Oil & Gas Outline

- Petroleum composition
- Deposit formation
- Petroleum exploration
- Petroleum extraction (a.k.a. “production”)
- Uses
- Production & Consumption by country
- Environmental impacts
- Alternatives to petroleum
Petroleum Composition

Composition by Weight

<table>
<thead>
<tr>
<th>Element</th>
<th>Percent range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>83 to 87%</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>10 to 14%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.1 to 2%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.1 to 1.5%</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.5 to 6%</td>
</tr>
<tr>
<td>Metals</td>
<td>less than 1000 ppm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hydrocarbon</th>
<th>Average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraffins</td>
<td>30%</td>
<td>15 to 60%</td>
</tr>
<tr>
<td>Naphthenes</td>
<td>49%</td>
<td>30 to 60%</td>
</tr>
<tr>
<td>Aromatics</td>
<td>15%</td>
<td>3 to 30%</td>
</tr>
<tr>
<td>Asphaltics</td>
<td>6%</td>
<td>remainder</td>
</tr>
</tbody>
</table>

Octane, a hydrocarbon found in petroleum, lines are single bonds, black spheres are carbon, white spheres are hydrogen (from Wikipedia)

Natural gas is a gaseous fossil fuel consisting primarily of \textit{methane} but including significant quantities of \textit{ethane}, \textit{propane}, \textit{butane}, and \textit{pentane} —heavier hydrocarbons removed prior to use as a consumer fuel — as well as \textit{carbon dioxide}, \textit{nitrogen}, \textit{helium} and \textit{hydrogen sulfide}.

\begin{itemize}
\item \textit{Methane}
\item \textit{Propane}
\item \textit{Pentane}
\end{itemize}
Deposit Formation

- Environment
- Burial and Preservation
- Source Rock
- Cooking in the Oil Window
- Reservoir Rock
- Traps
Oil & Gas Formation

Most of the world’s oil & natural gas resources were formed in two brief epochs of extreme global warming at 90 Ma and 150 Ma.

Oil & gas can take millions of years to form and require specific geological conditions to mature and become trapped in reservoirs.

First, a nutrient trap must be available.

**Bottom Line:** It’s renewable, but only on geologic time scales!

From: K. S. Deffeyes, “Hubbert’s Peak” (2001)
Burial: River Deltas

Sediment plume from Po Delta, Adriatic Sea

Where the “serious” (rapid, abundant) Sedimentation & Organic Burial occurs...

Schematic of Delta Structure
Oil & Gas are not evenly distributed

Almost all of the oilfields in the Middle East would fit into the north-central region of the United States. More than a quarter of the world’s oil production comes from this limited area. (Jeffrey L. Ward)

From: Kenneth S. Deffeyes, Beyond Oil (2005)
The source rock or formation will usually be a fine-grained clastic marine or lacustrine (lake) sedimentary rock such as a shale that is rich in organic matter. It may not be very thick, sometimes only a few feet.
Cooking in the Oil Window

Earth's heat "cracks" the complicated organic residues of dead plants (usually, marine plankton) to create oil. In general, the material must have, at some point, been trapped between 7,000 and 15,000 feet below the earth's surface. This is called the "oil window." Closer to the surface, temperatures are too low to make oil; deeper down, it is so hot that the material gets turned into natural gas (Deffeyes, 2001).

Modified from Pepper and Corvi, 1995
Reservoir Rock

Oil and gas can move through rocks if they are porous and have high permeability. The pore space of these rocks would be great and they would not be cemented very well. Pure sands are the best reservoirs and the oil acts as the glue to keep the sands together. When we extract oil from strata we sometimes have to "pump" another liquid, like salt water to prevent the overlying ground from sinking. Strata that is fractured can also allow oil to be trapped within the "cracks".

Core of a rock showing excellent porosity.

Diagram of a fractured reservoir rock.
A cap of impermeable rock must seal the oil & gas within the reservoir rock. Anhydrite from evaporated seawater is an excellent caprock material.
Trap Types

From: http://www.lloydminsterheavyoil.com/traptypes.htm
Structural oil traps take a variety of forms. Clockwise from the upper left are an anticline, a fault trap, an angular unconformity, and a salt dome. Oil accumulations are shown in solid black.

Deffeyes (2001)
Exploration Methods

- Geologic mapping
- **Seismic reflection & refraction surveys**
- **Gravity surveys (e.g., salt domes)**
- Magnetic surveys (e.g., igneous plugs)
- Electromagnetic (E-M) sounding surveys
- Geochemical surveys (e.g., gas sniffers)
- **Drilling**
  - Down-Hole Logging (e.g., temperature, resistivity, gamma)
  - Coring, drilling fluid, drilling chip analysis
Evolving Oil Extraction Methods

**Young Fields**
- **THEN** (1950-1990)
- Vertical Wells, Self-Pressurized Flow

**Mature Fields**
- **NOW** (2004-->)
- Lateral Well Drilling, Water Flooding

From: Matthew R. Simmons, Twilight in the Desert (2005)
Major Oil Fields of Saudi Arabia

Ghawar Field: King of Kings, since 1951

Figure 5.4 The core Saudi production region covers only 17,140 Square miles and fits into a corner of Utah.

SOURCE: Simmons & Company International

From: Matthew R. Simmons, Twilight in the Desert (2005)
Ghawar Drilling & Extraction Wells

Source: Joules Burn
ASPO-USA 2008
North Ghawar Depletion

- 400+ new wells
- Horizontal/MRC
- 1-10k b/d
- Now where?

