Fossil Fuels Extraction for the World and the United States

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Introduction

Available energy makes possible plant and animal life. It allows humans to organize into civilizations. Many books and web pages have been written about the uses of energy by humans, so I will not belabor that here.

The main source of available energy for human use since humans evolved was solar energy, which is manifested in many ways; for example, direct radiation, wind and water. The amount of energy available for use by humans greatly increased when ways to efficiently mine coal were developed in the nineteenth century. Then the amount increase even more when ways to efficiently extract petroleum and natural gas from the Earth were developed in the twentieth century.

However, those fossil fuels provide much smaller available energy over time than do solar energies. In fact, humans have extracted the fossil fuels so fast, that the extraction peaks occur within about a century after the extraction started at high volume.

Herein are shown the time dependence of fossil fuels extraction for crude oil, natural gas and coal for the world and for the United States. It is shown that humans do not have much time left to use the remaining fossil fuels to develop the infrastructure for efficient use of solar energies.

To be realistic one must consider depletion functions to determine the amount of fossil fuels left for human use. It is meaningless to consider only the time remaining at current usage rates, since usage rates vary with time.

Some mathematics are required to understand the time dependence of fossil-fuels extraction. A depletion function that allows asymmetry with time is needed; a good choice is the Verhulst function (http://www.roperld.com/science/minerals/VerhulstFunction.htm):

$$P(t) = \frac{Q_\infty}{n\tau} \frac{\left(2^n - 1\right)\exp\left(\frac{t - t_{\frac{1}{2}}}{\tau}\right)}{\left[1 + \left(2^n - 1\right)\exp\left(\frac{t - t_{\frac{1}{2}}}{\tau}\right)\right]^{\frac{n+1}{n}}}$$

The Q parameter is the total amount eventually to be extracted. The n parameter is a measure of the asymmetry: symmetric is n=1, skewed to early times is n<1 and skewed to later times is n>1.

For more information about minerals depletion see http://www.roperld.com/science/minerals/DepletTh.htm.

Crude Oil

Good data are available for crude-oil extraction rates for the United States and the world: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5&pid=57&aid=1&cid=regions&syid=2006&eyid=2010&unit=TBPD

United States Crude-Oil Extraction

Figure 1 shows a fit of the Verhulst function to the crude-oil extraction data for the United States.

