Understanding Coal's Challenges and Recommended Regulatory Responses

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Executive Summary

Coal has been a mainstay of U.S. energy production for almost 150 years. That is especially true for electricity generation, where coal has fueled roughly half of the total U.S. supply. In 2011, coal generated 42% of total U.S. electricity (EIA, 2011). However, coal faces three important challenges.

One challenge is whether and for how long coal will continue to remain available at low cost. Some recent estimates of coal and natural gas reserves call into question coal's long-term future status as the consistently lowest-cost fuel source for generating electricity. Depletion of the highest-quality, easiest-to-mine coal will eventually lead to higher prices. The price of delivered coal is also sensitive to oil price increases, because diesel fuel is an important input for mining and transportation. Increasing energy demands throughout the world, especially in China and India, are also putting upward pressure on coal and oil prices. Together, these factors resulted in near double-digit annual coal price increases in the early years of this century.

A second challenge is environmental constraints and the costs associated with meeting new pollution-control requirements. New and pending environmental rules are expected to increase substantially the costs of operating existing or building and operating new coal plants, and some of the technologies proposed to better manage emissions are not yet fully commercial. Another unknown is whether, when, and how greenhouse gas emissions might be regulated. At present, burning coal releases more greenhouse gases than the other fossil fuels. If, as many observers expect, those emissions are somehow taxed, priced, or restricted in the future, that is generally expected to add even more cost to coal-plant operations.

Coal's third major challenge comes from other energy-supply and demand-side options that sometimes have lower costs and lower risk profiles. Examples include energy efficiency, demand response, load management, some renewable energy supply options, and gas-fired electricity that is presently benefitting from ample supplies of low-cost fuel.

Together, these challenges raise important questions regarding the extent of coal's future use. The question for public utility commissioners is whether and how decision-making practices should be changed to account for the risks associated with future dependence on coal-fueled electricity generation. This paper recommends that commissions consider four practices to ensure that regulated utilities:

1. use best practices in managing portfolios of coal supply contracts;
2. value diversity in fuels, technologies, and suppliers in integrated resource planning;
3. fully evaluate pollution-control investments for existing power plants; and
4. secure option values by evaluating practical options, investigating those that are most promising, and procuring those that produce the most value under the broadest range of plausible future conditions.

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I. Introduction: Coal's Three Major Challenges

Coal has been a mainstay of U.S. energy production for almost 150 years. That is especially true for electricity generation, where coal has fueled roughly half of the total U.S. supply. In 2011, coal generated 42% of total U.S. electricity (EIA, 2011). In some regions, coal generates over two thirds of all electricity.

The latest projections from the U.S. Department of Energy, Energy Information Administration (EIA 2013) include:

- Total U.S. coal consumption declining 2.7% per year from 2011 to 2016 and then increasing 0.7% per year from 2016 to 2040;

- U.S. coal-fired electricity generation declining from 42% in 2011 to 35% in 2040, reflecting 2011 capacity of 318 gigawatts (GW), declining to 278 GW in 2040;

- Future U.S. coal use dampened by combinations of slow growth in electricity demand, competitively priced natural gas, programs encouraging renewable fuel use and increasing energy efficiency, and new environmental protection rules;

- Average U.S. annual mine-mouth coal prices increasing by 1.4% per year, from $2.04 per million British thermal units (mmBtu) in 2011 to $3.08/mmBtu in 2040, which "reflects an expectation that cost savings from technological improvements in coal mining will be outweighed by increases in production costs associated with moving into reserves that are more costly to mine";

- A continued rise in construction costs for new coal-fired power plants and retirements of U.S. coal-burning electric generation far outpacing new additions, including "sizable" coal-plant retirements associated with tightening environmental standards through 2016;

- U.S. coal consumption increasing slowly after 2016 as remaining coal-fired capacity is used more intensively and coal exports increase, but little new coal-fired electric generating capacity is added;

- Market concerns about greenhouse gas emissions dampening the expansion of coal-fired capacity, even under current laws and policies; and

- The first U.S. coal-to-liquid fuels plants coming on line in 2023.

Coal now faces three major challenges, namely: (1) long-term resource availability, associated with increasing production and delivery costs; (2) environmental constraints and related pollution-control costs; and (3) competition from other energy options. Other energy options include: low-cost energy efficiency and demand response, which temper electricity demand; certain renewable energy resources; and gas-fired power, which is presently benefiting from ample supplies of low-cost natural gas. Together, these three factors are at least temporarily changing the order of economic dispatch of electric power generation in the U.S., resulting in closures for some existing coal plants and reducing the quantities of energy provided by others. Many commissions around the country are being asked to make decisions about utility coal plants, regarding closures, environmental retrofits, and new construction. This paper briefly summarizes current information about these challenges and provides recommendations for policies and practices that state regulators can employ to best protect ratepayers from hardships that could otherwise result from continuing high levels of dependence on coal-fired electric power supplies.

