Richard Heinberg: Coal in the United States

Posted by Prof. Goose on May 30, 2008 - 9:30am
Topic: Supply/Production
Tags: coal, coal reserves, depletion, energy, united states [list all tags]

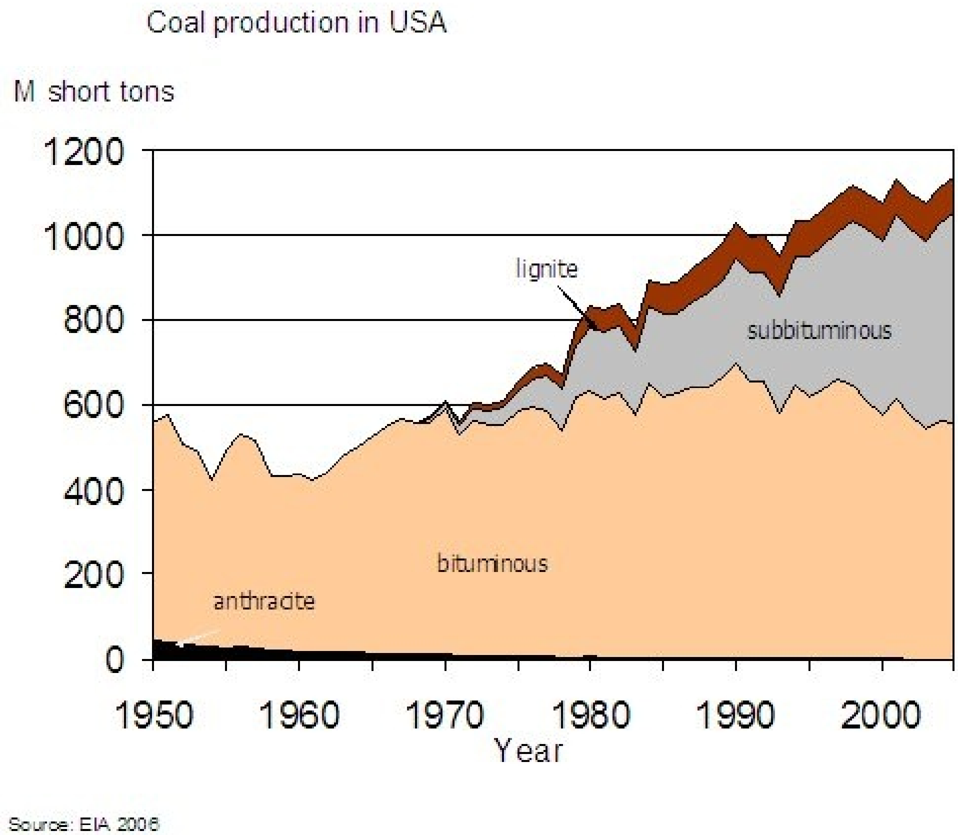
This is a post by Richard Heinberg, Senior Fellow of The Post Carbon Institute and author of Peak Everything, The Party's Over: Oil, War and the Fate of Industrial Societies, Powerdown: Options and Actions for a Post-Carbon World, and The Oil Depletion Protocol. A special thanks to Global Public Media for facilitating publication of Heinberg's work; GPM is a wonderful resource and plays an important role in peak oil activism. This article is a draft chapter from a forthcoming book, currently titled ***Coal's Future/Earth's Fate****.*

With oil and natural gas prices rising and coal prices still relatively low, the return of the US to a greater reliance on coal might seem inevitable. However, several recent reports suggest that coal reserves, which have shrunk dramatically during the past century, may still be overstated. Coal prices are likely to rise precipitously during the next two decades due to transport bottlenecks and higher transport costs, falling production trends in many current producing regions, and the lack of suitable new coalfields. This information should give pause to any agency planning new coal power plants today.

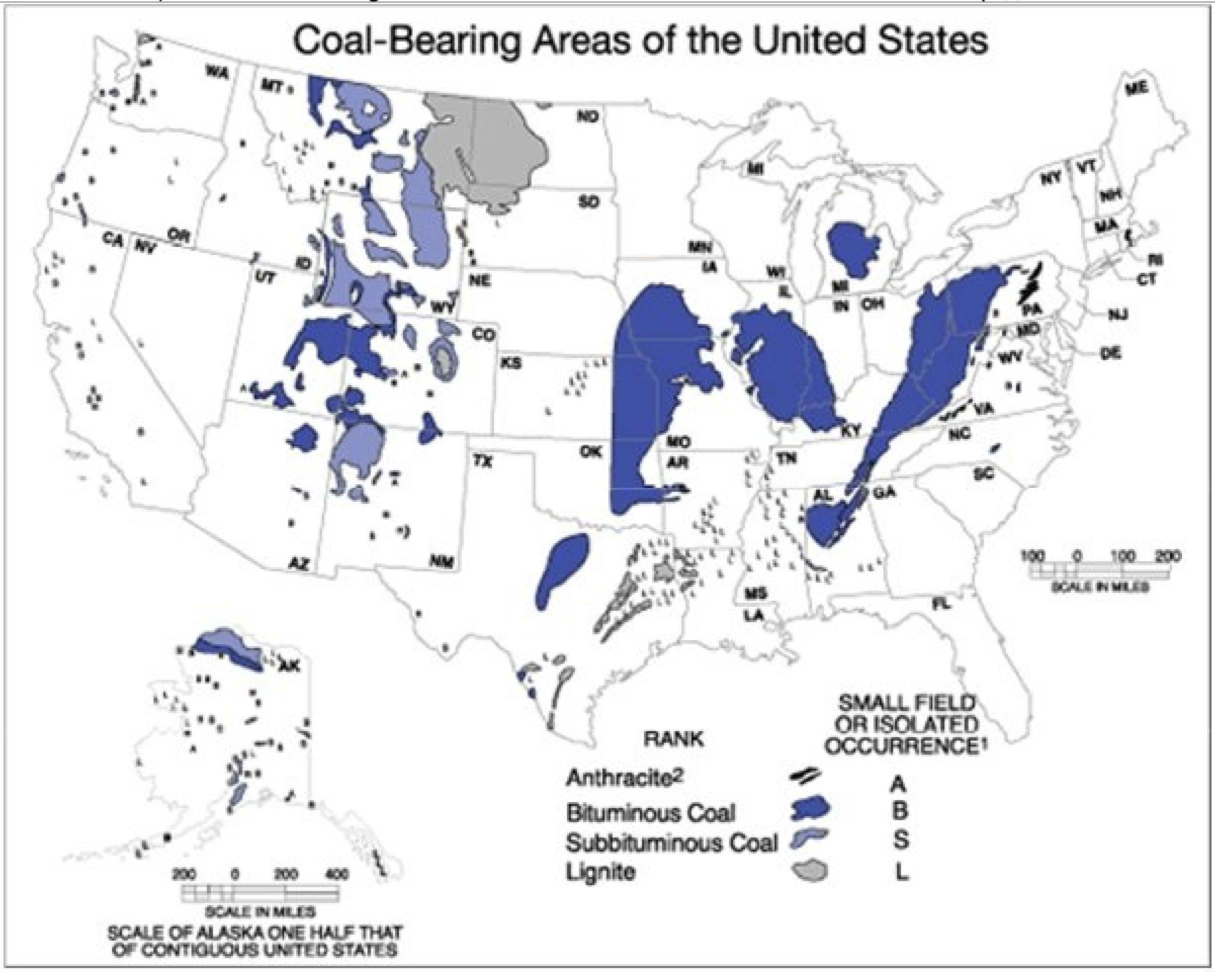
Because the US has the world's largest coal reserves, it has sometimes been called "the Saudi Arabia of coal." It is the world's second-largest coal producer, after China, but surpasses both the number three and four producer nations (India and Australia) by nearly a factor of three.

