World Crude-Oil Future

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Introduction

In this Anthropocene era (http://en.wikipedia.org/wiki/Anthropocene) the amount of crude oil extracted from the Earth and burned for fuel was crucial for the continuation of the industrial revolution c 1900 after coal got it started c1760 (http://en.wikipedia.org/wiki/Industrial_Revolution) and now is crucially deleterious for the survival of *Homo sapiens sapiens* on the Earth. See http://en.wikipedia.org/wiki/Crude_oil for much information about crude-oil.

This document discusses many salient facts and displays many graphs about the extraction of crude oil from the Earth and burning it for fuel. Especially emphasized will be the environmental effects of burning crude oil, including the effects on the health of humans and the effects on global warming (aka climate change)(http://en.wikipedia.org/wiki/Global_warming).

Environmental Effects of Crude-Oil Extraction

Conventional oil wells are not extremely detrimental to the environment as surface coal mines, unless they are drilled very close together as has been the case sometimes in Oklahoma and Texas.

However, unconventional crude-oil extraction can be very detrimental to the environment.

- Tight oil (shale oil) (http://en.wikipedia.org/wiki/Tight_oil) horizontal wells involve putting millions of gallons of water and a mix of chemicals, some of which are toxic, and sand into a well in order to use high pressure to fractionate the shale (http://en.wikipedia.org/wiki/Fracking). Both the source of the water used and the final deposition of the water mix can be detrimental to the environment. Also, such oil wells deplete much faster than conventional oil wells, so that many more of wells have to be drilled to extract the crude-oil than is the case for conventional crude oil. (http://en.wikipedia.org/wiki/Oil_depletion , http://www.postcarbon.org/drill-baby-drill/)

- Oil sands (bituminous sands, tar sands) (http://en.wikipedia.org/wiki/Oil_sands) sources for crude-oil extraction involve many processes detrimental to the environment. The main location of oil sands in North America is in the boreal forests (taiga, http://en.wikipedia.org/wiki/Boreal_forest) in Alberta, Canada. The oil sands are extracted from large surface mines, which involve great destruction of the landscape. There are many steps in the process of extracting crude oil from oil sands: http://www.cdnoilsands.com/operations/ProductionProcess/default.aspx , all of which can be detrimental to the environment.

Environmental Effects of Burning Crude-oil Products for Energy Production

The major energy fuels produced from crude oil are:

- Gasoline (http://en.wikipedia.org/wiki/Gasoline): There are many ways burning gasoline in vehicles can harm the environment (http://en.wikipedia.org/wiki/Gasoline#Environmental_considerations). In most countries vehicles that burn gasoline must be equipped with devices, such as catalytic converters, (http://en.wikipedia.org/wiki/Catalytic_converter) to control emissions and must be designed for high efficiency.
- Diesel (http://en.wikipedia.org/wiki/Diesel_fuel): Diesel fuel used to contain large amounts of sulfur, which caused acid rain, smog and respiratory problem. In most countries vehicles that burn diesel the refining process must eliminate most of the sulfur and vehicle must be equipped with devices to reduce other emissions.
- Kerosene for airplanes (http://en.wikipedia.org/wiki/Jet_fuel): Jet trails in the upper troposphere causes cooling of the Earth's surface, as was measured when passenger jets were grounded for three days after the 11 September 2001 terrorist attacks (http://en.wikipedia.org/wiki/9-11) in the United States (http://en.wikipedia.org/wiki/Jet_trails#September_11.2C_2001_climate_impact_study)

Global Warming Due to Burning Crude-oil Products for Energy Production

There has been a movement to use the term "climate change" instead of "global warming". The author prefers "global warming" because the average warming of the Earth due to more solar energy being absorbed by the Earth is what is causing climate change. The warming of the Earth is not uniform; in fact, it is possible that some areas will be colder than they were before global warming started. The artic is warming about twice as fast at the temperate and tropic areas.

Burning fossil fuels for energy releases greenhouse gases (GHG) into the atmosphere (http://en.wikipedia.org/wiki/Greenhouse_gases#Relative_CO2_emission_from_various_fuels):

Fuel	CO_2 emitted ($g/10^3J$)
Natural gas	~50
Gasoline	~67
Coal	~90

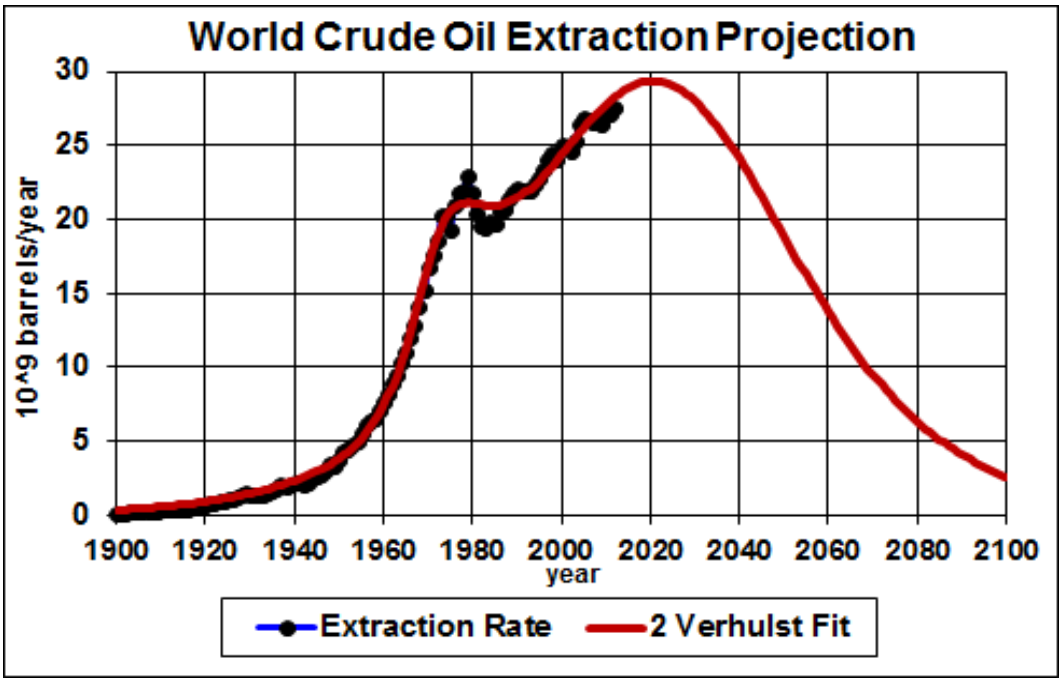
So, quitting burning coal for energy will have the largest effect in mitigating global warming than quitting burning natural gas or gasoline. Next in line for GHG emissions is burning gasoline or diesel, which emits slightly more than gasoline (http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=11).