A. Long-term availability associated with increasing production and delivery costs: How much coal can be mined and delivered, and at what cost?

The essence of this challenge is that supplies of high-quality, low-cost, readily retrievable coal might not be as large as previously thought, relative to current and expected future use. Remember, too, that high-grade coal, called *metallurgical* or *coking coal*, is used in steel production worldwide, where substitutes are not readily available.[1] Lower grades of coal, typically termed *thermal coal* or *steam coal*, are used primarily in steam-production facilities for electric power generation. With coal demand increasing rapidly in China, India, and other developing countries, and with tightening supplies of all fossil fuels in world markets, there is a pressing need for sober, objective assessments of future coal supplies. If thermal coal does become more expensive in coming years, there are important implications for both new coal plants and for retrofitting or repowering existing coal plants. The crux of the issue is that utility plans that appear reasonable in light of recent coal prices might not be among the lowest-cost choices if coal prices rise substantially in the future.

1. Challenges with the estimates of coal resources and reserves

Conventional wisdom once held that the U.S. lower-48 states had at least a 250-year supply of available coal resources that could be recovered and delivered economically. In recent years, though, the U.S. Geological Survey has revised estimates downward, based on more thorough investigations of coal reserves, better reflecting mining economics (Ruppert, et al., 2002; Luppens, et al., 2009; Grubert, 2012, p. 179).[2]

As with any other resource found in the earth's crust, the tendency is first to extract the highest-quality and easiest-to-obtain coal, and then gradually move to lower-quality and harder-to-extract reserves. As that trend continues, though, production costs tend to rise, especially in concert with rising exploration costs and the mining of smaller, more difficult-to-reach deposits. Rogner, Aguilera, et al. (2012, p. 431) conclude, "[B]ecause of these constraints[,] only a fraction of [known] resources is likely to be produced."

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[1] Steelmaking uses coal directly in basic oxygen furnaces. At present, about two thirds of total global steel production uses coal as a direct input, which accounts for about one eighth of total hard coal consumption worldwide (World Coal Association, 2012; Mitchell, 2012).

[2] Estimates of coal resources in Alaska are equal to or greater than the total for the lower-48 states (National Research Council, 2007, p. 52).

Zittel and Schindler (2007, p. 5) explain that only about half or less of any identified coal resource can be economically recovered using current technologies. Production limits result from combinations of several factors: (a) underground mining requires some columns of coal to remain to support tunneling; (b) some coal is of low quality and some of such high sulfur content that it is not practical for mining (Zittel and Schindler, 2007, p. 14); (c) some coal is found at depths below what is considered commercially viable for mining today (Luppens, et al., 2009, p. 1); (d) coal beds can be too thin or too steep to allow for cost-effective mining (Luppens, et al., 2009, p. 1); and (e) societal or environmental restrictions can prevent resource development (Luppens, et al., 2009, pp. 1, 13). The relative influences of these restrictions differ between surface and subsurface mines and based on the geology in different coal-resource regions (Luppens, et al., 2009, p. 6).

Estimates of coal *resources* are intended to include both coal reserves and additional discovered and undiscovered or inferred, assumed, or speculative quantities of coal. Coal *reserves* are supposed to represent finds that are both known and recoverable. The intent is to classify reserves as proved, if they "can be recovered in the future under present and expected local economic conditions with existing available technology" (Zittel and Schindler, 2007, pp. 5, 9).

Recently, some researchers have reported that available data on coal resources and reserves have been of generally poor quality (Heinberg, 2009, 2010; Zittel and Schindler, 2007). Heinberg (2009, pp. 21-23) reviews the reasons why coal-reserves estimates could be mistaken. These include the large number of "judgment calls" involved, "the fact that private coal companies often keep their data proprietary," the lack of any internationally recognized, uniform method for assessing and reporting reserves, varying definitions of reserves and resources, and a lack of verification "through independent geological surveys." Rogner, Aguilera, et al. (2012, p. 433) also note that different organizations use different classification schemes. For example, the U.S. Energy Information Administration uses the term "estimated recoverable reserves," which is equivalent to the World Energy Council's "proved recoverable reserve" and the International Energy Agency's "proved reserve" (Zittel and Schindler, 2007, p. 9). The World Energy Council (WEC, 2010, pp. 2, 9) also notes that "there is no universally accepted system of demarcation between" the different types of coal, especially for differentiating among bituminous, sub-bituminous, and lignite.[3]

A broadly accepted assumption is that, over time, production and exploration activities will allow some of the resources to be reclassified as reserves. Coal-supply optimists (such as Thielemann, Schmidt, and Gerling, 2007, pp. 2-3) project that coal supply and demand can remain balanced at least through the beginning of the next century. They believe that additional research, geological exploration, and increased ingenuity will continue to turn ample quantities of resources into reserves. Rogner, Aguilera, et al. (2012, p. 430) point out that over the entire history of coal production, growing knowledge and technology improvements "largely counterbalanced otherwise dwindling resource availabilities or steadily rising production costs." They question, however, whether and for how long those two factors can "sustain growing levels

[3] Coal types are described at http://www.eia.gov/energyexplained/index.cfm?page=coal_home.

of finite resource production" and ask, "What will be the necessary stimulating market conditions?" Ultimately, they explain, the amount of coal mined will depend on demand, market prices, technological capabilities, and environmental limitations.

