

Carbon and Bioenergy Feedstocks

Lecture 3 – Fossil Fuels

<http://aleklett.wordpress.com/2013/08/01/the-economist-oil-is-yesterdays-fuel/>

Week 2 – Carbon and Bioenergy Feedstocks

-Learning Objectives-

- ▶ List the major carbon resources on earth and describe both strengths and weaknesses of each in terms of availability, cost, uses, and sustainability.
- ▶ Explain the realities of the food vs. fuel argument and the environmental costs of biomass feedstocks.

In a world restricted by energy, but unrestricted by chemistry, what carbon resource do you start with?

- ▶ Oil made organic chemistry a part of our everyday lives
- ▶ We are quite capable of using any carbon source to support all organic chemistries
- ▶ If no carbon source is inherently bad, how do you choose?



Start with the Facts!

Common Types of Fossil Fuels

- ▶ **Petroleum (oil)**
 - ▶ Sweet light crude
 - ▶ WTI, Brent, Russian Export, OPEC
 - ▶ Heavy crude (bitumen)
- ▶ **Coal**
 - ▶ Anthracite
 - ▶ Bituminous
 - ▶ Sub-bituminous
 - ▶ Lignite
 - ▶ Peat
- ▶ **Natural Gas**
 - ▶ Wet gas & Dry gas
 - ▶ LNG (liquefied natural gas)
 - ▶ NGL (natural gas liquids)

I will not have time to go over all of these, but if you are interested in fossil fuels, you should Google anything you don't know. There are many different types of petroleum, but most can be categorized as one of the three mentioned above. Likewise, there are four major types of coal and peat from which many coals form. Natural gas really only comes in two types (wet and dry), but knowing the difference between LNG and an NGL's is extremely helpful given all the gas news in the media these days.

Petroleum – How is it formed?

Petroleum		
Primary - Type I Kerogen (aquatic organism oils)		
Secondary - Type II Kerogen (plant cuticles/oils)		
Requires anoxic conditions to form		
Increasing Time, Pressure & Temp ↓	Evolution	Product
	Diagenesis	Methane
	Catagenesis	Oil + Wet Gas
	Metagenesis	Methane
	Metamorphism	Methane

- ▶ Aquatic plants are the primary biological source of petroleum
- ▶ Lots of geologic opportunities for gas to form, but not so with oil

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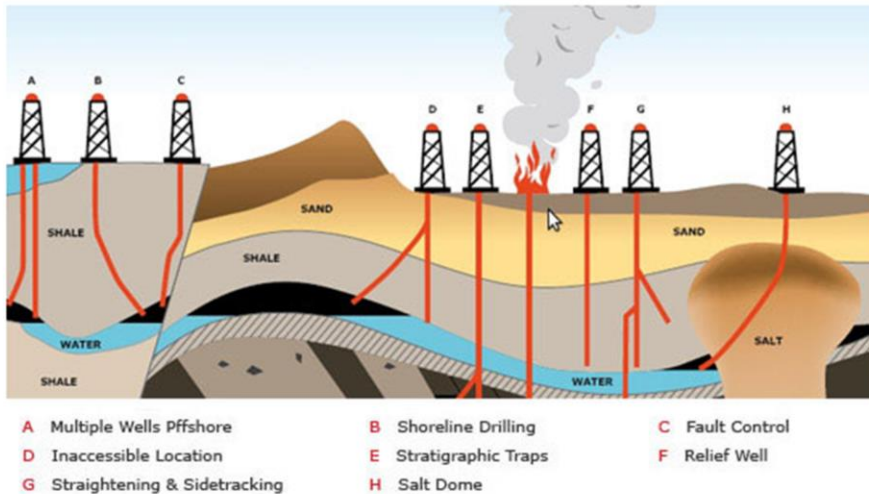
Petroleum is an oil and forms from sources rich in oil

Aquatic plants are the primary biological source of petroleum - terrestrial plants have not contributed much to the petroleum reserves we utilize today.

Aquatic plants, just like land plants, have cell walls composed of cellulose or cellulose-like molecules.

Aquatic organisms are a unique and convenient source of fatty acids – lignin is a structural chemistry that isn't needed by cells floating in water.

