World Fossil-Fuels Depletion

L. David Roper
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http://www.roperld.com/personal/RoperLDavid.htm

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- Projection of World Fossil Fuel Production with Supply and Demand Interactions, Steve Mohr PhD Thesis
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- Fracking for Tight Oil and Shale Gas in the U.S.
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- Natural-Gas Boom and Coming Bust in Texas
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- US_Marcellus_Natural Gas Graphs
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Using the Depletion Theory that I have previously developed, I show here fits to United States and World extraction of crude oil, natural gas and coal. The depletion equation used to fit the extraction data is the Verhulst function:

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

The amount left to be extracted is:

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

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 0 < n < 1 and skewed to later times is n > 1.

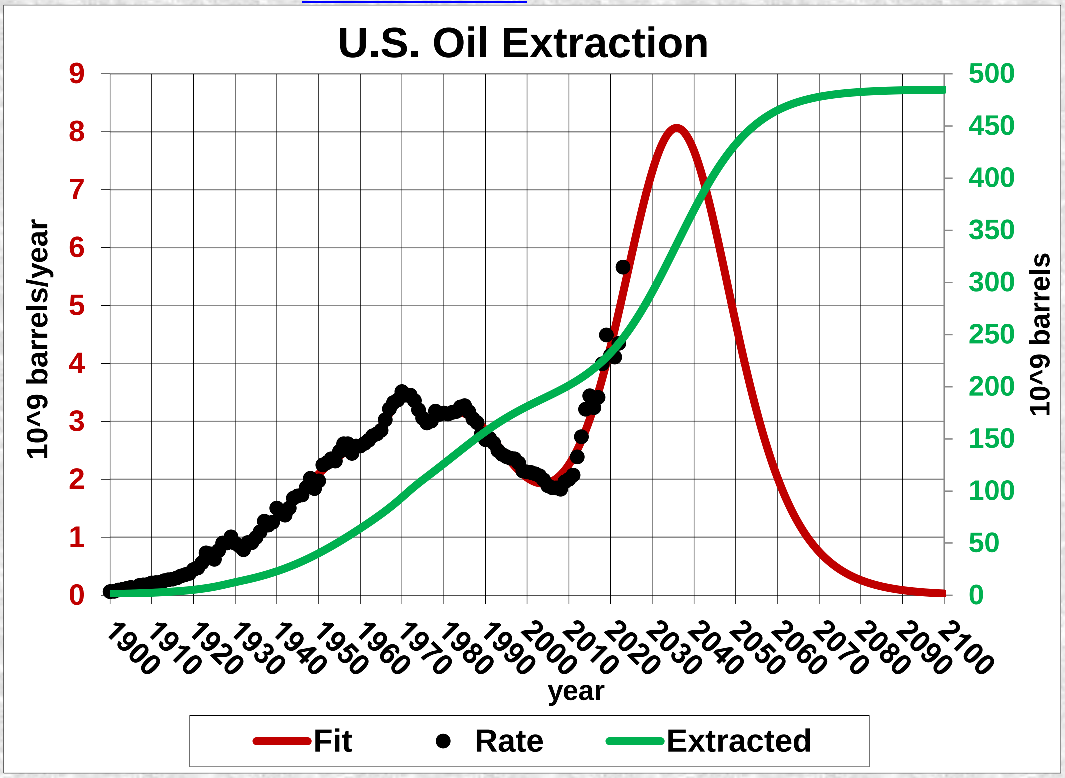
United States Crude-Oil extraction
These data came from http://www.eia.doe.gov/pub/international/iealf/table24.xls.

United States Crude-Oil Extraction

Current Crude-Oil-Futures Price

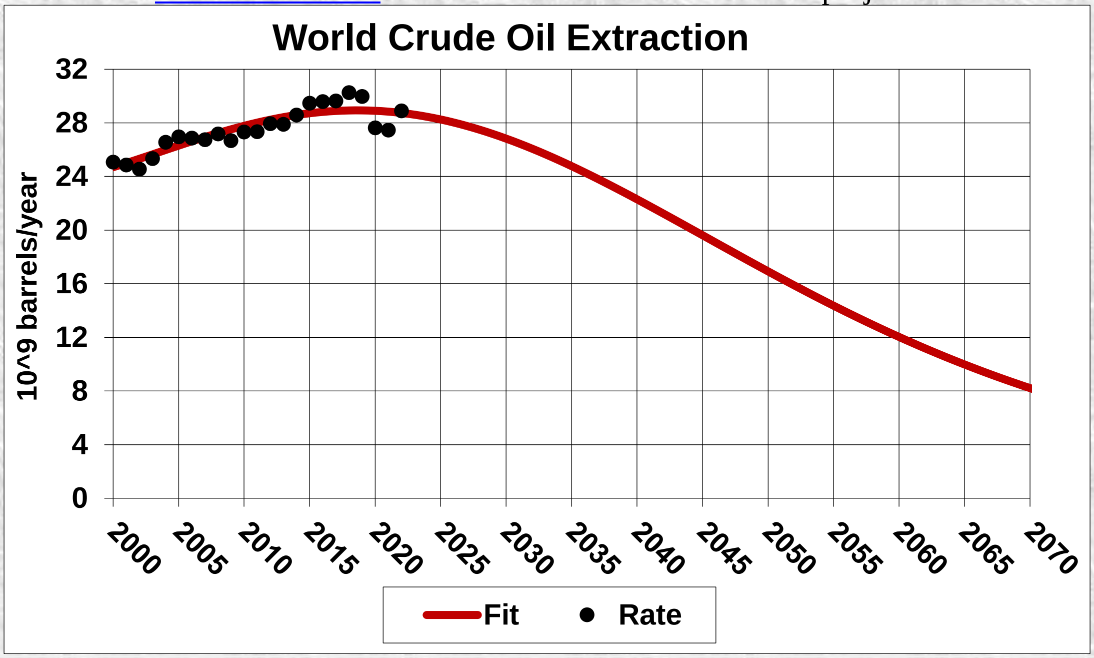
U.S. crude-oil discoveries (http://www.durangobill.com/Rollover.html) and a Verhulst-function fit to the data.
The USA are Burning Strategic Oil Reserves (several graphs)

Fit of the Verhulst function to U.S. crude oil extraction:



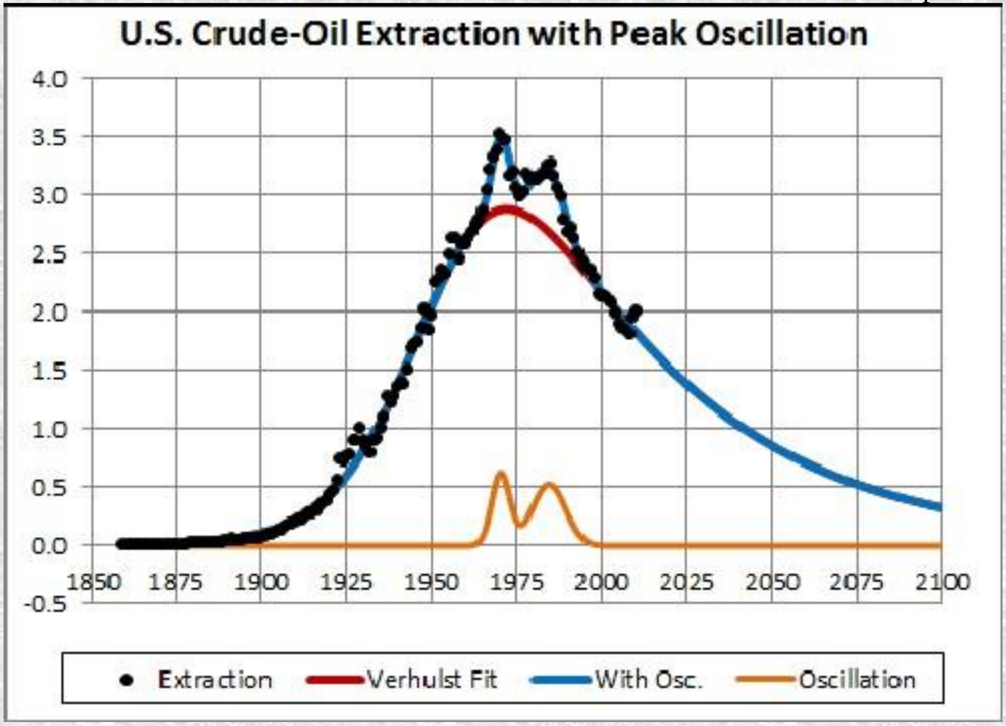
The large recent peak is due to fracking, starting with vertical fracking and now with horizontal fracking.

Fit of the Verhulst function to World crude oil extraction and projection to 2070:



When natural resources peak, they usually oscillate around the peak.

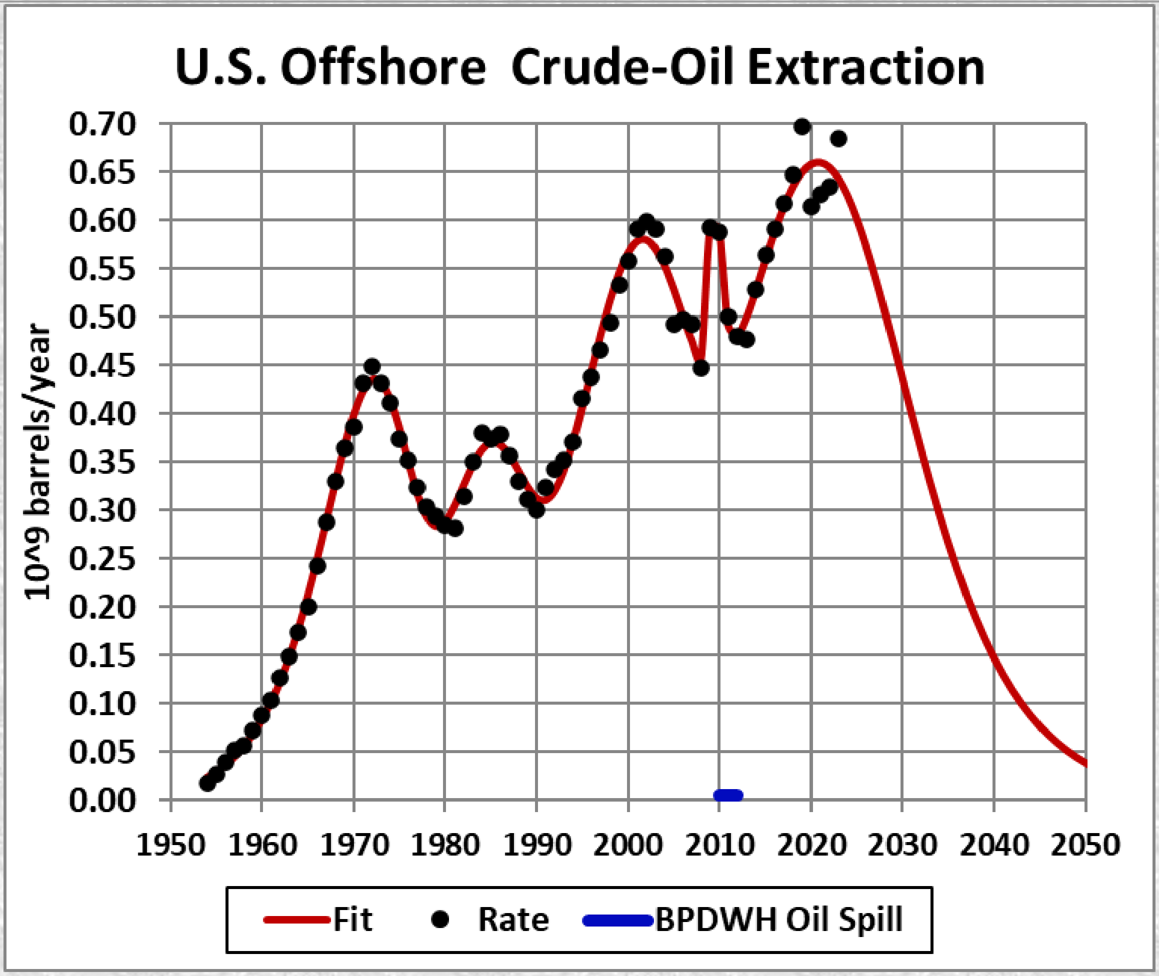
U.S. Crude-Oil Extraction with sinx/x oscillations on both sides of the peak:



The oscillation is mathematically represented by two sinx/x functions, one before the peak and one after the peak; they are added to the Verhulst function. An equally good fit can be obtained by using two Gaussian functions instead of sinx/x functions.

My reasoning for the oscillation is that, when starting to peak, great effort is made to keep the extraction increasing; after that fails and extraction starts to fall, great effort again is made to keep it from falling. Eventually that final great effort also fails.

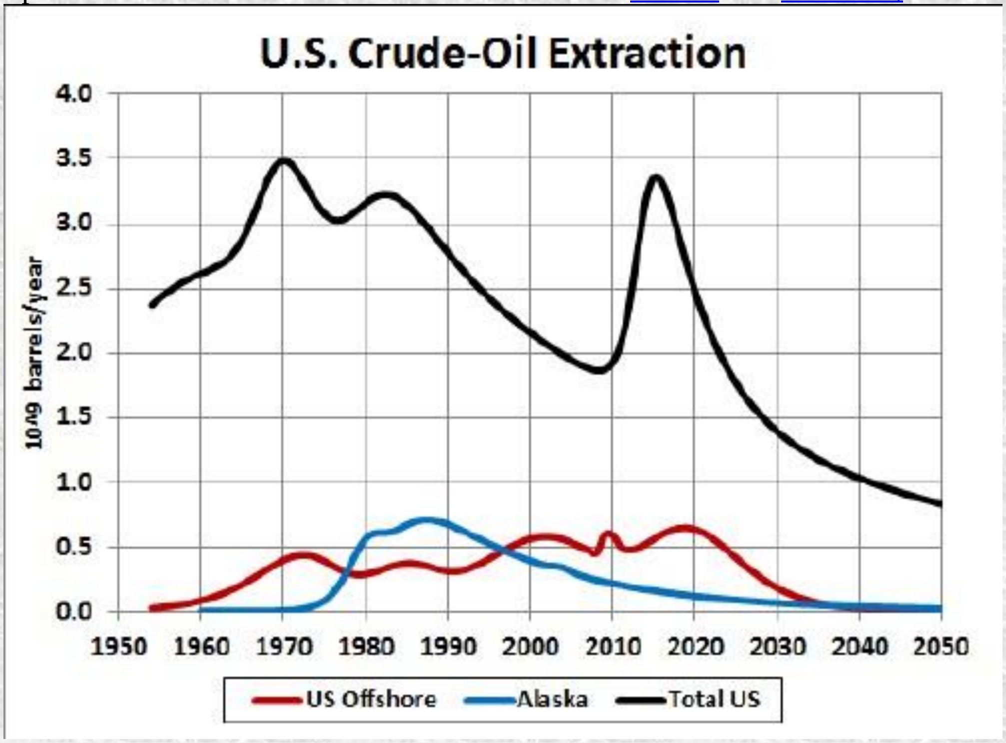
Fit of the Verhulst function to U.S. crude oil offshore extraction and projection to year 2050:



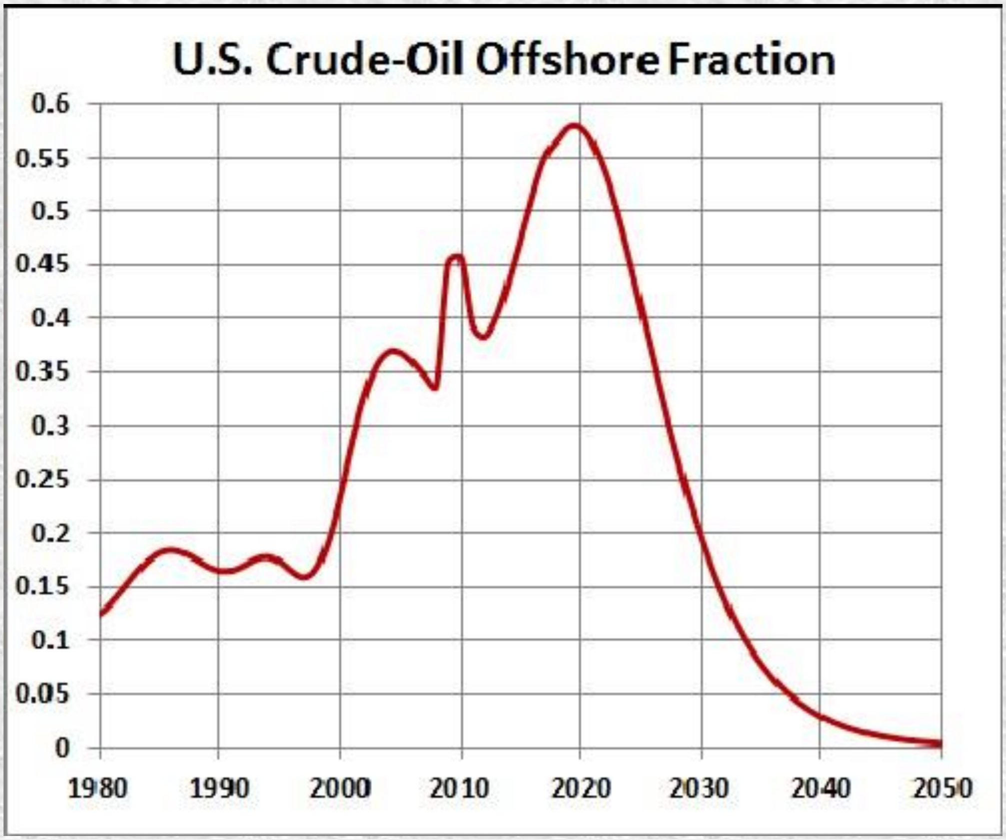
The Deepwater Horizon oil spill caused a drastic reduction in offshore extraction after 2010.

BP Deepwater Horizon Oil Spill and Offshore Drilling

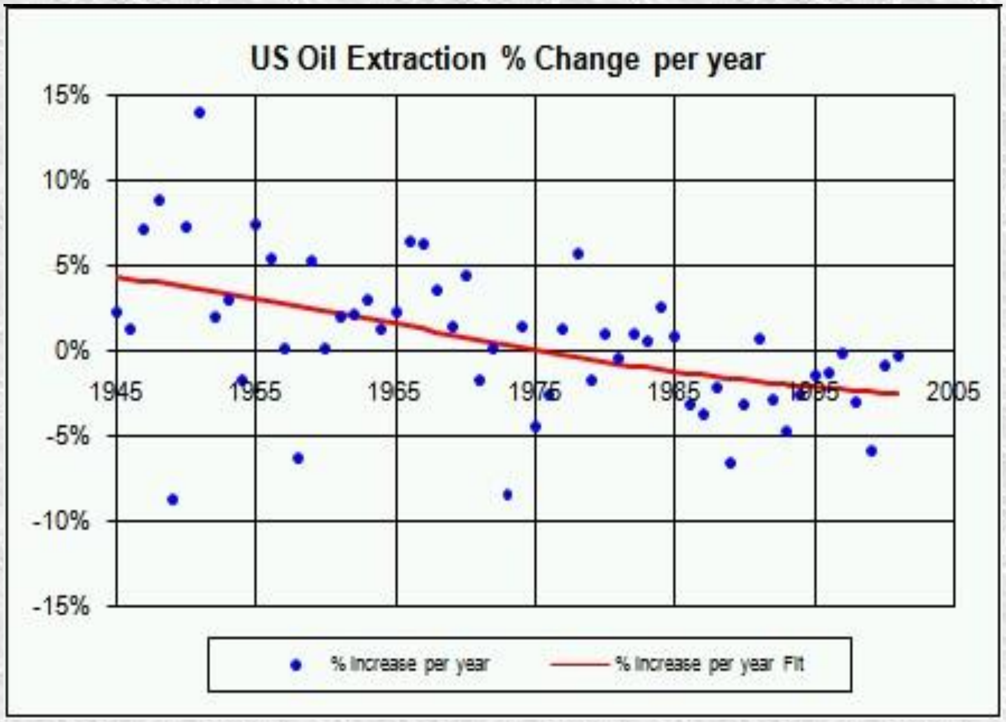
Comparison of U.S. offshore crude-oil extraction to Alaska and total U.S, extraction:



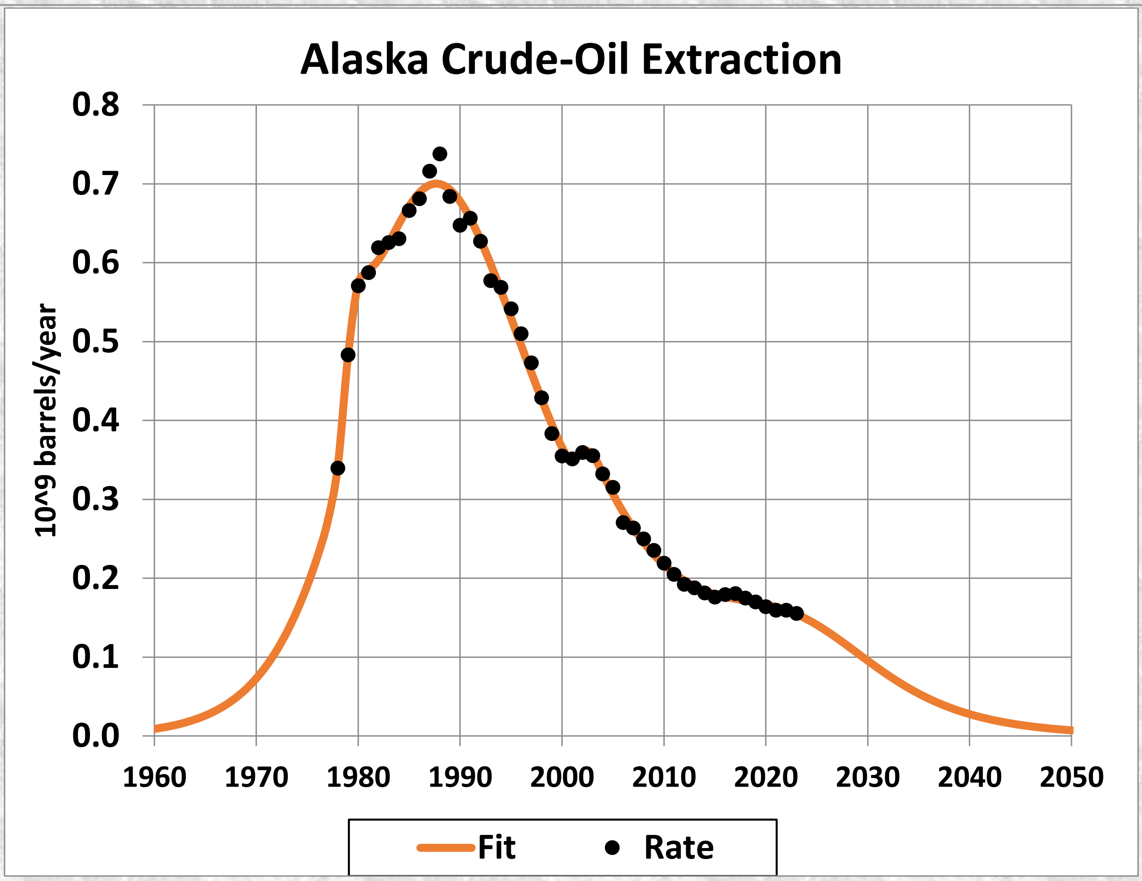
Best fit to U.S. offshore crude-oil extraction of the total extraction:



This shows the change in U.S. crude oil extraction since 1945. The biggest recent yearly decrease was -6.7% in 1989 during the BushGHW administration. The average yearly decrease was -3.1% for the BushGHW administration and -2.7% during the Clinton administration. Note that the yearly changes oscillate depending on many factors, but the general trend is downward. No administration should be blamed for most of these factors and no administration can change the fact that the U.S. is running out of economically feasible crude oil.



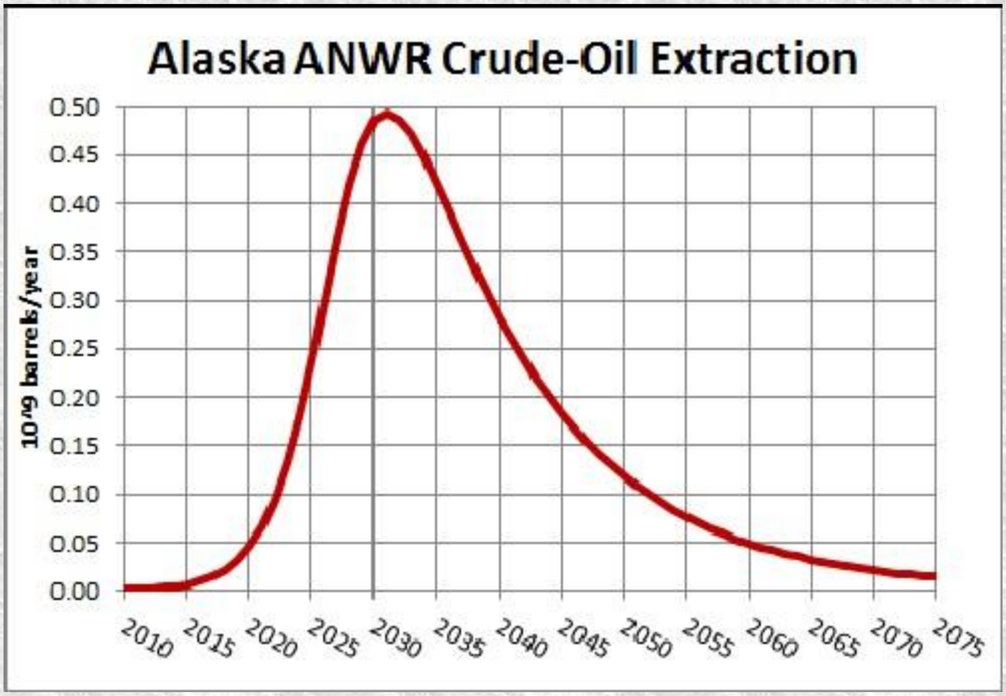
Alaska Crude-Oil Extraction



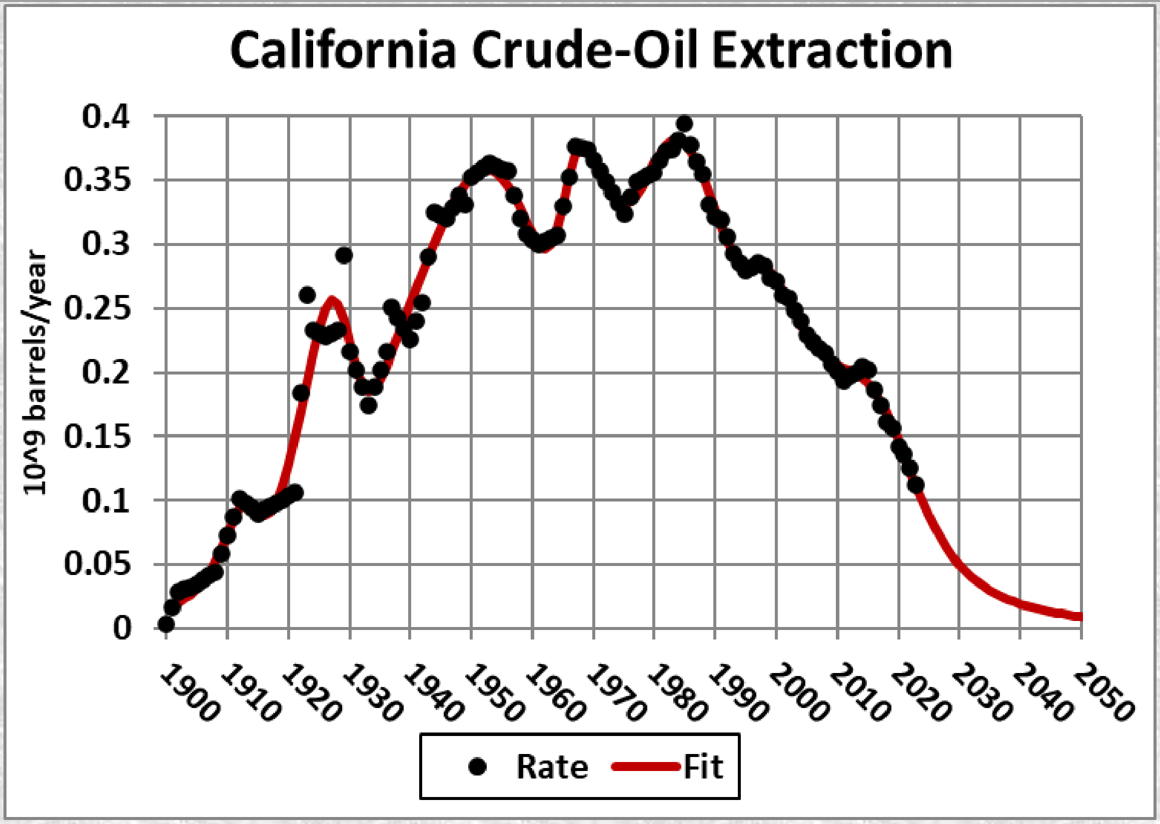
Data are from:
http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPAK1&f=M
http://www.tax.alaska.gov/programs/documentviewer/viewer.aspx?426

The extraction peak occurred in less than 2 decades after the big Prudhoe Bay discovery.

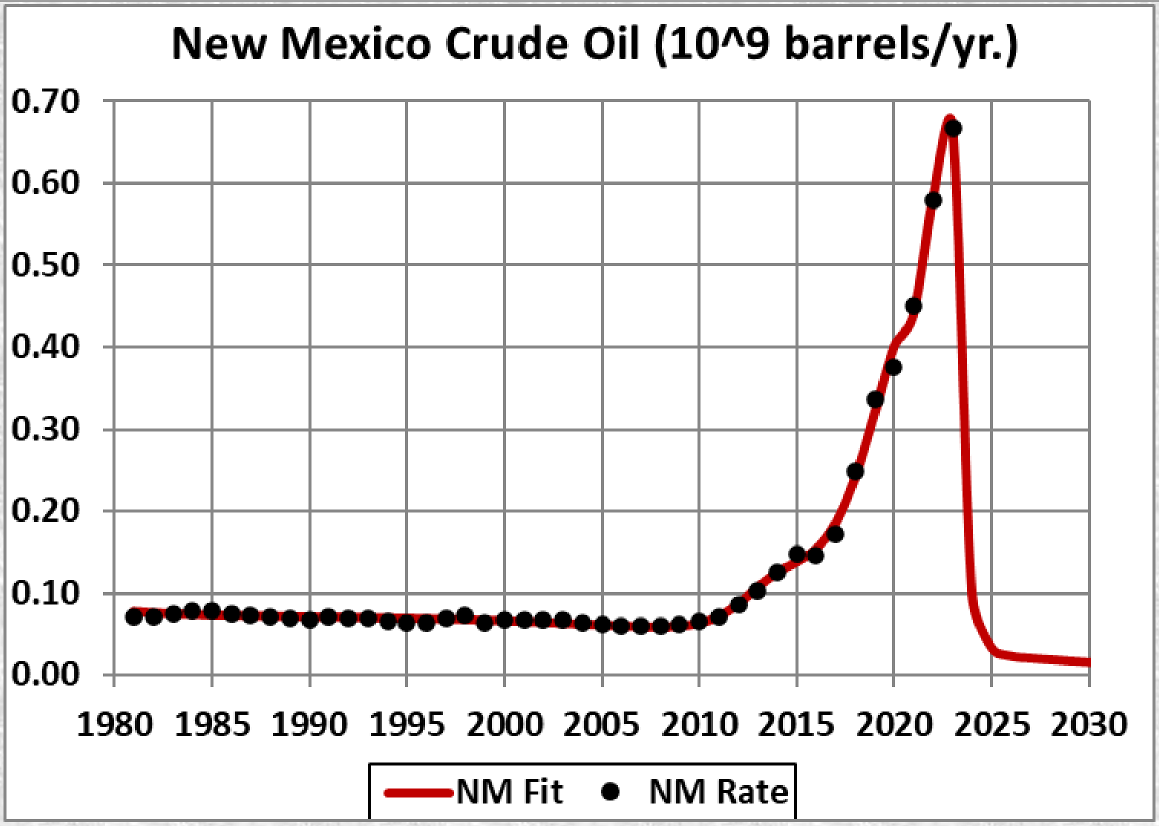
Possible Alaska ANWAR crude-oil extraction:



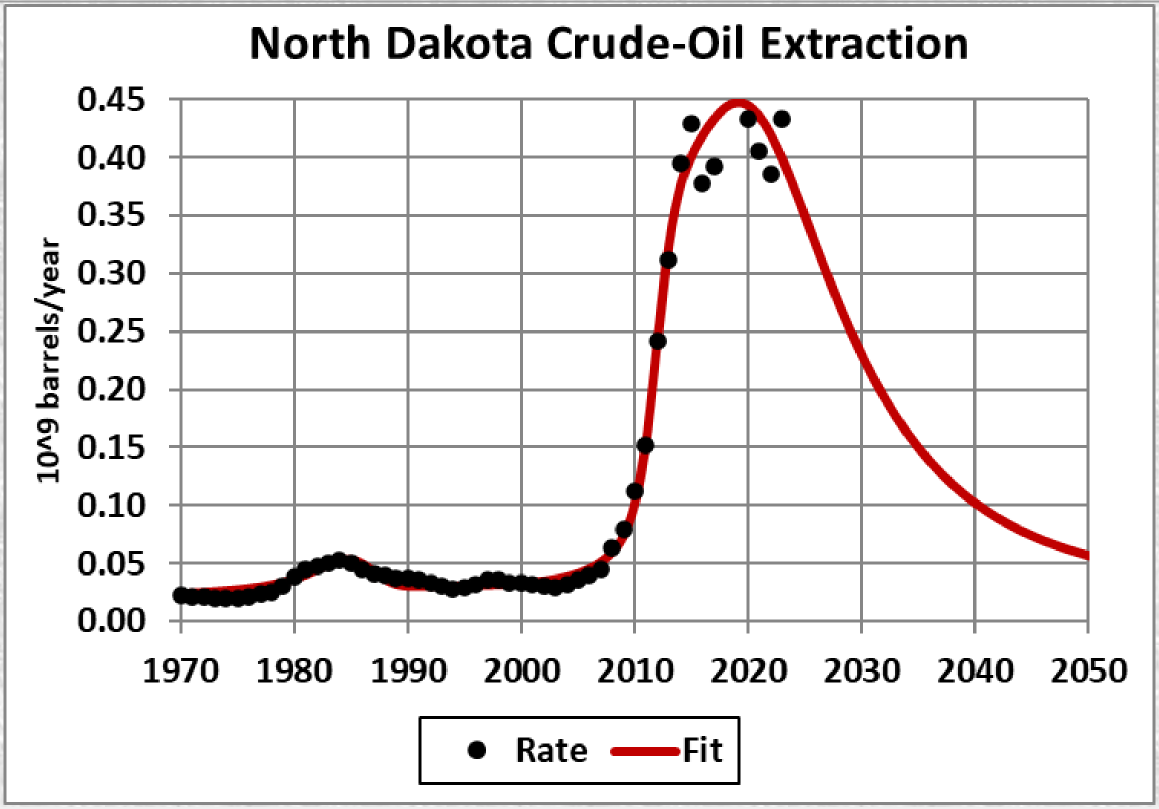
A high-value assumption has been made that the eventual total extraction will be 10^{10} barrels. Further assumptions are that the initial speed of extraction will be ~30% less than the Prudhoe-Bay speed and that the asymmetry will be the same as for Prudhoe-Bay extraction.

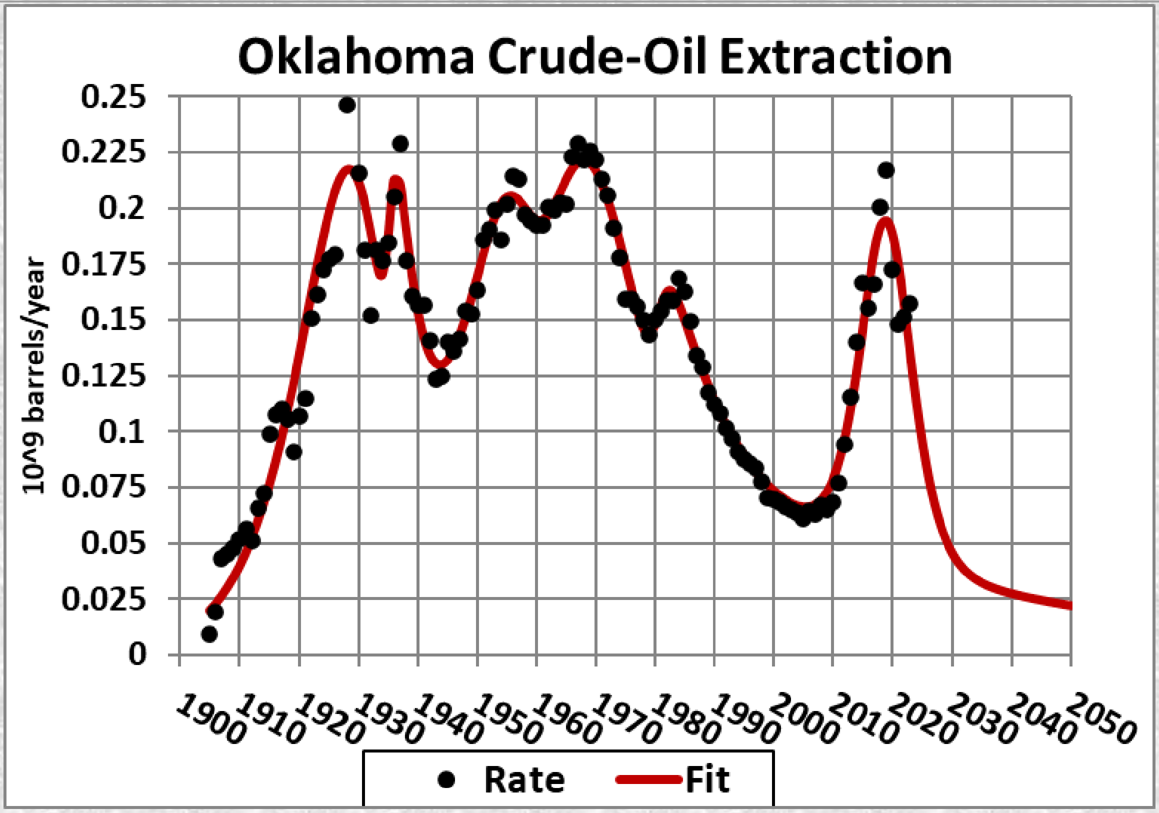


This is included because of claims that there will be future increases in crude-oil extraction in California. The sum (31.9 x 10^9 barrels) of the 2014 EIA estimate of reserves (~2.854 x 10^9 barrels) and the amount already extracted (~29.0 x 10^9 barrels) is smaller than the area under the curve (38.4 x 10^9 barrels). Thus, if the EIA reserves estimate is correct, there is no major future for crude-oil extraction in California.

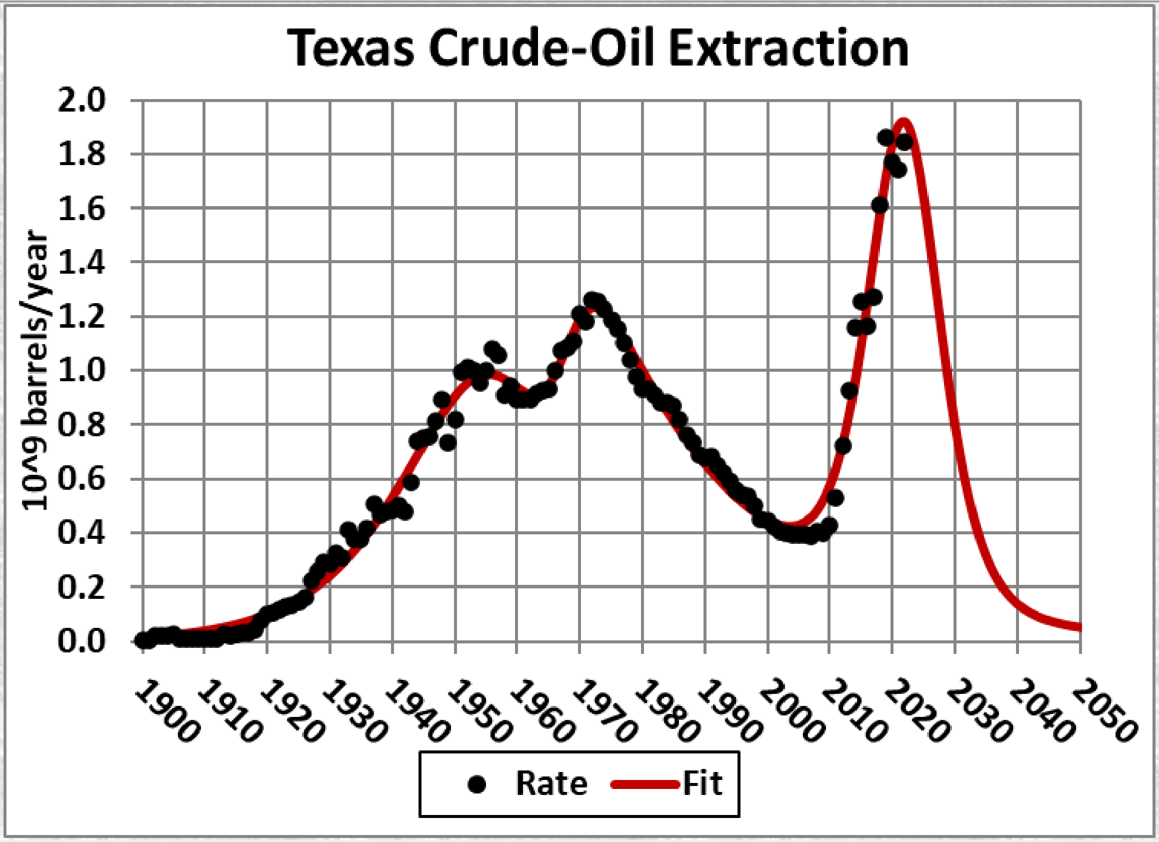


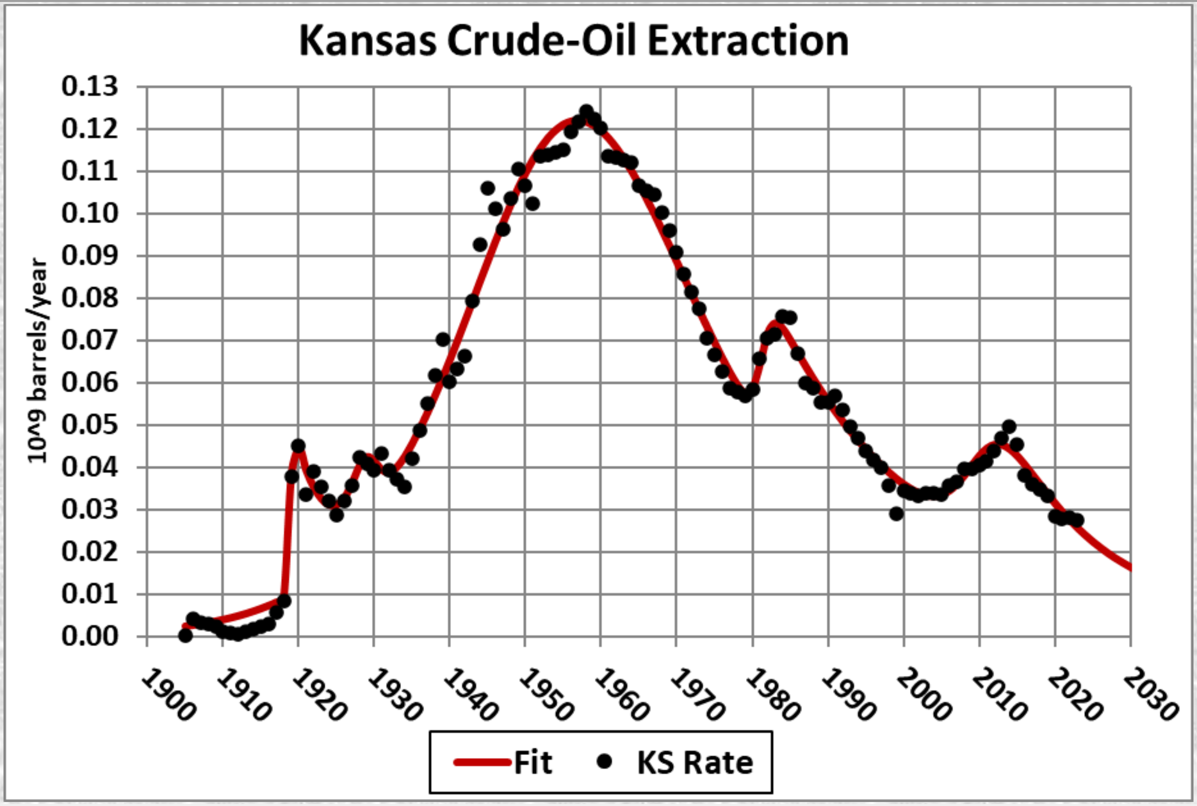
This is for reserves larger than the 2014 reserves of 1.558 x 10^9 barrels.





The last peak is fracked oil. The recent rise is horizontal fracked oil.

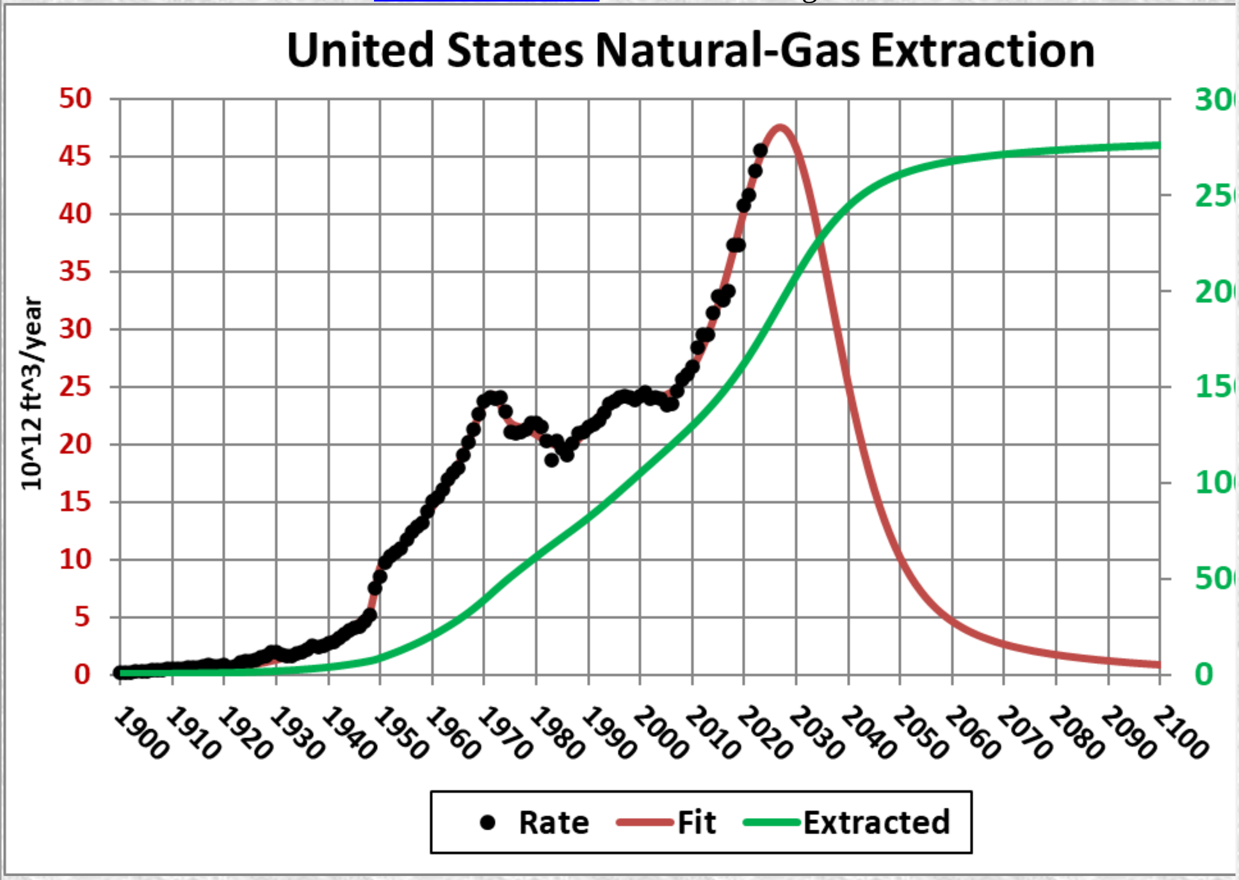




United States Natural-Gas Extraction

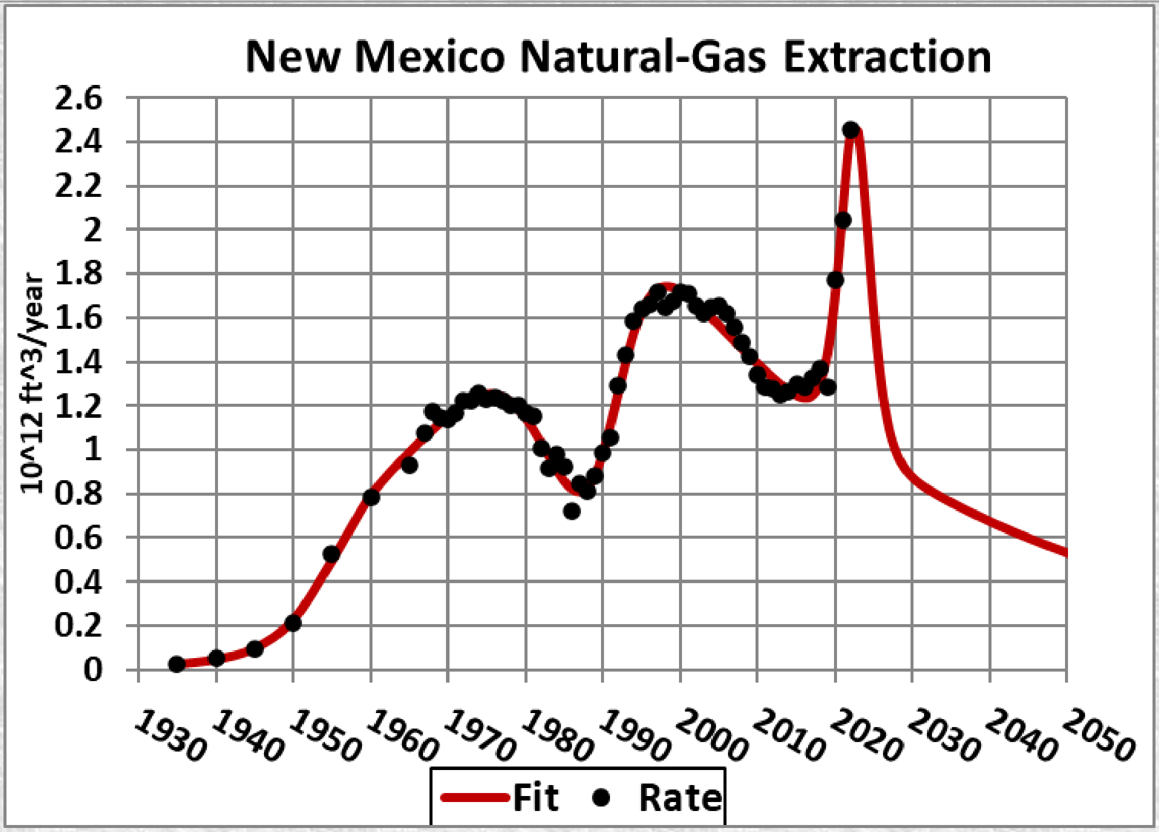
Current Natural-Gas-Futures Price

Fit of the Verhulst function to U.S. natural gas extraction.



The short large blip is shale gas. So, shale natural gas adds a short large blip to the natural-gas extraction for the United States. It could be reduced in size and stretched out over a larger time interval, but I doubt it will be. The U.S. will probably extract and use it as fast as possible.
See http://www.roperld.com/science/minerals/NaturalGasUS.htm .
See http://www.roperld.com/science/minerals/USGasBoom_Bust.htm

The jump just before 1950 is because the previous data did not include wet natural gas.

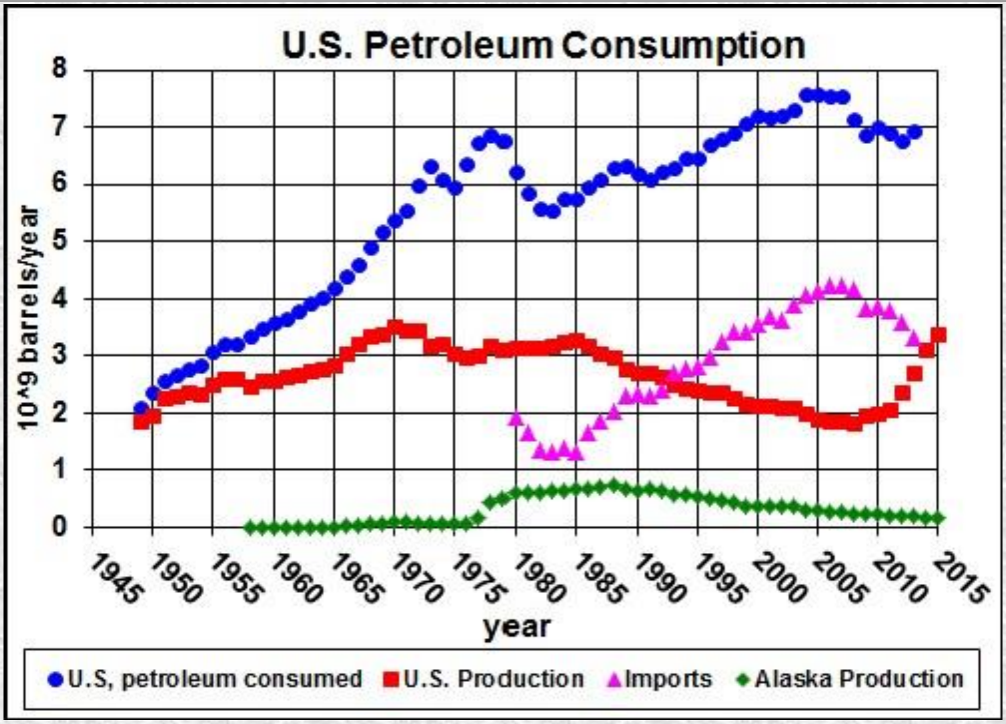


This is for reserves much larger than the 2014 reserves of 15.28 x 10^12 ft^3.

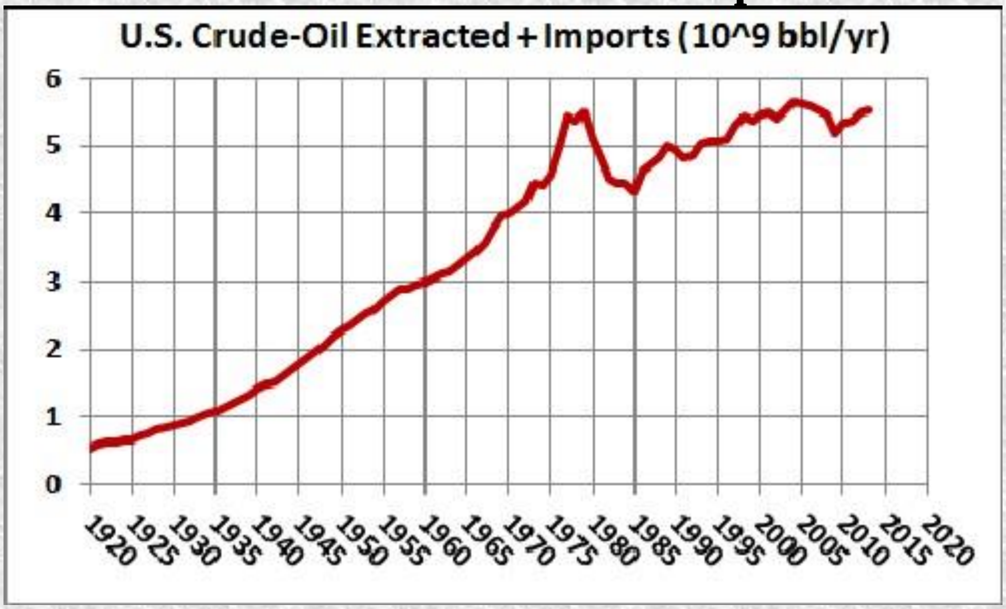
- Duration of Shale-Gas Extraction in the United States

United States Petroleum Consumption

U.S. petroleum consumption since 1949. Note the sharp downward turn during the Carter administration (1977-1980); but then the increases started again by the end of Reagan's first term (1981-1988). Then consumption leveled off during the Bush administration (1989-1992) and then continued the upward trend during the Clinton administration (1993-2000). Note how the onset of Alaska extraction caused a temporary rise in U.S. extraction; but then, after a decade, began to decline. The Arctic National Wildlife Refuge is estimated to contain 7 x 10^9 bbl of oil. This is about one year's consumption, but it will probably be extracted over a decade or longer, which will be a negligible blip on these curves.