In any case, world coal-reserves estimates have been declining. Heinberg (2009, p. 24) notes that "since 1986, all nations with significant coal resources (excepting India and Australia) that have made efforts to update their reserves estimates have reported *substantial downward revisions*" (emphasis in original). As Heinberg explains, the declines "cannot be explained by the volumes of coal produced" between survey periods.

The World Energy Council (2010) reports,

> Coal is the most abundant and economical of fossil fuels; on the basis of proved reserves at end-2008, coal has a reserves-to-production ratio of about 128 years, compared with 54 for natural gas and 41 for oil.[4]

However, it is worth noting that: (a) many countries have reduced their reserves estimates (Aleklett, 2007, p. 13), with worldwide estimates revised downward by about 60% between 1980 and 2005 (Heinberg, 2009, 25); (b) reserves-to-production ratios represent current, not future usage, and even modest long-term growth rates in usage will shrink the estimated time horizons; (c) future production could prove more costly; and (d) the rate of production could decline, regardless of the quantity eventually extracted.

Furthermore, Aleklett (2007, p. 12), Heinberg (2009, Chapter 2), and Zittel and Schindler (2007, Annex 3) all report that U.S. coal production has already peaked, when measured in terms of energy content; that is, the volume of coal produced and burned is increasing, but the total energy content is decreasing, as production shifts to lower-quality coal. Zittel and Schindler (2007, p. 6) report that the U.S. has already passed its peak production of high-quality coal, such that "coal production in terms of energy" has been declining since 2002. They question whether this trend can be reversed. Zittel and Schindler (2007, pp. 7, 15) forecast that world coal production, "in the best case," will peak around 2020-25 at 30% above present production levels.

The problem with reaching a peak in resource extraction is not absolute unavailability of supply, though. Instead, it is the supply rate and how supply relates to demand. Heinberg (2010, pp. xx-xxi) explains:

> Depletion of oil, gas, coal and other non-renewable resources is often wrongly portrayed as "running out," as though it indicated the complete exhaustion of the substance. What

[4] U.S. and world natural gas reserves increased markedly in recent years as a result of improved exploration and extraction techniques, notably the use of hydraulic fracturing in shale-gas formations. However, those supply increases will be offset to some extent by increased gas utilization, so it is not yet possible to determine how substantial the change in this metric will be. For example, a 54-year supply at current rates of use translates to a 37-year supply with an average 2% annual growth rate and a 30-year supply at 4%.

> we are really talking about are the inevitable consequences of the tendency… to take the low-hanging fruit first, and to leave difficult, expensive, low-quality… resources to be extracted later. … Geologists and others who routinely deal with mineral ores and fossil fuels commonly speak of a "resource pyramid:" The capstone represents the easily and cheaply extracted portion…; the next layer…can be extracted with more difficulty and expense…; while the remaining bulk…represents resources unlikely to be extracted under any realistic pricing scenario.

The most accurate data about coal-resource availability is gathered one coal field at a time, estimating the depth and thickness of coal beds as best as can be achieved using data from bore holes, gamma-ray studies, and geological modeling and mapping. A recent example (Scott, Haacke, et al., 2011) reviews detailed information for two dozen coal beds in the Northern Wyoming Powder River Basin. In summary, that study finds that only 1% of the total original resource could be "mined, processed, and marketed at a profit," given current restrictions, mining technologies, and economic factors. As this resource assessment shows (Scott, Haacke, et al., 2011, Figure 97, p. 133), at higher prices much more coal could be made available, but at those higher prices and for many years into the future coal will be competing against relatively low-cost natural gas. Studies of other U.S. coal-bearing regions show similar results, too (e.g., Boyd Company, 2011; Luppens et al., 2008).