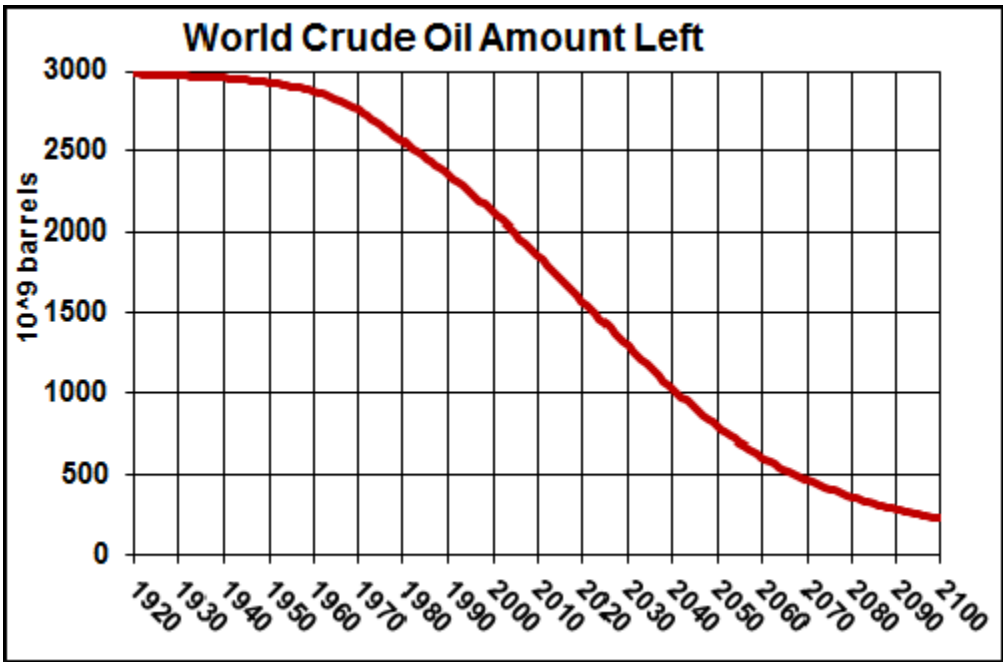
Amount of Crude Oil Available for Extraction from the Earth

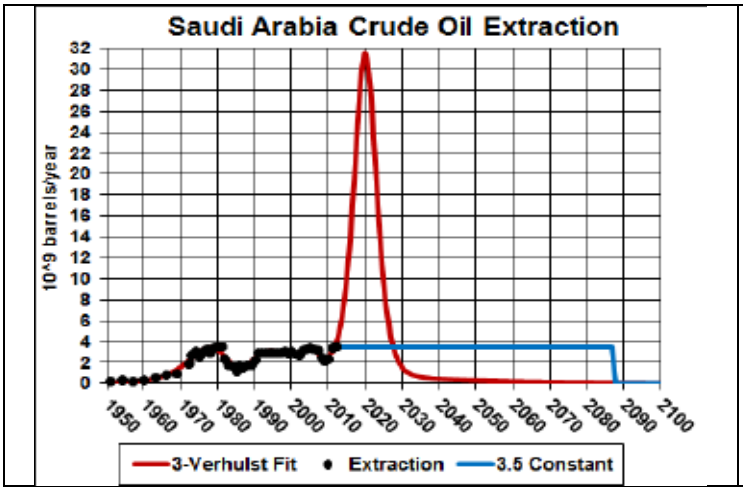
In the following fits to crude-oil-extraction data:

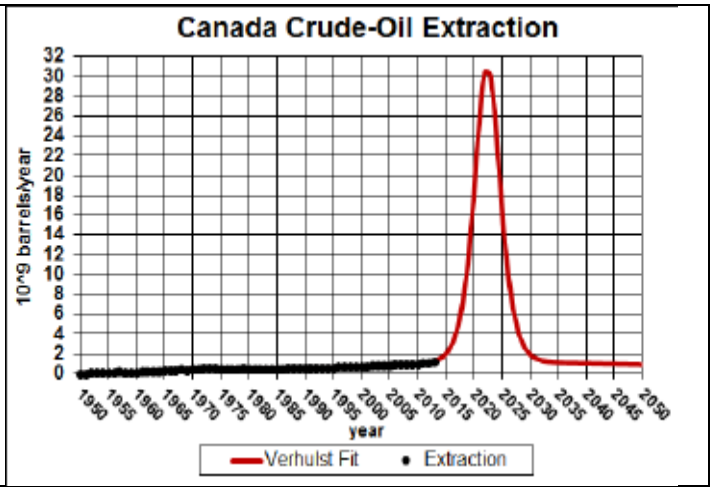
- If the data are decreasing during the last few years, a best fit is done.
- If the data are rising during the last few years, a fit is done using the current recoverable-reserves value with the assumption that the future peak will be symmetric.

World Crude-Oil Extraction



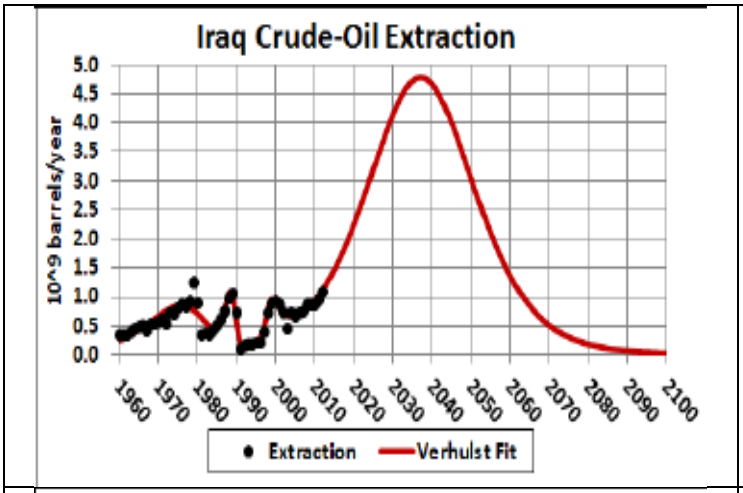


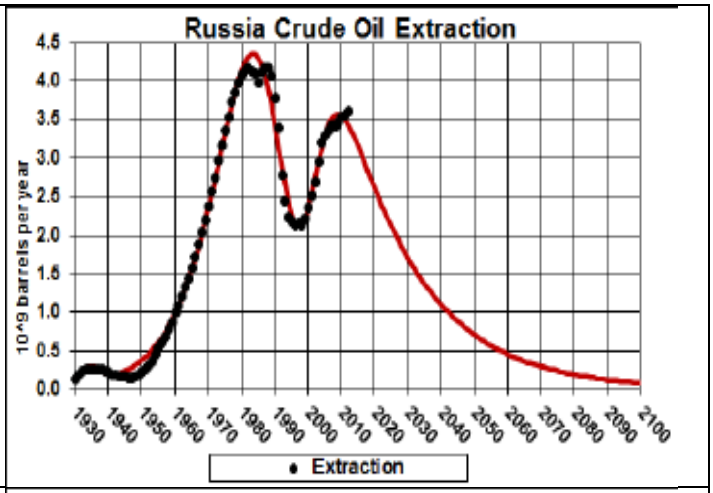


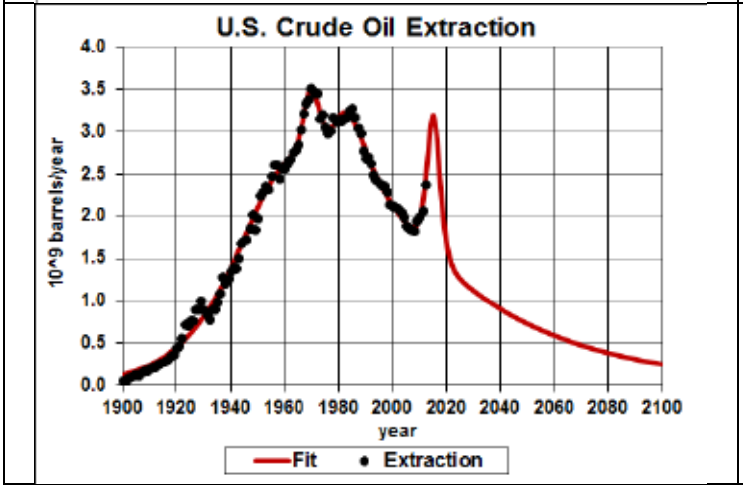


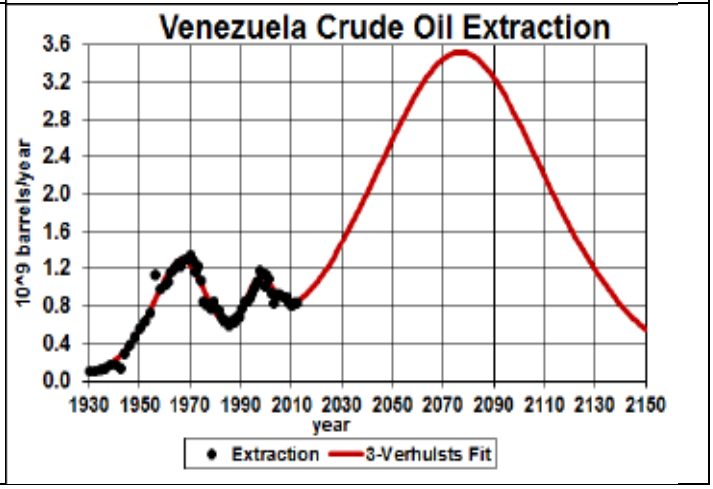
Saudi Arabia and Canada are on exponential rises in crude-oil extraction. If those exponential rises continue the large peaks shown above will occur. Of course, there could be smaller peaks instead of one large peak.