Petroleum – How do we drill?



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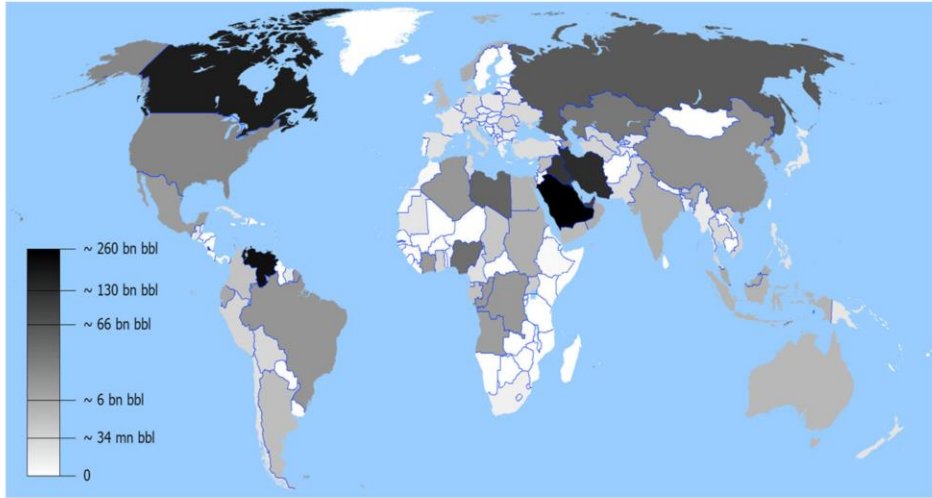
<http://drilleng-group4-directionaldrilling-1.wikispaces.com/Applications>

Driving a directional drill rig these days is like flying a spaceship through the earth. Subsurface techniques have advanced to a degree that we can use things like 4D seismic mapping to steer a drill over 7 miles deep and 7 miles horizontally over and around undrillable obstacles, eventually hitting a target area the size of a bus. The most advanced drill rig in the world is Exxon's Sakhalin 1, nicknamed Yastreb (the Hawk). That well is deeper (40,000 ft) than Everest is tall (29,000 ft) and was then steered horizontally for miles with an accuracy of up to a few feet – it is incredible.

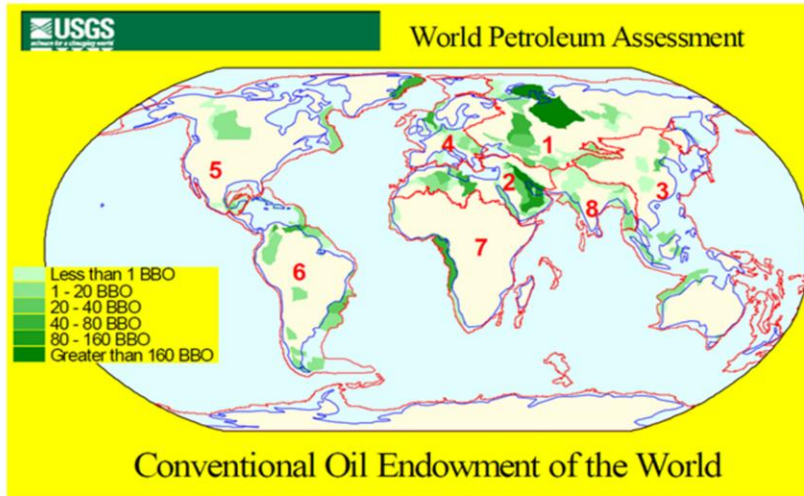
Ocean drilling rigs are equally amazing.

4D seismic mapping is a three-dimensional (3D) seismic time-lapse study that uses two or more migrated 3D seismic images obtained months or years apart.

Very Important! Earth's oil reserves will continue to produce for very long time



What we have nearly depleted is the cheap, easy oil



Coal – How is it formed?