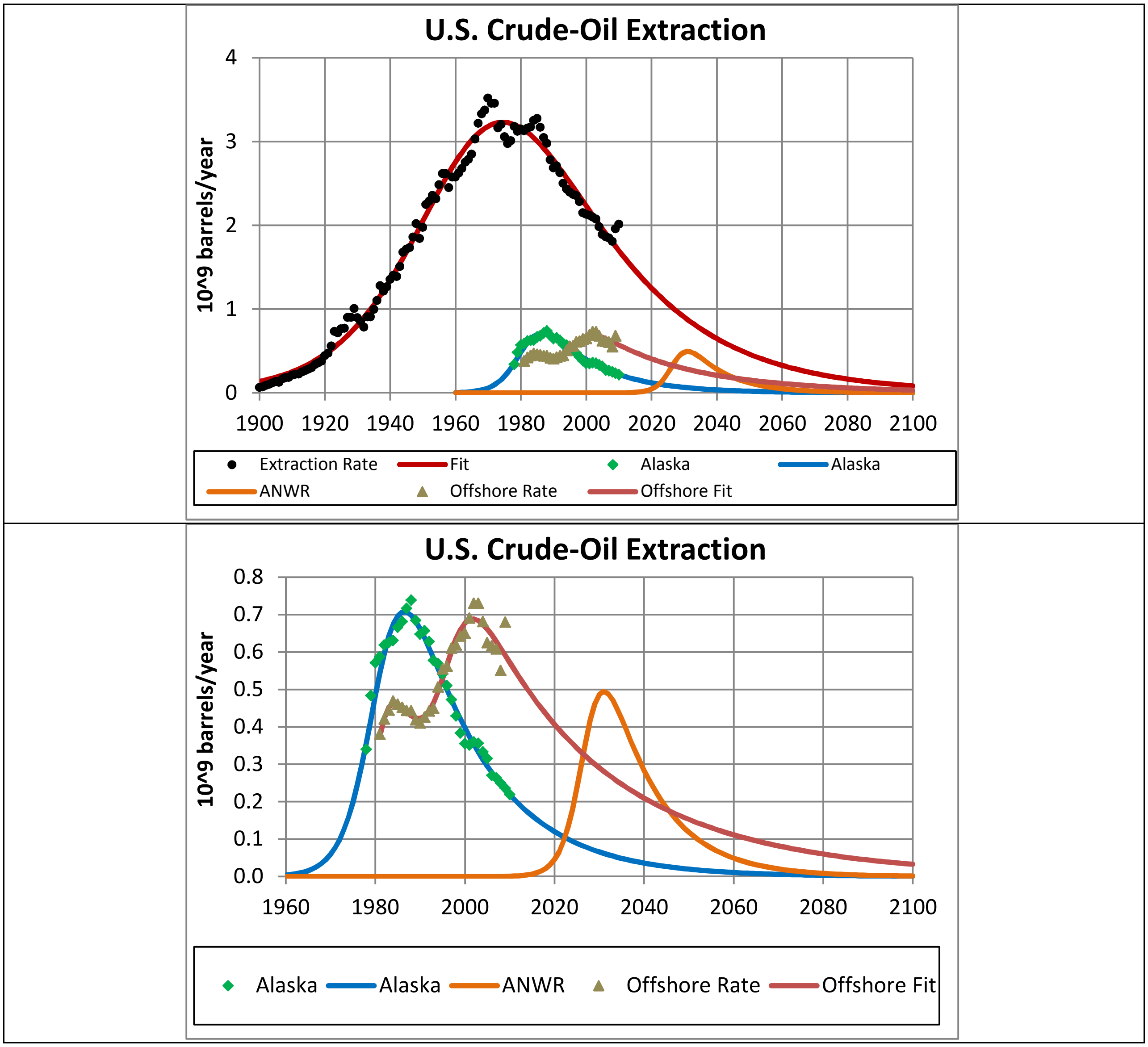


Figure 1. U.S. Crude-Oil Extraction

Note the fit to the Alaskan extraction (green data points and blue curve), which caused a small blip in the overall U.S. extraction curve and similarly for offshore extraction. The orange curve shows a guess at the extraction curve for the proposed extraction of crude oil in the Alaskan National Wildlife Refuge (ANWR; http://en.wikipedia.org/wiki/ANWR), assuming total extraction of 10 billion barrels (http://www.warriorsfortruth.com/alaska-oil-anwar.html); doubling the amount to be extracted in ANWR will not change the peak position by more than a few years. As for the Prudhoe Bay, Alaska extraction and offshore extraction, ANWR extraction would only be a small blip in the overall U.S. extraction curve.

World Crude-Oil Extraction

Figure 2 shows a fit of two Verhulst functions to the crude-oil extraction data for the world.