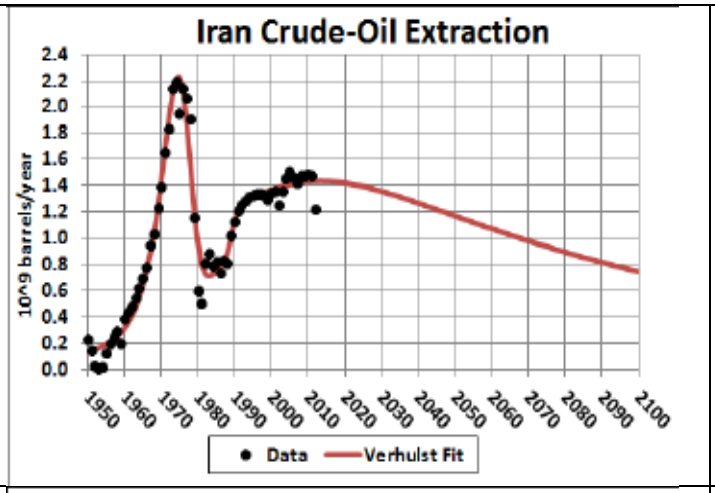
The case of Canada is for processing crude oil from oil sands, a process very detrimental to the environment. So, with the continuing awareness of the disasters to come because of global warming, extraction of crude oil from oil sands may be curtailed such that the large peak for Canadian oil extraction will not be so large after all.

