Electric Power Networks Efficiency and Security, Edited by Lamine Mili and James Momoh.
ISBN 0-471-XXXXX-X

Chapter XYZ

Distributed Generation and Momentum Change in the American Electric Utility System: A Social-science systems Approach

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1. Introduction

The past two decades have witnessed significant change in the American electric utility system. The once-stable, secure, and regulated system no longer retains as much government oversight as in the past, being moved increasingly by the invisible hand of a competitive marketplace. While proponents of the evolving new system laud many of its benefits, others point to disturbing signs of increased susceptibility to terrorist attacks (and other disruptions) and decreased overall reliability. Novel approaches for restructuring the utility system continue to be made, reflecting the uncharacteristically fluid state of affairs that exists today.

This chapter explores the long-term trends in the electric utility system and the beginning of efforts to restructure it. To frame the analysis, the chapter draws on a non-engineering version of the systems approach that has been fruitfully developed for understanding socio-technical endeavors. The social-science systems approach provides a macroscopic way to view long-term trends. Going beyond consideration of engineering concerns, it encourages an understanding of the stakes, interests, and actions of a host of participants who make and use technologies. Such a view suggests that engineering concerns held by managers and technical leaders often do not necessarily determine the way a technological system emerges. Rather, economic, social, and political factors may play more important roles in moving elements of a system.

Applying the social-science systems approach, the chapter views the present time as a rare opportunity in which entrepreneurs can pursue implementation of a nontraditional type of generation technology. Known as distributed generation (DG), the family of technologies consists of small-scale, decentralized hardware that, if structured properly, can provide greater reliability, security, and efficiency to the utility system.

The chapter begins with a discussion of the social-science systems approach, highlighting the notion of momentum, a combination of technical and social components that give a system an apparent direction, speed, and inertia. It describes the origins of momentum in the system and explores the reasons why that momentum has diminished dramatically starting in the 1970s. To help create new momentum, proponents of distributed generation seek to gain acceptance for a host of potential benefits while eliminating impediments and uncertainties. The chapter concludes with an analysis of DG within the business environment and a suggested model that may succeed in advancing the new technology within a system that develops new momentum.

2. Overview of Concepts: Using the Systems Approach to Understand Change in the Utility System

To gain a sense of the development of electric utilities, we employ the social-science version of the systems approach that was originally conceived of by Thomas Hughes. In his influential *Networks of Power: Electrification in Western Society* [1] and other publications, Hughes posits that the generation, transmission and distribution of power takes place within a technological system. The system, however, goes beyond consideration of engineering elements (though they are components), including a "seamless web" of factors characterized as economic, administrative, educational, legal, and technical. Modern technological systems weave these considerations into one fabric, as system-builders (often business managers) seek to "construct or ... force unity from diversity, centralization in the face of pluralism, and coherence from chaos."[2]   When successful, the managers help the system expand and flourish. At the same time, the system closes itself. Put differently, as the system grows, the influence on it from the outside environment diminishes, largely because the system's scope has enveloped elements that might have altered it.[3]

The systems approach also comprehends the notion of momentum, which Hughes describes as a mass of "machines, devices, structures" and "business concerns, government agencies, professional societies, educational institutions and other organizations" that contains "a perceptible rate of growth or velocity."[4] In other words, momentum can be viewed as a "mass of technological, organizational and attitudinal components [that tend] to maintain their steady growth and direction."[5] The inclination of a system to evolve in a certain direction stems from the actions of a host of participants, such as regulatory bodies, educational institutions, the investment of money in operating hardware, and the efforts and industry culture of people working within the system. Momentum may also be aided by barriers to entry that favor established players, market and corporate dominance in an industry, and the lengthy lead times needed to develop new technologies. At the same time, momentum can grow due to the inertia of customers who may see few motivations to change buying habits, as well as due to market education and difficult-to-alter product life cycles. Together, these elements encourage business as usual and the noticeable demonstration of momentum. Hughes further argues that momentum can be abetted through employment of "conservative" inventions, namely new hardware that maintains the existing system. Leaders of system momentum clearly seek to preserve their dominance, and they avoid encouragement of novel and "radical" technologies that would displace their control. For example, Internet telephony and cell phones could be considered radical inventions by the corporate leaders of the conventional wired communications network.

In short, the social-science systems approach views the development of systems as the result of managers' efforts to command elements that exploit the human, natural, and technical environment. As systems gain momentum and mature, they resist change. Even so, momentum does not imply determinism (which suggests that social or technical elements determine technological development) or autonomy (which implies that technologies evolve independent of human action). Instead, system momentum can often be changed due to a confluence of technical, economic, and political factors. As will be described in this paper, the electric utility system has recently seen its momentum change in a way that provides opportunities for the introduction of distributed generation facilities.

