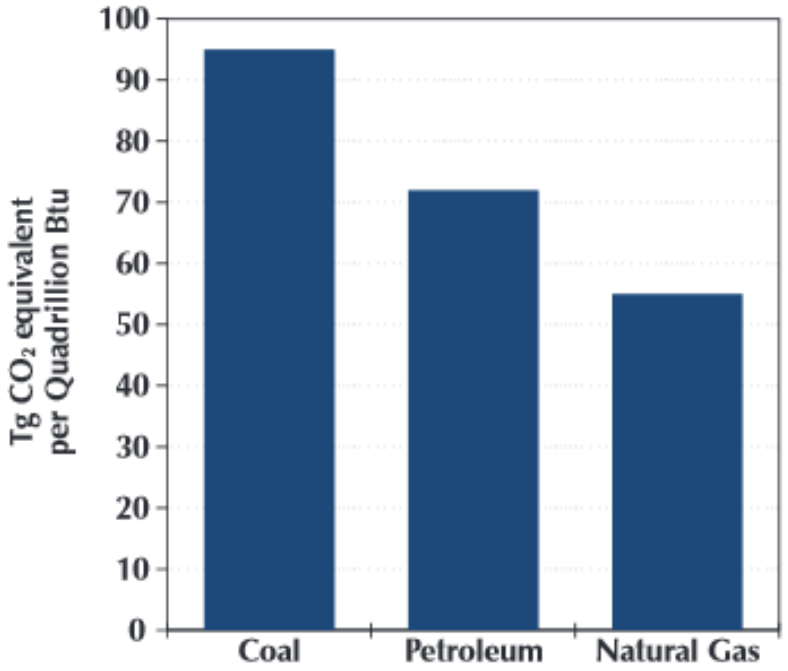
TABLE 1: Average Fossil Fuel Power Plant Emission Rates (pounds per Megawatt Hour)

GENERATION FUEL TYPE	CO_2 LB/MWH	SULFUR DIOXIDE LB/MWH	NITROGEN OXIDES LB/MWH
Coal	2,249	13	6
Natural Gas	1,135	0.1	1.7
Oil	1,672	12	4

Source: Environmental Protection Agency, "Clean Energy—Air Emissions," 2012. Available at: http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html

Emissions of fossil fuels

FIGURE 1: CO_2 Emissions from Fossil Fuel Combustion



Source: Environmental Protection Agency, Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011. 2013. Chapter 3 and Annex 2. Available at: http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

Fuel Switching to Gas – "the challenge"

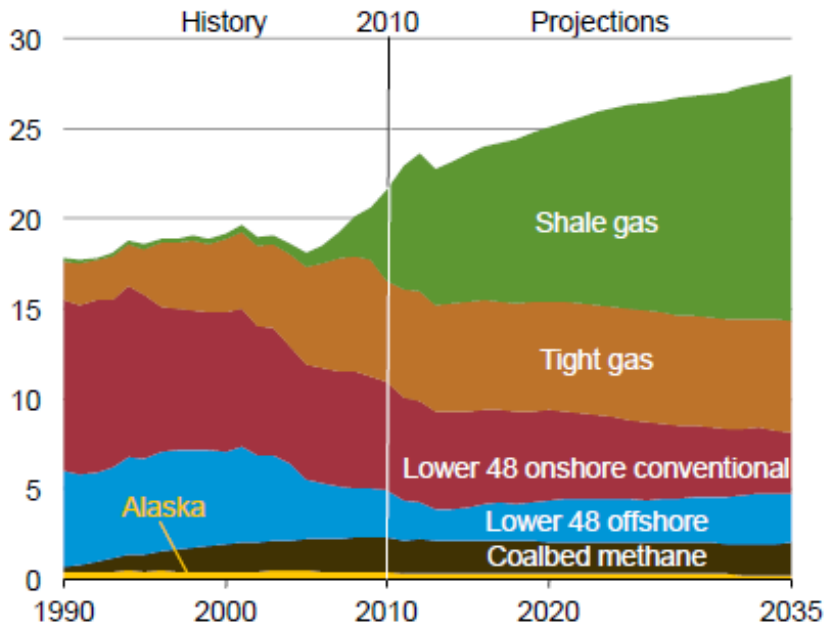
Growth almost all in shale gas which will require:

As with tight oil, there are unresolved uncertainties surrounding the technological advances that have made shale gas production a reality.