United States Crude-Oil Imports

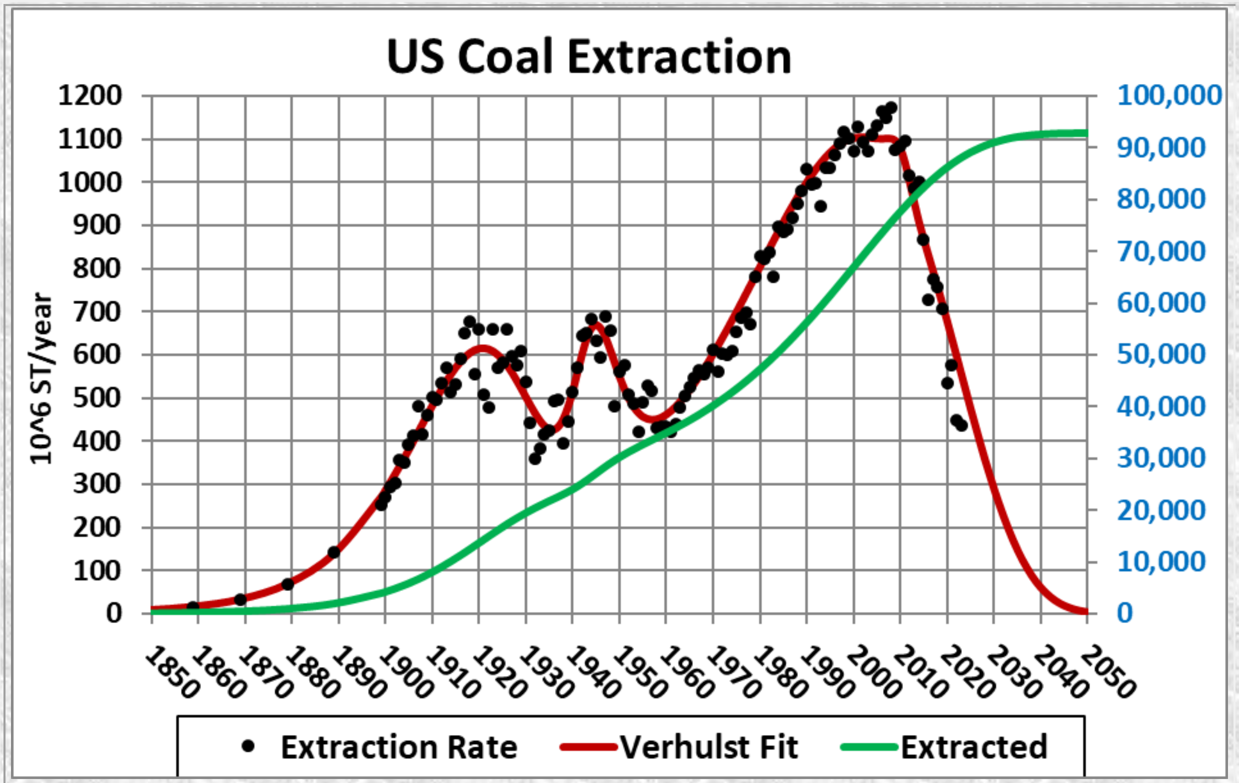


The sum was ~5.5 x 10^9 barrels/year for the last decade.

United States Coal Extraction

Current U.S. Coal Spot Prices

Here is a fit with three Verhulst functions:

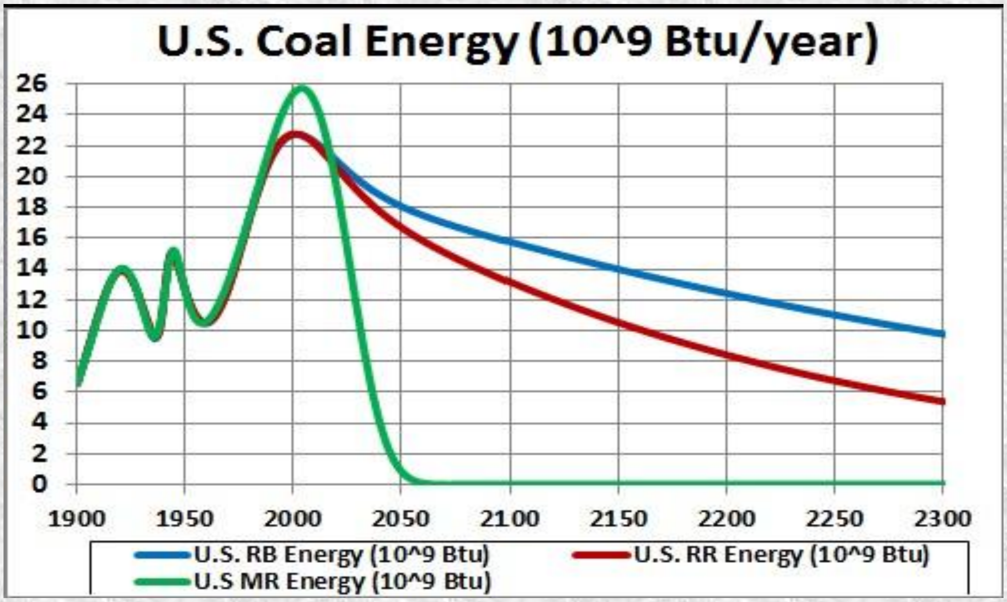


It appears that "peak coal" has arrived for the United States at about year 2005.

U.S. Coal energy/volume and a hyperbolic-tangent function fit to the data:

As seen below the final asymptote is somewhat above the energy content of lignite (14 MBTU/ST), as it should be. The initial asymptote is equivalent to mostly bituminous (20.5 MBTU/ST), as it should be.

Putting the last two graphs together, the energy available from coal in the U.S. is

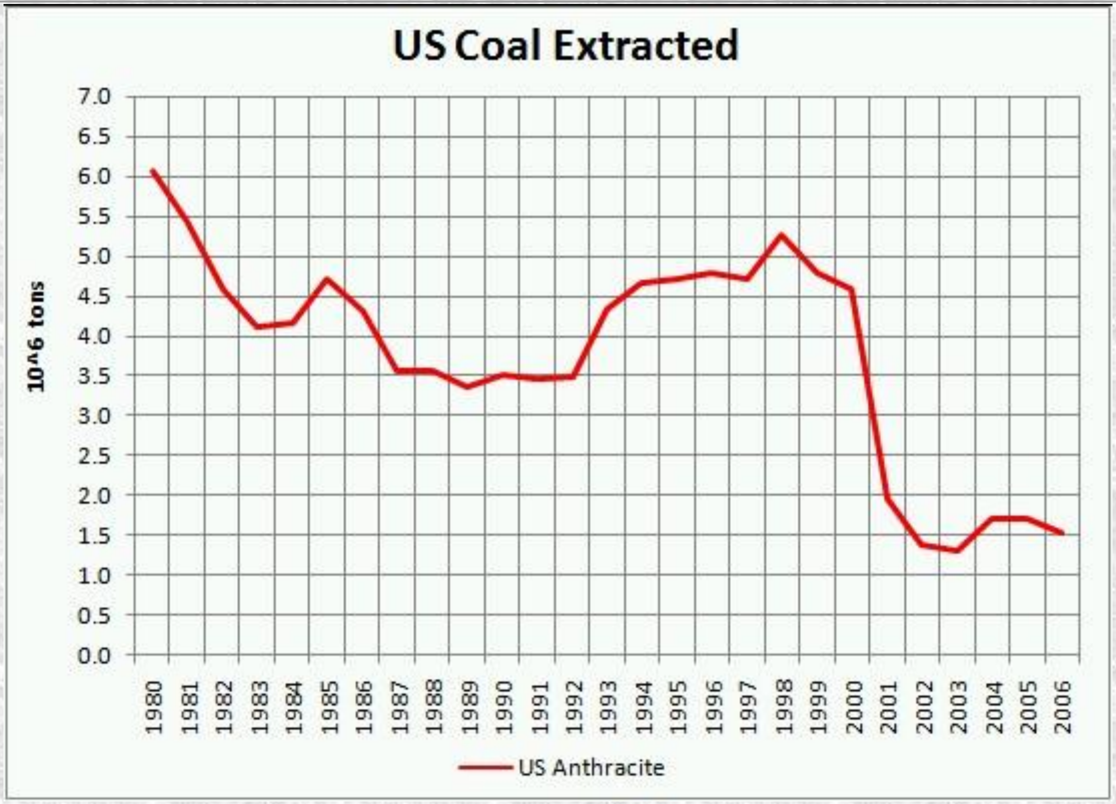


Although U. S. coal extraction peaks at ~2004-2012, U.S. coal energy peaks at ~2000-2004.

The energy contents of the three different classes of coal are (1 MBTU/ST = 0.8598 MJ/kg):

Coal energy density:	**MJ/kg**	MBtu/ST
Anthracite	32.50	28.0
Bituminous	24.00	20.5
Lignite	16.50	14.0

Most of the coal mined in the U.S. is bituminous, with a little lignite. Anthracite extraction is almost negligible:



U.S. Coal Areas:

Central Appalachia 12,500 Btu/lb, 1.2 SO2/lb	Northern Appalachia 13,000 Btu/lb, <3.0 SO2/lb	Illinois Basin 11,800 Btu/lb, 5.0 SO2/lb	Powder River Basin 8,800 Btu/lb, 0.8 SO2/lb	Uinta Basin 11,700 Btu/lb, 0.8 SO2/lb

1 BTU = 1055.056 joules = 2.930711x10^{-4} kWh
1 lb = 0.45359237 kg
1 MJ/kg = 429.9226 BTU/lb

Here are relevant data for coal extraction in millions of tons per year for the United States:

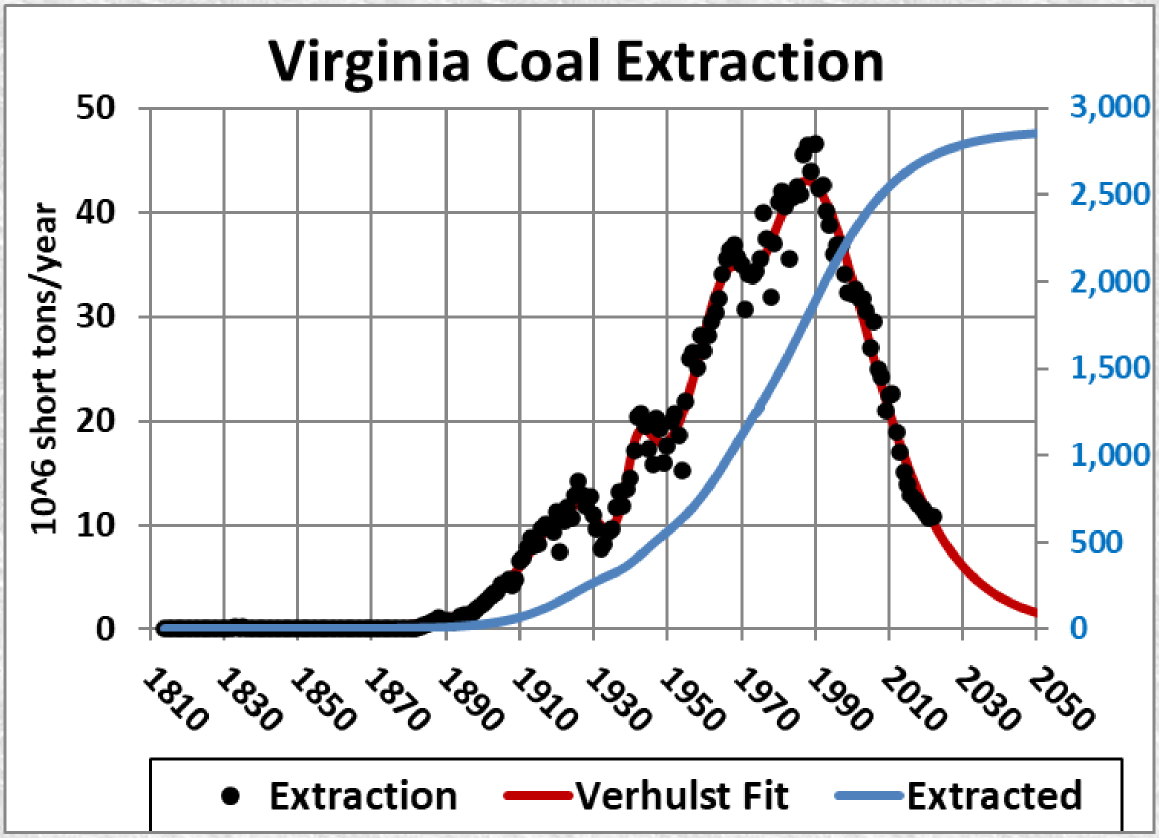
State	Peak Coal Extraction	Peak Year	% drop to 2012
United States	1172	2008	13%
Wyoming	467.6	2008	14%
Pennsylvania	277.4	1918	80%
West Virginia	181.9	1997	34%
Kentucky	173.3	1990	48%
Illinois	89.3	1918	46%
Texas	55.8	1990	21%

Ohio	55.1	1969	49%
Virginia	46.4	1988	59%

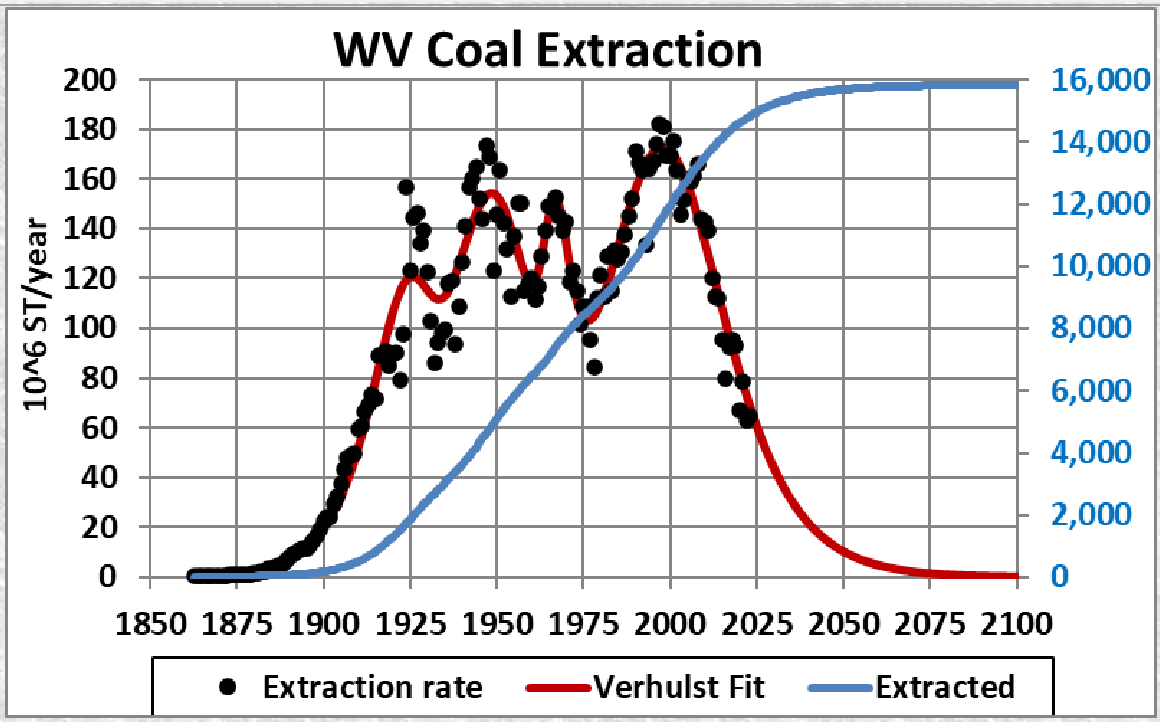
The list is for the United States and seven states that have had peaks of more than 50-million tons per year and Virginia.

Virginia and West Virginia Coal Extraction

The red curve is the best fit to the data.

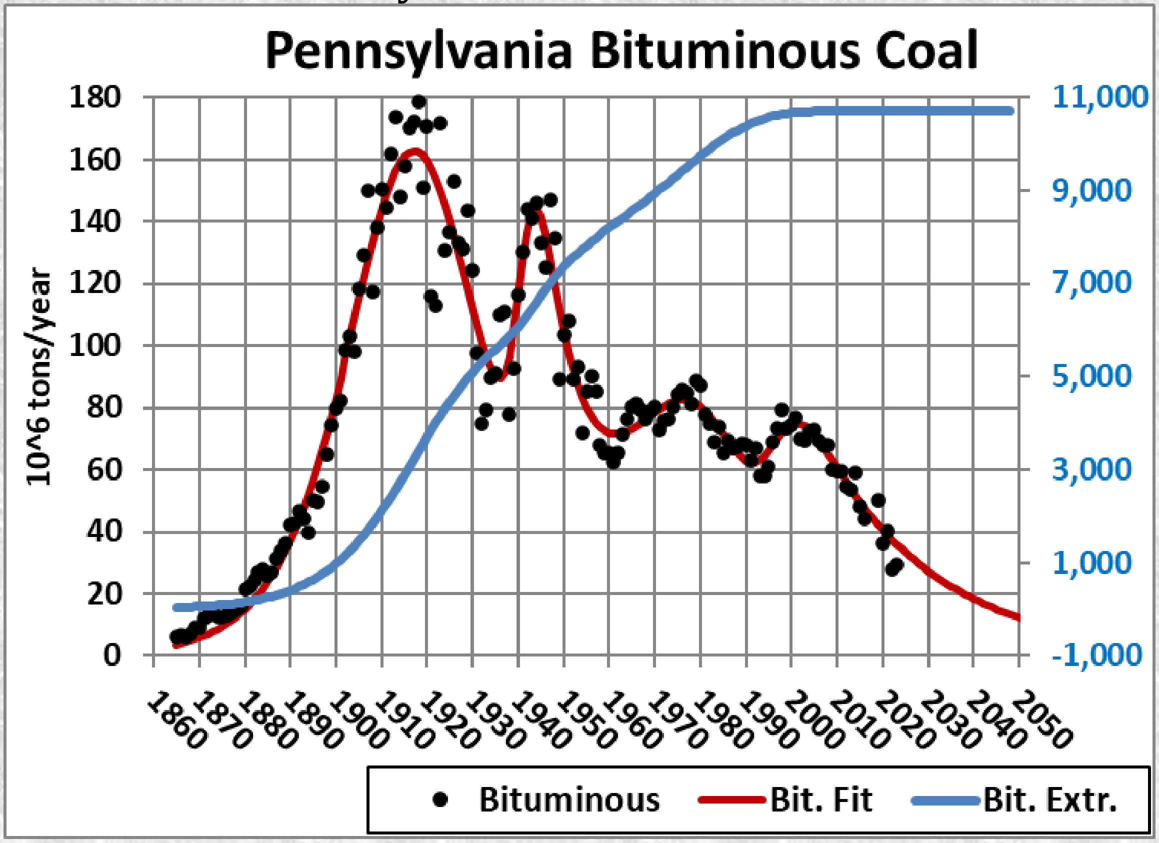


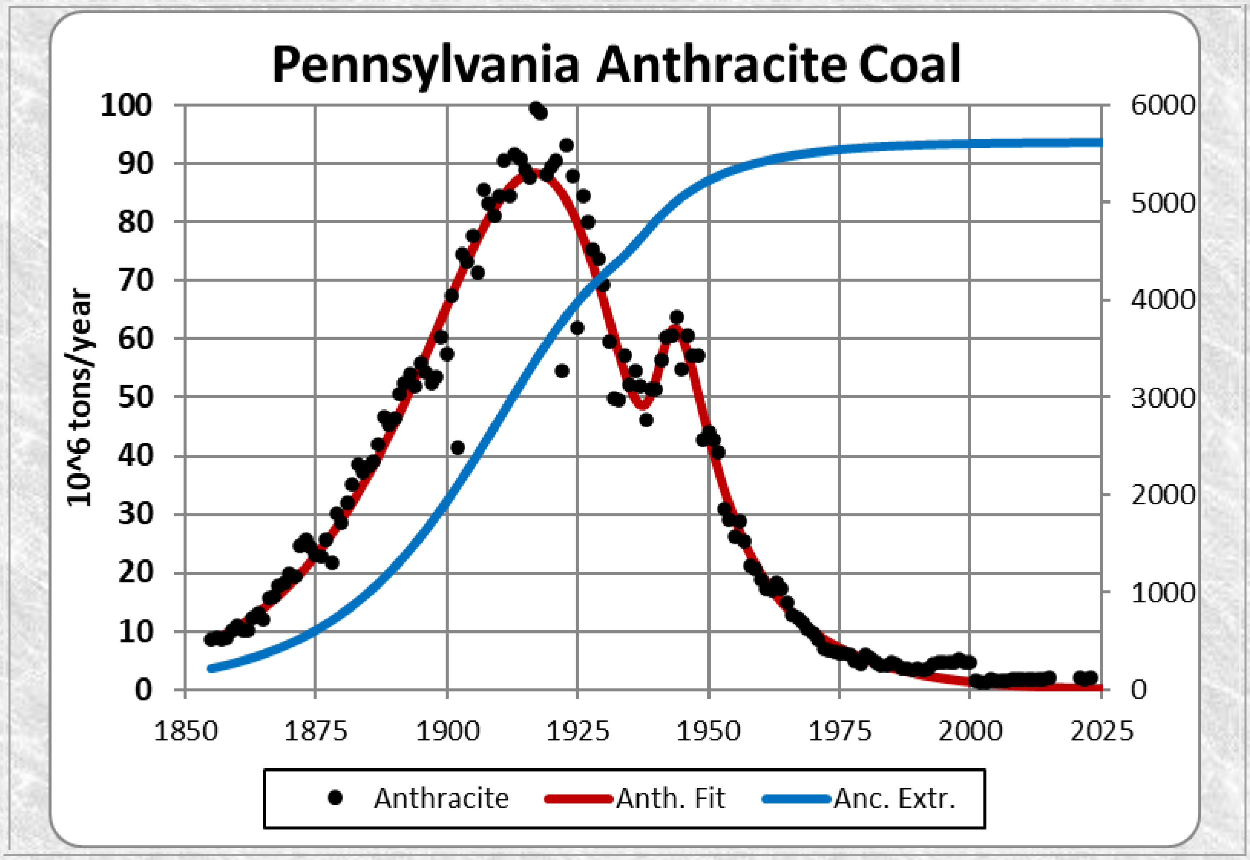
Note that the current long decline started in 1992 during the George H. W. Bush presidency.



West-Virginia coal extraction may extend into the far future; more likely it will continue the current decline.

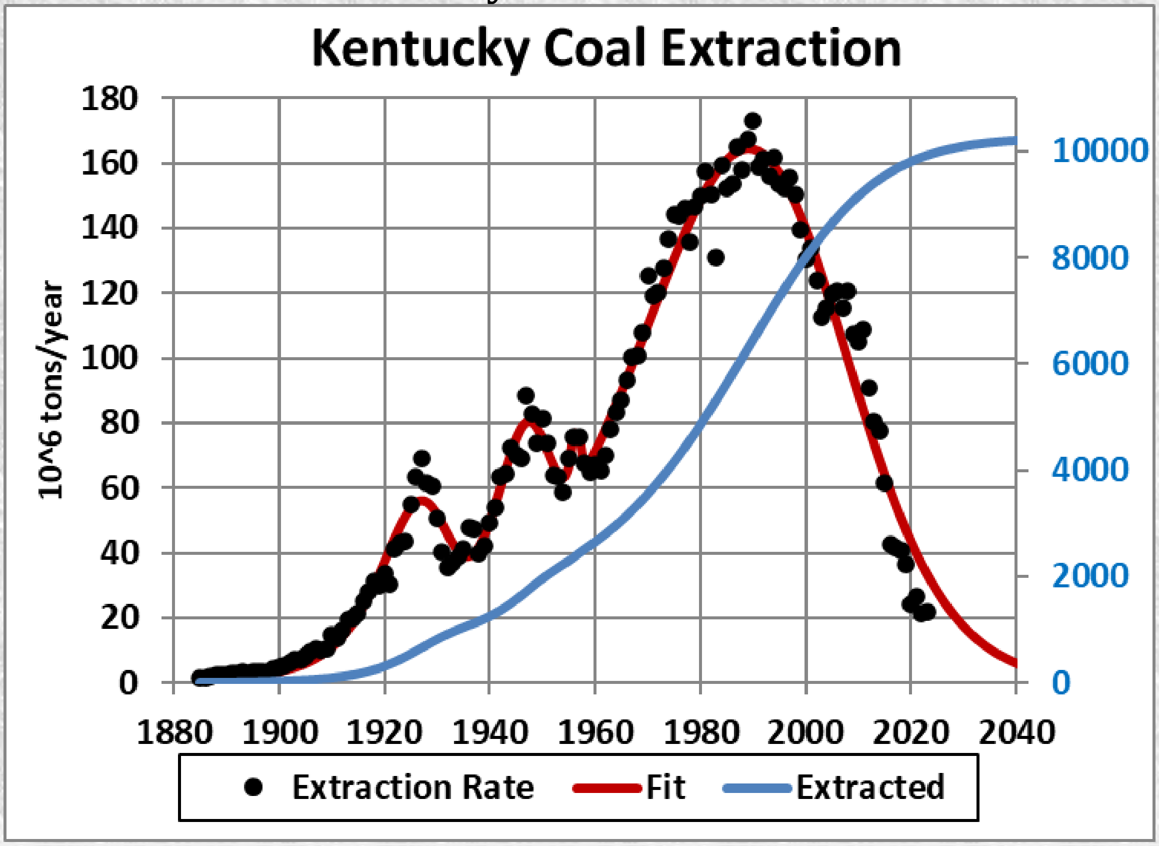
Pennsylvania Coal Extraction



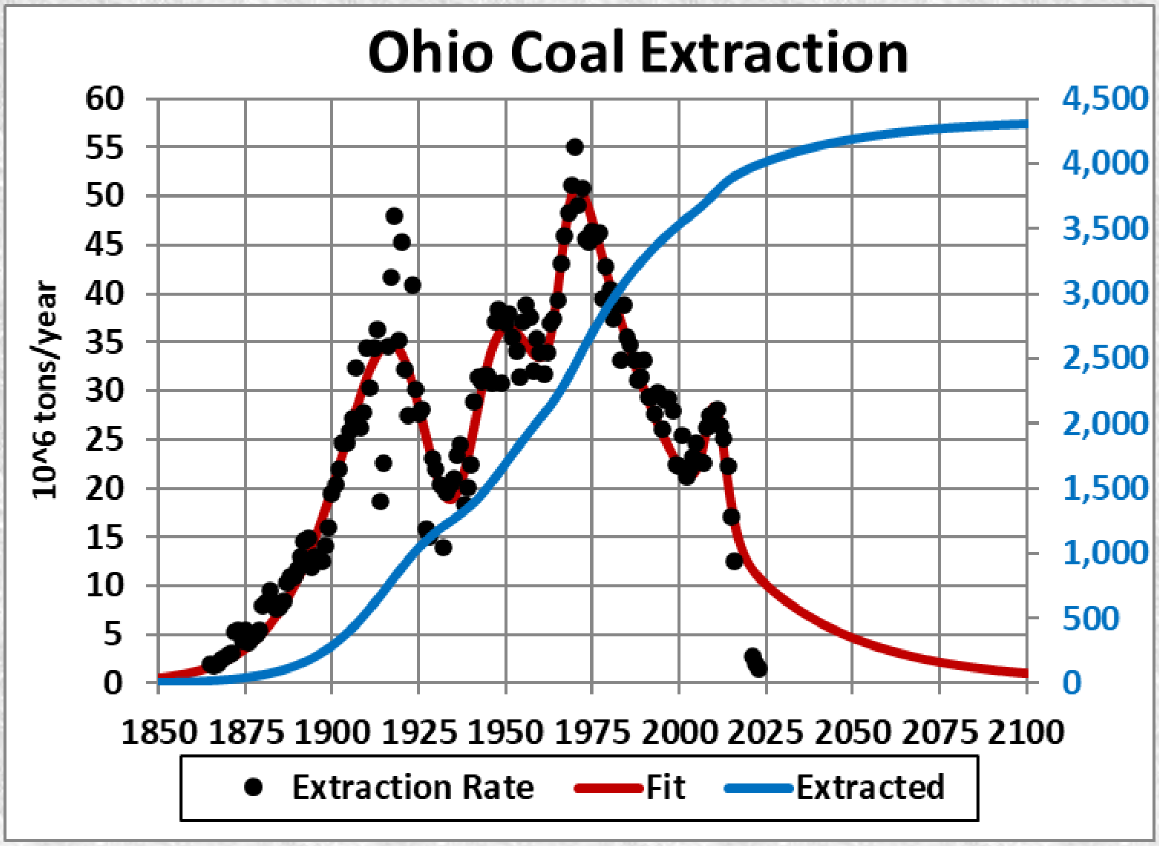


Pennsylvania Anthracite Coal
10^6 tons/year
100
90
80
70
60
50
40
30
20
10
0
6000
5000
4000
3000
2000
1000
0
1850
1875
1900
1925
1950
1975
2000
2025
Anthracite
Anth. Fit
Anc. Extr.

Kentucky Coal Extraction

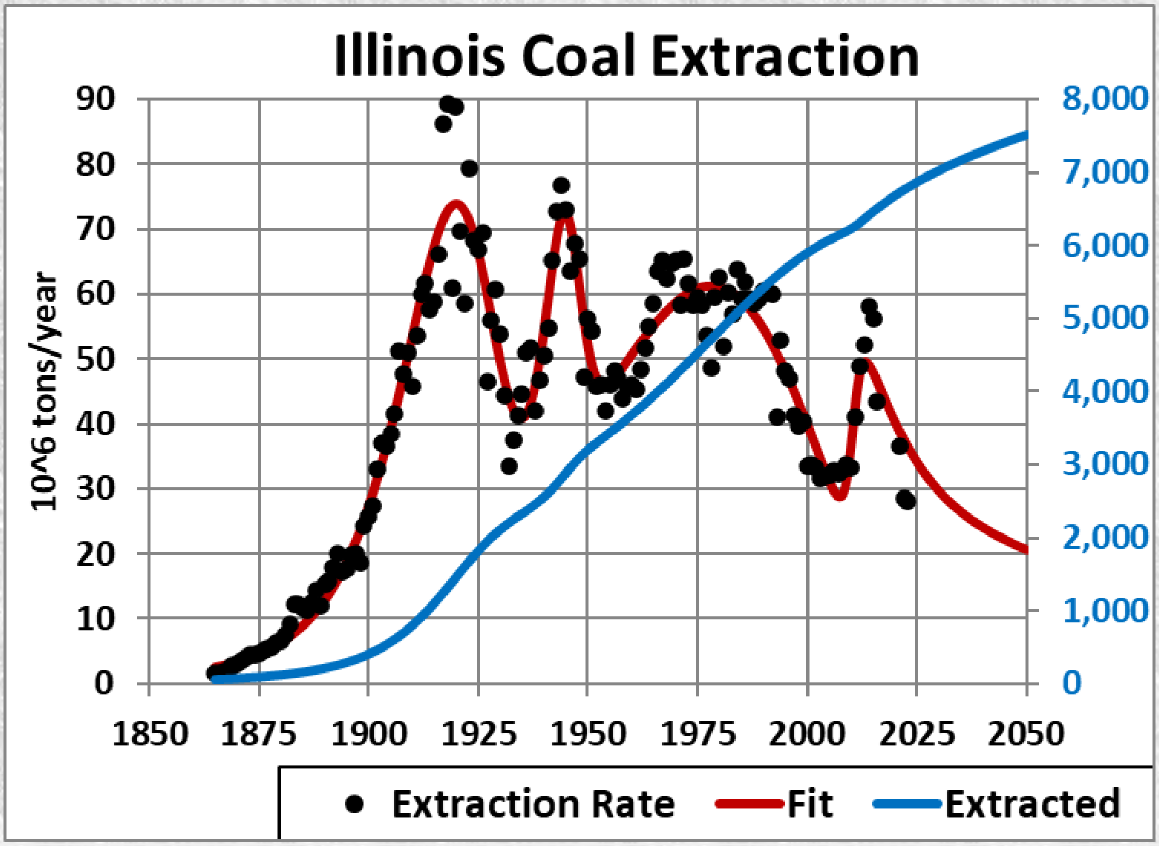


Ohio Coal Extraction

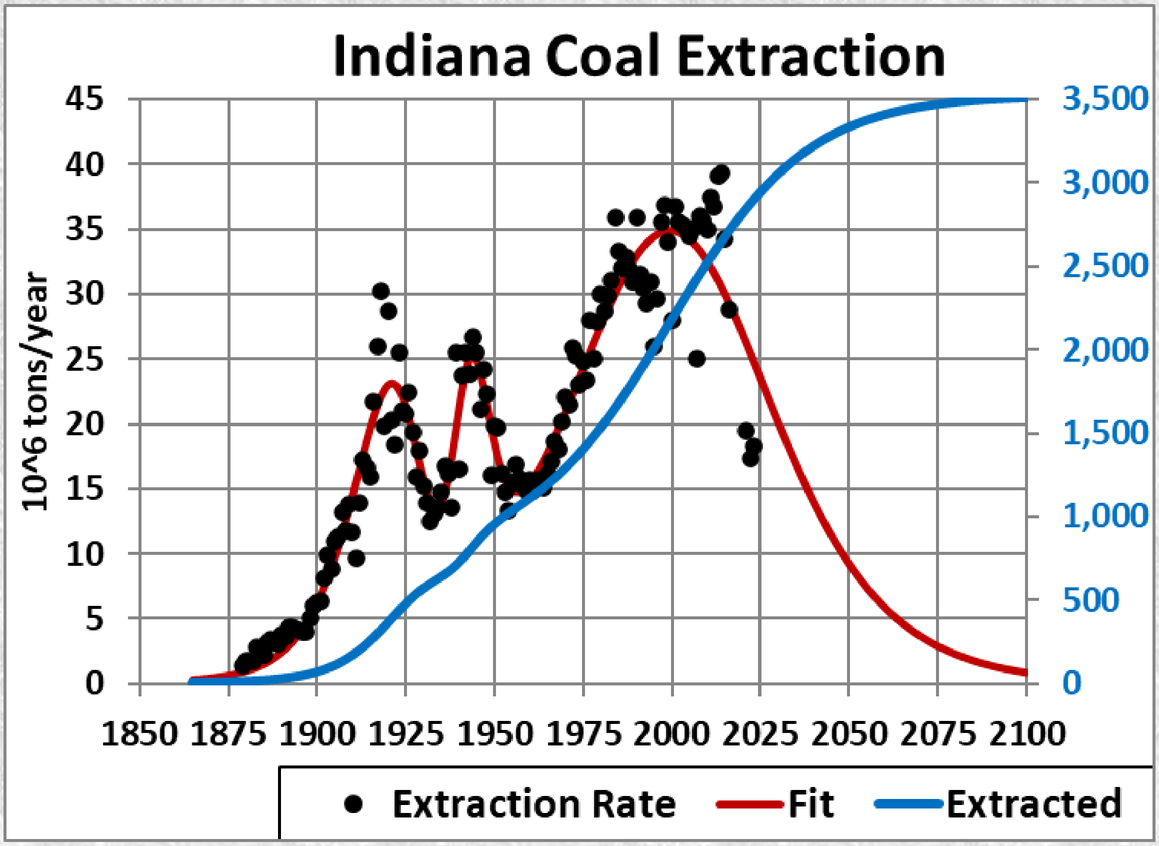


It appears that another small peak has occurred at year ~2010.