Wood was this nation's primary fuel until the mid-1880s, when deforestation necessitated greater reliance on abundant coal resources. Coal then remained America's main energy source until the 1930s, when it was overtaken by oil. Today coal fuels about 50 percent of US electricity production and provides about a quarter of the country's total energy.

The US currently produces over a billion tons of coal per year, with quantities increasing annually. This is well over double the amount produced in 1960. However, due to a decline in the average amount of energy contained in each ton of coal produced (i.e., declining resource quality), the total amount of energy flowing into the US economy from coal is now falling, having peaked in 1998. This decline in energy content per unit of weight (also known as "heating value") amounts to more than 30 percent since 1955. It can partly be explained by the depletion of anthracite reserves and the nation's increasing reliance on sub-bituminous coal and even lignite, a trend that began in the 1970s. But resource quality is declining even within each coal class.

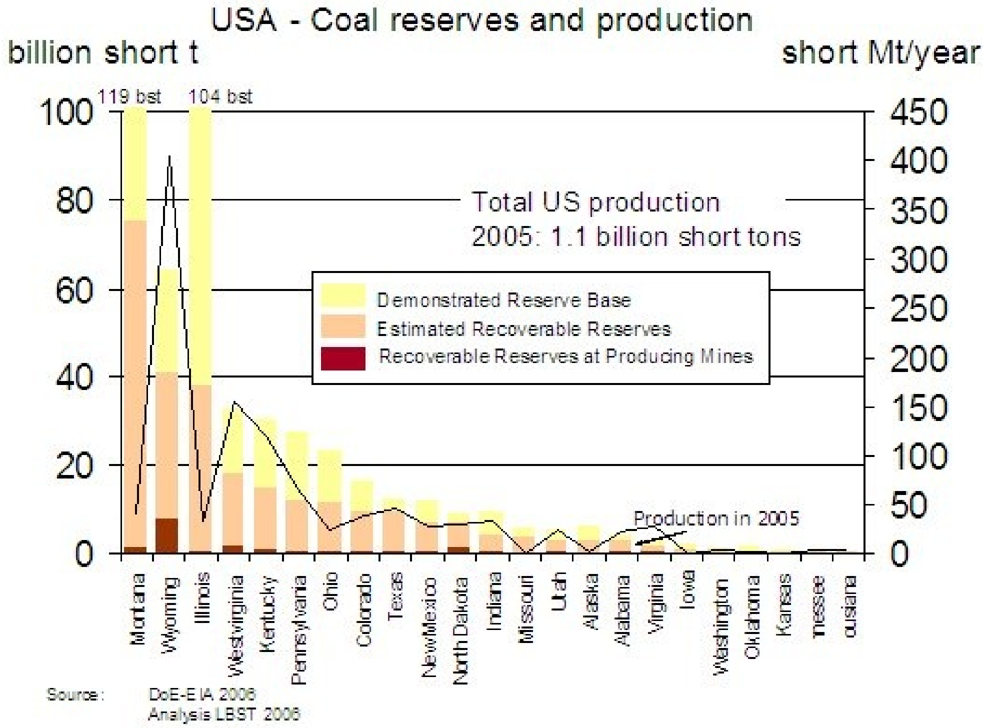


While there are coal resources in many states, the main concentrations are in Appalachia, Illinois, Wyoming, and Montana (see map below). The 53 largest coalmines in the US, located in just a few states, account for almost 60 percent of total production.



Three states (Pennsylvania, Kentucky, and West Virginia) produce 52 percent of the higher-quality coal in the US. All three of these states seem to be in decline or plateau. Since the Northeast was the area of the nation earliest settled and was long a primary center for industrial manufacture, it is not surprising that the coal of this region was exploited preferentially. Today, Pennsylvania's anthracite is almost gone. Mining companies there are now exploiting seams as thin as 28 inches. West Virginia, the second largest coal-producing state (after Wyoming), where much coal is surface mined in an environmentally ruinous practice known as mountaintop removal, is nearing its maximum production rate and will see declines commence within the next few years, according to a recent USGS report. (www.byronwine.com/files/coal.pdf)

The interior region—consisting of Illinois, Arkansas, Indiana, Kansas, Western Kentucky, Louisiana, Mississippi, Missouri, Oklahoma, and Texas—is the smallest coal producer of the three main producing regions. The Illinois basin boasts large reserves of bituminous coal, but production has fallen there since the mid-1990s. Its coal generally has a high sulfur content (3 to 7 percent), which runs afoul of US environmental laws, especially the Clean Air Act of 1990. Prior to this legislation, power plants burning high-sulfur coal released emissions resulting in acid rain that decimated forests throughout much of the nation. The lignite steam coal of Louisiana is an exception within the region: its sulfur content is low and so production has risen substantially in recent years. After 2018, sulfur scrubbers will be mandatory for coal-fired power plants in the US, perhaps facilitating a move to increase production of coal from the Illinois Basin.



Wyoming has some bituminous coal, but most of its reserves consist of sub-bituminous and lignite. Production from the state (primarily from the Powder River Basin) has increased sharply since 1970, because its coal is abundant, cheaply surface-mined, and low in sulfur. Wyoming is currently responsible for 80 percent of coal production west of the Mississippi.

Montana also has large deposits of lower-quality coal (sub-bituminous and lignite), but these have not been tapped. The current state governor, Brian Schweitzer, is pushing for development of these resources using gasification and carbon sequestration technologies, but there are reasons to doubt whether this will occur soon or on a meaningful scale. Montana's coal contains salts that will almost inevitably find their way into the environment if widespread surface mining occurs, contaminating rivers and creating problems for cattle ranching—the state's economic engine and a locus of considerable political clout.

For the nation as a whole, future supply hinges on the question of how long rising production of lower-quality coal from Wyoming—supplemented in the future perhaps by coal from Montana and the Illinois Basin—can continue to compensate for declining amounts of high-quality coal from the East. Clearly, the US has the potential to produce enormous quantities of coal. But the gradual depletion of coal with higher heating value is already necessitating the mining of larger quantities of lower-quality coal to yield an equivalent amount of energy, and as coal is sourced more from Montana and the Illinois this will require the building of more rail transport infrastructure and the overcoming of environmental problems and regulatory hurdles.