3. Application of Principles: Origins and Growth of Momentum in the Electric Utility System

The electric utility system had humble beginnings near the end of the nineteenth century when the United States saw creation of a flourishing corporate-based economy. Large multi-level companies exploited the potentials of new communications and transportation technologies to manage production and distribution of quantity-produced goods, thus overthrowing the once-common family-owned and operated businesses. The railroad industry served as the epitome of modern enterprises that exploited new technologies to eliminate regional competition, to gain octopus-like political and economic power, and to earn the contempt of many of its customers.[6]

The fledgling electric utility companies that emerged after Thomas Edison opened his small Pearl Street, New York City power station in 1882 did not appear to be in the same class as the large, and often reviled, railroad corporations. After all, Edison conceived of a decentralized system within cities that included scores of relatively small generation plants, each providing direct current (DC) power to individual businesses. But rapid innovation in electric power production equipment altered the relatively benign character of business. Adopting alternating-current (AC) transmission and steam-turbine technologies, early utility entrepreneurs quickly found they could emulate trends in other industries. Through the use of transformers made available in the late 1880s, AC transmission allowed companies to distribute high-voltage power over long distances. And in the first decade of the twentieth century, utility managers began employing compact steam turbines as prime movers that further encouraged centralization because the new machines offered tremendous economies of scale. (Put simply, as the turbines, connected to generators, produced larger capacities of power, the unit cost of electricity declined over a broad range of output.) Becoming the core conservative technologies used in the electric utility system, steam-turbine generators and alternating current technologies yielded exponentially growing supplies of power, produced at higher thermal efficiencies and lower costs and prices. Electricity changed from being viewed as an expensive product used only in special situations to a cheap commodity that

Americans considered a necessity and right. While residential customers in 1892 paid about 544 cents per kWh (in adjusted 2004 terms), they only paid 10 cents for the equivalent amount of electricity in 1970.[7] (Figure 1)

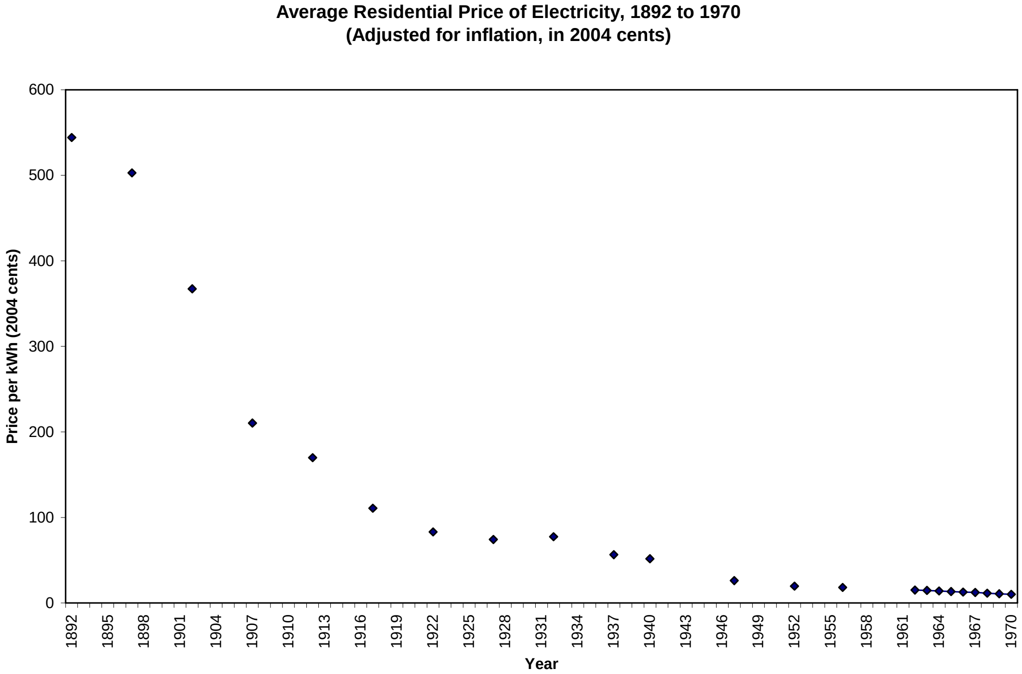

Figure 1: Average residential price of electricity, 1892 to 1970

Employment of conservative, slowly improving hardware enhanced the utility system's momentum. But non-engineering elements also did. Because it explicitly addresses such elements, the social-science systems approach focuses attention on the social nature of technological evolution. In the case of the utility system, the creation of regulatory bodies constituted a major driver of momentum. Unlike the railroad industry, which became regulated by government to stem perceived abuses, the electric utility industry actually sought oversight by state officials. As early as 1898, industry leader Samuel Insull argued that government oversight would offer legitimacy to power companies as monopolies. Once companies won dominance in a region, regulation would effectively create a barrier to entry and allow them to solidify their control. Government oversight would also reduce financial risks because utility commissions would be required not only to protect customers against monopoly abuses, but to ensure that utilities earned enough money from customers to provide good service.[8] Winning the day, Insull saw state regulation spread rapidly after New York and Wisconsin created the first public utility commissions in 1907. Soon after the Progressive era ended during World War I, the quality of state regulators declined markedly, enabling utility managers largely to run the power system with only the appearance of dutiful oversight. Utility managers had effectively "captured" the regulatory mechanism, which helped them control a system that was developing significant momentum.[9]

The system's momentum also grew because of the support of other stakeholders within society. Investment bankers, manufacturers of electrical equipment, educational institutions, and customers found reason to encourage development of an industry that employed large-scale technologies and appeared to bring universal benefits.[10] In other words, a variety of social groups implicitly supported a big, technology-dominated and regulated electric utility system. By the 1970s, the utility system had gained a huge amount of momentum that appeared unalterable.