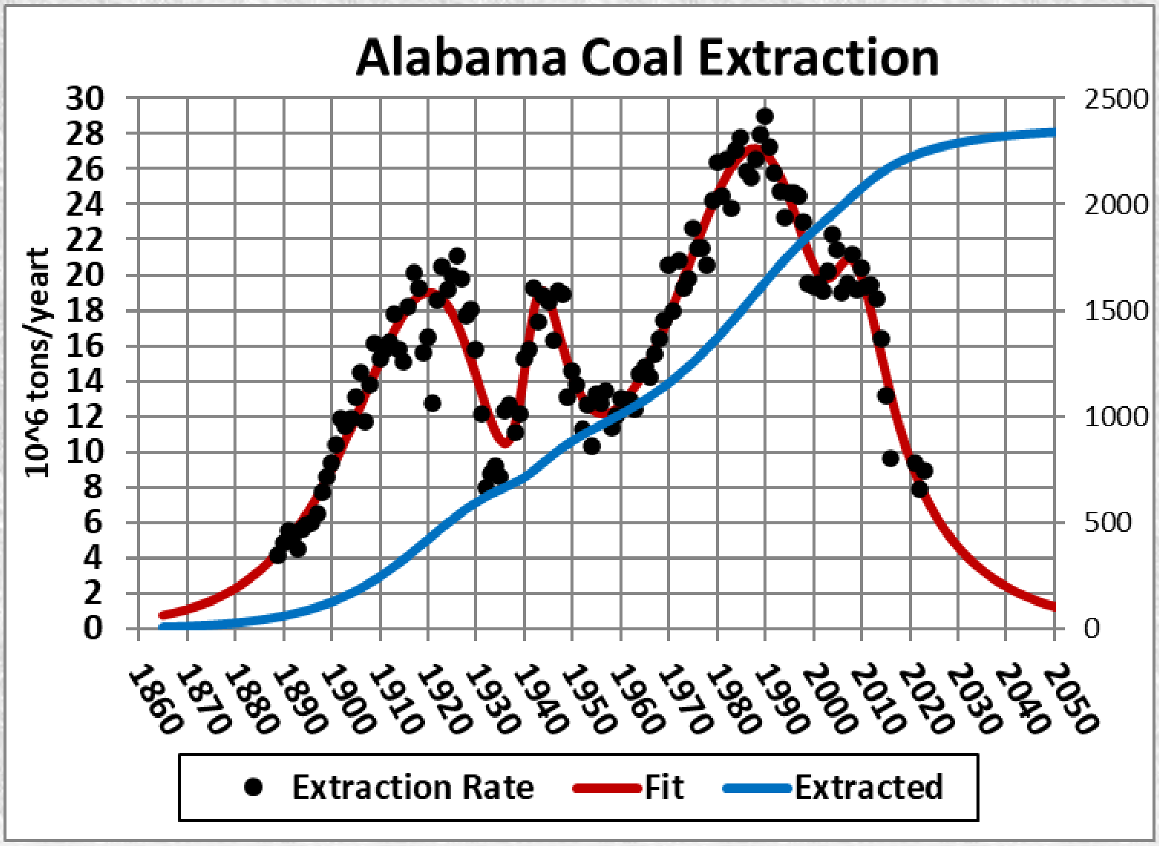
Illinois Coal Extraction



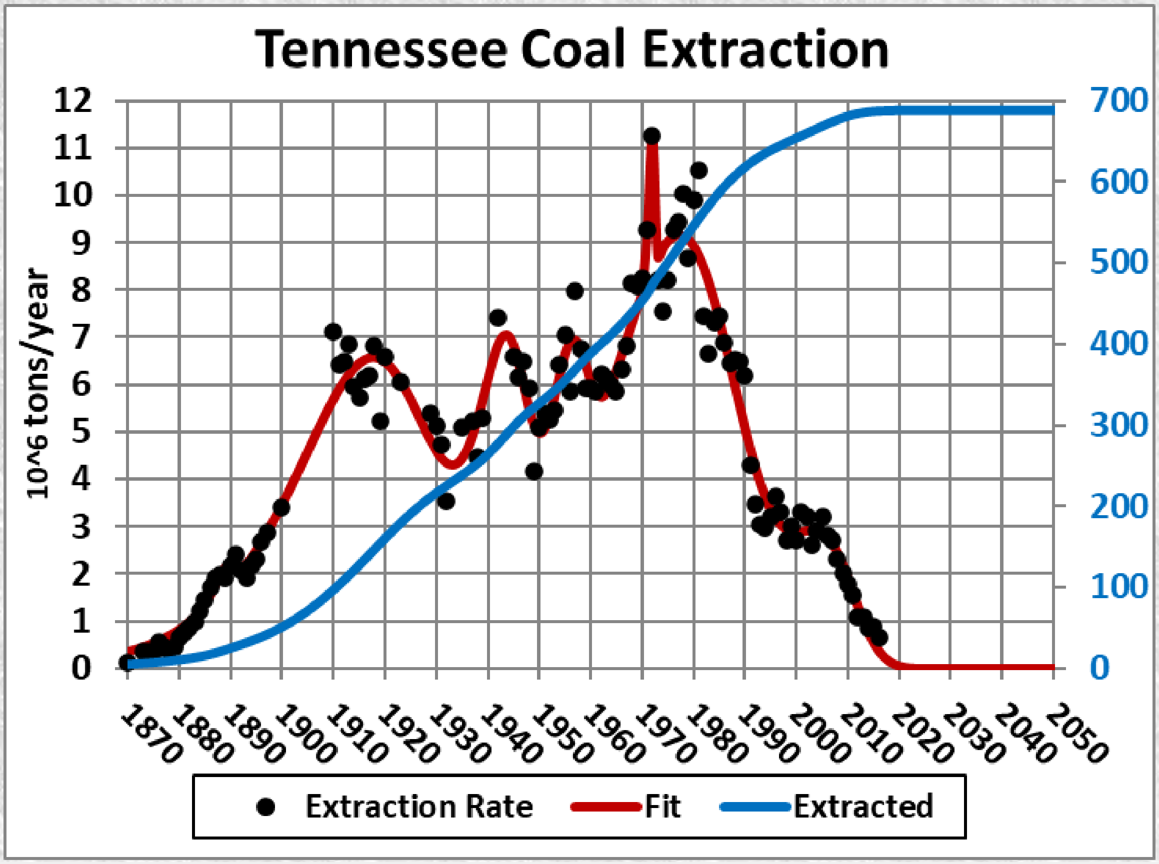
Indiana Coal Extraction



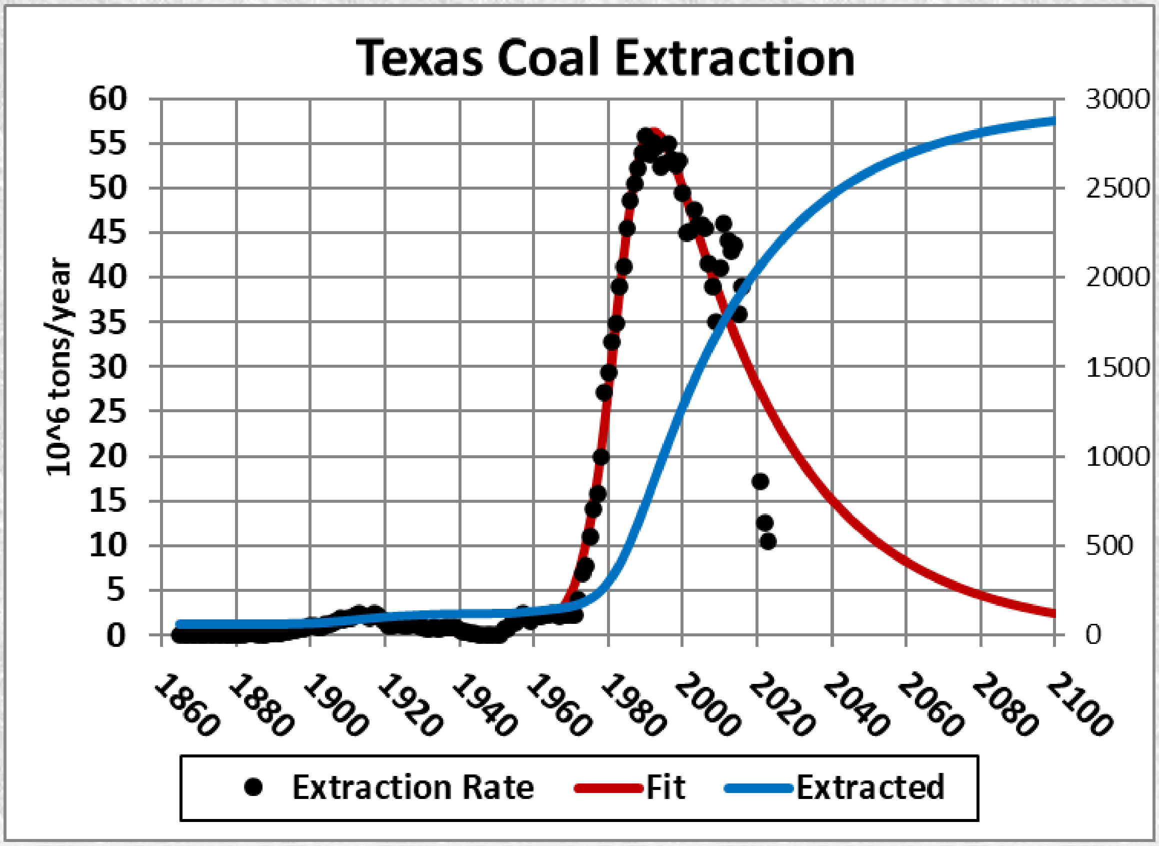
Alabama Coal Extraction



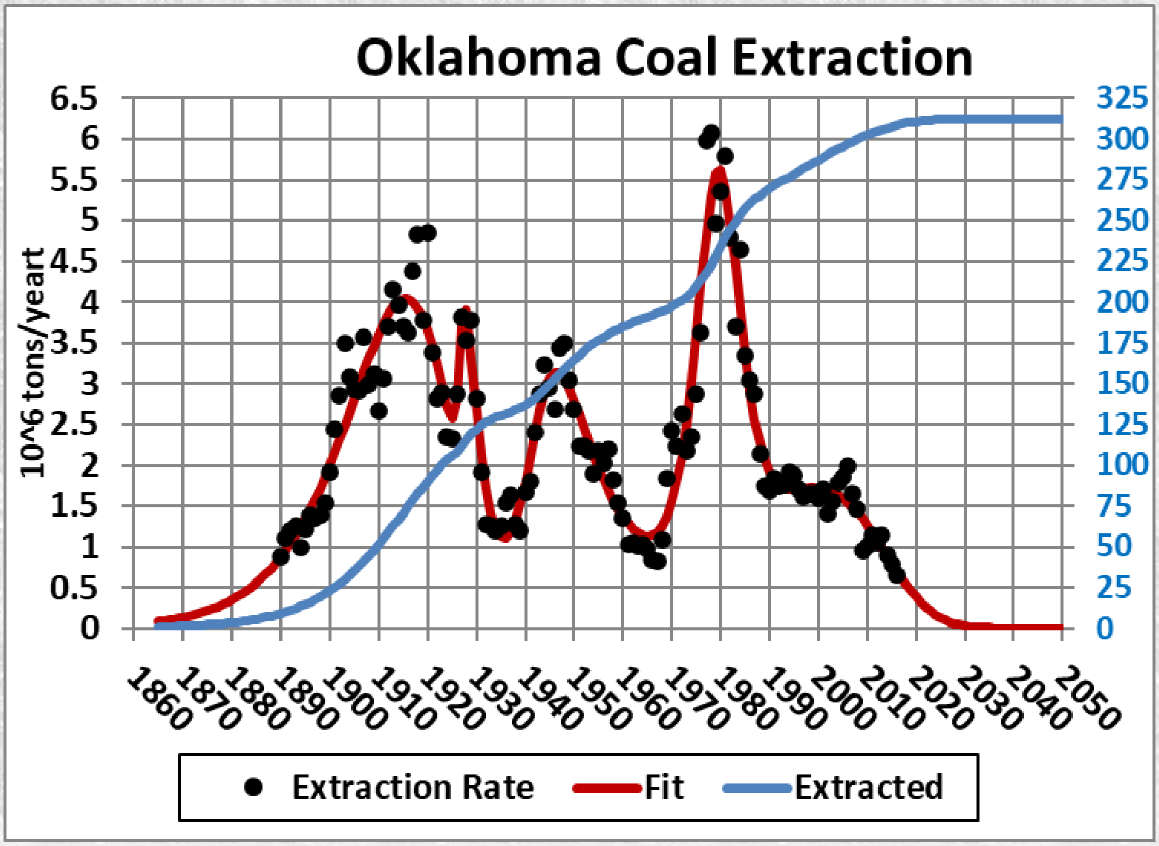
Tennessee Coal Extraction



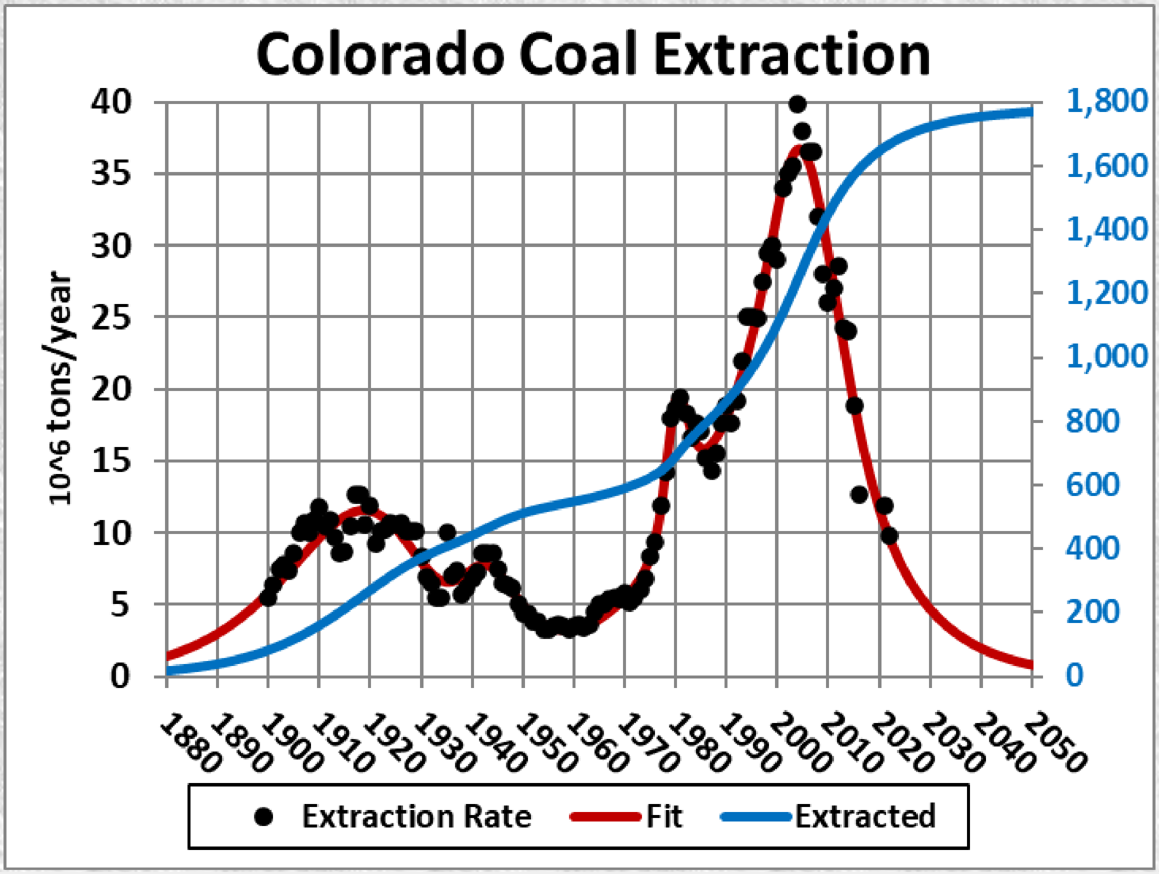
Texas Coal Extraction



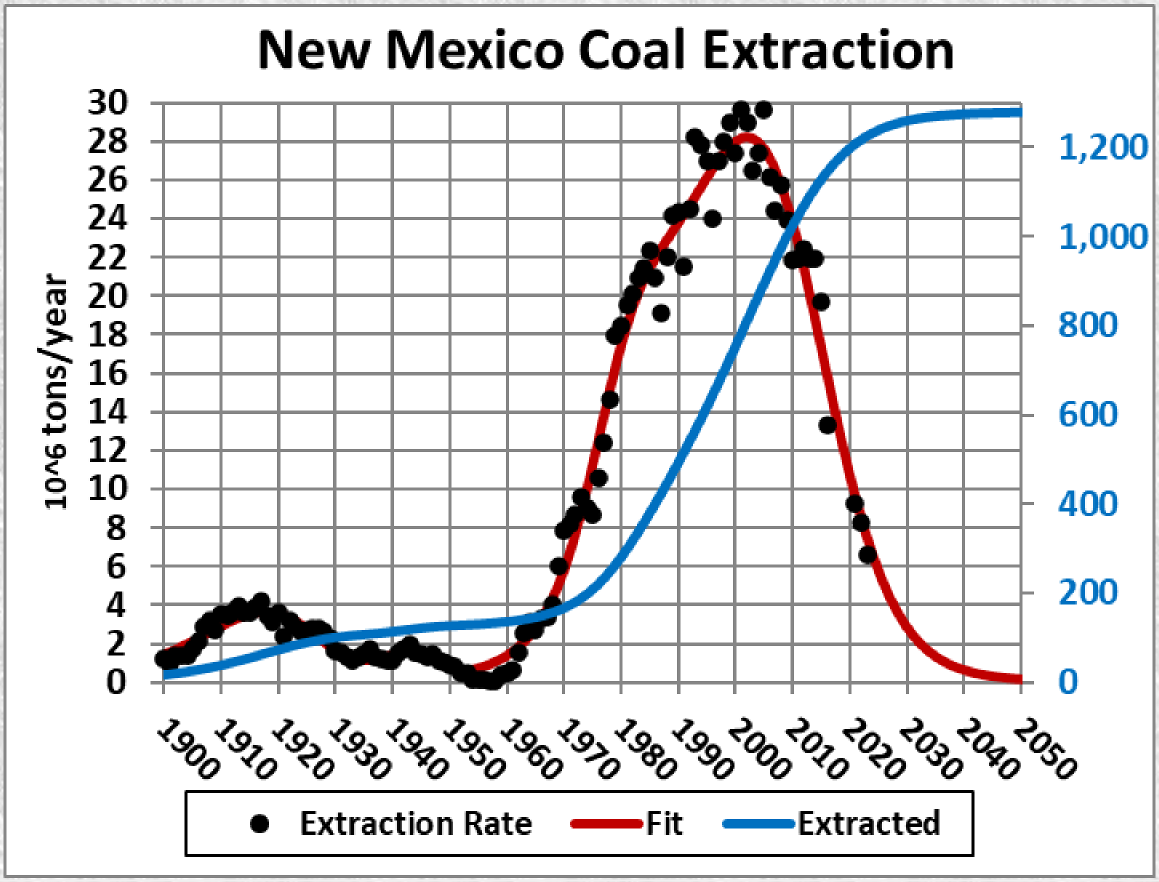
Oklahoma Coal Extraction



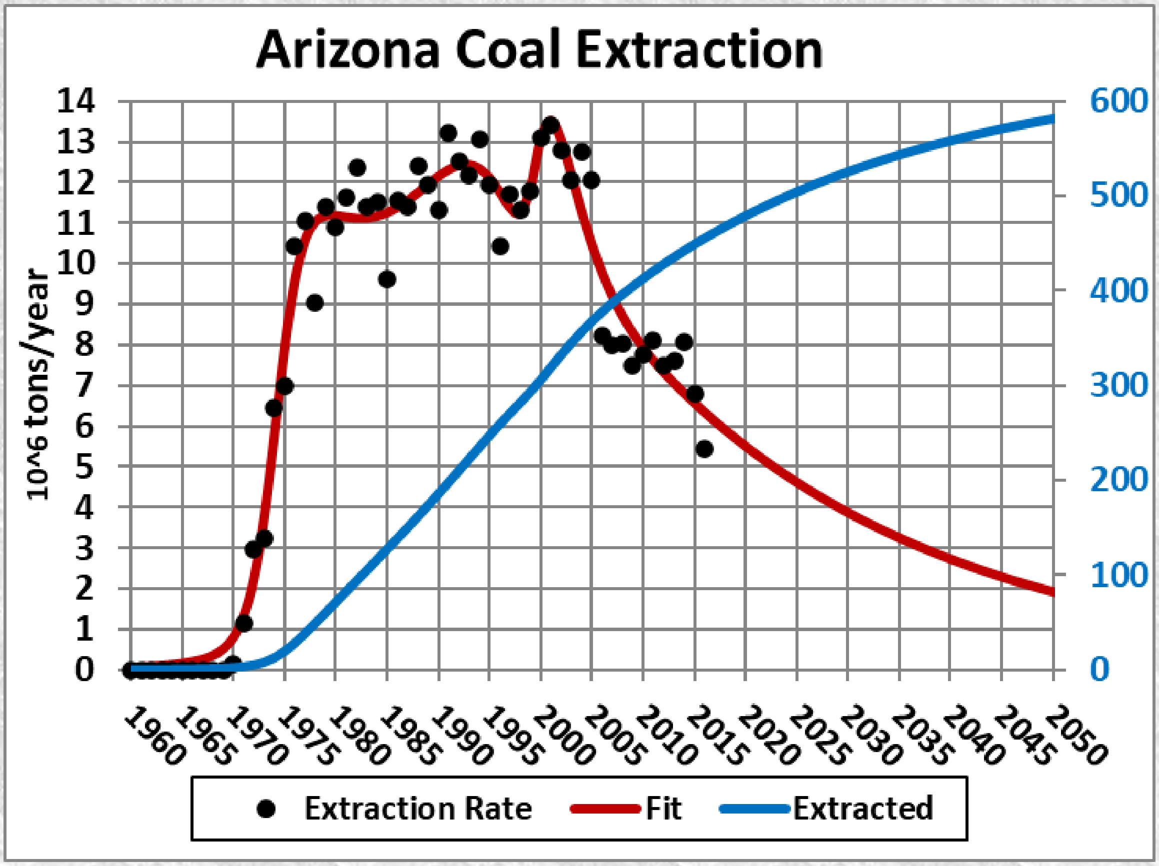
Colorado Coal Extraction



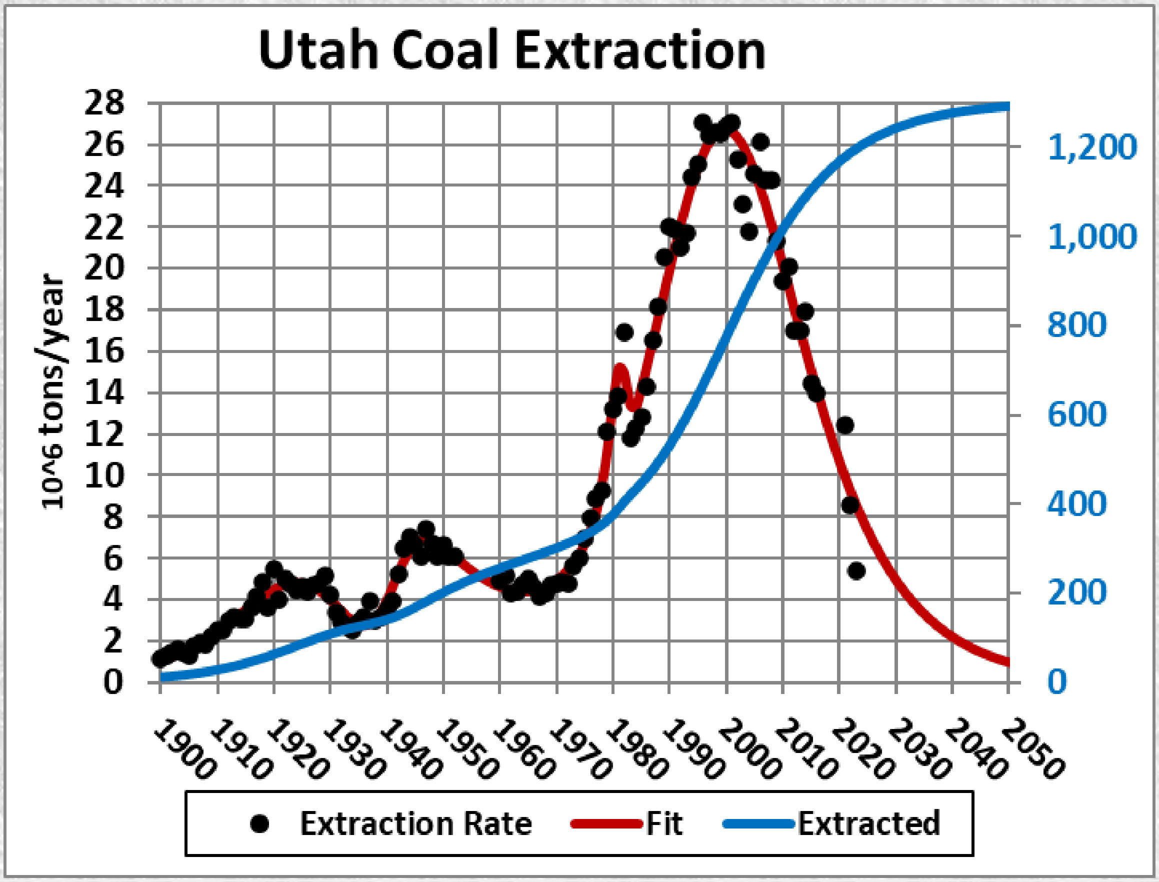
New Mexico Coal Extraction



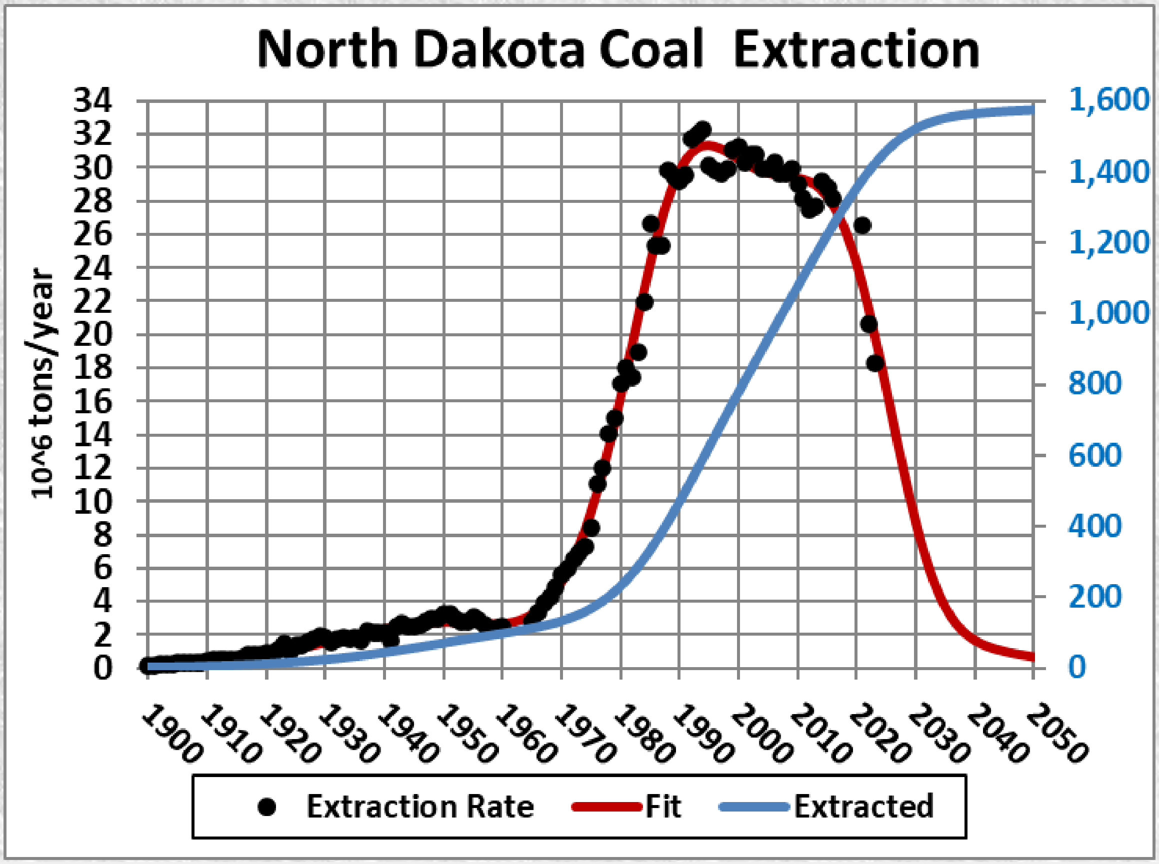
Arizona Coal Extraction



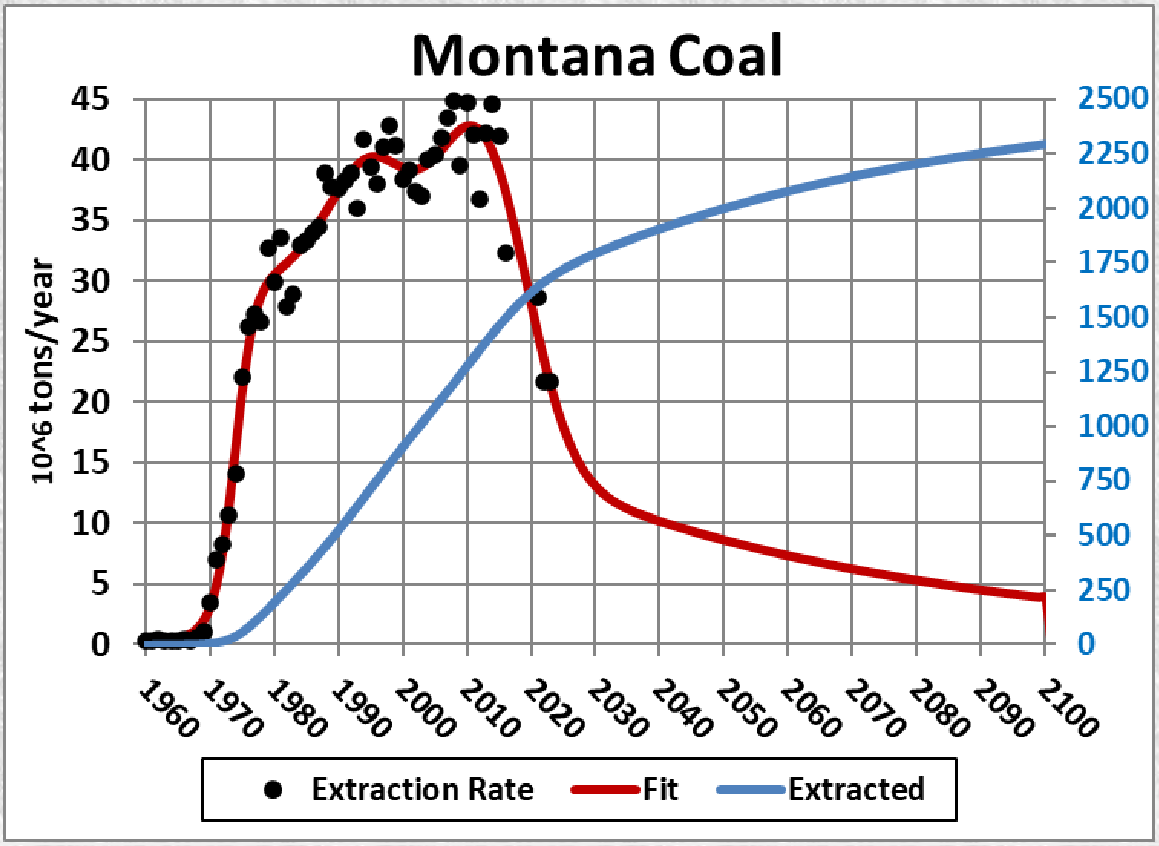
Utah Coal Extraction



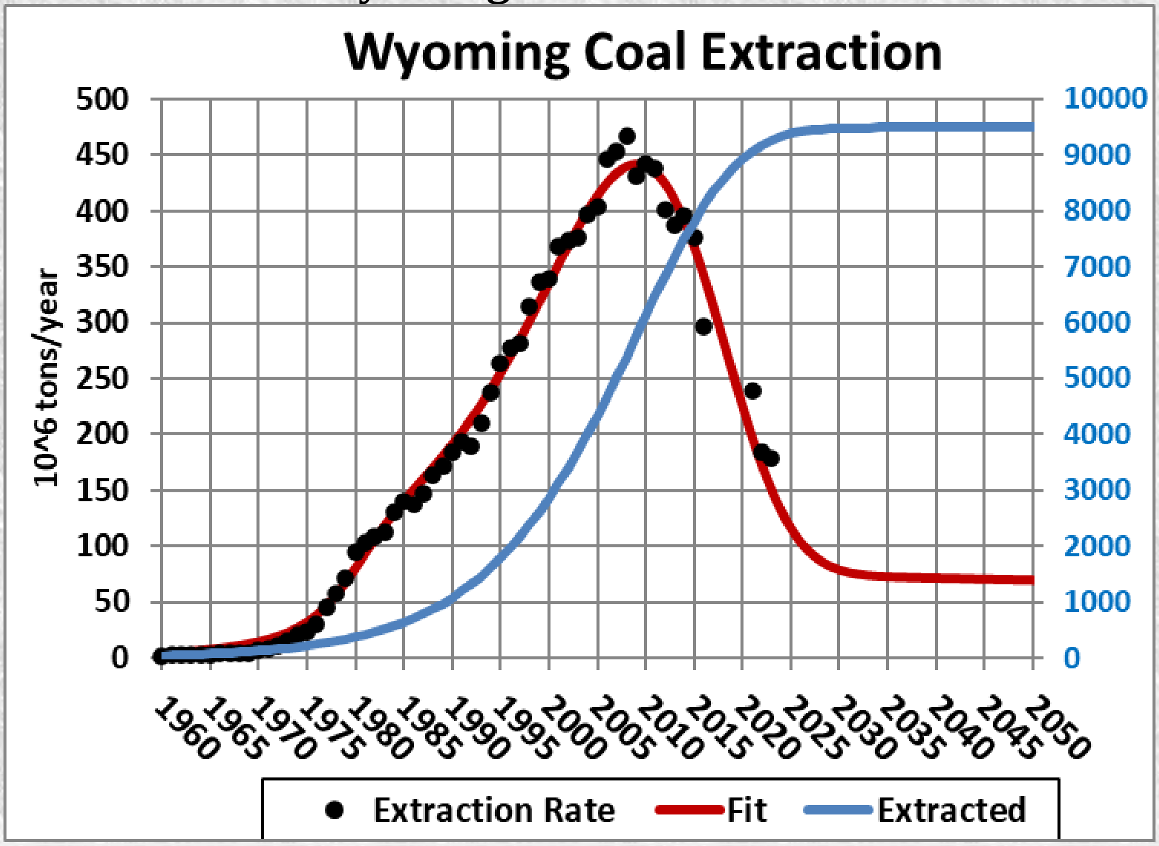
North Dakota Coal Extraction



Montana Coal Extraction



Wyoming Coal Extraction

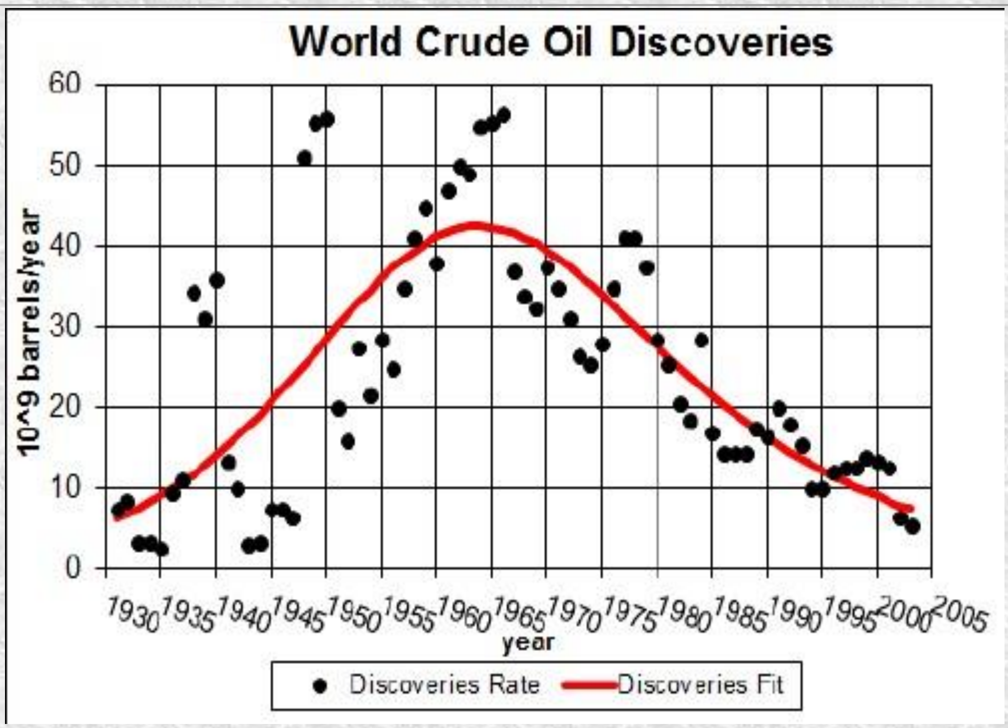


The several graphs above make it clear that coal extraction is essentially economically depleted in the United States.

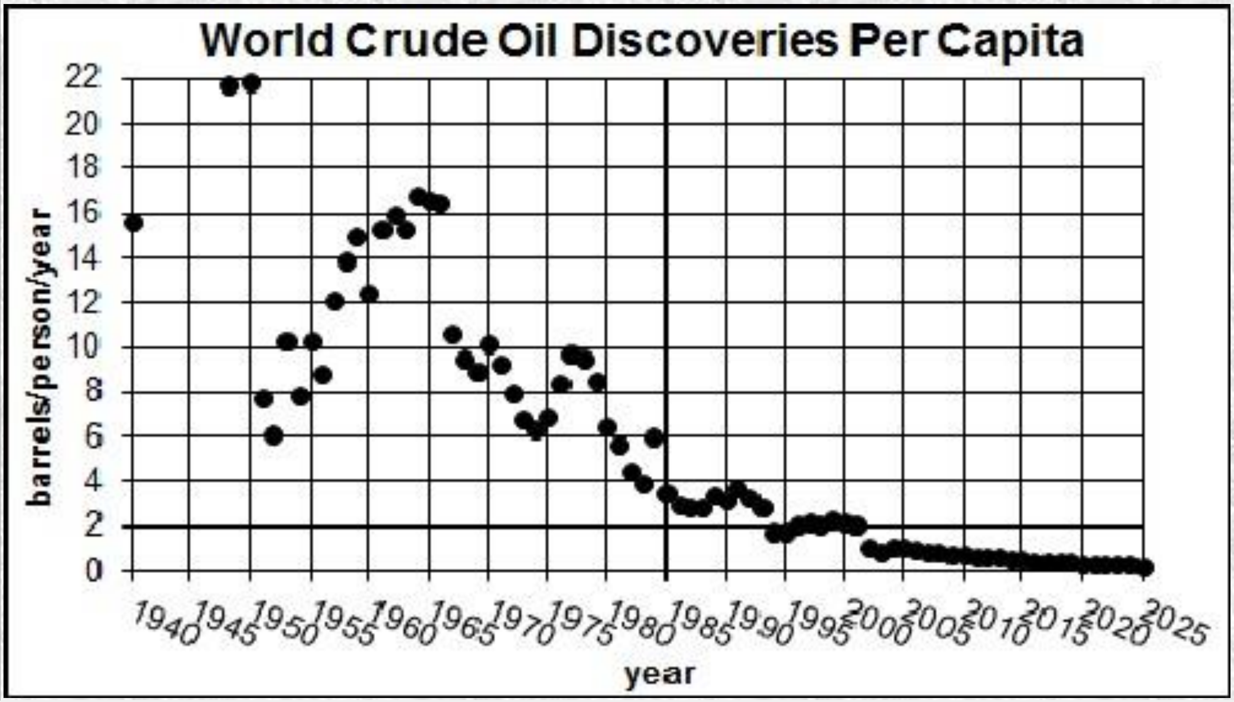
Coal Prices Prediction

World Crude-Oil Extraction

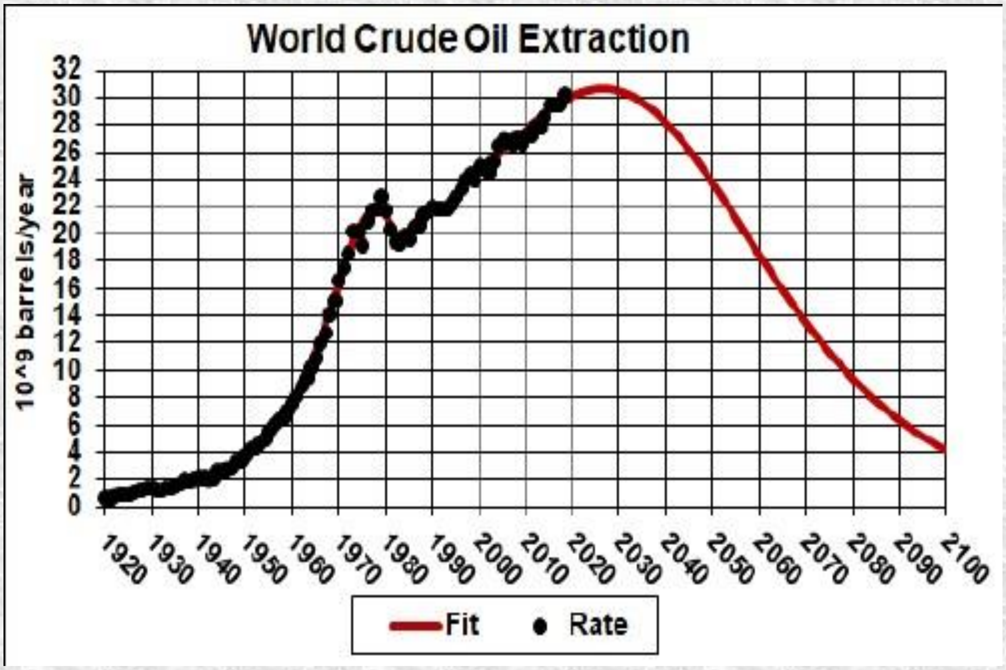
World crude-oil discoveries and a Verhulst-function fit to the data.
The total amount of World crude oil to be discovered is slightly less than 2 x 10^{12} (2 trillion) barrels.



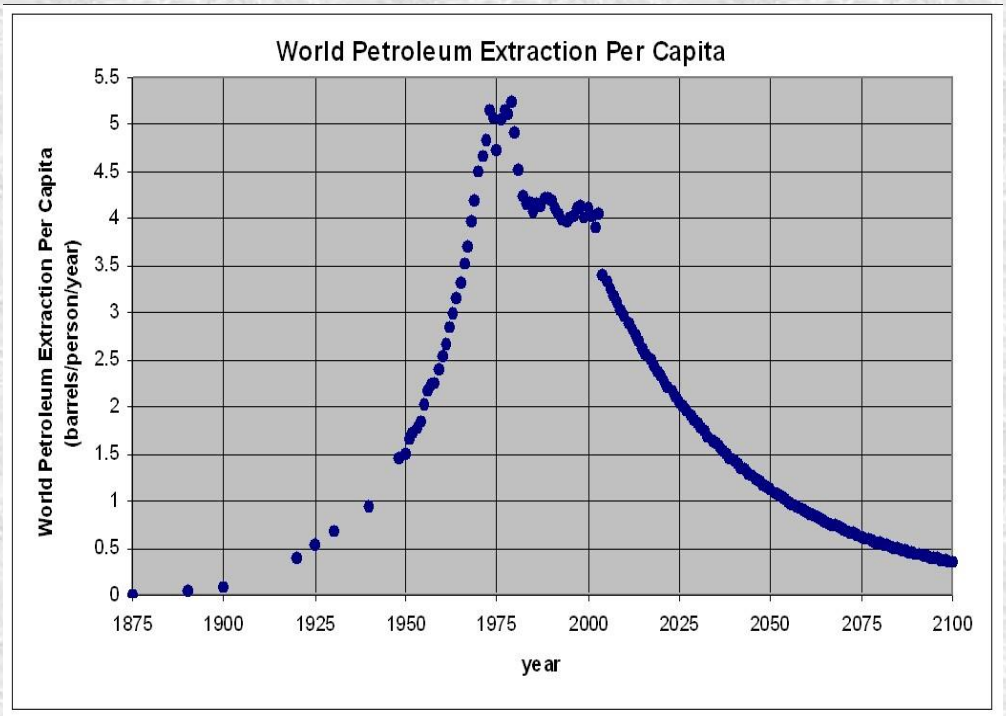
Current discoveries of 10^9 barrels are normal.



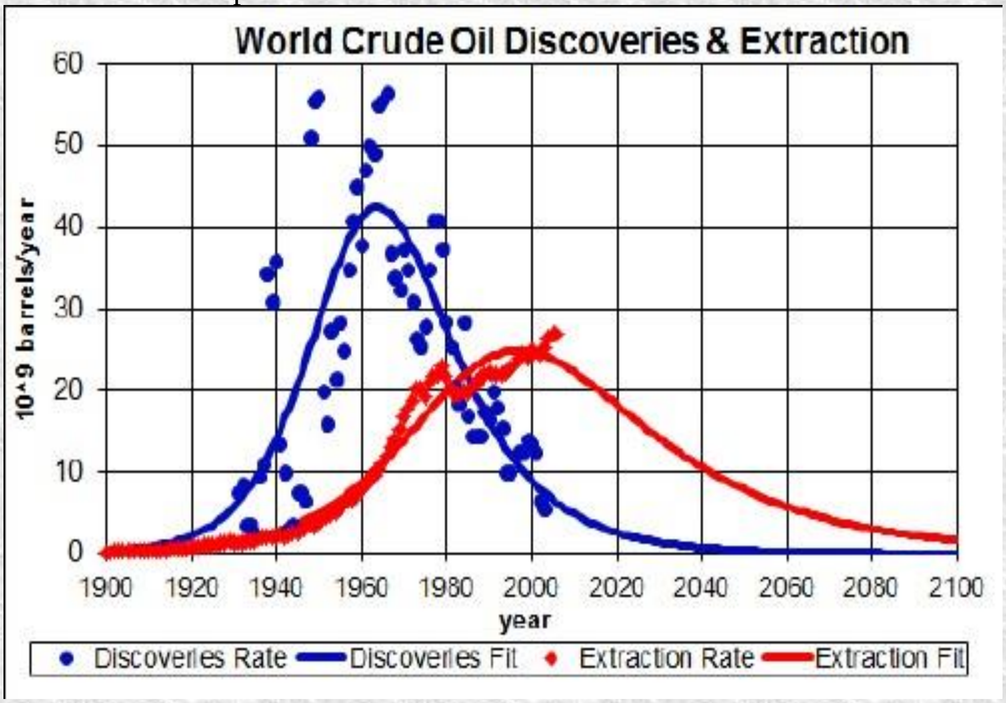
World crude-oil extraction rate and a Verhulst-functions fit to the data obtained by restricting the amount to be extracted in accord with the 2013 estimated reserves value of ~1.656 x 10^{12} (trillion) barrels.



World crude-oil extraction per capita. The extrapolation into the future is obtain by using a fit to World population extrapolated into the future.



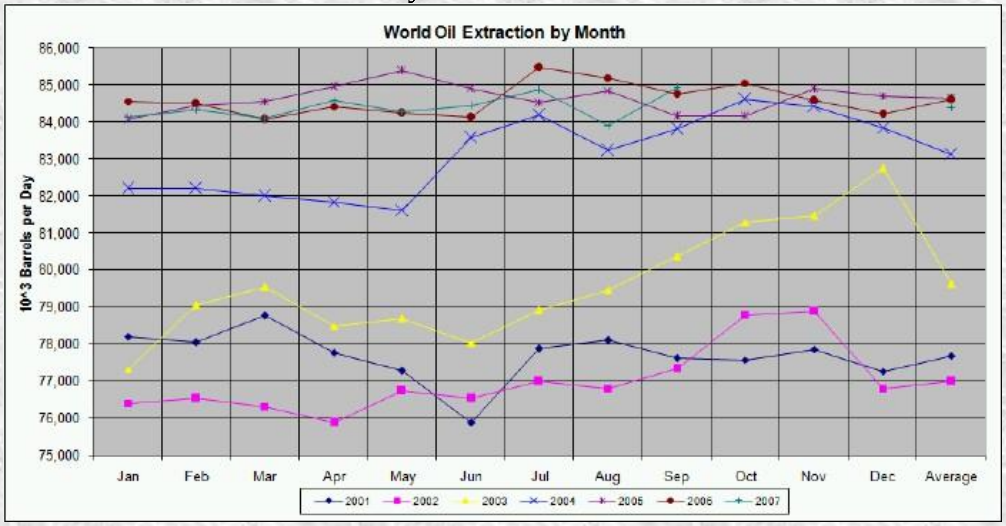
Comparison of world oil discoveries and extraction.



The amount under both curves is about 2×10^{12} barrels.

This graph contains information that probably will have the greatest effect on those now living and born in the future. **Crude Oil cannot be extracted if it has not been discovered! This graph shows very clearly why it is very unlikely that the final amount to be extracted will exceed 2×10^{12} barrels. So far the amount extracted has exceeded 1×10^{12} barrels, so we are more than halfway there!**

Monthly world oil extraction.

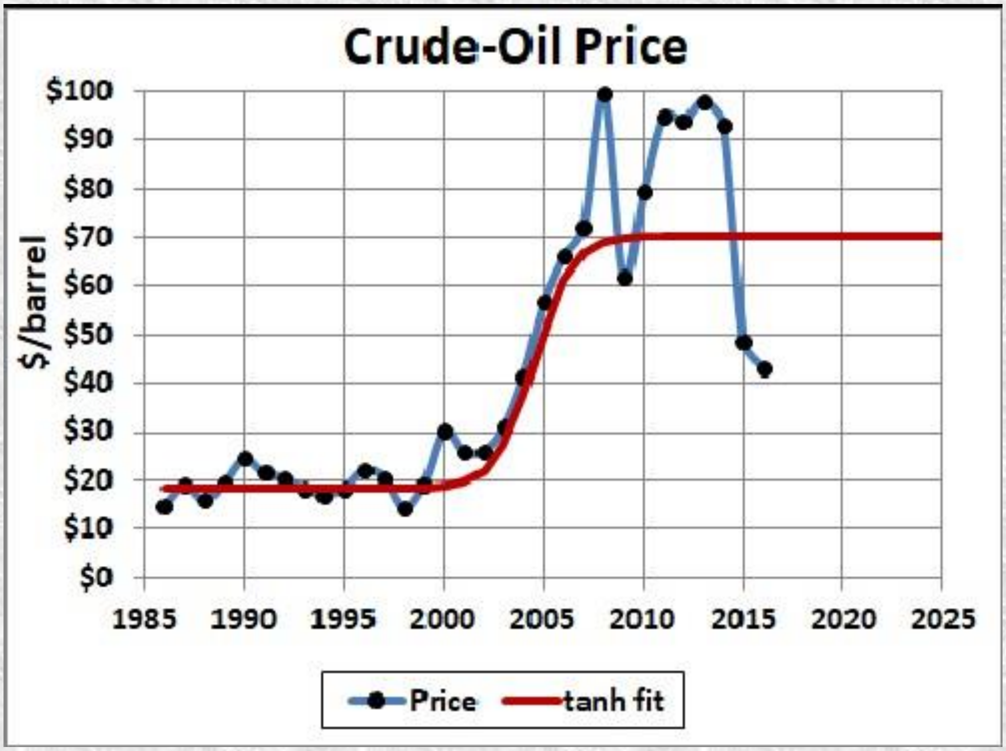


The amount extracted per month has been nearly level for three years.

World crude-oil prices

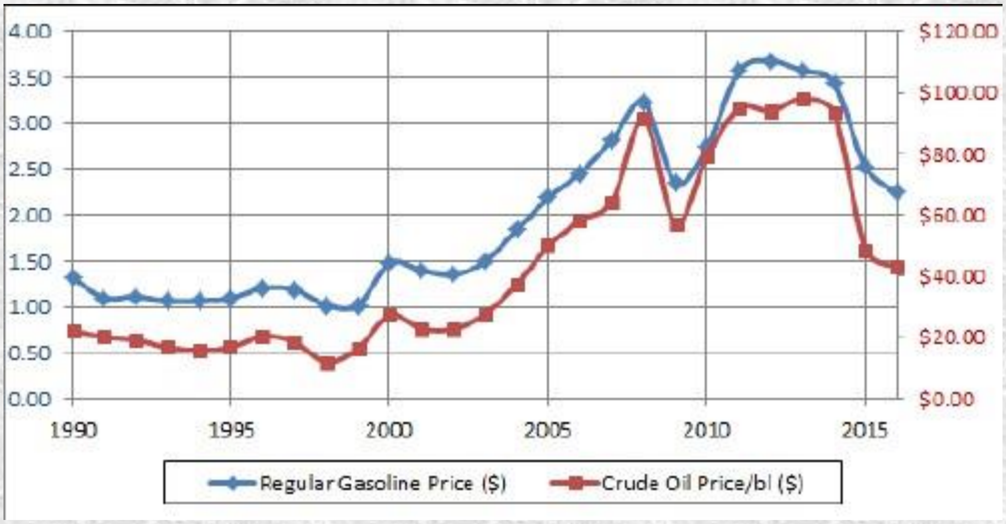
Current Crude-Oil-Futures Price

It appears that the average annual crude-oil price may be leveling off just below ($100/barrel):

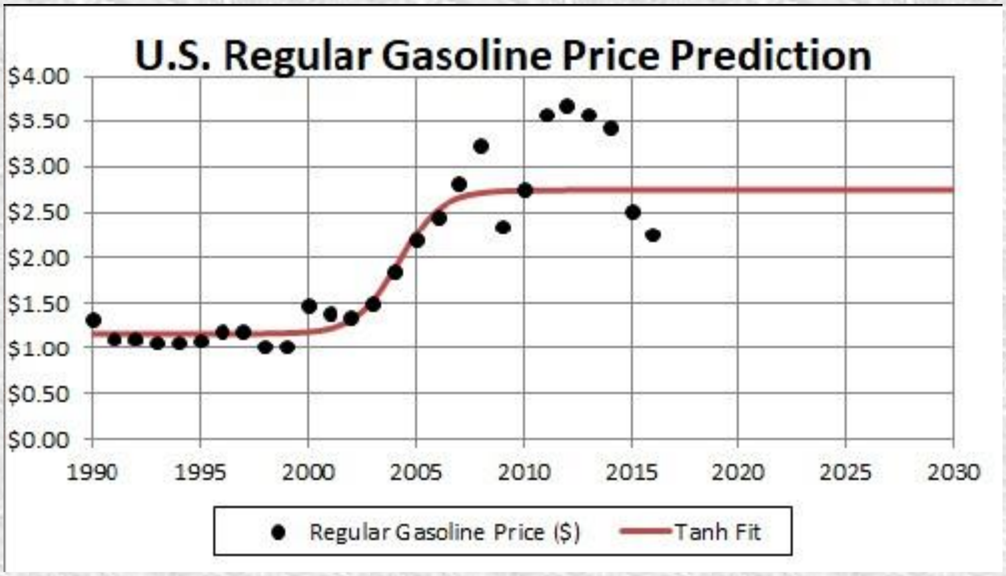


Gasoline Prices in the United States

This result can be used to predict the future price of gasoline in the United States for 1 January; it should be approximately linear in the price per barrel of crude oil. Here are those two prices:



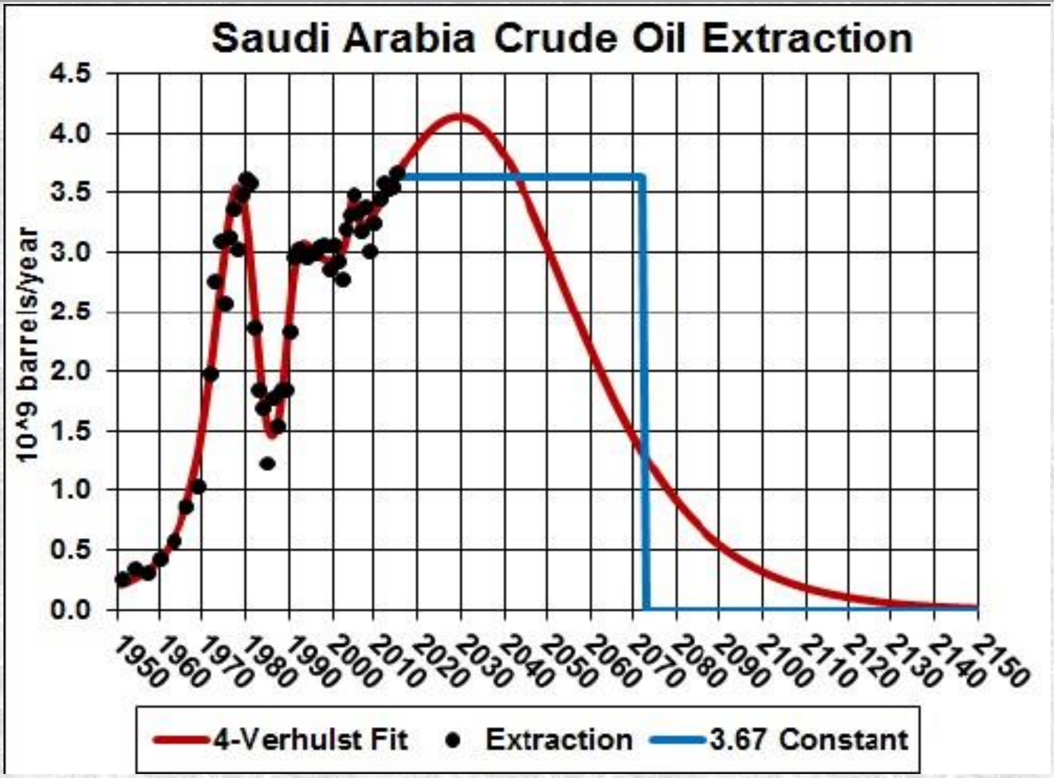
A hyperbolic-tangent fit of the U.S. regular gasoline price yields:



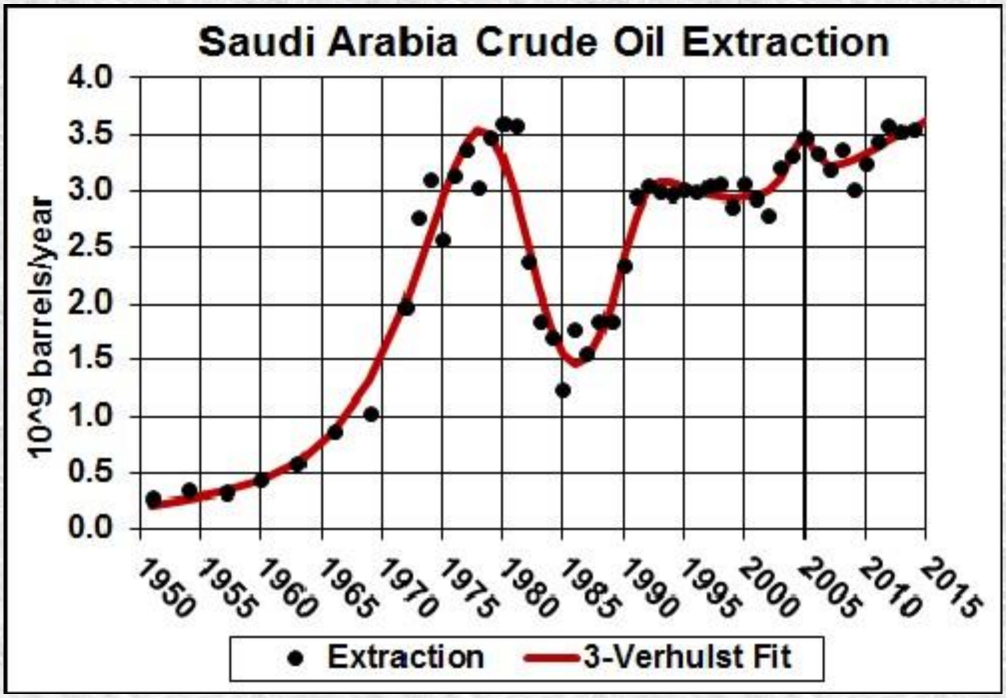
Correlations of Energy-Minerals Prices and Consumer Energy Prices

Saudi Arabia crude-oil extraction

This is a four-Verhulst fit to the Saudi Arabia crude-oil extraction data with the set value of Q=350x10^9 barrels, which is larger than the reported reserves (~268x10^9 barrels) plus the amount already extracted (~56.5x10^9 barrels) in 2014. The fit is made with the assumption that the current rise will continue until the peak at ~2020 year and that the last peak will be symmetrical.



There could be several future peaks instead of only one big one.

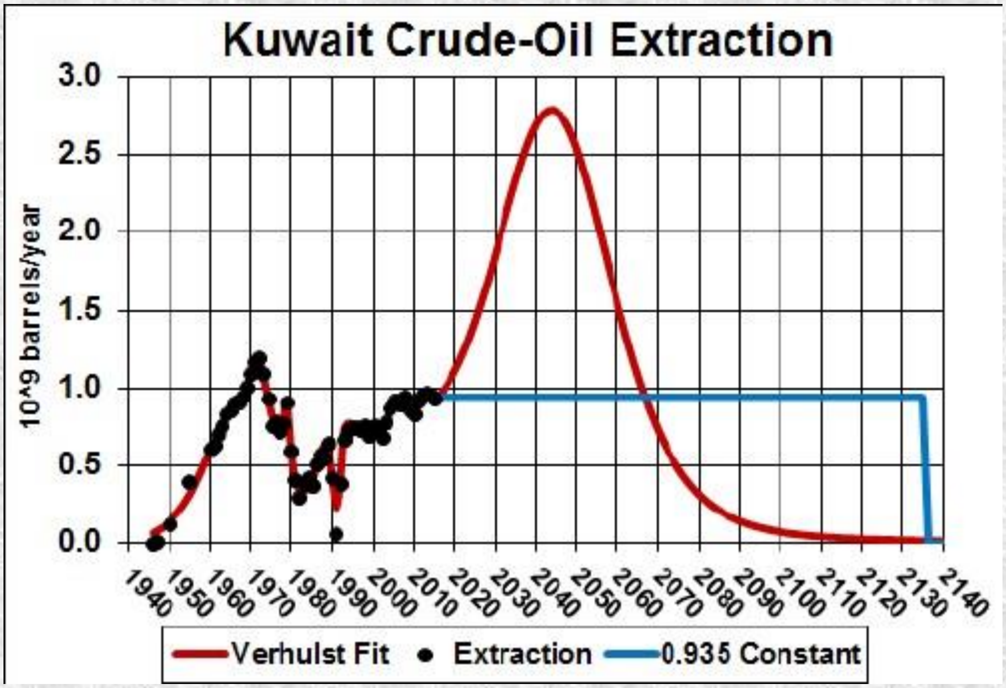


The blue curve would be the case if crude-oil extraction were fixed at $3.63x10^9$ barrels per year until the $208x10^9$ barrels of current reserves ran out at about year 2072. The actual case will probably be some curve in between the red and blue curve, with perhaps more than one peak in the future.

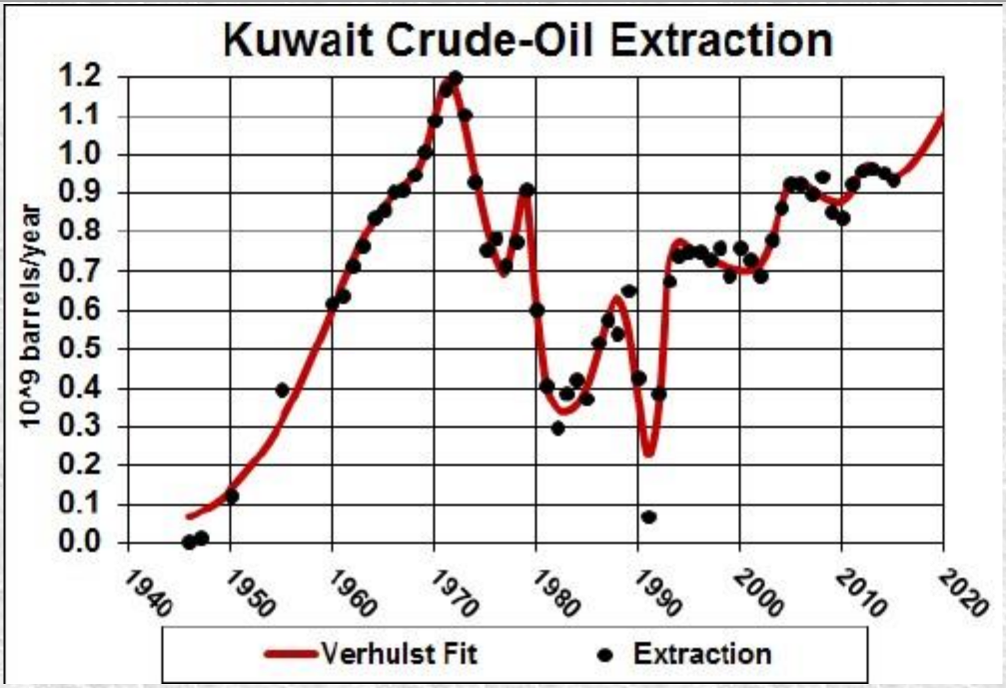
It is easy to see why Saudi Arabia is installing renewable energy at a rapid pace.

Kuwait crude-oil extraction

This is a two-Verhulst fit to the Kuwait crude-oil extraction data. The total amount to be extracted was set at $155x10^9$ barrels, which is slightly larger than the 2014 reported reserves ($\sim104x10^9$ barrels) plus the amount already extracted (about $\sim46.7x10^9$ barrels). The last peak is assumed to be symmetrical.



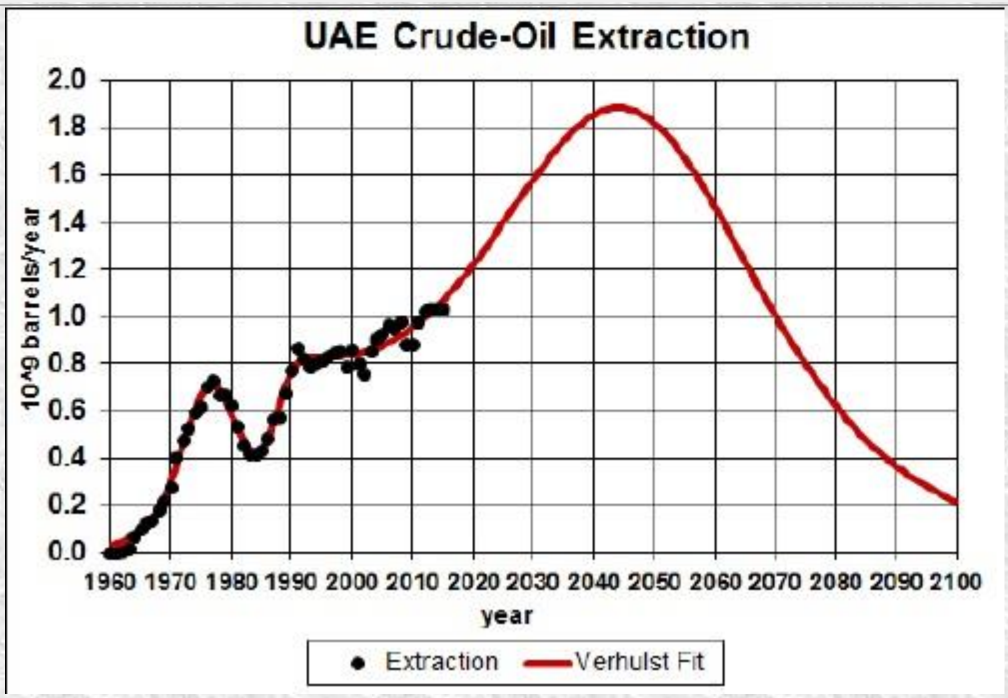
There could be several future peaks instead of only one big one.



The blue curve would be the case if crude-oil extraction were fixed at 0.935x10^9 barrels per year until the 104x10^9 barrels of current reserves ran out at about year 2134.

United Arab Emirates crude-oil extraction

This is a 3-Verhulst fit to the UAE crude-oil extraction data. The total amount to be extracted was set at Q=140x10^9 barrels, which is larger than the 2014 reported reserves (~97.8x10^9 barrels) plus the amount already extracted (~33.5x10^9 barrels). The final peak is assumed to be symmetrical.

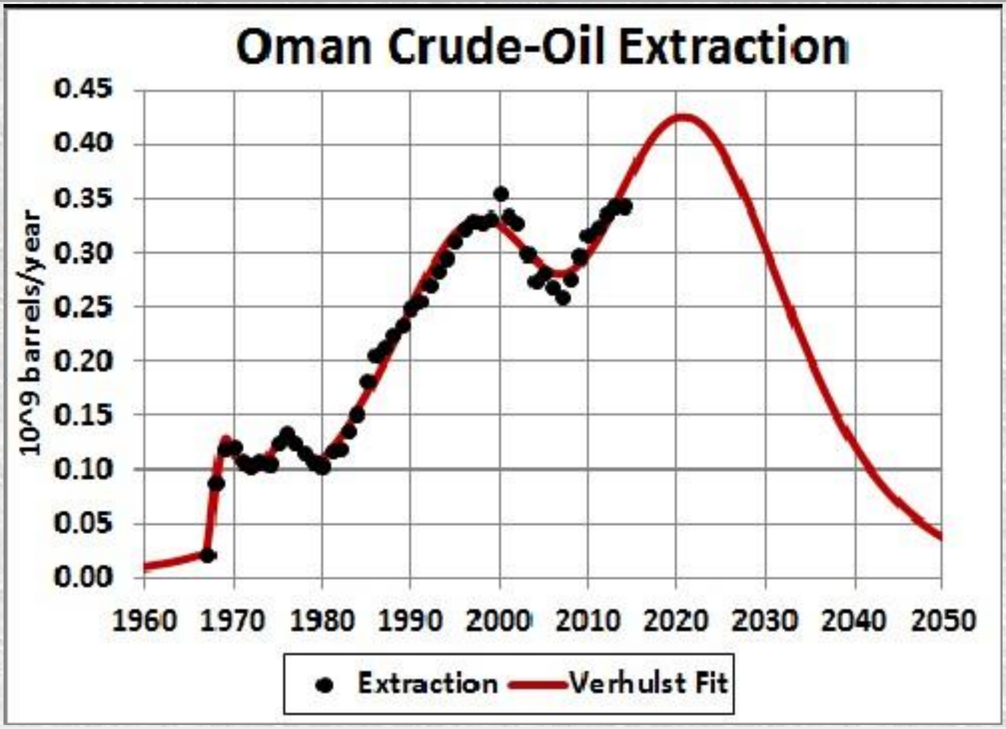


The blue curve would be the case if crude-oil extraction were fixed at 1.0×10^9 barrels per year until the 98×10^9 barrels of current reserves ran out at about year 2130.

Seven emirates comprise UAE: Abu Dhabi, Ajman, Dubai, Fujairah, Ras al-Khaimah, Sharjah, and Umm al-Quwain.

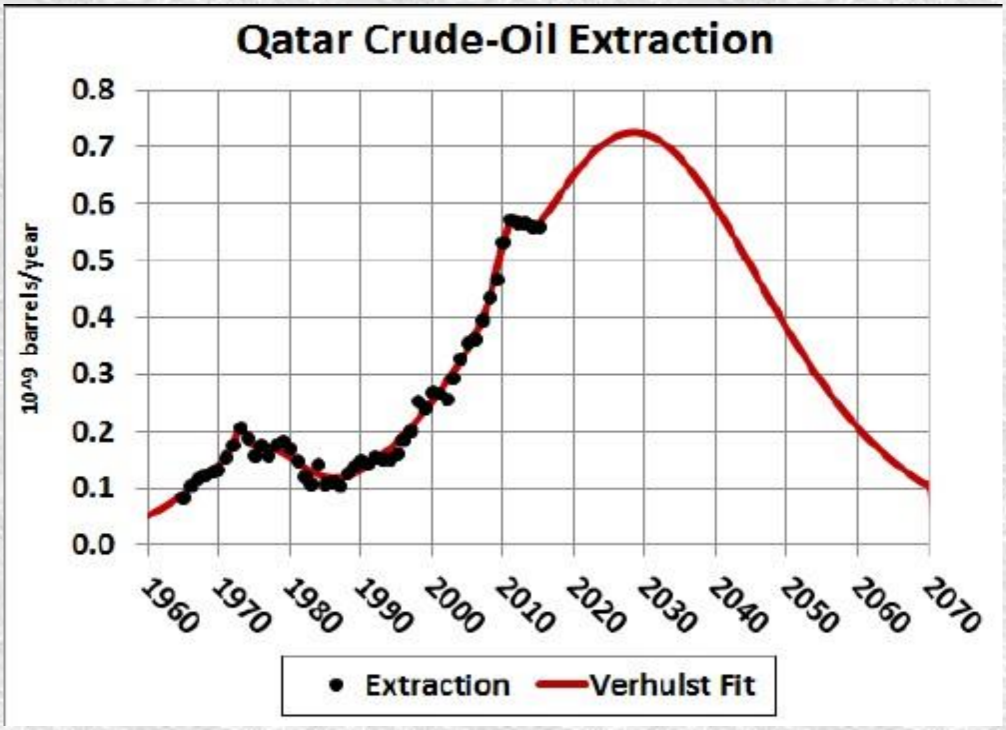
Oman crude-oil extraction

The total amount to be extracted was set at 20×10^9 barrels for a 3-Verhulst fit, which is larger than the 2014 reported reserves amount (~5.5×10^9 barrels) plus the amount already extracted (~10.7×10^9 barrels barrels). The final peak is assumed to be symmetrical.



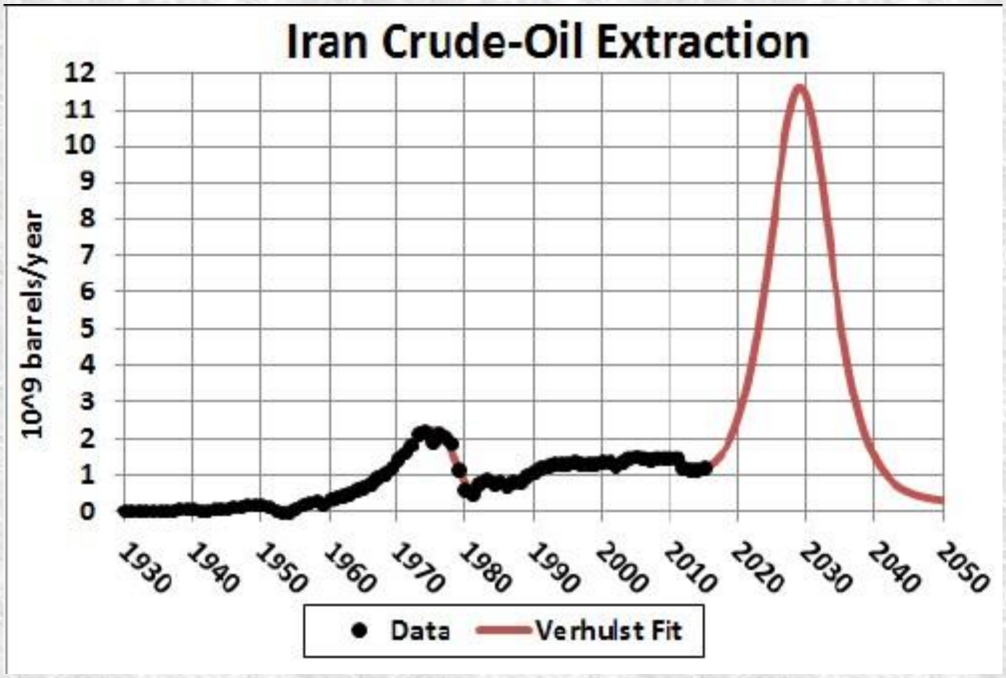
Qatar crude-oil extraction

The total amount to be extracted was set at $40x10^9$ barrels for a Verhulst fit which is slightly larger than the 2014 reported reserves amount (~$25x10^9$ barrels) plus the amount already extracted (~$12.6x10^9$ barrels barrels).The final peak is assumed to be symmetrical.

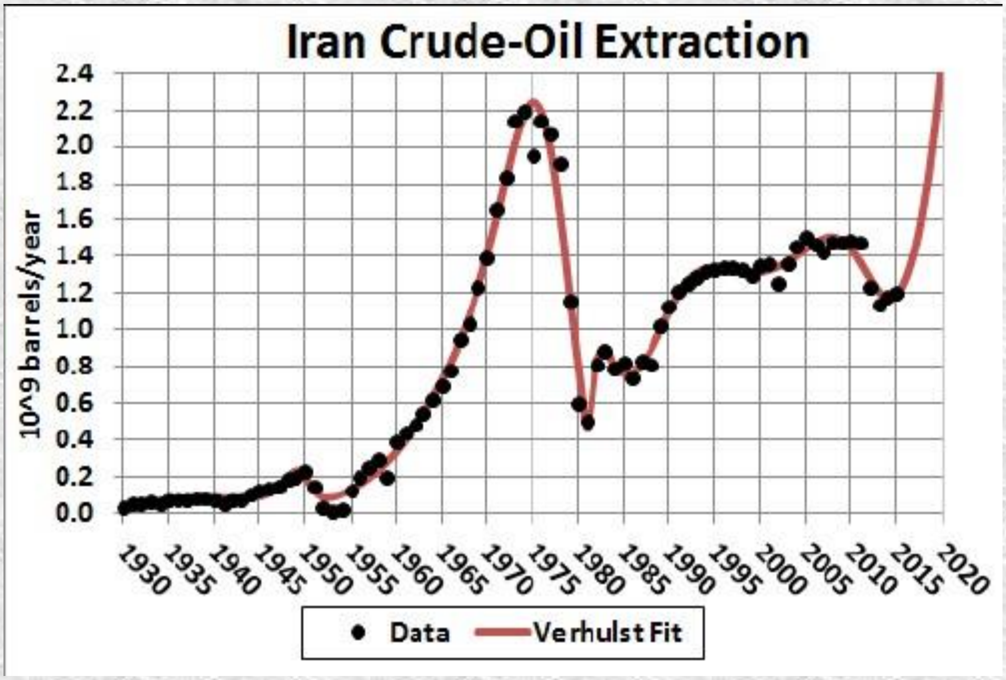


Iran crude-oil extraction

The total amount to be extracted is set at 230x10^9 barrels, which is about the same as the 2014 reported reserves (~157x10^9 barrels) plus the amount already extracted (~68x10^9 barrels).



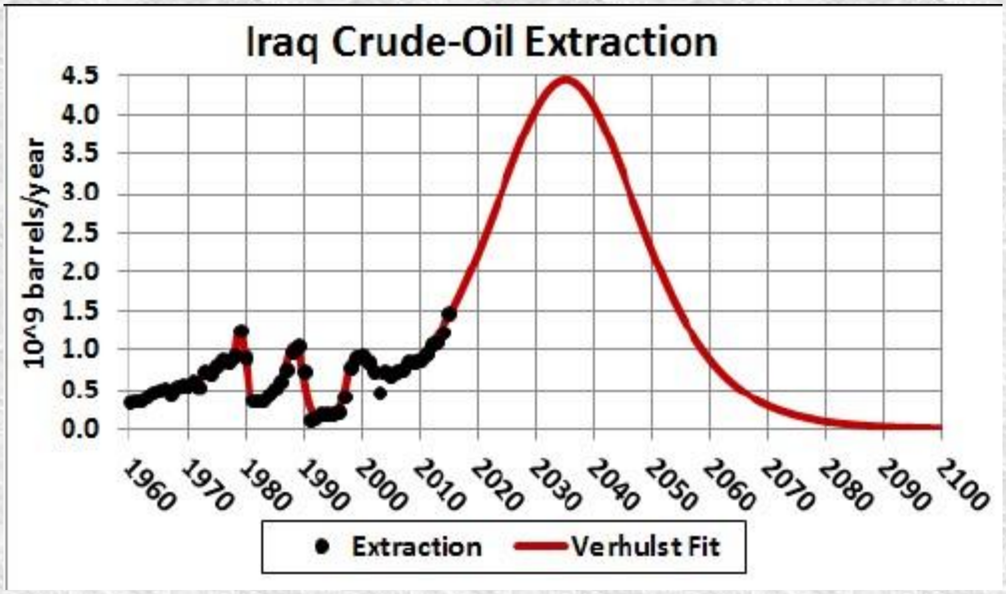
There could be several future peaks instead of only one big one.



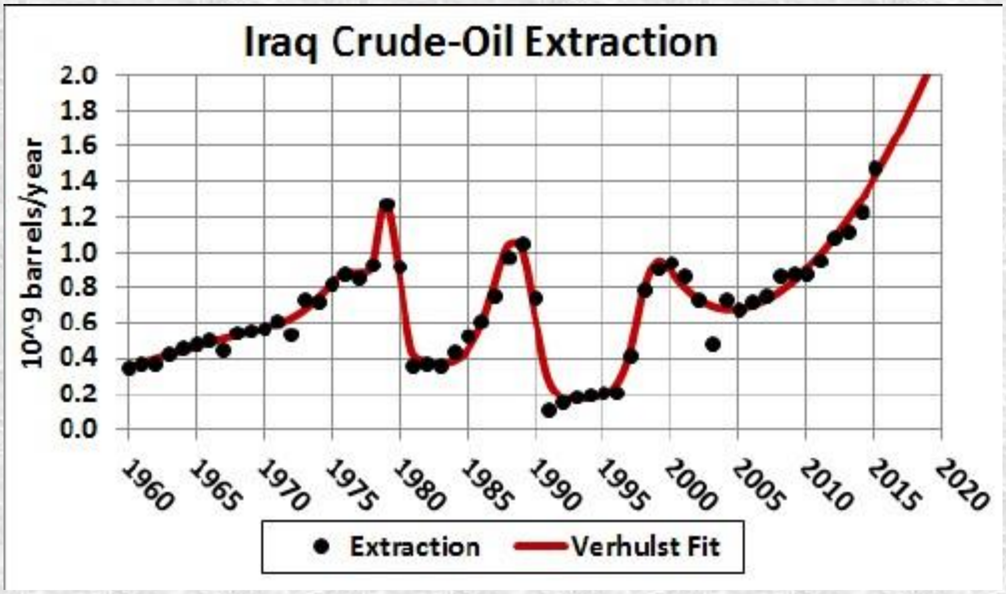
The 2013 low was due to economic sanctions on Iran.