Over sixty percent of coal mined in the US is dug from the surface. This is a higher percentage than in most nations, and it is largely due to the contribution of Wyoming. In the eastern states, most coal still comes from deep mines, which are moving toward the recovery of ever-thinner seams. Highwall mining systems and new technologies for longwall mining may lead, ultimately, to remote-control mining involving few or no personnel working underground. These new and more efficient technologies will enable some coal to be mined that would otherwise be left behind, but they are unlikely to be applied throughout the entire industry due to high up-front investment costs.

In surface mining, the largest extraction cost is often incurred in removing overburden (soil and rock). Over the years, the coal industry has introduced ever-larger earth-moving machines for this purpose. However, truck size has probably reached a practical maximum, as the biggest vehicles cannot be maneuvered on roads.

However coal is mined, the industry must always confront the bottom line: the cost of getting coal out of the ground cannot exceed the market price for produced coal. Thus the current price determines whether marginal coals will be mined profitably, or simply left in the ground. On the other hand, however, as the costs of bringing coal to market rise, this can cause the price of coal to increase—unless and until higher prices suppress demand. Given that demand for electricity continues to expand, and that cheap alternatives to coal for power generation do not exist in sufficient quantity in the short run, there seems to be no near-term cap to coal prices. As a result, marginal coalfields are now more likely to be mined.

During the two-year period from January 2006 to January 2008, prices rose from about $100 a ton to $250 a ton for high-quality metallurgical grades of US coal. Central Appalachian steam coal is currently selling for about $90 a ton, up from $40 two years ago. During this time production costs have risen as well, though not at the same pace.

The cost of producing coal is related to the price of oil. Consider the case of Massey Energy Company, the nation's fourth-largest coal company, which annually produces 40 million tons of coal using about 40 million gallons of diesel fuel—about a gallon per ton (the company also uses lubricants, rubber products, and explosives, all made from petroleum or natural gas). If the price of diesel goes up one dollar, this translates directly to $40 million in increased costs; indirectly related costs also climb.

These costs and prices need to be seen in proportion: while coal generates half of America's electricity, in effect providing much of the essential basis for all economic activity within the country, US coal industry revenues are only about $25 billion—one-tenth those of WalMart.

During some recent years, the US was a net coal importer, since coal brought by ship from South America was often cheaper to supply to coastal cities than US coal moved there by rail. This was partly a result of rail transport bottlenecks that are now being addressed with the laying of more rails and the construction of more coal cars. Now, however, with coal prices high and imports growing in China and India, the US has begun exporting larger quantities. Mines are employing more workers and production is booming.

History of Reserves Estimates

The US has seen a long controversy between coal resource optimists and pessimists—a controversy that is somewhat mirrored in the global coal resource picture.

In 1907, Marius R. Campbell, Director of the USGS, headed the first attempt at a scientific survey of US coal, concluding that ultimately recoverable reserves amounted to 3157.2 billion tons. Since production in that year was 570 million tons, simple arithmetic yielded an R/P ratio of 5500/1, which was interpreted as meaning that the nation had a 5,500-year supply. That implied an effectively limitless amount for the practical purposes of economic planning.

Campbell did hedge his estimate by pointing out that much of this coal was not minable, or was inaccessible for other reasons. He also wrote that ". . . the bulk of coal being mined today is the best in the country, and before long, perhaps before 50 years [i.e., by 1959], much of the high-rank coals will be exhausted." (Putnam 234) Still, Campbell's figure for total reserves was for many years taken at face value.

Soon, state surveys began gathering more detailed and accurate information, which resulted in the downgrading of regional reserves. Thus when the US Coal Commission mounted a new survey in 1923, it reduced all state reserves figures and dropped some states entirely from its list of active or likely coal producers. Yet through the early decades of the 20th century, the USGS and the Bureau of Mines stuck to the position that America would have plenty of coal for several millennia.

Shortly after World War II, Andrew B. Crichton (a coal engineer and mine operator in Johnstown, Pennsylvania) undertook a state-by-state informal review of existing reserves estimates, publishing his results in an article titled "How Much Coal Do We Really Have? The Need for an Up-To-Date Survey," in *Coal Technology* (August 1948). Crichton minced no words:

> It was asserted at the Denver [USGS] meeting last October that no one should have the temerity to question the Government figures unless they submitted maps and records proving their statements. Well, that is quite a burden to impose upon an individual to justify an opinion regarding our coal reserves. But that is exactly what could be done in many cases in the east where many have knowledge of the wide discrepancy between the Government figures and private records based on prospecting and actual development. It is these wide differences that prompt the fears and lead to the belief that these fantastic and unbelievable figures of the United States Geological Survey are wrong and dangerously misleading and should be corrected promptly.

Citing instance after instance in which USGS reserves figures for well-mined regions had turned out to be highly inflated, Crichton went on to offer his own estimate of national coal reserves as 223 billion tons—a number not that much smaller than the current official estimate.

Crichton's article, while causing understandable consternation and embarrassment for the USGS, could not be ignored. It was cited repeatedly in Palmer Putnam's authoritative book *Energy In the Future* (1953), which also offered pessimistic assessments of US oil and natural gas supplies. Indeed, Putnam demonstrably erred on the conservative side, forecasting that America's oil production would peak between 1955 and 1960 (the actual peak was in 1970); and that coal production would begin to decline by 1990—whereas, as we have seen, actual produced amounts continue to grow annually.

