

Market-based Valuation of Coal Generation and Coal R&D in the U.S. Electric Sector

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ABSTRACT

Coal-fired power plants currently generate over half of all electricity consumed in the United States. This report investigates the effects of improving coal technology for a portion of existing generation (25%), versus replacing this portion with natural gas-fired capacity in order to reduce environmental impacts. The cumulative benefits within the electric sector over the period 2007-2050 for improving coal technology and reducing exposure to higher-priced natural gas fired generation exceed \$300-1,300 billion (\$2000). The range reflects different assumptions about natural gas prices, discount rates, and the groups of stakeholders sharing in these benefits (power consumers, generators, or society). The report describes a large-scale financial, technical and operational analysis of the electric sector. Performed in partnership with LCG Consulting using the UPLAN model of the power network, the study applies techniques of modern business analysis (real options valuation) at an unprecedented scale to the public policy issues surrounding coal generation and coal technology R&D. In addition to contrasting the effects of the two principal scenarios, the report describes the results of an expanded analysis of business risk and uncertainty. Comprised of multiple simulations, the expanded analysis assesses the change in net income for generators adopting advanced coal technology. Private sector risk climbs rapidly as R&D costs reach the \$5-6 billion level. These two effects – high consumer benefits and private sector risk – support public-private partnership in advanced coal technology R&D and implementation.

Report Summary

The payoff from accelerated R&D in coal generation technology could be enormous, over \$300-\$1,300 billion. The prime beneficiary is the power-consuming public. This conclusion is supported by a comprehensive quantitative analysis of the U.S. electric sector. Cosponsored by LCG Consulting, this study provides a large-scale financial, technical, and operational analysis of the electric sector, applying techniques of modern business analysis at an unprecedented scale.

Background

Coal is a vital source of power generation in the United States, yet R&D to improve efficiency, cost, and emissions of coal power systems is necessary for coal to overcome environmental drawbacks. EPRI and other organizations have mapped out a Technology Road Map that outlines R&D needs and achievable goals for coal. While the technology community knows what needs to be done and how much it will likely cost, there is a further need to understand the value of coal R&D. To objectively assess value under real business conditions, techniques of real option valuation relying on detailed simulation of the U.S. electric sector were required.

Objectives

To test the application of real option valuation at a national scale and to estimate the value of coal R&D to electricity consumers and generators.

Approach

Investigators estimated the value of coal R&D by first simulating electric sector operations and market prices under two distinct scenarios (and several variants). They next conducted an expanded series of analyses based on Monte Carlo simulation techniques to measure possible financial risks to coal generators for implementing advanced technology. One scenario calls for 25% of coal generation to be refurbished or replaced with advanced coal technology. The second calls for 25% of coal generation to be converted to natural gas. This leads to higher power prices, greater gas use, and possibly higher gas prices (effects of which were evaluated for a range of gas prices).

These changes are assumed to take place progressively between 2007 and 2020. Investigators initially concentrated on a vast region comprising two-thirds of U.S. coal generation (some 200 GW), covering the eastern half of the United States except for the extreme Northeast and Florida. They performed detailed simulations to 2030 using the UPLAN database and modeling system developed by LCG Consulting. They then extended the results to 2050 and to the rest of the United States. The UPLAN system balances regional transmission requirements and generation on an hourly basis, replicating system operations and expansion in competitive wholesale power markets. Technology costs and performance characteristics were developed by EPRI in cooperation with the Coal Utilization Research Council (CURC), and natural gas price assumptions were aligned with U.S. DOE Energy Information Administration (EIA) forecasts.

Results

The principal finding is that estimated benefits of coal R&D for the period 2007-2050 range between \$360 billion and \$1,380 billion (in 2000 dollars). The value depends on assumptions about natural gas prices, on the definition or scope of benefits, and on discount rates applied to determine net present values.