Iraq crude-oil extraction

The 4-Verhulsts fit has a total amount to be extracted set to Q=180x10^9 barrels, which is slightly more than the 2014 estimated reserves (~140x10^9 barrels) plus the amount already extracted (~36.7x10^9 barrels). The final peak is assumed to be symmetrical.



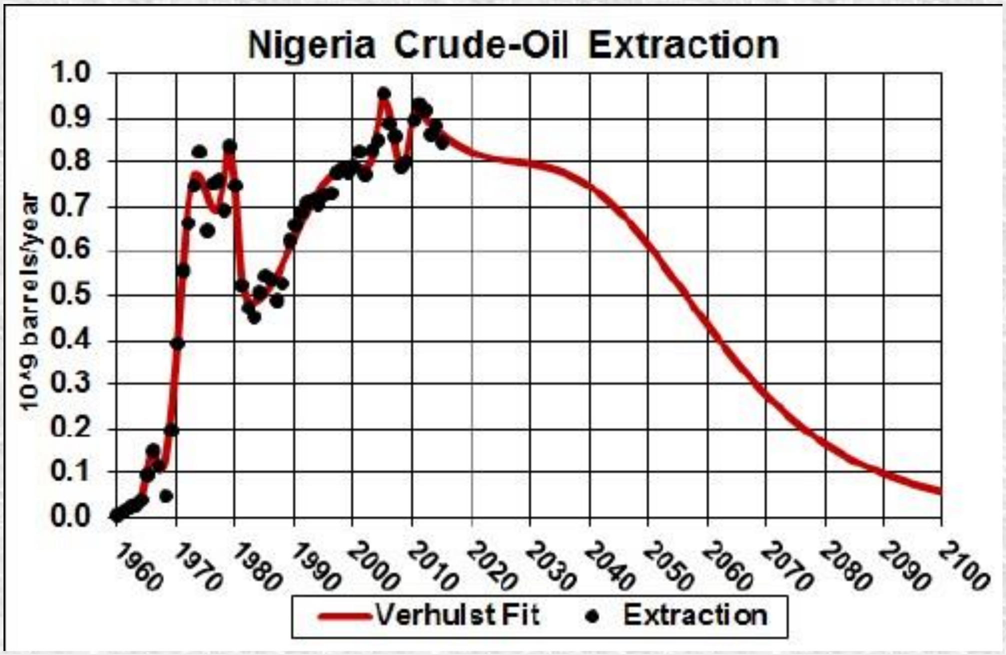
There could be several future peaks instead of only one big one.



Due to the animosity among three ethnic groups in Iraq, it is likely that its future crude-oil extraction will oscillate around its depletion curve.

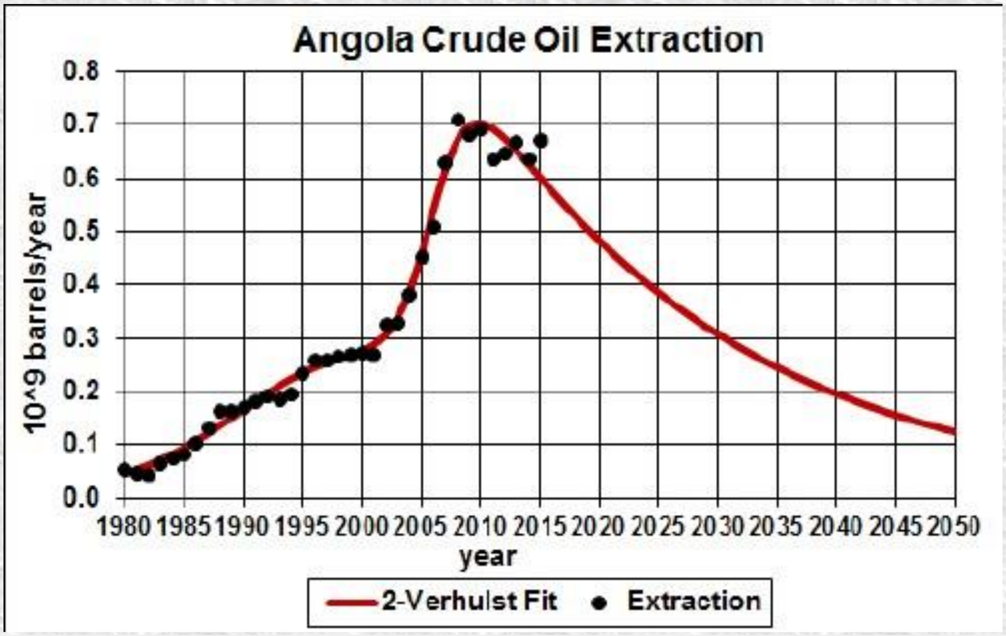
Nigeria crude-oil extraction

The total amount to be extracted was set at $70x10^9$ barrels for a 2-Verhulst fit, which is about the same as the 2014 reported reserves amount ($37x10^9$ barrels) plus the amount already extracted (~$33x10^9$ barrels). The final peak was assumed to be symmetrical.



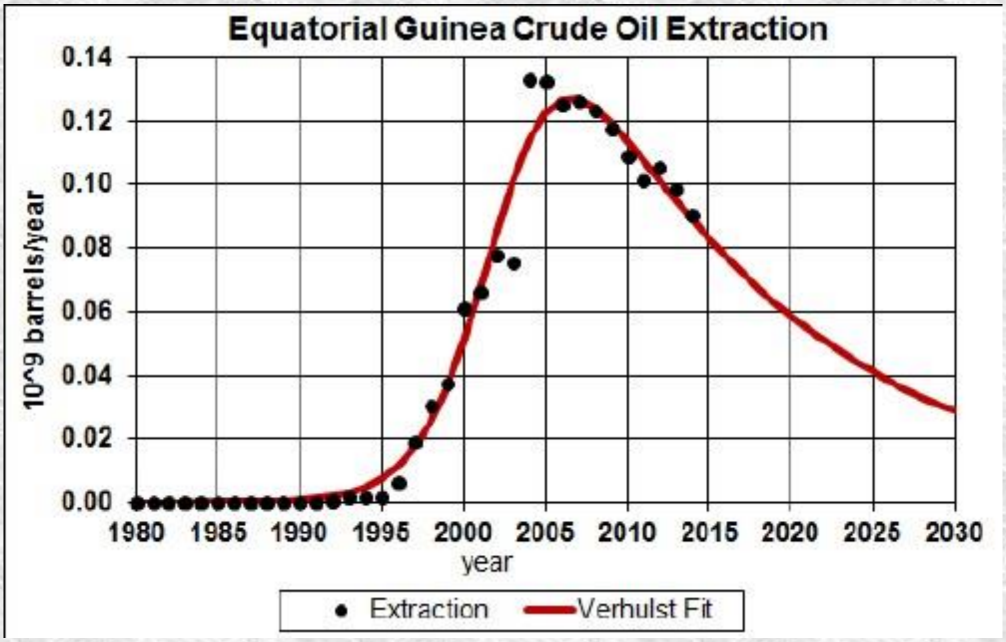
Angola crude-oil extraction

The total amount to be extracted was set at $25x10^9$ barrels for a 2-Verhulst fit, which is slightly less than the 2014 reported reserves amount ($9.1x10^9$ barrels) plus the amount already extracted (~$11.6x10^9$ barrels).



Equatorial Guinea crude-oil extraction

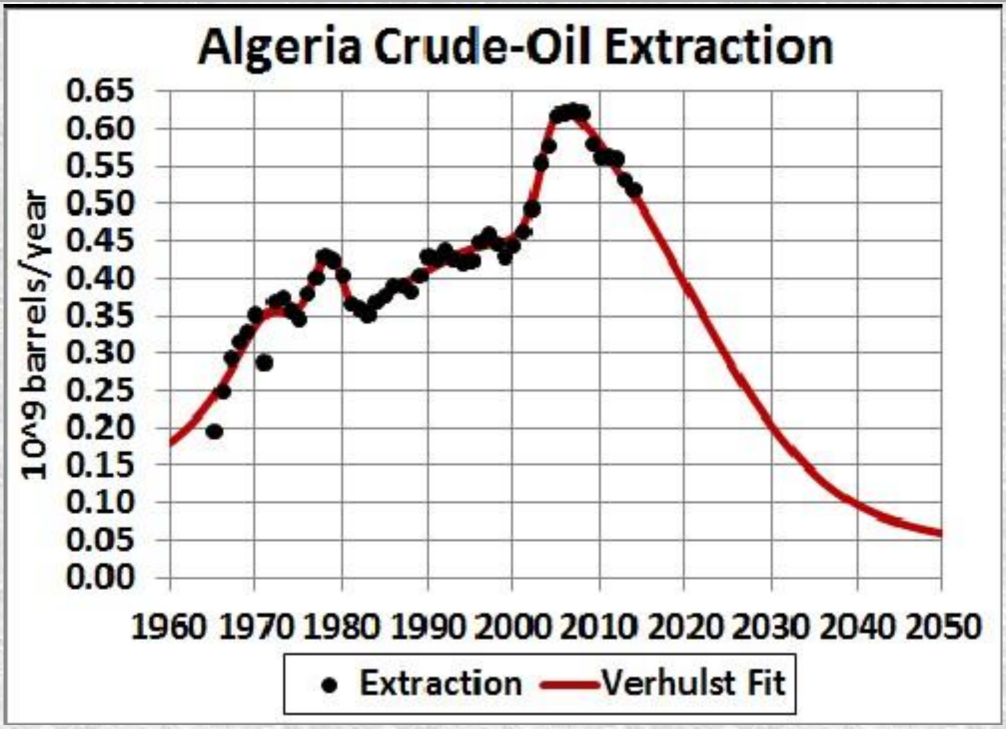
The total amount to be extracted searched to 2.87×10^9 barrels for a Verhulst fit which is smaller than the 2014 reported reserves amount (~1.1×10^9 barrels) plus the amount already extracted (~2.74×10^9 barrels).



The years before 1995 were not used in making the fit.

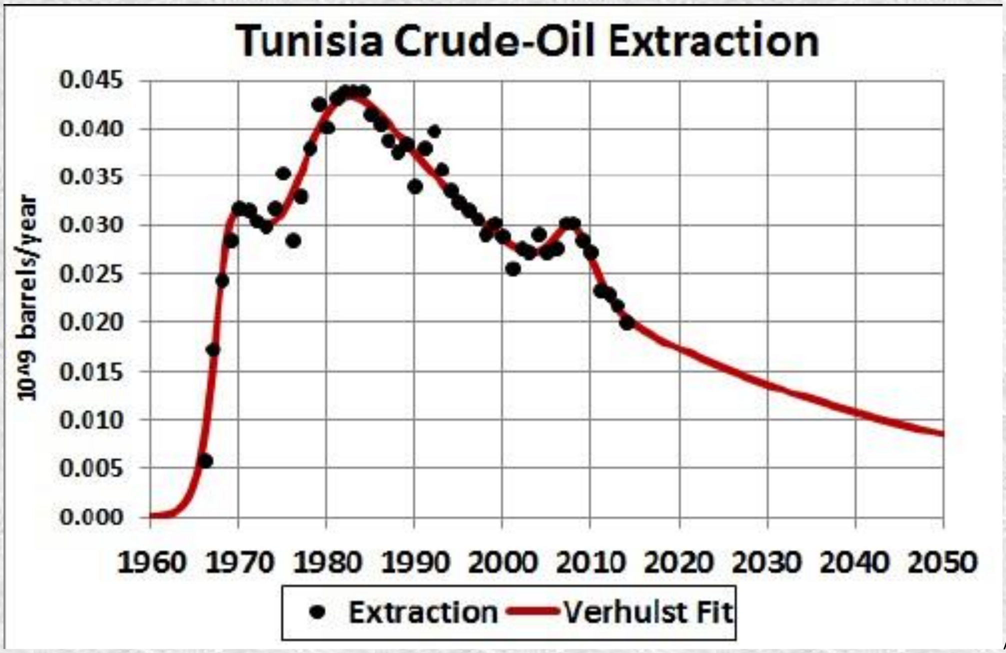
Algeria crude-oil extraction

The total amount to be extracted searched to 36.3×10^9 barrels for the Verhulst fit, which is slightly smaller than the 2014 reported reserves amount (~12.2×10^9 barrels) plus the amount already extracted (~26.5×10^9 barrels).



/Tunisia crude-oil extraction

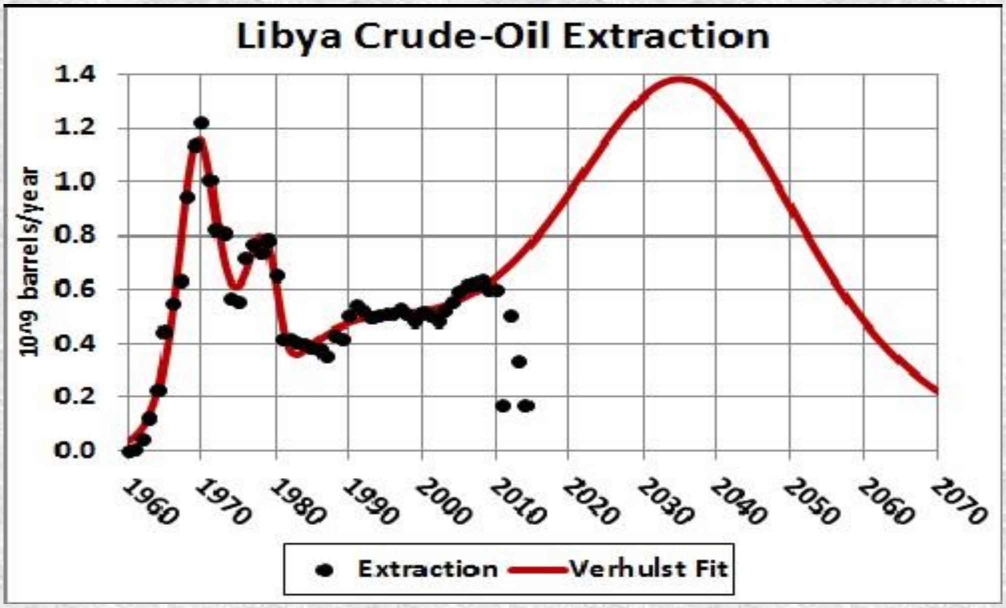
The total amount to be extracted searched to 2.16×10^9 barrels for the Verhulst fit which is slightly larger than the 2014 reported reserves amount (~0.425×10^9 barrels) plus the amount already extracted (~1.55×10^9 barrels).



/

Libya crude-oil extraction

The total amount to be extracted was set at $85x10^9$ barrels for the Verhulst fit which is slightly larger than the 2014 reported reserves amount (~$48.5x10^9$ barrels) plus the amount already extracted (~$30.3x10^9$ barrels). The final peak is assumed to be symmetrical.

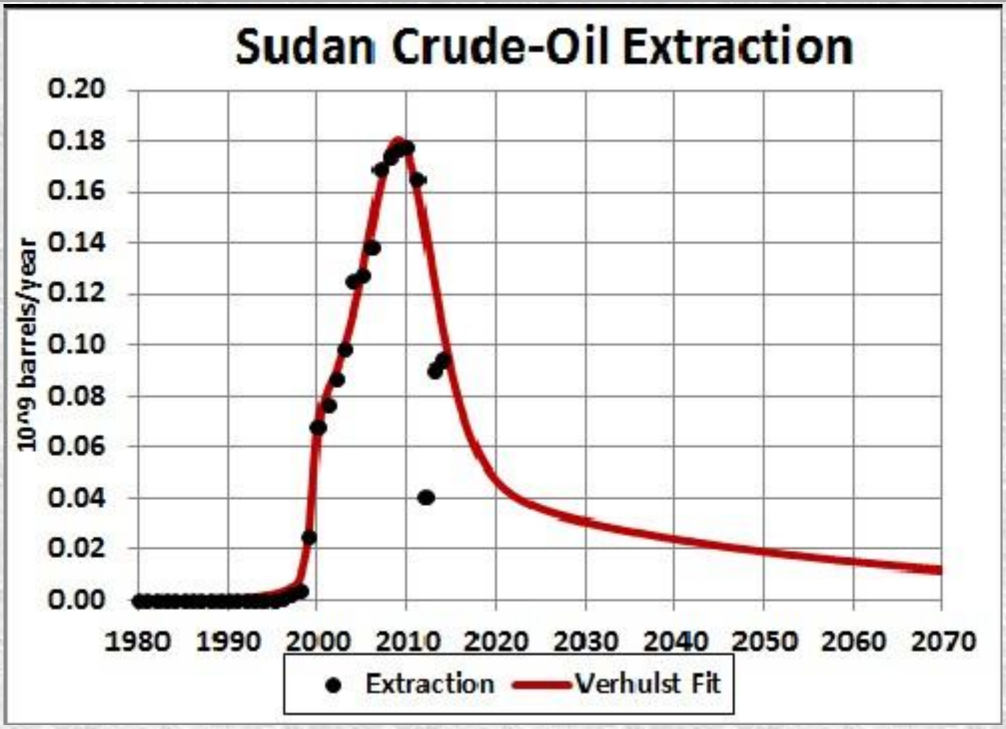


The fit curve is what could have occurred if the nation had not fallen into violence.

The last few years, whose low values were due to the civil war, were not used in making the fit.

Sudan crude-oil extraction

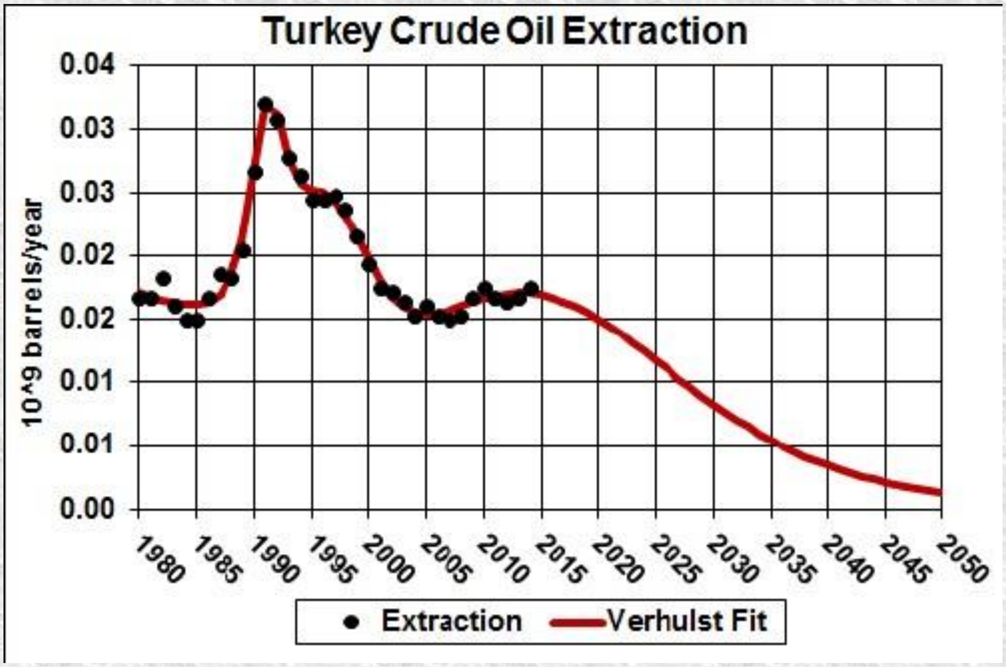
The total amount to be extracted was set at $4x10^9$ barrels for the Verhulst fit, which is about the same as the 2013 reported reserves amount (~$1.25x10^9$ barrels) plus the amount already extracted (~$1.84x10^9$ barrels).



Years before 2000 and the last 4 years were not used in making the fit.

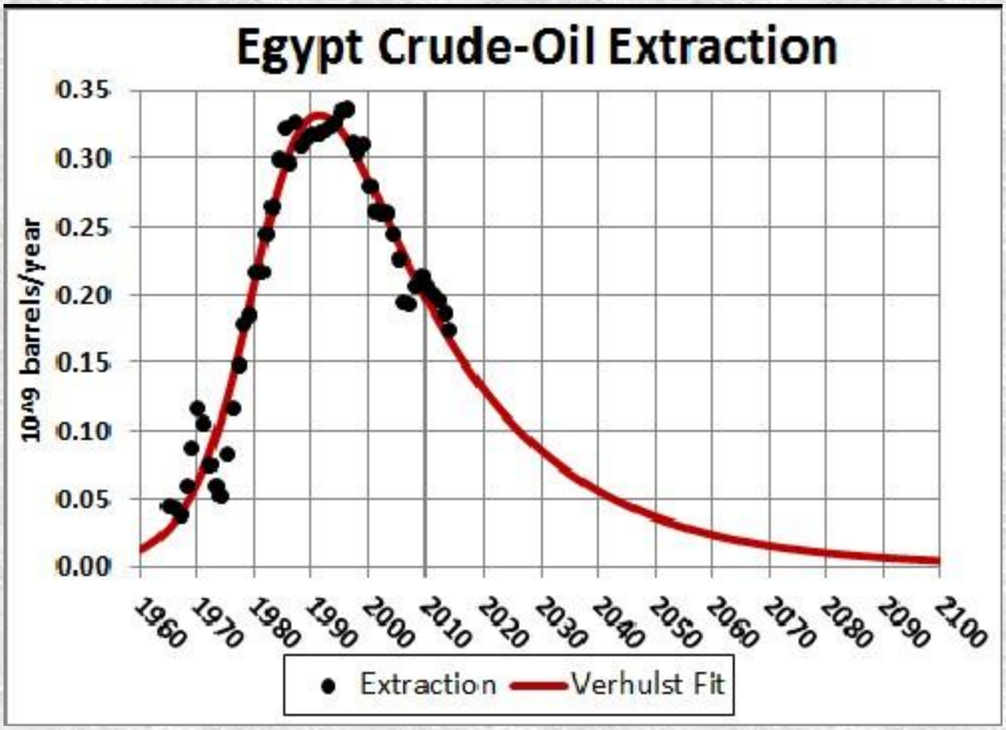
Turkey crude-oil extraction

The total amount to be extracted was set to $1.5\text{x}10^9$ barrels for the Verhulst fit which is about the same as the 2014 reported reserves amount (~$0.2948\text{x}10^9$ barrels) plus the amount already extracted (~$1.196\text{x}10^9$ barrels). The final peak was assumed to be symmetrical.



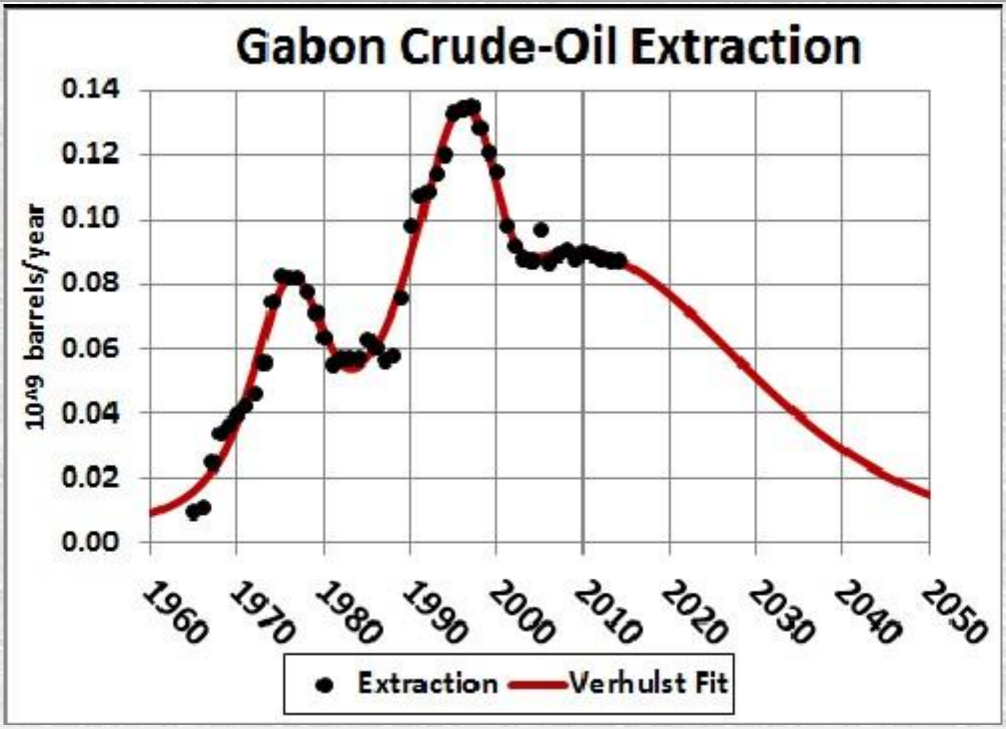
Egypt crude-oil extraction

The total amount to be extracted searched to $14.8x10^9$ barrels for the Verhulst fit which is about the same as the 2014 reported reserves amount (~$4.4x10^9$ barrels) plus the amount already extracted (~$10.8x10^9$ barrels).



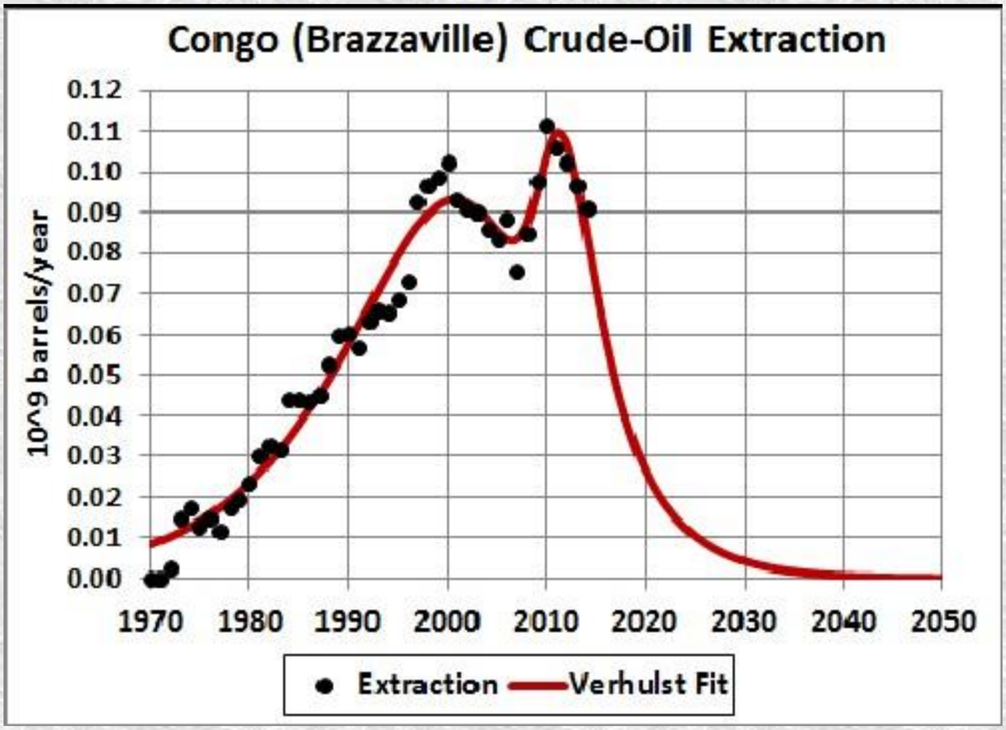
Gabon crude-oil extraction

The total amount to be extracted was set at $6x10^9$ barrels for the Verhulst fit which is about the same as the 2014 reported reserves amount (~$2x10^9$ barrels) plus the amount already extracted (~$4.07x10^9$ barrels).



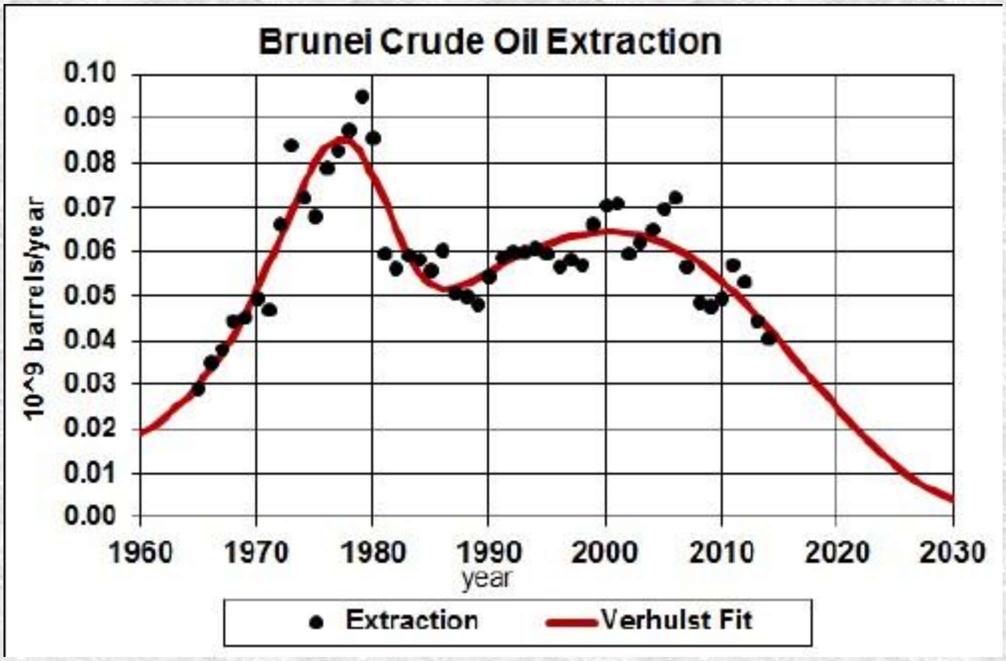
Congo (Brazzaville) crude-oil extraction

The total amount to be extracted searched to 3.08×10^9 barrels for the Verhulst fit, which is somewhat smaller than the 2014 reported reserves amount (~1.6×10^9 barrels) plus the amount already extracted (~2.7×10^9 barrels).



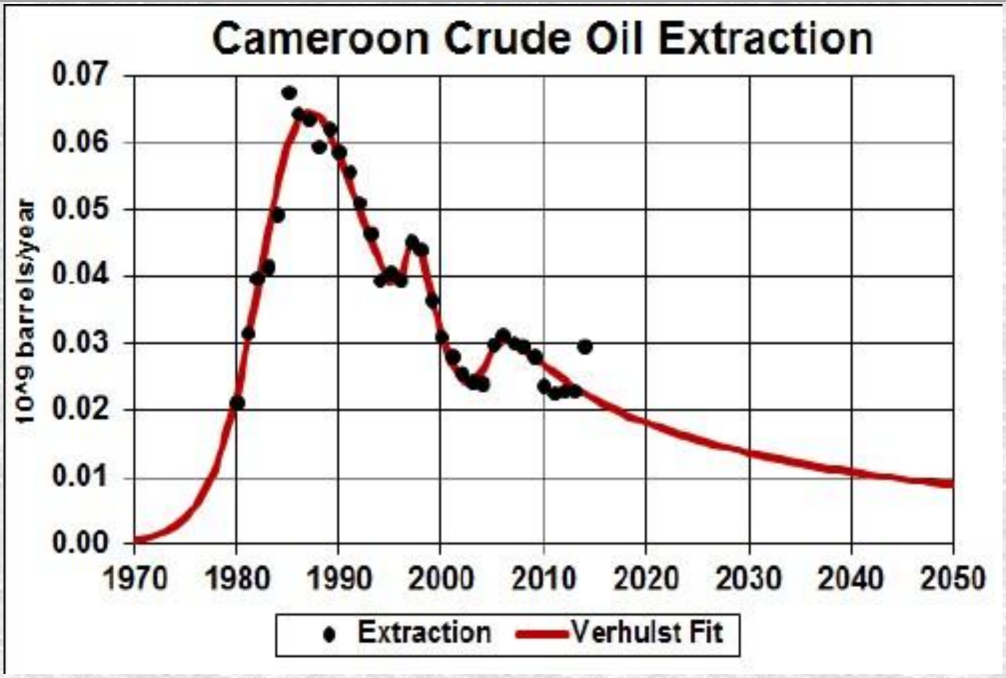
Brunei crude-oil extraction

The total amount to be extracted searched to $3.69x10^9$ barrels for the 2-Verhulst fit, which is considerably smaller than the 2013 reported reserves amount (~$1.1x10^9$ barrels) plus the amount already extracted (~$3.3x10^9$ barrels.



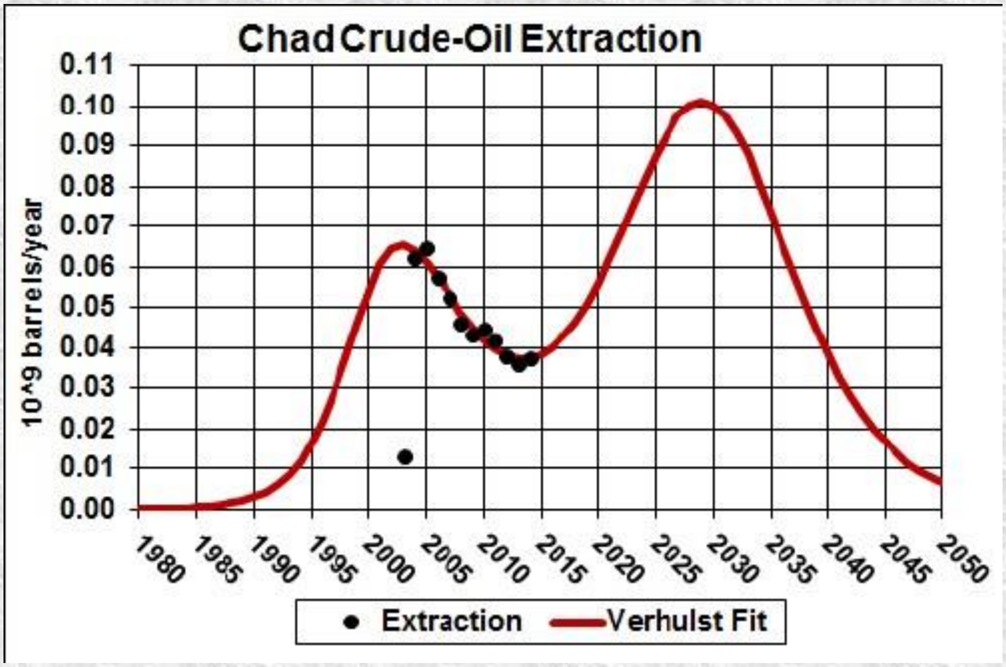
Cameroon crude-oil extraction

The total amount to be extracted searched to $2.37x10^9$ barrels for the Verhulst fit, which is larger than the 2014 reported reserves amount (~$0.2x10^9$ barrels) plus the amount already extracted (~$1.41x10^9$ barrels).



Chad crude-oil extraction

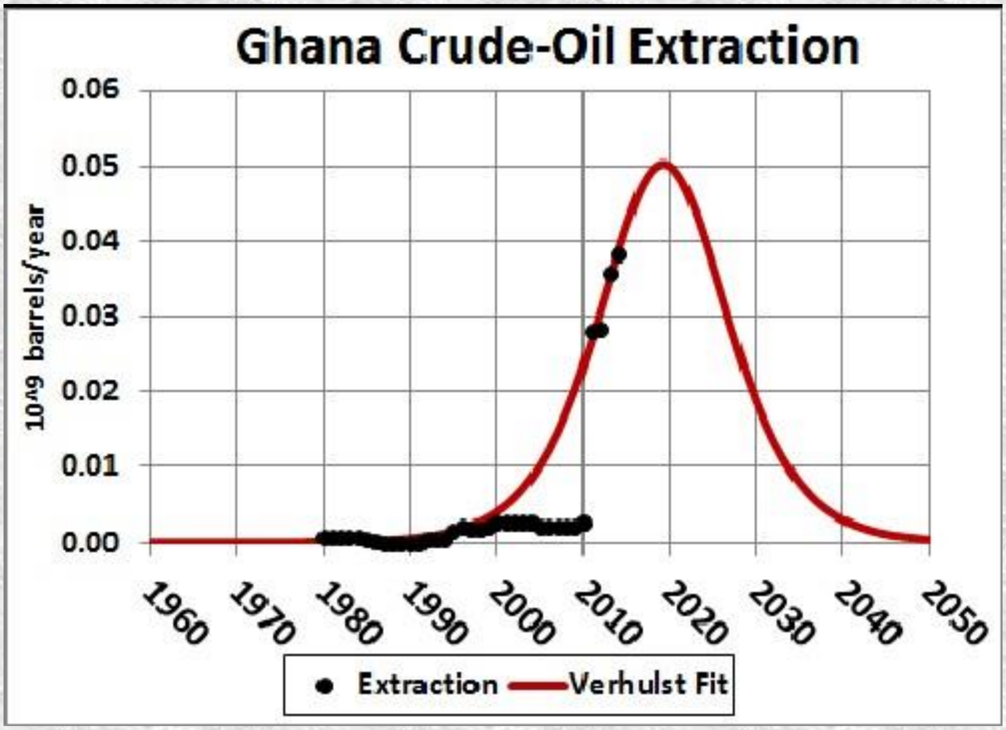
The total amount to be extracted was set to $3x10^9$ barrels for the Verhulst fit, which is larger than the 2014 reported reserves amount (~$1.5x10^9$ barrels) plus the amount already extracted (~$0.94x10^9$ barrels). The future peak was assumed to be symmetrical.



The earliest value was not used in the fit.

Ghana crude-oil extraction

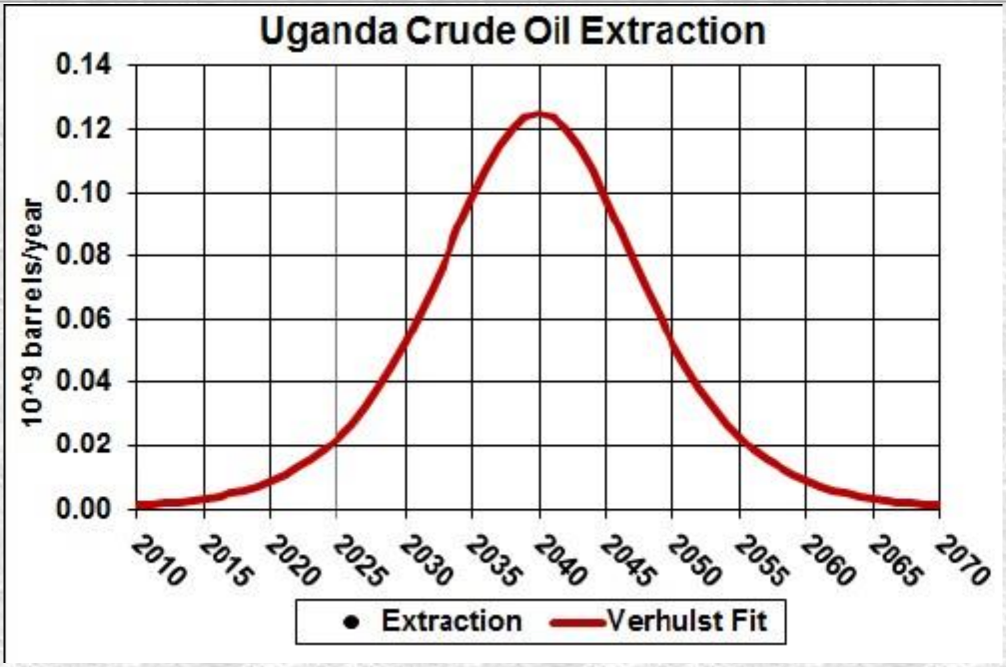
The total amount to be extracted was set to $1x10^9$ barrels for the Verhulst fit, which is larger than the 2014 reported reserves amount (~$0.66x10^9$ barrels) plus the amount already extracted (~$0.172x10^9$ barrels). The final peak was assumed to be symmetrical.



The fit used only the last 4 years' data.

Uganda crude-oil extraction

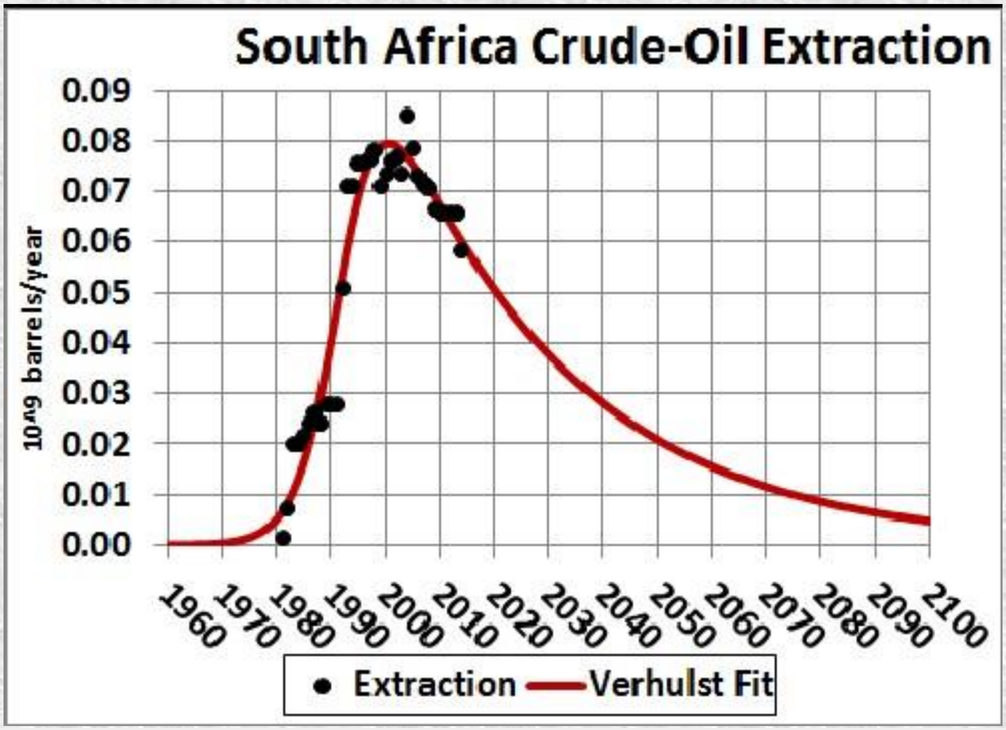
The total amount to be extracted was set to $2.5x10^9$ barrels for the Verhulst fit, which is the same as the 2014 reported reserves amount (~$2.5x10^9$ barrels). The peak was assumed to be symmetrical.



Uganda is supposed to start extracting crude oil in 2016; so this is an estimate of what the extraction might be.

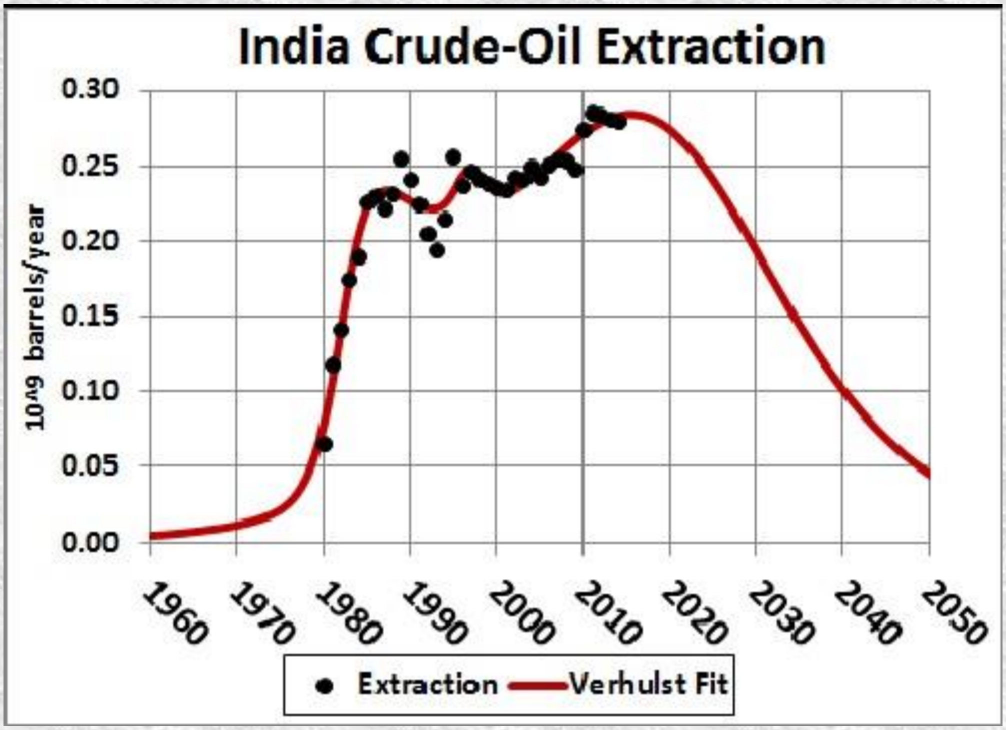
South Africa crude-oil extraction

The total amount to be extracted searched to 3.91x10^9 barrels for the Verhulst fit, which is larger than the 2014 reported reserves amount (~0.015x10^9 barrels) plus the amount already extracted (~1.86x10^9 barrels).



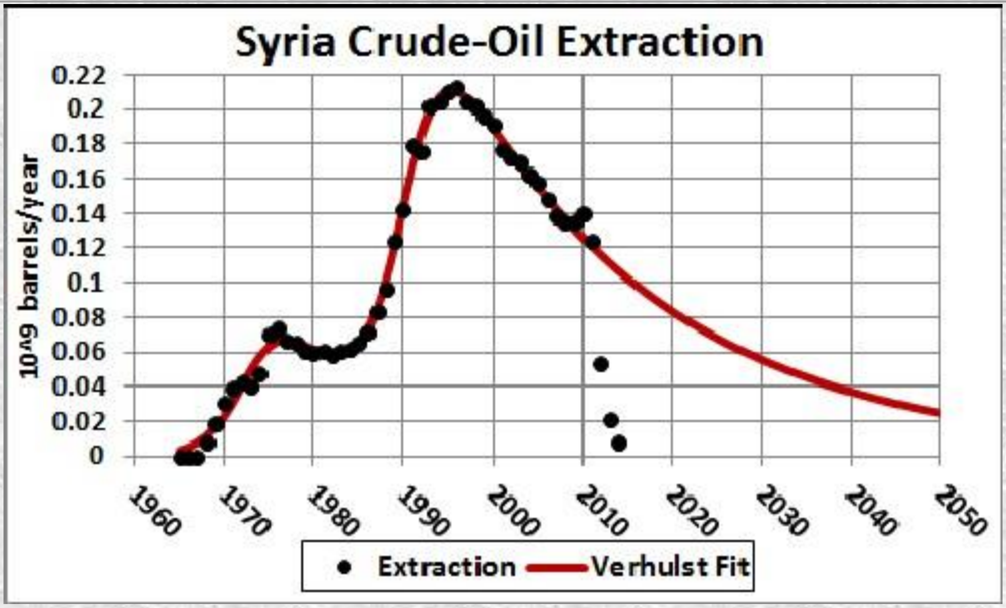
India crude-oil extraction

The total amount to be extracted was set to 15x10^9 barrels for the Verhulst fit, which is about the same as the 2014 reported reserves amount (~5.6x10^9 barrels) plus the amount already extracted (~8.3x10^9 barrels). The final peak was assumed to be symmetrical.



Syria crude-oil extraction

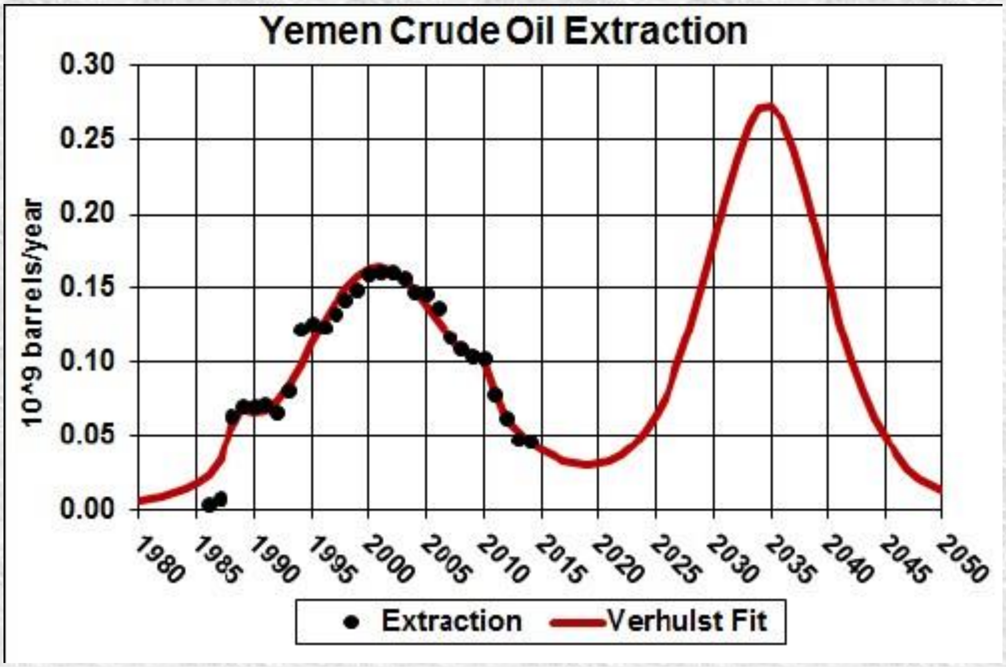
The total amount to be extracted was set at 8x10^9 barrels for the Verhulst fit, which is about the same as the 2014 reported reserves amount (~2.5x10^9 barrels) plus the amount already extracted (~5.2x10^9 barrels).



The last three years' values, due to the civil war, were not used in making the fit.

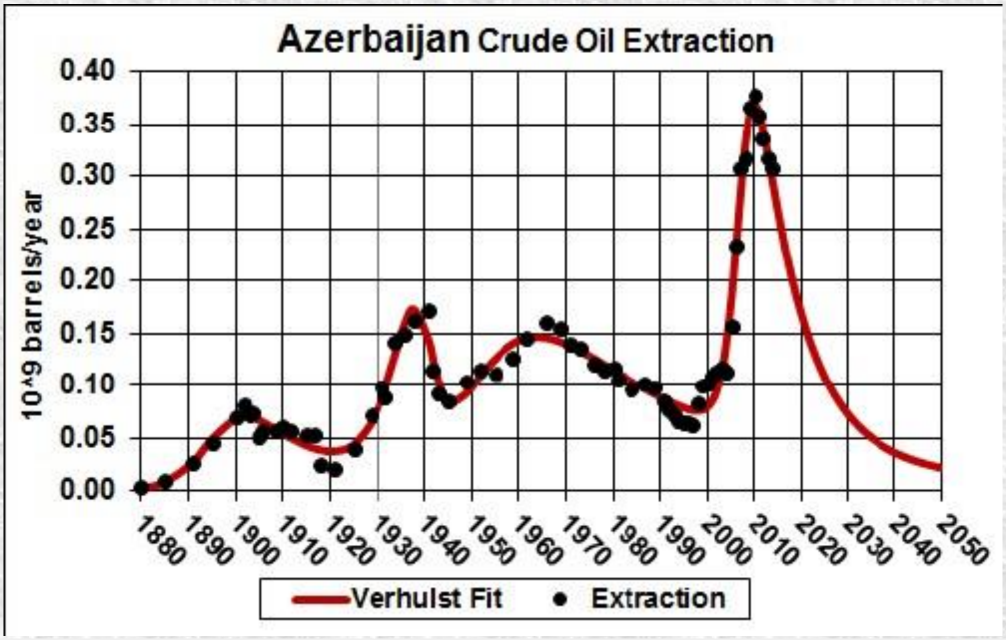
Yemen crude-oil extraction

The total amount to be extracted was set at $7x10^9$ barrels for the Verhulst fit, which is slightly larger tan the 2014 reported reserves amount ($\sim 3x10^9$ barrels) plus the amount already extracted ($\sim 3x10^9$ barrels). The final peak is assumed to be symmetrical.



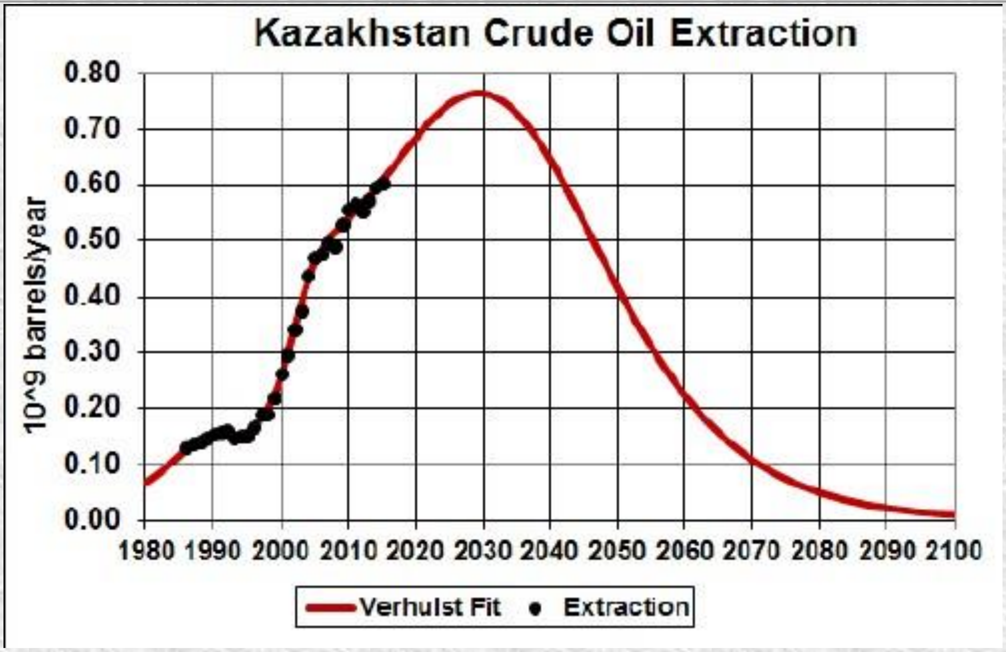
Azerbaijan crude-oil extraction

The total amount to be extracted searched to 17.8x10^9 barrels for the Verhulst fit, which is slightly less than the 2014 reported reserves amount (~7x10^9 barrels) plus the amount already extracted (~13.8x10^9 barrels).



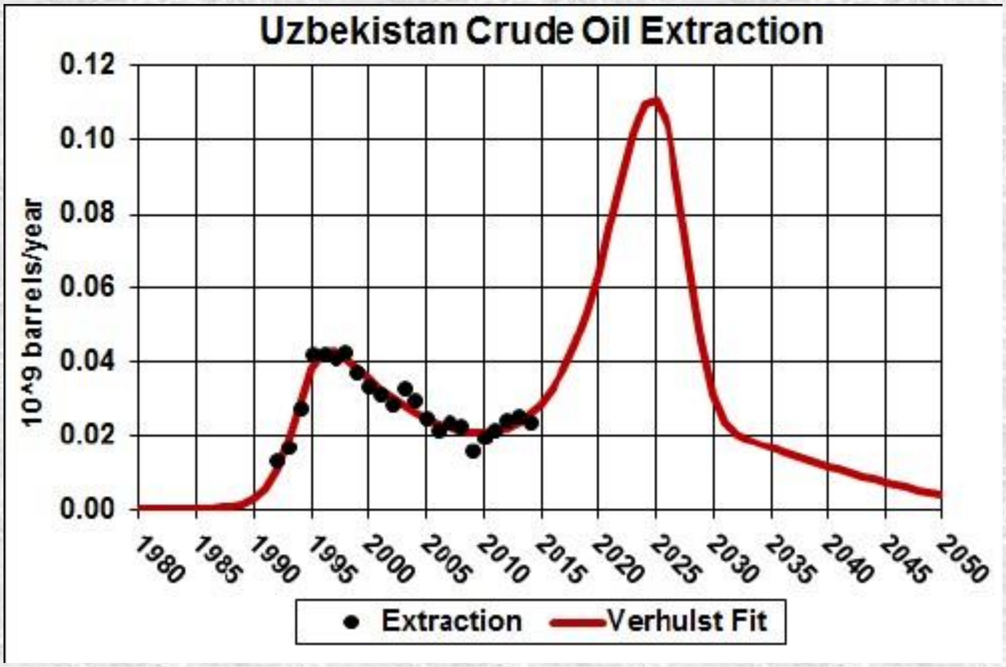
Kazakhstan crude-oil extraction

The total amount to be extracted was set at 40x10^9 barrels for the Verhulst fit, which is about the same as the 2014 reported reserves amount (~30x10^9 barrels) plus the amount already extracted (~9.9x10^9 barrels). The future peak was assumed to be symmetrical.



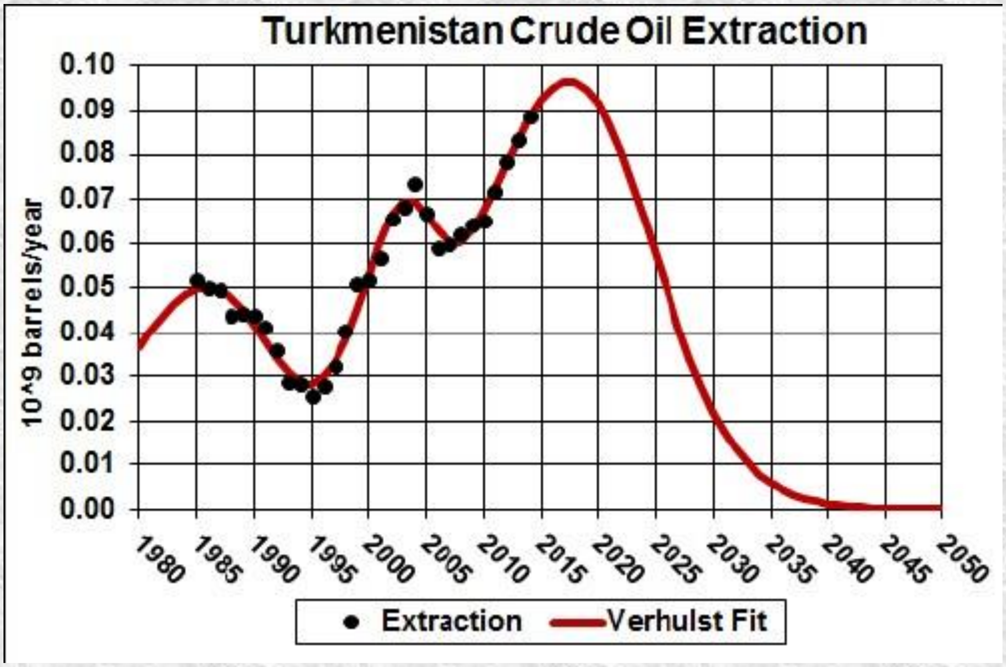
Uzbekistan crude-oil extraction

The total amount to be extracted was set at $2x10^9$ barrels for the Verhulst fit which is larger than the 2014 reported reserves amount (~$0.594x10^9$ barrels) plus the amount already extracted (~$0.641x10^9$ barrels). The future peak is assumed to be symmetrical.