Politics and System Momentum Change

And yet, momentum changed significantly, starting in the 1960s and 1970s. First, for a number of managerial and technical reasons, manufacturers could no longer obtain significantly higher thermal efficiencies or economies of scale from new steam turbine-generators. This phenomenon, called "technological stasis" or an apparent end to progress, became critical during the "energy crisis" of the 1970s, when fuel costs (especially oil costs, but also costs of other fossil fuels) skyrocketed. Unlike in the past, when improvement in the power-producing technologies mitigated hikes in labor and capital costs, stasis meant that utilities needed to request rate increases from formerly quiescent (but now increasingly activist) regulatory bodies. (Figure 2) Higher prices motivated conservation and energy-efficiency efforts. Electricity consumption grew at negative rates for a few years, while the long-term annual growth rate from 1973 to 2003 dropped from the decades-old rate of about 7 percent to just 2.4 percent.[11]

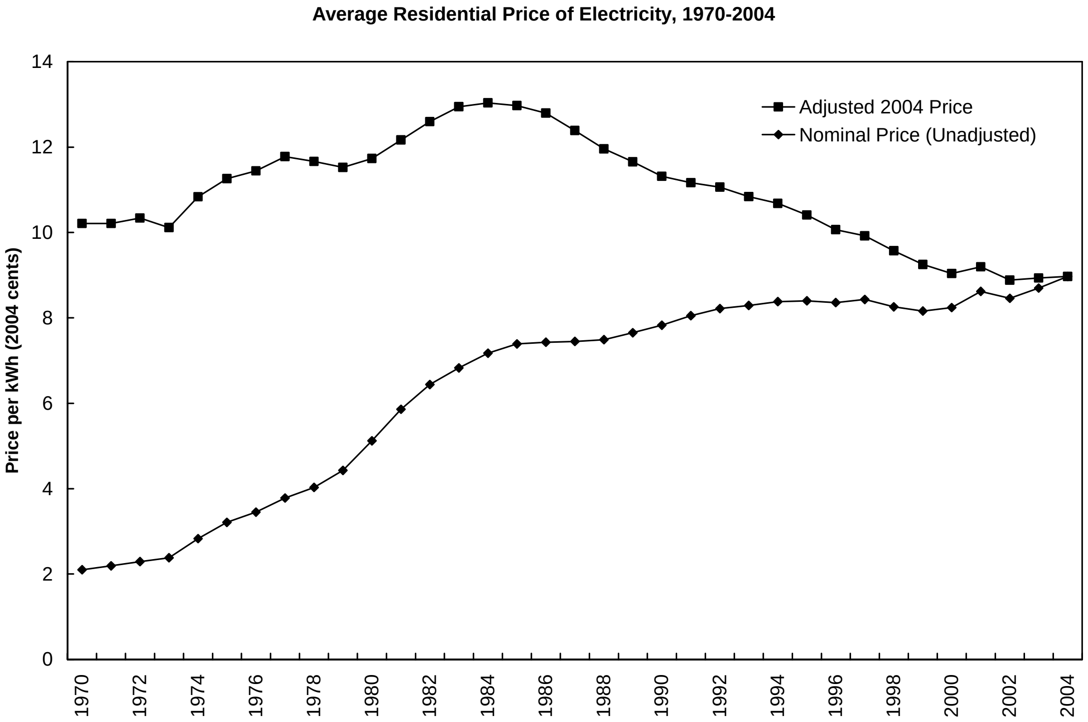

Figure 2. Average residential price of electricity, 1970-2004

The economic turmoil created by the energy crisis spurred policy makers into action. Making energy policy a top priority, President Carter won passage in 1978 of several laws that sought to encourage energy efficiency and increase domestic energy production. Though viewed as fairly tame, one of the laws, the Public Utility Regulatory Policies Act (PURPA), had at least three unintended consequences: it unexpectedly spurred creation of radical technologies; it began the process of deregulation; and it challenged the control held by power company managers. In the process, the law helped change the momentum of the utility system.

The salient portion of PURPA initially appeared to offer no threat to utility companies. It primarily offered incentives for the use of cogeneration plants—units that often generated less than 100 MW of power—about one-tenth the capacity that new utility-owned nuclear and fossil units yielded. But the smaller plants proved economically practical, even without economies of scale, because they employed waste heat for industrial processes or space-conditioning. Obtaining double duty from raw fuel in the form of two valuable products (electricity and process steam), cogeneration plants demonstrated an overall thermal efficiency rate of 50 percent or higher, which compared favorably to the 40 percent figure achieved by the best utility-owned power plants. President Carter hoped more widespread use of such plants would reduce the amount of energy used in power production. A related portion of the law also encouraged development of renewable technologies that used water, wind, or solar power to generate electricity. Unusually successful, this portion of PURPA (along with incentives offered by some states) helped drive down the cost of power produced by solar photovoltaic panels by about 70 percent between 1980 and 1995[12] and wind turbines by a similar margin. Most significantly, cogeneration plants and some wind plants offered power at costs that compared favorably with (or was priced cheaper than) power generated by conventional utility plants.[13]

