Coal Extraction in the United States

L. David Roper
http://arts.bev.net/roperldavid/
18 December, 2011

Introduction

The amount of coal that can be extracted inside the United States is a crucial number for the future of the country. This article does the math to arrive at an estimate at that number.

Crude-Oil Extraction and Reserves Data for the United States

The Energy Information Agency of the United States government has annual extraction data (they call it "production", which is incorrect verbiage; natural resources are extracted, not produced): http://www.eia.gov/coal/data.cfm#production . EIA also has reserves data: http://www.eia.gov/coal/data.cfm#reserves .

Depletion Function to Fit to Data

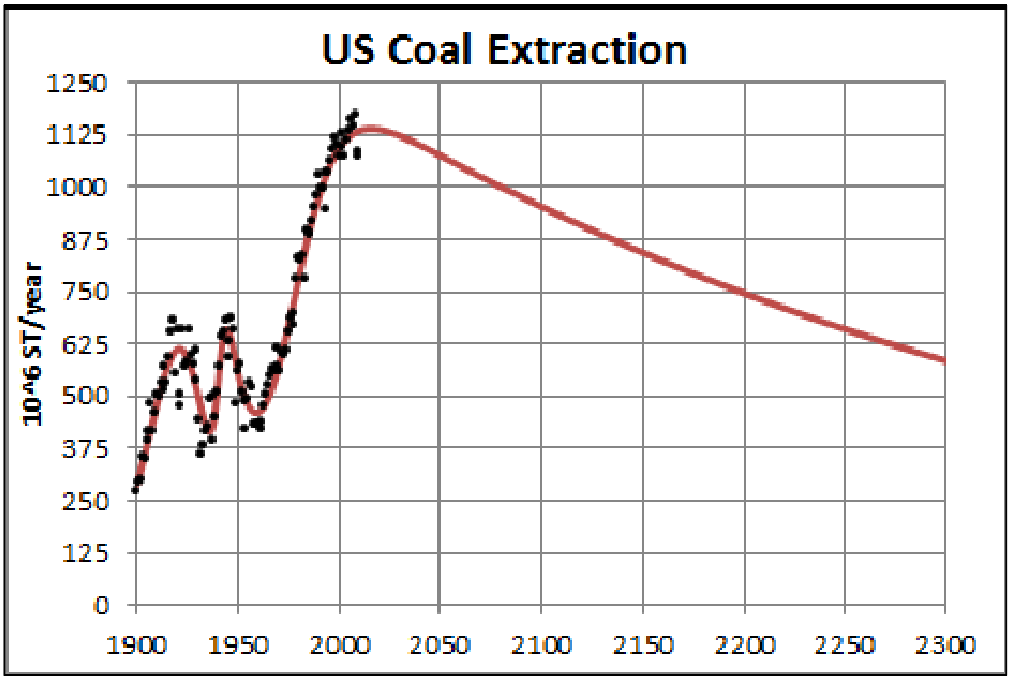
The depletion curve used to fit the data is the Verhulst function (http://www.roperld.com/science/minerals/VerhulstFunction.htm):

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

Q_∞ is the amount to be eventually extracted, τ is the rising exponential time constant, n τ is the declining exponential time constant and $t_{1/2}$ is the time at which the resource is one-half depleted. The maximum of P(t) occurs at $t_{max} = t_{\frac{1}{2}} + \tau \ln\left(\frac{n}{2^n - 1}\right)$, which yields $P_{max}(t_{max}) = \frac{Q_\infty}{\tau} \frac{1}{(n+1)^{\frac{n+1}{n}}}$.

Depletion Fit to Total United States Crude-Oil Extraction Data

The three-Verhulst- function fit to the U.S. extraction data is:



The amount to be extracted (area under the curve) is 562,000x10^6 ST (486,100x10^6 ST reserves in 2009 + 72,495x10^6 ST already extracted by 2009). (I.e., about 14% has already been extracted.) I suspect that the currently-shown "peak" will go higher, which means that the drop will then be faster. And there might be later peaks instead of a smooth decline in extraction, which would be followed by a faster drop.

