Most scientists agree that oil comes from creatures the size of a pinhead. These one-celled creatures, known as diatoms, aren't really plants, but share one very important characteristic with them - they take light from the sun and convert it into energy.

Diatoms float in the top few meters of the oceans (and lakes - which is part of the reason why not ALL oil comes from ocean deposits!) and also happen to be a major source of food for many forms of ocean swimmers.
Plankton

- Two types
  - Phytoplankton: Plants of the Sea
  - Zooplankton: Sea Animals
- Plankton either float passively in the water, or possess such limited powers of swimming that they are carried from place to place by the currents.

- Plankton range in size from tiny microbes, which are invisible to the naked eye, to jellyfish meters long.
- Apart from bacteria, planktonic organisms are the most abundant life form on earth.
- They are a critical part of the carbon energy chain.
- The total amount of carbon in the ocean is about 50 times greater than the amount in the atmosphere, and is exchanged with the atmosphere on a time-scale of several hundred years.
- At least 1/2 of the oxygen we breathe comes from the photosynthesis of marine plants.
Oil

- Oil is formed from the preserved remains of prehistoric plankton (diatoms) and algae which have been settled to the sea (or lake) bottom in large quantities in water depleted of oxygen.
- Terrestrial plants, on the other hand, tend to form coal.
- Over geological time this organic matter, mixed with mud, is buried under heavy layers of sediment. The resulting high levels of heat and pressure cause the organic matter to chemically change, first
  - into a waxy material known as kerogen which is found in various oil shales around the world,
  - then with more heat into liquid and gaseous hydrocarbons—Oil and Natural Gas

- Depending on the balance of fresh water versus evaporation this can change with time and reverse providing different layers
- This is why oil is often found just off shore or in regions that used to be water covered
  - Like the Middle East and Gulfs
Source Rock

- Oil comes from rocks (source rocks)— not big caverns
- There is "oil window" which is the temperature range that oil forms in— below the minimum temperature oil remains trapped in the form of kerogen, and above the maximum temperature the oil is converted to natural gas
- This corresponds to a certain depth in the earth
- A rock won’t have oil if:
  - It wasn’t a rock with lots of organic material
  - If the rock hasn’t been that deep
  - It was deeper than that depth

Three conditions must be present for oil reservoirs to form:
- a source rock rich in organic material buried deep enough for subterranean heat to cook it into oil;
- a porous and permeable reservoir rock for it to accumulate in;
- a cap rock (seal) or other mechanism that prevents it from escaping to the surface.

Within these reservoirs fluids will typically organize themselves like a three-layer cake with a layer of water below the oil layer and a layer of gas above it, although the different layers vary in size between reservoirs.
The vast majority of oil that has been produced by the earth has long ago escaped to the surface and been biodegraded by oil-eating bacteria.

Oil companies are looking for the small fraction that has been trapped by this rare combination of circumstances.

Oil sands are reservoirs of partially biodegraded oil still in the process of escaping, but contain so much migrating oil that, although most of it has escaped, vast amounts are still present – more than can be found in conventional oil reservoirs. It is usually in the form of asphalt and is mined...

On the other hand, oil shales are source rocks that have never been buried deep enough to convert their trapped kerogen into oil.
Are we going to run out of oil in next 20-30 yrs?

1. Probably
2. Probably not

US Oil Production (1 barrel = 42 gallons)

- 1991 – 7.4 million barrels/day
- 2009 – 5.3 million barrels/day
Hubbert

Marion King Hubbert (1903–1989) geoscientist at Shell Oil

Predicted the end of the Oil Age

"Our ignorance is not so vast as our failure to use what we know."

---

**Energy from Fossil Fuels**

M. King Hubbert, Associate Director, Exploration and Production Research Division, Shell Oil Company, Inc.

The Earth may be regarded as a material system whose gain or loss of matter over the period of our interest is negligible. Into and out of this system, however, there enters a

---

**Fig. 8. Human affairs in time perspective.**
**Hubbert’s basic idea**

- There is only so much oil recoverable on Earth
  - Therefore we eventually use it all up

![Graph showing oil usage over time]

**Hubbert’s basic idea**

- We can instead plot the rate of usage

![Graph showing peak oil and Hubbert's peak]

"Peak Oil"
Hubbert’s peak

Hubbert Theory with Norway’s production
Have we already reached peak oil?

1. Yes
2. No
3. Not sure
Best Fit World Data

Fig. E12.4.6 The world oil production rate curve from 1915 to 2004 fit to a normal curve (red curve) assuming the value for $Q_\infty$ is 3 Tbl. Peak production occurs in 2021.
Look at rate of discoveries...