Turkmenistan crude-oil extraction

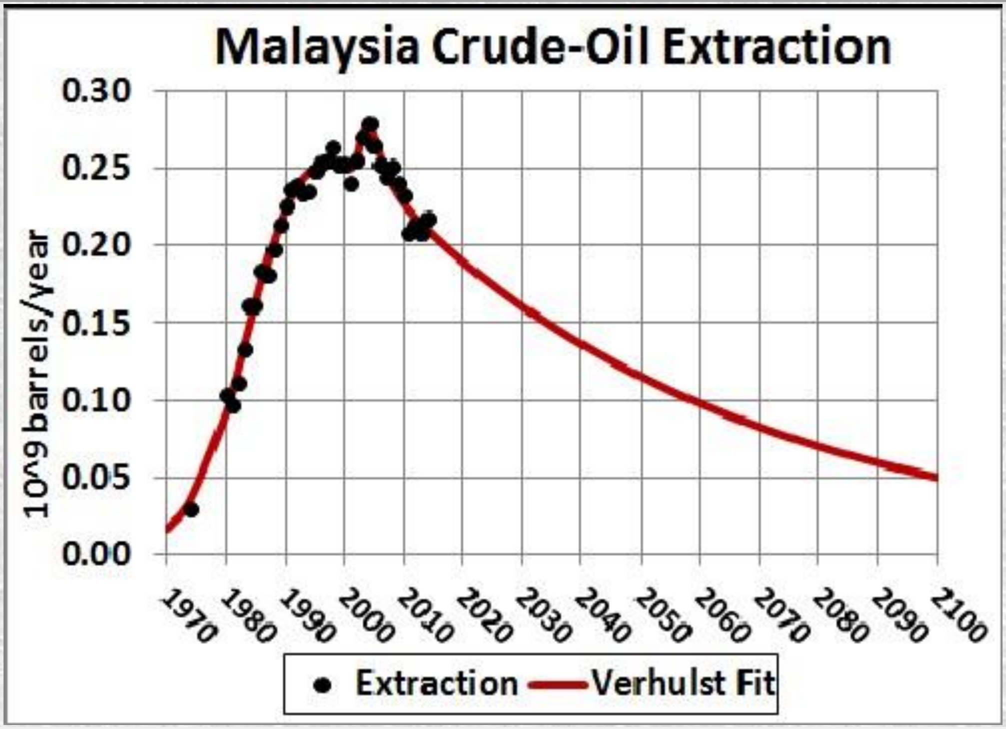
The total amount to be extracted was set at $5x10^9$ barrels for the Verhulst fit which is much larger than the 2014 reported reserves amount (~$0.6x10^9$ barrels) plus the amount already extracted (~$2.04x10^9$ barrels). The final peak is assumed to be symmetrical.



It would be helpful to have extraction data before 1980.

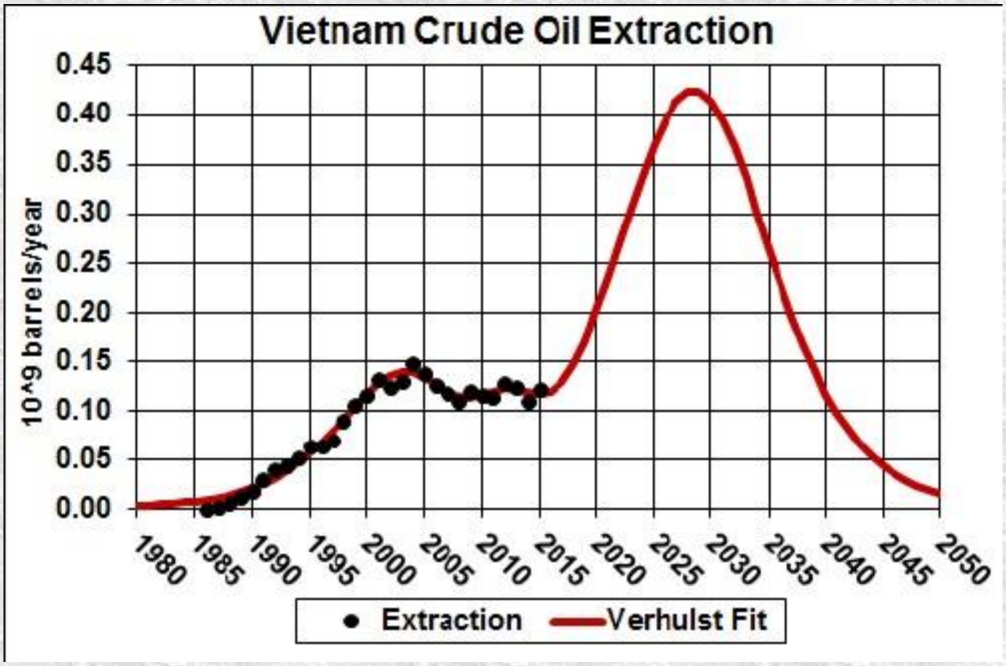
Malaysia crude-oil extraction

The total amount to be extracted searched to $20.5x10^9$ barrels for the Verhulst fit, which is slightly larger than the 2014 reported reserves amount (~$4x10^9$ barrels) plus the amount already extracted (~$12.8x10^9$ barrels).



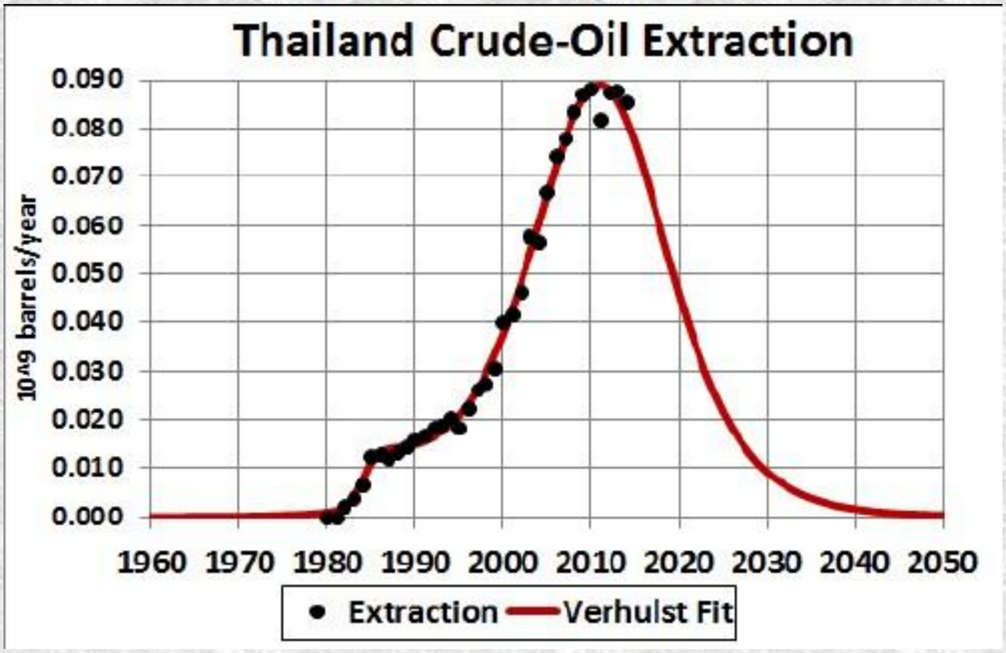
Vietnam crude-oil extraction

The total amount to be extracted was set to 10x10^9 barrels for the Verhulst fit, which is larger than the 2014 reported reserves amount (~4.4x10^9 barrels) plus the amount already extracted (~2.6x10^9 barrels). The future peak is assumed to be symmetrical.



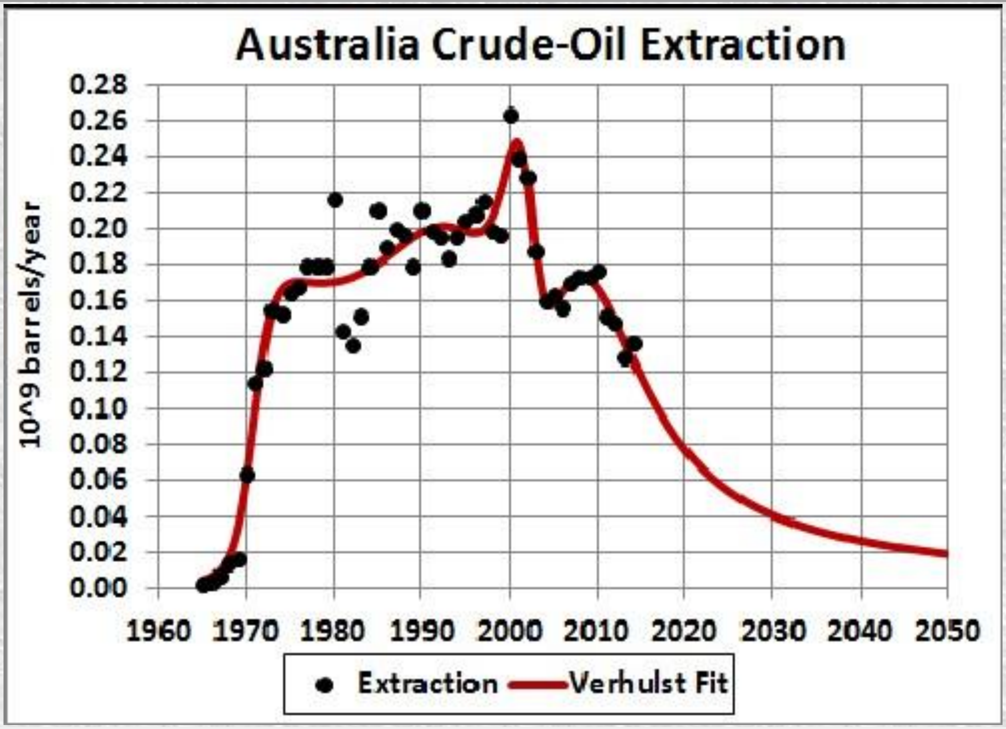
Thailand crude-oil extraction

The total amount to be extracted was set to $2x10^9$ barrels for the Verhulst fit which is slightly larger than the 2014 reported reserves amount (~$0.4488x10^9$ barrels) plus the amount already extracted (~$1.32x10^9$ barrels). The peak was assumed to be symmetrical.



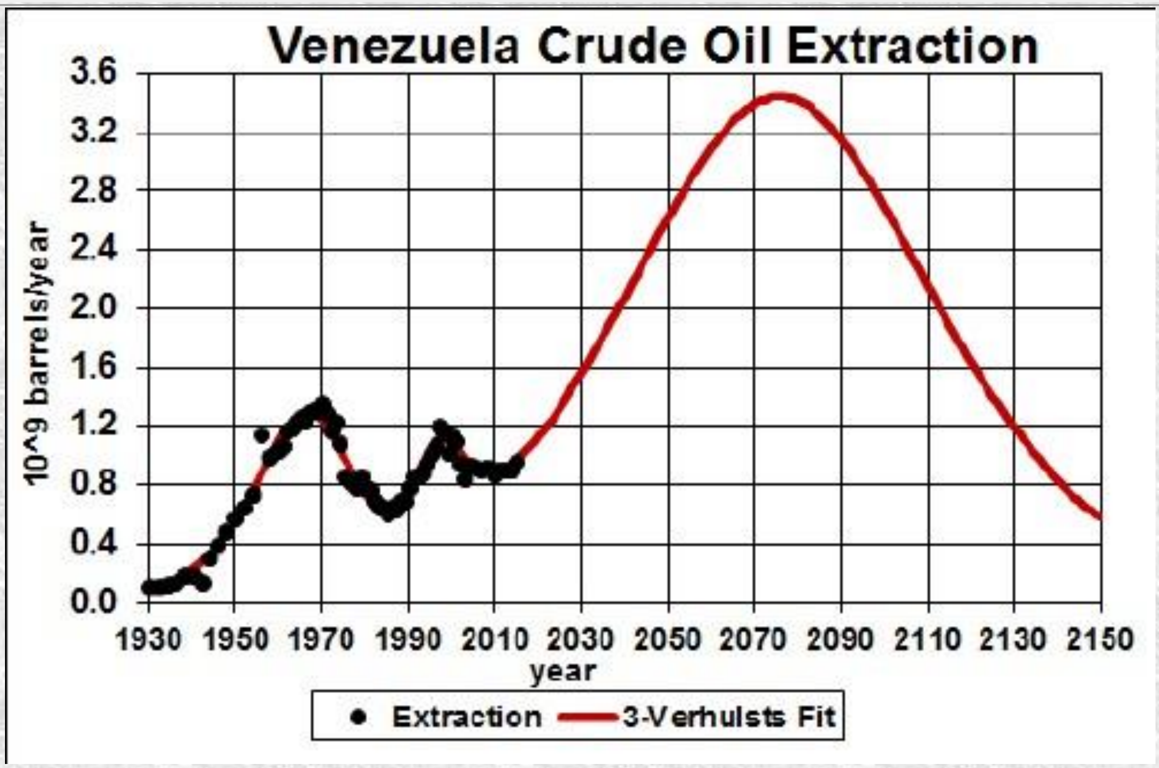
Australia crude-oil extraction

The total amount to be extracted searched to $10.3x10^9$ barrels for the Verhulst fit which is about the same as the 2014 reported reserves amount (~$1.4x10^9$ barrels) plus the amount already extracted (~$8.0x10^9$ barrels).



Venezuela crude-oil extraction

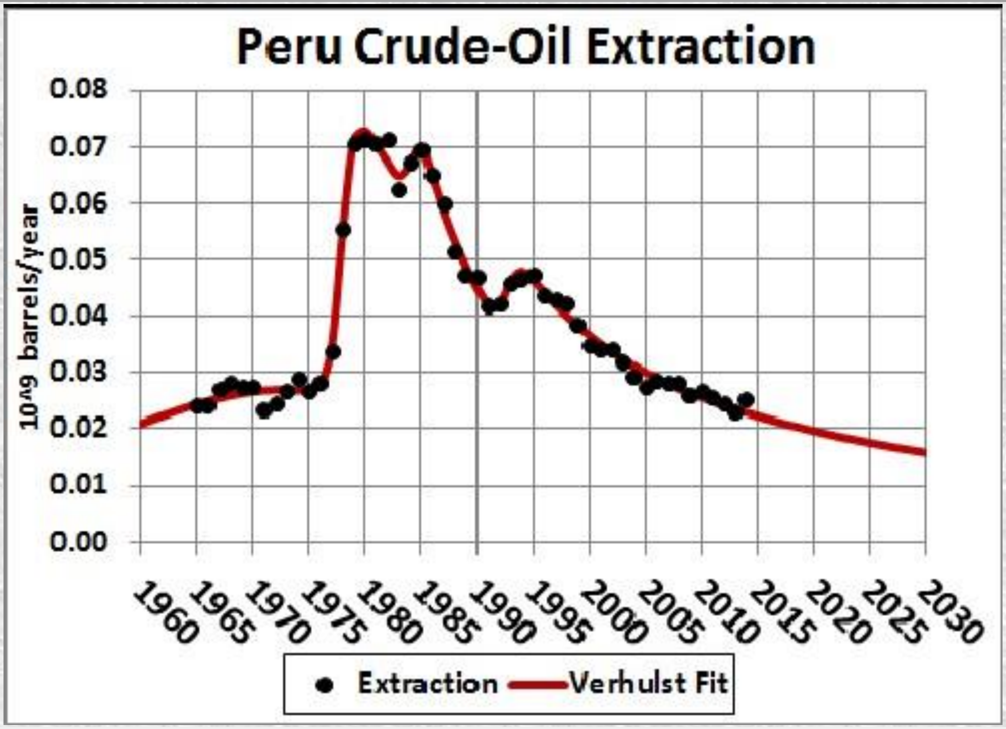
The total amount to be extracted was set at 375×10^9 barrels for the single-Verhulst fit, which is slightly larger than the 2014 reported reserves amount (~298×10^9 barrels) plus the amount already extracted (~67×10^9 barrels). The final peak is assumed to be symmetrical.



The future peak is mostly heavy oil.

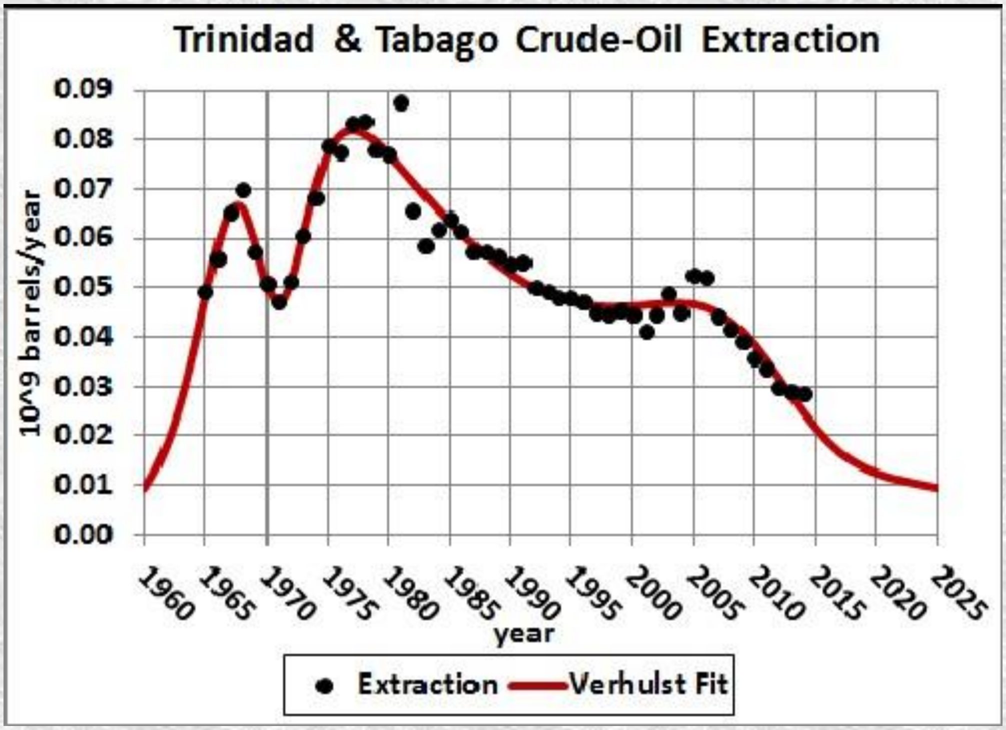
Peru crude-oil extraction

The total amount to be extracted searched to 3.97×10^9 barrels for the Verhulst fit which is larger than the 2014 reported reserves amount (~0.6329×10^9 barrels) plus the amount already extracted (~2.47×10^9 barrels).



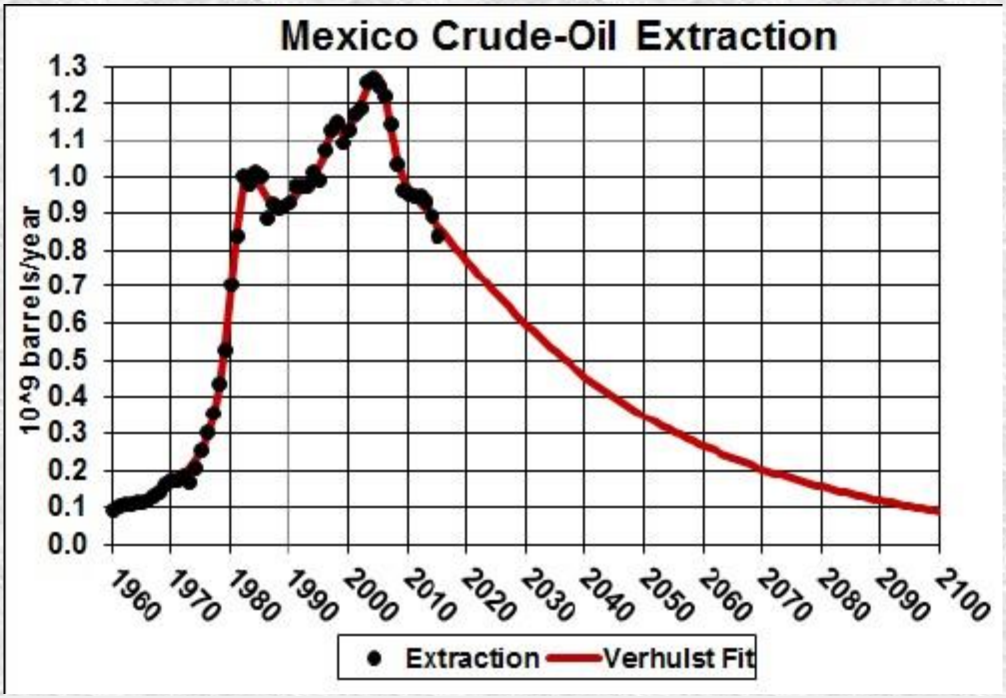
Trinidad & Tobago crude-oil extraction

The total amount to be extracted searched to $3.2x10^9$ barrels for the 3-Verhulst fit which is slightly smaller than the 2014 reported reserves amount (~$0.73x10^9$ barrels) plus the amount already extracted (~$2.8x10^9$ barrels).



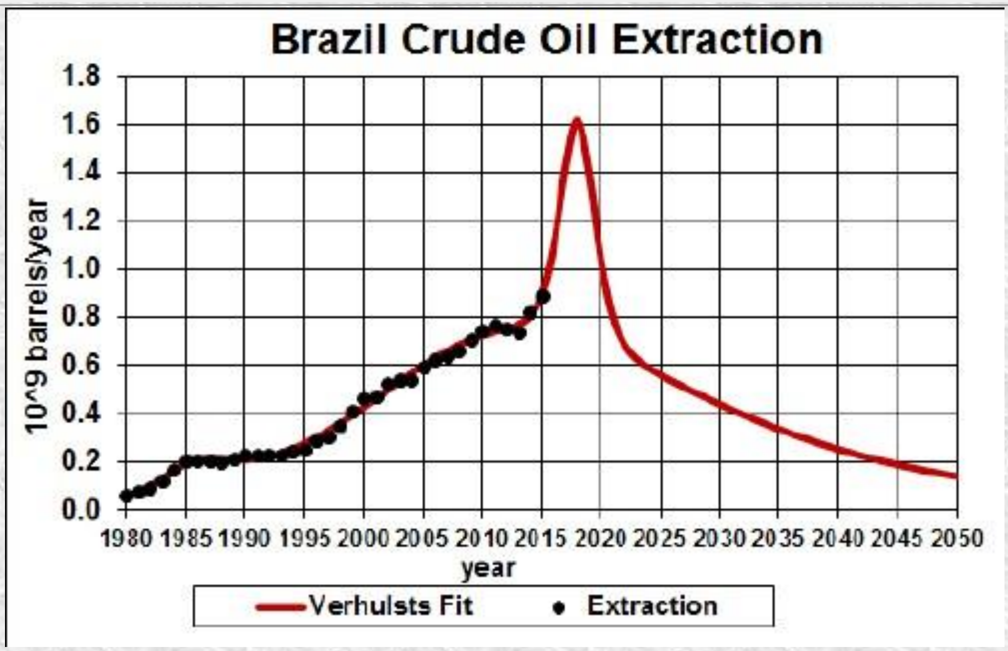
Mexico crude-oil extraction.

For the Verhulst fit the total amount to be extracted searched to 59x10^9 barrels which is slightly larger than the 2014 reported reserves amount (~10x10^9 barrels) plus the amount already extracted (~38.1x10^9 barrels).



Brazil crude-oil extraction

The total amount to be extracted was set to 35x10^9 barrels which is slightly greater than the 2014 reported reserves amount (~13.2x10^9 barrels) plus the amount already extracted (~14.7x10^9 barrels). The final peak is assumed to be symmetrical.



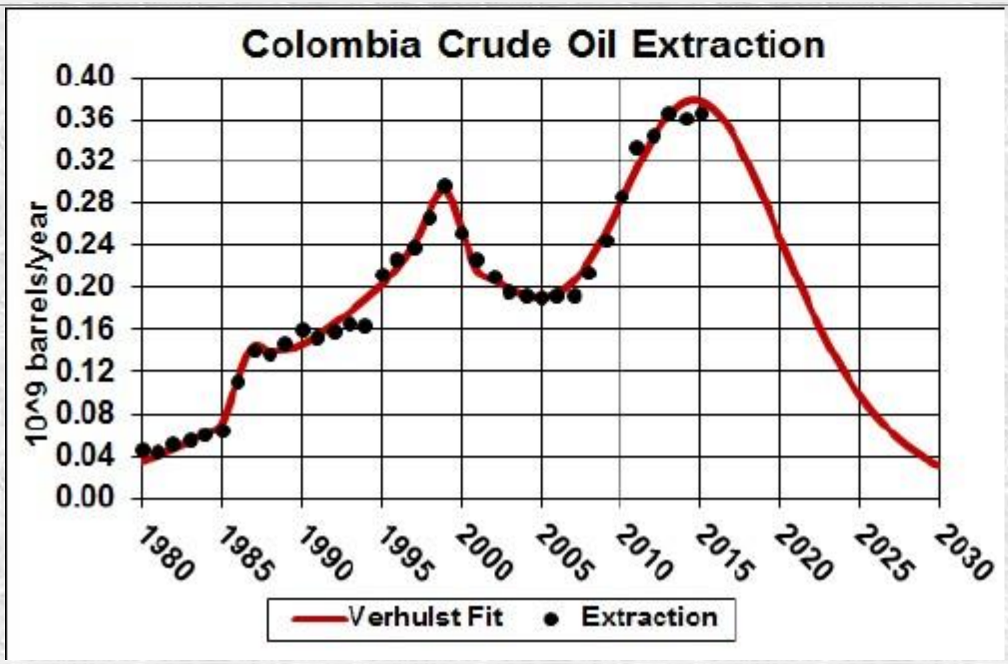
The reserves used in this calculation was posted by the U.S. Energy Information Agency in 2013. Obviously, it does not include the recent off-shore discoveries called Pre-sal, with estimates up to $100x10^9$ barrels.

The best article I found about Pre-sal is :http://www.economist.com/displayStory.cfm?story_id=13348824. I think that it is very uncertain as to how much oil can actually be recovered from Pre-sal. The Economist article mentions many problems with extracting oil from Pre-sal.

Countries almost always greatly exaggerate oil discoveries. $50x10^9$ barrels or more would be an amazing discovery. None that large have been discovered for over 40 years. I don't believe the numbers given by Petrobras for the Pre-sal discovery.

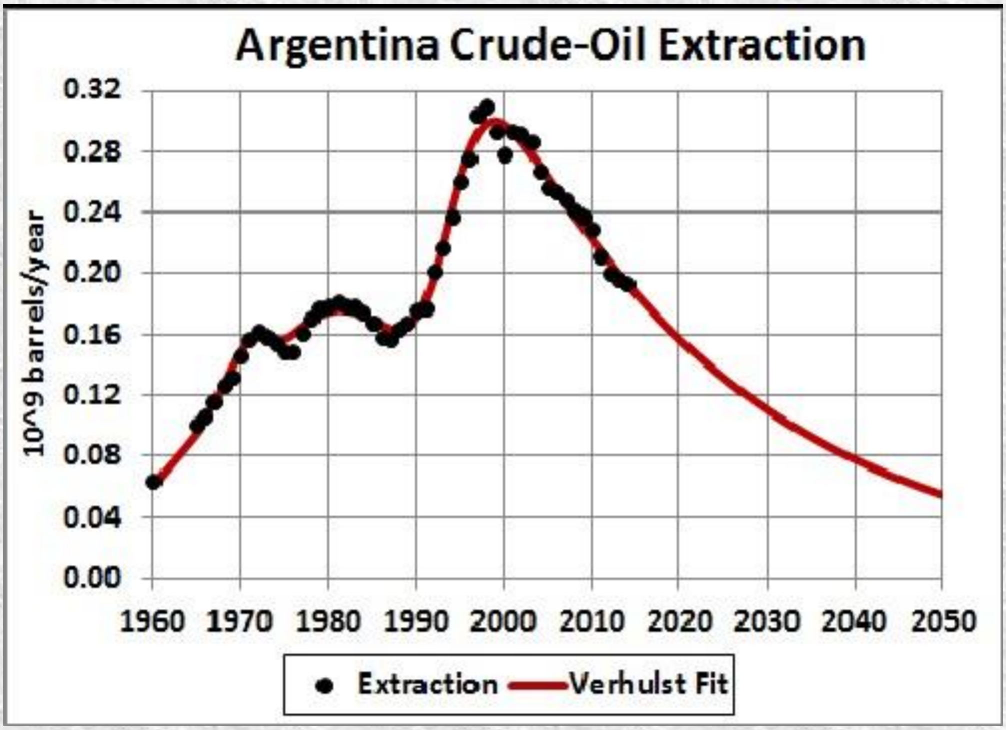
Colombia crude-oil extraction

The total amount to be extracted was set at $10x10^9$ barrels for the Verhulst fit which is slightly larger than the 2014 reported reserves amount (~$2.4x10^9$ barrels) plus the amount already extracted (~$7.1x10^9$ barrels). The final peak is assumed to be symmetric.



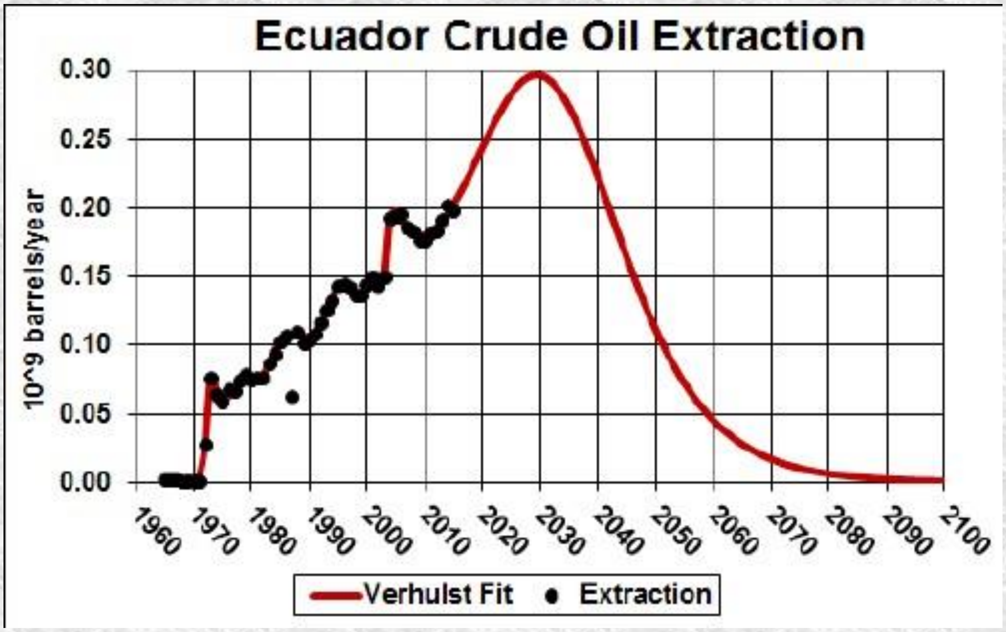
Argentina crude-oil extraction

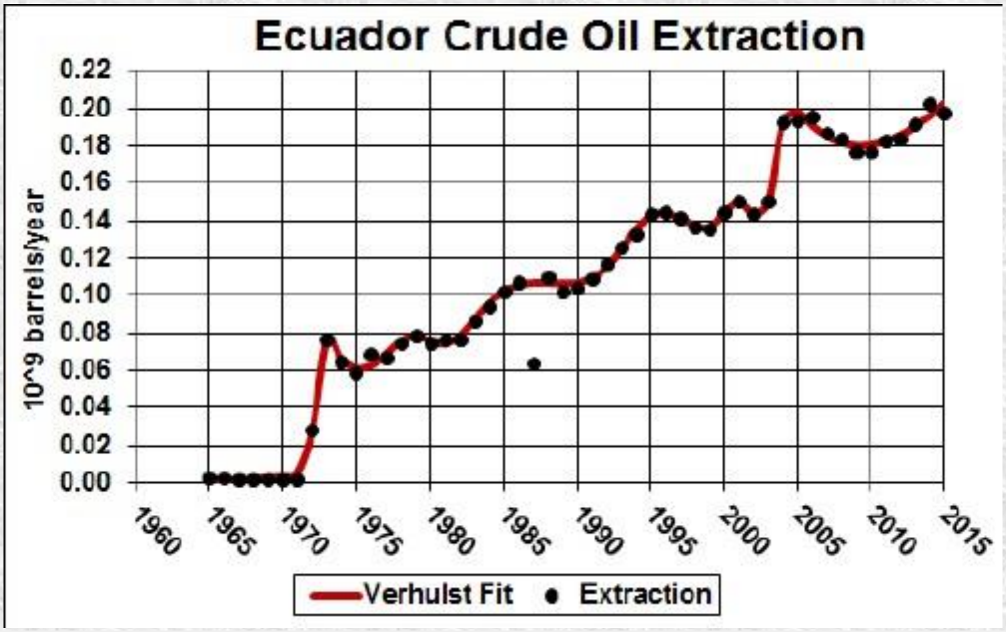
The total amount to be extracted searched to 16.5x10^9 barrels for the 3-Verhulst fit which is slightly larger than the 2014 reported reserves amount (~2.8x10^9 barrels) plus the amount already extracted (~11.0x10^9 barrels).



Ecuador crude-oil extraction

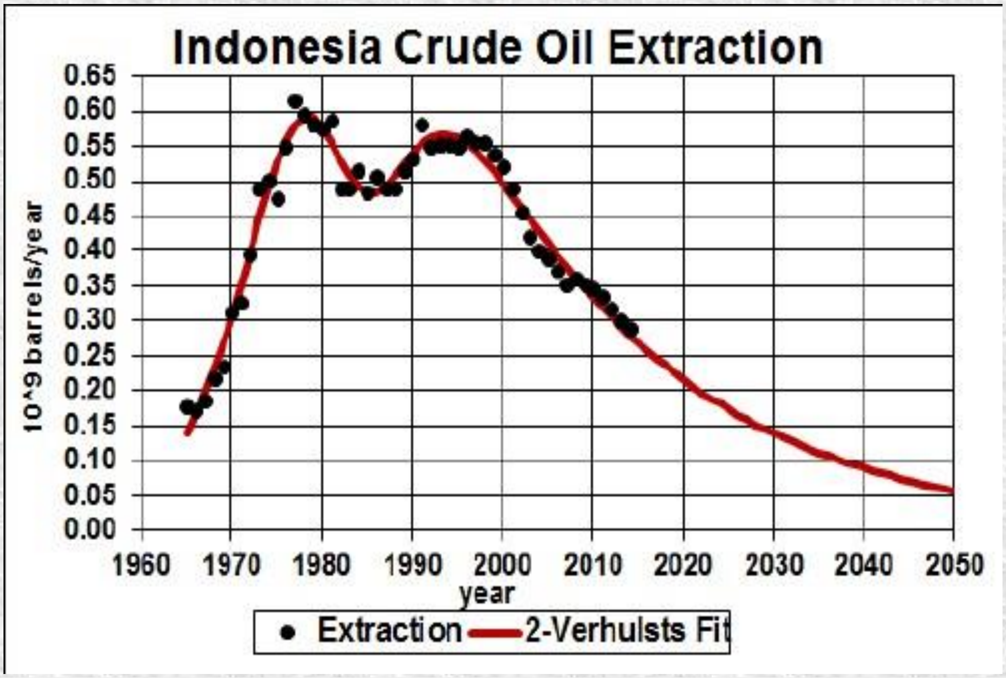
The total amount to be extracted was set to $15x10^9$ barrels for the Verhulst fit which is slightly larger than the 2014 reported reserves amount (~$8.24x10^9$ barrels) plus the amount already extracted (~$5.5x110^9$ barrels). The final peak is assumed to be symmetrical.





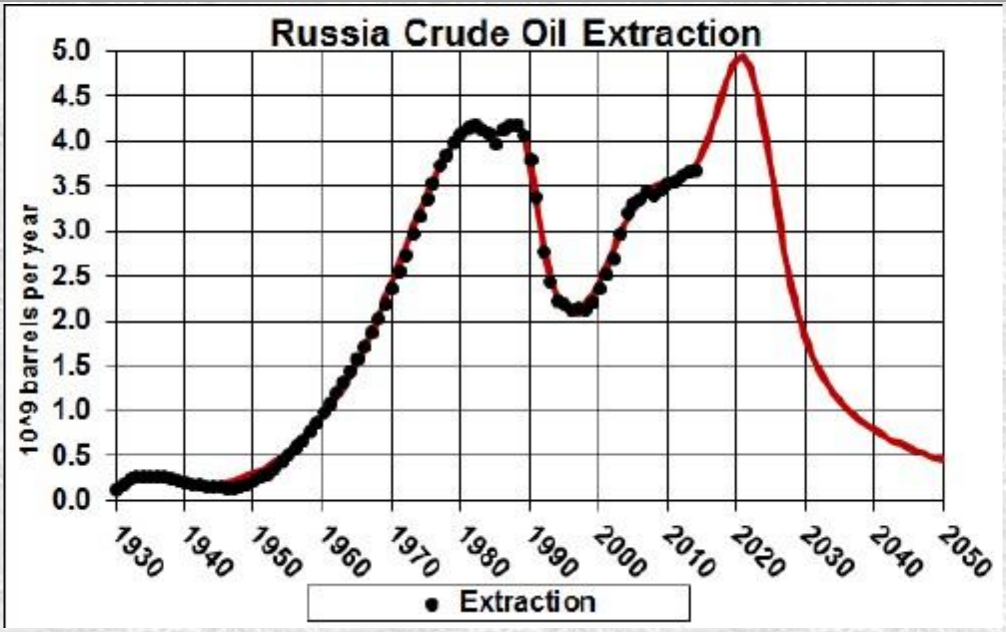
Indonesia crude-oil extraction

The total amount to be extracted searched to 29.2×10^9 barrels for the 2-Verhulst fit which is slightly larger than the 2014 reported reserves amount (~3.59×10^9 barrels) plus the amount already extracted (~22.8×10^9 barrels).



Soviet-Union/Russia crude-oil extraction.

The total amount to be extracted was set to 260×10^9 barrels which is about the same as the 2014 reserves estimate of ~80×10^9 barrels plus the amount already extracted (~173×10^9 barrels).

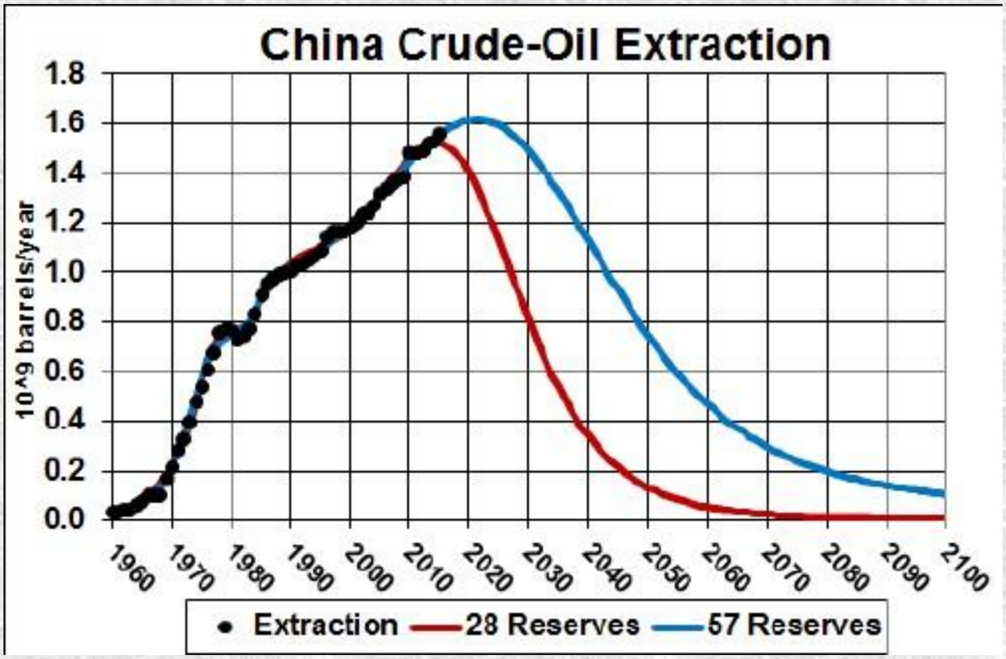


Note the drastic drop when the [Soviet Union collapsed ~1990](#).

Of course, the first peak is for the entire Soviet Union and the second peak is for Russia alone.

China crude-oil extraction

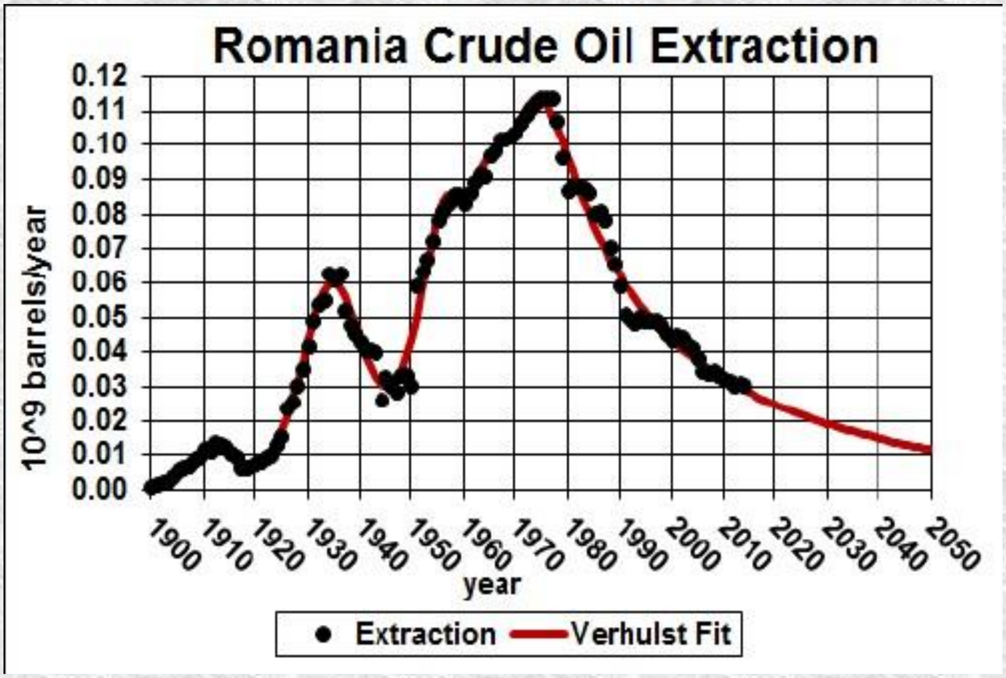
The red-curve Verhulst fit was set at Q=75x10^9 barrels, which is slightly more than 2015 reserves of 24.6x10^9 barrels and ~46.7.3x10^9 barrels already extracted. However, a better fit was obtained with a reserves value of 66.5 x10^9 barrels, the blue curve.



Both fits assume that the peak is symmetrical.

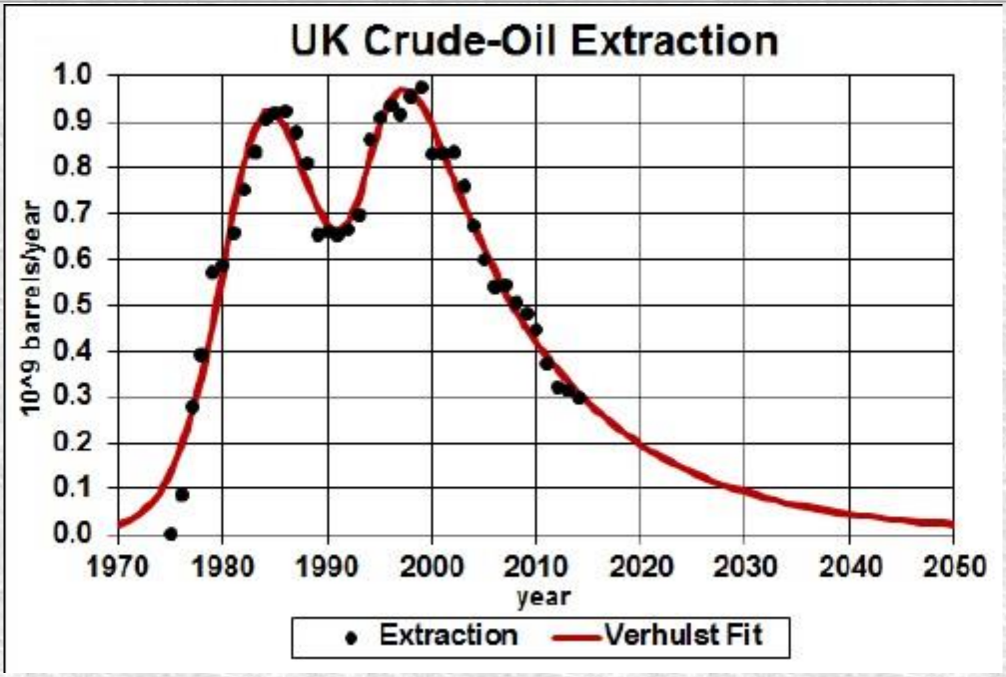
Romania crude-oil extraction

The total amount to be extracted searched to 6.9×10^9 barrels for the Verhulst fit which is slightly larger than the 2014 reported reserves amount (~0.6×10^9 barrels) plus the amount already extracted (~5.8×10^9 barrels)..



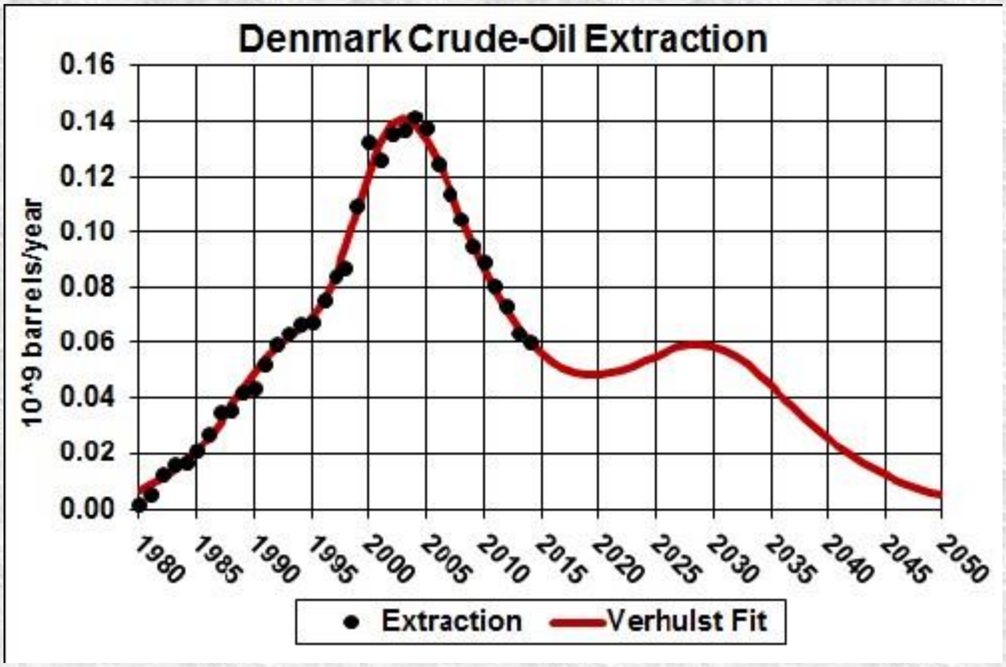
United Kingdom crude-oil extraction

The total amount to be extracted for a 2-Verhulst fit searched to $Q=30.3 \times 10^9$ barrels, which is slightly more than the reported reserves amount (2.98×10^9 barrels) plus the amount already extracted (~26.1×10^9 barrels)



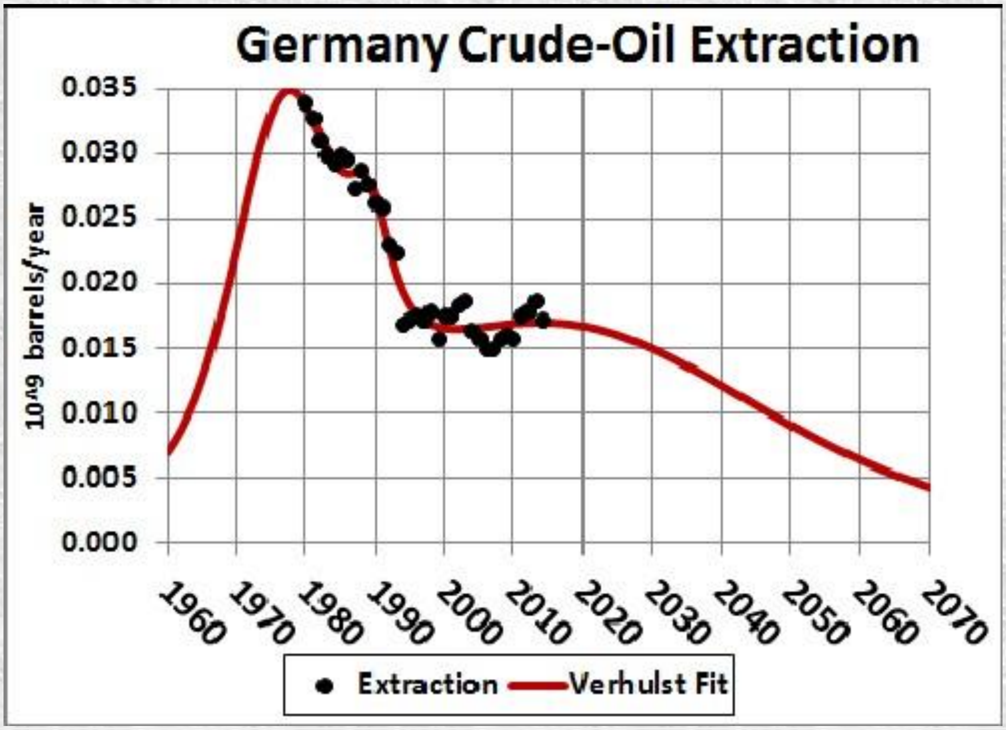
Denmark crude-oil extraction

The total amount to be extracted for a Verhulst fit was set to Q=4x10^9 barrels, which is slightly larger than the 2014 reported reserves amount (~0.8051x10^9 barrels) plus the amount already extracted (~2.54x10^9 barrels). The future peak is assumed to be symmetrical.



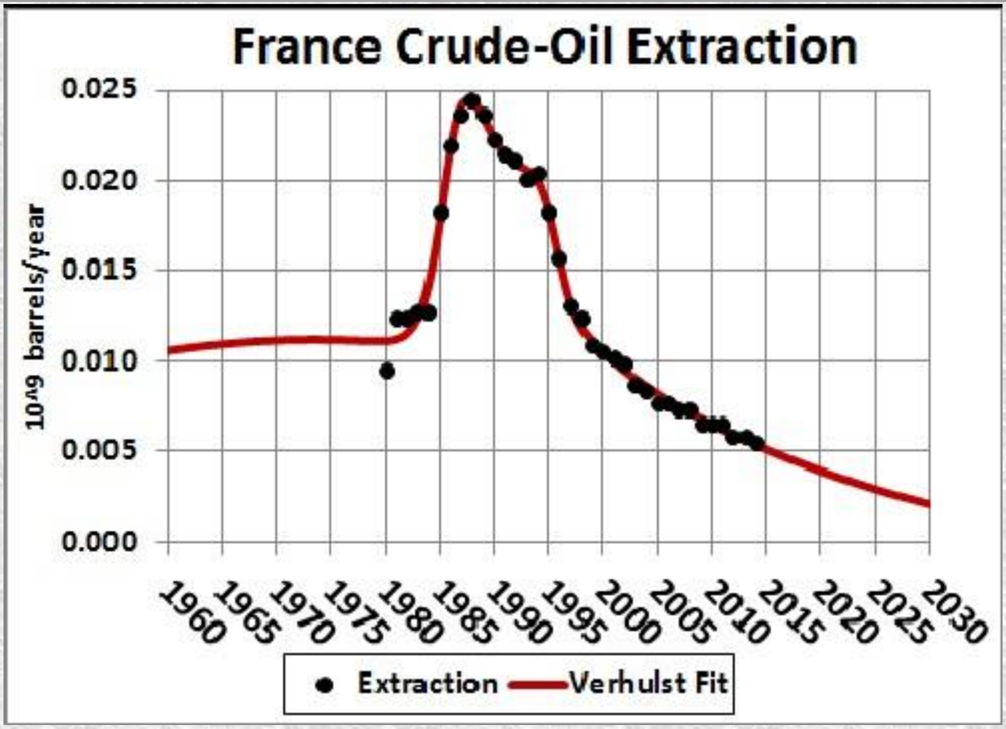
Germany crude-oil extraction

The total amount to be extracted for a Verhulst fit was set to to $Q=2x10^9$ barrels, which is larger than the 2014 reported reserves amount (~$0.2326x10^9$ barrels) plus the amount already extracted (~$1.3x10^9$ barrels). The initial and final peaks were assumed to be symmetrical.



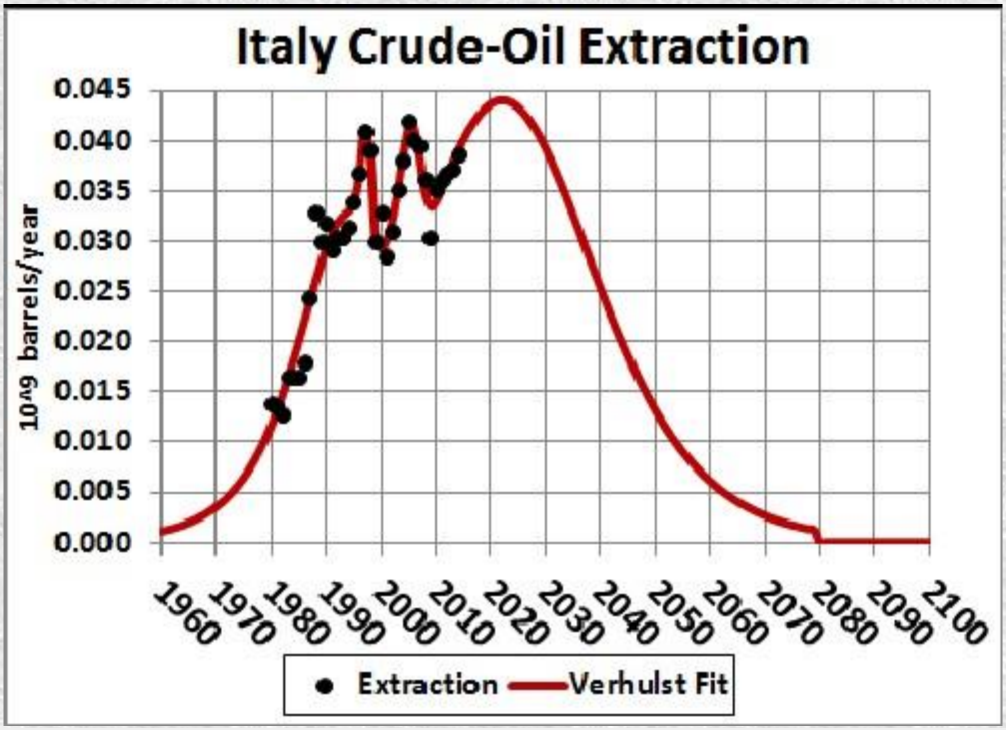
France crude-oil extraction

The total amount to be extracted for a Verhulst fit searched to $Q=1.3x10^9$ barrels, which is slightly larger than the 2014 reported reserves amount (~$0.08957x10^9$ barrels) plus the amount already extracted (~$1.2x10^9$ barrels).



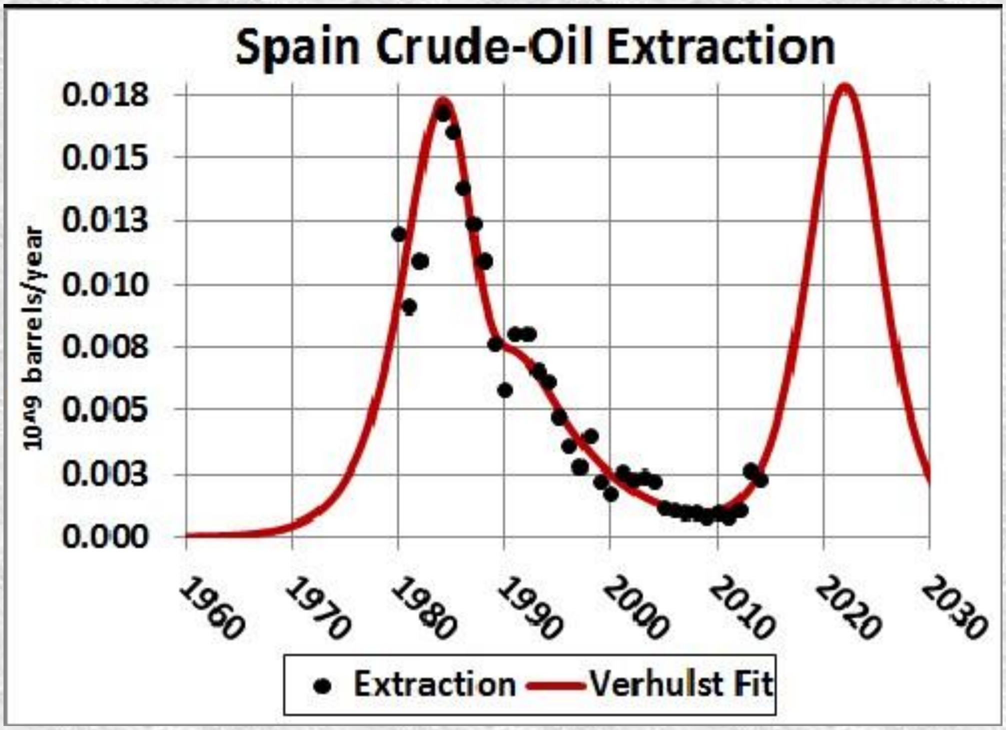
Italy crude-oil extraction

The total amount to be extracted for a Verhulst fit was set to Q=2.5x10^9 barrels, which is larger than the 2014 reported reserves amount (~0.5605x10^9 barrels) plus the amount already extracted (~1.1x10^9 barrels). The future peak was assumed to be symmetrical.