The National Research Council (2007, p. 55) finds:

> The United States is endowed with a vast amount of coal. Despite significant uncertainties in generating reliable estimates of the nation's coal resources and reserves, there are sufficient economically minable reserves to meet anticipated needs through 2030. Further into the future, there is probably sufficient coal to meet the nation's needs for more than 100 years at current rates of consumption. However, it is not possible to confirm the often-quoted suggestion that there is a sufficient supply of coal for the next 250 years. A combination of increased rates of production and more detailed reserve analyses that take into account location, quality, recoverability, and transportation issues may substantially reduce the estimated number of years of supply. Because there are no statistical measures to reflect the uncertainty of the nation's estimated recoverable reserves, future policy will continue to be developed in the absence of accurate estimates until more detailed reserve analyses—which take into account the full suite of geographical, geological, economic, legal, and environmental characteristics—are completed.

Grubert (2012, pp. 174, 182-83) calls current coal-reserve data "inappropriate for continued use by policymakers and investors." Thus, she proposes "[g]overnment intervention to correct the market failure in information that currently exists… ." This, she says, will require substantial efforts by the Energy Information Administration, Environmental Protection Agency, U.S. Geological Survey, and Securities and Exchange Commission, to "correct reporting deficiencies and fill information gaps."

2. Challenges related to declining oil and natural gas supplies

The picture for future coal resource utilization is even more complex when considering price and availability relationships among all fossil fuels—coal, oil, and gas. As oil and natural gas become more scarce and expensive, society could turn to coal liquefaction to replace oil supplies and gasification to replace natural gas supply. There will be increasing interest in converting coal to liquid and gas fuels and industrial chemical feedstocks, if—as most geologists and resource analysis presently predict—oil and gas are being depleted more rapidly when more coal remains. Murray and King (2012) report that world crude-oil prices since 2005 are already reflecting a new status: "Production is now 'inelastic', unable to respond to rising demand." Heinberg (2010, p. 150, reference omitted) observes:

> [F]actoring in dramatic increases in usage (to substitute for declining oil and gas supplies)… extraction rates will inevitably begin to decline long before the coal actually runs out—and the fact that coal resources are of varying quality and accessibility leads to the surprising conclusion that a global peak in coal production could arrive as soon as a decade from now.

Heinberg (2010, p. 153) concludes:

> The dates for global production peaks for [fossil] fuels are of course still a matter for speculation; however, it is reasonable to estimate that we might see a 25 to 45% decline in energy available… over the next quarter century as a result of depletion.

Furthermore, coal-mining equipment, lubricants, explosives, and transportation by rail and truck all rely on petrochemicals, especially diesel fuel. Therefore, oil price increases put upward pressure on the delivered price of coal (EIA, 2012b). Under U.S. Surface Transportation Board regulations, railroad companies use fuel surcharges to pass through diesel fuel price increases to customers (CSX, 2011, p. 5; Union Pacific, 2012, pp. 12, 25).[5] In the most extreme cases, transportation accounts for as much as 80% of the total price of delivered coal, for specific plants with coal deliveries coming from specific regions (Gerking and Hamilton, 2008, p. 933).

3. Rising costs and increased price volatility

For a variety of reasons, coal prices have recently been increasing and becoming more volatile. As Heinberg (2010, pp. xxi) relates, there is a risk of repeating cycles, where (1) rising demand is associated with falling supply, which results in (2) rapid rises in price, followed by (3) reduced demand because of the higher prices, which is then associated with (4) collapsing prices that result in reduced exploration and development, eventually triggering (5) another price rise.

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[5] The fuel surcharges are the subject of class action lawsuits, first filed by rail shippers in 2007, that are pending in federal court in the District of Columbia (CSX, 2011, pp. 17-18; Union Pacific, 2012, pp. 17-18).

Foster, Smith, and Glustrom (2012) report that the U.S. average annual price increase for delivered coal from 2004 to 2011, measured in dollars per million British thermal units (mmBtu), was 11.4%, or 8.75% compounded annually. It ranged from as little as 5.7% per year (4.91% compounded annually) for New Mexico to 23.8% (15.07% compounded) for New York. In this analysis, average annual increases were reported as being between 5 and 10% for 10 states, between 10-15% for 21 states, between 15-20% for seven states (Georgia, Maryland, Mississippi, Nebraska, Pennsylvania, Tennessee, and Wisconsin), and more than 20% for two states (Montana and New York). This cycle resulted, in part, from increased global demand for coal coming from China and India, combined with the pass-through of higher diesel fuel prices affecting mining, processing, and delivery. It is unclear whether or how much this upward price cycle also reflected resource scarcity. There is also a long-term trend, since 2000 and now forecasted to continue through 2035, toward lower coal-mining labor productivity (meaning less coal mined per worker) (EIA, 2012a, p. 151).

The most recent cycle that began in late 2008 reflects falling U.S. coal demand as a combined result of the stagnant and then sluggish U.S. and world economies, low natural gas prices, the ramping up of state and utility policy supports for energy efficiency and renewable energy, and public announcements of many coal-burning power plant closures or conversions to natural gas or biomass fuels, as new environmental rules take effect in the coming several years (Crooks, 2012; Reuters, 2012c). U.S. electric utilities have already announced nearly 300 coal-plant closures, representing about 42 GW of capacity (Cleetus et al., 2012, pp. 27-28).