Possible environmental, health and safety risks.

Shale gas provides largest source of growth in U.S. natural gas supply

Figure 107. Natural gas production by source, 1990-2035 (trillion cubic feet)



Source: US Energy Information Administration

Clean Coal

- Why isn't it called "cleaner coal technologies"? Coal is not clean, nor will it ever be. But, new technological processes that clean it can make it "better". Is "better" okay? - Heather

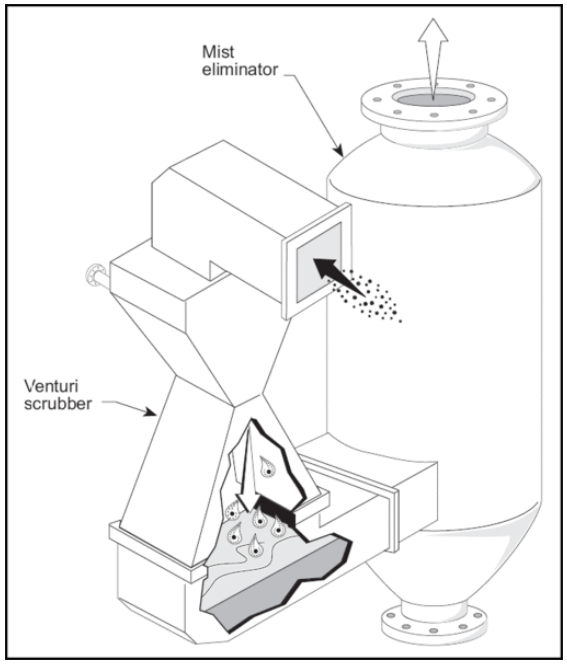
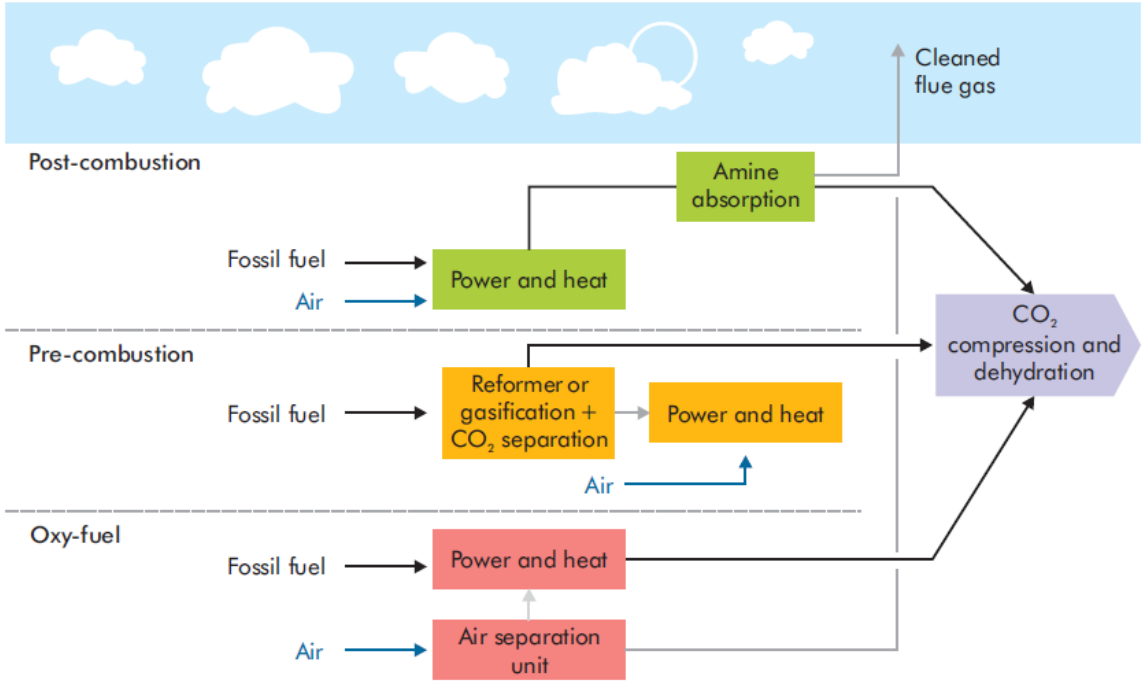