Spain crude-oil extraction

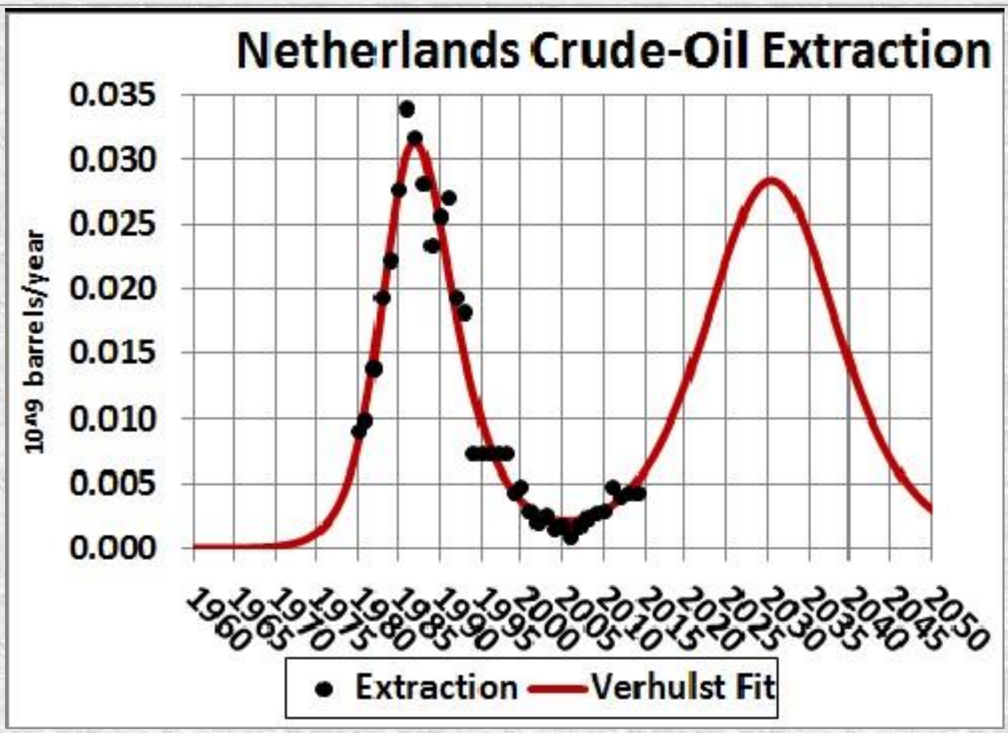
The total amount to be extracted for a Verhulst fit was set to $0.4x10^9$ barrels, which is slightly larger than the 2014 reported reserves amount (~$0.15x10^9$ barrels) plus the amount already extracted (~$0.21x10^9$ barrels). The future peak was assumed to be symmetrical.



The earliest three data were not used in the fit.

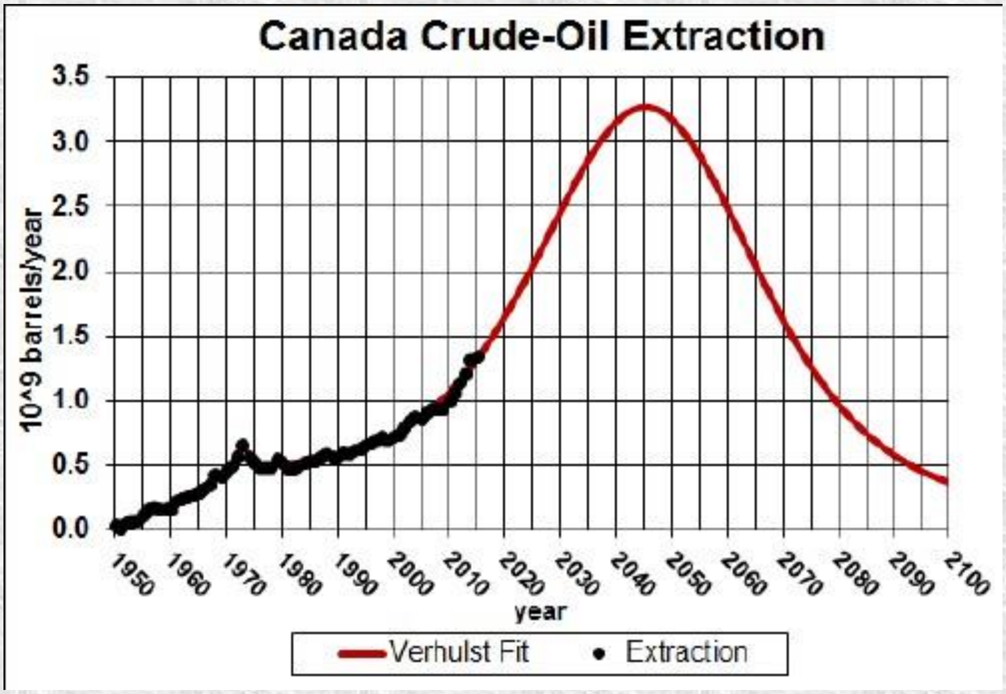
Netherlands crude-oil extraction

The total amount to be extracted for a Verhulst fit was set to $Q=1x10^9$ barrels, which is larger than the 2014 reported reserves amount (~$0.3026x10^9$ barrels) plus the amount already extracted (~$0.41x10^9$ barrels).

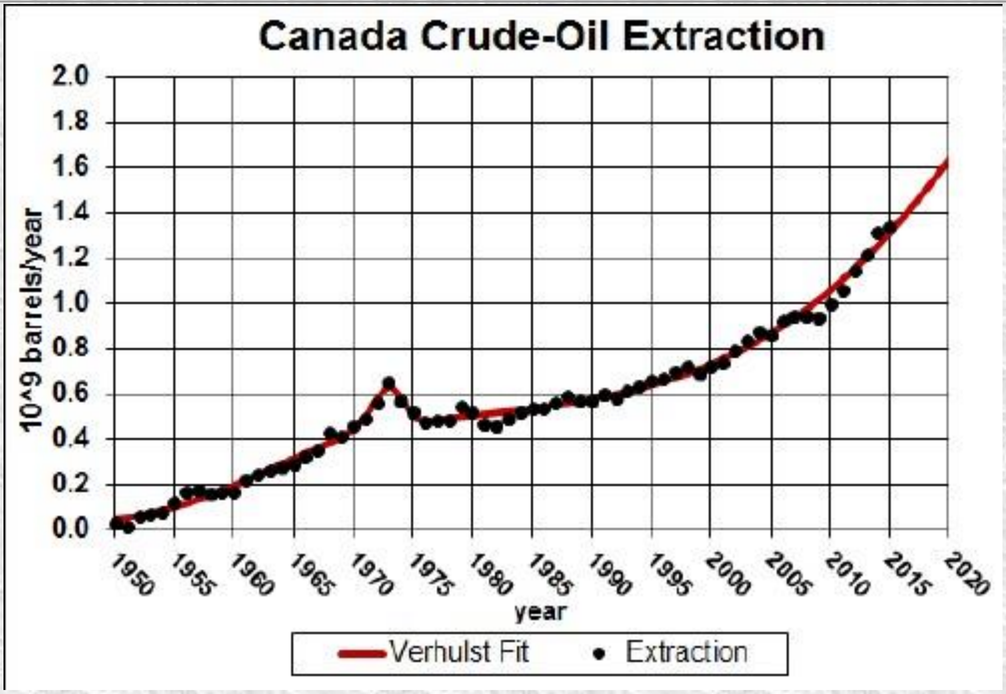


Canada crude-oil extraction

The 2014 reserves value is ~173×10^9 barrels. This fit uses a value slightly larger than that:



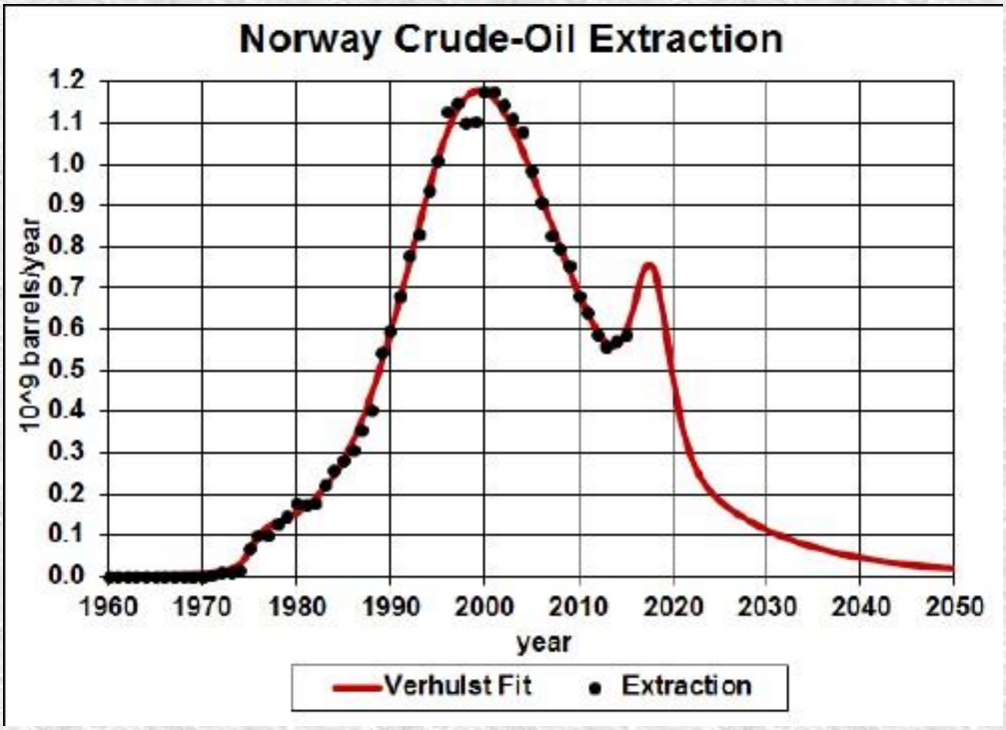
It is assumed that Canada oil sands are maximally extracted, which would be disastrous for global warming.



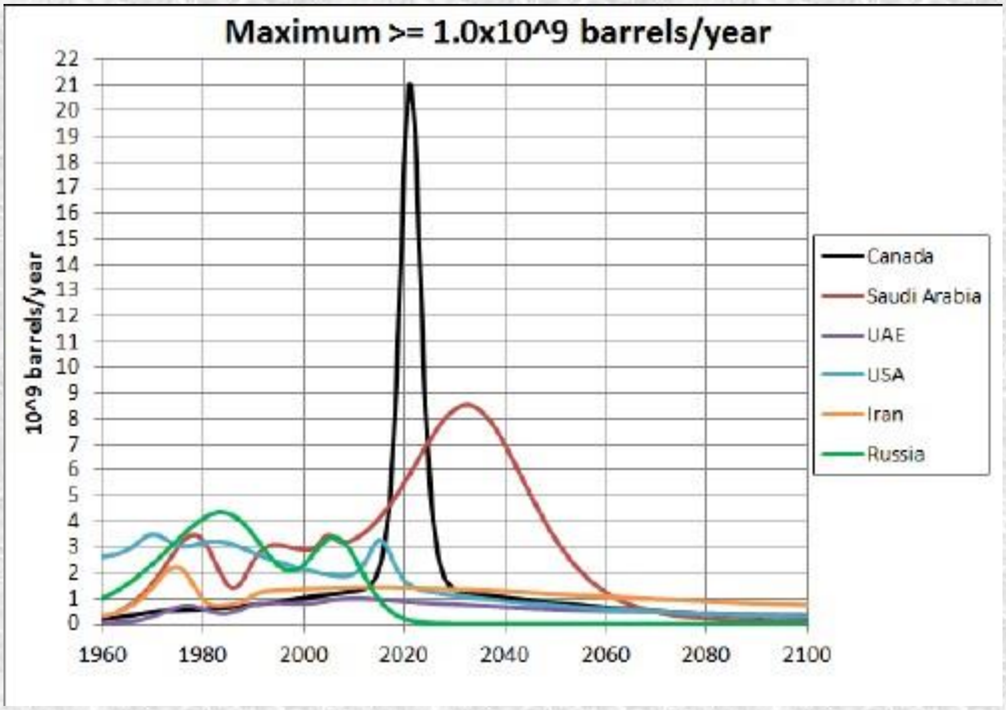
The recent fast rise and big future peak is due to extraction of crude oil from oil sands. The fit assumes a symmetric future peak.

Norway crude-oil extraction

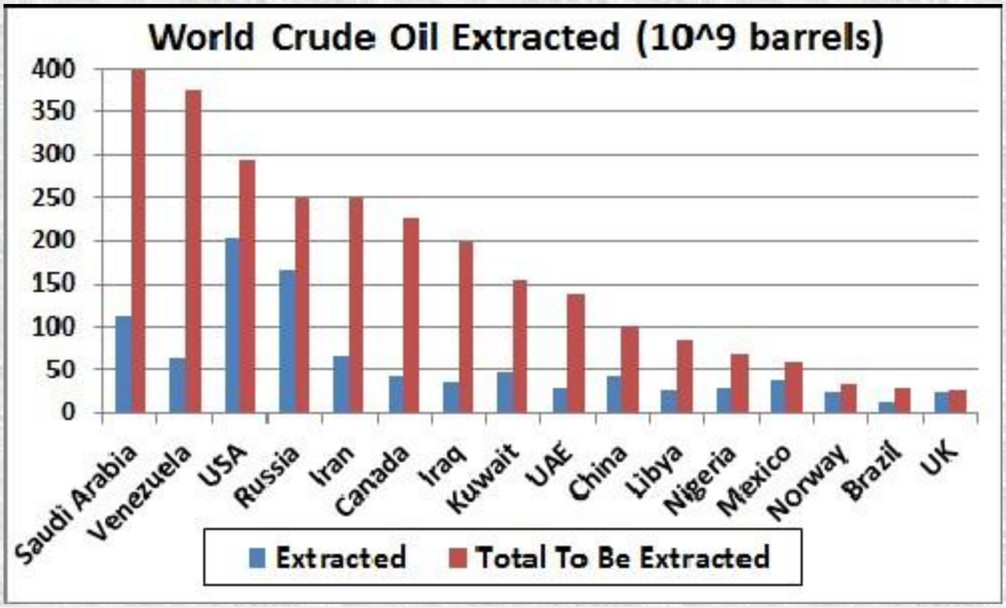
The 2014 reserves reported for Norway (5.825×10^9 barrels) is about the same as the set Q value (32×10^9 barrels) minus the amount already extracted (~25.6×10^9 barrels).



Nations with extraction maximum >= 10^9 barrels/year



It is assumed that Canada oil sands are maximally extracted, which would be disastrous for global warming.



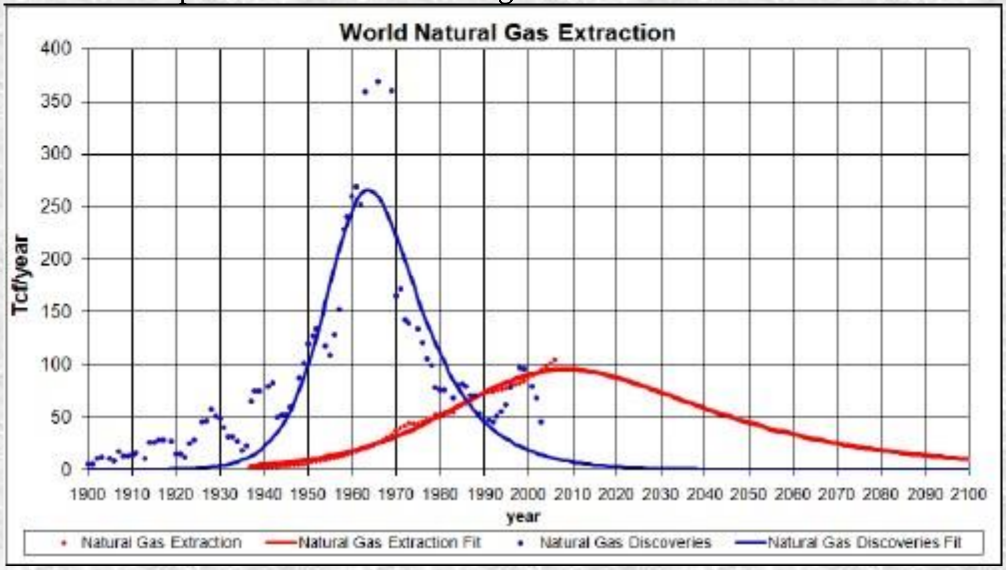
World Natural-Gas Extraction

Current Natural-Gas-Futures Price

World Natural-Gas Discoveries

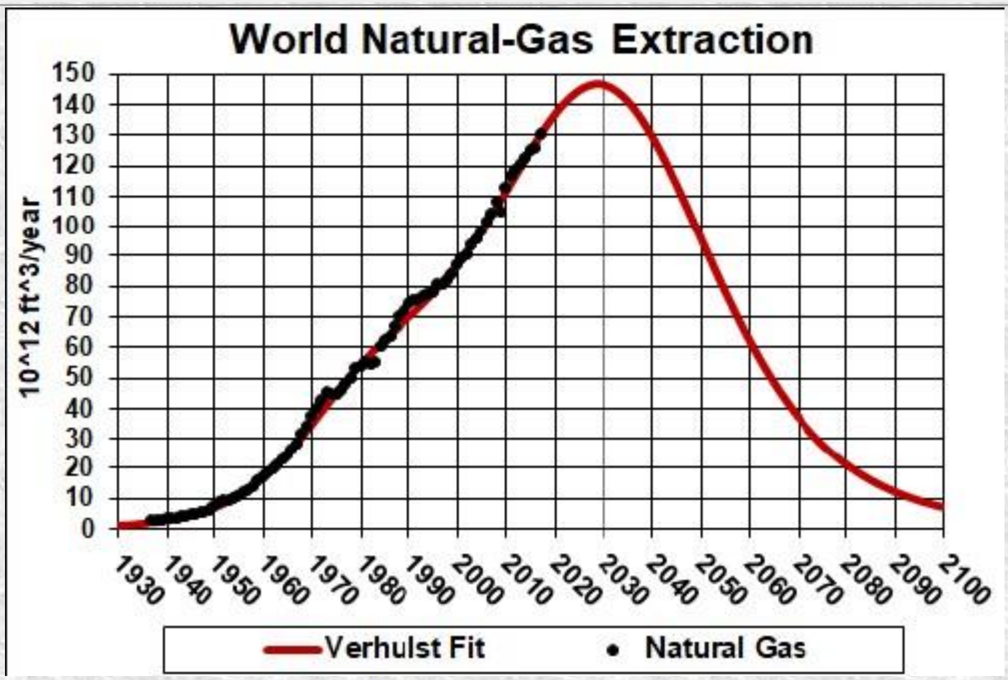
This and the curve below for world natural-gas extraction were fitted together with a common value for amount eventually discovered and extracted ($7.8x10^{15}$ ft^3).

Comparison of world natural-gas discoveries and extraction.



This does not include shale gas. The amount under both curves is about 7.8×10^{15} ft^3.

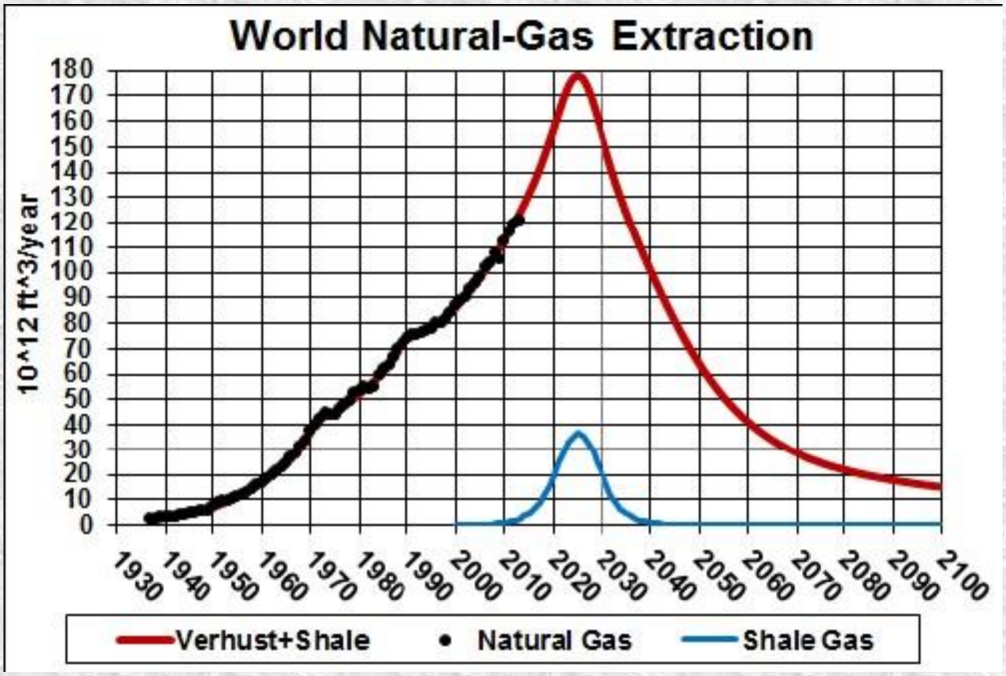
This graph contains information that probably will have the greatest effect on those now living and born in the future. **Natural gas cannot be extracted if it has not been discovered! This graph shows very clearly why it is very unlikely that the final amount to be extracted will exceed $8x10^{15}$ ft^3. So far the amount extracted is about $3x10^{15}$ ft^3, so we are more than one-third of the way there!**



The amount to be eventually extracted was set to 10.5×10^{15} ft^3, which is slightly larger than the sum of the 2012 reserves (~6.845×10^{15} ft^3) and the amount already extracted (~3.5×10^{15} ft^3)

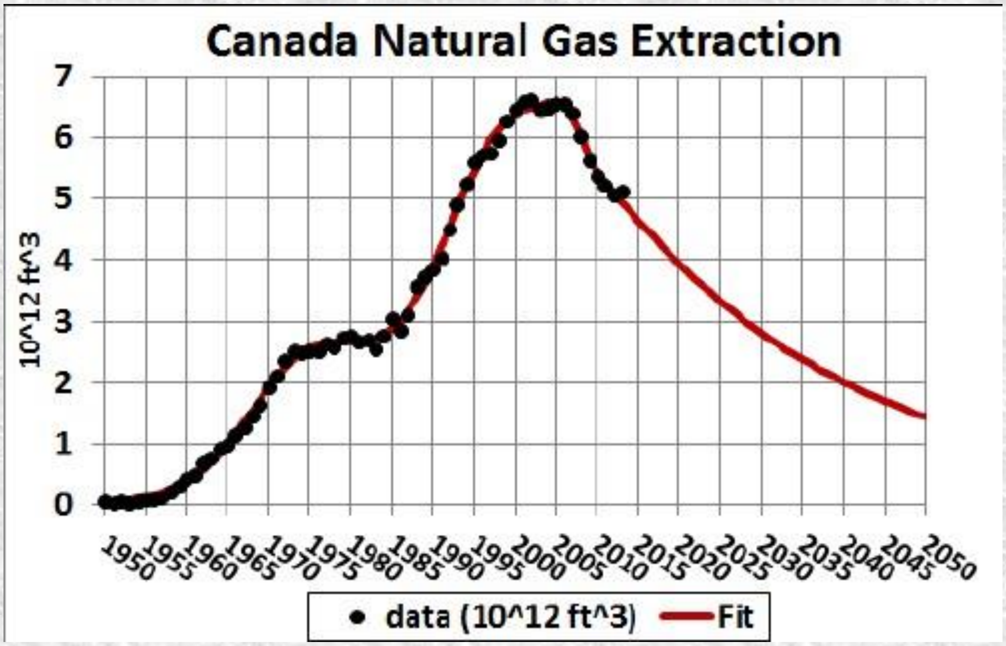
This does not include uncertain shale gas; see below.

Adding in uncertain shale gas:



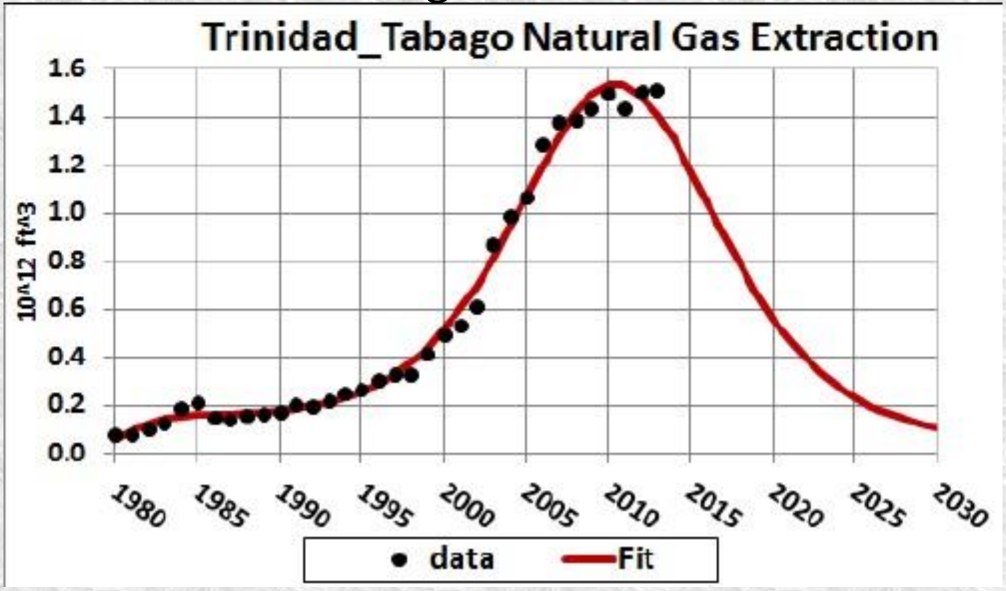
The short large blip is an estimate of shale gas extraction . So, shale natural gas may add a short large blip to the natural-gas extraction for the World. It could be reduced in size and stretched out over a larger time interval, but I doubt it will be. The world will probably extract and use it as fast as possible.

Canada Natural-Gas Extraction



The area under the curve is consistent with the ~72x10^{12} ft^{3} reserves estimate for 2015.

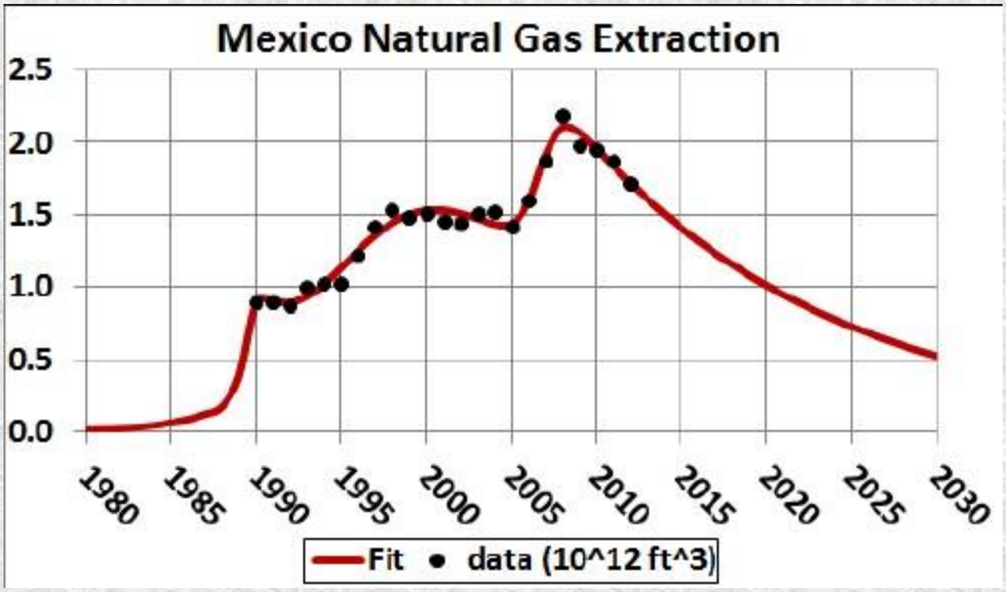
Trinidad and Tabago Natural-Gas Extraction



The area under the curve is consistent with the ~12x10^{12} ft^{3} reserves estimate

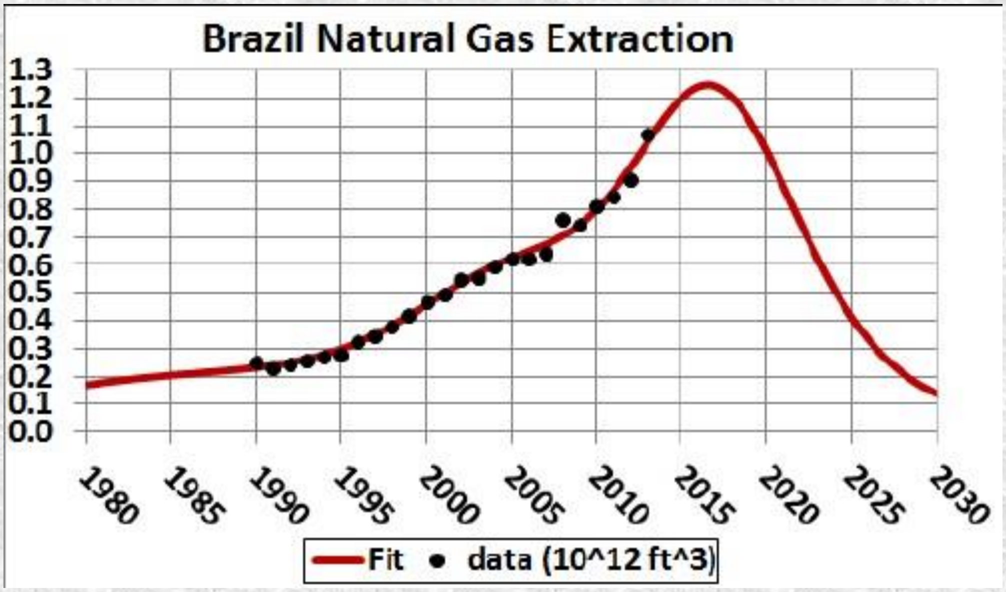
for 2015.
The future peak was assumed to be symmetrical.

Mexico Natural-Gas Extraction



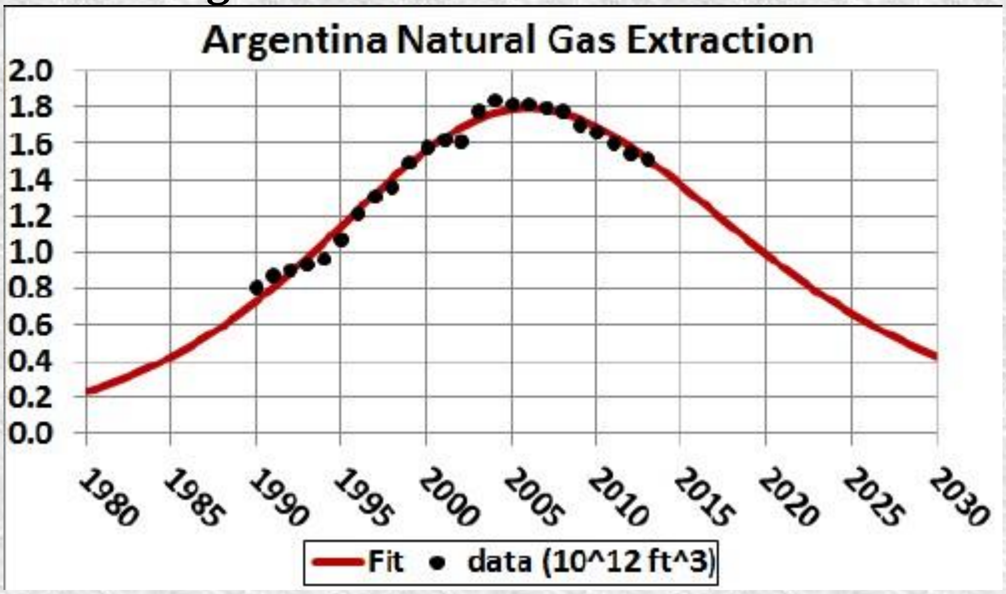
The area under the curve is consistent with the ~17.1×10^{12} ft^3 reserves estimate for 2015.

Brazil Natural-Gas Extraction



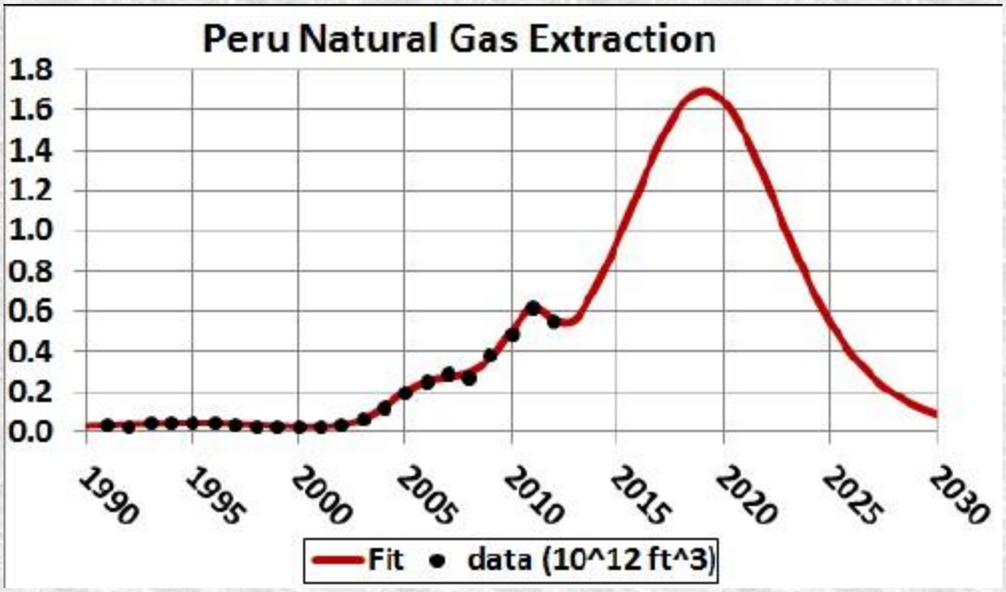
The area under the curve is consistent with the ~13.7×10^{12} ft^3 reserves estimate for 2013.
The future peak was assumed to be symmetrical.

Argentina Natural-Gas Extraction



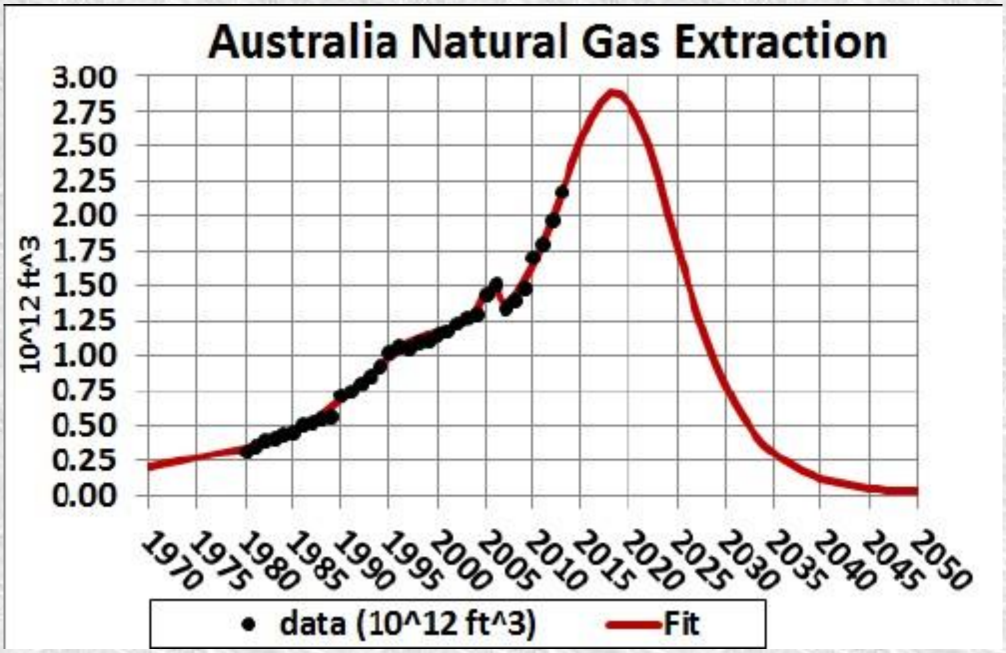
The area under the curve is consistent with the ~13.377x10^{12} ft^3 reserves estimate for 2013.

Peru Natural-Gas Extraction



The area under the curve is consistent with the ~15.376x10^{12} ft^3 reserves estimate for 2013.
The future peak was assumed to be symmetrical.

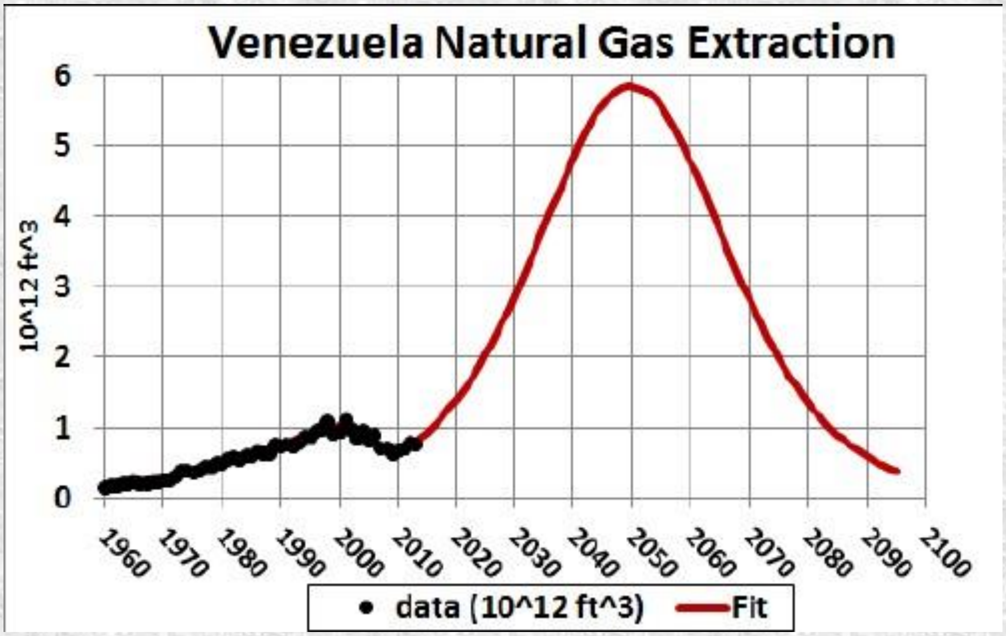
Australia Natural-Gas Extraction

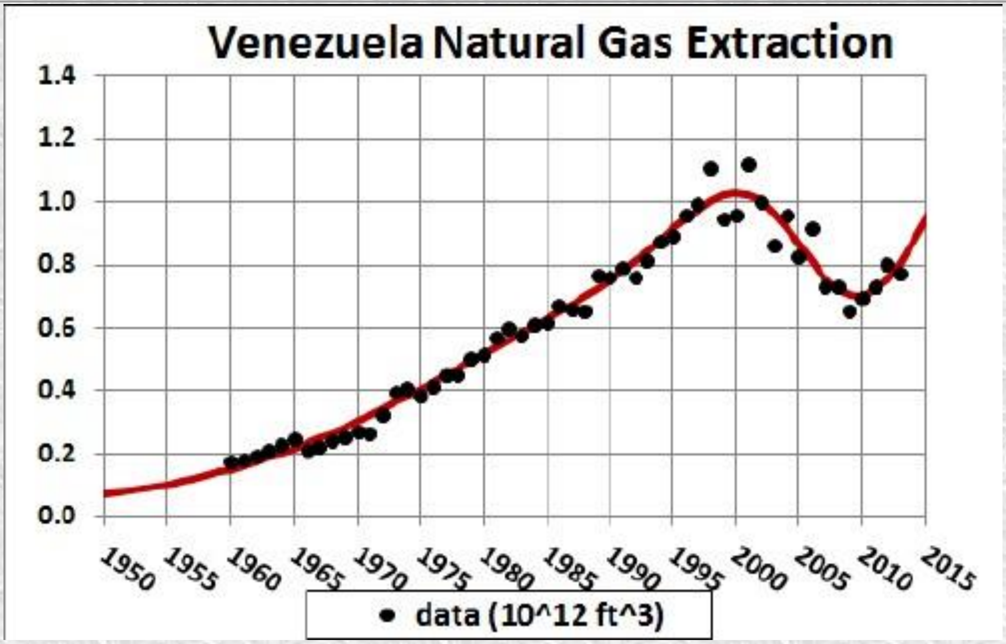


The area under the curve is consistent with the ~30x10^{12} ft^3 reserves estimate for 2015.

The future peak was assumed to be symmetrical.

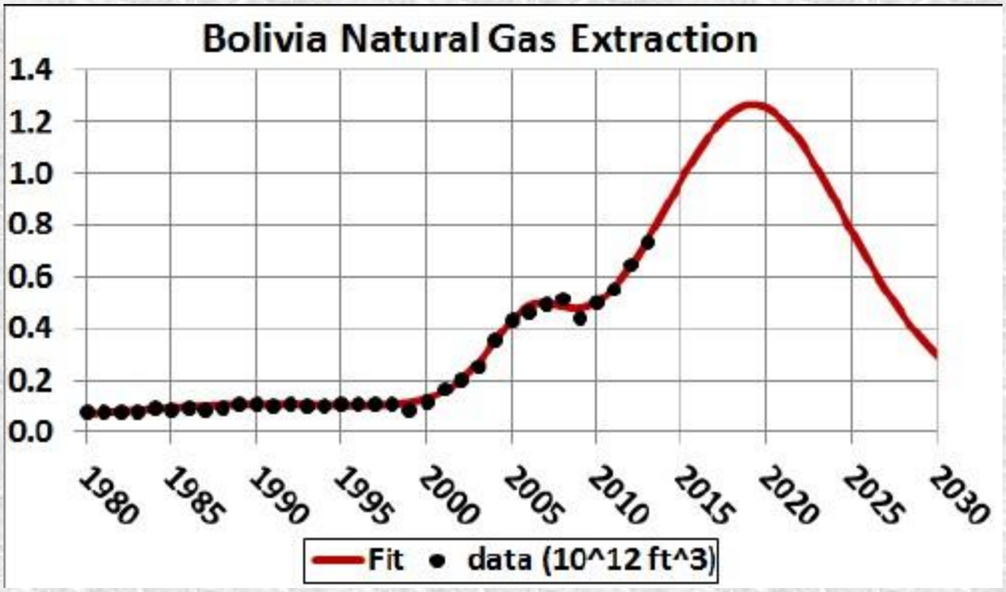
Venezuela Natural-Gas Extraction





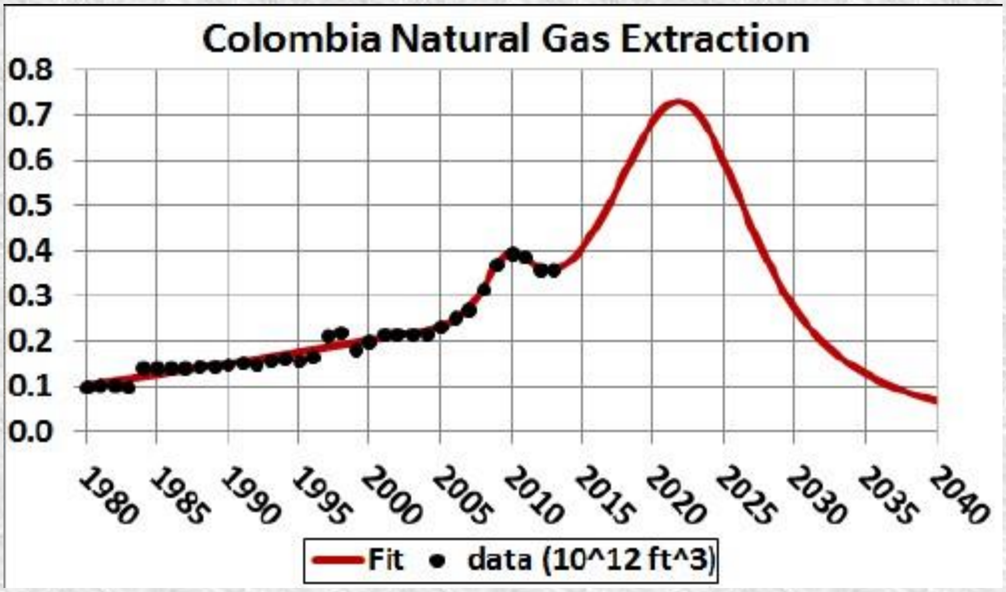
The fit used an optimistic2015 reserves value of $197x10^{12}$ ft^3 .
The future peak was assumed to be symmetrical.

Bolivia Natural-Gas Extraction



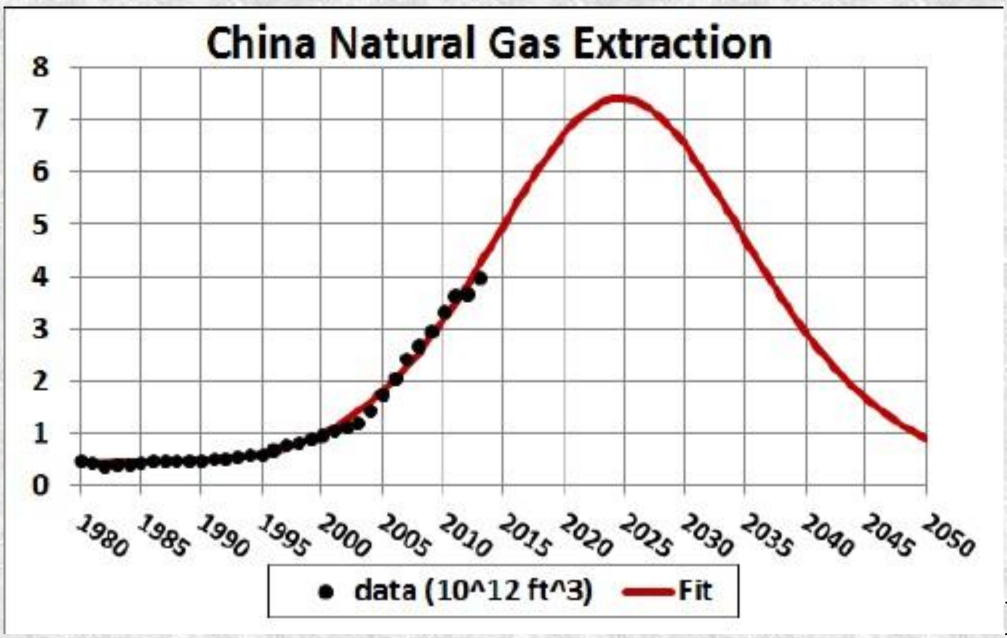
The fit used an optimistic2015 reserves value of $9.9x10^{12}$ ft^3 .
The future peak was assumed to be symmetrical.

Colombia Natural-Gas Extraction



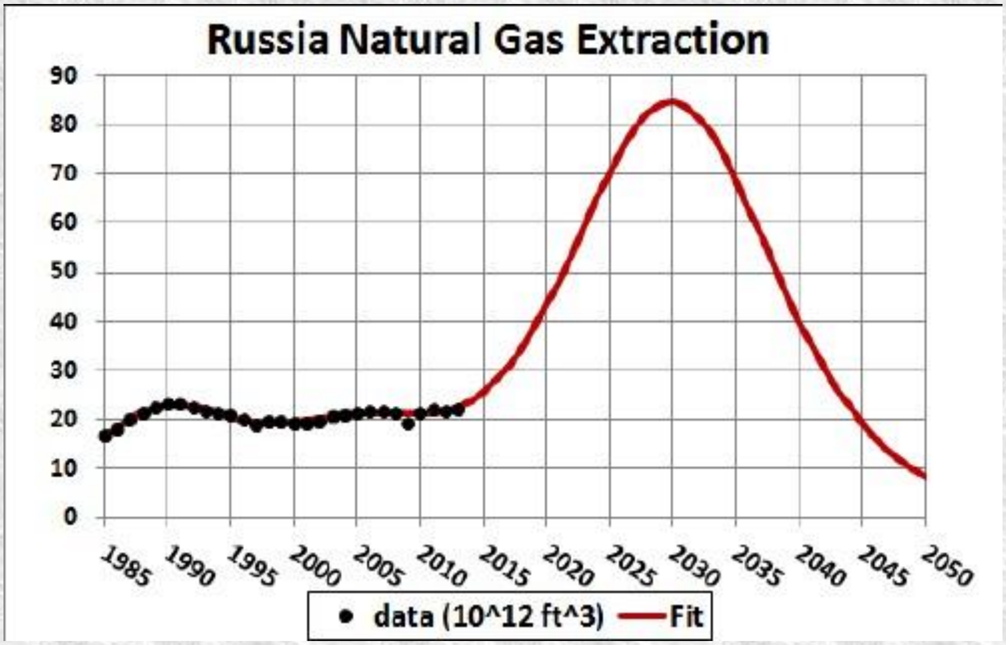
The fit used an optimistic2015 reserves value of 6.4x10^{12} ft^{3} .
The future peak was assumed to be symmetrical.

China Natural-Gas Extraction



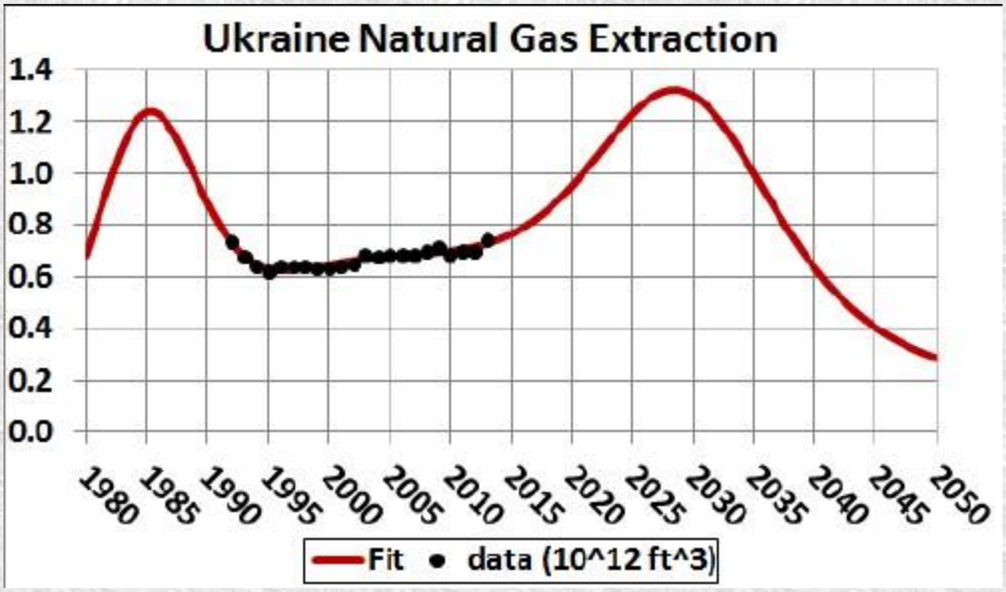
The fit to the data uses the 2015 reserves value of ~164x10^{12} ft^{3}.
The future peak was assumed to be symmetrical.

Russia Natural-Gas Extraction



The fit to the data uses the 2015 reserves value ~1688x10^{12} ft^3.
The future peak was assumed to be symmetrical.

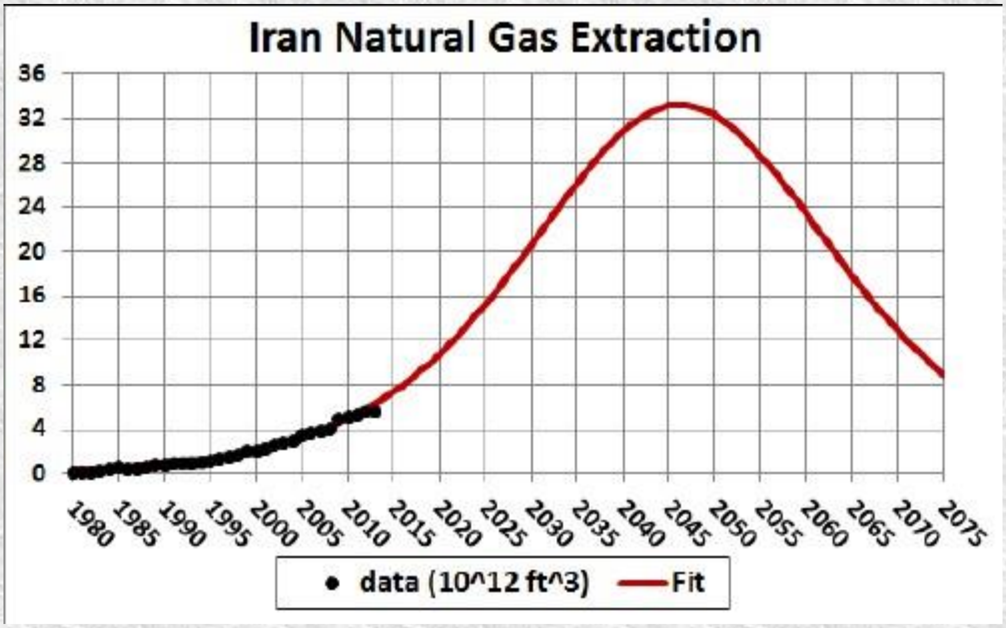
Ukraine Natural-Gas Extraction



The fit to the data uses the 2013 reserves value ~38.987x10^{12} ft^3.

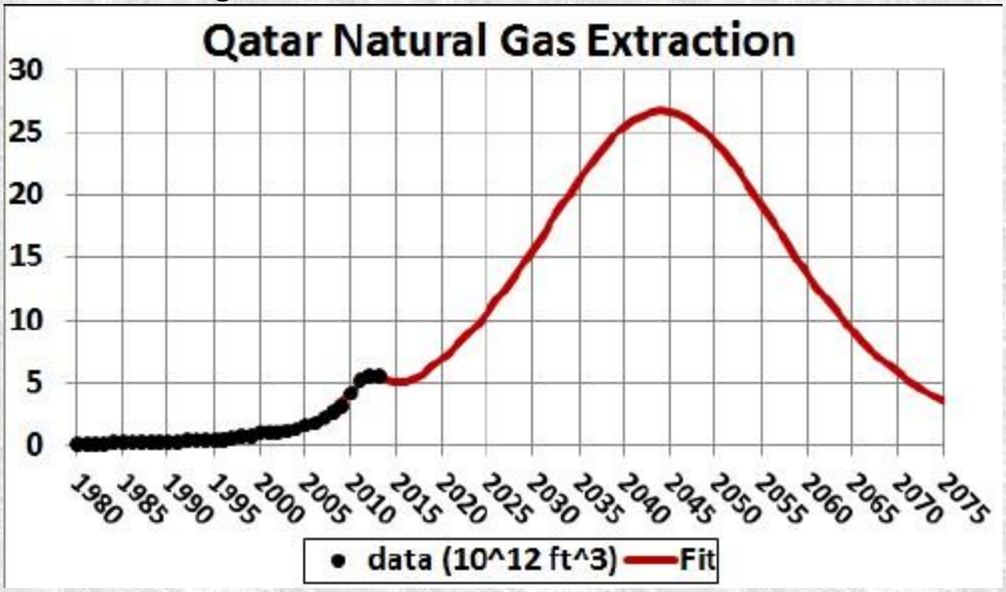
A guess was made as to the natural-gas extraction in the Ukraine state before it left the Soviet Union. Both the first and last peak were assumed to be symmetrical.

Iran Natural-Gas Extraction



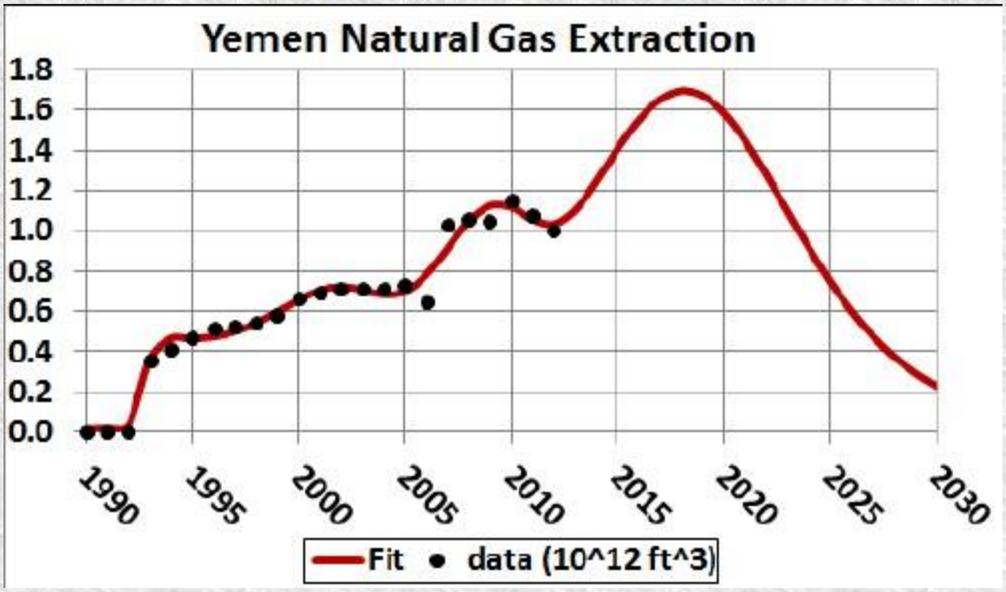
The fit to the data uses the 2015 reserves value ~1201x10^{12} ft^{3}.
The future peak was assumed to be symmetrical.

