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Are Reserves of the Largest US Coal Field Overstated by 50%?

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United States coal reserves are taking a beating in a new examination by the USGS of recoverable reserves of Gilette in Wyoming, the largest field in the US with 37% of total coal production in 2006. Its present reserves have been downgraded by half thanks to an improved methodology which incorporates a new dataset with ten times as many datapoints as used in the previous assessment. Of 182 billion metric tonnes of resource in place, 9.16 billion (6% of original resource total) were found to be recoverable under "current technological and economic circumstances". This compares to an earlier assessment from 2002 by the USGS in which 20.87 billion metric tons were estimated to be recoverable.

The one catch is that the term "present economic circumstances" depends very much on the price of coal. If the price of coal increases significantly, the newly estimated reserve level of 9.16 billion metric tons can be expected to increase, perhaps several-fold. Although the USGS takes a shot at determining the price-sensitivity of reserves by discussing its effect, there still are a lot of open ends. Nonetheless the economic aspect of coal recoverability should be taken seriously; hence the question mark in the title.

The new USGS assessment does show that the statement made by the US National Academy of Science two years ago, that US coal reserves are likely overstated, should be taken seriously. The National Academy of Science concluded at that time that coal recoverability estimates are based on outdated assessment methods--these methods have not been reviewed or revised since 1974 and primarily reflect input data from the early 1970s.

More information on the USGS study, including estimates by the US of the effect of changing economic conditions on coal availability in Gillette, can be found below the fold. The study itself is available through this weblink (Beware! 92 megabyte, 123 pages)

The USGS study approach

Mining in the Gillette coal field has so far only taken place in two out of eleven coal beds identified in the Gillette coal field, namely Anderson and Canyon. These are the thickest and most contiguous beds with average thickness of 45 and 26 feet respectively. To assess the resources and reserves in all the coal beds, a dataset was made with old and new drill hole data totaling 10,210 data points. This is ten times as many data points as in the 2002 study.

> "In addition, prior to this study the distance between data drill holes used in the correlation process was sometimes large, thus creating uncertainty in correctly correlating individual coal beds from one drill hole to the next. Previous reports relied on drill hole data that were up to ten or more miles apart. However, with the recent drilling

> and development of CBM in the PRB, data from over 10,000 new drill holes in the Gillette coalfield alone are now available. Utilizing the more closely spaced coalbed methane drill holes, it was possible to more confidently define coal bed correlations, determine split lines, and outline paleo-channels (USGS 2008, pp. 6-7)."

For each coal bed, a geological grid model was made including coal thickness, parting thickness, coal height (coal plus parting), and roof and floor structures, with the aid of PC/Cores, a multi-bed modeling program. By using these models it was found that in 6 out of 11 coal beds, mining could take place in the future thanks to suitable geological characteristics. The six coal beds are the Roland, Smith, Dietz and Anderson Rider coal beds as well as Anderson and Canyon beds where mining already takes place. This assessment was based on coal bed thickness and the stripping ratio. This latter factor shows the amount of waste rock to coal. A stripping ratio of 4:1 implies that four tons of rock have to be moved to get one ton of coal. The larger the stripping ratio, the greater the technical difficulties and cost will be to get the coal out of the ground. Specifically, the USGS used the following criteria:

> The basic assumptions used to qualify coal beds for potential reserve evaluation were to include: (1) coal beds above the Anderson or Canyon 5 ft or greater with significant areal extent and (2) coal beds below the Anderson or Canyon 5 ft or greater with significant areal extent and an incremental stripping ratio of 4:1 or less. The minimum thickness of at least 5 ft and the maximum incremental stripping ratio of 4:1 criteria for beds below the Anderson or Canyon were selected on the basis of current mining practices at existing mines in the Gillette coalfield (USGS 2008, p.10)."... "This stripping ratio criterion eliminated all beds below the Canyon. Six beds with significant areal extent and exceeding 5 ft thick were evaluated for potential recovery and reserves. In addition to the Anderson and Canyon beds, the Roland, Smith, Anderson Rider, and Dietz coal beds were included in the mine models (USGS 2008, pp. 22-23)."

As a result of the new dataset, a considerable number of insights were gained on the detailed geology of the Gillette coal field. An example is the Anderson coal bed which was found to be less continuous and thick at the eastern margin of the north-south traverse. At this side also the Smith bed previously thought to be quite thick appears to be much thinner at 20 ft or less. Hence the stripping ratio there is much larger, and this creates an economic barrier to mining.