In the language of Hughes' systems approach, these PURPA-inspired, small-scale technologies constituted radical technologies that helped alter the utility system's momentum. Through their use, the technologies enabled nonutility companies to compete (at least in the generation sector) with utilities that previously enjoyed vertically integrated monopolies. At the same time, the unintended experiment with competition encouraged some regulators and legislators in the 1980s—a period when several other industries (i.e., the airline, telecommunications, and natural gas industries) had been deregulated—to suggest that increased competition and less regulation would benefit participants in the electric utility industry. The Gulf War of 1991 spurred further legislative changes, as Congress passed a modified form of President George H.W. Bush's energy plan that opened up the electricity transmission network so it would serve as a common carrier. The Energy Policy Act of 1992 also allowed states to begin competition on the retail level. Taking advantage of the law, 23 states (and the District of Columbia) had established mechanisms (by September 2001) for a competitive marketplace for electricity.

These events suggest that momentum of the utility system has been altered significantly. Perhaps most important, the shifting momentum has displaced utility managers as the key controllers of the system. No longer in charge of the large-scale, gradually improving, and conservative generation technologies, the managers ceded political and economic power to entrepreneurs who, in some cases, use small-scale conventional and renewable energy technologies. From 1992 to 2003, the portion of the country’s power capacity managed by nonutility firms grew from 1.5 percent to 34.7 percent.[14] At the same time, utility managers lost the legitimacy provided by regulation of their companies’ status as natural monopolies and have been forced to alter their business culture and practices to deal with life in the competitive market. And as other stakeholders (such as financiers, equipment manufacturers, and educators) saw momentum change, they shifted their allegiances to reflect the new environment. New stakeholders also entered the arena. Environmental advocates in many states, for example, won seats at negotiating tables and influenced the terms of restructuring laws, which often included expenditures of funds for renewable energy and energy-efficiency technologies.[15] Meanwhile, the California electricity crisis of 2000 and 2001, along with the Enron scandal and the massive blackouts of 2002 and 2003, focused new attention on the changed nature of the utility system and caused policy makers to rethink their enthusiasm for a free market of electricity. In the following years, the Federal Energy Regulatory Commission and state policy makers have been feuding about new scenarios for operation of the system and for dealing with specific problems, such as the underinvestment of capital in an increasingly fragile-looking transmission network.[16] Using the language of the social-science systems approach, it appears that the human and technical components of the utility system have been severely altered, forever changing what had been substantial momentum.

4. Application of Principles: The Possibility of Distributed Generation and New Momentum

The semi-chaotic state of affairs that exists in the early twenty-first century has enabled distributed generation to gain a foothold. In fact, one can view the present time as a rare inflection point when stakeholders started negotiating a new paradigm (or at least part of a new paradigm) and began establishing momentum that diverges from what existed for almost a century. Distributed generation facilities constitute a collection of decentralized, modular, smaller, and onsite power production technologies. Supporters of DG argue that the decentralized plants (often having capacities of between 1 and 100 MW) offer less expensive, more efficient, more reliable, more flexible, and less environmentally damaging alternatives to traditional utility-owned power plants.

DG technologies are often classified by net generation capacity (ranging from 1kW to more than 100 MW) and location. Because a significant number of electricity generators can be located onsite, DG encompasses a wide range of technologies. Many renewable energy systems—such as wind turbines and photovoltaic technologies—are small and decentralized, and they serve as examples of DG technologies. Even generation equipment that employs fossil fuels, such as natural gas and coal, can be considered as valuable DG resources, especially when they exploit waste heat generated through combustion or fuel conversion. These include cogeneration plants (also known as combined heat and power [CHP] facilities) that were originally encouraged by PURPA. They may also consist of very small steam turbines known as microturbines that produce power in the range of 25 to 500 kW while employing waste steam for water or space heating needs.[17] Phosphoric acid fuel cells are also being pursued as DG technologies. The devices (which are being tested in 200 kW to 11 MW sizes) take in hydrogen-rich fuel and create electricity through a chemical process rather than by combustion, thus yielding few particulate wastes.[18] The process also yields heat, which can be used as a profitable by-product. Beyond these DG technologies are modular internal combustion engines that run on diesel fuel or gasoline. In their smallest versions (about 1 kW), they provide backup power for recreational vehicles and homes. In larger packages, these engines provide backup power for hospitals and other large commercial enterprises. DG facilities may be established as isolated "islands"—disconnected from the transmission grid—or attached to it. In the latter case, they may constitute the primary producers of power for a user or serve as backup units. They can also be set up to add power to the grid for use by other customers.