Assume 300 billion bbls new discoveries
Peak Oil - 2012

Assume 600 billion bbls new discoveries
Peak Oil - 2040
### Total World Oil Reserves

- Oil Sands, Bitumen 30%
- Conventional Oil 30%
- Extra Heavy Oil 25%
- Heavy Oil 15%

### Greatest Oil Reserves by Country, 2006

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Proved reserves (billion barrels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saudi Arabia</td>
<td>264.3</td>
</tr>
<tr>
<td>2</td>
<td>Canada</td>
<td>178.8</td>
</tr>
<tr>
<td>3</td>
<td>Iran</td>
<td>132.5</td>
</tr>
<tr>
<td>4</td>
<td>Iraq</td>
<td>115.0</td>
</tr>
<tr>
<td>5</td>
<td>Kuwait</td>
<td>101.5</td>
</tr>
<tr>
<td>6</td>
<td>United Arab Emirates</td>
<td>97.8</td>
</tr>
<tr>
<td>7</td>
<td>Venezuela</td>
<td>79.7</td>
</tr>
<tr>
<td>8</td>
<td>Russia</td>
<td>60.0</td>
</tr>
<tr>
<td>9</td>
<td>Libya</td>
<td>39.1</td>
</tr>
<tr>
<td>10</td>
<td>Nigeria</td>
<td>35.9</td>
</tr>
<tr>
<td>11</td>
<td>United States</td>
<td>21.4</td>
</tr>
<tr>
<td>12</td>
<td>China</td>
<td>18.3</td>
</tr>
<tr>
<td>13</td>
<td>Qatar</td>
<td>15.2</td>
</tr>
<tr>
<td>14</td>
<td>Mexico</td>
<td>12.9</td>
</tr>
<tr>
<td>15</td>
<td>Algeria</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td>Top 20 countries</td>
<td>1,224.5 (95%)</td>
</tr>
<tr>
<td></td>
<td>Rest of world</td>
<td>69.1 (6%)</td>
</tr>
<tr>
<td></td>
<td>World total</td>
<td>1,292.6</td>
</tr>
</tbody>
</table>
Criticisms of “Peak Oil”

- Doesn’t account for new technology
  - Production
  - Discovery
- Oil companies are overly conservative in what “proven” means
- Where there is a will there is a way...
  - If the price is high enough, other sources will be tapped
**Oil (Tar) Sands**

- Oil sands or tar sands, are a type of unconventional petroleum
- A mixture of sand, clay, water, and a dense and extremely viscous form of petroleum technically referred to as bitumen
- Oil sands are found in large amounts in Canada and Venezuela
- It is a thick, sticky form of crude oil, so heavy and viscous (thick) that it will not flow unless heated or diluted with lighter hydrocarbons

**Keystone XL Pipeline**

- They want to build a pipeline to bring oil from tar sands to Houston
- There are pros and cons
Should we build the pipeline?

1. Yes
2. No

Offshore drilling in the US

- Most areas were put off limits in 1981 by congress, 1989 by Pres. Bush(Sr) after Exxon Valdez spill

Sept. 30, 2007 - Congress lets ban expire…except for Eastern Gulf of Mexico
What can (should) the US do?

- Drill offshore
- Drill in ANWR

Estimates:
ANWR: 5-10 billion bbls.
US offshore: 45 billion bbls.

World: **1237 billion bbls.**

“The projections in the OCS access case indicate that access to the Pacific, Atlantic, and eastern Gulf regions would not have a significant impact on domestic crude oil and natural gas production or prices before 2030.” - US Dept. of Energy 2007 report
Digging deep for major oil find: drill sinks into Earth as high as a jumbo flies

September 3, 2009

The ultra-deepwater semi-submersible rig Deepwater Horizon, which drilled the Tiber well in the Gulf of Mexico. Photo: AP

British energy major BP has made a "giant" oil discovery in the Gulf of Mexico after drilling one of the industry's deepest wells.

"BP announced today a giant oil discovery at its Tiber Prospect in the deepwater Gulf of Mexico," the company said in a statement on Wednesday.

"The Tiber well was drilled to a total depth of approximately 35,055 feet [10,685 metres] making it one of the deepest wells ever drilled by the oil and gas industry," it added.
Wed. March 31  Pres. Obama gives speech from Andrews Air force base

Tuesday, April 20  Deepwater Horizon suffers explosion in the Gulf of Mexico

Wed. April 21  Firefighters and rescue ships fight ongoing fire on Deepwater Horizon

Thursday, April 22, Earth Day, Deepwater Horizon sinks. Eleven crew missing

April to July, approx. 52,000 to 63,000 Barrels per day (3 Million Gals. per day) leaked

June 2010  President Barack Obama imposed a moratorium on deepwater drilling

July 15, 2010  Cut-off well head capped

Sept 19, 2010  Well declared dead after filling top and bottom with cement

The moratorium was lifted in October 2010 after new safety regulations were established and the first deepwater drilling permit was issued on February 28, 2011
Should the US drill in

1. ANWR
2. Offshore
3. Both
4. Neither

Hirsch Report of DoE 2005

- World oil peaking is going to happen, and will likely be abrupt.
- Oil peaking will adversely affect global economies, particularly those most dependent on oil.
- Oil peaking presents a unique challenge ("it will be abrupt and revolutionary").
- The problem is liquid fuels (growth in demand mainly from transportation sector).
Hirsch report

• Mitigation efforts will require substantial time.
  – 20 years is required to transition without substantial impacts
  – A 10 year rush transition with moderate impacts is possible with extraordinary efforts from governments, industry, and consumers
  – Late initiation of mitigation may result in severe consequences.
• Both supply and demand will require attention.
• It is a matter of risk management (mitigating action must come before the peak).
• Government intervention will be required.
  – Economic upheaval is not inevitable (“given enough lead-time, the problems are soluble with existing technologies.”)
  – More information is needed to more precisely determine the peak timeframe.