Gas prices by the year 2020 match public estimates, averaging about \$3.74/mmBtu (\$3.54 \$/GJ) delivered to utilities. The level of new merchant gas-fired capacity is expected to increase dramatically even if no coal generation is shutdown and replaced by natural gas units. Gas demand for power generation by 2020 could increase by over 5 trillion cubic feet (142 billion cubic meters) in the study region alone, and would be 1.4 trillion cubic feet (40 billion cubic meters) greater if gas replaces a share of coal generation. Sensitivity cases explored several instances of slightly higher-priced gas (up to 12% higher) in the event natural gas units substitute for coal generation. The magnitude and duration of such an increase is very uncertain. This report provides information on power prices for the different cases.

An extended set of Monte Carlo simulations yielded estimates of income to generators under the different scenarios. These simulations showed that generators who implement advanced coal technology face rapidly increasing financial risk if their R&D costs approach \$5-6 billion. This result—coupled with consumer benefits worth hundreds of billions of dollars derived from lower power prices made possible by advanced coal technologies—supports a public-private partnership to pursue coal technology R&D.

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MARKET-BASED VALUATION OF COAL GENERATION AND COAL R&D IN THE U.S. ELECTRIC SECTOR – SUMMARY¹

Market-Based Analyses Suggest That Advanced Coal R&D Offers Substantial Economic Benefits

Because of its low cost and domestic availability, coal is currently the most widely used fuel for generating electricity in the United States. Over the next several decades, however, analysts anticipate that U.S. coal power-generation capabilities will decline significantly. This is, to a large extent, because many U.S. power producers may retire some of their existing coal capacity in response to new and more stringent environmental regulations focused on criteria pollutant emissions (SO₂, NO_x, and particulates), hazardous air pollutants (such as mercury) and greenhouse gases (chiefly CO₂). At the same time, the U.S. is adding new natural gas-fired plants, because today's natural gas power systems require less capital investment, are faster to construct, and produce fewer pollutants and greenhouse gases than other fossil-fueled plants. Taken together, these two trends could result in the replacement of significant U.S. coal generation capacity with natural gas-fired plants.

According to a recent study jointly funded by EPRI and LCG Consulting ("LCG"), a leader in energy market simulation, such a switch from coal to natural gas for power generation could have significant societal costs in the form of higher electricity prices. An innovative market-based model was used to compare two potential futures: a "Coal R&D" scenario, in which 25% of existing coal-fired power plants are refurbished or replaced with advanced coal technologies and a "Natural Gas Substitution" scenario, in which gas-fired plants replace the same 25% of existing coal plants.

Study results showed that the Coal R&D scenario produced significantly lower electricity prices than the Natural Gas Substitution scenario. However, for power producers, the study also suggested that the Coal R&D scenario poses technological and financial risks beyond private-sector norms. Based on these results, EPRI has concluded that a shared public-private commitment to coal power R&D may be the most effective way to ensure the availability of

¹ EPRI-LCG report, *Market-based Valuation of Coal Generation and Coal R&D in the U.S. Electric Sector*, Palo Alto, Calif.: 2002. 1006954. Summary of findings and implications prepared by EPRI based on research conducted by LCG Consulting, Los Altos, Calif., cosponsor and principal investigator. An additional summary by EPRI was presented to Power-Gen International Conference, Las Vegas, December 2001: "Real Options Valuation of Coal-Fired Generation – Why Coal Makes Economic Sense to Our Society" by S. Dalton, J. Platt and A. Armor.

better-performing advanced coal technologies that can help preserve U.S. coal generating capabilities while mitigating some of the environmental impacts of the existing coal fleet.

Coal Power Systems R&D—Technology Roadmaps in Place; Main Challenge Is Funding

There is a consensus long-term vision for coal-based power generation in the United States: a new fleet of highly efficient, low-emission, moderate-cost, and flexible coal-fueled power plants designed to operate in a co-production environment; technological requirements for these advanced plants are outlined in the Department of Energy’s Vision 21 program and in EPRI’s Electricity Technology Roadmap.

