The Half-Life of Policy Rationales

How New Technology Affects Old Policy Issues

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Technology and Electricity

Overcoming the Umbilical Mentality

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Supplying electricity to a community is ordinarily a three-stage process: generation, transmission, and distribution. Electricity generators running on fossil fuel, wind, solar, hydro, or nuclear energy spin magnets inside copper wire coils to generate a flow of electrons. The current is sent through high-voltage, high-capacity transmission lines to local regions. There it is transformed to a lower voltage and sent through local distribution wires to final users. The electricity is transmitted and distributed through a network of cables and wires traversing steel towers, wooden poles, and underground vaults that make up a system often referred to as *the grid*.

The so-called deregulation of electricity has focused on introducing competition—but only in its generation and only among restrictively authorized high-tension wholesalers. For its transmission and distribution, reformers have called for "open access" to the power grid: commercial, residential, and industrial customers must be allowed to choose any electricity provider they prefer, and the local utility must be required to distribute the new provider's electricity for a fee. In the new setting, electricity producers—whether the conventional vertically integrated utilities or newer and smaller generators—must be able to sell to whomever they chose via the grid. Utilities would be required, however, to relinquish control of their lines to regulatory agencies.

But few would invest in grid technologies and innovations if authority over such investments were surrendered and the fruits of their efforts were divided according to the machinations of a political authority or a regimented, nonprofit industry association. That is, what is politically possible often diverges from what is really desirable, and vice versa.

Although few political players favor full-scale decontrol, such a policy is, in our assessment, the most desirable one. Full-scale decontrol would mean the elimination of exclusive territorial franchises. It would mean the de-regimentation and de-politicization of distribution as well as generation. The resources used for generation and distribution would be deemed the private property of the owners, and freedom of contract would be granted. In conjunction with a free-enterprise policy, governments could allow reasonable and fair access to the public's right of way. Problems of emissions, noise, vibrations, and risk could be treated by tort action, negotiation, or, especially in the case of emissions, by simple and fair pollution charges based on direct measurements of emissions at each exhaust pipe or smokestack. Such an approach differs substantially from many current regulations.

The root of utilities' monopoly is usually found in such legal devices as "certificates of convenience and necessity" requiring permission to compete in the marketplace. The law from the state of Colorado is typical: "No public utility shall begin the construction of a new facility, plant, or system or of any extension of its facility, plant or system without first having obtained from the [public utilities] commission a certificate that the present or future public convenience and necessity require or will require such construction" (Colorado Revised Statutes). Here we can clearly see the exclusion of competition, the attenuation of authority over supposedly privately owned resources, and the pretense of knowability (of "present and future public convenience").

We believe that the case for free-enterprise electricity has always been strong. Technology, however, is making the case even stronger, in two ways. First, technology is making less and less tenable the notion of natural monopoly in electricity. Decentralized generation and distribution are increasingly economically viable. Second, technology is opening up so many new possibilities that the field has become more complex and hence unknowable to regulatory authorities. Now more than ever, policymakers should recognize that complex productive activities call for experimentation, heterogeneity, spontaneity, and flexibility, which are especially the virtues of private property rights and the freedom of contract.

A central failing of industry regulation and regimentation, a failing that pertains to much of what follows in this chapter, is the almost complete neglect of time-of-use pricing. In Atlanta in the middle of August, the price of electricity at 5:00 A.M. is the same as the price during the peak usage at 5:00 P.M. Varying the price with time of use, however, would avoid peak crunches and level the load. Price changes mobilize the help and cooperation of electricity users. These benefits are well known to telephone companies, airlines, hotels, and movie theaters. In electricity, it would be easy for each end user to have LED displays at hand, like those on digital alarm clocks, showing the price of electricity right now and the price later on. This type of pricing would be easy technically, since the power line could also serve this informational and metering function. In the middle of a hot summer afternoon, the householder would then have a strong financial incentive to refrain from running the electric clothes dryer until an hour when electricity were less scarce. The householder might decide to turn down the air conditioner, take a cold shower, or go for a swim or to the shopping mall. In a thousand different ways, people substitute one option for another when given an incentive to do so (Borenstein and Bushnell 2000, 48). Businesses and large-volume customers would, of course, respond assiduously to time-of-use pricing. Electricity suppliers then could better optimize their build-versus-buy choices and other decisions. But for political and bureaucratic reasons, the regulators and utility monopolies have forsaken a simple, practical innovation that, by itself, would be a huge leap forward in managing load and capacity.