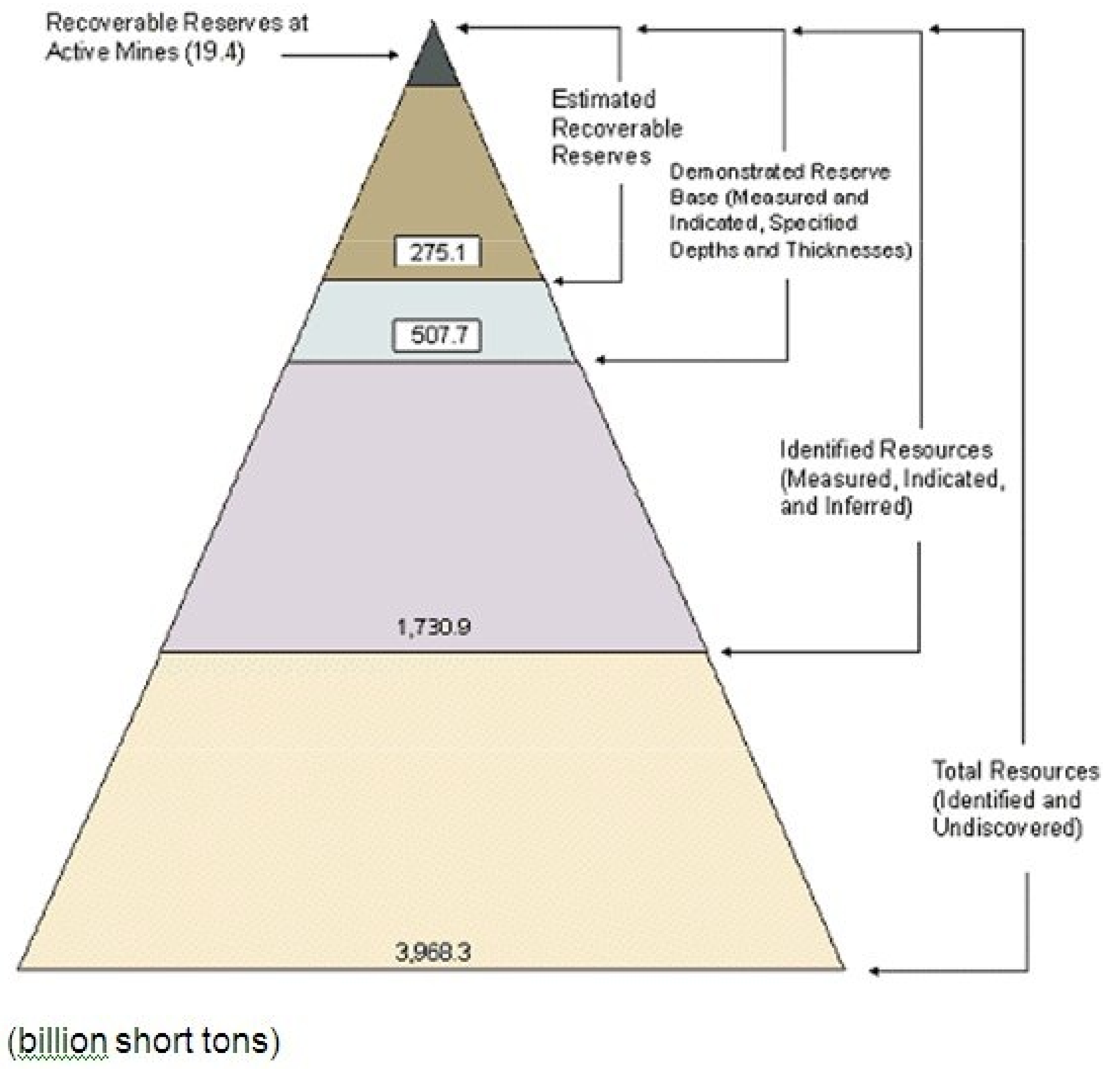
The USGS and the Bureau of Mines, which was later absorbed into the Department of Energy, responded by gradually reducing estimates of coal reserves figures for many states and the nation as a whole. Yet through the 1950s, national reserves remained at well over 500 billion tons—still above 1,000 years in terms of R/P forecasting.

In the 1960s, concerned that reserves figures were not making sufficient allowances for factors that would prevent much of the resource from ever being produced, the USGS commissioned surveys by geologist Paul Averitt, culminating in the publication, in 1975, of *Coal Resources of the US*. By now the official estimate of recoverable reserves had been whittled down to the current range of 260 to 275 billion tons. This was seen as no cause for alarm, as the reserves-to-production ratio forecast remained at comfortably above 200 years; also, it was believed that new technologies (such as longwall mining and underground gasification) would eventually be able to convert substantial quantities of resources back into reserves.

In 1995, the USGS began work on the National Coal Resource Assessment (NCRA), a multi-year effort to create a digital assessment on a region-by-region basis, which is still in process, with few of the crucial results currently publicly available.

According to the EIA website, as of January 1, 2007 the Estimated Recoverable Reserves for the US amounted to 267 billion tons. Since production for 2006 was 1,162,750 tons, that would indicate an R/P ratio of about 230/1.

A graphic from the Department of Energy (EIA), using 2005 data, is helpful in visualizing the various categories within the overall coal resource base.



As we are about to see, the long process of revising national coal reserves figures downward may not be at an end.

New Studies

1. Coal: Research and Development to Support National Energy Policy (National Academy of Sciences [NAS], July 2007, http://books.nap.edu/). This book-length report concluded that "there is no question that sufficient minable coal is available to meet the nation's coal needs through 2030," and also that "there is probably sufficient coal to meet the nation's needs for more than 100 years at current production levels"—though this latter judgment does not appear to be based on a peaking analysis. In sum, however, the report is a plea for better, more realistic reserves estimates:

> [I]t is not possible to confirm that there is a sufficient supply of coal for the next 250 years, as is often asserted. A combination of increased rates of production with more detailed reserve analyses that take into account location, quality, recoverability, and transportation issues may substantially reduce the estimated number of years supply. This increasing uncertainty associated with the longer-term projections arises because significant information is incomplete or unreliable. The data that are publicly available for such projections are outdated, fragmentary, or inaccurate.

These doubts about current reserves figures were based upon recent Coal Recoverability Studies undertaken in Kentucky, Illinois, Pennsylvania, and Wyoming—in effect, spot checks to determine whether reserves figures were indeed reliable within restricted areas where coal recoverability could be determined with some accuracy as the result of mining experience.

> A total of 65 areas in 22 coal fields have been analyzed, and these studies suggest that 8 to 89 percent of the identified resources in these coal fields are recoverable and 5 to 25 percent of identified resources may be classified as reserves. Because they are based on site-specific criteria, these studies provide considerably improved estimates compared to the ERR [Estimated Recoverable Reserves].

One such study, of the Matewan quadrangle of eastern Kentucky, concluded: "a strong argument can be made that traditional coal producing regions may soon be experiencing resource depletion problems far greater and much sooner than previously thought." (http://pubs.usgs.gov/)

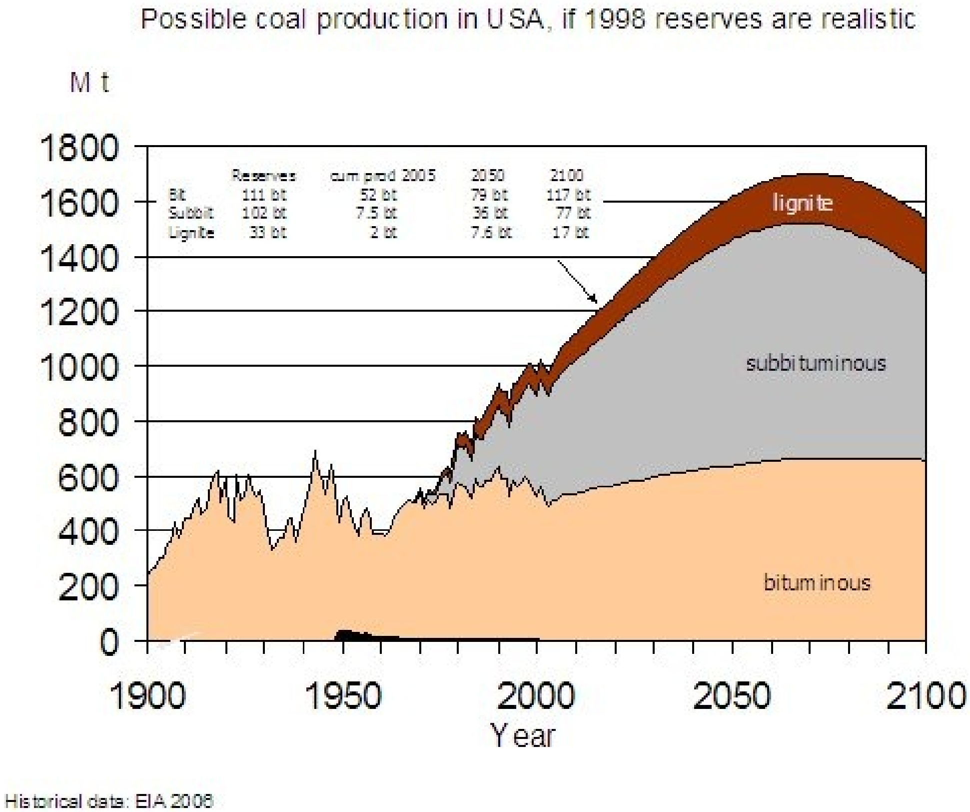
The NAS report enumerates the problems that the US coal industry will face in coming decades:

> Almost certainly, coals mined in the future will be lower quality because current mining practices result in higher-quality coal being mined first, leaving behind lower-quality material (e.g., with higher ash yield, higher sulfur, and/or higher concentrations of potentially harmful elements). The consequences of relying on poorer-quality coal for the future include (1) higher mining costs (e.g., the need for increased tonnage to generate an equivalent amount of energy, greater abrasion of mining equipment); (2) transportation challenges (e.g., the need to transport increased tonnage for an equivalent amount of energy); (3) beneficiation challenges (e.g., the need to reduce ash yield to acceptable levels, the creation of more waste); (4) pollution control challenges (e.g., capturing higher concentrations of particulates, sulfur, and trace elements; dealing with increased waste disposal); and (5) environmental and health challenges.

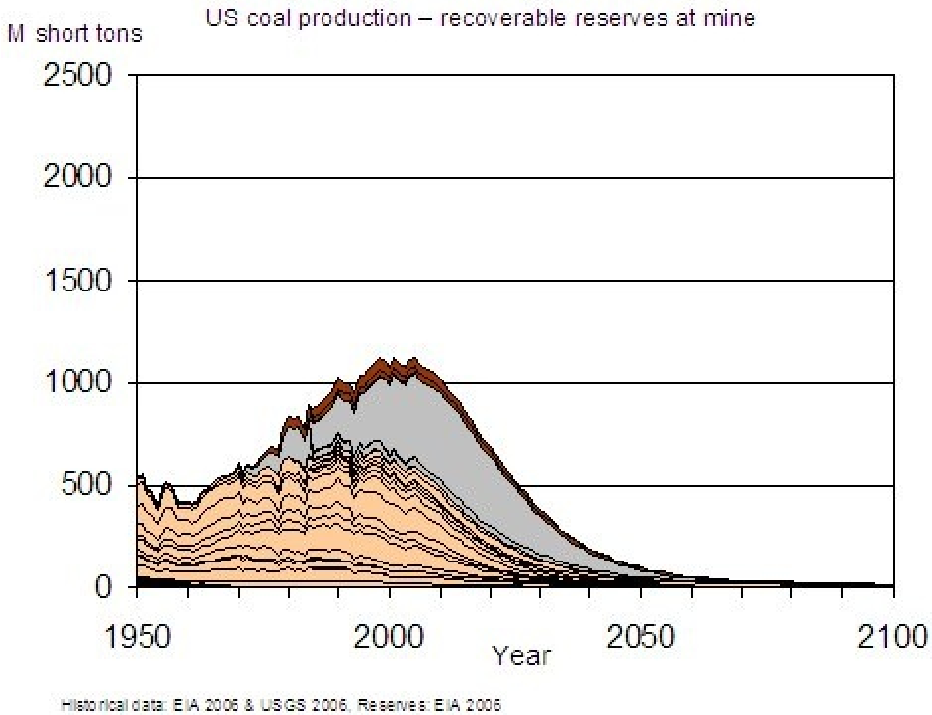
2. Coal: Resources and Future Production (Werner Zittel and Jörg Schindler, Energy Watch Group [EWG], March 2007, www.energywatchgroup.org/). This report contains ten pages of analysis specific to US coal supplies. The EWG authors note,

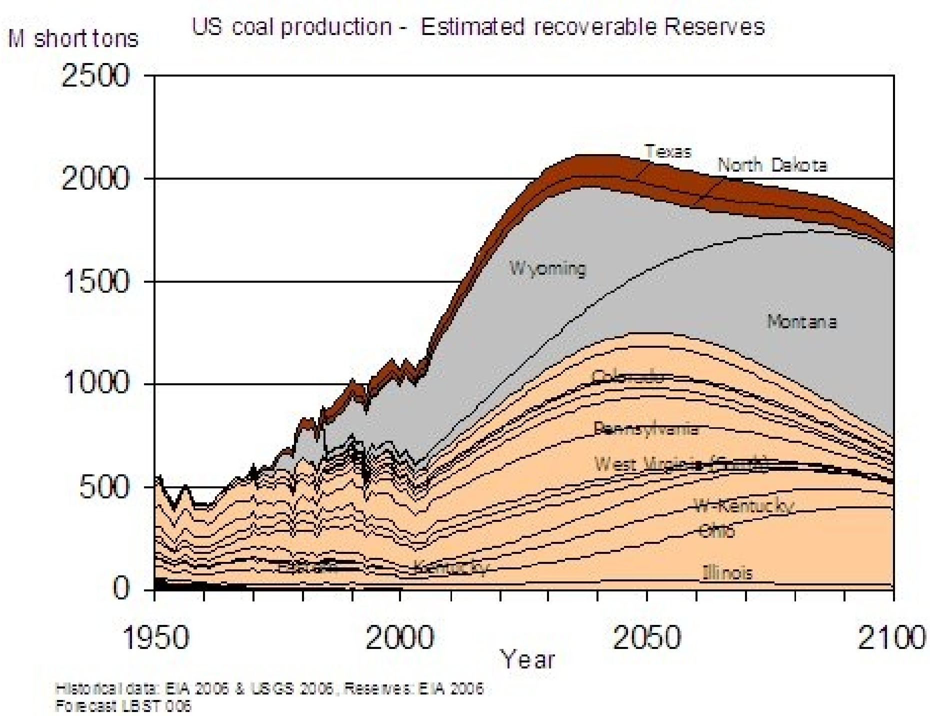
> Until the year 2000, productivity [the amount of coal produced per worker hour] steadily increased for all types of coal produced covering surface and subsurface mining. But since then productivity has declined by about 10%. . . . The decline in productivity can only be explained by the necessity of rising efforts in production. This might be due to deeper digging and/or to a higher level of waste production. Are these already indications for the era of ‘easy coal’ drawing to a close?