Coal		
Primary - Type III Kerogen (plant cell walls)		
Secondary - Type IV Kerogen (plant cell walls)		
Can form under various conditions		
Increasing Time, Pressure & Temp ↓	Evolution	Product
	Lignite	Brown Coal
	Sub-Bituminous	Broan Coal
	Bituminous	Hard Coal
	Anthracite	Hard Coal

- ▶ Land plants are the primary biological source of coal
- ▶ Neither coal or oil are formed at the same rates anymore (fungus & oceans)

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Coal is a product of pyrolysis and forms from plant matter composed of sugars and aromatics.

Once fungus evolved to degrade cell walls, earth's production of coal started taking a major dip. Likewise, earth no longer has an abundance of warm shallow seas, so the level of algae and plankton produced is nowhere near what it was back when the ingredients for making petroleum were being consolidated. We need to cherish these resources because they will get harder and harder to obtain.

Land plants are the primary biological source of coal – cells and aquatic plants have not contributed much to the coal reserves we utilize today.

Land plants have cell walls composed of cellulose or cellulose-like molecules.

Coal – How is it mined?

- ▶ Very dependent on where it is mined
- ▶ Uses largest bulldozers, dump trucks, and cranes on earth



When oil gets too expensive we will probably move onto coal



We are currently wasteful with our coal because it is so cheap and plentiful compared to oil. Almost no petroleum is burned for electricity anymore, even though it used to be common. Why? Considered from a carbon mineral perspective; coal is very undervalued and will almost certainly be tapped as a resource for the production of carbon materials in the future. For now it is primarily valued for its carbon content and thus energy content, but as oil gets expensive this will probably change. Humanity's addiction to carbon energy may someday wane, but our addiction to carbon will never end, there's simply no other element like it at Earth conditions.

Common Types of Fossil Fuels

- ▶ **Petroleum (oil)**

- ▶ Availability
- ▶ Cost
- ▶ Uses
- ▶ Sustainability

- ▶ **Coal**

- ▶ Availability
- ▶ Cost
- ▶ Uses
- ▶ Sustainability

- ▶ **Natural Gas**

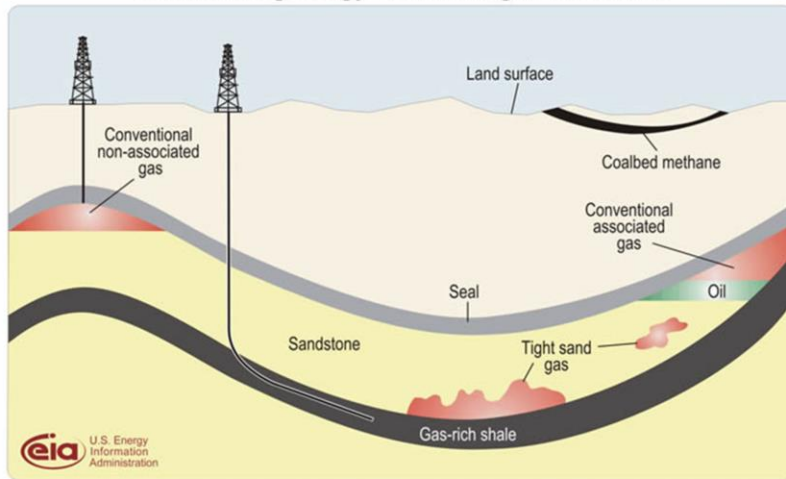
- ▶ Availability
- ▶ Cost
- ▶ Uses
- ▶ Sustainability

I am missing one last MAJOR carbon reserve. Can anyone tell me what it is?

It is CO₂. Humans output about 30 gigatons of CO₂ a year and the oceans probably contain on the order of 400 gigatons – this is rapidly becoming a more interesting source of carbon.

Natural Gas – How is it produced?