B. Environmental constraints

Existing and new environmental regulations represent major challenges for coal combustion. The issues are: (1) negative environmental effects associated with coal's entire fuel cycle, from mining through waste disposal; (2) high and potentially growing capital, operating, and energy costs associated with power-plant pollution controls; and (3) more carbon content than any other fossil fuel, and thus the potential for releasing more greenhouse gases into the atmosphere.

Negative environmental side effects are associated with the entire coal fuel cycle, from mining and extraction though transportation and production, including combustion and the disposal of wastes associated with combustion (Orem et al., 2010). Epstein et al. (2011, p. 73) estimate that the total negative externalities associated with coal use in the U.S. at somewhere between $300 billion and over $500 billion annually. And, they note, many of those externalities are cumulative, year upon year. "Accounting for the damages," they report, "conservatively doubles to triples the price of electricity from coal per kWh generated."

Near the end of the 20th century, it was not unusual for a quarter or more of the total cost of building a coal-fired power plant to be associated with environmental-pollution-control equipment. Additional environmental regulations that are in the early stages of implementation and other regulations still in development could increase substantially the costs of operating existing or building and operating new coal plants (Farnsworth, 2011; Hornby et al., 2012; Sovacool et al., 2011, pp. 4665-4667).

In addition to the fixed capital and variable operating costs associated with pollution-control equipment, there is also some loss in plant efficiency from installing pollution-control devices. More of the energy inherent in coal fuel could be needed just to run the power plant itself, including all of its associated pollution-control devices, which would leave less of the coal's energy to be converted to grid electricity.

Also, coal burning (without carbon capture and storage) releases more greenhouse gases into the environment compared to other fossil fuels, producing 1.5 times more carbon dioxide emissions compared to oil and twice as much as natural gas, per equivalent amount of energy produced.[6] Four processes that are characterized as "clean coal" technologies are widely discussed proposed means of reducing greenhouse gases and other potentially harmful emissions from burning coal. They include (Sovacool et al., 2011, pp. 4664-4665, reference omitted):

> (a) supercritical pulverized coal plants that boost thermal efficiency by operating at higher temperatures, (b) integrated gasification combined cycle (IGCC) plants that use chemical processes to gasify coal and remove sulfur and mercury, (c) pressurized fluid bed combustion plants that use elevated pressure to capture sulfur dioxide and nitrogen oxides, and (d) carbon capture and storage (CCS) techniques such as deep underground geologic formations that are engineered to capture and store excess CO_2.

All of these technologies represent increased capital and operating costs and losses in energy-conversion efficiency, though, compared to the previous versions of coal-fired power-plant technologies and environmental controls. The costs and energy penalties of the future technologies are still largely unknown, however, with estimates ranging from as little as 10% to as much as 50% higher than the penalties of previous plants (Chung et al., 2011). Another wildcard technology in discussions about future coal-conversion technologies is underground coal gasification (UCG), and UCG with CCS. This technology is proposed as a low-cost means of obtaining energy from substantial quantities of coal, even coal that is otherwise not accessible to mining techniques, while reducing environmental harms (Kelly-Detwiler, 2012; Roddy and Younger, 2010). But, as reviewed by Sovacool et al. (2011), these technologies are still in the early stages of commercialization, costs are still uncertain, and some demonstration plants have experienced reliability problems.

Epstein et al. (2011, p. 74) estimate that carbon sequestration and storage will result in far higher costs, including the need to burn 25% to 40% more coal to generate the same amount of energy. Such cost and fuel-use increases could make new coal plants uncompetitive when compared to natural gas plants and other low- or no-emissions renewable energy options. Also, as Nel and Cooper (2009) point out, carbon sequestration and storage could prove to be unaffordable. They surmise that investments might better be targeted toward "energy efficiency, advanced nuclear fuel cycles, incremental expansion of renewable resources," and other

[6] Greenhouse gas emissions as a result of natural gas production, delivery, and use are uncertain and the subject of some controversy. Some researchers question whether or how much switching electricity generation from coal to natural gas fuel will reduce atmospheric greenhouse gases. *See* O'Sullivan and Paltsev, 2012; Tollefson, 2013.

“sustainable” infrastructures. Sovacool, Cooper, and Parenteau (2011, p. 4669) also note the high opportunity costs inherent in any major transition to clean-coal technologies. They conclude:

> In a world of scarce resources and [with] only a few decades… to address climate change, scaling up coal systems seems a dangerous waste of resources. We cannot afford to build out two huge energy infrastructures at the same time… . [P]ursuing more [carbon capture and storage] and [coal to liquids] research and development risks delaying more durable measures and diverts resources from more effective alternatives like energy efficiency and renewable resources.

