The Coal Question, Revisited

Posted by Euan Mearns on December 15, 2010 - 10:20pm

This is a guest post by Professor Dave Rutledge (DaveR), of the California Institute of Technology (Caltech).

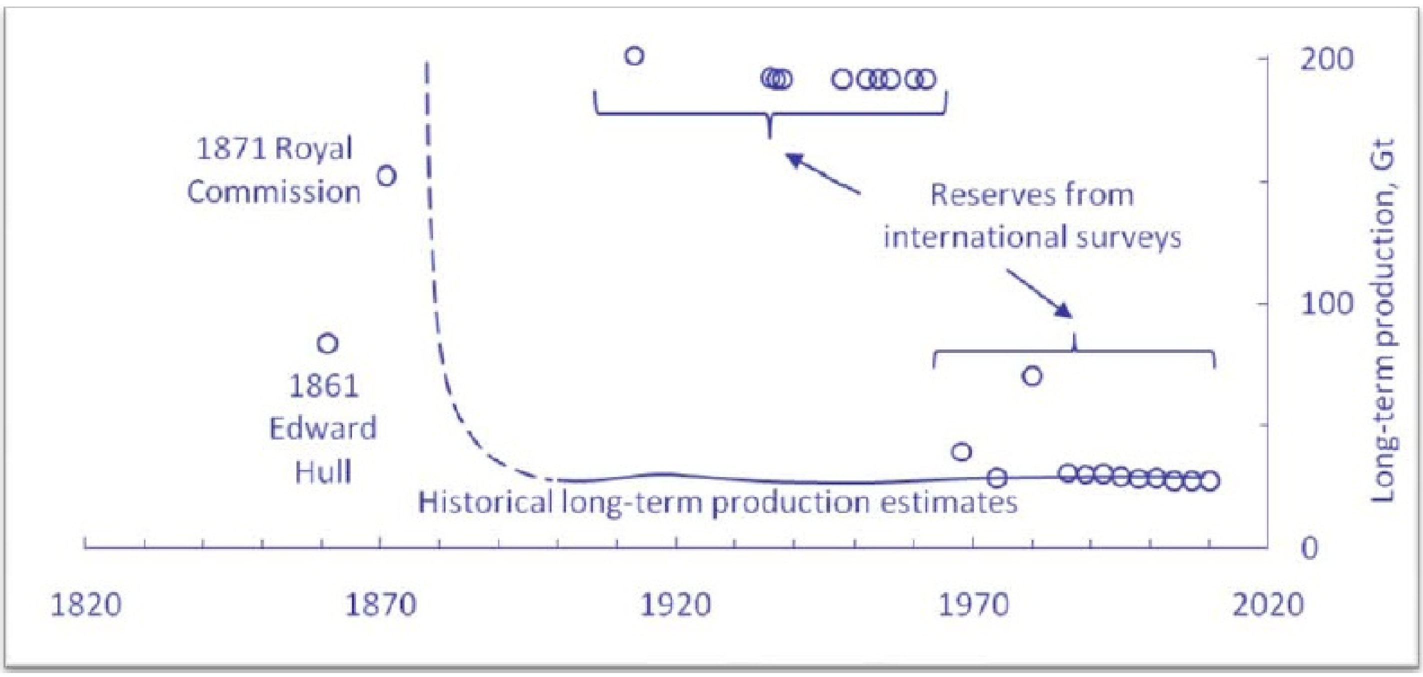
In the summer of 2007, Professor Kyle Saunders (Professor Goose) invited me to do a guest post for The Oil Drum. This post was "The Coal Question and Climate Change." In the post, Hubbert linearization was applied to make a regional analysis of world coal production. The estimate for long-term production, including both cumulative production and all future production, amounted to 724Gt. Many people, including Dave Summers (Heading Out) and Euan Mearns, made helpful critical comments on the post, particularly concerning British coal production. Overall, I was encouraged by the response. The Oil Drum is a great place to try out new ideas.

I now have a paper "Estimating Long-Term World Coal Production with Logit and Probit Transforms" that is in press at the International Journal of Coal Geology. People who are interested can download a pdf preprint at my web site. There is also an Excel workbook with the data for the paper at the site. The paper makes several changes from the original post. At that time, I did not have complete production data, and I was relying on cumulative production totals from reports by the BGR, the German resources agency. These turned out to be incomplete. However, over time, I was able to fill in the gaps in the production histories. Steve Mohr at the University of Newcastle in Australia gave wonderful help, and Nadia Lapusta, a Ukranian engineering professor at Caltech, located Russian language histories for the different Soviet republics. I was able to fill out the early American state production numbers from Harold Eavenson's 1942 book, *The First Century and a Quarter of the American Coal Industry*.

In addition, I became dissatisfied with Hubbert linearization. Hubbert linearization involves annual production directly, and this gives larger fluctuations in the estimates than an approach based on cumulative production. This is a particular problem for coal, which shows large production drops in strike years. Hubbert linearization assigns weak weight to the later years in the production cycle, and this means one often has to make a judgment call about throwing out a large number of the earlier points, because their influence is too strong. Also, Hubbert linearization is based on the logistic function, and a cumulative normal is a better fit for some regions. In the new paper, the logit transform is used to linearize the cumulative production history for the logistic fits and the probit transform for the cumulative normal fits. One way to understand how these linearizing transforms work is to think in terms of an exhaustion function, defined in the paper as the fraction of the long-term production that has already been produced. The exhaustion starts off at zero, and then monotonically increases, eventually reaching unity when the last mine shuts down. It has the same properties as a cumulative density function in statistics. From this perspective the probit transform is the inverse of the standard cumulative normal function, and the logit transform is the corresponding inverse function for the logistic distribution. The statistical quantity r^2 (correlation coefficient squared) is maximized to find the long-term production estimate. This is a simple one-parameter fit, and it takes about one second in Excel. There are two regions where production is developing that do not give a maximum value for r^2, South Asia and Latin America. For these regions, I used the reserves as an estimate for future production, even though the experience with the mature regions indicates that these numbers are likely to be too high.