The parameters of the fit are:

Verhulst Number	Q_∞	$t_{1/2}$	τ	n
1	24175	1917.7	12.56	0.3542
2	11272	1952.1	2.041	8.006
3	526,553	2260.3	11.37	36.0

Some Interesting Facts about Coal

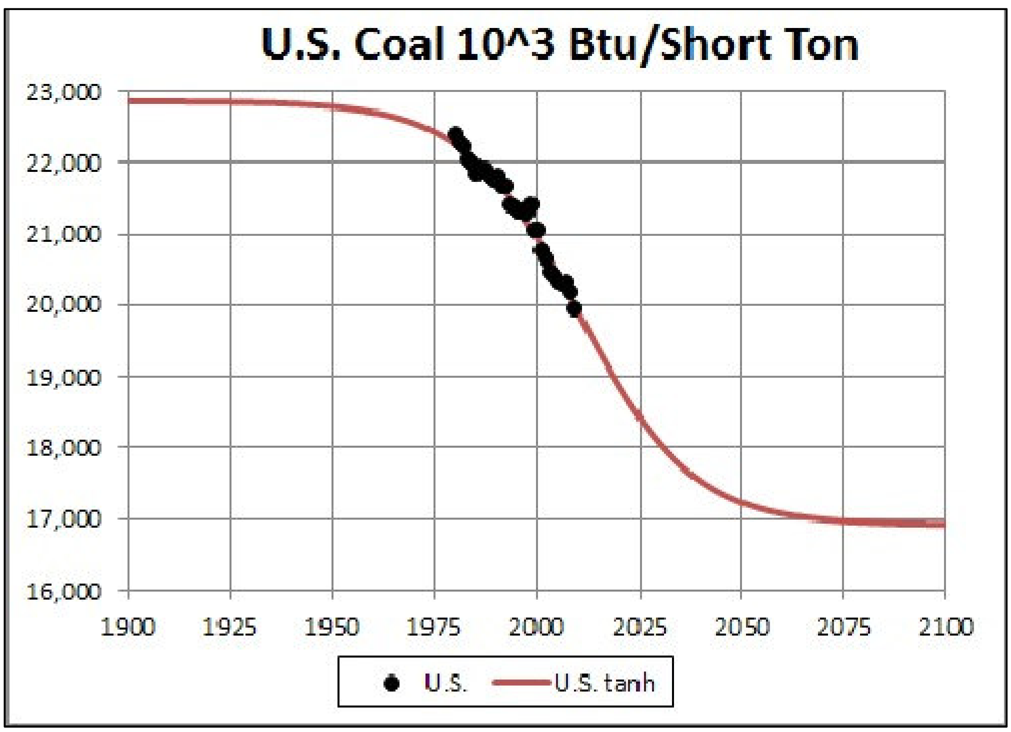
Energy Content of Coal

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

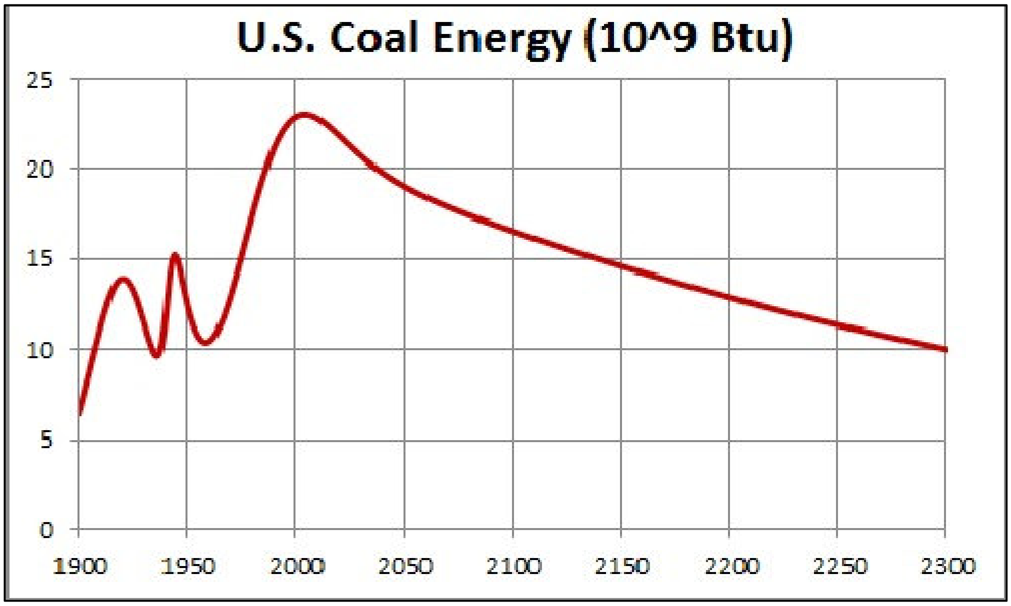
U.S. Coal energy/weight