> "One of the most important findings of this assessment was the influence of the major north south distributary channel on long-term, deeper surface mining in the Gillette coalfield. From the 2002 assessment of this area (Ellis and others, 2002), it appeared that the thick Anderson coal bed was continuous throughout the coalfield. The comparison of the Upper Wyodak (Anderson) coal bed isopach map from the 2002 study and the current Anderson isopach (fig. 52), as well as the comparison of the significant changes in coal bed correlations (figs. 7 and 8), illustrate the important interpretational revisions of this assessment. The Anderson and Canyon beds pinch out along the eastern margin of the major north-south channel complex. The Smith bed extends over the major channel and thickens rapidly to over 60 ft to the west, but east of the channel, where the Anderson and Canyon beds are thinning and pinching out, the Smith bed is only 20 ft or less thick. Thus, there are areas along the eastern margin of

> the major channel where no thick coal beds are present, causing a rapid increase in the cumulative stripping ratio and thus effectively creating an economic barrier to down-dip surface mining (USGS 2008, p.16)."

After the geological model, a mining model was made to evaluate coal reserves based on a program named CoalVal developed by the USGS. This program is used to calculate recoverable coal resources, operating costs and a discounted cash flow at a given rate of return for the recoverable coal. The portion of recoverable coal that is economically minable at or below the current sales price of coal is designated as reserves. The mining model focused on new technology which uses large draglines in concert with truck-shovel pre-stripping operations. This approach is stated by the USGS to be a more cost effective overburden removal system. The 2002 study on the other hand anticipated mainly truck-shovel mining. According to the USGS, CoalVal will be made available to the public in 2009 so that it can be used by others.

Results of the study based on current technological and economical circumstances

- First, original resources were calculated for all coal resources of greater than 2.5 ft thickness with no restrictions. The six coal beds suitable for extraction were found to contain 149.72 billion metric tons of coal before mining began. When the other five beds were included, it was found that 182.4 billion metric tons of resources were present before mining began.
- Second, remaining resources were calculated by extracting coal mined so far. Around 5.5 billion metric tons have so far been mined, leaving 144.2 billion metric tons of remaining resources in the six coal beds.
- Third, mining restrictions including too thin coal seams, land use and other technical restrictions were estimated. Approximately 52% of remaining resources were found to be limited due to restrictions of these types, leaving 69.9 billion metric tons of technically available resources for recovery. Of this total 41.2 billion metric tons are in the Anderson coal bed, 16.8 in Canyon, 5.8 in Smith, 4.9 in Roland, 0.7 in Anderson Rider and 0.5 in Dietz.
- Fourth, economic restrictions were calculated based on data from the Anderson coal bed. By looking at costs at different stripping ratios and all respective indirect factors involved such as acquisition costs, royalties and taxes, the cost per ton of recovery were calculated. A cost curve was developed to assess those reserves recoverable at or below the current estimated sales price. Discounted cash flow costs were calculated at a 8 percent rate of return. Based on the actual sales price of 10.47 dollars per ton for Anderson and Canyon reached in January 2007, it was found that 9.16 billion metric tons of the total 69.9 of technically available resources can be recovered economically.

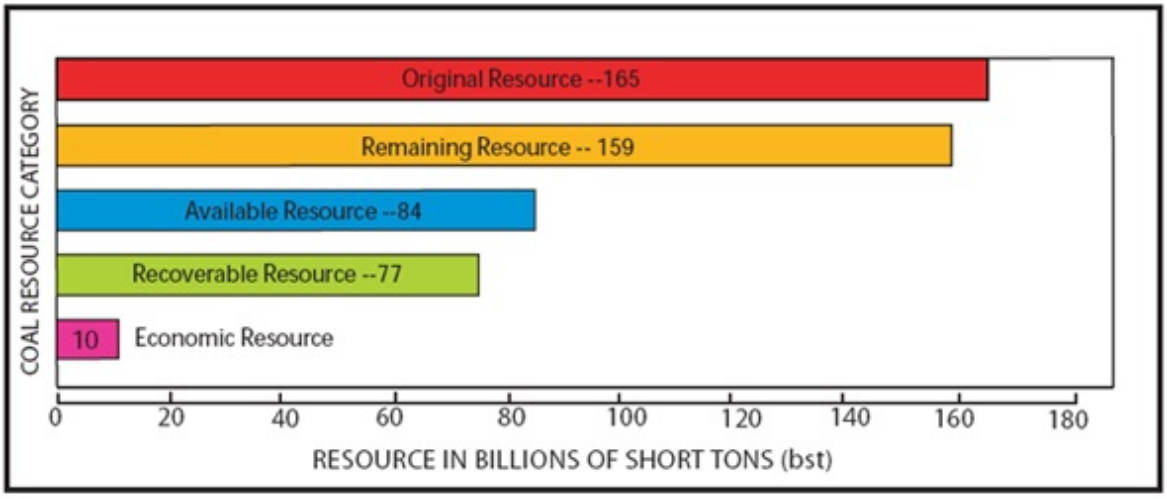

Figure 1 - Bar graph showing resources in different resource categories for the six coal beds in the reserve evaluation (5.0 ft thick or greater, 10:1 stripping ratio or less) of the Gillette coal field, reported in short tons (at a sales price of 10.47 dollars per ton as of January, 2007). This reserve estimate would nearly double to 18.5 bst if the market price were 14 dollars per ton.