OLDUVAI THEORY
ONE VIEW OF THE FUTURE

World Energy Production, Population Growth, And the Road to the Olduvai Gorge  Richard C. Duncan Institute on Energy and Man


Named for the Olduvai Gorge in Tanzania where remains found are crucial to understanding human evolution were found.
Olduvai Theory

- Defined by the ratio of world energy production and population.
- It states that the life expectancy of Industrial Civilization is less than or equal to 100 years: 1930–2030.
- After more than a century of strong growth — energy production per capita peaked in 1979.
- Moreover, it says that energy production per capita will fall to its 1930 value by 2030, thus giving Industrial Civilization a lifetime of less than or equal to 100 years.
- This analysis predicts that the collapse will be strongly correlated with an 'epidemic' of permanent blackouts of high-voltage electric power networks — worldwide.
World Energy Production per Capita: 1920-1999
When you are 50 years old, the world’s standard of living will be

1. Better than today
2. About the same
3. Somewhat worse
4. Catastrophically worse

Duncan’s View

- A keen question is posed: "Why are you confident about the Olduvai theory?"
  - My response: "Because Mother Nature then solves for us the (apparently) insuperable problem of the Tragedy of the Unmanaged Commons, which the human race seems either incapable or unwilling to solve for itself."
- Governments have lost respect. World organizations are ineffective. Neo-tribalism is rampant. The population is over six billion and counting. Global warming and emerging diseases are headlines. The reliability of electric power networks is falling. And the instant the power goes out, you are back in the Dark Age. If God made the Earth for human habitation, then He made it for the Stone Age mode of habitation.
- The Olduvai theory is thinkable.
The earth's immune system, so to speak, has recognized the presence of the human species and is starting to kick in. The earth is attempting to rid itself of an infection by the human parasite. — Richard Preston, 1994

Natural Gas

Since the late 1990s, natural gas has been the fuel of choice for the majority of new generating units, resulting in a 99.0 percent increase in natural gas-fired capacity since 1999.

The construction of natural gas plants began increasing in 1999, peaked during 2002 and 2003, but has since declined considerably.

On December 31, 2006, natural gas-fired generating capacity represented 388,294 MW or 39.4 percent of total net summer generating capacity. Although new natural gas-fired combined-cycle plants produce electricity more efficiently than older fossil-fueled plants, high natural gas prices can work against full utilization of these plants if such prices adversely affect economic dispatch.
## Natural Gas proven reserves

1. Russia 25%
2. Iran 16%
3. Qatar 14%
4. Saudi Arabia 4%
5. US 3%
6. United Arab Emirates 3%
7. Venezuela 3%
8. Algeria 2%

### World Reserves/Production Ratio - 60 years

## An alternative transportation fuel

Metro: 164 CNG buses (out of 1600)

Honda Civic GX - on sale in CA, NY
Energy usage will continue to increase

Growth in developing countries

Figure 1. World energy consumption, 1990-2035 (quadrillion Btu)
Fossil Fuel consumption will increase

- Energy Use in Quads 1990-2035

China will use a lot of energy and India is on the rise

Figure 13. Energy consumption in the United States, China, and India, 1990-2035 (quadrillion Btu)

Page 60
Asia will burn a lot of coal

Figure 5. World coal consumption by region, 1990-2035 (quadrillion Btu)

The world will emit a lot of CO₂

Figure 10. World energy-related carbon dioxide emissions by fuel, 1990-2035 (billion metric tons)
It will depend (somewhat) on the global economy!

Figure 17. World Marketed Energy Consumption in Three Economic Growth Cases, 1980-2030

Depends on prices

Figure 30. Nominal World Oil Prices in Three Cases, 1980-2030

Figure 31. World Liquids Supply in Three Cases, 2030
International organization of 30 countries that accept the principles of representative democracy and free-market economy. Most OECD members are high-income economies.

**Member Countries**

- Australia
- Austria
- Belgium
- Canada
- Czech Republic
- Denmark
- Finland
- France
- Germany
- Greece
- Hungary
- Iceland
- Ireland
- Italy
- Japan
- Korea
- Luxembourg
- Mexico
- Netherlands
- New Zealand
- Norway
- Poland
- Portugal
- Slovak Republic
- Spain
- Sweden
- Switzerland
- Turkey
- United Kingdom
- United States

Coal

Fossil fuels: petroleum, natural gas and coal (organic)
- Relatively short-lived, ~ 500 years
- Currently 85% of current US energy from fossil fuels
- Expected oil production peak: 2010-2030
- Consumption currently increasing
- Projected world oil production will be exhausted by 2100
- Produces significant and diverse pollution problems
  - Greenhouse gasses
  - Gaseous Sulfur and nitrogen oxides
  - Land-based disturbances

The Era of Fossil Fuels