(http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=1&pid=1&aid=10&cid=&syid=1980&eyid=2009&unit=TBTUPST) and a hyperbolic-tangent function (http://www.roperld.com/science/Mathematics/HyperbolicTangentWorld.htm) 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.

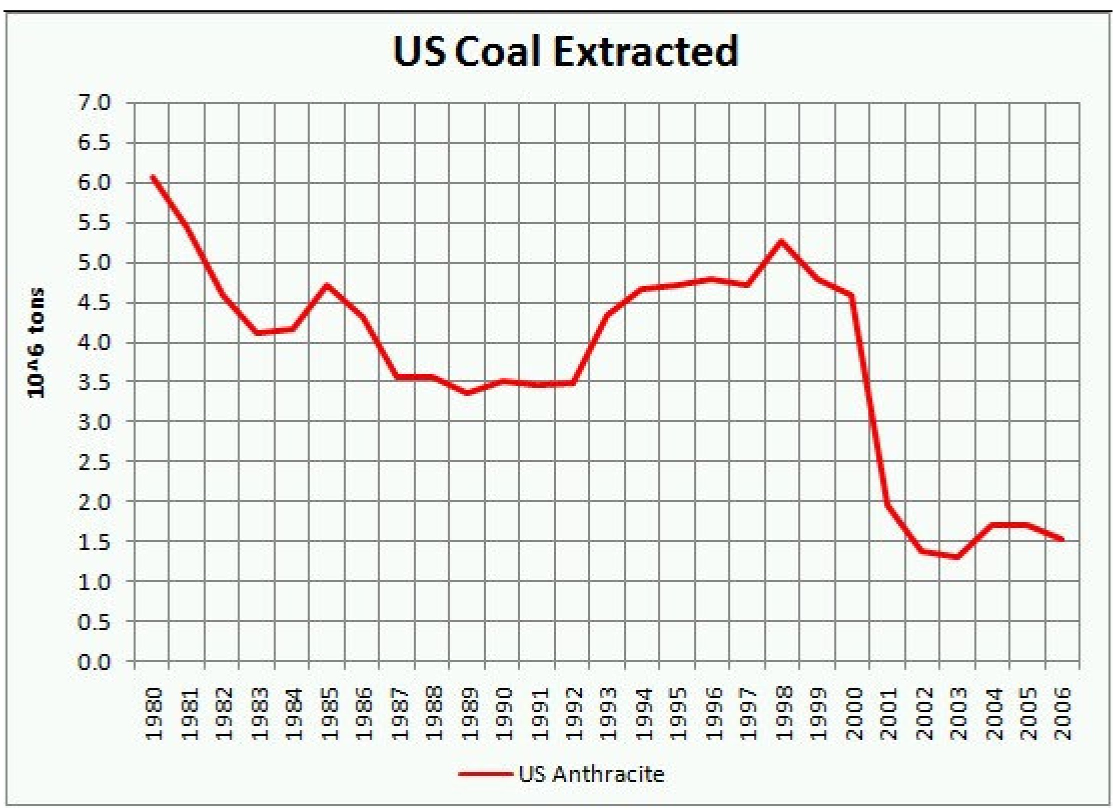
Putting the last two graphs together, the energy available from coal in the U.S. is



Although U. S. coal extraction peaks at ~2020, U.S. coal energy peaks at ~2005.