The EWG report offers several peaking scenarios for US coal. The most optimistic shows a peak in 2070:

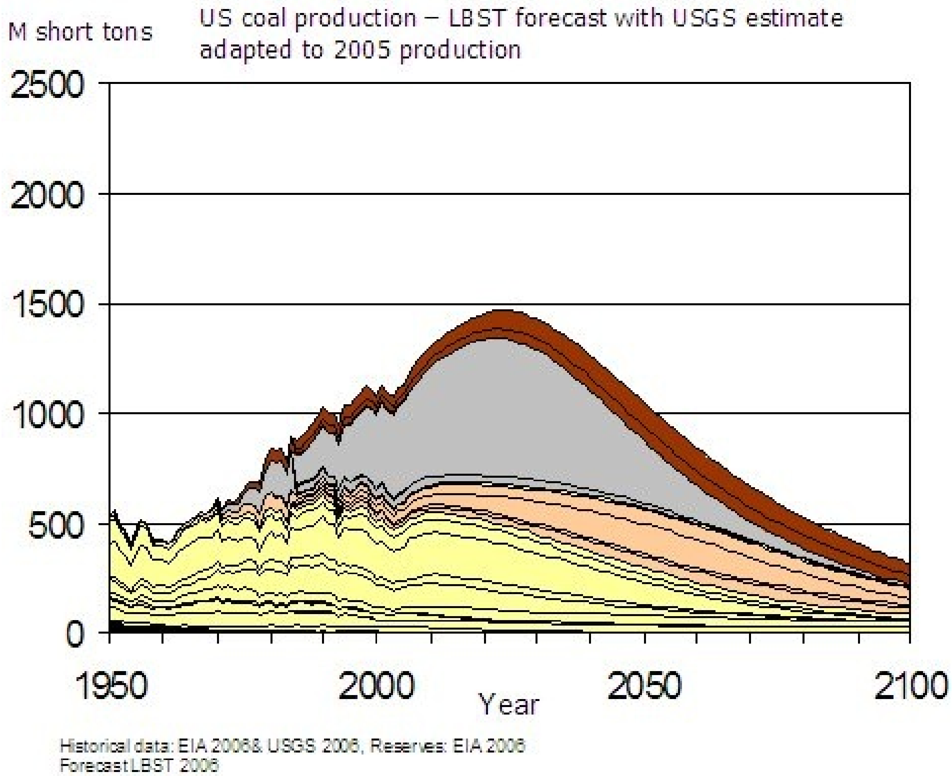


However, the authors warn that "Even if volumetric production rates can be increased by about 60% until 2070-2080 before decline sets in, the corresponding energy production will increase only by about 45-50% due to the increased share of sub-bituminous coal and lignite." Like the National Academy of Sciences, the EWG authors believe that the official estimated recoverable reserves figure is too large. They offer two alternative scenarios for future production: one in which only recoverable reserves at existing mines are considered producible (peak in 2015), and the other in which reported estimated recoverable reserves are all producible, but regional production trends are taken into account peak in 2040). They suggest that "The real profile will be somewhere between these two extremes."





A third peaking forecast is based on an LBST (German renewable energy consultancy Ludwig Bölkow Systemtechnik) analysis, which is itself based on USGS production forecasts in 2000 using 1995 data. The USGS forecast is corrected for actual production in the intervening years, and a future production profile is chosen in accordance with past production trends and likely production growth (Montana and Illinois are assumed to provide only marginally increased amounts). It is this fourth scenario, with a peak around 2025, that the EWG authors appear to consider most reasonable.



The authors conclude:

> Considering the insights of the regional analysis it is very likely that bituminous coal production in the US has already peaked, and that total (volumetric) coal production will peak between 2020 and 2030. The possible growth to arrive at peak measured in energy terms will be lower, only about 20% above today's level. . . . [T]he 250 billion ton figure [the current official estimate of recoverable reserves] should not be the basis for energy planning.

The various EWG scenarios suggest that if Montana and Illinois can resolve their production blockages, or the nation becomes so desperate for energy supplies that environmental concerns are simply swept away, then the peak will come somewhat later, while the decline will be longer, slower, and probably far dirtier.

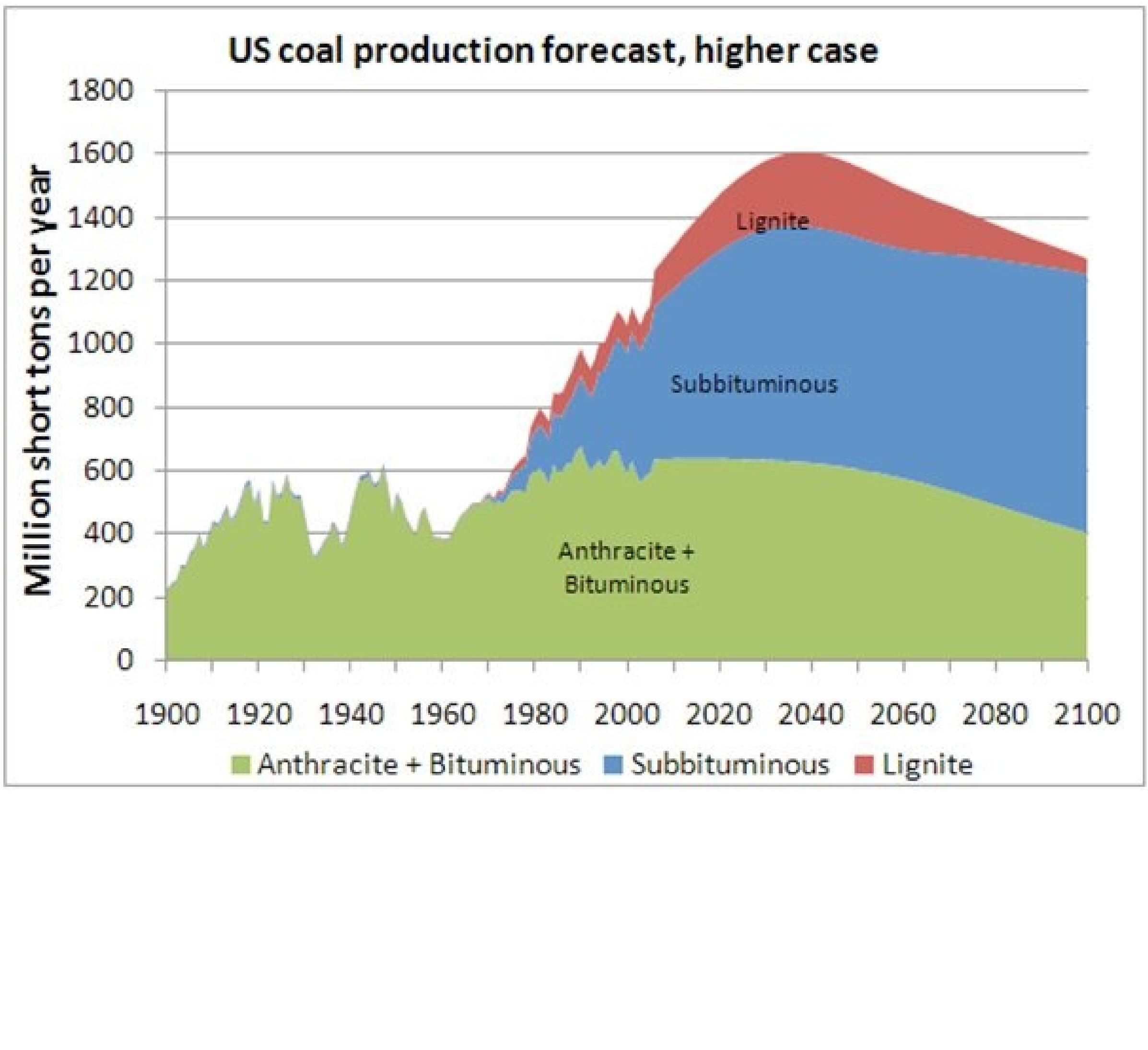
3. Lignite and Hard Coal: Energy Suppliers for World Needs until the Year 2100 – An Outlook(Thomas Thielemann, Sandro Schmidt, and J. Peter Gerling, German Federal Institute for Geosciences and Natural Resources [BGR], *International Journal of Coal Geology* Volume 72, Issue 1, 3 September 2007, http://www.sciencedirect.com/). This paper forecasts no bottleneck in coal supplies and a large potential for expanding coal-to-liquids (CTL) production. It offers relatively little detail for individual producing countries and makes no attempt at a peaking analysis. For the US, the explicit conclusion is that there will be no coal supply problems this century.

