WHITE PAPER

ADVANCED ANALYTICAL
CONSULTING GROUP

STRATEGIC RESOURCE OPTIMIZATION

Manage Uncertainty | Minimize Regulatory Compliance Costs | Optimize Resource Portfolio

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Power Generation Capital Planning and Emissions Compliance Challenges

The complex and interrelated challenges facing the electric power industry have never been greater. The estimated costs of meeting electric power demand while complying with existing and emerging emissions compliance issues have been estimated through 2030 at somewhere around $2 trillion. There are numerous complex and interrelated institutional, policy, and capital investment issues that will come to bear. How can power generation executives be expected to plan and run a capital intensive business in the face of these issues and the uncertainties they entail?

Making long-term, irreversible capital decisions in the face of uncertainties regarding technology, market behavior, and demand growth has always been difficult for the power industry, and billions possibly trillions of dollars have been lost on investments based on faulty projections.

The latest emissions regulations promulgated by the EPA up the ante and: 1) will require substantial incremental NOx and SO2 reductions in a timeframe that likely precludes major hardware retrofits; 2) force companies to analyze and address compliance requirements on their entire fleets within each state; and 3) exacerbate the uncertainties already imposed by the expected further reductions in particulate and ozone NAQQS requirements, potential federal CO2 regulations, and the Maximum Available Control Technology (MACT) requirements replacing the former CAMR rule for mercury reduction also struck down by the U.S. Circuit Court.

While federal legislation addressing CO2 with cap and trade regulation has been put on hold, most observers view such regulation on the federal level as inevitable, which has potentially large implications for both existing and new coal-fired power plants, given that power generation is by far the largest contributor to aggregate CO2 emissions, itself the most important of the so-called "Green House" gasses believed responsible for anthropogenic climate change.

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The difference between 70 and 65 PPM new 8-Hour ozone limits for the next round of NAAQS amounts to $77 billion dollars in compliance costs.

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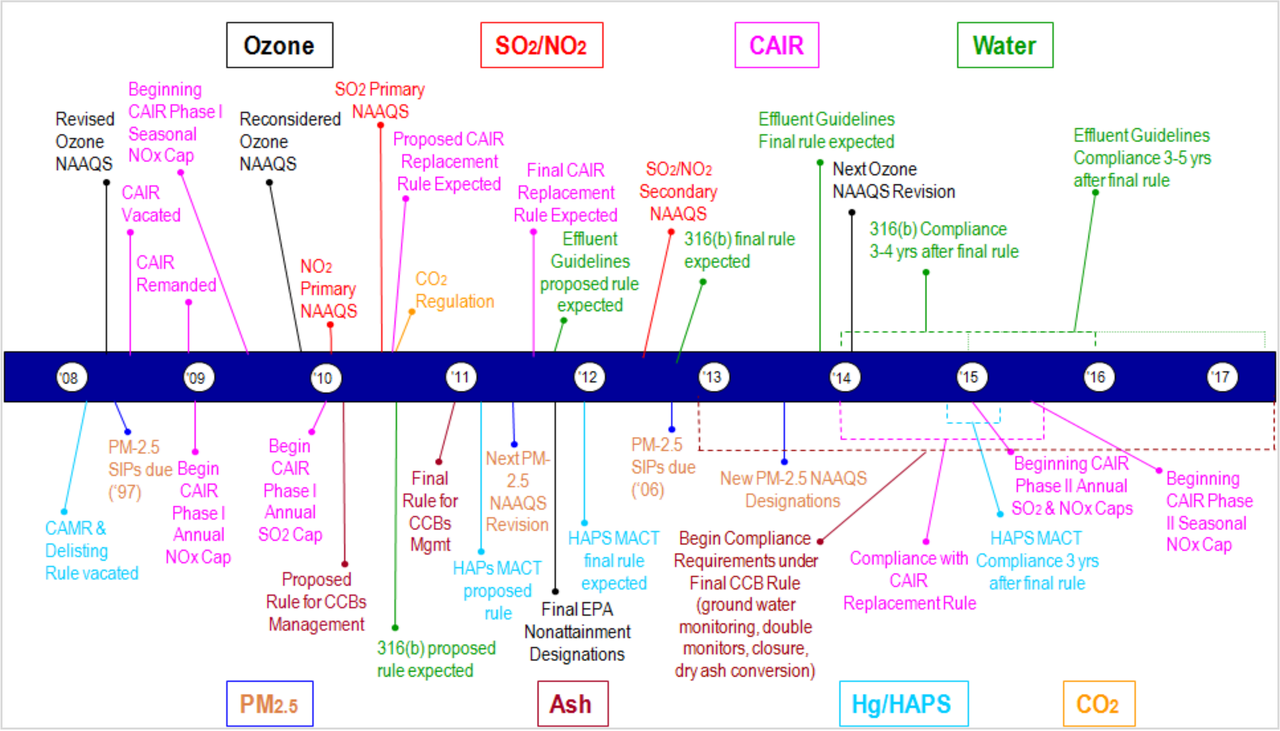
Moreover, a recent EPA decision was made to classify carbon dioxide emissions as a threat to public health—the so-called endangerment finding. This ruling has substantial implications, since it makes CO2 emissions eligible to be regulated under the Clean Air Act, as substances like SO2 and NOx already are under existing cap and trade programs embodied in the Clean Air Act of 1970 and more recent amendments to it.