Most of the coal mined in the U.S. is bituminous

(http://www.eia.gov/emeu/international/coalproduction.html), with lesser 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

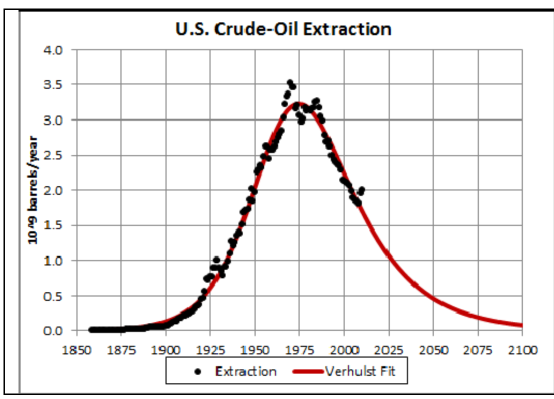
1 Btu = 1055.056 joules = 2.930711×10^{-4} kWh
1 lb = 0.45359237 kg
1 MJ/kg = 429.9226 Btu/lb

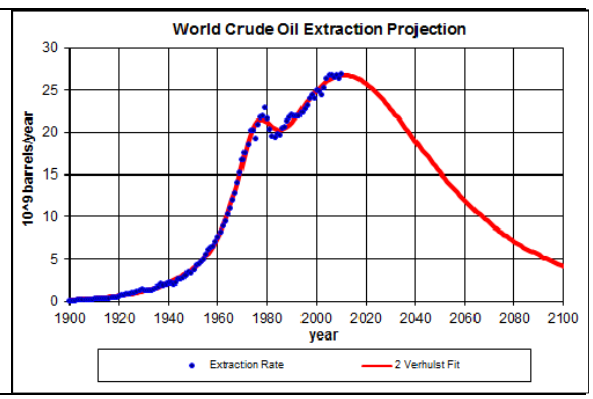
Coal Prices Prediction

http://www.roperld.com/science/minerals/coalpricesprediction.htm

What if Liquid Fuel from Coal becomes Viable?

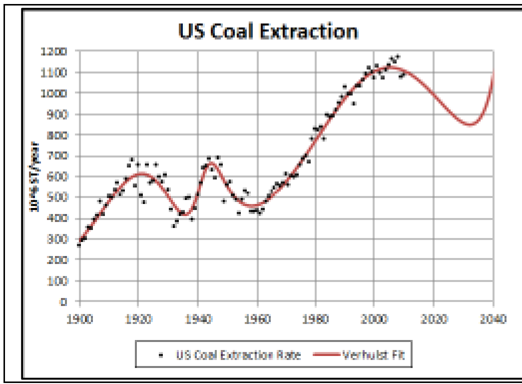
Because of the rapid depletion of crude-oil extraction in the United States and the world, a time may come when producing liquid fuels from coal becomes viable. Here are graphs of the probable future of crude-oil extraction in the U.S. and the world:

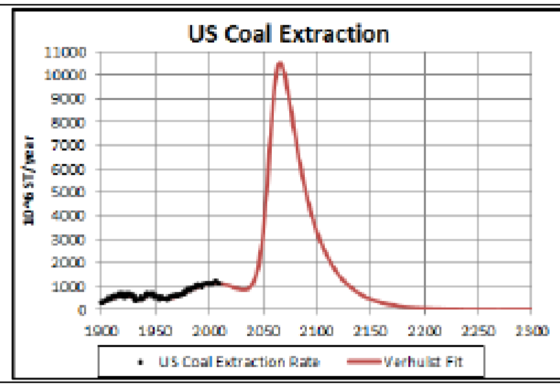




From these graphs 2050-2100 appears to be a time when liquid fuel production from coal might peak.

Here are graphs showing how producing liquid fuels from coal in the U.S. might affect coal extraction:





Because of environmental concerns, coal extraction might drop for a decade or longer and then rise rapidly as liquid-fuels production from coal occurs. Of course, it then has to fall rapidly after peaking because of depletion.

http://www.roperld.com/science/minerals/FossilFuels.htm