Developing these state-of-the-art power plants will take considerable effort and time, perhaps more than 25 years for the longest-range goals, such as “powerplexes” (including CO₂ capture) that support a hydrogen- and electricity-based economy. However, at the current pace of national coal power R&D investment—now just a fraction of the level it was in the late 1970s and early ’80s—technological advances may not be brought to market fast enough to make replacing existing coal power systems with more advanced equipment a technologically or financially sound decision for most power producers.

An Innovative Approach—Demonstrating a Dynamic Market-Based Model to Estimate the Economic Benefits of Coal Power R&D

Because markets determine the value of generation assets in today’s deregulated marketplace, the joint EPRI and LCG study applied an innovative market-based model to the challenge of quantifying the societal benefits of preserving coal as a viable fossil fuel option through increased funding for coal R&D. However, several key challenges motivated the selection and adoption of analytic techniques developed in the financial services sector.

First, there was a need to simulate the complex operational and financial decision-making processes of power plants in today’s deregulated environment to generate realistic electricity prices and generator revenues. Second, because most market-based models available today were designed to help individual companies and financial institutions make investment decisions, there was a need to find a model that could be extended to analyze numerous electric producers and consumers within a large geographical area, such as a subcontinental transmission grid. Third, there was a need to determine whether a market-based approach could properly address the public policy implications of coal R&D.

By using LCG’s UPLAN Network Power Model (“UPLAN”) for the market-based valuation of coal R&D benefits, the study’s architects addressed these challenges. UPLAN is highly scalable and combines electricity price forecasting with the ability to project power plant behavior, power transmission, and net income under a wide variety of market conditions. In addition, LCG developed a framework to quantify public policy impacts by structuring the study to produce both a consumers’ impact based on wholesale power prices and a power producers’ impact based on net revenues.

Applying the UPLAN Model—Developing Electricity Market Assumptions and Two Scenarios

Two plausible scenarios were designed to estimate the market value of coal R&D—the Coal R&D scenario and the Natural Gas Substitution scenario. In the Coal R&D scenario, increased coal R&D investment allows advanced coal technologies to replace older, less efficient power systems at 25% of existing coal plants. (This 25% figure was chosen because it matches the figure used by the DOE’s Energy Information Agency in several recent policy case studies analyzing the potential environmental and economic effects of more stringent CO₂ controls.) In the Natural Gas Substitution scenario, the same 25% of coal capacity is replaced with natural gas-fired units. Both scenarios were developed for a large interconnected transmission grid covering the Midwest, the Plains States, and the Southeast, which includes approximately two-thirds of U.S. coal-fired generation capacity.

Using market information to determine plant operations, dispatch, revenues, and, asset value of power plants located in the study region, the UPLAN model calculated benefits to consumers, producers, and “society” (i.e., the sum of consumer and producer benefits) by contrasting the Coal R&D and Natural Gas Substitution scenarios.

Coal R&D Promises Significant Economic Benefits to Society

Table 1-1 shows the financial impacts of coal R&D for different stakeholders. Overall, the Coal R&D scenario produces large consumer benefits derived from lower wholesale electricity prices relative to those under the Natural Gas Substitution scenario. Depending on natural gas price and discount rate assumptions, these benefits can approach \$1.4 trillion when results are extrapolated to the entire United States. At the same time, lower wholesale electricity prices consistently lead to lower income for producers, in effect a “lost opportunity” or negative net benefit.

Regardless of which gas price or discount rate assumptions are used, societal benefits associated with the Coal R&D scenario are hundreds of billions of dollars more compared to the Natural Gas Substitution scenario alternative.