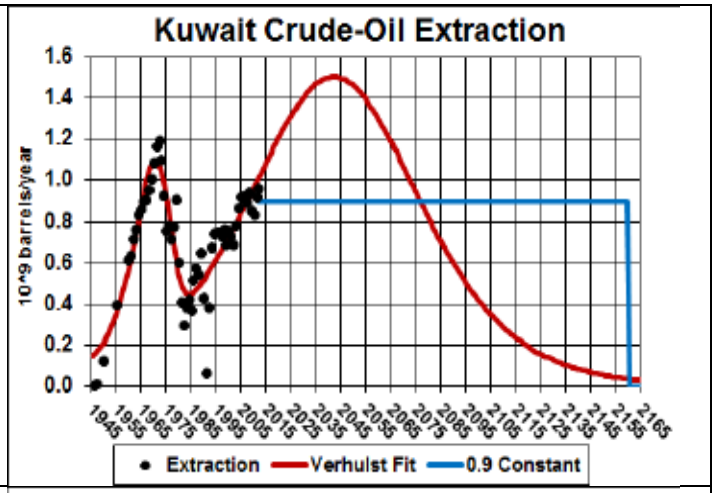


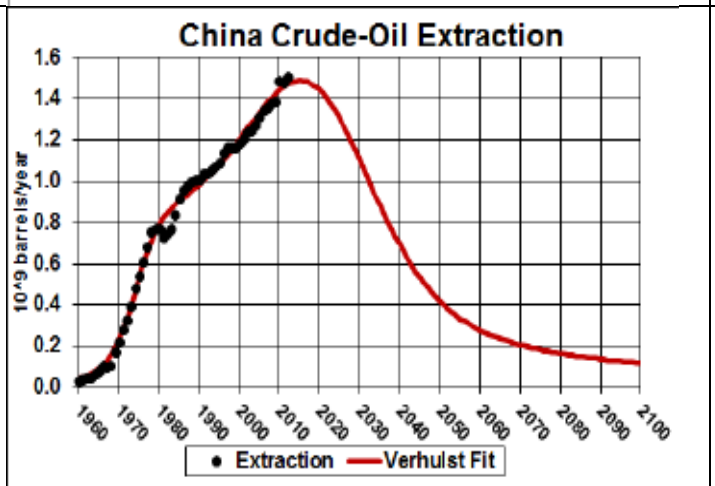


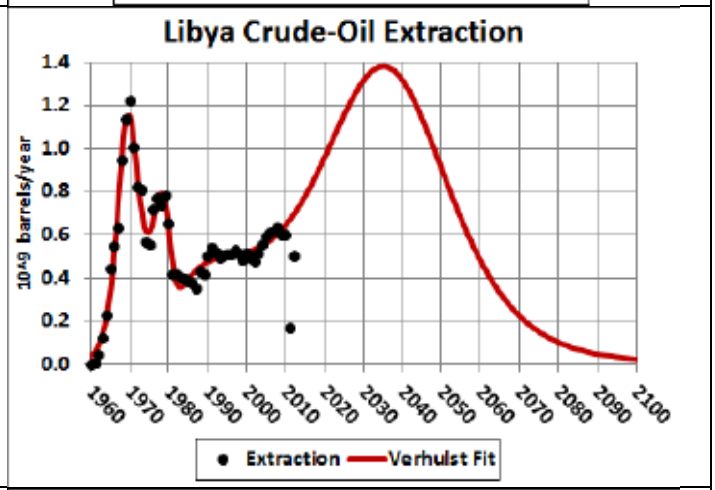


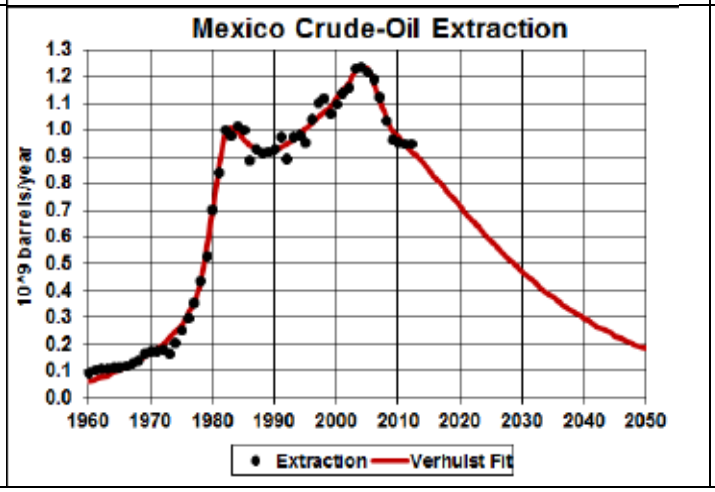


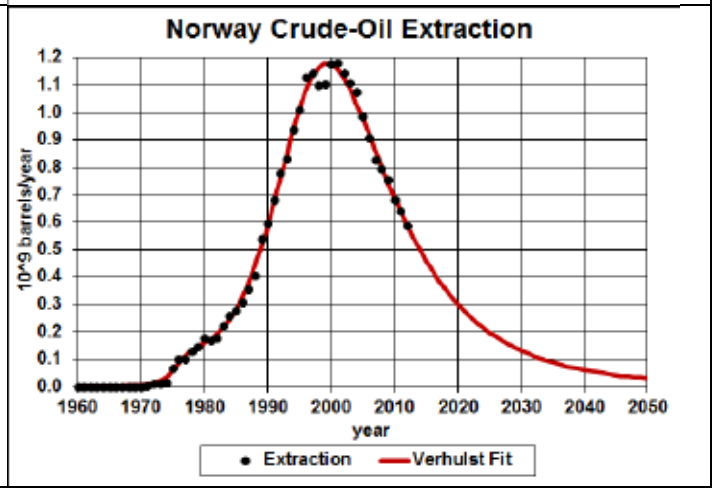

Iran Crude-Oil Extraction
10^9 barrels/year
Data
Verhulst Fit

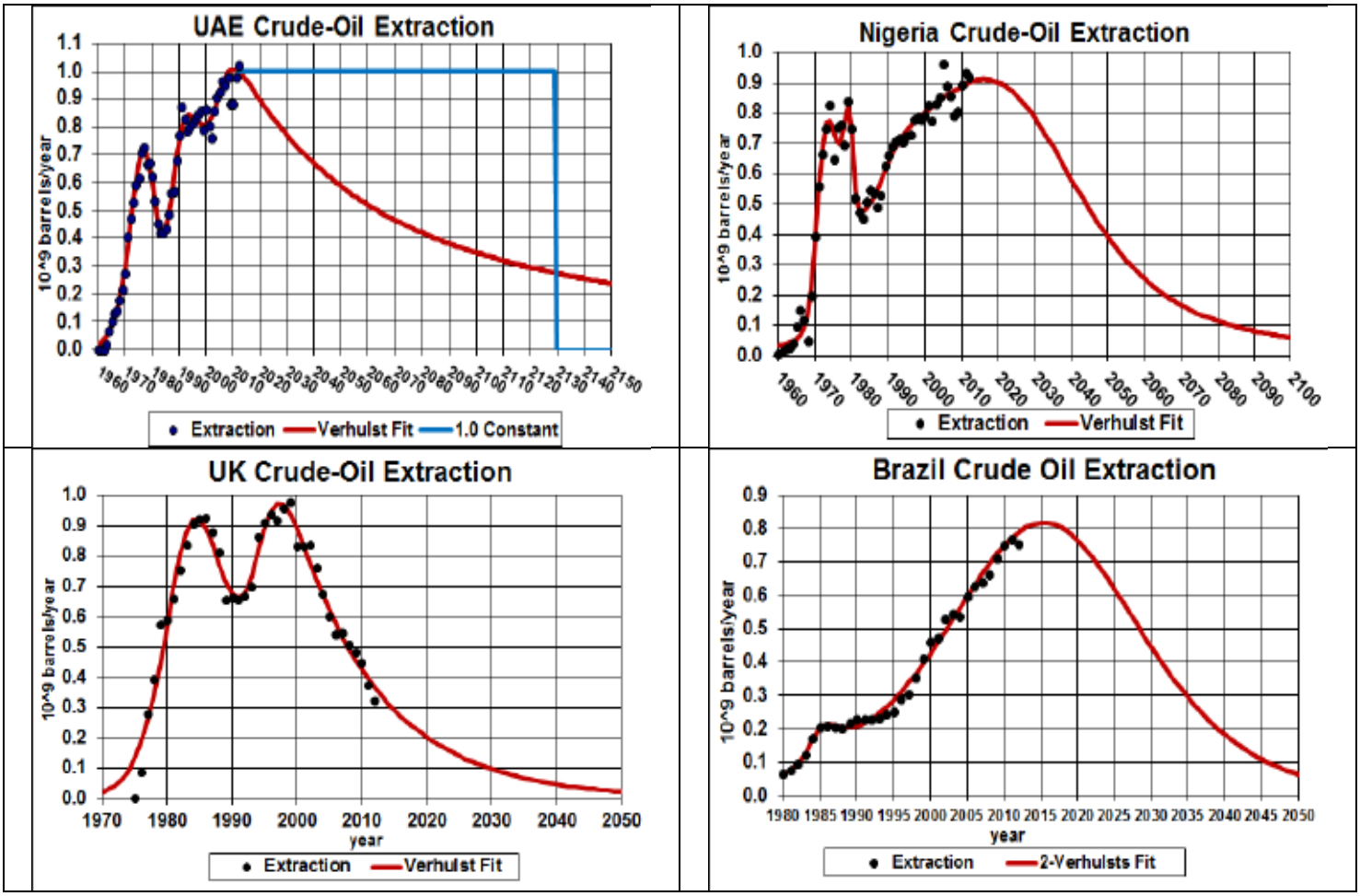

Kuwait Crude-Oil Extraction
10^9 barrels/year
Extraction
Verhulst Fit
0.9 Constant


China Crude-Oil Extraction
10^9 barrels/year
Extraction
Verhulst Fit


Libya Crude-Oil Extraction
10^9 barrels/year
Extraction
Verhulst Fit


Mexico Crude-Oil Extraction
10^9 barrels/year
Extraction
Verhulst Fit


Norway Crude-Oil Extraction
10^9 barrels/year
year
Extraction
Verhulst Fit



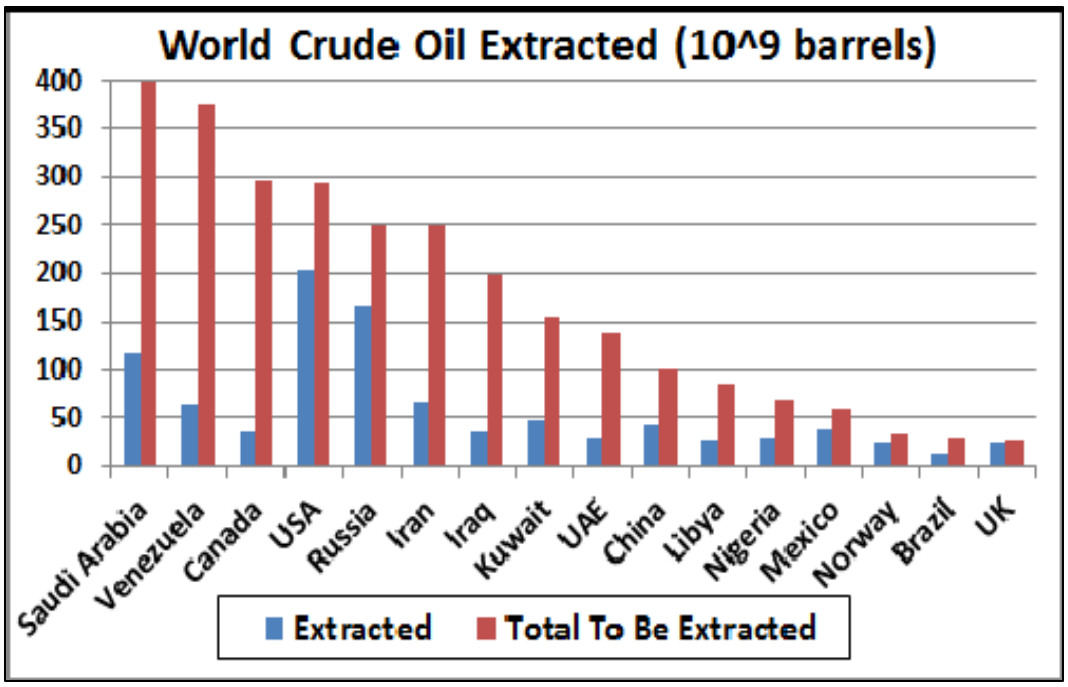
The extraction curves shown above are for the sixteen nations that will extract the most crude oil from the Earth. Of course, there are many other nations that have extracted crude oil from the Earth.

In the graphs above for Saudi Arabia, Kuwait and the United Arab Emirates (UAE), a blue curve shows when the estimated reserves would be extracted at the current rate of extraction, a very unrealistic, but often stated, case.