Schematic geology of natural gas resources



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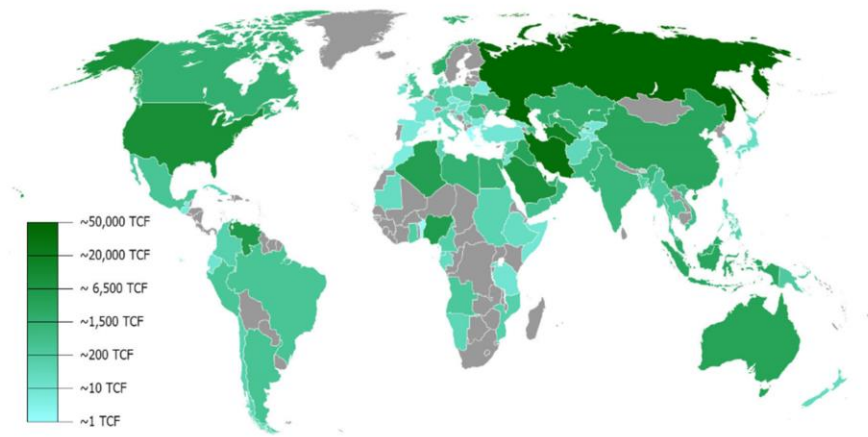
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The DOE and George Mitchell get a lot of credit for the current gas boom.

<http://www.agrfieldservices.com/investment-in-fracking-research-produced-natural-gas-surplus/> - "Geologists had always known that shale contained gas, but it was not widely pursued until 1975, when the Department of Energy (DOE) provided funding for experimentation. Early attempts resulted in explosions and other mishaps, and it took decades to perfect the process. Congress endorsed a tax incentive in 1980 specifically to encourage unconventional natural gas drilling. The Breakthrough Institute, a nonprofit that supports new thinking about energy and the environment, says that the DOE has invested \$137 million in gas research over three decades, and that the federal tax credit for drillers amounted to \$10 billion between 1980 and 2002."

<http://www.forbes.com/sites/lorensteffy/2013/10/31/how-much-did-the-feds-really-help-with-fracking/> - "Fracking technology has existed for more than a century, and the first commercial fracking job was done in 1947. His comment that, "the DOE started it," refers to the Eastern Gas Shales Project, a research effort in the Appalachia Basin from 1979 that proved shale rock was rich in natural gas. The DOE-supported project tested the use of nitrogen foam to fracture shale formations, and its analysis led to a deeper understanding of natural shale fractures. George Mitchell's team studied those results while developing the Barnett Shale near Fort Worth, the first modern fracking play. The company relied on research from the Sandia National Laboratory to use micro-seismic technology to map the shale fractures in wells, and Mitchell also benefited from federal tax credits for unconventional drilling, which helped underwrite the cost of developing hydraulic fracturing."

Natural Gas – finding more all the time

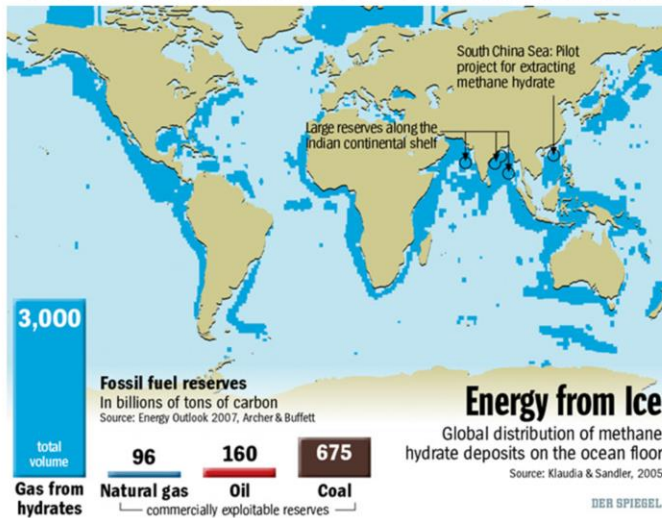


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Remember the slide on oil formation? Gas is formed far more commonly than oil and it is also formed during coal formation, so there is a lot of gas out there.

Natural Gas – Methane Clathrates



► By the time fracking shale gets old we will probably figure out how to utilize methane hydrates

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This is worth reading about if you are not familiar with the terms. 3000 gigatons is a lot of carbon.