Effects of Natural Gas Price Assumptions

Because power prices are very sensitive to natural gas prices, the study considered three different natural gas price assumptions. Under the Medium Gas Price Increase assumption, natural gas prices are 12% higher in the Natural Gas Substitution scenario than in the Coal R&D scenario. They are 6% and 0% higher, respectively, under the Low and No Gas Price Increase assumptions. As expected, the smaller the increase in gas prices, the lower the magnitude of societal benefits for coal R&D. The lowest benefit from coal R&D appears when calculations assume there is no increase in gas prices under Natural Gas Substitution—\$254 billion in the study region, which translates to \$360 billion for the entire country.

Table 1-1
Net Benefits of the Coal R&D Scenario vs. the Natural Gas Substitution Scenario, 2007-2050 with Net Present Value in Year 2000 Dollars

(\$ Billions)

Benefit	“Midwest Interconnect” Study Region*				U.S. Extrapolation
	Medium Gas Price Increase ¹	High Producer's Discount Rate ²	Low Gas Price Increase ¹	No Gas Price Increase ¹	Medium Gas Price Increase ¹
Consumer	971	971	880	305	1,379
Producer (Lost Opportunity)	- 519	- 98	-540	- 51	-737
Net Societal	452	872	340	254	642

* Midwest Interconnect: The North American Electric Reliability Council's MAPP, MAIN, ECAR, SERC, and SPP regions

¹ “Increase” is the amount natural gas prices are higher under Natural Gas Substitution relative to Coal R&D: 12% (Medium Increase), 6% (Low Increase), and 0% (No Increase).

² Applies 12% discount rate to Producers Lost Opportunity. Otherwise, no discount rate and a 2.3% “real” inflation rate are used in each case.

Effects of Discount Rate Assumptions

The study also applies different discount rates—No Discount Rate (i.e., inflation adjustment only) and a High Discount Rate of 12%—to the calculation of producers’ net income.

Using the High Discount Rate assumption, which is commonly used in private investment decision-making, electricity producers’ lost opportunity shrinks from -\$519 to -\$98 billion in the study region, thereby increasing net societal benefits from \$452 to \$872 billion. Extrapolated to the entire United States, the societal benefit associated with a higher discount rate for producers (combined with a Medium Gas Price Increase assumption) would be \$1.2 trillion, approaching the consumer benefit from coal R&D.

Coal R&D Investment Presents Business Risks for Coal Generators

To understand the business risks and payoffs for coal generators that refurbish or replace old units with advanced coal technologies made possible by additional investment in coal power R&D, results from the extended UPLAN model run are used to perform a “risk analysis” of their financial returns. Instead of simply running the model under “most likely” market conditions, the risk analysis involved running the model several times, using random sampling to obtain key inputs for load growth, fuel prices, system conditions, and other factors, thereby producing a

distribution of results instead of single-point estimates. This methodology closely matches the types of financial analysis often undertaken by firms to make investment decisions for individual plants, and it is sometimes called “real options” because technology choices represent “real” as opposed to “financial” options for the company.

EPRI’s interpretation of this analysis is that the private sector cannot invest more than approximately \$5-6 billion in coal power R&D over the period from 2007 to 2025 without a large risk of failing to recover their investment dollars. Moreover, under Low and Medium Gas Price conditions, individual coal generators stand to reap significant benefits by adopting a “business-as-usual” approach and continuing to run their existing coal power systems. Clearly, private generators do not currently have a financial incentive to increase their spending on advanced coal R&D. Yet the consensus forecast is that advanced coal R&D requirements over the study period will exceed available private funds.

Policy Implications—Additional Public-Sector Support for Coal Power R&D Is Required

Because society will reap hundreds of billions of dollars in benefits if advanced coal R&D is adequately funded, EPRI believes public investment in coal R&D designed to supplement private funding could provide society with an extremely attractive return-on-investment. EPRI asserts that the magnitude of foregone societal benefits associated with reducing coal capacity by even 25% should be considered in the ongoing deliberations over how and when to implement new CO₂ reduction requirement

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