Greenhouse gas and climate modeling calls into question the total quantity of fossil fuel that can be burned without the unacceptable risk of dangerous levels of practically irreversible climate change. Researchers have started to investigate how resource availability and the carbon intensity of each fossil fuel could translate into greenhouse-gas emissions under different scenarios. Because greenhouse gases have such long-term effects in the atmosphere, estimated at several hundred years or more, researchers have recently begun exploring the likely changes in climate that would be associated with extracting and burning the world’s remaining known supplies of coal, natural gas, and oil. Chiari and Zecca (2011) conclude that already-known fossil fuel reserves are more than sufficient to require implementing “emission control policies” to prevent the gases that are driving global climate change from reaching dangerous concentrations in the atmosphere. The general finding in this and similar greenhouse-gas studies (Kharecha and Hansen, 2008; Haszeldine, 2009) is that the world cannot afford to burn all of the known supplies of fossil fuels without causing practically irreversible and likely catastrophic damage.[7] IEA (2012b, p. 3), citing data showing that two thirds of global “carbon reserves” are associated with known coal reserves, explains, “No more than one third of proved reserves of fossil fuels can be consumed prior to 2050… unless carbon capture and storage (CCS) technology is widely deployed.” Thus, most climate researchers are concluding, greenhouse gas emissions from coal must be quickly reduced, by some combination of energy-efficiency improvements, fuel-switching to natural gas and low- or no-emissions renewable resources, and by burning coal only in facilities designed to accomplish nearly complete carbon capture, sequestration, and storage.

In totality, the preponderance of current information about coal’s environmental challenges suggests higher future costs for coal-fired electricity production, but with a broad range of uncertainty about how much higher those costs will be. Newly enacted, planned, and proposed environmental standards are reviewed in Farnsworth (2011) and Hornby et al. (2012, pp. 1-2 and Table A-1).

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[7] Hook et al. (2010) model coal production and use based on historical data from specific countries and a logistic model for estimating future production economics and restrictions. They question models reported by the Intergovernmental Panel on Climate Change (IPCC), EIA, and IEA, which predict increasing usage through 2100. Hook et al. expect world coal usage to peak by 2020-2050. In addition, Nel and Cooper (2009) believe that IPCC models overstate fossil-fuel reserves and thus predict more climate change than is likely to occur.

C. Competition from other energy options

Some other energy options are already or soon will be cost-competitive with coal-fired electricity supply (see, for example, Cooper, 2011, pp. 5-8). Some are already inherently cost-competitive, such as low-cost energy efficiency and demand response (York, Molina, et al., 2013). Others, like solar and wind power, can be cost-competitive today in certain locations and applications. Solar and wind, in particular, are generally characterized by steadily declining production costs that are gradually creating even more opportunities for competitively priced installations. In addition, natural gas presently benefits from ample supplies at low cost, which makes gas-fired electricity more economical than coal in some circumstances.

Thus, even without accounting for future coal delivered-price increases, added environmental costs, or means of pricing greenhouse gas emissions, some other supply- and demand-side energy options can be fully cost-competitive today. As those three major sources of cost increases take effect to further raise the cost of coal-fired electricity, even more of these other energy-supply options will become better buys.

D. Summary

To summarize, U.S. coal usage has recently declined, but some observers expect coal usage to stabilize and then grow again. Several major factors make coal's future usage uncertain, however, including:

- Rising costs for coal-fuel production and delivery;
- Rising coal-burning power-plant construction and operating costs, including major expenditures for pollution-control equipment;
- Environmental, public-health, and global climate-change concerns;
- Modest growth in electric energy usage; and
- Competition from other energy options, including energy efficiency, demand response, renewable resources, and natural gas.

These factors combine to create a difficult situation for all interested parties. In particular, the major concern addressed in this paper is that parties could be influenced by an incomplete picture of future coal availability and price, which could then prevent fully informed risk analysis and decisionmaking. Ideas for how best to manage such risks are the subject of Part II.

II. Implications for State Public Utility Regulators

The major concern for state utility regulators is not to determine which fossil-fuel resource estimates or environmental regulatory predictions are the most likely to prove correct. History has repeatedly shown that such forecasts can be mistaken. Rather, it is recommended that utility regulators should strive to ensure that utility plans and actions adequately reflect the uncertainties about the long-term availability and price of coal-fired electricity, the effects of new and possible future environmental policies, and how the risks and costs of coal plants compare to other options. In sum, in a world of uncertainty, the commission should try to ensure that regulated utilities manage risk in ways that maximize the public interest. When utility customers are risk averse, at a minimum the utility should strive to avoid worst-case scenarios that would burden customers with higher costs.