With the proposed emissions thresholds cited in the endangerment finding, EPA estimates that 400 new sources and modifications to existing sources would be subject to review each year for GHG emissions. Whether this rule carries the day or is superseded by cap & trade legislation, CO2 represents a new source of uncertainty, on top of existing uncertainties associated with the new regulations for NOx, SO2, mercury, and other hazardous air pollutants recently finalized by the EPA and planned to take start taking effect this year.

There exists, however, one omnipresent certainty: that environmental regulations are going to become more as opposed to less stringent; and that these more stringent regulations -- no matter the timing or details -- are going to add to the challenges coal-fired generators face in keeping aging plants with aging workforces reliable and economically viable. The plethora of different regulations facing fossil-fired power generation is shown below.

Environmental Regulatory Timeline for Coal Units



Natural Gas Prices

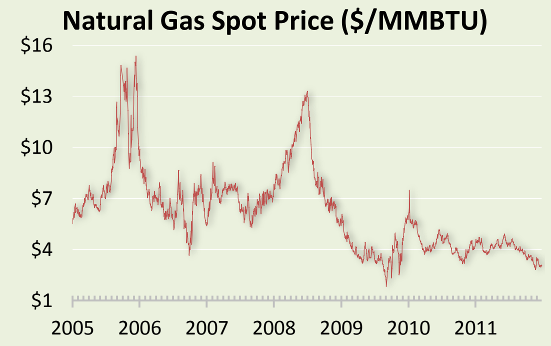
Some observers seem to view the use of natural gas for electricity generation as a general panacea, given its current low cost, cleaner emissions footprint, and the availability of combined cycle generation plants that burn it efficiently and with a relatively low capital cost. There are others however, who view singular reliance on a single fuel source subject to a wide variety of economic, technological, political, and environmental influences on it future price as risky. The most vocal among those with this view might be Duke Energy CEO Jim Rogers, who has referred to singular reliance on natural gas as the "crack cocaine of the electric power industry."

While this view might be discounted as biased coming from a CEO of a company with substantial coal and nuclear resources, there is no doubt that "putting all eggs in the natural gas basket" carries risk associated with unknown future prices and potential price volatility. Natural gas prices have indeed been at a sustained historical inflation-adjusted low of less than $4.00 per MMBtu, but these price levels have been the result of several years of depressed demand and associated abnormally high storage levels.

A recent quote from Public Utilities Fortnightly (Nov. 2011) places natural gas prices in the following context:

Even with recent large natural gas discoveries, significant technology advances, and higher-than-average inventories, the supply of natural gas is not elastic enough to handle the price impact of significant demand increases. As a result, as natural gas prices rise, the economics of environmental compliance investments for coal plants will also change. The result will be to push coal back into the money despite very high costs for compliance with potential EPA carbon emissions limitations and requirements. In any event, the prospects for increased natural gas consumption in the *utility sector are enough to indicate that gas prices likely will rise in the short term. The real questions everyone should be asking are how high and how fast?*

There are also constraints in both electricity transmission and natural gas transportation infrastructure that affect how much coal can be retired and replaced with gas. In the last two years several requests to retire older medium-sized coal units have been rejected by their respective ISO's on the basis or reliability and grid stability concerns. Moreover, much of the transmission capacity that was available for the wind farms that have already been developed is now used up, either in support of those wind resources, or with the greatly increased wholesale power trading that has characterized US bulk power markets since the passage of the Energy Policy Act of 1992.