Figure 10. Overview of main technology options for CO_2 capture from power plants



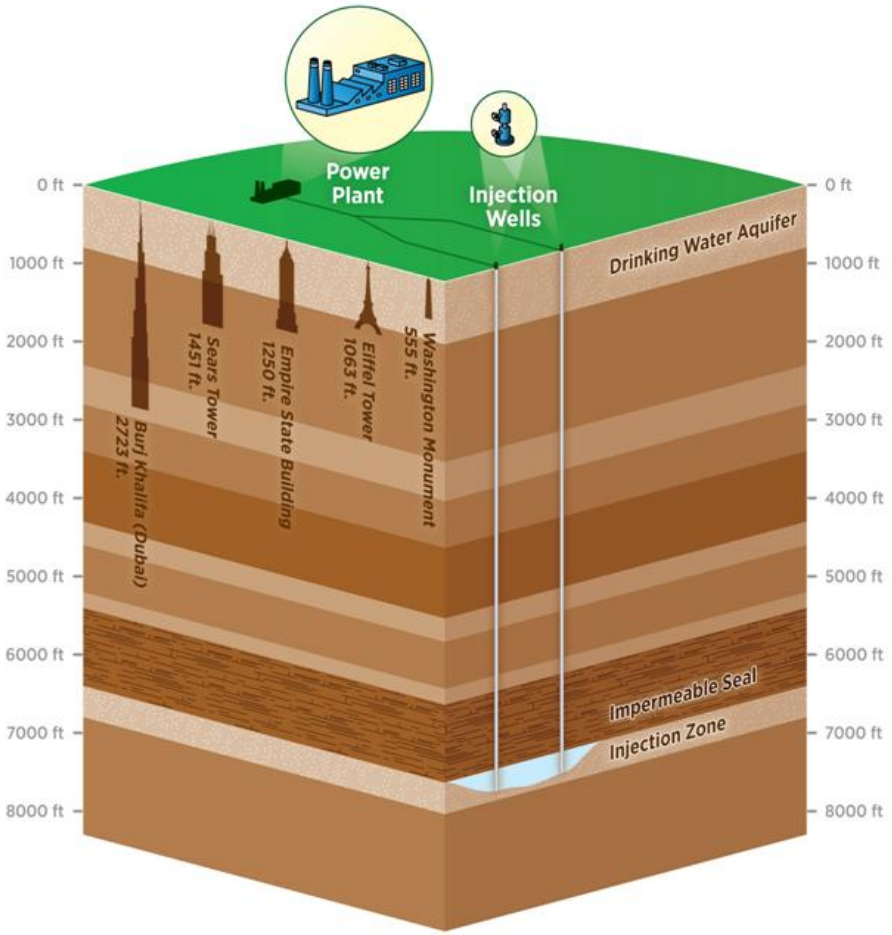
Source: ZEP, 2006.

http://en.wikipedia.org/wiki/Wet_scrubber

Clean Coal Technologies IEA **Accelerating Commercial and Policy Drivers for Deployment**

Carbon Sequestration

- Risks:
- Unknown lifespan
- Needs to be *forever*
- Decreases efficiency of power plant



Discussion Activity

•Use of coal is forecast to remain a dominant primary energy fuel source over the next 25 years (both globally and in the USA).

•Assuming you had budgetary control of a coal company, how would you prioritize the following factors?

- Changing fuel type? (Energy In)
- Improving conversion efficiency? (Transformation)
- Reducing pollution and waste? (Waste)
- Improving consumption efficiency? (Useful)