Ratepayer protections are best accomplished through: (a) accurate and robust integrated resource planning and scenario analysis; (b) best practices in portfolio management for all fossil-fuel purchases, including coal; and (c) appropriate sharing of risk between shareholders and ratepayers. These are not simple issues, though, and commission jurisdiction differs markedly in different states regarding decisions about generation capacity and the pass-through of fuel costs to consumers. In implementing these recommendations, each commission will have to fit its decisions in this context as best it can, based on its regulatory authority and the available information. The commission effectively acts as the customers' agent in deciding on tradeoffs between risk and other objectives.

This paper does not attempt to explain utility-commission decision-making practices and risk assessment for proposed utility investments and power supply portfolios. Binz, Sedano, et al. (2012) already provide a comprehensive guide for those subjects. Their work covers cost- and time-related risks, including construction-cost overruns, fuel-cost increases, alternative-fuel cost decreases, changing environmental rules, market changes, and more. Among the recommendations they review are: (1) diversifying utility supply portfolios; (2) utilizing robust planning; and (3) using financial and physical hedges. There is also a wealth of additional literature on specific aspects of many of the relevant regulatory concerns. For example:

- Aid (2010) explores the added complexities and difficulties in modeling best practices in portfolio management in restructured markets, where generation decisions are made by unregulated power suppliers;
- Cooper (2011) extensively reviews how integrated, least-cost planning principles "should be reaffirmed" and updated to account for "21st century… changes in the terrain of decisionmaking";
- Costello (2005, 2007, 2008, 2010) outlines fuel-supply-portfolio management issues and best practices;
- Duenas, Barquin, et al. (2012) explore the risks associated with long-term natural gas contracts and recommend practices for optimizing a portfolio of contracts while incorporating complicating factors such as transportation constraints, storage, and spot-market prices;
- Farnsworth (2011) and Hornby et al. (2012) provide comprehensive analyses of pending and future environmental regulations;

- Monast and Adair (2012) explore the regulatory dilemma associated with uncertainty about future environmental regulations; and
- Tierney and Schatzki (2009) review the many challenges of using competitive procurement to select generation resources and manage power-supply portfolios.

Given the extensive previous literature on these subjects, this paper highlights only a few specific issues and related decisionmaking practices raised by coal's current challenges. Those practices all focus on identifying risks and sharing them appropriately among all interested parties, especially taxpayers, utility shareholders, and ratepayers. The issues touched on here include:

- Managing portfolios of coal contracts;
- Valuing diversity in fuels, technologies, and suppliers;
- Evaluating pollution-control investments for existing power plants; and
- Securing option values.

A. Managing portfolios of coal contracts

Portfolio management is more complex for coal contracts than for natural gas or other commodities, because the qualities of coal vary so substantially by source in terms of heat rate, levels of pollutants (especially sulfur), ash production, and the like, and transportation arrangements are different for each source and destination. Coal purchasing is thus very different from the purchasing of natural gas, which is basically a single commodity that can be transported by pipeline from source to delivery point. Power-plant operators have limited opportunities to change the mix of coal used in order to ensure reliable operations while meeting pollution-control requirements (Buck, Elliott, et al., 2012, p. 5). Thus, buyers have limited opportunities to substitute different qualities of coal, but utilities should consider having contracts with multiple suppliers and with different commercial arrangements and a mix of viable transportation options for each basic type of coal. Purchasing a mix of spot-market coal and sets of long-term contracts with varying and overlapping terms is one example of a portfolio approach.

Buck, Elliott, et al. (2012) also explore the risks associated with coal transportation. Their study of risk management reports on American Electric Power, a midwestern and south-central electric utility that relies on coal for about seven eighths of its total supply. Rail repairs near the source of Powder River Basin coal threatened to interrupt the utility's coal supplies to several power plants. Buck, Elliott, et al. (2012, p. 12) explain:

> The fuel procurement process for coal includes contracting for coal and for its transportation from the source to the generation location. …Transportation arrangements may involve rail, barge, truck or conveyor depending upon the location of the mining source, the location of the generation facility, the total cost of transportation, and other factors. … A utility must also carefully watch its coal inventory. Issues such as appropriate storage space, facility capacity for unloading, and delivery schedules can impact coal inventory. Utilities typically maintain about one month's supply of coal, or more, at each coal-fired generation plant.

The upshot is that utilities need to carefully consider procuring a portfolio of coal contracts designed to manage risk and to appropriately share risks between the suppliers, the utility, and the utility's customers. Utilities should analyze their coal supply-chain logistics, determine how coal supply relates to energy security and reliability, and develop a management plan that addresses contingencies for changes in price, availability, and transportation (Brady and Pfitzer, 2007; Jacoby, 2012; Liu, 2008). The Boyd Company (2011) report to Xcel is an example of the first portion of this kind of study, for coal supply.