The economic viability of these DG technologies has improved in recent years. Technological advances in microturbines and reciprocating gas engines have lowered the cost and increased the efficiency of the small scale generation technologies.[19] Advances in net metering, fuel conversion technology, and thermal engineering have accompanied developments in automation and control, improving the economy of small units and reducing the need for periodic maintenance and inspection.[20] Small system technology can also be mass produced at a lower unit cost. For example, numerous companies offer fuel cell technology, which is viewed as having virtually no emissions, in ready-to-connect packages. Many policymakers also perceive gas turbines as having low initial investment, steam generation capabilities, and installation flexibility.[21]

The wide variety of DG technologies presents challenges for measuring the extent that such technologies are currently used. For instance, the Energy Information Administration characterized only 0.5 percent of electricity generation in 2000 as "non-utility" generation. The same study concluded that cogeneration systems in industrial sectors produced 3.6 percent of electricity for their own use. In contrast, an Electric Utility Consultants study observed that distributed generation units—classified as decentralized generators of capacities between 1 and 60 MW—provide an aggregate capacity of 234 GW produced from about 12.3 million units.[22] Similarly, the Electric Power Research Institute estimated in 1999 that more than 50 GW of electricity in the United States came from DG units.[23] A 2002 report on DG from the International Energy Agency noted that the generating capacity of diesel DG technologies in the United States was over 100 GW.[24] Likewise, a white paper by the consulting firm Arthur D. Little estimated the 1999 capacity for reciprocating engines and small gas turbines in North America was roughly 60 GW.[25]

Nevertheless, proponents of distributed generation emphasize that DG technologies should not be viewed as a replacement for the current power grid. The U.S. Combined Heat and Power Association notes that DG would not serve as a reliable substitute for all large, centralized power plants, since it is unlikely to meet the needs of customers in urban areas with severe land, permitting, and siting constraints. Moreover, the fact that small and modular generators can be more efficient and less costly does not negate the useful role of large and centralized generators on the power grid, since in many situations large plants placed near points of consumption maximize thermal efficiency. Gary Mittleman, President and CEO of Plug Power, a fuel cell manufacturer and advocate of DG, acknowledged that power "plants and the grid will remain a part of our infrastructure."[26] Similarly, the American Wind Energy Association clarifies that the use of wind turbines is primarily intended to augment rather than replace, the grid.[27]

Consumer advocates note that DG technologies can also provide more efficient electrical power. The transmission of electricity from large and centralized plants typically wastes between 4.2 and 8.9 percent of the electricity, since wire resistance, inconsistent enforcement of reliability guidelines, and growing bottlenecks all degrade the effectiveness of transmission systems.[28] Since customers pay a share of the cost of the transmission system in their electricity bills, employment of localized generation equipment can conceivably yield affordable and higher quality power. Moreover, self-generators can sell excess power to the grid and earn revenues, especially during times of peak demand.

Additionally, industrial managers, commercial business owners, and contractors have begun to recognize advantages of local power generation. Combined heat and power technologies permit these power users to recycle thermal energy that would normally be wasted. Energy-intensive industries, including iron and steel foundries, chemical processing facilities, and paper and pulp manufacturers already use CHP technologies to maximize the efficiency of their onsite electricity generation. Office and industrial managers have also begun to use CHP technologies to reuse energy normally needed for district heating (where excess heat is pumped through buildings in lieu of electrically produced heat) and surplus power provision (where the extra thermal energy from combustion is reused to produce more electricity). CHP technologies have also been proven to enhance industries working in aquaculture, greenhouse heating, desalination of seawater, increased crop growth and frost protection, and air preheating.[29]

Beyond efficiency, DG technologies can provide more reliable power for digital and telecommunications industries that require uninterrupted service. One study conducted by the Electric Power Research Institute noted that power outages and quality disturbances cost $119 billion in 1999, with between $21.2 and $33 billion lost in California and New York alone.[30] A comparable study undertaken by the American Superconductor Industry estimated that power outages cost California more than $10 billion every year.[31] The cost of a two-hour blackout for chip manufacturing and semi-conductor industry alone can cost as much as $48 million.[32] These numbers help explain why several companies already rely on DG facilities to ensure consistent power supplies.

Surprisingly, perhaps, DG facilities offer enhancements for the transmission of power. By producing local power for users, DG technologies can decongest the grid by reducing demand during peak times, one of the causes of the 2000-2001 California crisis and the 2003 blackout on the Eastern seaboard.[33] Most important, by constructing large numbers of decentralized power facilities rather than a few large plants located distantly from load centers, DG use can reduce the need to upgrade and expand transmission facilities during a period when investment in such facilities remains restricted due to siting policies and local opposition. And in an increasingly security-minded era, proponents further argue that DG technologies may enhance protection of the grid. Decentralized power generation reduces the terrorist targets that large nuclear and conventional facilities and natural gas refineries offer. It also helps the system by diversifying fuels, enhancing emergency stand-by generation, and better insulating the grid from failure if a large power plant goes down due to an attack.[34]

Finally, some environmentalists and academics have argued that DG technologies provide ancillary benefits to society at large. Large, centralized coal- and gas-fired power plants emit pollutants, such as carbon monoxide, dioxins, sulfur oxides, particulate matter, hydrocarbons, and nitrogen oxides. For many years, the Environmental Protection Agency (EPA) has reported the correlation between high levels of sulfur oxide emissions and significant health effects, including cancer and asthma. Moreover, combustion of fossil fuels tends to create acid rain, which suppresses crop growth and leeches nutrients from the soil. Because larger plants concentrate the amount of power they produce, they center their pollution and waste heat, which destroys fragile ecosystems and reduce marine biodiversity. On the other hand, some recent studies have confirmed that widespread use of DG technologies substantially reduces emissions: A British study estimated that domestic CHP production reduced carbon dioxide emissions by 41% in 1999. A report on the Danish power system argued that widespread use of DG technologies have reduced emissions by 30% from 1998 to 2001.[35]

