The Convergence of Environmental Issues—From Ecosystem Impacts to Technology Solutions

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Introduction

Complex systems, including banking systems and electricity transmission and distribution, require careful long-term planning in order to prevent potential breakdowns. Any failure to operate as expected can have significant effect on the economy, environment, society, or a combination of all of three. These breakdowns may be because of an unforeseen inability to deal with new needs, or incompatibility with new technology. One notable recent breakdown in complex systems is the electricity blackout in the northeast U.S. during the summer of 2003. Another, much anticipated, near breakdown was the "Y2K bug" of 2000.

This paper will discuss the need for better foresight, and creative long-term planning of complex systems, specifically electricity generation systems. First, the paper will describe complex systems, and the need for such systems to be adaptive. Second, the paper will present and discuss specific examples of how, in electricity generation systems, planners can take advantage of complexities and manage multiple environmental problems with one solution.

Background

Complex systems abound in the real world. Biological systems, banking systems, communications networks, the energy system, have all been described as complex or complex adaptive systems. A special class of complex adaptive systems relies on several embedded technologies to meet the societal objectives of the system. The energy system, observation/prediction information systems for the natural world (i.e., weather forecasting), and space enterprises are part of this subset. Many of these complex, technological systems are based on technologies established decades ago—the power sector relies on technologies first developed commercially in the 1830's—which form an adaptive network within a set of ill-defined boundaries. These networks are adaptive in the sense that they can and have changed over time; However, attempts to introduce radically new technologies to address emerging needs—needs not envisioned during the system's genesis—are often met with failure or require long lead times before such technologies penetrate significantly and become routine commercial practice. Development of these new technologies is often supported by public and private sector R&D programs that struggle to demonstrate the benefits that might be derived by successful development of new technologies and that use market failures to justify public sector support. This is particularly true of disruptive technologies, those that may utterly transform how a society provides for its needs. In the power sector, both distributed generation technologies and various forms of co-production (including integrated gasification—combined cycle systems that co-produce power, chemicals and fuels) have been cited as examples of disruptive technologies.

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We routinely seek to assess the comparative risk of competing technologies. However, while valuation methods have proliferated, none are well-proven and some lack rigor in application. Life-cycle assessments, material flow methods, real option analysis, R& D roadmaps are all used to analyze competing technological systems. In addition, many approaches tend to operate at the level of an individual technology and miss important questions about how such a technology integrates into a system of technologies which must then fit—in addressing a societal need—into a larger, complex (and largely non-technical) system.

Global climate change is one issue that crosscuts many technologies, and dealing with the full implications of the problem may require a complete transformation of our society. The issue is further complicated by our incomplete understanding of climate science. Pathways to addressing the issue include mitigation (technologies or approaches to reduce the change) and technologies and approaches to adapt to any changes that occur. These strategies go beyond technologies and include policies, regulations, creation of new markets, possible evolution of new ethical structures in society, etc. Much of the work to date that attempts to analyze both the issue and responses to it could be characterized as attempts to find the boundaries—to understand what should be included in looking for solutions and what may be excluded.

Examples of convergence in the power industry

Convergence is finding those points where complex systems intersect, where multiple issues come together. One aspect of the interaction of climate and energy technology is the convergence between fluctuations in natural cycles, such as the hydrologic cycle, and the performance of human-centered systems such as electricity production, transmission, and distribution. The National Energy Technology Laboratory (NETL) co-hosted a workshop with National Oceanic and Atmospheric Association that explored the nexus between energy and the weather. A number of presenters cited examples where weather information clearly could impact decision-making within the power sector at both the regional level and for an individual facility. Similarly, availability of water has become a key issue in determining a location at which to site power plants. Policies that protect water quality can complicate the decision. The intersections of air sheds with changing weather patterns may impact the ability of a plant to meet stipulations within its permit while providing power during times of high demand and high market prices for that power.

Another instance where natural cycles are converging on the performance of the power sector is in the interchange of waste. The electricity production cycle generates waste at many points, and the storage, or disposal, of this material impacts the hydrologic, nitrogen, and carbon cycles. In the U.S. alone, 100 million tons of coal combustion byproducts are generated each year—70 million tons of which ends up in impoundments and landfills. Changing air quality regulations affect the quality of this waste and its impact on the environment. For example, low-NO_x burners that use ammonia generate a high-nitrogen waste, and nitrogen leaching from waste can impact nearby watersheds creating algal blooms that impact aquatic ecosystems. Mercury controls are likely to yield a high-mercury byproduct which could impede current recycling efforts by forcing plant managers to follow hazardous waste disposal protocols.