Source: Joules Burn
ASPO-USA 2008
Thunder Horse at a glance:

Platform design: semi-submersible
Block: Mississippi Canyon 778/822
Platform production rating: 250,000 barrels of oil per day; 200 million cubic feet of gas per day
Owner/operator: British Petroleum
Drilling - Offshore

Drilling - Offshore

US Minerals Management Service
Petroleum Distribution by Region

Proven oil reserves at end 2004 --Source: British Petroleum
The World According to Oil

Who has the oil?

[Map showing oil reserves and consumption]

World Reserves of Oil

<table>
<thead>
<tr>
<th>Country</th>
<th>Reserves (Billion Barrels)</th>
<th>Percentage of World Reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabia</td>
<td>262.73</td>
<td>22.2%</td>
</tr>
<tr>
<td>Iran</td>
<td>132.46</td>
<td>11.2%</td>
</tr>
<tr>
<td>Iraq</td>
<td>115.90</td>
<td>9.7%</td>
</tr>
<tr>
<td>Kuwait</td>
<td>98.60</td>
<td>8.4%</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>91.80</td>
<td>7.8%</td>
</tr>
<tr>
<td>Venezuela</td>
<td>77.92</td>
<td>6.5%</td>
</tr>
<tr>
<td>Russia</td>
<td>52.23</td>
<td>4.4%</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>39.62</td>
<td>3.4%</td>
</tr>
<tr>
<td>Libya</td>
<td>39.12</td>
<td>3.2%</td>
</tr>
<tr>
<td>Nigeria</td>
<td>39.25</td>
<td>3.2%</td>
</tr>
<tr>
<td>United States</td>
<td>21.37</td>
<td>1.8%</td>
</tr>
<tr>
<td>China</td>
<td>17.62</td>
<td>1.4%</td>
</tr>
<tr>
<td>Canada</td>
<td>16.80</td>
<td>1.4%</td>
</tr>
<tr>
<td>Qatar</td>
<td>15.35</td>
<td>1.3%</td>
</tr>
</tbody>
</table>

Each country's size is proportional to the amount of oil it contains: 1 billion barrels. Source: EIA International Energy Annual 2004 & Energy Information Administration.
Current World Oil Production & Consumption
Properties & Uses of Oil

- Amazing Energy Density (45 MJ/kg, compared with 10-30 MJ/kg for coal, 16 MJ/kg for dry wood)
- Easily Transportable
- Safe (relatively)
- & Cheaply Storable

Major Uses:

- Transportation Fuel for motor vehicles, trains, ships & airplanes
- Fuel for Power Plants
- Industrial Applications, e.g. mining, farming, manufacturing
- Source of Petrochemicals, including pesticides, herbicides, plastics & pharmaceuticals
Environmental Impacts: natural & man-made oil seeps & spills

Environmental Impacts: Oil Spills

*Exxon Valdez Oil Spill, 1989*
11 million gallons spilled.

Prince William Sound, Alaska
Environmental Impacts: Habitat and groundwater destruction from mining

Athabasca tar sand mine, Alberta, Canada. Is it really worth it?
http://cache.boston.com/universal/site_graphics/blogs/bigpicture/efa_10_06/18_r.jpg
http://www.boston.com/bigpicture/2008/10/earth_from_above_comes_to_nyc.html
Environmental Impacts: CO$_2$-induced global warming & sea level rise

Stop Sea Level Rise

Florida’s shoreline after about a 5 meter rise in sea level

Source: Randy Udall, ASPO-USA 2008
# The List of Alternatives

<table>
<thead>
<tr>
<th>Category</th>
<th>Brief Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Heavy Oil</td>
<td>Most helpful in near future</td>
</tr>
<tr>
<td>• Oil Sands</td>
<td>Moderate supply</td>
</tr>
<tr>
<td>• Coal-Derived Liquids</td>
<td>Moderate supply</td>
</tr>
<tr>
<td>• Liquefied Natural Gas</td>
<td>Minor supply</td>
</tr>
<tr>
<td>• Natural Gas</td>
<td>N.A. post-peak; world will soon follow</td>
</tr>
<tr>
<td>• Coal</td>
<td>Maybe 100-200 more years--see CDL</td>
</tr>
<tr>
<td>• Methane hydrates</td>
<td>Abundant on and off-shore--impacts unknown</td>
</tr>
<tr>
<td>• Solar-voltaic</td>
<td>Moderate supply</td>
</tr>
<tr>
<td>• Hydro-electric</td>
<td>Moderate supply--local impact</td>
</tr>
<tr>
<td>• Wind</td>
<td>Moderate supply--local impact</td>
</tr>
<tr>
<td>• Tidal, Waves, Currents</td>
<td>Minor supply--local impact</td>
</tr>
<tr>
<td>• OTEC</td>
<td>Scaleable to 5 TW, but impacts unknown</td>
</tr>
<tr>
<td>• Biomass</td>
<td>Land forms are net energy losers; marine?</td>
</tr>
<tr>
<td>• Geothermal</td>
<td>Minor supply--local impact</td>
</tr>
<tr>
<td>• Nuclear Fission,</td>
<td>Most helpful in far future--probably</td>
</tr>
<tr>
<td>Nuclear Fusion</td>
<td>our only long-term hope</td>
</tr>
</tbody>
</table>
Crude Oil Alternatives -- Alberta, Canada
Heavy Oil Sands

* currently 1 million barrels (MB)/day
* projected to 3 MB/day in 2020
* projected to 6 MB/day “in future”
* reserves equal to oil of Saudi Arabia
* environmental impacts huge & scaleable

USA Consumption vs. Alternative Oil Supplies

Global Consumption vs. Alternative Oil Supplies