Impediments to Decentralized Electricity Generation

Despite its potential benefits, the transition to a new DG paradigm will not occur effortlessly because of the existence of social, technical, political, and business related impediments. The most significant impediment may be the belief that decentralized units cost more than large centralized facilities. Cost projections for electricity often only include the capital cost of a generator, maintenance, and fuel. Such estimates exclude "external costs" in the form of pollution, decommissioning, and price swings for fuel and labor. These pricing schemes also fail to include many of the potential benefits—including reliability, efficiency, and security—that DG systems can provide. Consequently, policymakers and consumers often think that renewable technologies (in particular) cannot compete effectively on costs with traditional fossil fuel sources of electricity.[36]

The largest technical impediment consists of problems related to the connection of DG technologies to the grid. This interconnection conundrum really constitutes a set of aggregated technical problems: voltage control (keeping voltages within acceptable ranges), the balancing of reactive power (properly synchronizing power within the grid), and safety (ensuring the protection of people working on the grid, especially when parts of it are blacked out). Customers using DG technologies today often rely on custom-designed electronics packages to resolve these problems. But the large cost to create such packages serves as a disincentive for many users. Recognizing this problem, an IEEE Standards Coordinating Committee has begun developing rules for interface technologies that would enable DG users to "plug" into the grid directly and safely. However, agreement on the specific details of the new standards remain years away. As of January 2, 2002, the list of committee members included 385 names of people, representing scores of investor-owned and public power utilities, manufacturers, government laboratories, state agencies, and consultants. Each player sees advantages and disadvantages to acceptance of any single technical standard, meaning that a consensus will be difficult to fashion. The problem again illustrates the social nature of technological change, as different players in the system view benefits and costs differently.[37]

Possibly more important, regulatory and political inertia within the United States, in the form of financial subsidies and incentives, still favors fossil fueled electricity generation from large plants. For example, the tax code contains $13 billion in production, research and development tax credits for energy production in the years 2000-2004. Of that amount, fossil fuel technologies received $10.2 billion of incentives, nuclear power users got $1.5 billion, and renewable energy technologies were allocated only $400 million.[38] This unbalanced subsidization means, for instance, that wind energy technologies may not improve as rapidly as they did in the past.[39] Similarly, lingering monopoly rules and discriminatory rate structures (often taking the form of exit fees, backup tariffs, and connection surcharges) still exist in many states and create political obstacles to investments in DG technologies. Customers who seek to use DG often face extra charges imposed by utilities that seek to recover stranded costs.

In addition, many old coal-fired power plants have been exempted from the 1972 Clean Air Act. This exemption gives them a further advantage because it allows them to operate under older environmental standards, unlike DG technologies that must meet current (and more stringent) permitting and siting requirements. [40] Similarly, the Congressional Budget Office notes that the costs of environmental monitoring for DG technologies would be more costly than enforcement of regulations for large central plants because power generators would be more dispersed, and that utilities would have to invest large amounts of money in computer software and transmission upgrades to manage DG facilities on the grid.

To be sure, some of these impediments can be mitigated by effective public policy. As noted, DG implementation suffers because some of the costs involved in producing power in the conventional sense are not borne directly by the companies that create those costs. Known generally as “externalities,” these costs are imposed on society and are not included in the cost of conventional methods to produce power, thereby skewing conventional analyses of alternative power choices. However, government policies can impose taxes and other disincentives on activities that cause perceived harm to society. At the same time, they may provide incentives for use of technologies that will enhance public health, security, power reliability, and welfare—benefits that are difficult to quantify using traditional economic analyses. Several policy initiatives have been suggested for improving the likelihood of obtaining the society-wide benefits of DG implementation. They include creation of interconnection standards and contractual requirements so DG owners can gain access to the power grid at a fair cost and with reasonable, uniform technical requirements. Such an approach would minimize the need for expensive, time-consuming efforts to manufacture custom-designed interfaces. At the same time, DG implementation would benefit from establishment (by policy makers) of hourly retail markets for the trading of power between DG owners and the distribution grid. Such a market would allow DG owners and other consumers to benefit from the value of DG in reducing peak-load generation from utilities. Such markets remain in the experimental stage, though similar markets have been shown to provide useful incentives to small-scale generation technology users and energy-efficiency technologies. Finally, some argue that creation of a level "playing field" among all types of generators (owned by utilities and nonutilities) would help eliminate unseen subsidies, costs, and benefits, and encourage proper consideration of alternatives. Government policy would establish standardized requirements for emissions allowances, land use, building codes, and other key components of the production of power, helping users choose the most efficient design of a power delivery network. It would aid in the analysis of energy-efficiency alternatives as well by elucidating the true costs of all supply-side and demand-side alternatives.

5. Practical Consequences: Distributed Generation as a Business Enterprise

In the "real" world, these potential benefits and impediments are evaluated by men and women in the business community who seek to exploit opportunities in the altered electric utility system. This section examines in more detail the ways business people consider these factors and develop business decisions. The discussion ends with an analysis of a business model that incorporates economic and strategic factors to create a possible niche in the evolving utility system.