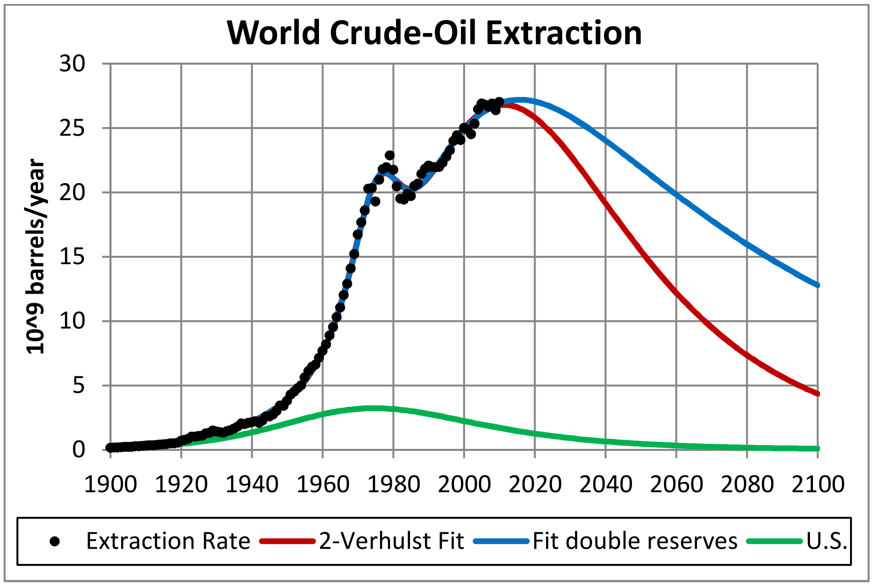
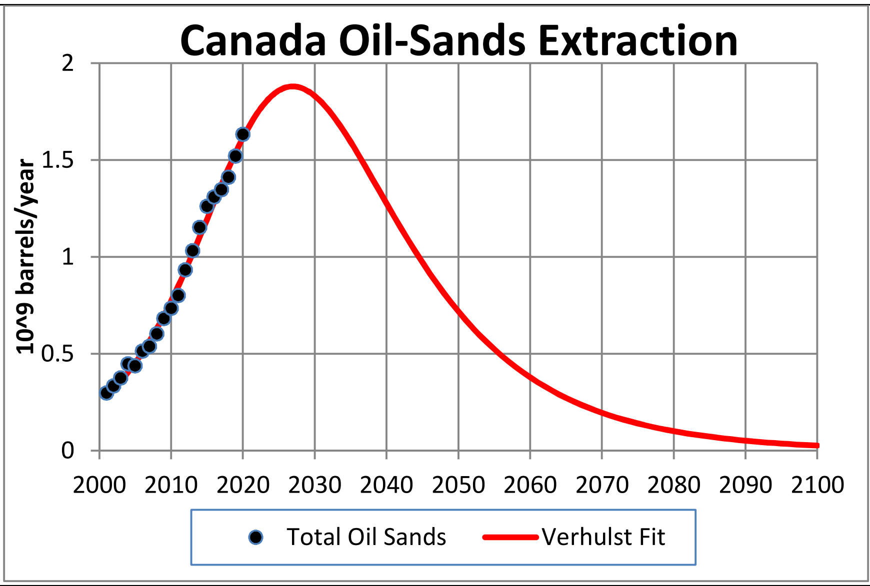


Figure 2. World Crude-Oil Extraction

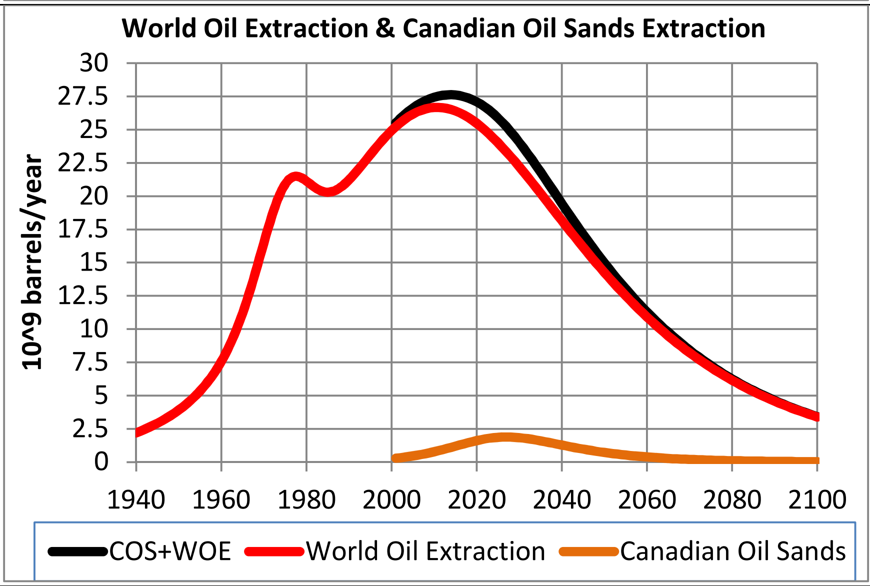
The red curve assumes an optimistic (http://www.eia.gov/international/reserves.html) world crude-oil reserves of 1500 billion barrels and the blue curve assumes unrealistic double reserves of 3000 barrels. The peaks differ by only ~4.5 years.

Canadian Oil Sands Extraction of Crude Oil

Some are touting Canadian oil sands as a large contributor to crude-oil supplies for the United States. Using data from http://www.capp.ca/aboutUs/mediaCentre/Pages/2008CanadianCrudeOilForecast.aspx#L2WklAD74HHm, which forecasts crude-oil extraction from Canadian oil sands to the year 2020, a Verhulst fit yields the curve in Figure 3.