Daily Henry Hub Gulf Coast
Source: EIA.gov

While substantial new domestic gas supplies have been made available through new "horizontal drilling" technologies for extracting natural gas from shale deposits, it is widely acknowledged that even with expected technology-driven cost reduction, this new source of gas supply is likely to be "shut-in" (i.e. not economical to extract) at price levels below $6-8 per mmBtu. And any future technological gains that further reduce the cost of horizontal drilling are likely to be outweighed by environmental constraints and water scarcity.

So given the reality that market prices will be set by the marginal costs of new supply, it is very likely that we will see substantial increases in natural gas prices over the next year or two as economic conditions continue rebounding and recent historically high storage inventories are drawn down and return to normal levels. While the volatile and extremely high ($13-$15/mmBtu) natural gas prices experienced in the early-middle part of last decade may never return, price increases of less than half of this historical high could make decisions to rely entirely on natural gas not only costly but also calamitous.

But if coal is highly susceptible to current and emerging environmental regulation, and natural gas subject to unacceptable price-risk, what other alternatives remain? While the industry is still reeling from the first two consecutive years of negative demand growth since the Depression, positive demand growth has returned to virtually all areas of the country.

Responding to Demand Growth

The US Energy Information Agency (EIA) estimates that 450 million MWh of additional power that will be needed over the next five years based on the most current estimates of demand growth. What resources are available to meet this level of demand growth? We have already discussed the emissions constraints associated with coal and the price risks for natural gas. Getting additional nuclear plants on-line would be challenging enough if they were already permitted now and a supply chain for reactor cores magically were to appear. And obviously there are only a handful of projects in the US where this is the case. Wind and solar are inherently intermittent, not located near the major sources of demand, and would require substantial additional transmission capacity to even make a dent.

Not only will there be challenges in meeting even the most carefully estimated projections of electricity demand growth, the last 40 years of history for the industry have shown that actual electricity demand often deviates substantially from projected demand, not only in the short-term due to fluctuations in weather and the economy, but due to structural changes affecting our society's use of electricity. And at the current time, there are a variety of major developments either underway or on the near-term horizon driving such structural changes.

Moving demand in the downward direction are developments such as general improvements in end-use equipment efficiency, appliance efficiency standards, and new market mechanisms such as the demand-response mechanisms now implemented for industrial and large commercial electricity users in organized locational marginal price (LMP) markets such as PJM or MISO. But there are also a host of developments exerting upward pressure on demand, including proliferation of consumer electronics, the power needed to support large-scale cloud computing and the electrification of the transportation sector. How these different influences will play off one another over the next two decades is very difficult to predict, and yet massive capital investments must be predicated upon these inherently uncertain projections.

So the key investment questions that need to be addressed by power generators include:

- How fast will the demand for power grow, based on the countervailing influences of demand-side management and end-use efficiency; and economic growth combined with electrification of the transportation sector?
- Which existing power plants are worth the large amounts of new capital investment required to meet current and emerging emissions regulations, and which would be better to mothball or retire?
- What are the most cost-effective retrofit options for existing plants as they apply to required NOx, SO2, Mercury and CO2 regulations?
- How much new generation will be required to meet future demand, given what existing plants are retired and what technologies and fuel source constitute the best choices given the economic, regulatory and technological uncertainties?
- How might investments in energy efficiency and demand-side management (DSM) be used to help mitigate risk and meet financial objectives?
- What are the best strategies for hedging risk, and how do we identify and execute on them?

Modeling and Optimization Methods for Uncertainty and Risk

Traditional trend line forecasting, optimization analysis and sensitivity modeling, while all important, are insufficient in this new era of uncertainty to capture the full range of interdependencies and associated risk. What is needed is an approach that allows power planners to make explicit and documented assumptions about the probability distribution best describing that uncertainty, and get explicit and documented results that describe not only the range of possible outcomes, but the probability of a given outcome as well, and the ability to identify investment strategies that are robust across the full range of interdependent assumptions about the future over the relevant planning horizon.