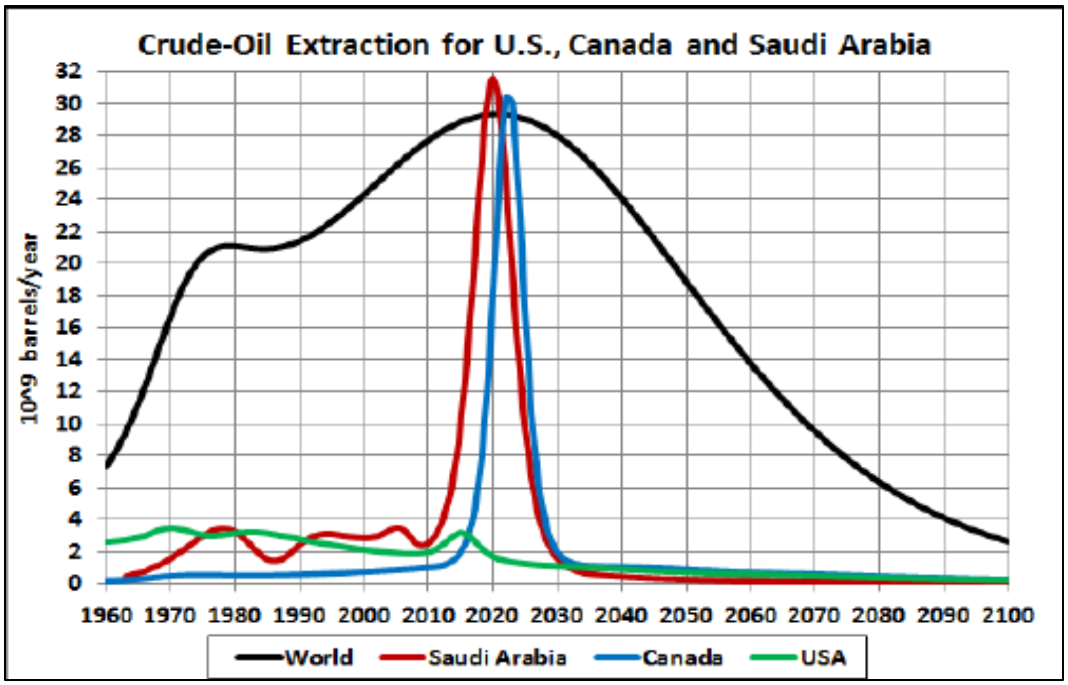
Special comments:

- Iraq: The curve assumes that Iraq will soon become politically stable such that crude-oil extraction can follow its natural course under a stable nation.
- Libya: The curve assumes that Iraq will soon become politically stable such that crude-oil extraction can follow its natural course under a stable nation.
- Venezuela (http://www.eia.gov/countries/cab.cfm?fips=ve): Reserves are for extra-heavy oil in the Orinoco Belt, which requires specialized refineries.

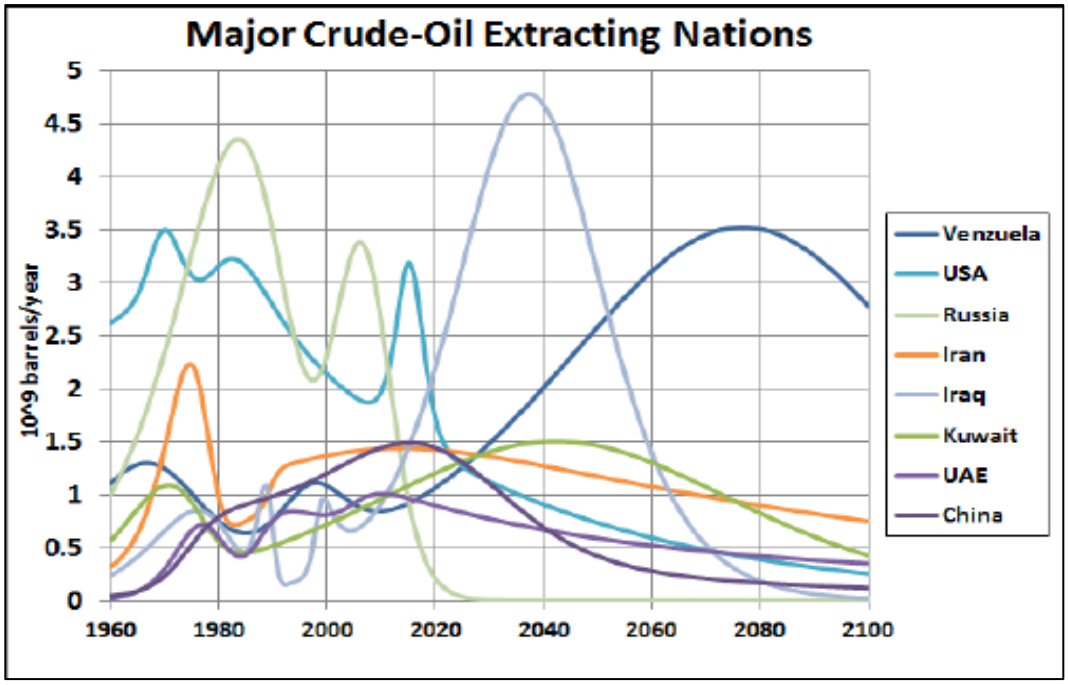
The following graph shows the amount already extracted and the total amount to be extracted for the sixteen nations with the largest extraction amounts.


World Crude Oil Extracted (10^9 barrels)
400
350
300
250
200
150
100
50
0
Saudi Arabia
Venezuela
Canada
USA
Russia
Iran
Iraq
Kuwait
UAE
China
Libya
Nigeria
Mexico
Norway
Brazil
UK
Extracted
Total To Be Extracted

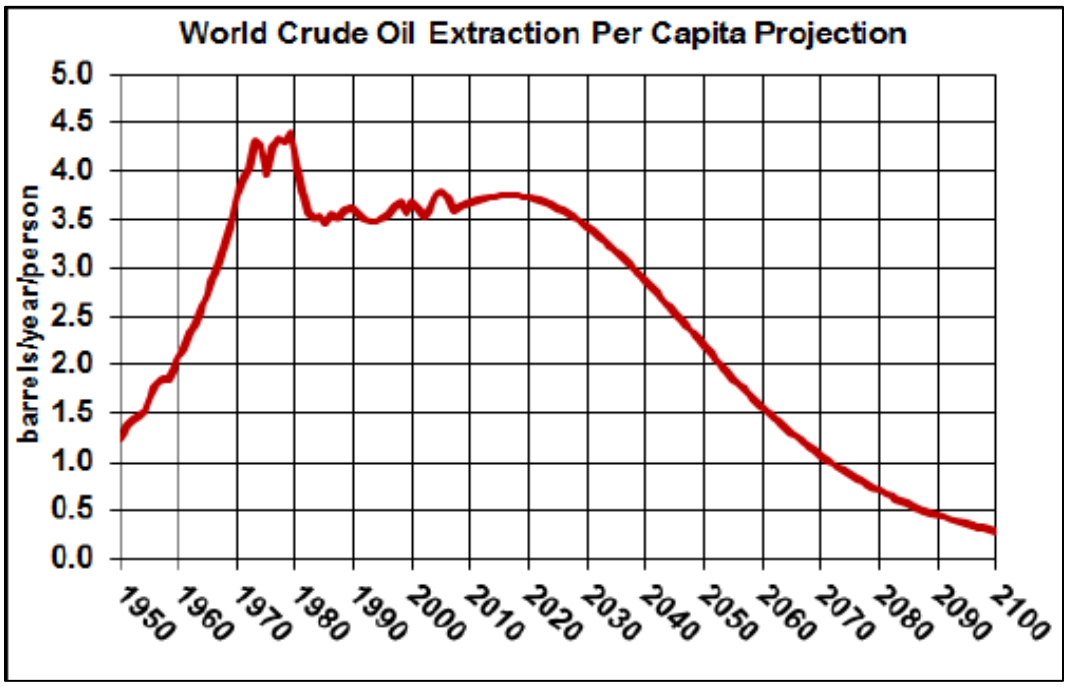
The following graph shows the extraction rates versus year for Saudi Arabia and Canada, compared to the U.S. and the world.