The estimated effects of changes in the price of coal

The reserve estimate at a coal price of 10.47 dollars per ton appears to be rather limited, which is also confirmed by the USGS. They give the example of a price increase to 14 dollar per ton, which occurred in March of 2008. Incorporating this price would lead to nearly a doubling in the reserve figure to 16.8 billion metric tons as shown in figure 2 below, under the assumptions in the economic model.

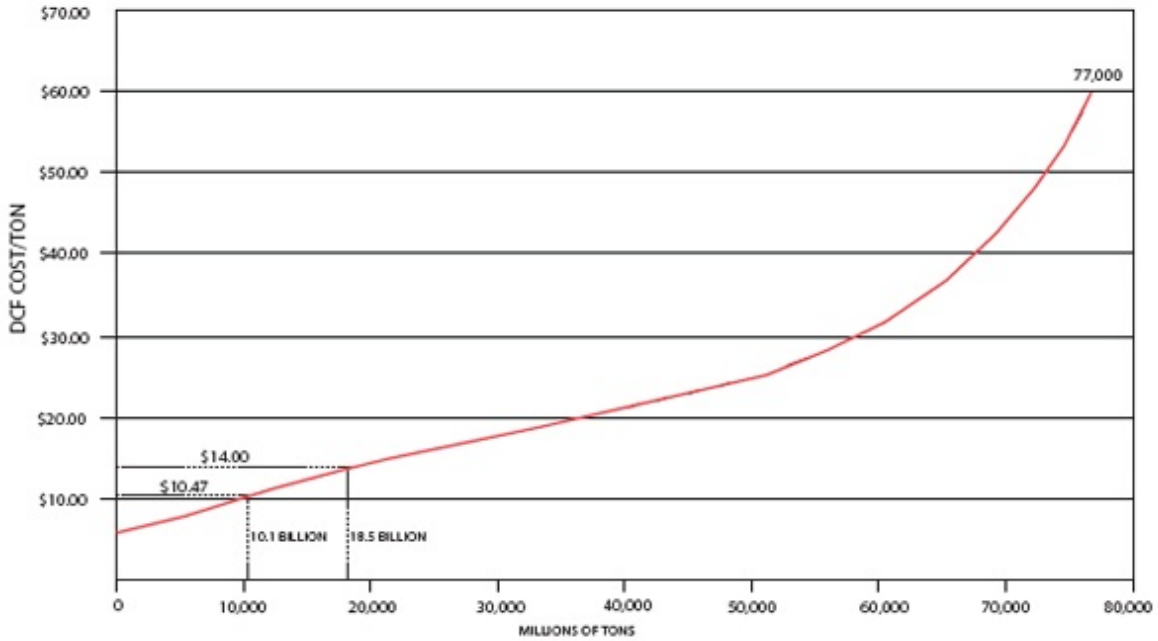

Figure 2 - Cost curve showing reserves estimates for the Gillette coalfield at different coal prices per ton.

> "Because a coal reserve estimate is based on a single reference point in time, the use of cost curves is particularly useful. From the cost curve, the relationship between sales

> price and estimated reserves can readily be demonstrated. As of March, 2008, the sales price for the Gillette coalfield had increased to $14.00 per ton (Platts, 2008). If it is assumed that operating costs remained essentially unchanged over the past year since the reserve study was completed, there would be approximately 18.5 billion short tons of reserves (USGS 2008, p.30)."

However, as stated in the quote above, the economic model operates under the condition that operating costs do not change essentially over time. This is one of the open ends to the USGS study. Market conditions and technological change can lead to a significant alteration of operating costs. There is no quantification nor extensive discussion on changing operating costs over time. Only the following quote is given by the USGS.

> "With continued favorable sales prices as well as productivity and technological advances in mining that positively affect economics, resources once considered to be subeconomic may be elevated to the status of reserves. Therefore, reserve studies should be considered a cyclic process and models should be adjusted periodically using the most recent data and reassessed utilizing the most current recovery technology and economics (USGS 2008, p.31)."