Optimization is the process of trying to find the best solution to a problem that may have many possible solutions. Most problems involve many variables that interact based on given formulas and constraints. Capital intensive investment decisions made by electric power producers with an array of technological alternatives but many interdependent uncertain variables that will affect the outcome of any given combination of decisions is a classic, if very challenging example of such an optimization problem.

As recent industry experience has demonstrated, detailed chronological dispatch models designed for production costing and merit order dispatch cannot deal effectively with either the array of decision variables or the uncertainties around key modeling assumptions needed to effectively address today's generation investment decisions.

AACG has developed a new modeling framework referred to as Strategic Resource Optimization (SRO) that employs a combination of genetic algorithms to find the best solution for a given set of model objectives, inputs, and constraints and Monte Carlo simulation to explicitly address the uncertainties and associated risks that affect the relationships between today's decisions and tomorrow's unknown states of technology, market behavior and regulation.

Genetic algorithms employ Darwinian principles of natural selection by creating an environment where hundreds of possible solutions to a problem can compete with one another, and only the “fittest” survive. Just as in biological evolution, each solution can pass along its good “genes” through “offspring” solutions so that the entire population of solutions will continue to evolve better solutions.

With genetic algorithms, one does not have to “compromise” model accuracy simply because the algorithms employed cannot handle real world complexities. Traditional solvers (statistical and linear programming tools) force the user to make assumptions about the way the variables in their problem interact, thereby forcing users to build over-simplified, unrealistic models of their problem. By the time the user has simplified a system enough that these solvers can be used, the resulting solution is often too abstract to be practical. Problems involving large amounts of interdependent variables, non-linear relationships, if-then statements, or stochastic (random) elements cannot be solved by these methods.

Another advantage of this methodology is the ability to use "soft constraints" by penalizing those solutions which reflect non-preferred states, but may be a "necessary evil" under some future circumstances. Unlike a hard constraint which must be met, solutions that result in such non-preferred states are penalized by a function in the model which checks for violations and is reflected in the model outputs. Over time, these invalid solutions will be discarded from the evolving population of possible solutions. Soft constraints allow exploration of very good solutions even if they may violate some number of soft constraints, which could be more valuable than a severely sub-optimal solution that meets all the constraints.

Uncertainty and Risk in Electric Power Planning

A large part of the value in this type of modeling approach lies in the ability to capture the interactive effects of several simultaneous sources of uncertainty. For example, the model can be used to demonstrate that even given single point base case assumptions, two different resources of equivalent lifecycle cost can in fact have very different effects on system-wide present value revenue requirements when fuel cost, loads, and new environmental mitigation requirements are treated as explicitly uncertain parameters.

Power generation and emissions compliance investment decisions represent a classic application for the use of these techniques, given the abundant uncertainties, and the potentially large costs of making bad decisions. This is particularly the case for older coal-fired plants where the capital investment and increased operating costs needed to make them compliant with new and emerging emissions regulations may render them uneconomic under some futures states of the world. Moreover, today's planning environment for electric utilities necessitates consideration of a broad range of new power resources. These resources involve very different types of risks, which manifest at different points over their resource lifecycles.

The risk-related differences between resource types include differences inherent to the resources themselves. DSM resources, for example, are decentralized and come "on-line" (i.e. are deployed and affect aggregate demand) in a gradual manner, while generation plants generally come on-line all at once, and (with the exception of planned and forced outages) maintain steady output over their physical or contract lifetime. Wind power can produce large amounts of energy with virtually no variable costs, but the power generated is intermittent, inversely correlated with the time periods of greatest demand and often located far from load centers, consequently placing strains on both existing fossil generation sources and the transmission grid. These attributes can be viewed as endogenous, resource-specific risk characteristics.