The regulators seem to have an obsession with price controls stemming from a tradition of trying to control a monopoly of their own creation. As a result, they act as if their policies are exempt from the consequences of supply and demand, which they cannot control.

The neglect of time-of-use pricing is just one of the travesties of industry regimentation. We will highlight others in making two central points about how technology enhances the case for de-regimenting the industry. The first part of the chapter deals with dispersed generation, and the second deals with heightened complexity.

Dispersed Generation: Now More Than Ever

Unnatural History, Unnatural Doctrine

For decades, the market for electricity delivery has been said to be a natural monopoly, that is, a service featuring a high fixed cost and an ever declining cost per unit, so that a single large firm could produce and sell output more cheaply than two or more smaller ones could (Stiglitz 1993: 411, 455–60). The theory of natural monopoly implies that a free market naturally gravitates toward dominance by one firm (a summary of this theory may be found in this volume's introduction).

Historically, however, electric utilities never achieved natural monopoly status before the advent of the state public utility commissions that arose to regulate them. According to economist Richard Geddes, "State regulation was instituted not to correct private market failure and to increase social welfare, but to provide firms with a way to insulate themselves from the discipline of competition" (1992, 76). The idea that it is optimal to have a solitary power grid under unitary administration really has no solid grounds, especially considering the inefficiencies that result when authority and residual claimancy are divided and politicized.

If regulation really helped consumers, prices should have fallen and the quantity of power supplied should have increased after the transition to regulation. Instead, as an article by economist Greg Jarrell (1978) demonstrates, customers paid more for electricity under the rate of return regulation than they did under the prior competitive environment. Jarrell found that the states in which utilities were first subjected to rate-of-return regulation were those that had been charging the *lowest* prices, rather than those charging "monopoly" prices. Furthermore, following regulation, the prices in the early-regulated states were higher relative to those of the late-regulated states (Jarrell 1978, 287). Also following regulation, the output of electricity fell while the return on assets rose (see also Stigler and Friedland 1962).

One of the common pitfalls of electricity-policy discourse has been to overemphasize the distinction between generation and transmission/distribution. Intellectuals and regulators try to impose order on the world just to get a handle on it. But the strong distinction really presumes a natural-monopoly fate for electricity. Joseph Stiglitz's textbook says: "The electricity industry could be divided into electric power generation and distribution. Some competition may be viable in electric power generation" (1993, 460). But of course, not distribution. As the distinction determines the course of policy, monopoly, though *un*natural, becomes a predetermined outcome.

Consider what a natural-monopoly presumption would imply for the delivery of restaurant meals. There would be central sources of meal generation and a monopoly grid of distribution to dining points everywhere (somewhat like WebVan or the frozen dinners distributed through supermarkets). Such a distinction between generation and distribution is highly artificial. Restaurant-meal production is a complex process that melds and mixes various stages of generation and distribution, that is, *dispersed generation.*

Of course, there are important differences between restaurant meals and electricity, differences that make it much more natural in the case of electricity to distinguish generation and distribution. The dispersed-generation model has long been economically viable, however, and technology is making it more so.

Generator Sets ("Gensets")

A *genset* is a self-contained, stand-alone, usually transportable electric power plant consisting of a prime mover (engine), a dynamo, and some controls. The word *plant* as used here should not be construed as a grand industrial installation. Rather, it implies merely that the unit is located, installed, and hooked up for usage. Gensets are capable of producing electricity for use in isolated, local applications, in team with other gensets, or in parallel with large central stations via the power grid.

A diesel locomotive is a genset on rails. A hybrid automobile is an electric car fitted with a genset (and getting 80 miles to the gallon in all-around driving). Other familiar gensets are the small units that make electricity for motor homes, boats, and other independent facilities. Available for ordinary household installation, many gensets are equipped with automatic starting and grid isolation transfer switching for standby or emergency service, such as when the grid service is interrupted by weather and the household needs secure power for medical appliances such as respirators (for a selection of such devices, see www.mcmaster.com).