Qatar Natural-Gas Extraction



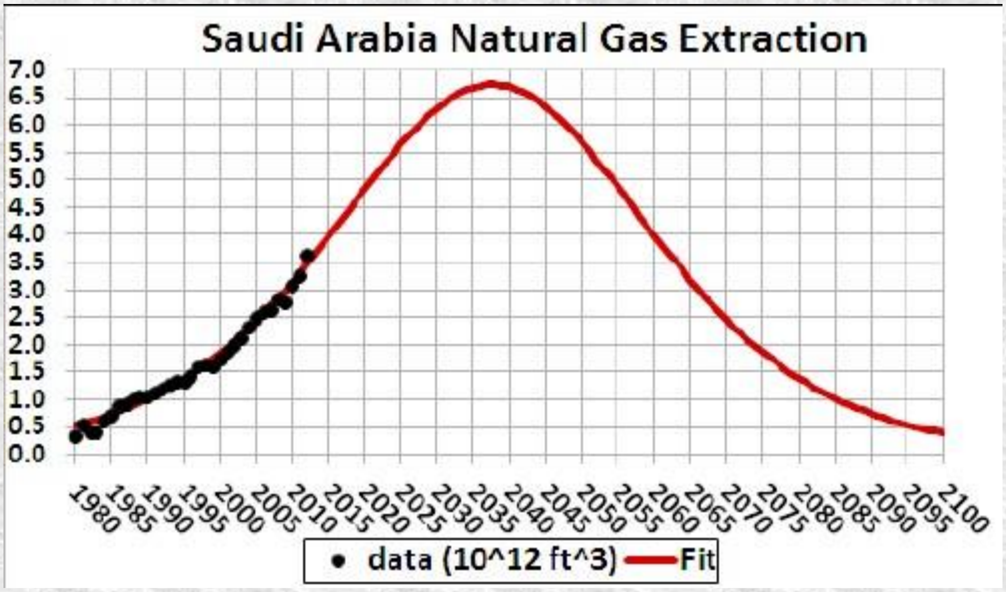
The fit to the data uses the 2015 reserves value ~872x10^{12} ft^{3}.
The future peak was assumed to be symmetrical.

Yemen Natural-Gas Extraction



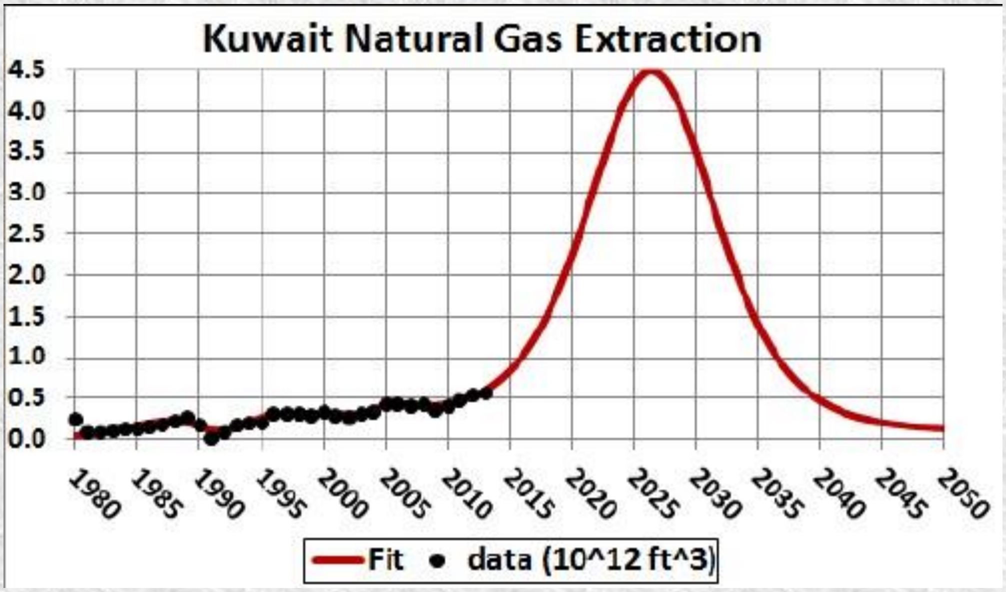
The fit to the data uses the 2013 reserves value ~1898x10^{12} ft^3.
The future peak was assumed to be symmetrical.

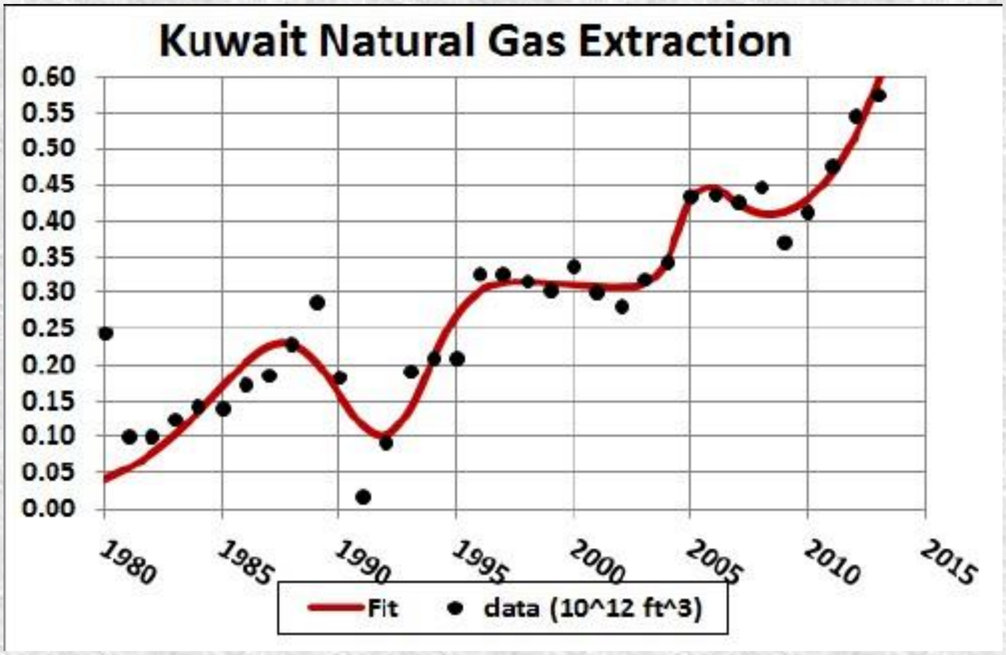
Saudi Arabia Natural-Gas Extraction



The fit to the data uses the 2015 reserves value ~294x10^{12} ft^3.
The future peak was assumed to be symmetrical.

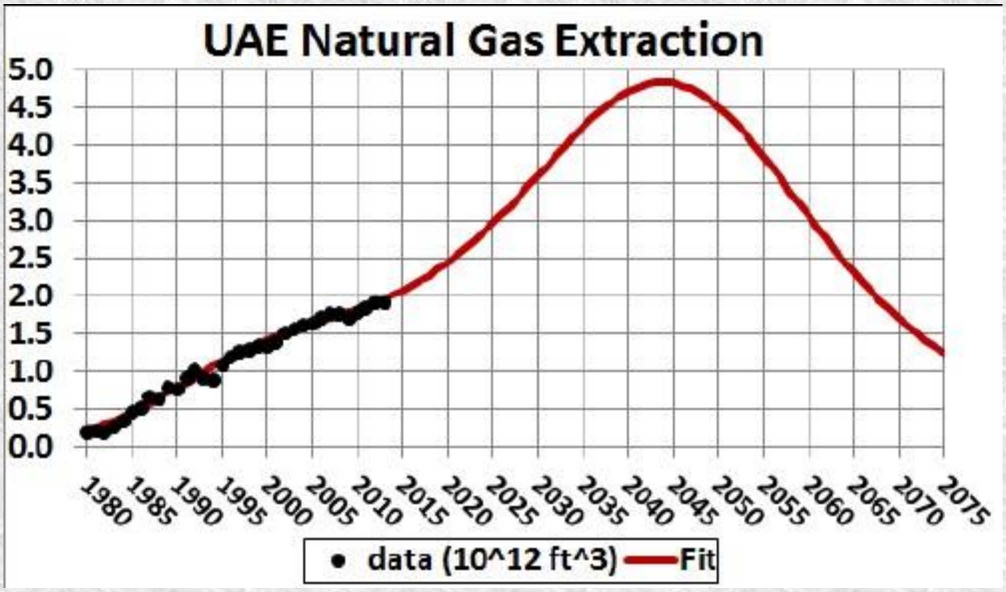
Kuwait Natural-Gas Extraction





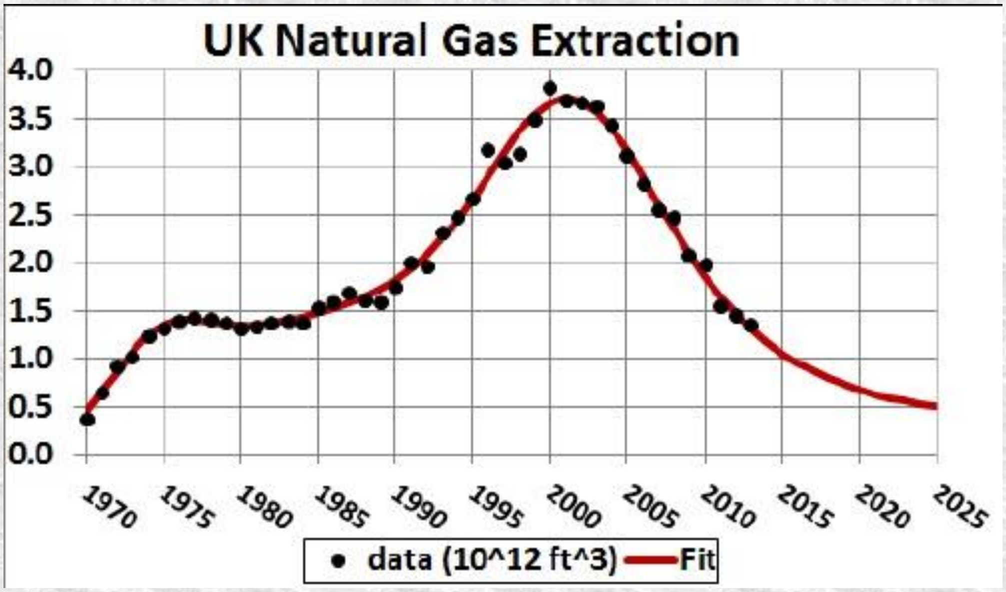
The fit to the data uses slightly more than the 2015 reserves value ~64x10^{12} ft^3.
The future peak was assumed to be symmetrical.

UAE Natural-Gas Extraction



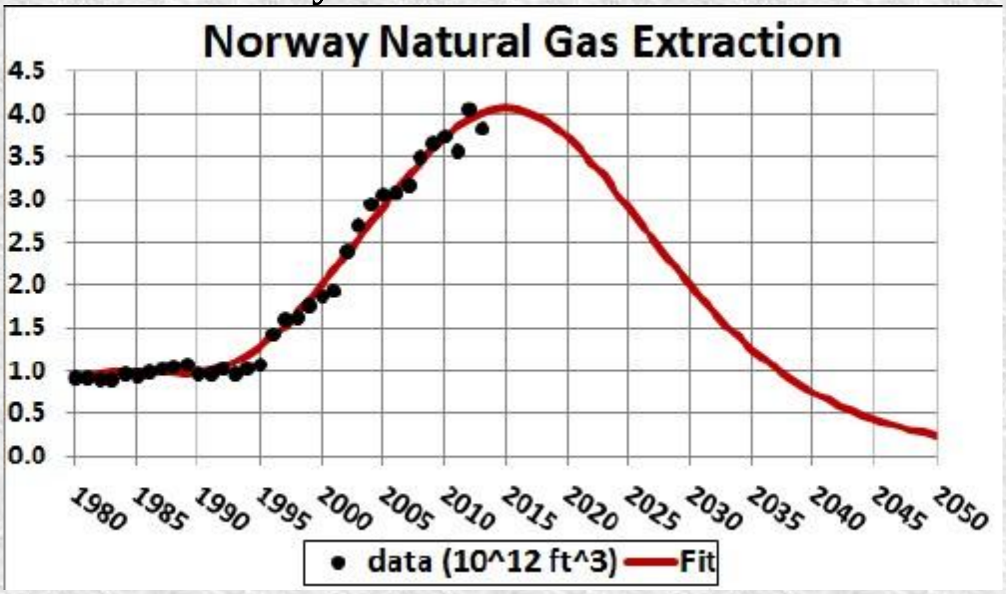
The fit to the data uses the 2015 reserves value ~215x10^{12} ft^3.
The future peak was assumed to be symmetrical.

UK Natural-Gas Extraction



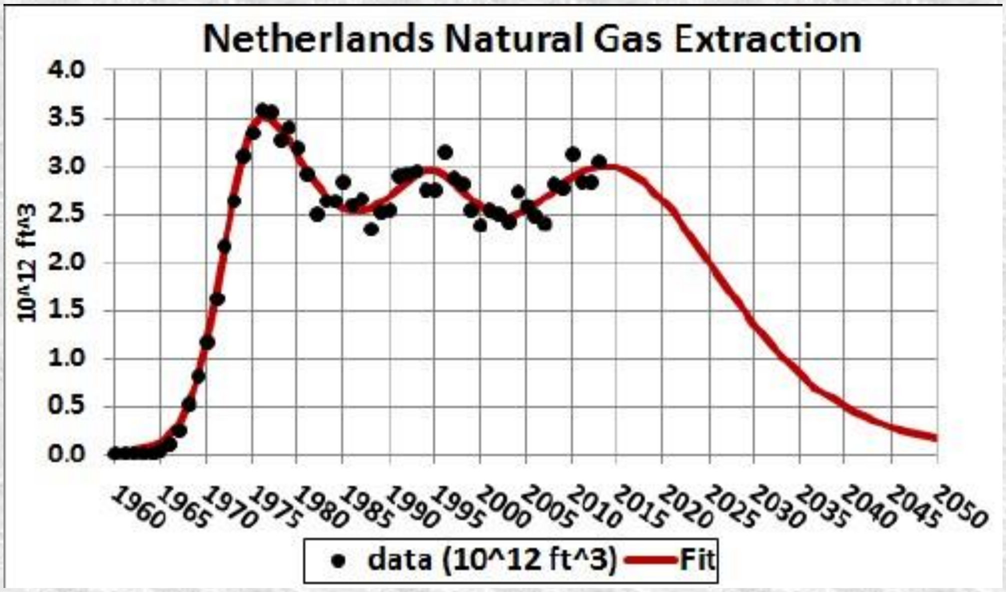
The fit to the data uses slightly more than the 2015 reserves value ~8.5x10^{12} ft^3.

Norway Natural-Gas Extraction



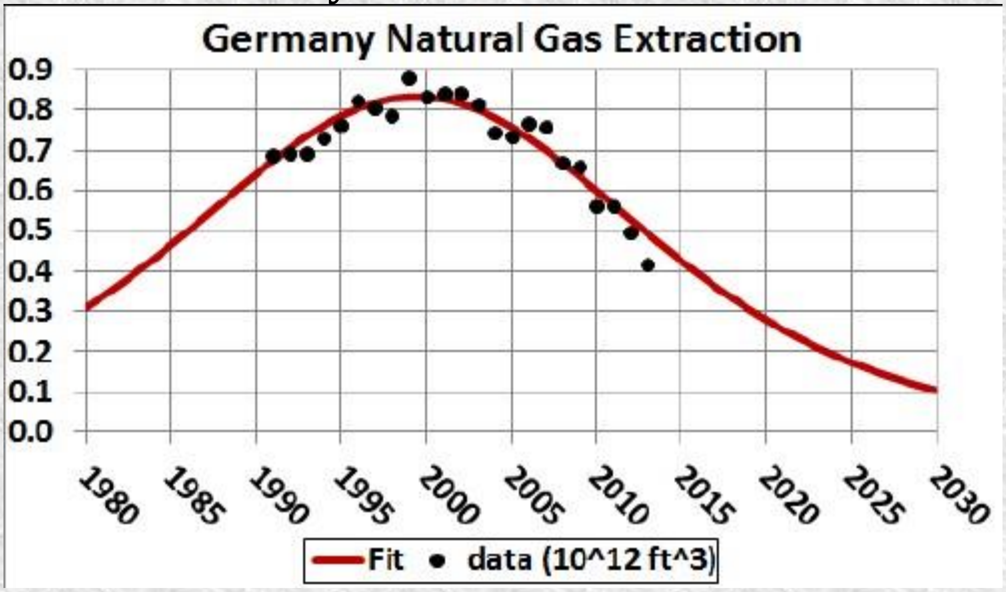
The fit to the data uses slightly more than the 2015 reserves value ~72x10^{12} ft^{3}. The future peak was assumed to be symmetrical.

Netherlands Natural-Gas Extraction



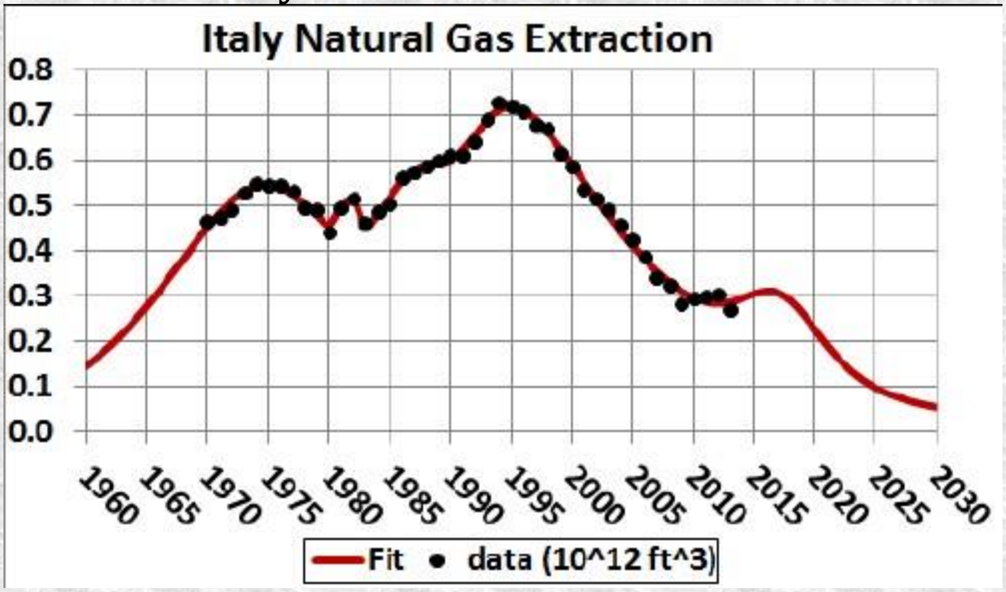
The fit to the data uses slightly more than the 2015 reserves value ~32x10^{12} ft^{3}. The future peak was assumed to be symmetrical.

Germany Natural-Gas Extraction



The fit to the data uses slightly more than the 2013 reserves value ~4.097x10^{12} ft^3.

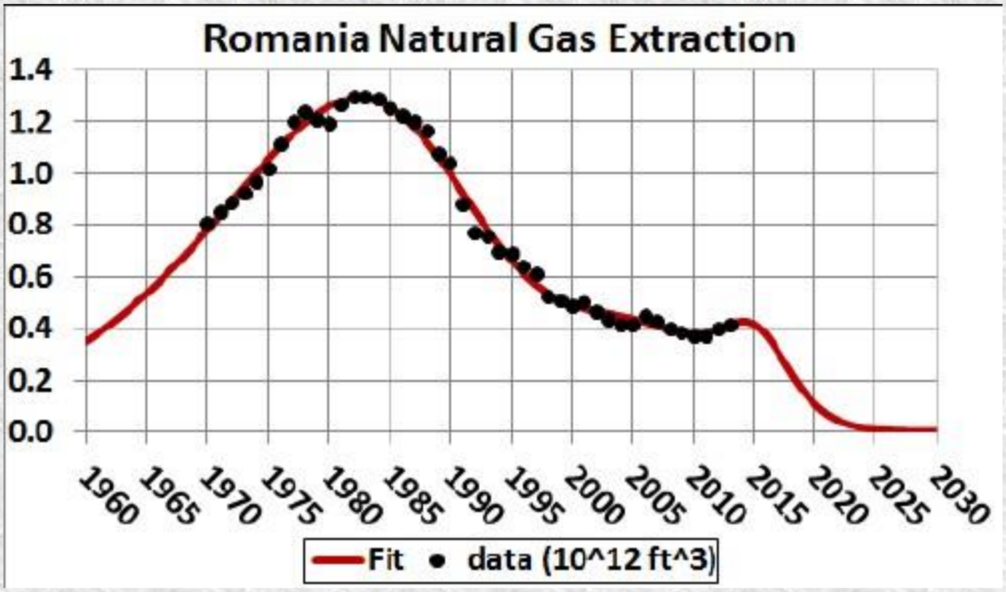
Italy Natural-Gas Extraction



The fit to the data uses slightly more than the 2015 reserves value ~6.4x10^{12} ft^3.

The future peak was assumed to be symmetrical. .

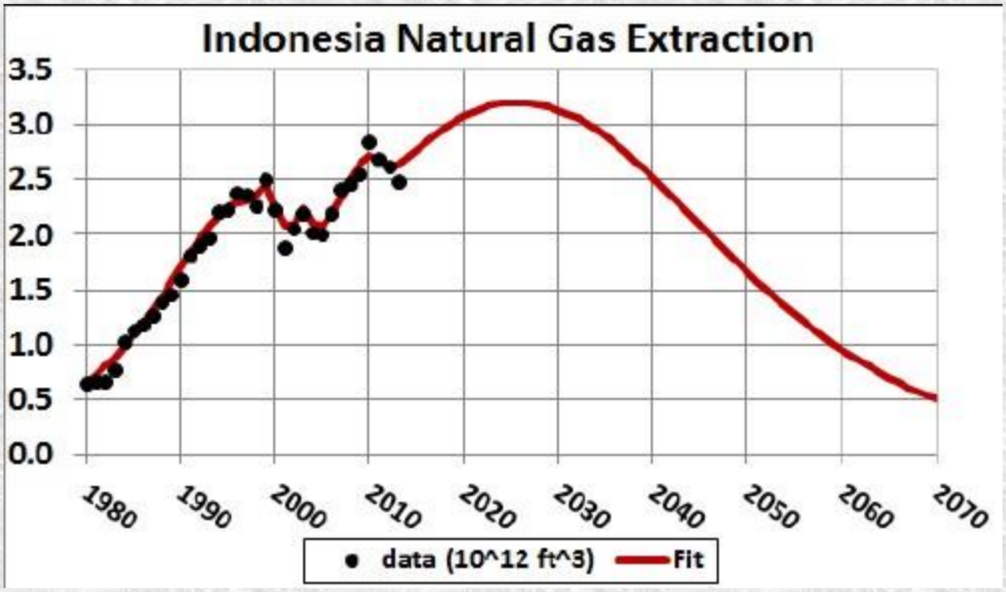
Romania Natural-Gas Extraction



The fit to the [data]() uses slightly more than the 2013 [reserves value]() ~3.726x10^{12} ft^3.V.

The future peak was assumed to be symmetrical. .

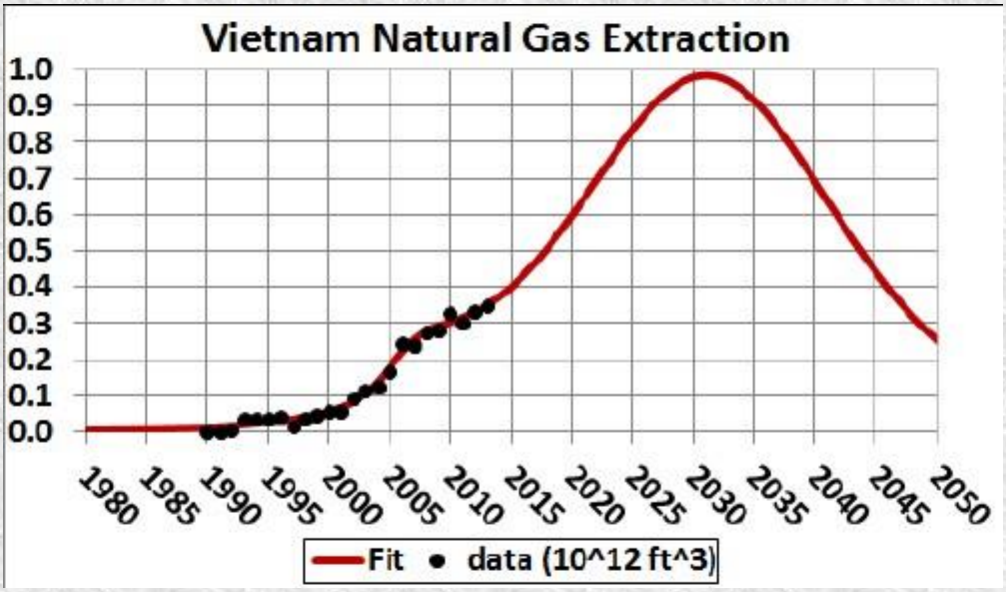
Indonesia Natural-Gas Extraction



The fit to the [data]() uses slightly more than the 201.53 [reserves value]() ~103x10^{12} ft^3.

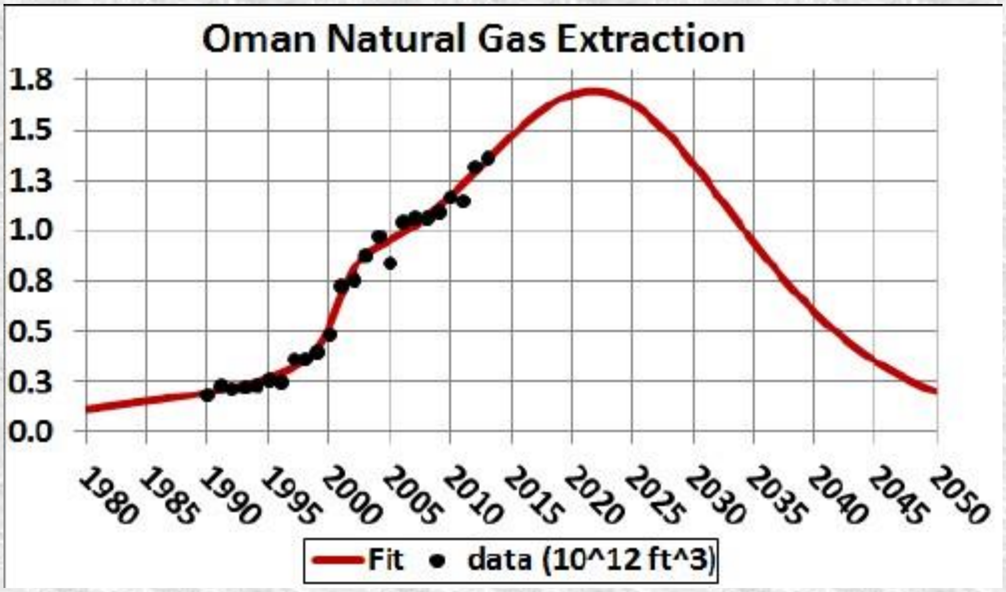
The future peak was assumed to be symmetrical. .

Vietnam Natural-Gas Extraction



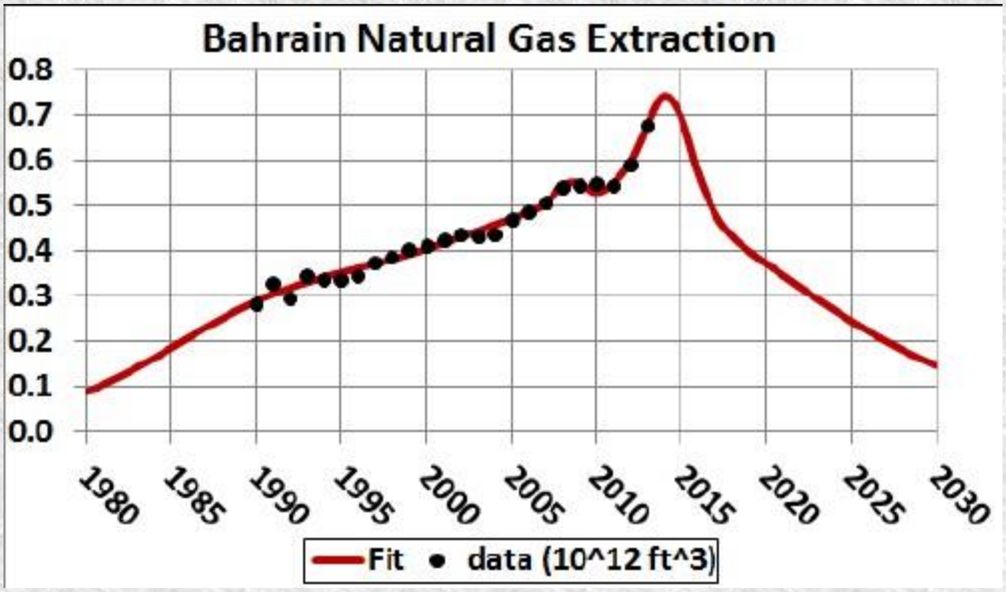
The fit to the data uses slightly more than the 2015 reserves value ~25x10^{12} ft^3. The future peak was assumed to be symmetrical.

Oman Natural-Gas Extraction



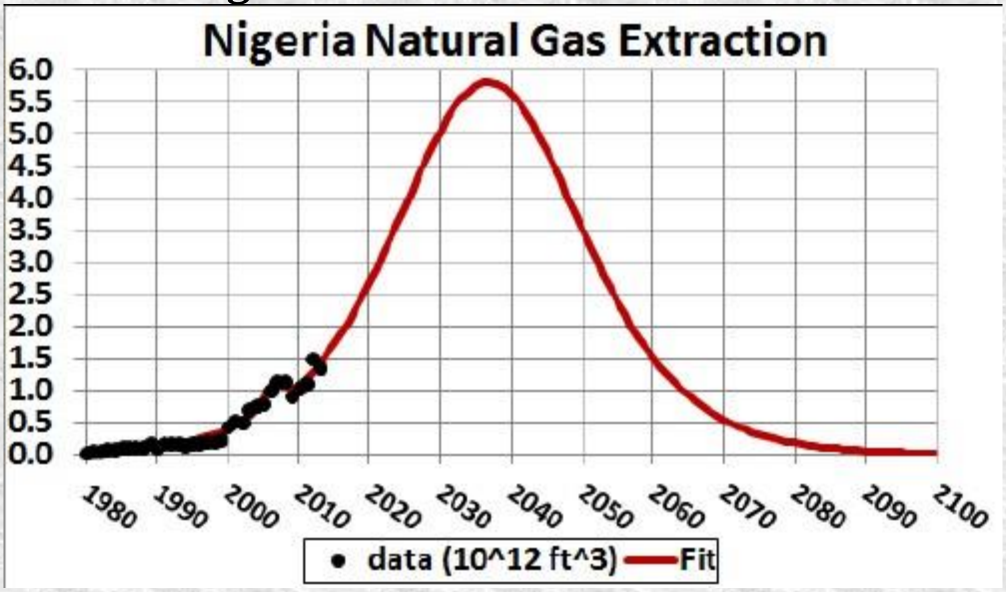
The fit to the data uses slightly more than the 2015 reserves value ~25x10^{12} ft^3. The future peak was assumed to be symmetrical.

Bahrain Natural-Gas Extraction



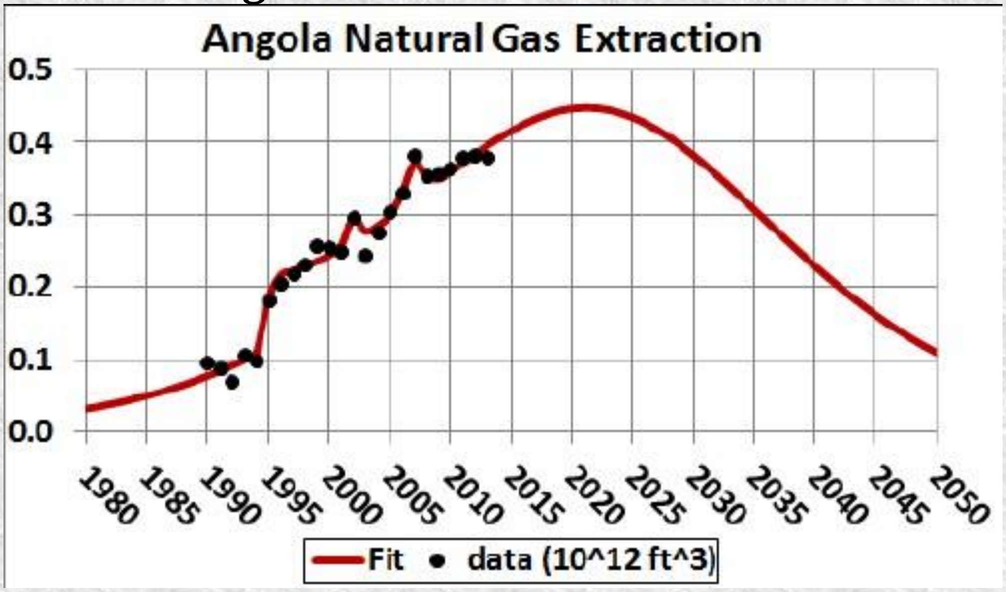
The fit to the data uses slightly more than the 2013 reserves value ~3.25x10^{12} ft^{3}.
The future peak was assumed to be symmetrical.

Nigeria Natural-Gas Extraction



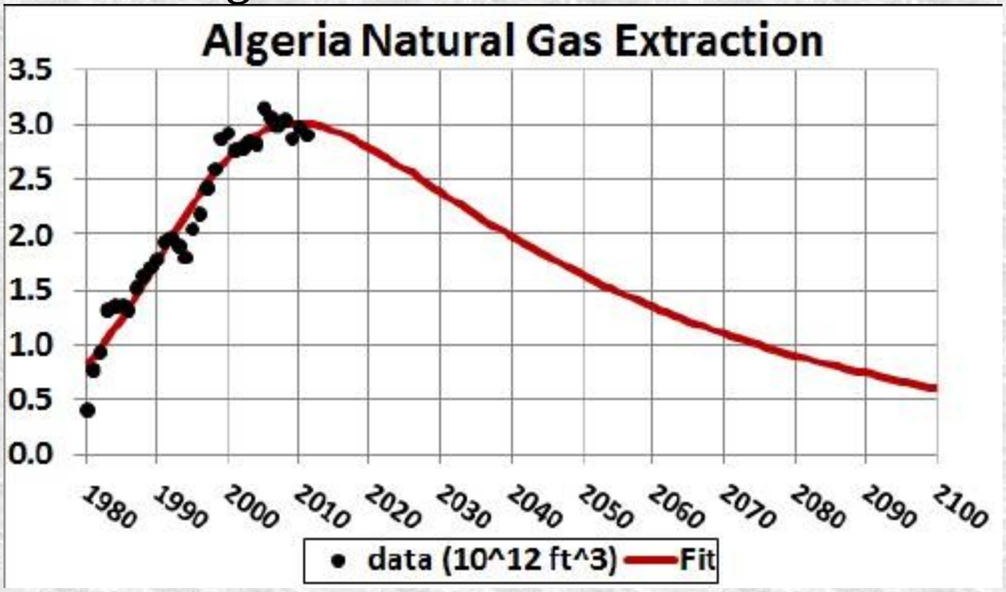
The fit to the data uses the 2015 reserves value ~180x10^{12} ft^{3}.
The future peak was assumed to be symmetrical.

Angola Natural-Gas Extraction



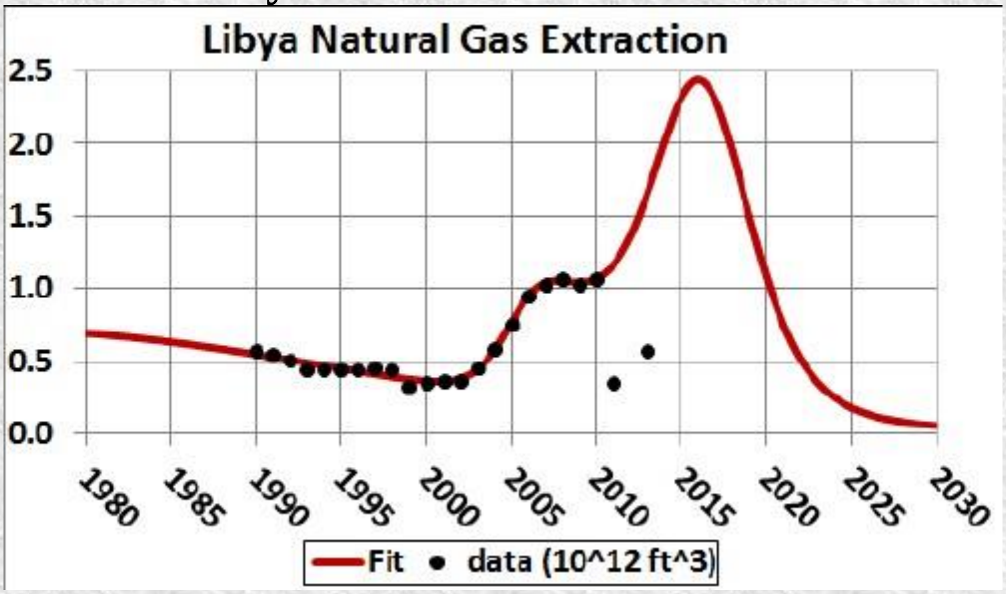
The fit to the data uses the 2015 reserves value ~9.7x10^{12} ft^3.
The future peak was assumed to be symmetrical.

Algeria Natural-Gas Extraction



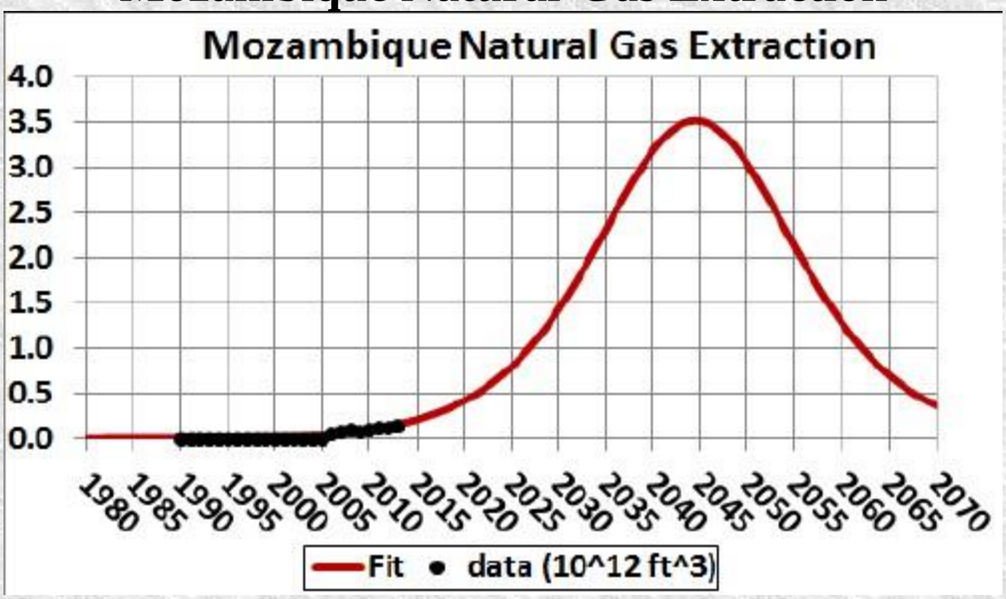
The fit to the data uses slightly more than the 2013 reserves value ~159x10^{12} ft^3.

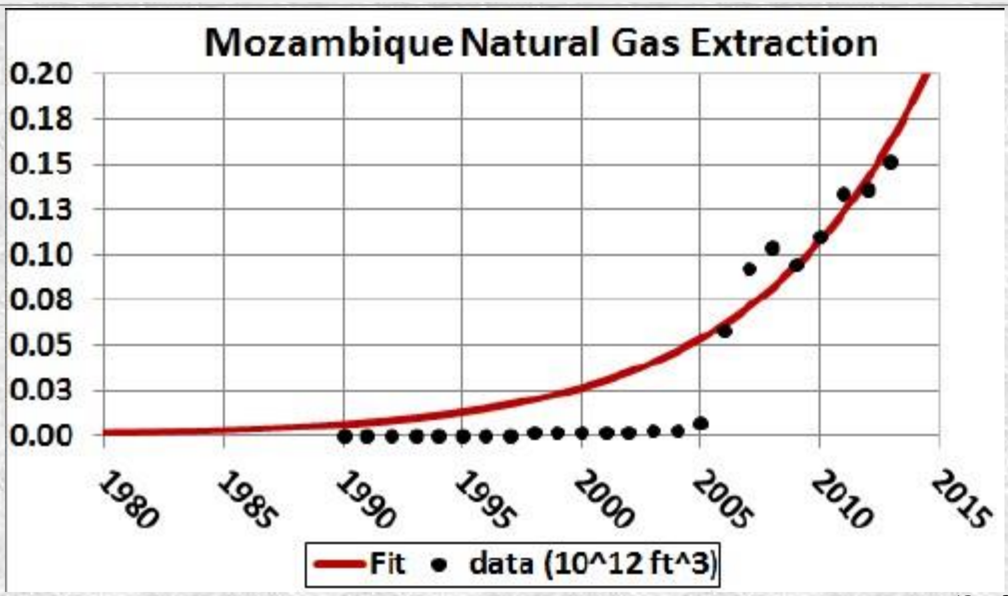
Libya Natural-Gas Extraction



The fit to the data uses slightly more than the 2015 reserves value ~53x10^{12} ft^3.
The low recent years were not used in the fit.
The future peak was assumed to be symmetrical.

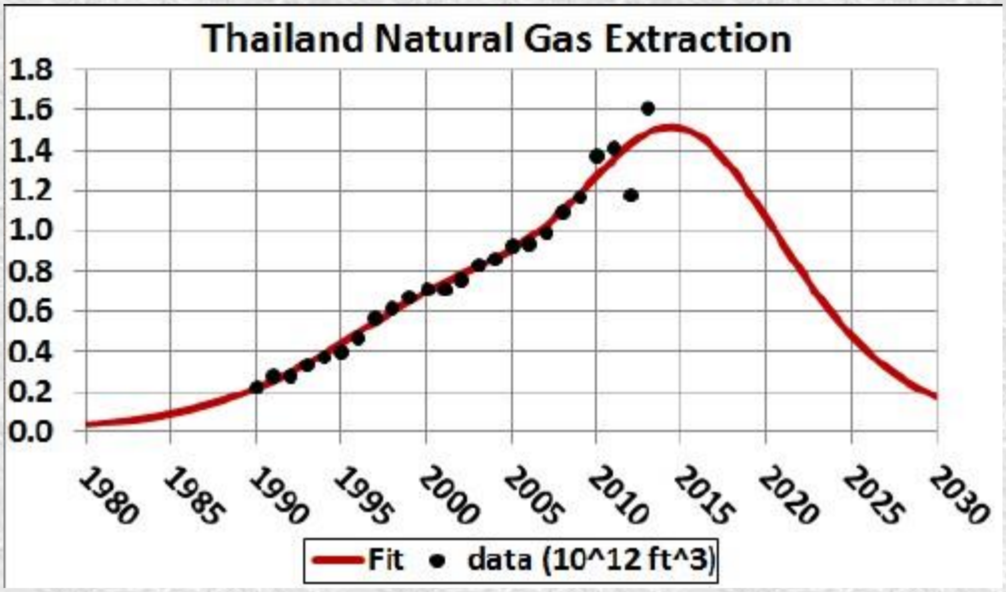
Mozambique Natural-Gas Extraction





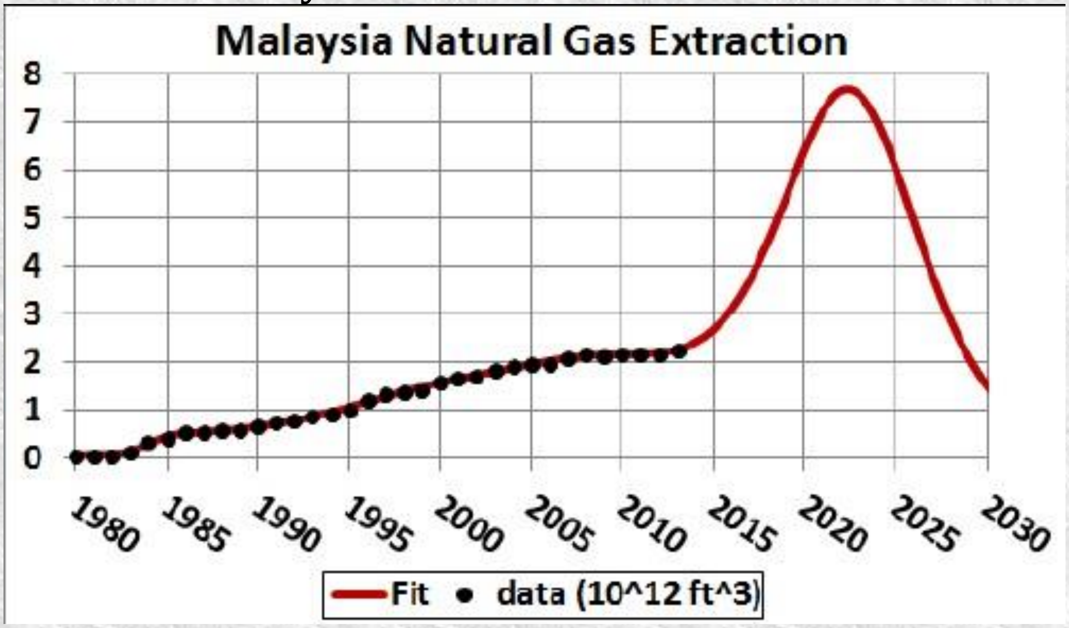
The fit to the data uses slightly more than the 2015 reserves value ~100x10^{12} ft^3.
The future peak was assumed to be symmetrical.

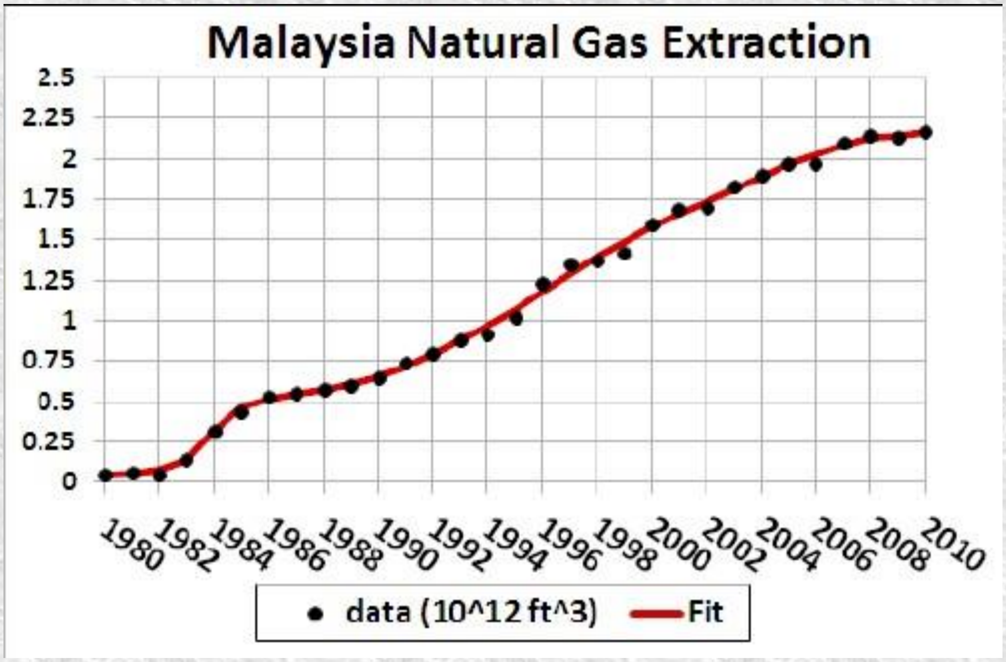
Thailand Natural-Gas Extraction



The fit to the data uses slightly more than the 2015 reserves value ~8.4x10^{12} ft^3.
The future peak was assumed to be symmetrical.

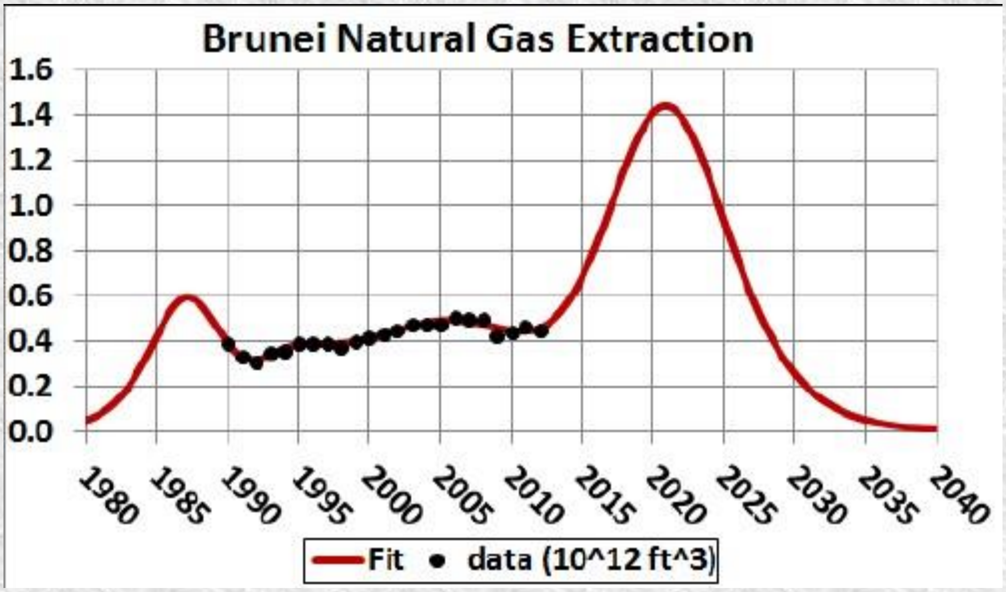
Malaysia Natural-Gas Extraction





The fit to the data uses slightly more than the 2013 reserves value ~83x10^{12} ft^3.
The future peak was assumed to be symmetrical.

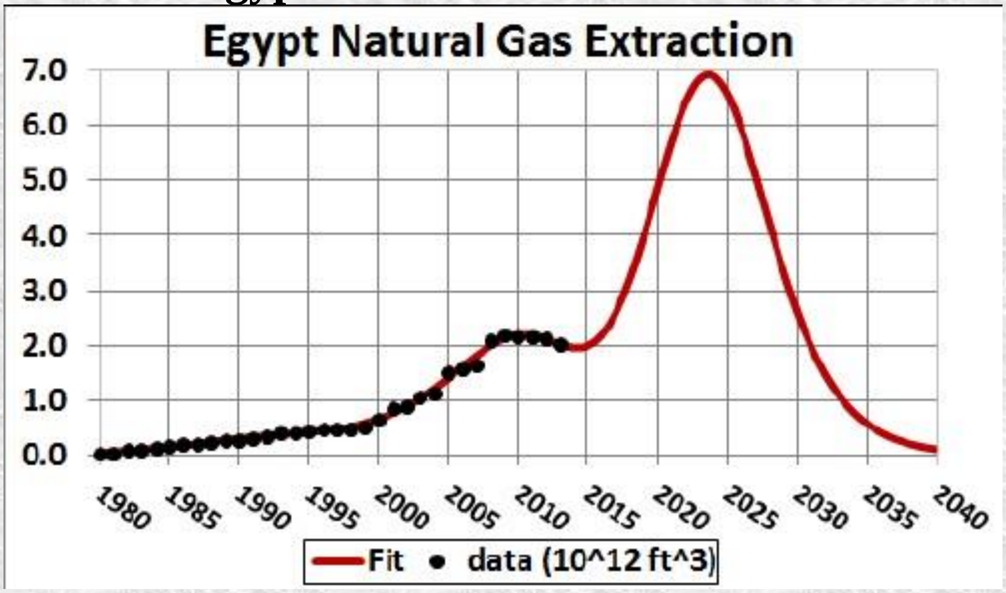
Brunei Natural-Gas Extraction



The fit to the data uses the 2015 reserves value ~14x10^{12} ft^3.

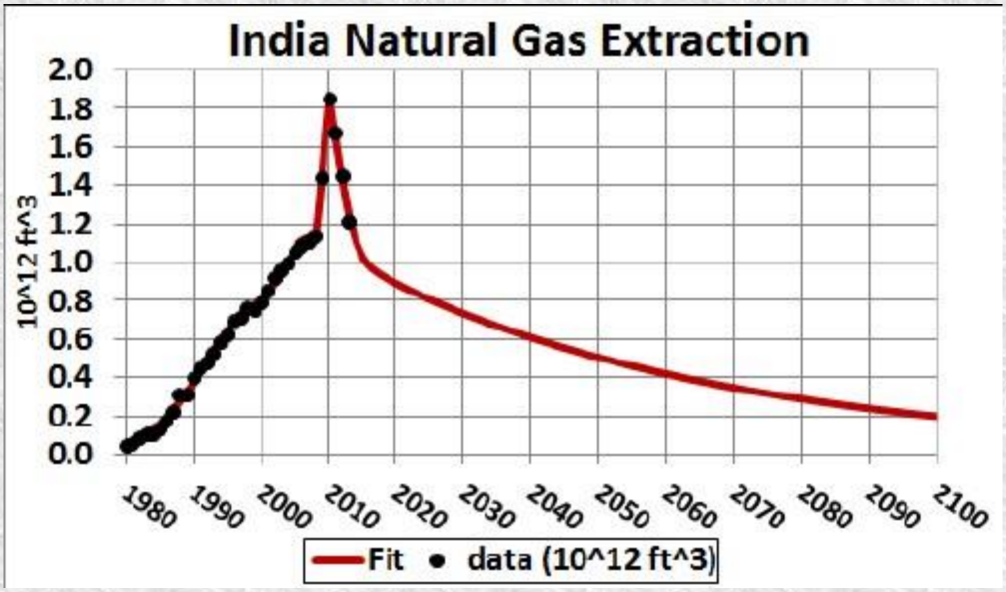
A guess was made as to the peak before the given data. Both the first and last peak were assumed to be symmetrical.

Egypt Natural-Gas Extraction



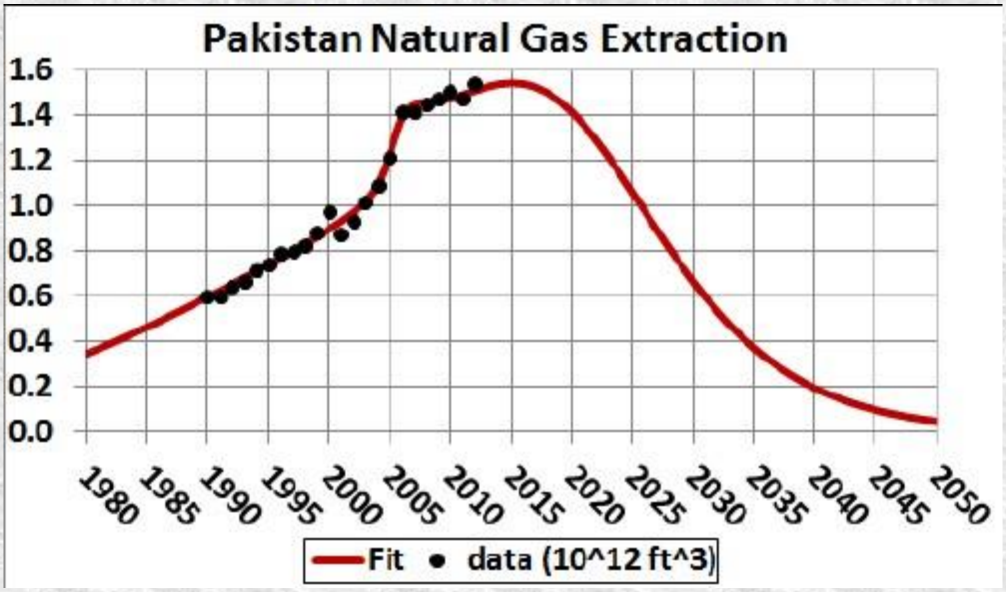
The fit to the data uses the 2015 reserves value ~77x10^{12} ft^3.
The future peak was assumed to be symmetrical.

India Natural-Gas Extraction



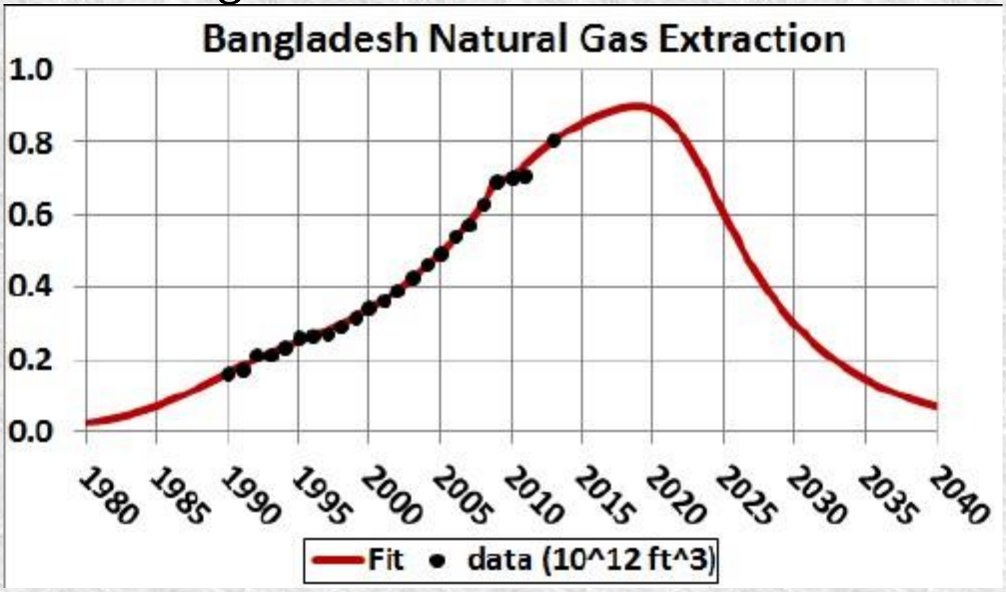
The fit to the data searches to slightly less than the 2015 reserves value ~50x10^{12} ft^3.