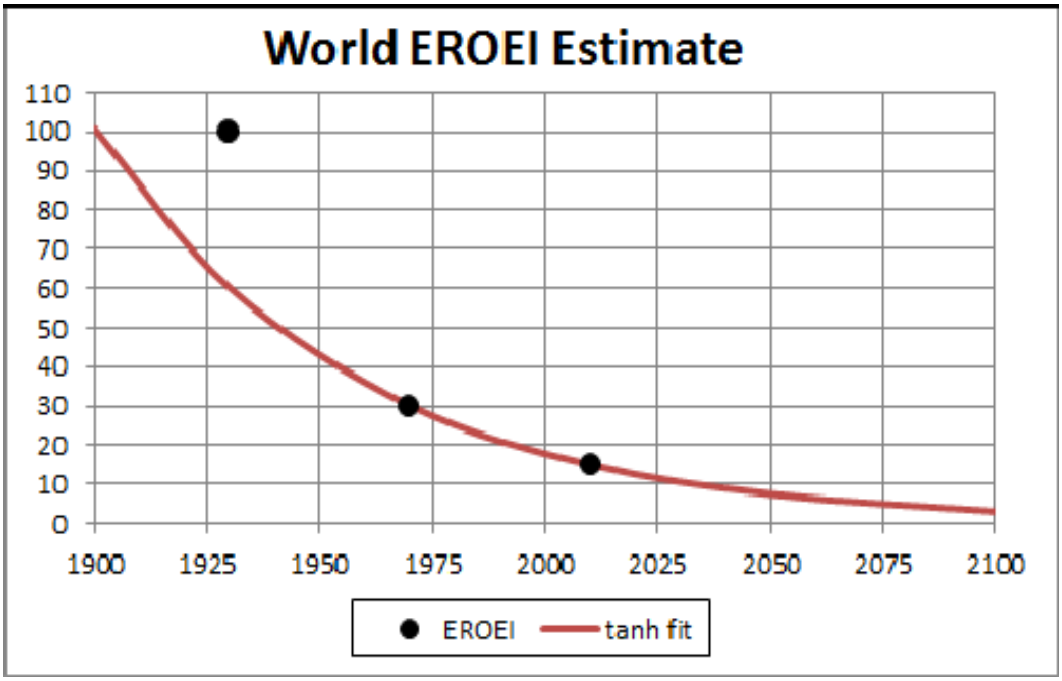
The following graph shows the extraction rates versus year for the eight nations with the largest extraction, excluding Saudi Arabia and Canada.



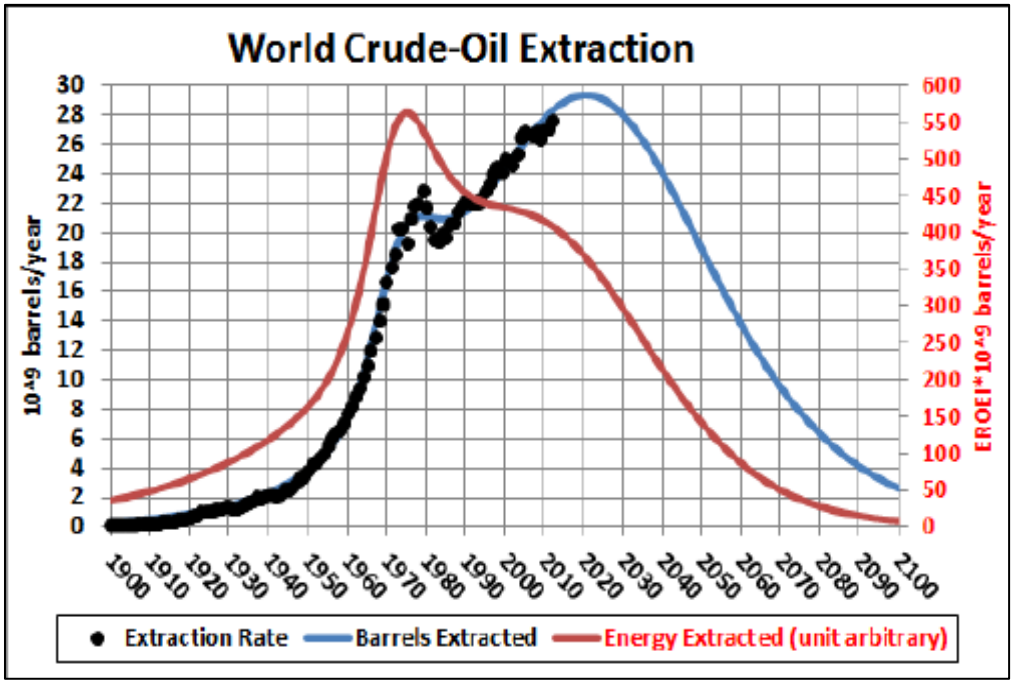
World crude oil per capita peaked in year ~1980:



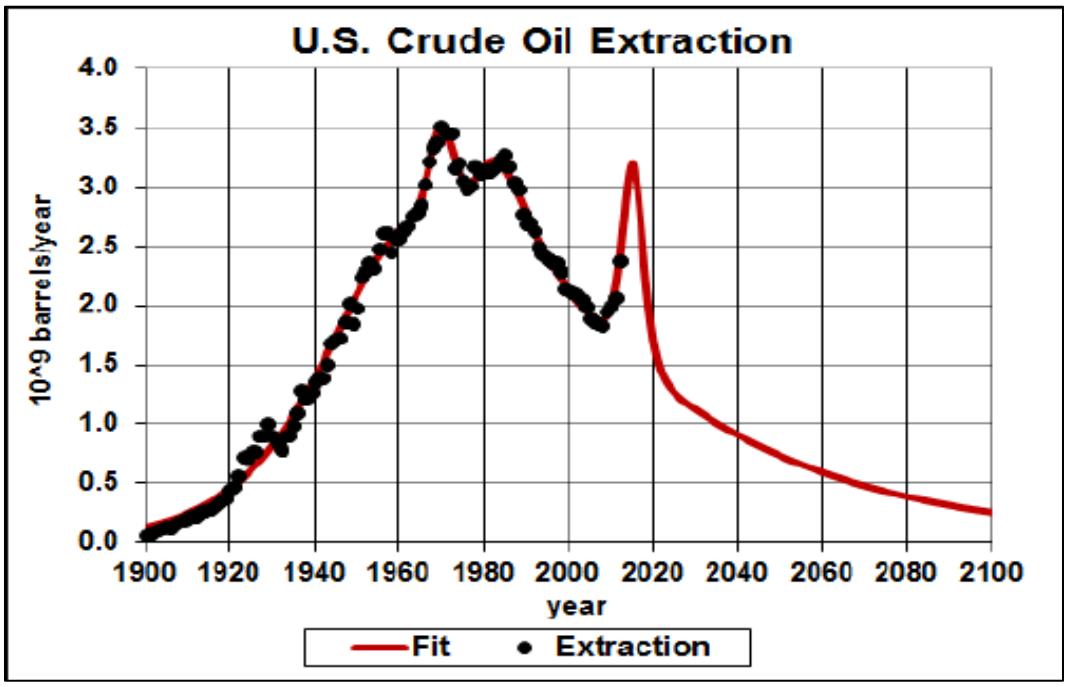
A fit to rough estimates of Energy-Returned-For-Energy-Invested (EROEI) for world crude-oil extraction yields the curve:



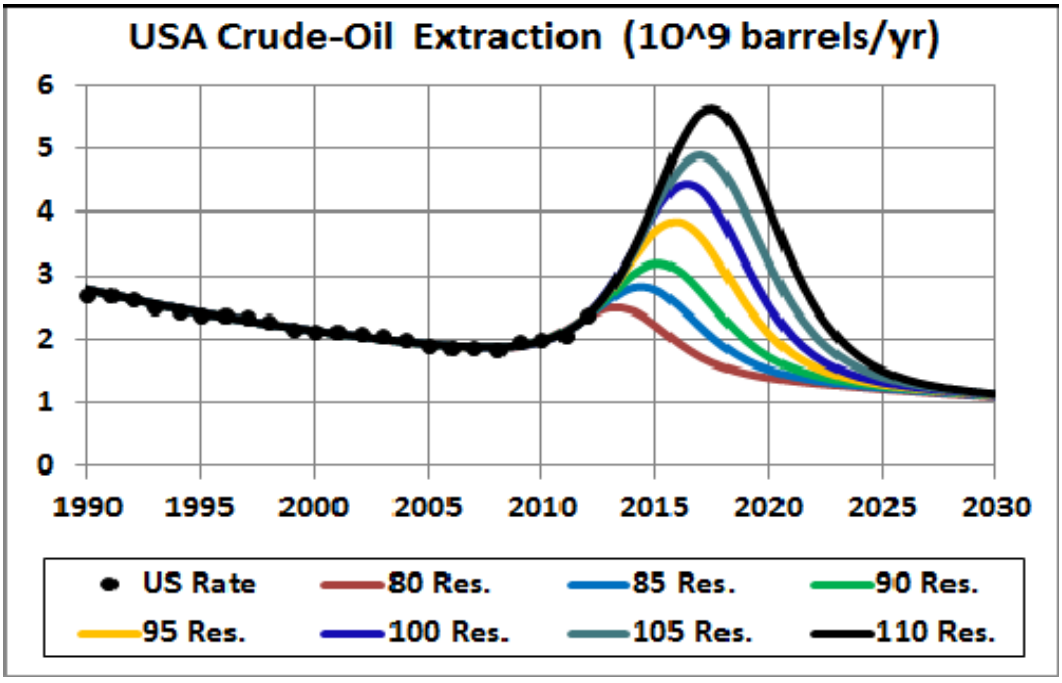
Using the EROEI curve, the energy available for world crude oil peak in ~1975:



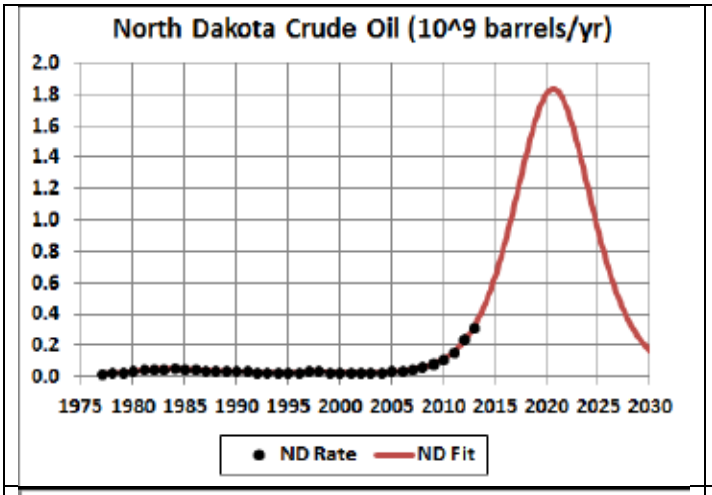
United States Crude-Oil Extraction

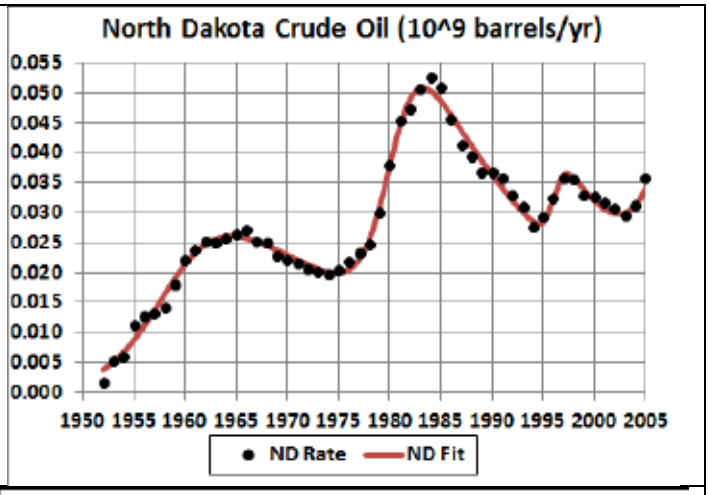


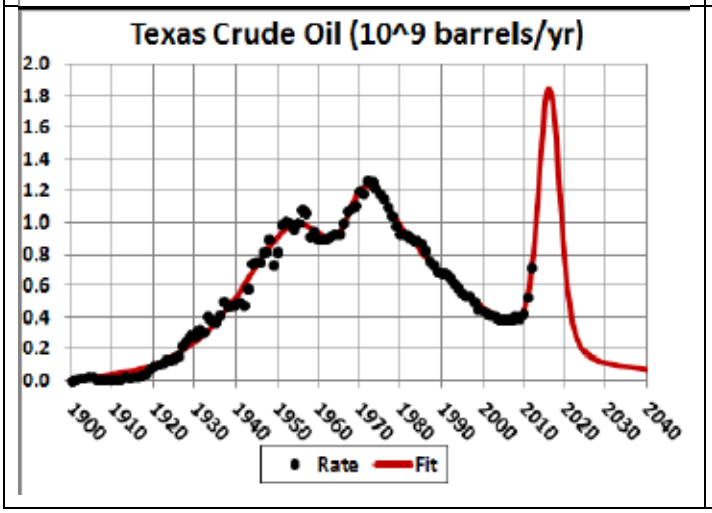
Increasing the reserves by large amounts will not change the peak data by very much:

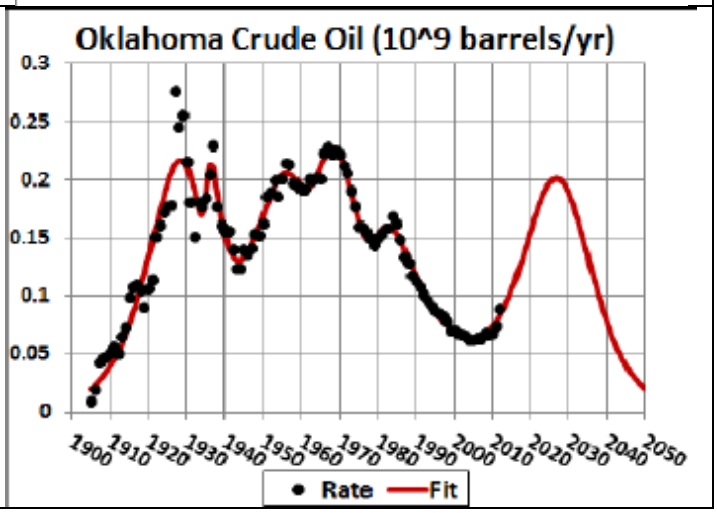


The following graphs show crude-oil extraction data for the three US states with the largest extraction. The red curves are the best fits to the data using the Verhulst function (http://www.roperld.com/science/minerals/VerhulstFunction.htm) to fit the data.