As the power sector begins to diversify existing power sources, from predominately coal or natural gas fired stationary plants to distributed generation and an increased percentage of renewable energy sources, the impact of power production on the carbon cycle will in many ways decrease. But at the same time, this switch will also require changes in regional land use patterns. For instance, large wind farms may become common. And these changes may also, in turn, affect climate directly. A preliminary climate modeling study by David Keith of Carnegie Mellon University suggests that increases in wind power affects climate causing climate change[2].

Daniel Esty, a professor of environmental law at Yale University, has said, "Climate change is 500 times more complicated than any other environmental problem we have faced" and as such it represents a prime example of convergence in many senses. Each of the examples cited so far has direct ties to the climate issue. In many ways climate change is forcing us to think about environmental problems and solutions in terms of convergence. The convergence of environmental issues can be seen as an opportunity for creative problem solving and generate interest in tackling multiple environmental problems with synergistic solutions.

Synergistic Answers in the Power Industry

There are several examples of this convergence in solutions already in practice in the power sector, including the reuse of carbon dioxide. Carbon dioxide (CO_2) has been used for enhanced oil recovery in the United States since the 1970s, well before there was known value in storing CO_2, however CO_2-EOR, and to a lesser extend enhanced coalbed methane recovery with CO_2, has gained increasing attention as a greenhouse gas mitigation strategy when that uses waste CO_2. Currently only about 10% EOR operations in the U.S. use waste CO_2 from natural gas reprocessing and fertilizer plants, but that fraction is predicted to increase[3]. In lieu of waste CO_2, the gas can be harvested from natural deposits, however with the current industrial price for CO_2 approaching $200 per ton[4], waste CO_2 utilization is becoming cost-competitive, independent of environmental benefits. Research in this area is beginning to explore the possibility of co-sequestering criteria pollutants along with CO_2, theoretically eliminating the need and costs associated with multiple environmental control technologies.

Electricity generation impacts land in many ways, from the mining process to waste disposal issues—it can leave a legacy of environmental and safety problems. Several utilities have integrated land application of coal combustion byproducts with restoring native, carbon sequestering habitat. Two NETL-funded projects take the solution the next step and attempt to holistically address environmental problems. At a TVA plant in Kentucky, researchers are growing a test plot of trees using flue gas desulphurization product as mulch to keep weeds under control and irrigating the plants with high-nitrogen water from one of the wastewater ponds. Another project in West Virginia is attempting

[2] Personal Communication with David Keith, currently unpublished study, January 2004.
[3] 1998 data. From Barriers to Overcome in Implementation of CO2 Capture and Storage (1) Storage in Disused Oil and Gas Fields, IEA Greenhouse Gas Report Number PH3/22.
[4] Personal communications with Scott Stevens, Advanced Resources International, March 2003.

to both reclaim an abandoned mine site and mitigate water quality with a land application of coal combustion byproducts. The goal is restore habitat and mitigate water quality problems, generating ecological assets that can then be traded as “credits” in emerging environmental markets.

NETL recently conducted a study that compared the costs and performance of an Integrated Gasification Combined Cycle (IGCC) plant employing different strategies for addressing the challenges of water availability and climate change. As expected dry cooling had a greater impact on system performance when compared to wet cooling, and carbon sequestration had a greater impact that either cooling option. However, when a hydrate desalination process, in which CO_2 from a Selexol unit is used in combination with aqueous brine harvested from a geologic reservoir to form CO_2 hydrates which can then be stored in the reservoir, was used, the performance was more efficient than CO_2 capture and sequestration alone. The costs of this scenario were increased; however the hydrate formation process yields potable water, which can then be sold, making this novel approach more cost-effective. Although the study was theoretical, it illustrates the benefits of jointly tackling multiple environmental issues.

FutureGen type plants will enable convergence in solutions through state of the art technology. These IGCC-based plants will be designed to produce hydrogen from coal—hydrogen that can then be used for electricity production with steam turbines and fuel cells, or after refining, as transportation fuel. The CO_2 will be used for EOR or sequestered in geologic formations. Future energy plants may also be designed with the flexibility to use different feedstocks, allowing for incremental increases in the percentage of renewable fuels. FutureGen is seen as the first step towards a hydrogen economy, and provides an opportunity to shrink the environmental footprint of fossil fuels used in both the power and transportation sectors.

Conclusion

The convergence of environmental issues appears at first to be a daunting obstacle. Climate change itself is an unimaginably complex issue, and it is difficult to understand the scope of the problem or its potential impacts on the power sector. Devoting limited resources to addressing long-term issues like climate change seems impossible when faced with other immediate problems like water quality and availability or waste disposal. However, the convergence that presents such a problem can also be seen as an opportunity. The integrated nature of natural systems makes synergistic solutions possible. Managers with limited resources can find opportunities to take a step towards addressing climate change while solving some of the more immediate environmental problems.