Regulators should provide utilities with clear "guidelines regarding the degree of price risk customers should be expected to bear, and the amount of money that customers should be expected to pay for the rate stability that hedging can provide" (Makholm, Meehan, and Sullivan, 2006, p. 23). In achieving an optimal risk strategy, regulators should strive to match customers' willingness to pay for mitigating price risk with the amount the market requires them to pay. This practice will provide both utilities and regulators with the appropriate criteria by which to evaluate the utility's fuel-portfolio management.

B. Valuing diversity in fuels, fuel suppliers, and technologies

Diversity creates utility customer value from both an engineering and reliability standpoint, and in financial and economic terms (Lovins and Rocky Mountain Institute, 2002, p. 163). The value of diversity and flexibility must be considered on a wide variety of time scales, too. On an hourly or daily basis, utilities need some flexibility in how to respond to changes in demand. Some excess capacity and redundancy in the transmission network helps to serve those functions. In the more medium term, on a time scale of several weeks or months, to the extent that its power-plant designs and operations allow, a utility could usefully employ some fuel-switching flexibility in response to fuel-price volatility, delivery constraints, and other contingencies. On a longer-term basis, on the scale of years and decades, utilities sometimes make resource-planning decisions that require commitments of large amounts of capital.

Essentially, to hedge against price, fuel-supply, technology, and governmental/regulatory risks, utilities should be relying on diverse and flexible sets of resources. Hanser and Graves (2007) analyze electric-utility-company supply diversity. They note that the initial impetus for utility-company supply diversity was borrowed from financial-portfolio theory. But, they caution, the theoretical principles from financial-portfolio management must be applied with caution, because the utility-supply business is fundamentally different. The primary reason is because the items held in a financial portfolio are frequently ready, fungible substitutes for one another. Also, it is often possible to identify investments with little, if any, correlation with others and even investments with expected countercyclical performance. That is, when some investments decrease in value, others can be expected to increase, and vice versa.

Different utility power plants, on the other hand, have decidedly different costs and operating characteristics. Each power plant, therefore, has limited capabilities to help a utility meet its particular supply requirements, for example for reliability, load-following, and voltage support, at specific geographic locations. The import for regulators is to ensure that electric-utility resource plans maintain ample diversity and flexibility to meet obligations under a wide variety of potential contingencies and future planning scenarios. This kind of analysis requires complex modeling of power supplies and demands. Commissions should ensure that the modeling is done in sufficient detail and that the assumptions and findings are made available for interested parties to review.

C. Evaluating pollution-control investments for existing power plants

Decisions about environmental retrofits for existing coal-fired power plants add a new level of complexity to integrated-resource-planning analyses. Options for each existing plant need to be developed at a level of detail necessary to forecast future capital and operating costs. A thorough analysis should be completed, with the goal of determining that the new pollution-control investments meet three important criteria:

1. They can be amortized at reasonable cost, over something less than the likely projected lifetime of the existing plant;
2. They can be made at reasonable cost compared with other available resource options; and
3. They are cost-effective under a broad range of plausible future high, medium, and low prices for coal, natural gas, and greenhouse gas emissions.

Regulators, before approving plans for environmental retrofits, should insist that utilities complete a thorough analysis of the options for each power plant that affirmatively answers all three questions.

D. Securing option values

Real options represent value-enhancing opportunities to adapt to changing circumstances at relatively low cost as uncertainty is resolved over time. An option value is worth acquiring whenever the cost of developing the option is likely to be less than the cost savings it can achieve, accounting for the risk profile of utility customers and the probabilities of different outcomes. The risk associated with an option is what it costs to develop, assuming the contingency to use the option is never presented. (Lovins and Rocky Mountain Institute, 2002, pp. 137-8). Option value theory says that in a world of uncertainty a utility might not want to make a high-cost, long-term commitment. It can be preferable to wait until additional information is available before locking in to a large financial commitment.

When considering all power-supply and demand-management options, many can be adjusted over time without making large, irreversible financial commitments. For example, as needs materialize over time, many kinds of power supplies can be developed in modules, and energy-efficiency programs can be ramped up or down. For power plants specifically, sometimes one or more option values can be created through engineering designs that allow for sequential reconfigurations. Examples could include the ability to reconfigure a power plant for dual-fuel or multiple fuel choices (Hanser and Graves, 2007, p. 27). Importantly, some coal plants can be designed and constructed to be ready to add CCS capabilities later, with minimal extra cost compared to installing CCS at the outset.

Finding and evaluating all plausible options is a near-impossible task, but regulators should require utilities to triage practical options, carefully investigate those that are most promising, and procure the ones that produce the most value under the broadest range of plausible future conditions. Options with little or no incremental cost and risk should be acquired. For many options, though, trade-offs exist, which require the commission to determine which option or combination of options will best advance the interests of utility customers and society as a whole.

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