Four different categories of business entities appear likely to consider the implementation of DG technology as an element of a strategic plan. These include:

- Investor owned utilities (IOUs) and publicly owned utilities that may want to install DG units for supplying peak demand in areas that are located behind congested transmission lines.
- Manufacturers of DG systems, which have already advanced the technologies for DG on several fronts and, with the exception of large gas turbines, appear to be pacing their capacity growth by market growth.

- The new generator and consumer (NGC) that sees operation of DG units as a potential substitute for some or all of its purchases of electricity from utilities. Included in this category are industrial sites, apartment complexes, government agencies, military bases, universities, hospitals, shopping malls, and the like. On the horizon, NGCs may also become wholesale energy suppliers by interconnecting DG units.
- The contractor industry (CI) that performs one or more of the functions of designing, building, installing, and operating DG units. The viability of contractors depends on the rate of adoption of DG by the above categories of business entities.

For any organization, strategic business planning begins with an analysis of the organization's mission and the threats and opportunities that exist in the external environment. It continues with an examination of the firm's weaknesses and strengths (i.e., its internal environment). External threats include uncertain and rising electricity costs and the unreliability of power supplied by utilities. As managers scope out opportunities for changing their organization and developing a new strategic plan, they often consider four general categories: redesign and repositioning in the marketplace of the organization's products and services, improved selection and design of the processes that the organization uses to pursue its mission, expansion or contraction and the reallocation of capacity, and improvements to operations control systems.[41]

Among these categories of action, managers view process improvement as the mechanism through which they often take advantage of technological innovation. But technological innovation is neither deterministic nor autonomous. It results from a series of choices pursued by managers and events occurring in the marketplace (which is itself affected by others' choices and actions). In the strategic business plan of new customers and generators, DG is viewed as a potentially new process for the creation of electricity, a basic commodity that serves as a critical input into business activities. Its price, availability, security, and quality may affect an organization's ability to produce the products or services that define its mission.

The most common business model for DG adoption and growth may consist of one that partners new consumers and generators with DG contractors. By doing so, companies seeking electricity and heat do not need to develop extensive expertise outside their core competencies. Rather, they can depend on contractors who have developed the skills and knowledge from operating DG units for other firms and who can provide other services. The employment of DG would therefore not become a distraction to a company's core competencies or become a burden to its mission.

Even with a competent contractor working to develop DG units for a firm, an array of risks confronts the nontraditional new player in the utility system. The list of risk factors includes the impediments noted earlier. However, business managers may look at them differently, combining several into these general categories:

- Technological uncertainty. Owners must deal with the chance that the DG technology will not perform as reliably or as efficiently as its specifications. In particular, interconnected DG systems may actually reduce the reliability of a distribution grid due to the inability of grid operators to control unit dispatches under rapidly changing conditions.
- Fuel cost uncertainty. The price of natural gas, coal, and oil will affect the financial performance of any DG unit that uses any of these fuels. Owners of renewable energy technologies (such as wind turbines) will not need to worry about the cost of energy resources, but the price they receive for surplus power will depend to a large extent on the price of conventional fuels that provide competitive benchmarks prices.
- Load uncertainty. The growth and volatility of electricity demand within the transmission grid that serves the NGC must be considered. Ironically, efforts to reduce the cost of electricity in the form of demand-side response could reduce the value of DG units that are most beneficial in supplanting expensive peak-load power from utilities.[42]
- Electricity price uncertainty. The financial performance of a DG unit depends on the cost of electricity from utilities that the unit supplants. Future prices of electric power in the United States remain highly uncertain due to variability in fuel costs, regulation, and technological change.

- Regulatory and public policy uncertainty. The viability of DG projects depends, to a certain extent, on the treatment by government entities. NGCs need to consider the chance that any tax incentives, subsidies, or easements associated with a DG implementation may be offered or repealed by future legislatures and executives. Given the spotty history of utility system restructuring and deregulation, it is difficult to predict the effects of government policies on evolving electricity markets.

These uncertainties create financial (and nonfinancial) risks for NGCs. As with any capital investment option, the cash flows of a proposed DG facility must be viewed as random variables, and measures of financial risk must be computed from the probability distributions of these variables. Investments that look acceptably profitable on the basis of expected cash flows may be deemed unworthy when the risk associated with these cash flows is estimated. The energy industry is a motivating force behind new methods for assessing risk, and it currently is replacing the traditional evaluation of net present value with the view of investments in generation capacity as real options. This more enlightened view of financial risk directs the investor's attention to both the downside loss potential as well as the upside gain potential.[43]

Aggregated Dispatch as a Means to Stimulate Economic Momentum with DG

This analysis suggests a host of potential and real problems faced by businesses considering use of DG technologies, making DG a somewhat risky, marginally profitable opportunity. Nevertheless, opportunities for the use of DG exist, especially if structured in a new fashion, namely as an element of an aggregated entity that can dispatch power to the grid. In such a way, a DG owner might obtain a significant revenue stream while also enhancing grid reliability and reducing pollution levels. It would employ electricity and waste heat for its own needs when power remains cheap, and it would sell surplus power to the grid when spot prices for electricity are high. To participate in the market for power, DG units must be dispatched at times and locations where they are most needed. This kind of dispatch requires coordination of all DG units in a distribution grid. By doing so, owners provide society with some of the promised benefits of DG while also making financial profits for themselves.