Canada Oil-Sands Extraction
10^9 barrels/year
2
1.5
1
0.5
0
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Total Oil Sands
Verhulst Fit



World Oil Extraction & Canadian Oil Sands Extraction
10^9 barrels/year
30
27.5
25
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
1940 1960 1980 2000 2020 2040 2060 2080 2100
COS+WOE
World Oil Extraction
Canadian Oil Sands

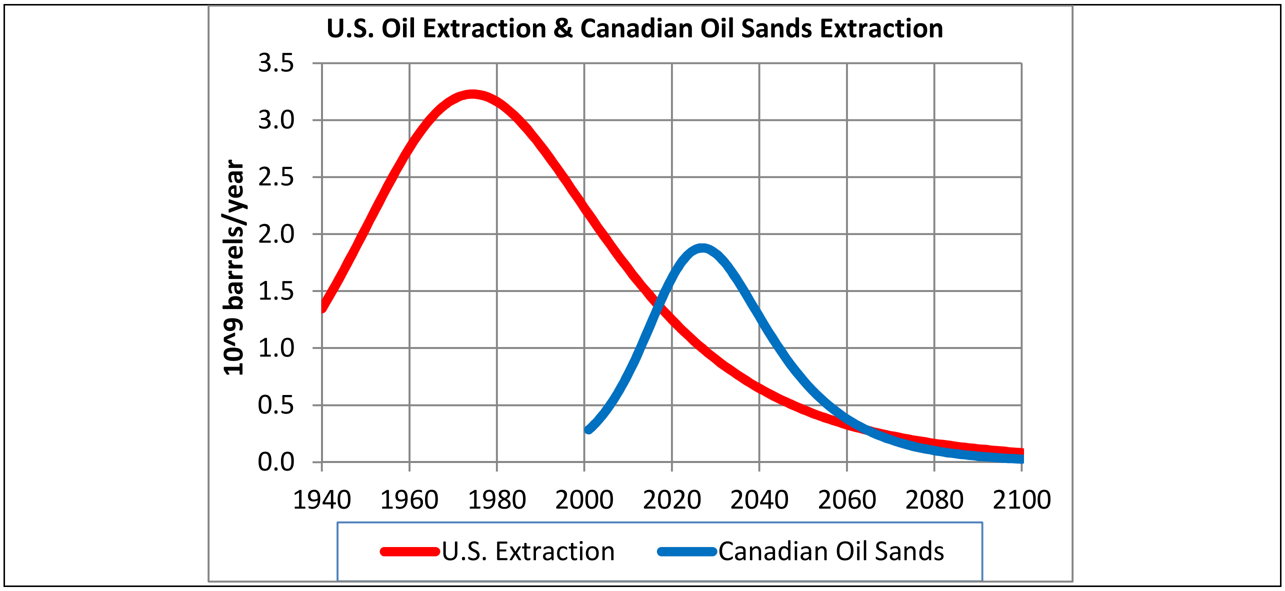


Figure 3. Crude-Oil Extraction from Canadian Oil-Sands

The curve is the best fit of a Verhulst function to the forecasted Canadian oil-sands extraction "data"; it has a Q value of 73.4 billion barrels, which is much more than would be expected from the reserves given (http://www.capp.ca/library/statistics/basic/Pages/default.aspx#qOSe3lL0upC6: 2006 reserves of ~12 billion barrels). That is, by 2010 about 7 billion barrels had been extracted; add that to 12 billion and Q would be 19 billion, much more than 73 billion. The second graph shows the small blip of crude oil from Canadian oil sand on the total world extraction curve. The third graph compares Canadian oil-sand extraction to United States crude-oil extraction.

From the world viewpoint, Canadian oil sands would be a small blip on the extraction curve (~2 billion barrels/year compared to ~25 billion barrels/year).

It appears that, in an unlikely case where the United States would get most of the crude oil from Canadian oil sands, the result would be a peak before year 2030 of slightly more than one-half of the extraction peak for United States crude oil that occurred ~1975.

Conclusion about the Availability of Crude Oil

Humans do not have much time left to use the remaining fossil fuels to develop the infrastructure for efficient use of solar energies. Future generations will ask why their ancestors burned fossil fuels so extravagantly instead of using it to make materials and for creating future energy infrastructure.

Natural Gas

Good data are available for natural-gas extraction rates for the United States and the world: http://www.eia.gov/emeu/aer/txt/ptb0602.html.