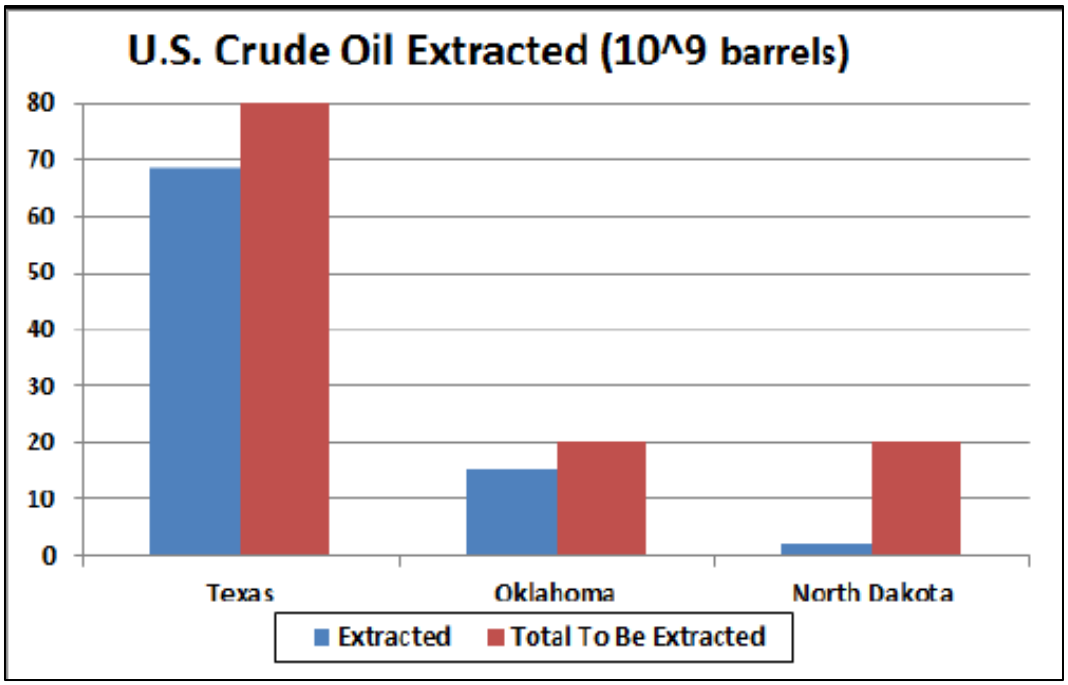




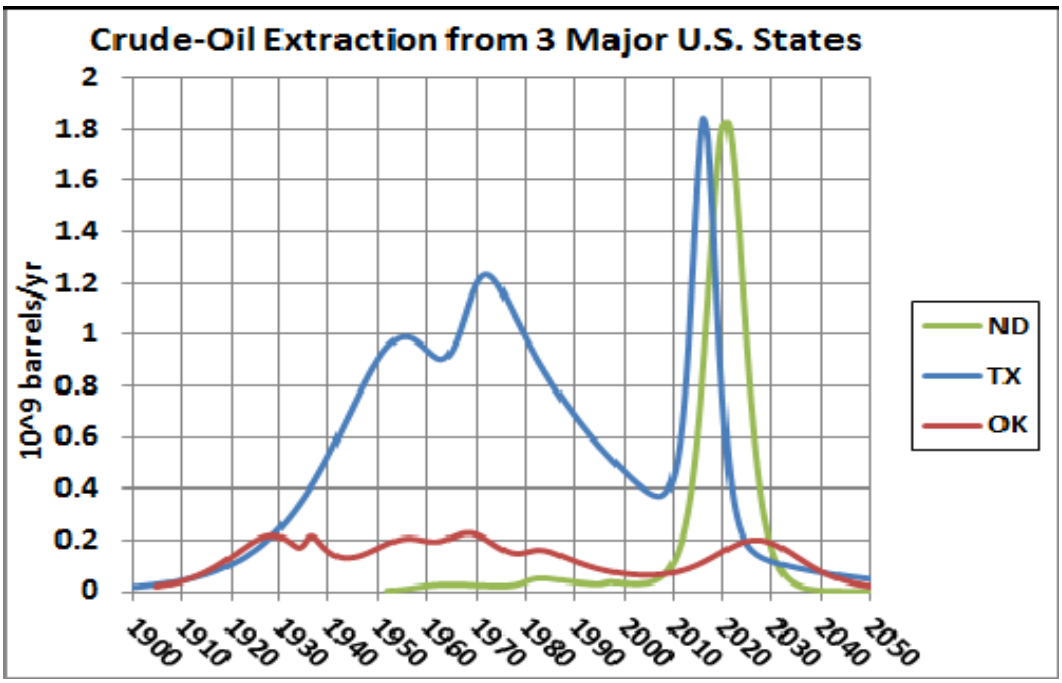




The following graph shows the amount already extracted and the total amount to be extracted for the three states with the largest extraction amounts.



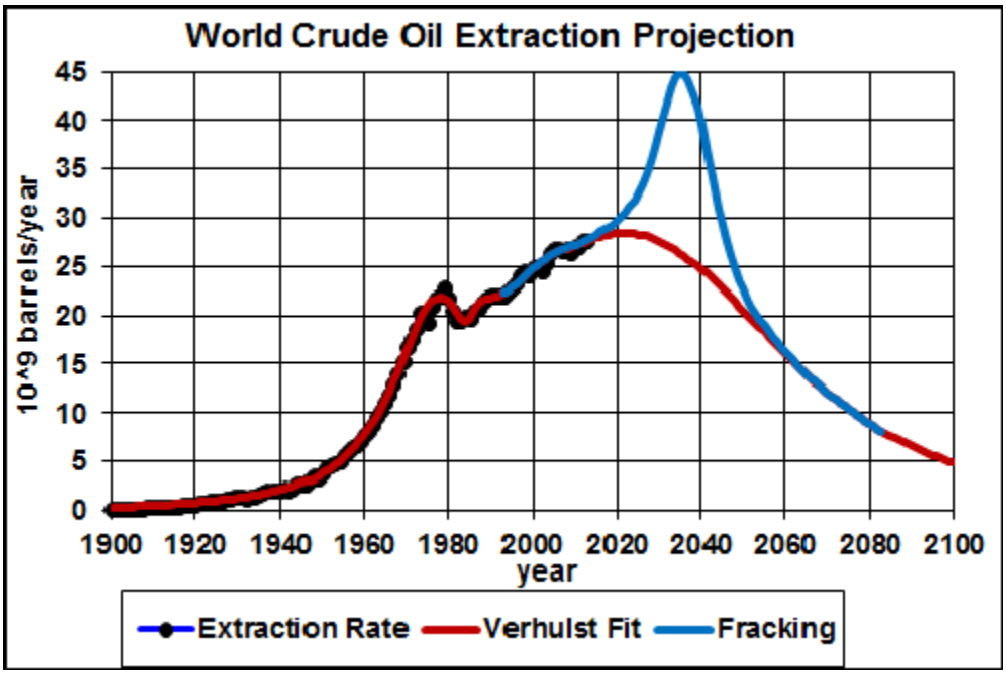
The following graph shows the extraction rates versus year for the three states with the largest extraction.



The large recent peaks for Texas and North Dakota are due to fracking (http://en.wikipedia.org/wiki/Fracking); the crude oil is being extracted so fast that extraction will peak very soon.

Fracking for Tight Crude Oil

The Energy Information Administration estimates that the world technically recoverable resources for tight oil are 345 billion (10^9) barrels. Using 300 x 10^9 barrels as the amount of world tight oil reserves and reasonable values for the peak position and rising time constant for world tight oil, the following is a reasonable depletion curve for world crude oil:



So, fracking for tight oil might delay the extraction peak for world crude oil by ~15 years, which will be followed by a fast decline.

Replacing Crude Oil as a Source of Energy

The curves above make it very clear that other sources of energy beside crude oil must be developed very soon. Fortunately, wind and solar energy are well underway, but their development needs to be greatly accelerated. Fortunately, wind is most available at night and solar energy is most available during the day, so they complement each other.

The major use of crude oil for energy is in producing gasoline, diesel and kerosene fuel for vehicles. The world needs to move very rapidly to replace gasoline vehicles and some diesel vehicles by electric vehicles, large diesel vehicles by biodiesel vehicles and airplane fuel (kerosene) by biodiesel airplanes.

A large fleet of electric vehicles would enable those vehicles to be used as energy storage, when not being driven, for renewable wind and solar energy. Also, when slightly less capacity batteries are replaced in electric vehicles, the replaced batteries can be used for storage for renewable wind and solar energy.

References

- http://www.roperld.com/science/minerals/minerals.htm
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- http://www.roperld.com/science/minerals/CrudeOilExtractionUS.pdf
- http://www.roperld.com/science/minerals/USOilBoom_Bust.htm