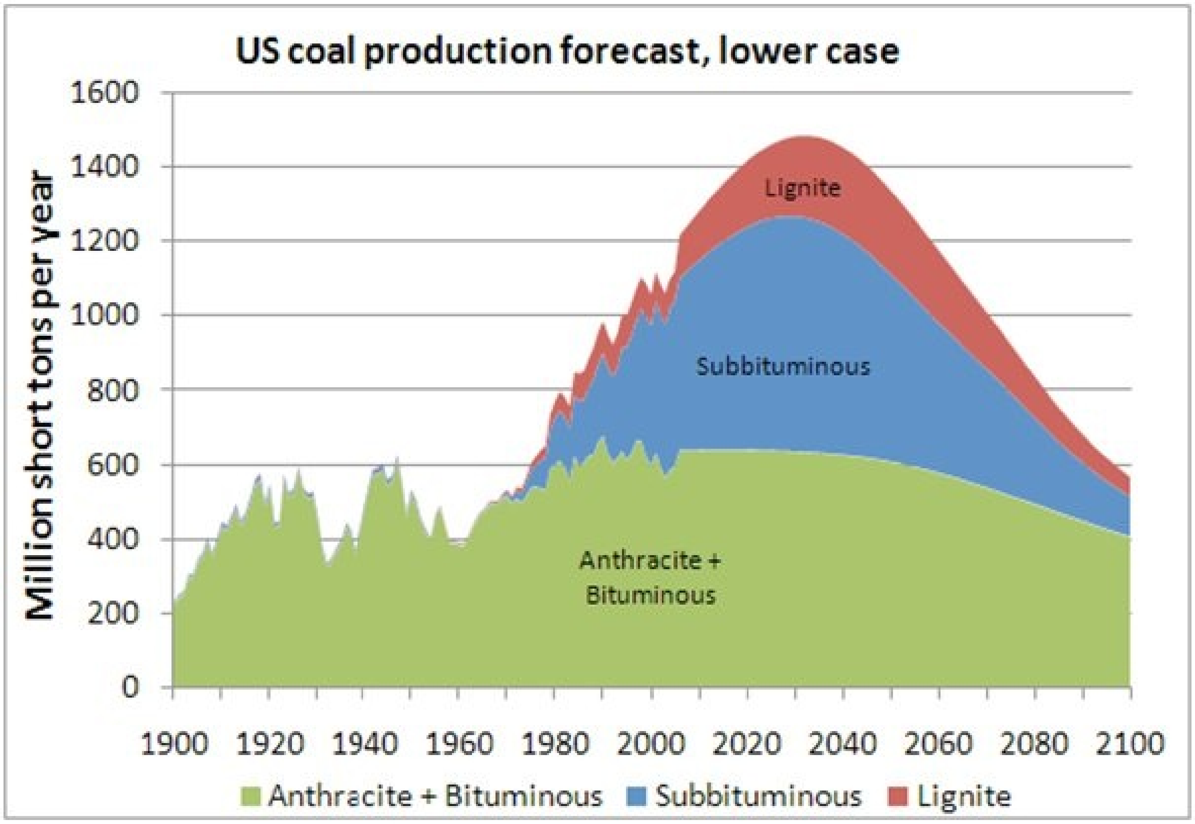
4. A Supply-Driven Forecast for the Future of Global Coal Production (Höök, Zittel, Schindler, and Aleklett;*Energy Policy,* in press, www.tsl.uu.se/). Much of this report repeats data and arguments from the prior EWG publication. The conclusions for the US are also similar:

> It is reasonable that USA with its huge energy consumption will be among the first in

the Big Six to peak in coal production. All major coal-producing states, except Wyoming, seem to be near or past peak production. It should however be noticed that environmental laws and other socioeconomic restrictions probably prevent a significant amount of coal from being produced in the near future, especially high-sulfur coals. A relaxation of the restrictions will therefore probably be able to increase the reserves, but whether this relaxation will happen or not is hard to tell and not considered in the forecast. . . . The decline in heat value shows that the best American coals are gone and that poorer and poorer coals are exploited each year. The decrease in mining productivity is an also in line with the fact that the most easy-accessible coal is gone.

"A Supply-Driven Forecast" contains two new charts, one a high-case and the other a low-case scenario. The higher case "depicts a continued rapid expansion of Wyoming together with a build-up of the capacity in Montana." The lower case "does not envision a dramatic increase of the Montanan coal production and consequently the production level from Montana remains at its current level." In the higher case, production peaks around 2040; in the lower case, which the authors regard as "more realistic," the decline commences around 2030.