Common Types of Fossil Fuels

▶ Petroleum (oil)

- ▶ Availability – Recoverable reserves continue to grow, technically challenging access, easy to transport (pipeline, road, rail, boat), density fairly high
- ▶ Cost – between \$500-700/ton
- ▶ Uses – engine fuels, many chemicals, and plastics

▶ Coal

- ▶ Availability – largest proven carbon reserve, easy access, hard to transport (road, rail, boat only), but density is highest
- ▶ Cost – between \$10-50/ton
- ▶ Uses – electricity, heat, and coke

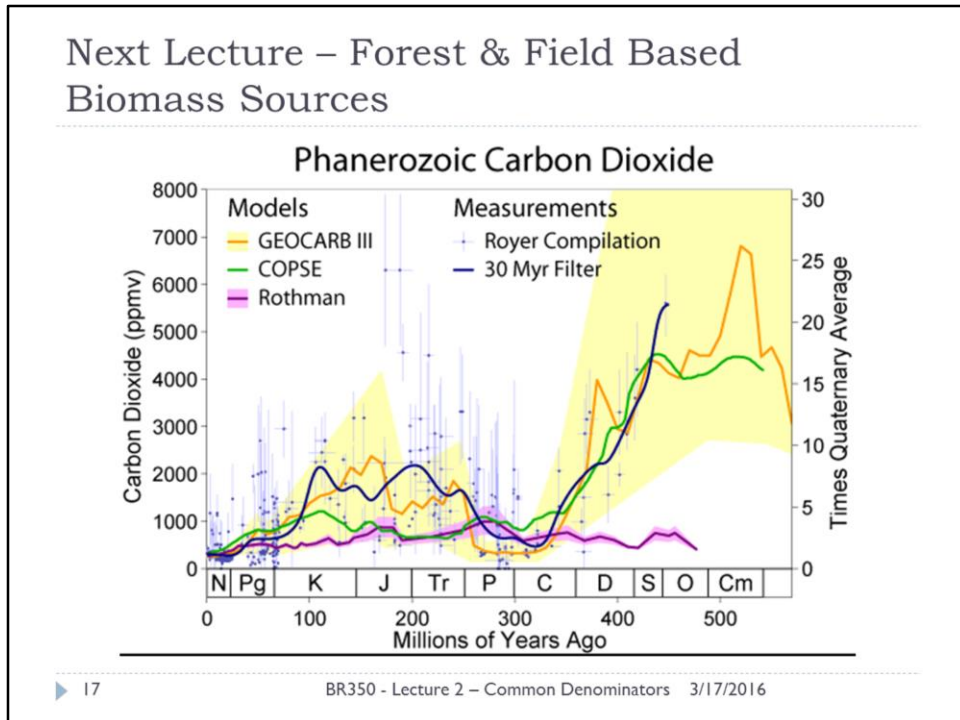
▶ Natural Gas

- ▶ Availability – very large reserves, technically challenging access but widely available (fracking), easier to transport than coal, but harder than oil because density is low (pipeline, road, rail, boat)
- ▶ Cost – between \$220-260/ton
- ▶ Uses – electricity, heat, hydrogen, and plastic

I am missing one last MAJOR carbon reserve. Can anyone tell me what it is?

It is CO₂. Humans output about 30 gigatons of CO₂ a year and the oceans probably contain on the order of 400 gigatons – this is rapidly becoming a more interesting source of carbon. Current price of industrial CO₂ is \$20-30/ton and dropping.

Next Lecture – Forest & Field Based Biomass Sources



What does this mean to you?

http://en.wikipedia.org/wiki/Carbon_dioxide_in_Earth's_atmosphere - Changes in carbon dioxide during the Phanerozoic (the last 542 million years). The recent period is located on the left-hand side of the plot. This figure illustrates a range of events over the last 550 million years during which CO₂ played a role in global climate.[21] The graph begins (on the right) with an era predating terrestrial plant life, during which solar output was more than 4% lower than today.[22] Land plants only became widespread after 400Ma, during the Devonian (D) period, and their diversification (along with the evolution of leaves) may have been partially driven by a decrease in CO₂ concentration.[23] Towards the left-hand side of the graph the sun gradually approaches modern levels of solar output, while vegetation spreads, removing large amounts of CO₂ from the atmosphere. The last 200 million years includes periods of extreme warmth, and sea levels so high that 200 metre-deep shallow seas formed on continental land masses (for example, at 100Ma during the Cretaceous (K) Greenhouse).[24] At the far left of the graph we see modern CO₂ levels and the appearance of the climate under which human species and human civilization developed.