The proven reserves value has been rising over the last few years (http://www.rigzone.com/news/article.asp?a_id=101780) due to fracking for shale gas. For an estimate of future shale extraction I use a very optimist reserves for shale gas of ~500 trillion cubic feet.

United States Natural-Gas Extraction

Figure 4 shows a fit of the Verhulst function to the shale-gas extraction data for the United States using a Q value of 500 trillion cubic feet:

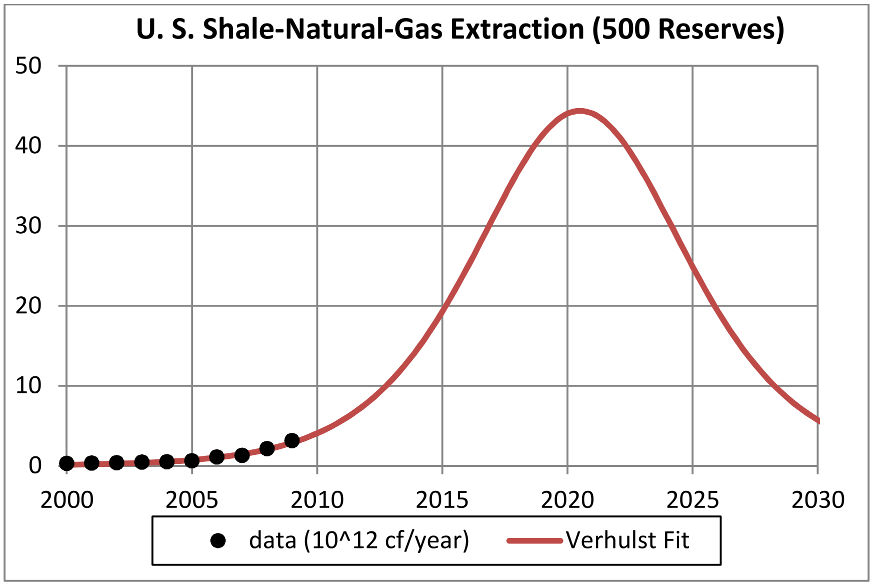


Figure 4 U.S. Shale-Gas Extraction

An assumption was made that the curve is symmetric, although it probably will be asymmetric, perhaps falling off faster than rising if environmental degradation increases due to the extraction or perhaps falling slower than rising.

Figure 5 shows a fit of a two Verhulst functions fit to all natural-gas extraction data for the United States using the shale-gas fit of Figure 4.

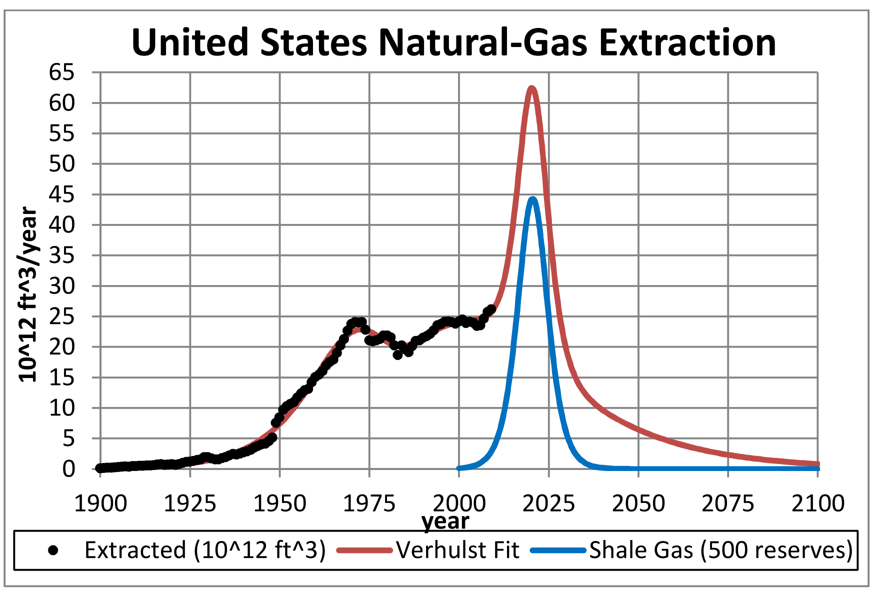


Figure 5 U.S. Natural-Gas Extraction