Is such dispatch possible? An experiment in New York, funded by the New York State Energy Research and Development Authority (NYSERDA) and the U.S. Department of Energy, suggests that such dispatch can occur efficiently. The experiment engaged the services of a private contractor, ELECTROTEK, to link fifty backup generators (providing a capacity of 35 MW) to centralized control points for dispatch to the power grid. Not only technically feasible, the aggregated system demonstrated its economic value by saving $1.5 million in one year through the use of DG only for load curtailment.[44]

The experiment highlights the new business model of aggregated dispatching for DG. In this model, DG owners would submit, under contractual limitations, their units to the control of a central dispatcher who trades off the cost of generation from the DG units against the spot prices available from the wholesale market. In addition, the volatility of spot prices motivates financial risk management through the trading of derivatives. Given the special expertise and close attention that such trading requires, DG owners would likely assign these duties to a contractor as well. Here again, DG owners would most likely try to avoid moving beyond their core competencies. An experienced contractor would design, install, maintain, and operate DG units for the owners. It would also trade the power produced by the units and manage risks associated with operation of the units within an integrated distribution grid. The contractor further would play (as in the NYSERDA experiment) the role of a load serving entity (LSE) for a group of DG owners. It purchased bulk electricity from utilities and sold it in the day-ahead market in different parts of New York. When real-time prices exceeded the cost of generation from the DG units, the LSE dispatched the DG units and earned revenues. This complex business operation proved financially successful and illustrates clearly the viability of a contractor industry in the DG economy. As the financial benefits of this business model become recognized, members of the contractor industry might even benefit from economies of scale. They would collect, under one roof, the broad expertise necessary for coordinated management of DG.

Parenthetically, it should be noted that this analysis currently focuses on the profit seeking new consumer and generator segment of the market. Perhaps in a later study, the authors will examine in greater detail the potentially large interest in DG by government entities, such as federal, state, and municipal agencies. Decision makers in these bodies may (or should) evaluate energy situations differently than do managers in profit-making corporations. For example, a city manager may look to the increased reliability and security benefits of DG technologies as a prime consideration of a government that needs to maintain emergency services during a blackout caused by accident or by terrorists. DG technologies would provide backup power at critical times for the city to provide critical communications and rescue functions, displacing economic factors (such as the simple cost of electricity per kilowatt-hour) as top considerations. As another example, the U.S. Department of Energy's Federal Energy Management Program, operated by Oak Ridge National Laboratories, may desire to employ DG technologies as a way to obtain secure electrical supplies for government facilities as a way to deal with potential terrorist attacks or natural disasters. In fact, because government managers may view DG positively for such uses, they may be among the largest (and quickest) adopters of the new small-scale technology, thereby providing its proponents with a substantial market.

6. Conclusion

Made up of a diverse set of economic, educational, legal, administrative, and technical components, the American electric utility system developed much momentum during most of the twentieth century. Supporting the use of large-scale hardware that exploited economies of scale, the system's stakeholders generated huge amounts of power at declining costs and produced financial and social benefits for millions of people. The system's momentum, a metaphor for the social and technical components aligned in such a way as to resist change, grew consistently and seemed to favor everyone.

But starting in the 1960s, problems with the standard (and previously improving) generating technology became evident. Combined with the energy crisis of the 1970s and the political response to it, however, momentum change began occurring. The monopolistic utility industry first saw competitors generate power using small-scale and cost-effective equipment that employed raw energy more efficiently. Government incentives also spurred increased production of power from environmentally preferable equipment such as wind turbines. Following passage of the Energy Policy Act of 1992, partly as a result of the Gulf War, the existing structure of the utility system changed further, with wholesale and retail competition further eroding the momentum of the former system.

Efforts to restructure and partially deregulate the utility system have not been without difficulties. It appears that, like in other industries, restructuring the utility system will remain a messy business and may take a long time for stakeholders to work out a new paradigm. The inherent messiness highlights the notion that momentum in the system has changed and that stakeholders—some new ones in particular, such as those that employ distributed generation technologies—have an opportunity to introduce new ideas for how the utility system will emerge in the near future.

This paper has suggested that, at a time when momentum change is occurring, opportunities exist for the increased employment of DG technologies in the utility system. Focusing on possible strategies for various business entities, it concludes that ominous risks appear for companies that seek to generate power largely for themselves. In many cases, it is understandable why DG has not yet seen greater penetration into the marketplace. However, some of those risks would diminish if government policy recognized better the subsidies it offers to conventional fuel users and made companies pay for the significant external costs they impose on society. Such a policy may be difficult to pursue for political and economic reasons. Still, policy should then provide incentives for DG enterprises to recognize the real, but difficult-to-quantify benefits to society overall, such as increased reliability, heightened security for the grid, and reduced (or stabilized) transmission costs.

Even if policy makers fail to pursue some of these measures, DG may still be embraced by the business community in a novel form. This paper suggests a business model that employs experienced contractors to serve as load-serving entities for DG units owned by several parties. The contractors would dispatch the units in a real-time marketplace and earn revenues when spot prices surpass the cost of producing power. Recent experiments with this business model appear promising. The authors plan to continue to explore ways to make DG a larger element in a utility system whose momentum continues to shift.

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