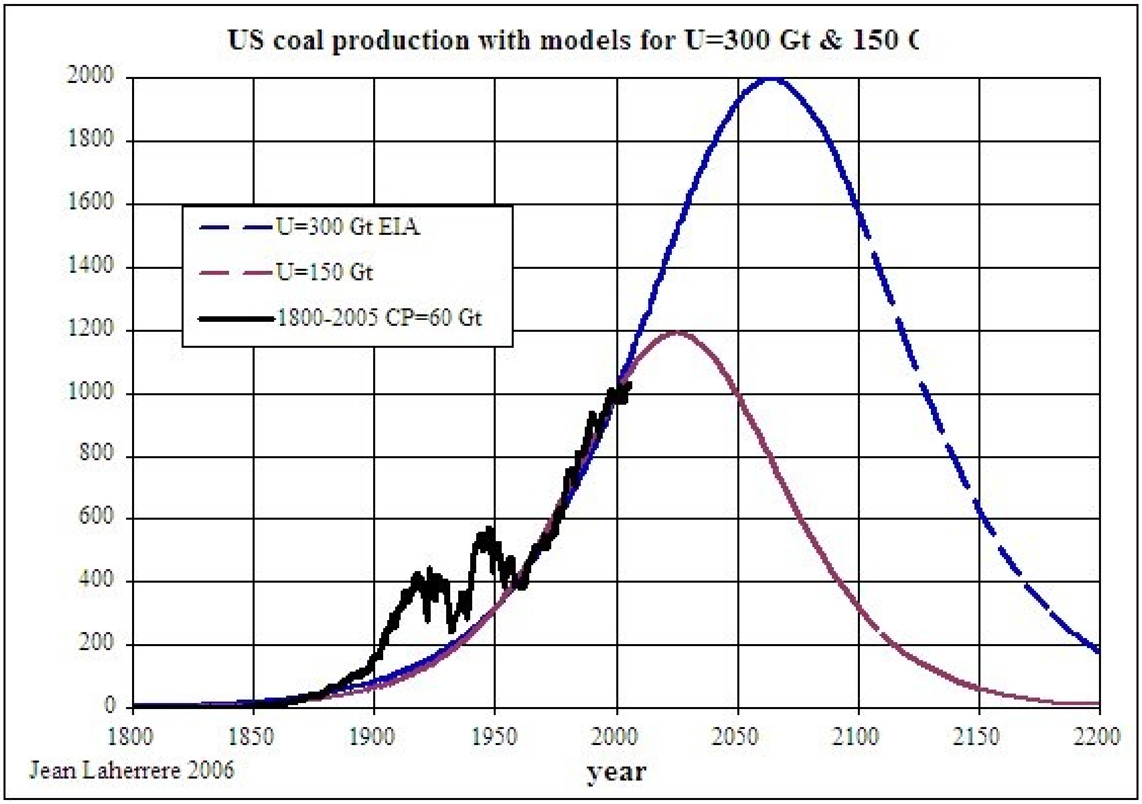




5. Hubbert linearization and curve-fitting (Rutledge and Laherrère). David Rutledge, Tomiyasu Professor of Electrical Engineering at the California Institute of Technology and Director of Caltech's Lee Center for Advanced Networking, in a presentation at Caltech in October 2007, used Hubbert linearization analysis to estimate future global coal production (http://rutledge.caltech.edu/). Rutledge argues that, in any region for which we have something close to a complete production history (i.e., production has declined substantially due to resource depletion—e.g., British coal or US lower-48 oil), historic reserves estimates typically have turned out to be too high. As we have seen, this position is now in effect supported by NAS on the basis of recent site-specific case studies. Rutledge goes on to argue that Hubbert linearization often yields a more accurate forecast of ultimately recoverable reserves.

Rutledge applies linearization to North American coal producing regions, "with trends for the East (40Gt), West (25Gt), reserves for Montana (68Gt), and trends for Canada and Mexico (2Gt total)." This results in an estimate of total ultimately recoverable reserves of 135 billion tons, roughly half the reserves figure now used by official agencies.

Veteran petroleum geologist Jean Laherrère has charted two Hubbert curves for US coal ("Combustibles fossiles: quel avenir pour quel monde?" http://aspofrance.viabloga.com/), one assuming an ultimate production of 150 billion tons (which is roughly in line with Rutledge's conclusion just cited), and the other assuming 300 billion tons (which is somewhat more than the current official ERR). The production peak in the former case occurs in 2025; in the latter case, decline commences after 2060.



Implications

With oil and natural gas prices rising at alarming rates, the return of the US to a greater reliance on coal might seem inevitable. The nation is currently paying over $620 billion per year for petroleum imports, and this ongoing transfer of wealth abroad cannot help but have a substantial negative impact on the domestic economy. There are three ways to moderate that impact: reduce consumption of liquid fuels through conservation; produce more fuels domestically; or electrify transport, which will require more electricity. Coal could help with either of the latter two strategies. Given that the nation possesses so much coal, and that energy from coal is still relatively cheap, it would seem inevitable that strong arguments will be made for a dramatic increase in coal production to help solve the nation's energy problems.

Yet if most of the recent analyses cited here are correct, this strategy has a short shelf life. Within the planning horizon for any coal plant proposed today lie much higher coal prices and perhaps even resource scarcity.

The sheer amounts of coal that will be needed in order to offset any significant proportion of oil (and perhaps also natural gas) consumption, and to meet the projected increased demand for electricity, are mind-boggling. Coal is a lower-quality fossil fuel in the best case, and America is being forced to use ever lower-quality coal. Just to offset the declining heating value of US coal while meeting EIA forecasts for electricity demand growth by 2030, the nation will then have to mine roughly 80 percent more coal then than it is doing currently. If carbon sequestration and other new technologies for consuming coal are implemented, they will increase the amount of coal required in order to produce the same amount of energy for society's use, since the energy penalty for capture and sequestration is estimated at up to 40 percent. A broad-scale effort to produce synthetic liquid fuels from coal (CTL) will also dramatically increase coal demand. If the current trend to expand coal exports continues, this would stimulate demand even further. Altogether, there is a realistic potential for more than a doubling, perhaps even a tripling, of US coal demand and production by 2030—which would hasten exhaustion of the resource from many current mining regions and draw the inevitable production peak closer in time.

Assuming this higher demand scenario (from CTL, increased exports, and growing electricity consumption), by 2030 the nation's dependence on coal will be much greater than is currently the case, and coal's proportional contribution to the total US energy supply will have grown substantially. But at the same time, prices for coal are likely to have increased precipitously because of transport bottlenecks and higher transport costs (due to soaring diesel prices), falling production trends in many current producing regions, and the lack of suitable new coalfields. The interactions of high and rising coal prices with efforts to maximize output are hard to predict.

As limits to domestic coal production appear, exports could diminish and there could instead be efforts to import more coal, probably from South America. But in that case the US economy would suffer increasingly from economic dependencies and geopolitical vulnerabilities that already hobble the nation as a result of its oil imports.

It may be tempting to think of coal as a transitional energy source for the next few decades, while a longer-term energy strategy emerges. But in that case, an important question arises: Will there be sufficient investment capital and technical resources in three or four decades to fund the transition to the *next* energy source, whatever it may be? By that time (assuming EIA projections are reasonably accurate), demand for energy will be higher. The price of oil, gas, and coal will be higher—perhaps much higher—and so the nation will be spending proportionally much more of its GDP on energy than it does now. Meanwhile, the energy cost of building new infrastructure of any kind will be higher. Therefore it is likely that insufficient investment capital will be available for the large number of new energy projects required. The transition if deferred will thus be more expensive and difficult than it would be now. Indeed, the longer a transition to an ultimate (and sustainable) energy regime is put off, the harder that transition becomes.

Coal currently looks like a solution to many of America's fast-growing energy problems. However, this is a solution that, if applied on a broad scale, seems certain only to exacerbate the nation's energy dilemma in the long run, as well as contributing to an impending global climate catastrophe.

(Note: This article is a draft chapter from a forthcoming book, currently titled Coal's Future/Earth's Fate, to be published by Post Carbon Press in spring 2009. *The author wishes to thank Werner Zittel, David Rutledge, Jean Laherrère, David Strahan, Julian Darley, and Jason Brenno for assistance with this article.*

Previous MuseLetters on global coal supply issues are archived on Global Public Media (www.globalpublicmedia.com):

- *MuseLetter #193: It's Happening,*
- *MuseLetter #190: The Great Coal Rush (and Why It Will Fail), and*
- *MuseLetter #179: Burning the Furniture.*