Finally, in my original post, I had considered Montana as a separate region. Montana has enormous reserves, 68Gt at year-end 2008, but only modest annual production, 36Mt in 2009. I had used Montana's reserves as an estimate for its future production. After studying the USGS assessments for the area I came around to the view that this was not appropriate. The main production in Montana is from the Powder River Basin (PRB), and it appears that Wyoming drew much the better hand in the PRB. I believe that the differences in PRB production for Wyoming and Montana represent geology at least as much as any other factors. For more discussion, see "Potential for Coal-to-Liquids Conversion in the U.S.-Resource Base," by Gregory Croft and Tad Patzek, *Natural Resources Research*, volume 18, pp. 173-180. Montana does follow the same two-cycle pattern that other Western US production does, and I believe that Montana production is appropriately captured in a curve fit for the Western states.

Recently, Dave Summers addressed the topic of future British coal production in his Oil Drum post, "Future Coal Supplies - More, Not Less!" The British production experience parallels that of the three other mature regions in my paper, Pennsylvania anthracite, France and Belgium, and Japan and South Korea. Production in each of these regions is less than 10% of the peak production. Also, in each region, the early reserves were much larger than the production that followed. On average, the early reserves plus contemporary cumulative production have been four times the current cumulative production. On the other hand, in each case, the curve fits gave appropriate estimates for the long-term production, by 1900 for the UK, Pennsylvania anthracite, and France and Belgium, and by 1950 for Japan and South Korea. This is shown in the figure for British production.



Comparison between the reserves in the international surveys and the historical long-term production estimates for British coal. The range in the historical estimates since 1900 has been 26.8-30.0Gt. The current cumulative production is 27.4Gt, while the producton in 2009 was only 18Mt.

At the time of my original post, there were seven collieries with producing longwall faces in the UK. Since then, two have closed, Tower, and Welbeck. Five remain: Daw Mill, Hatfield, Kellingley, Maltby, and Thoresby. In addition, maintenance is being done on Harworth Colliery so that it could be brought back into production at some point. For comparison, William Ashworth's *History of the British Coal Industry* states that there were 803 producing faces in 1973. For completeness, it should be noted that there are also small underground mines that together contribute 1% of British underground production. In addition, there are surface mines. Surface mining in the UK started during the Second World War and peaked in 1991. The decline in surface production has been slower than for underground production, to the extent that by 2009 surface production was actually a third larger than underground production [3]. The largest coal company in Britain is UK Coal, which operates Daw Mill, Kellingley, Thoresby and Harworth. UK Coal's online financial reports indicate that its underground mining group has lost money ten years in a row, and that the company has debts of £250,000,000, twice its market capitalization. These mines are the last survivors out of thousands. As they run out of seams to work, they will close, one by one.

The new estimate for total world production, past and future, is 680Gt. This is 6% less than the earlier one in my original Oil Drum Post, primarily because the reserves for Montana no longer figure in the total. To get a feeling for the uncertainty, I check the stability of the estimate by making historical fits that use only the data available in an earlier year. The estimate for long-term production has varied in a range from 653-749Gt (14%) since 1995. I can make a comparison with Steve Mohr and Geoffrey Evans' [2] and Tad Patzek and Greg Croft's [3] recent estimates. Mohr and Evans use Hubbert linearization at the national level to get 702Gt, and Patzek and Croft use a multi-cycle analysis to get 630Gt. In addition, Patzek and Croft have possible contingencies of 70Gt for Siberia and 55Gt for Alaska. I view the three estimates as supporting each other, because they are calculated in different ways. My estimate is 58% of the current cumulative production plus current World Energy Council reserves, 1,163Gt. However, all the estimates for the long-term production, and the cumulative production plus reserves are completely different from what the IPCC (United Nations Intergovernmental Panel on Climate Change) assumes is available for production in its scenarios. The maximum cumulative production in an IPCC scenario through 2100 is about 3,500Gt. This actually understates the difference, because in this scenario, A1C AIM, production is still rising in 2100, implying substantial production after 2100.

The transform analysis also gives time parameters through a linear regression. These are expressed as the years of 10% and 90% exhaustion. The last region to reach 90% exhaustion is Russia, in 2101. For world production, the curve fits indicate 2070 as the 90% year. This gives a time frame for thinking about alternatives. The time parameters have an additional element of uncertainty compared with the estimates for long-term production, because in some regions there have been shocks that are associated with a change in the pace of production. The most important example was the collapse of the Soviet Union, when production in Russia and Eastern Europe slowed. For this reason, it would be appropriate to view the year 2070 as a current estimate, subject to future shocks.

References

[1] British coal production statistics are available at the web sites of the Coal Authority and the Department of Energy and Climate Change

[2] Mohr, S.H. and Evans, G.H., 2009, ìForecasting coal production until 2100, *Fuel, Vol. 88, pp. 2059-2067*.

[3] Patzek, T. and Croft, G., 2010, "A global coal production forecast with multi-Hubbert cycle analysis," *Energy, Vol. 35, pp. 3109-3122*.