There are also differences in the way that different resource types are affected by events in the utility's operating environment. These differences can be referred to as exogenous risk characteristics. Natural gas fired-plants, for example, are vulnerable to increases in natural gas prices, and could be rendered economically inoperable by the effects of such price run-ups. Whatever the specific technology, coal plants are vulnerable to factors such as emissions credits market dynamics and the ability to procure and install scrubber technology in a timely manner. All combustion resources are affected by the potential effects of legislation governing carbon dioxide emissions.

Monte Carlo simulation enables SRO to model the full range of possible outcomes on an annual basis from a given resource acquisition strategy and set of user specified planning uncertainties, then provides detailed tabular and graphic statistical information about the results.

Monte Carlo simulation is a technique that allows outcomes to be modeled as a function of multiple uncertain inputs. The uncertainty associated with key model inputs is quantified and summarized through the use of probability distributions. Monte Carlo simulation generally allows uncertainty about future conditions to be modeled through the specification of discrete and continuous probability distributions.

The results of a Monte Carlo simulation can -- like uncertain input parameters -- also conveyed with probability distributions. These distributions reflect the frequency of a given output value over a given number of model iterations, and result from the model randomly drawing from each input distributions for each iteration. In other words, the modeling results reflect the random and simultaneous interaction of all assumptions specified as probability distributions.

SRO allows any model outputs to be specified as probability distributions. Single point outputs, such as the net present value of revenue requirements are described with histograms. Time-series outputs, such as average system rates, can be described with trended means, standard deviations, and 95 percent confidence intervals. Viewing outputs in this manner allows you to examine not only the expected values for a given objective function, but also the level of variability, as well as the symmetry (or lack thereof) of down-side risks as compared to up-side rewards.

Conclusion

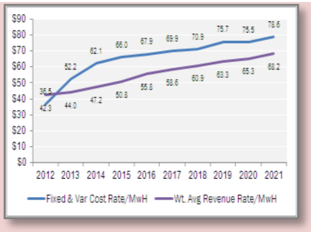
Existing simulation approaches focus primarily on chronological dispatch methodologies based on hourly production costs and locational marginal prices. While these models fulfill their intended purpose, they have limited applicability toward higher-level strategic planning issues such as emissions compliance, future technology options, asset retirements and retrofits and capital planning in an era of unprecedented risks.

SRO is a new framework from Advanced Analytical Consulting Group (AACG) designed from the ground-up to analyze strategic planning issues while considering the future uncertainty affecting every aspect of the power generation business. It combines powerful genetic algorithms with Monte Carlo simulation to offer true stochastic optimization, allowing rigorous analysis of a large number of optimization parameters, variables and constraints, all within a unified environment using the familiar and flexible Microsoft Excel for the user interface.

Unlike "black-box" modeling tools developed when mainframes were the only available computing hardware, SRO provides interactive dashboard views for operational and financial outputs, and dynamic updating for relevant decisions and outcomes as optimization occurs.

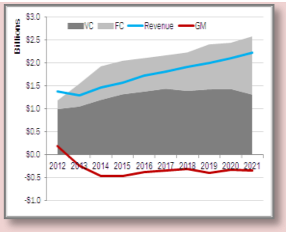
This modeling framework is specifically designed to help you address the most important strategic decisions you are faced with as they affect the viability and financial success of your company as the power industry moves into an era of profound change, vexing uncertainty and unprecedented risks.

PRICING

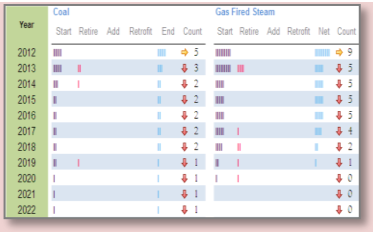


ENERGY FORECAST

FINANCIALS



ASSET STRATEGY



Year	Coal						Gas Fired Steam					
	Start	Retire	Add	Retrofit	End	Count	Start	Retire	Add	Retrofit	Net	Count
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2013						⇩ 3						⇩ 5
2014						⇩ 2						⇩ 5
2015						⇩ 2						⇩ 5
2016						⇩ 2						⇩ 5
2017						⇩ 2						⇩ 4
2018						⇩ 2						⇩ 2
2019						⇩ 1						⇩ 1
2020						⇩ 1						⇩ 0
2021						⇩ 1						⇩ 0
2022						⇩ 1						⇩ 0

TRACKING RENEWABLE MANDATES