Pakistan Natural-Gas Extraction



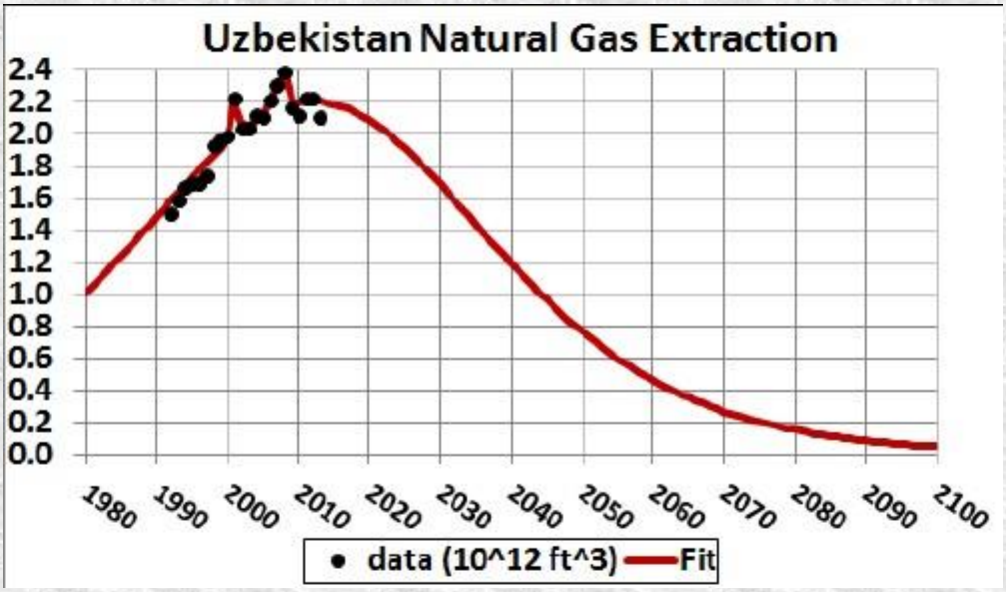
The fit to the data uses the 2013 reserves value ~26.648x10^{12} ft^3.
The future peak was assumed to be symmetrical.

Bangladesh Natural-Gas Extraction



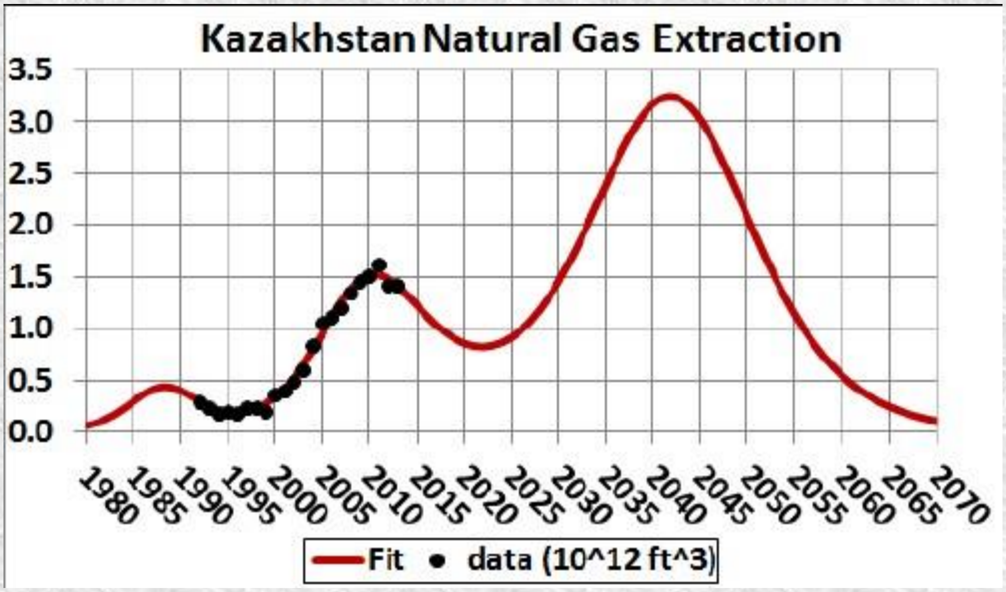
The fit to the data uses the 2013 reserves value ~9.344x10^{12} ft^3.
The future peak was assumed to be symmetrical.

Uzbekistan Natural-Gas Extraction



The fit to the data uses the 2015 reserves value ~65x10^{12} ft^3.
The future peak was assumed to be symmetrical.

Kazakhistan Natural-Gas Extraction

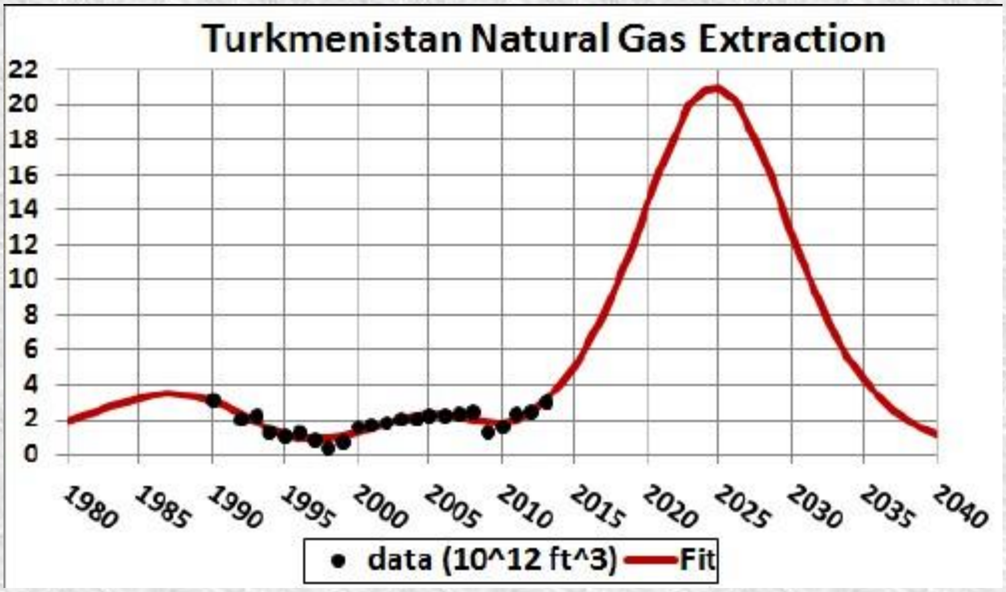


The fit to the data uses the 2015 reserves value ~85x10^{12} ft^3.
The future peaks were assumed to be symmetrical.

Azerbaijan Natural-Gas Extraction

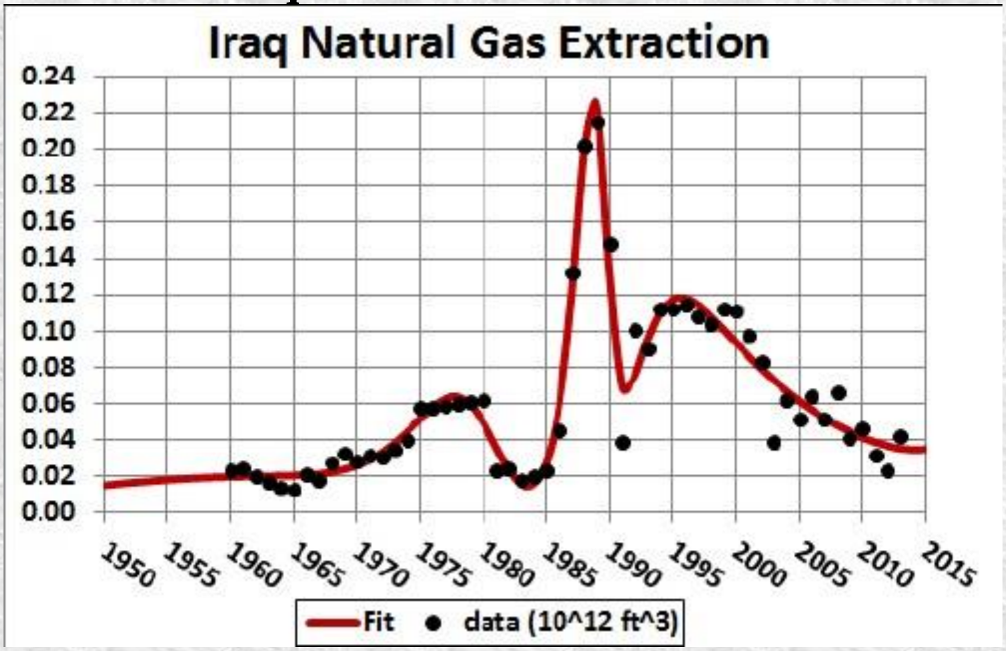
The fit to the data uses the 2013 reserves value ~35x10^{12} ft^3.
The future peak was assumed to be symmetrical.

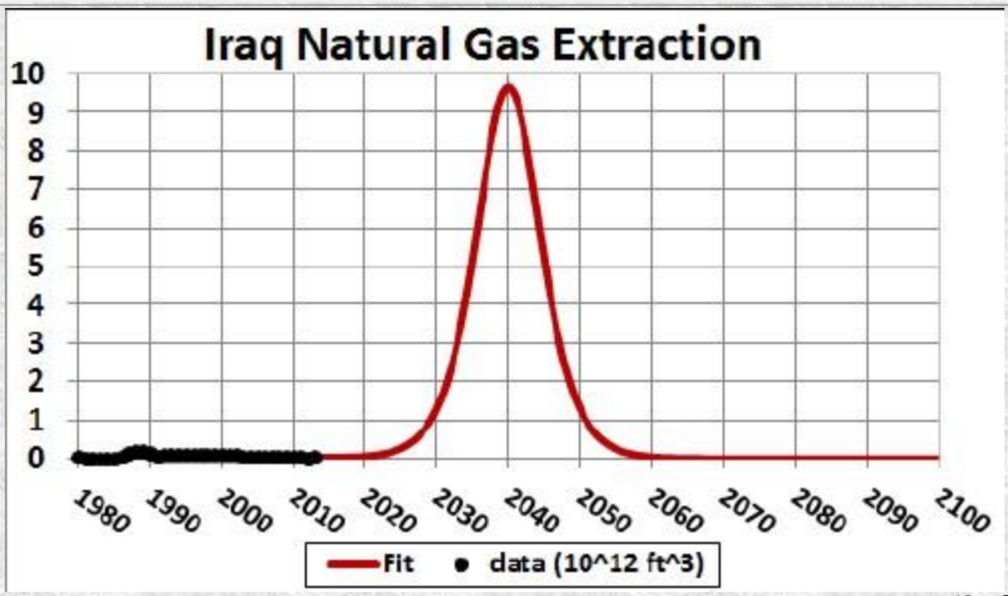
Turkmenistan Natural-Gas Extraction



The fit to the data uses the 2015 reserves value ~265x10^{12} ft^3.
The future peak was assumed to be symmetrical.

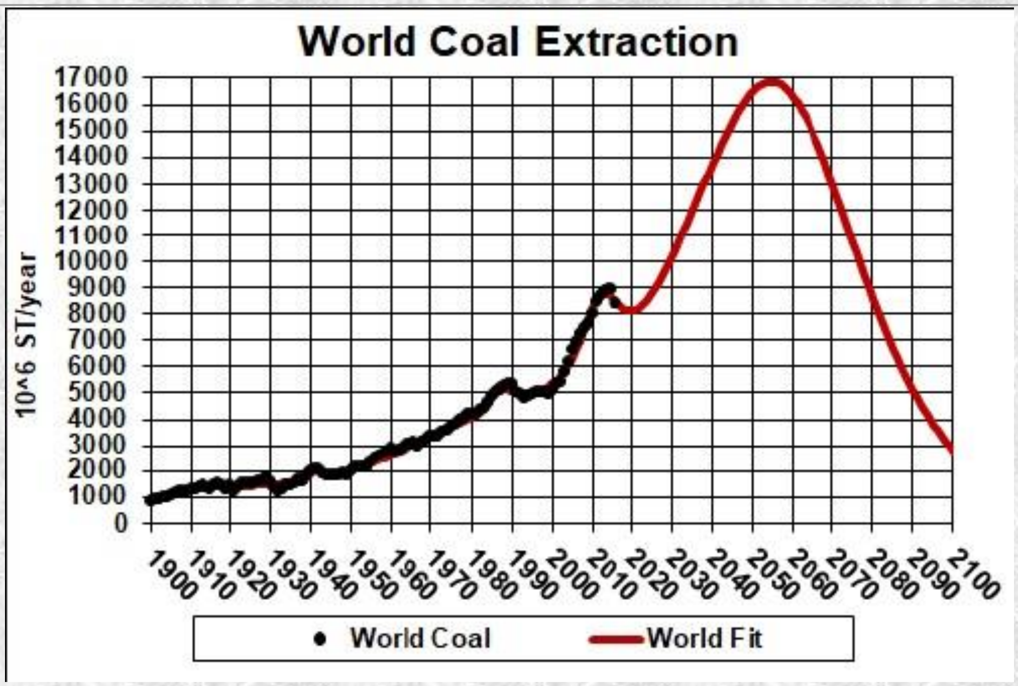
Iraq Natural-Gas Extraction





The fit to the data uses slightly more than the 2015 reserves value ~$112x10^{12}$ ft^3.
A possible future peak in natural-gas extraction for Iraq was assumed to be symmetrical.

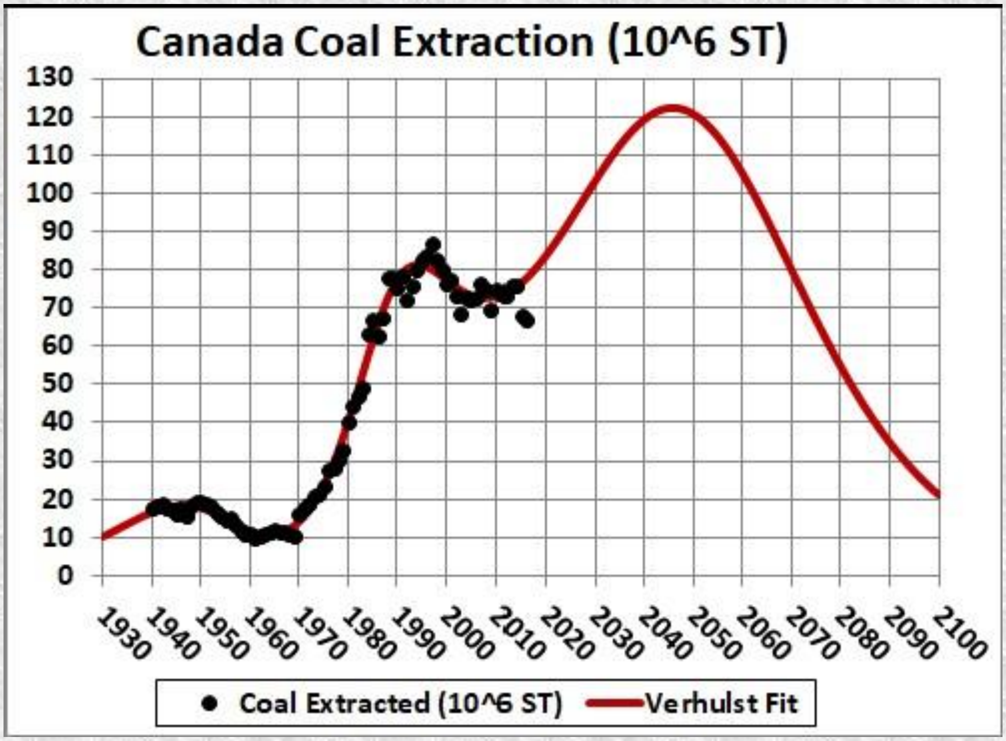
World Coal Extraction



The final peak is assumed to be symmetric.

USA EIA. There are some indications that the estimated reserves value is too high; if that is so, the peak will occur sooner than

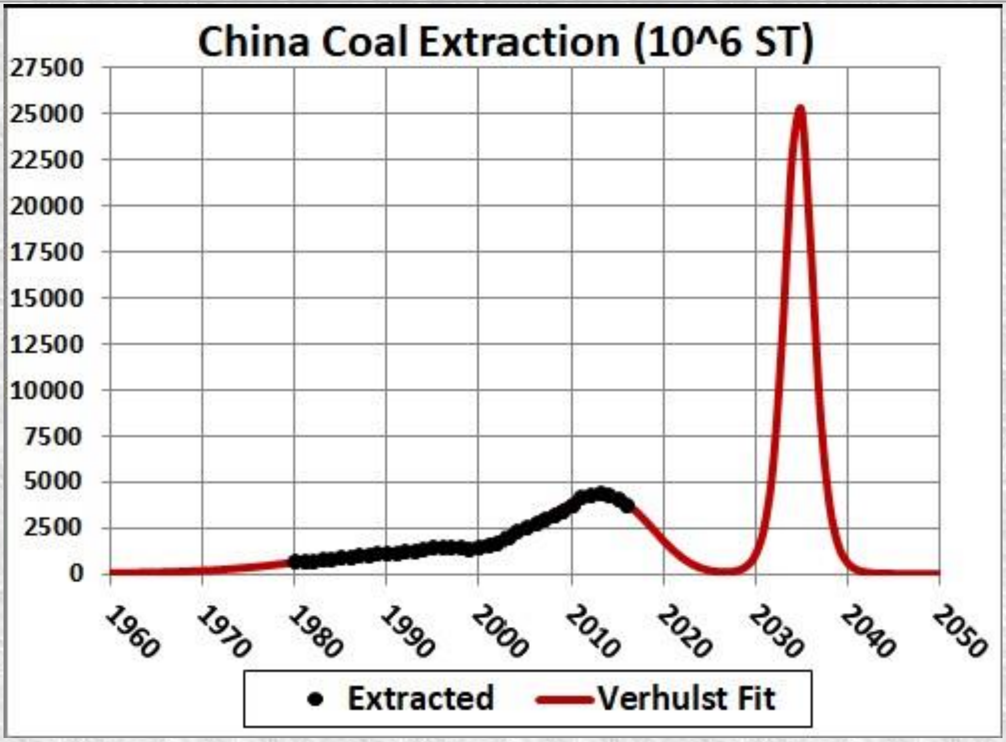
Canada Coal Extraction



The fit to the data uses slightly more than the 2011 reserves value ~72.6×10^9 tons.

China Coal Extraction

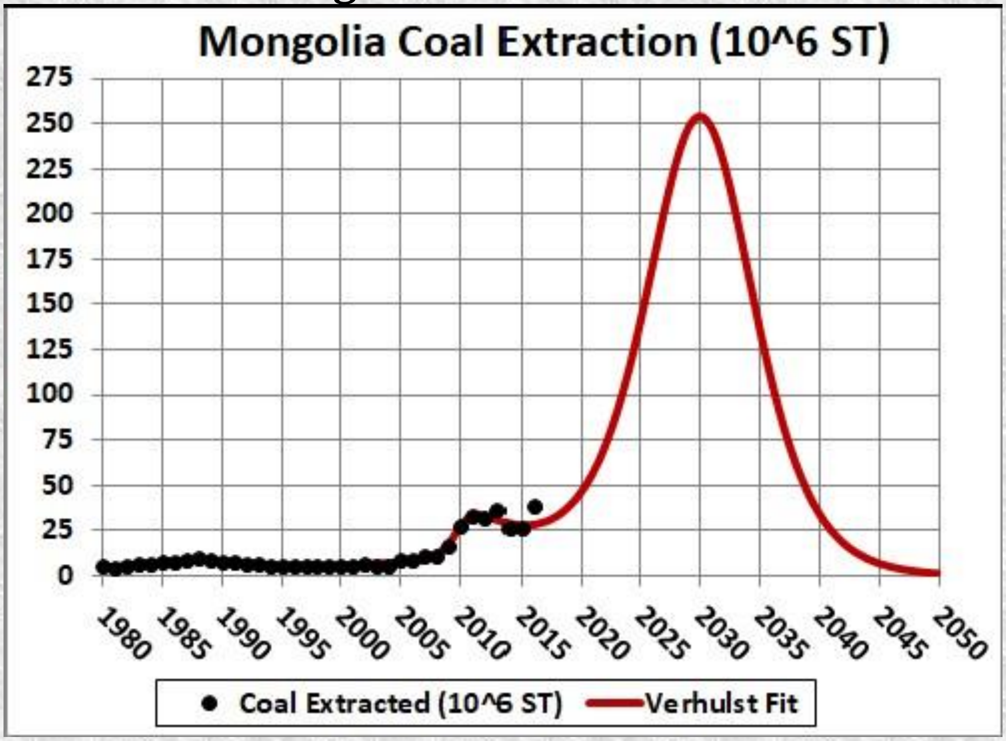
rves in China: 187 x 10^9 or 115 x 10^9 short tons. (The 2008 EIA estimate of reserves is 126.215 x 10^9 short tons.) The following



The final peak is assumed to be symmetric.
The lower curve is the better fit to the data.

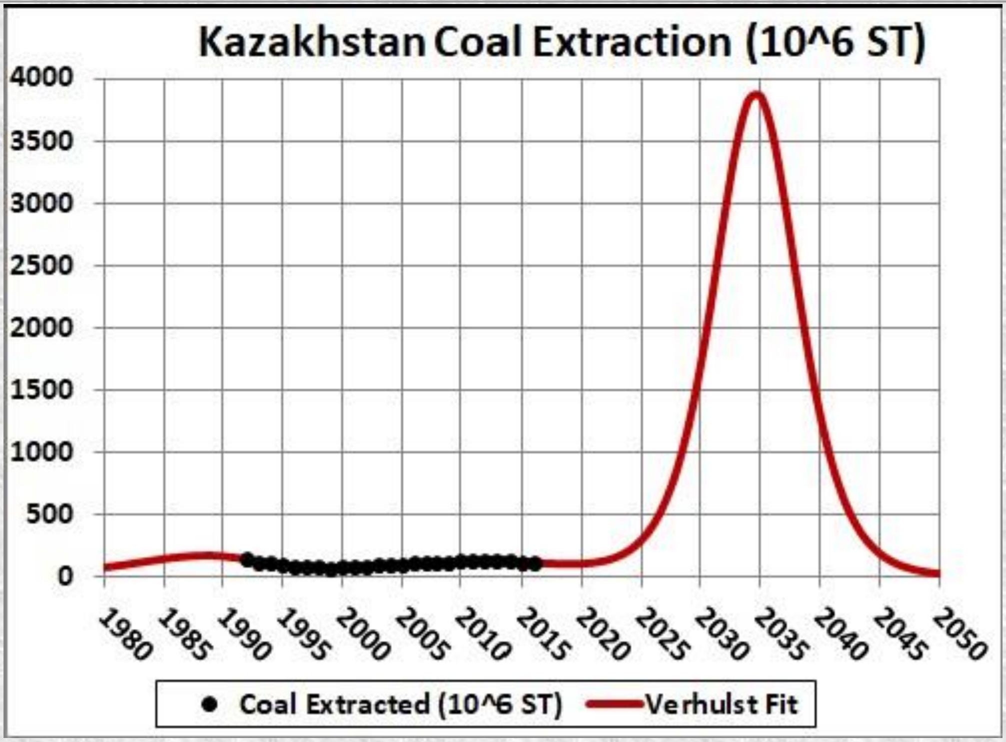
carbon-capture-technology/
ure-and-storage

Mongolia Coal Extraction



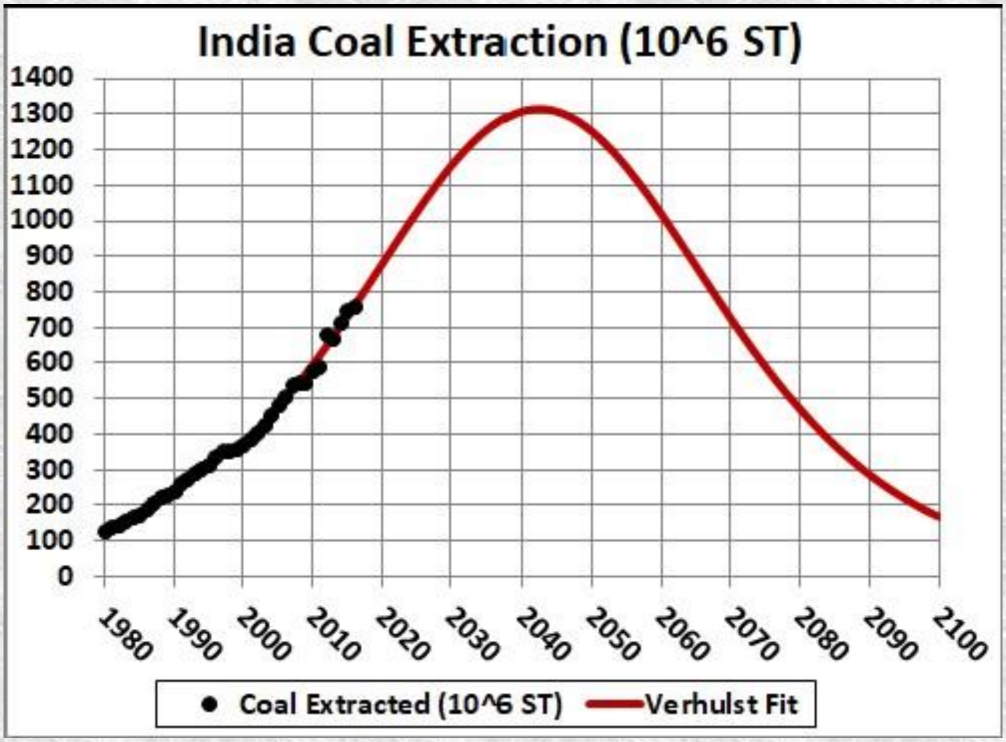
The fit to the data uses slightly more than the 2011 reserves value ~2.778×10^9 tons.

Kazakhstan Coal Extraction



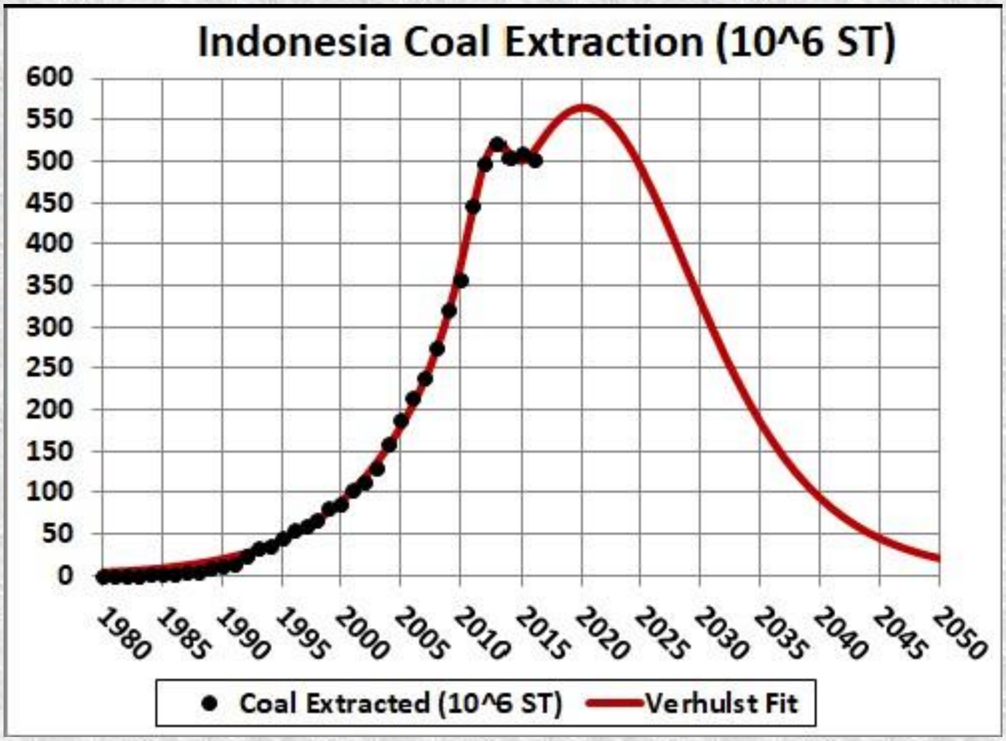
The fit to the data uses slightly more than the 2016 reserves value ~33.6x10^9 tons.

India Coal Extraction



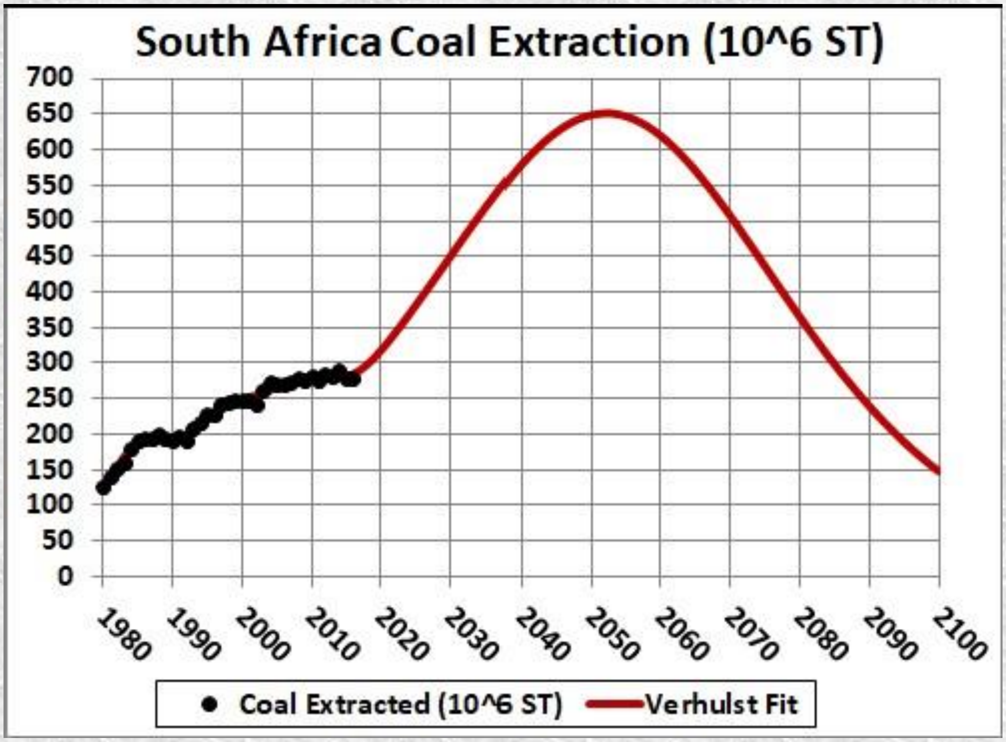
The fit to the data uses slightly more than the 2008 reserves value ~66.8x10^9 tons.

Indonesia Coal Extraction



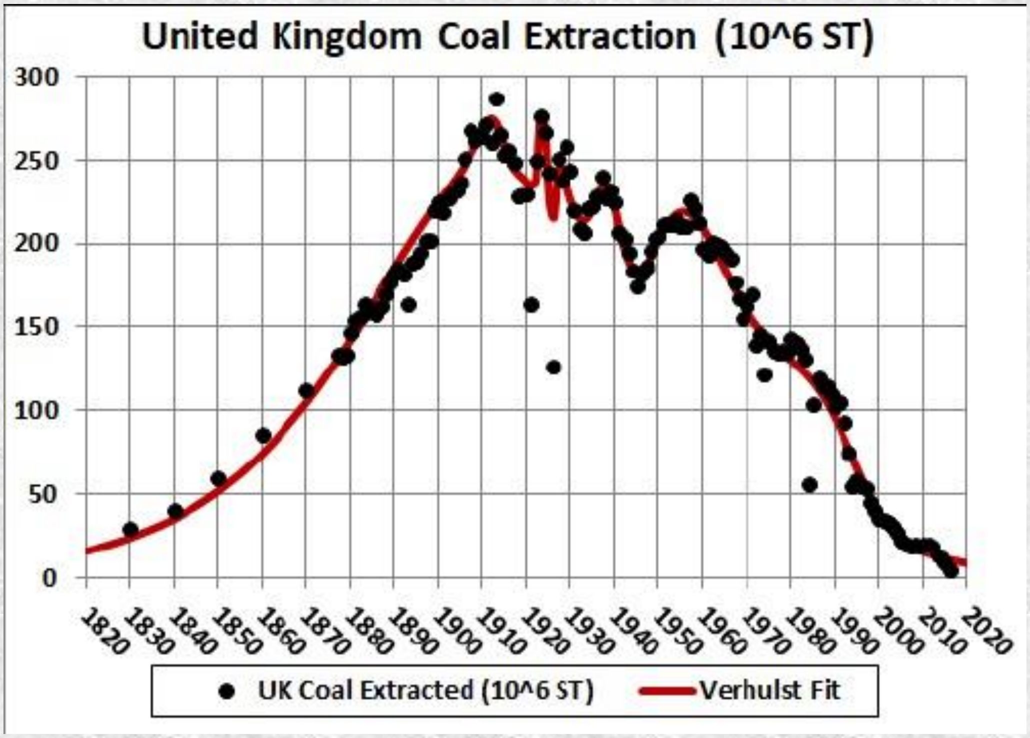
The fit to the data uses slightly more than the 2008 reserves value ~6.095×10^9 tons.

South Africa Coal Extraction

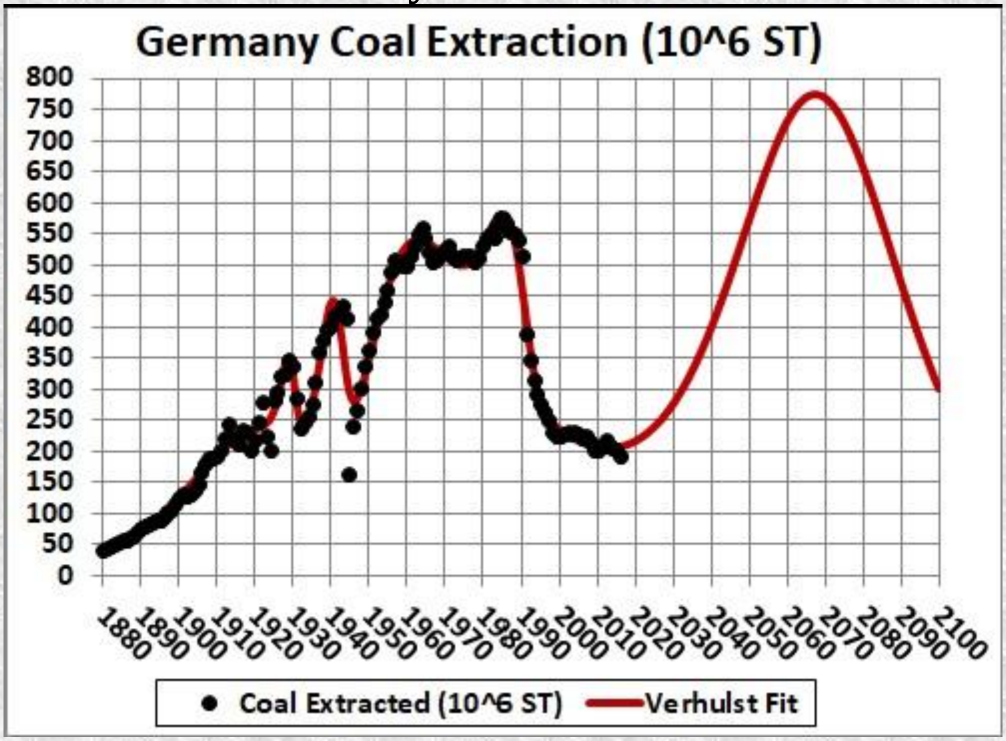


The fit to the data uses slightly more than the 2011 reserves value ~33.2413×10^9 tons.

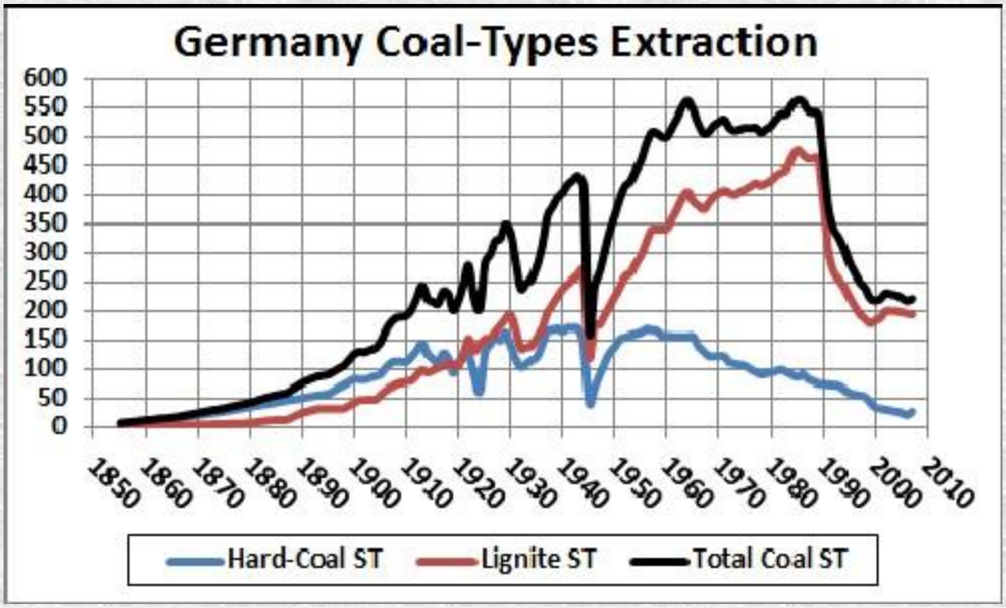
United Kingdom Coal Extraction



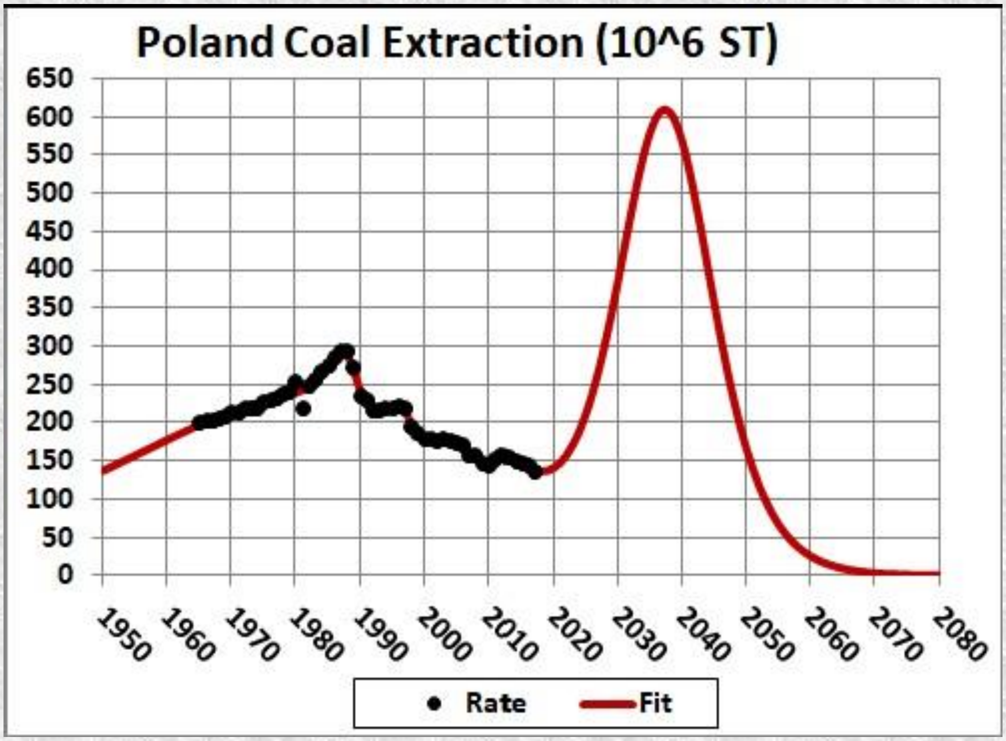
Germany Coal Extraction



The fit to the data uses slightly more than the 2008 reserves value ~44.863x10^9 tons.

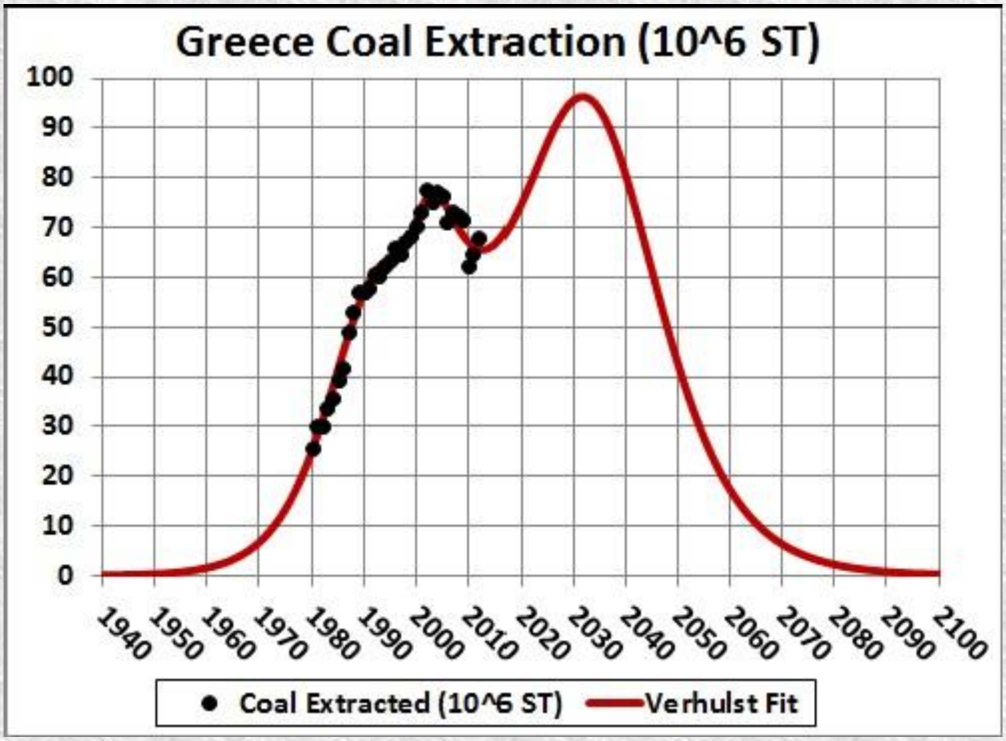


Poland Coal Extraction



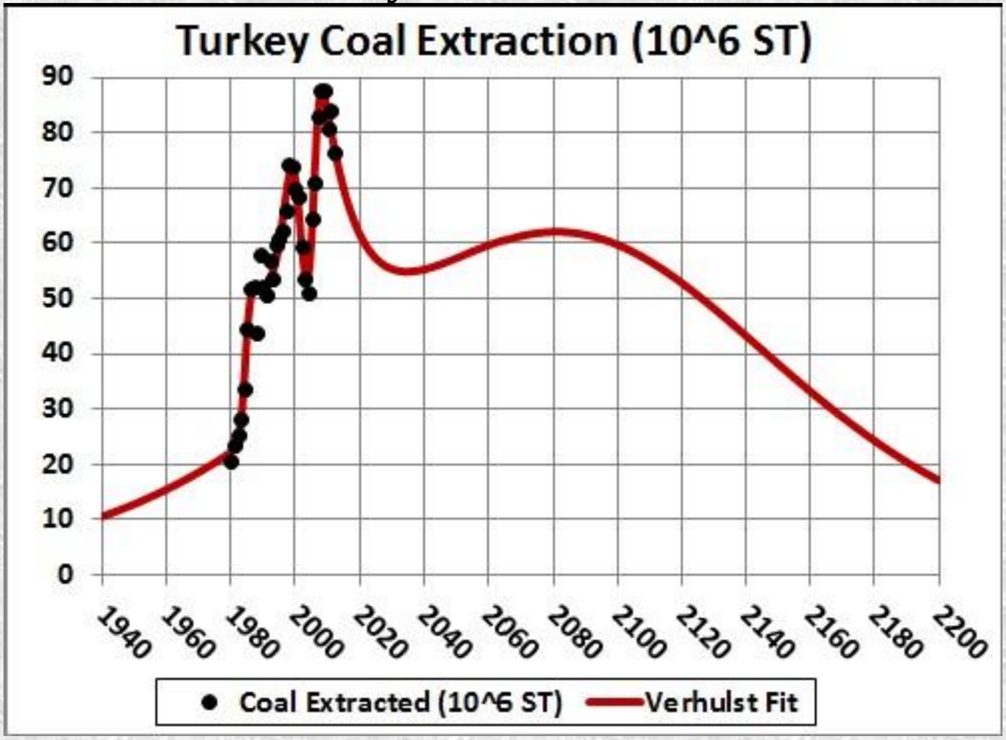
The fit to the data uses slightly more than the 2011reserves value ~6.293x10^9 tons.

Greece Coal Extraction



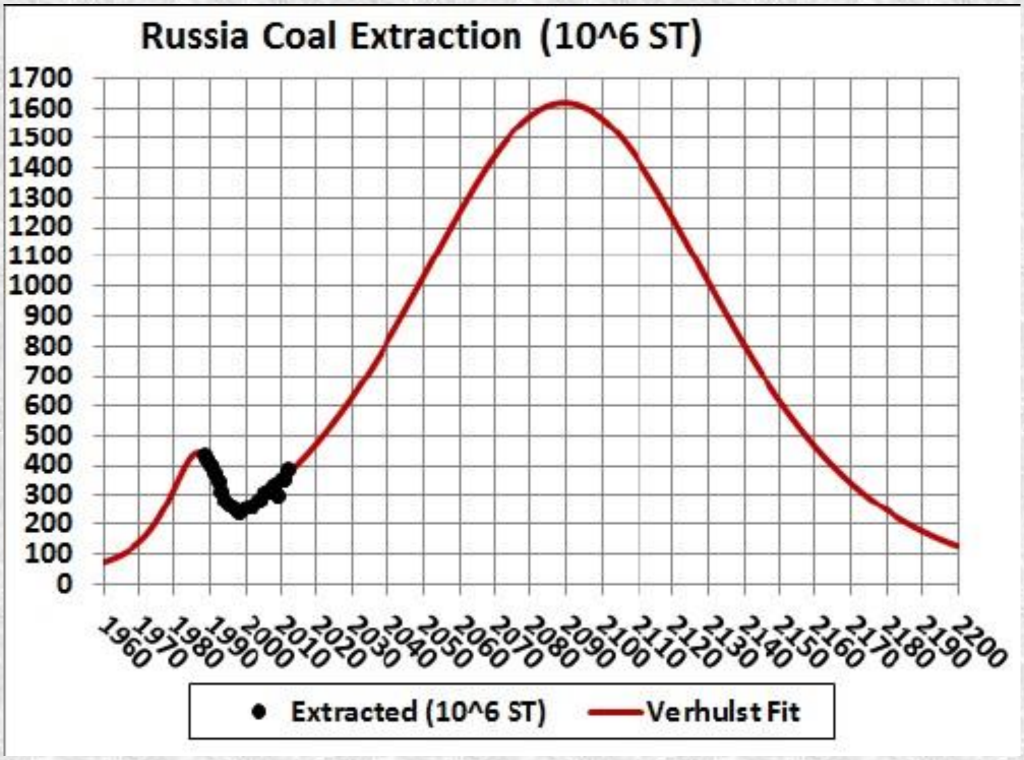
The fit to the data uses slightly more than the 2011reserves value ~3.329×10^9 tons.

Turkey Coal Extraction



The fit to the data uses slightly more than the 2011reserves value ~9.592×10^9 tons.

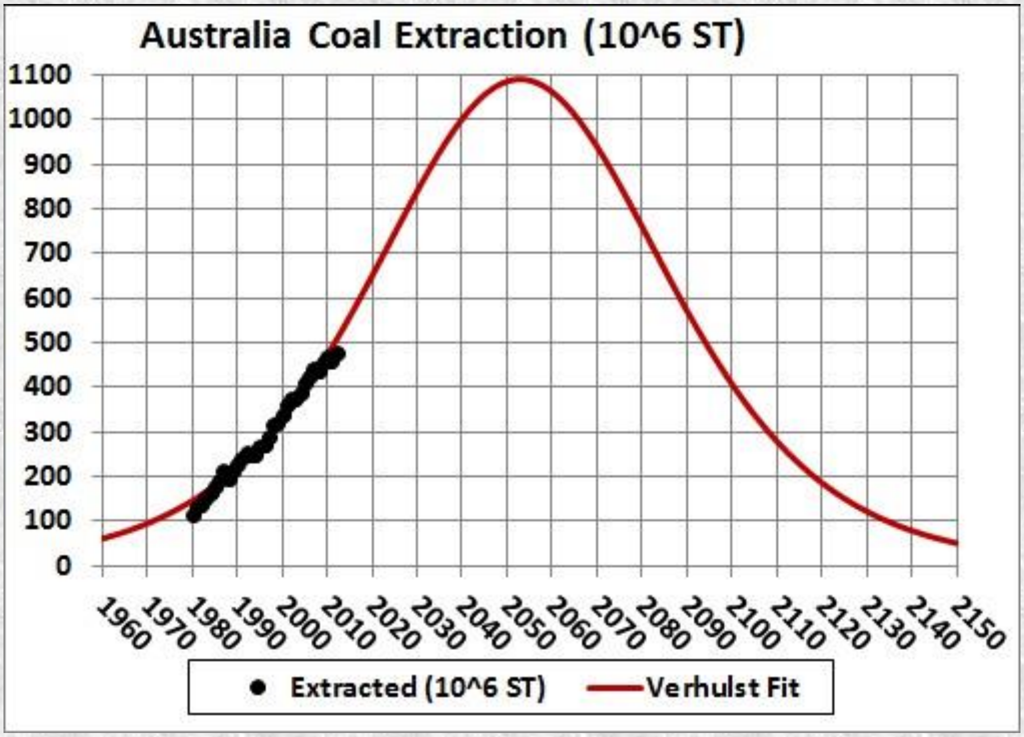
Russia Coal Extraction



The final peak is assumed to be symmetric.
This fit is done using the EIA estimated reserves of 173.074 x 10^9 short tons.

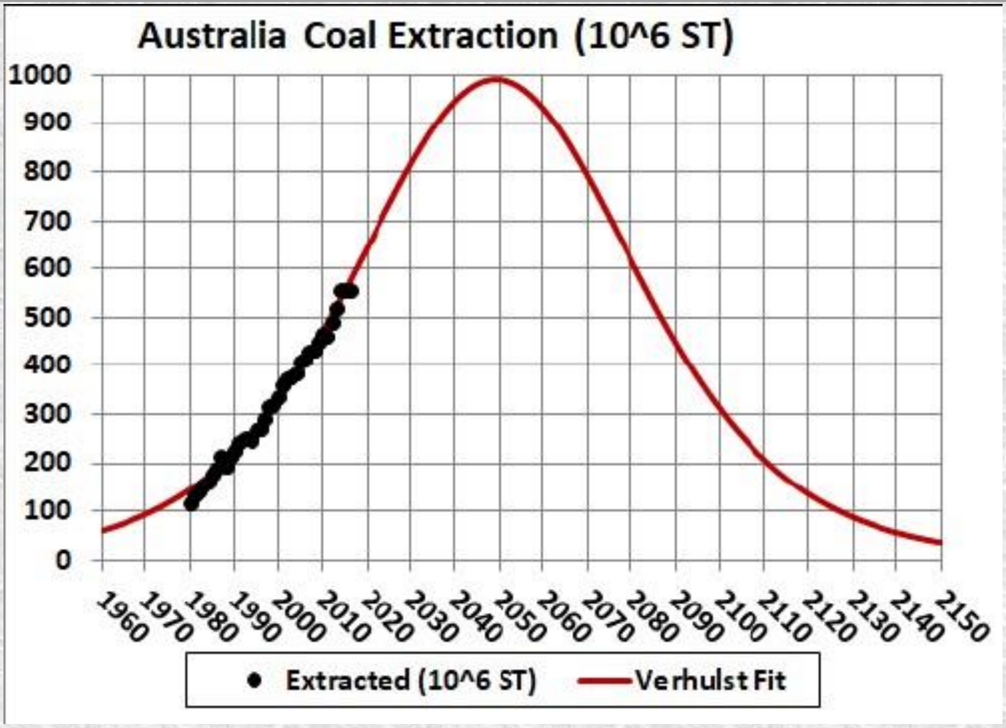
0&eyid=2009&unit=TST

Australia Coal Extraction



The final peak is assumed to be symmetric.

This fit is done using the EIA estimated reserves of 84.217 x 10^9 short tons.



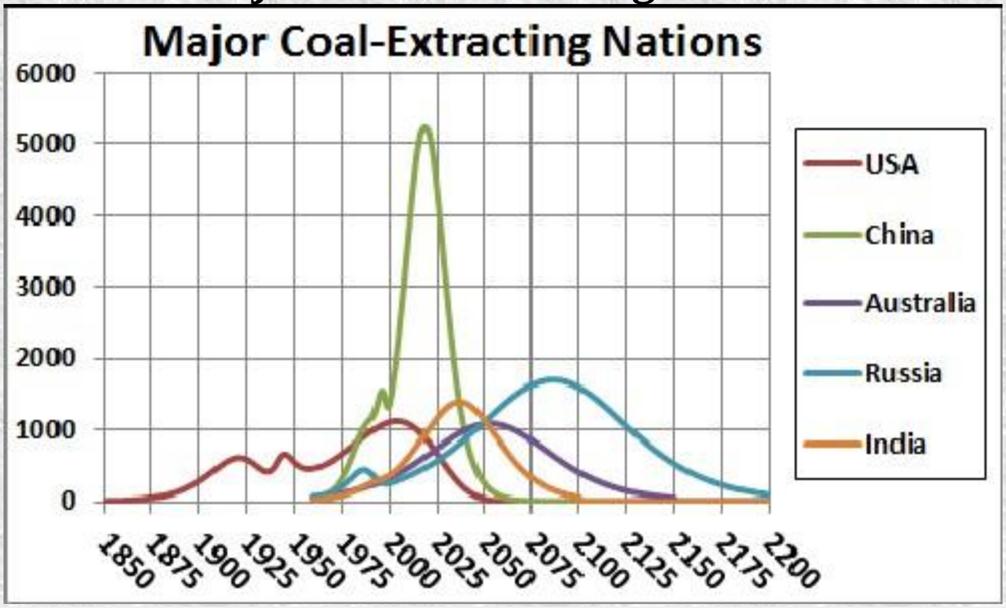
The final peak is assumed to be symmetric.
The total amount to be extracted eventually is 32.294 x 10^9 short tons.

dy extracted (~ 15.17 x 10^9 short tons) plus the EIA 2008 reserves estimate (84.217 lx 10^9 short tons), the fit to the data searches

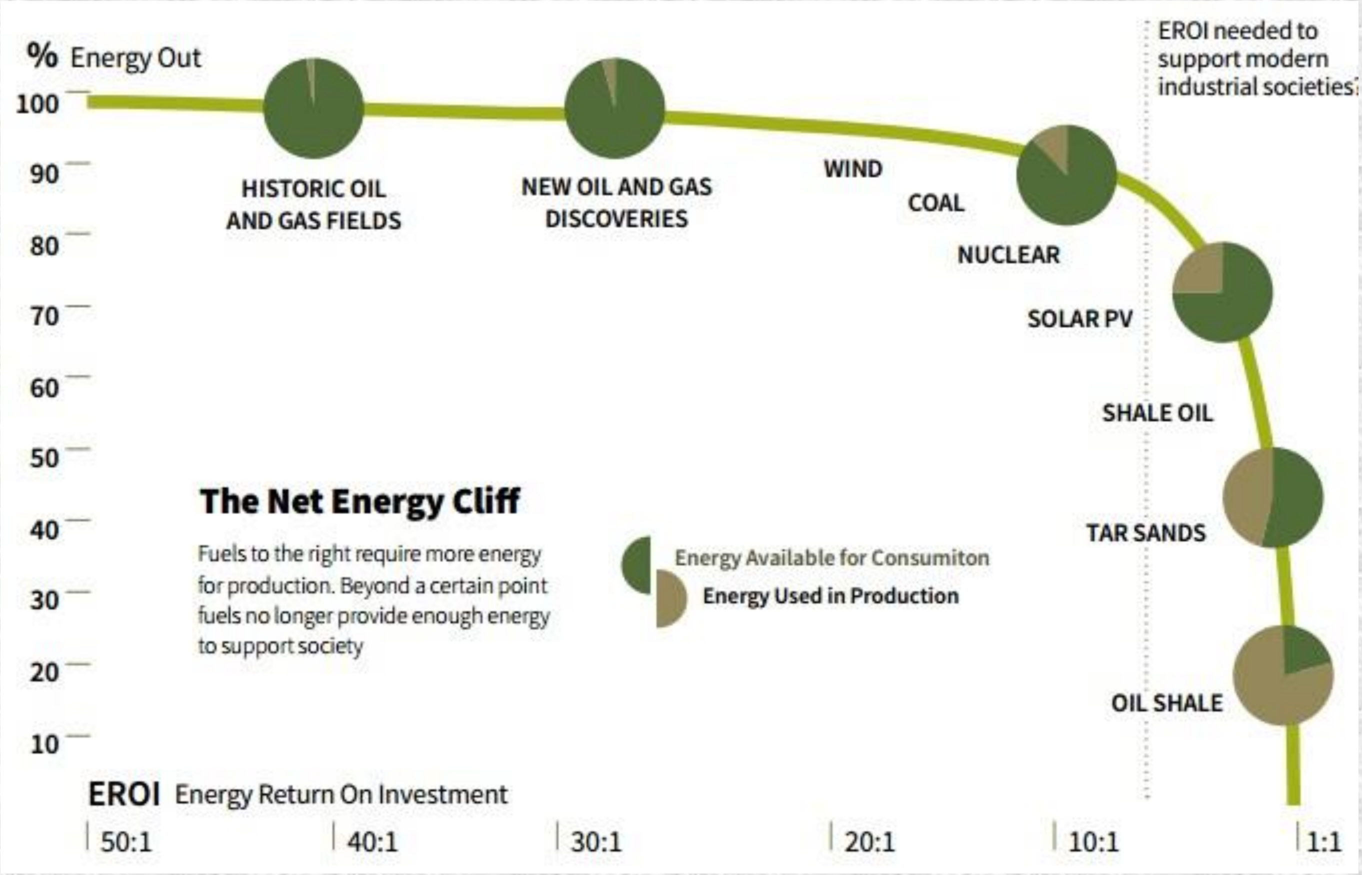
0&eyid=2009&unit=TST

hina_goes_green.html

Major Coal-Extracting Nations



Excel spreadsheet listing some of the data used in the analyses above



Coal Prices Prediction

Coal Education

- http://www.wou.edu/las/physci/GS361/Fossil%20fuels/Coal.htm
- http://www.ucsusa.org/clean_energy/coalvswind/brief_coal.html

L. David Roper interdisciplinary studies