A typical genset consists of a combustion engine mechanically coupled to a self-excited synchronous generator or permanent magnet alternator mounted on a rigid base. Also mounted are the control console, fuel supply, and cooling provisions, including a radiator. The combustion engines, whether piston ("internal combustion") or turbine ("external combustion"), can use diesel, gasoline, kerosene, alcohol, propane, or natural gas. Gensets are usually enclosed in weatherproof housings for outside location on the ground, in parking lots, or on rooftops. For mobility, they may be mounted on skids, wheels, or barges. They offer low setup and operating costs with a high reversibility of investment. For most locations, their emissions are very manageable and acceptable to all reasonable people. Noise pollution is rendered insignificant by ordinary engineering measures such as sound-absorbing construction, sound insulation, mufflers, baffles, and considerate and prudent siting ("prudent" because any operator would be liable for nuisance).

A Glimpse at the Current Genset Catalog

Mass-produced engines from various fields (automotive, aviation, marine, and railroad propulsion) are available with a wide range of heavy-duty power ratings suitable for genset application. Such engines, suitable as genset prime movers operating on gasoline and propane, cost as little as \$30 per horsepower rising to more than \$50 per horsepower for operation on diesel and natural gas. Diesel and natural gas engines dominate the 100- to 3000-kW output range.

Natural-gas burning gas turbines are new to the genset field. Two new entrants into this field of engine power deserve to be mentioned here.

Although their purchase price is ten times that of internal combustion engines of equal power output, engines popularly known as *microturbines* or *microturbogenerators* are being manufactured and marketed by several firms, both recent startups and those long established in the field (e.g., www.capstoneturbines.com, www.honeywell-des.com, www.distributed-energy-solutions.com). The advantages of these microturbines over internal combustion engines for dispersed power application are their much lower size, weight, vibration, noise, and maintenance requirements. Weighing only a few hundred pounds and often with only a single moving part, these small self-contained units are about the size of a large refrigerator. They are designed for unattended operation nearly maintenance free to produce from 25 to 75 kW—adequate to power a 7-Eleven store, a McDonald's restaurant, a group of homes, a condominium complex, or an apartment building. These units capitalize on recent developments in materials, turbomachinery design, heat exchangers, electromagnetic machinery design, automatic controls, and microprocessors to form a package that is highly efficient, durable, compact, lightweight, and portable. Their high reliability and long service life are attributed to the development of foil bearings that support the turbogenerator shaft on a film of air rather than oil. Because of the recuperation technology employed, the operating costs of these units are reputed to be competitive with conventional engine-powered units (www.microturbine.com).

The developers of the microturbine products have incorporated certain new technologies to improve their competitiveness. One such innovation is the recuperation of waste heat in the heat-engine cycle, a process that significantly increases fuel efficiency. Recuperated turbine engines approach the fuel efficiency of internal combustion engines. Another innovation is the use of foil bearings that eliminate dependence on lubricating oil and thus the requisite maintenance and wear.

One "microturbine" example is AlliedSignal's 75 kW TurboGenerator, which sells for $40,000 to $50,000, or almost $670 per kW. At 1998 fuel prices, operating costs are 4.5 cents per kilowatt-hour (kWh), while total costs, including recovery of capital, are 6.7 cents per kWh (see www.worldbusinessreview.com/underwriters/AlliedSignal/).

New Energy Ventures is marketing this system widely in the western states (see www.newenergy.com/press/detail.cfm?nid=445&sid=2). McDonalds is a prominent customer (www.wbrtv.com/underwriters/unicom). Allison Engines (now part of Rolls-Royce) and Capstone Turbine Corporation also produce microturbines (www.capstoneturbines.com, www.honeywell-des.com, www.distributed-energy-solutions.com).

In 1996 the Electric Power Research Institute of Palo Alto, California, predicted reliable, low-maintenance commercial applications of these units could be available for under $300 per kW within three to five years (Preston and Rastler 1996, 15). Given the five years already passed, what are the facts today? After shipping its first unit for commercial installation in December 1998, Capstone Turbine Corporation of Tarzana, California (www.capstoneturbine.com), announced on November 27, 2000, that it had shipped its one thousandth microturbine unit. This unit was one of a "six-pack" sold to Peoples Energy PLC for installation in the Fulton Street Brewery of the Goose Island Beer Company of Chicago. These natural gas–fired cogeneration units are dedicated to critical production equipment and processes that must be protected from utility blackout.

It is easy to envision hospitals, commercial firms, shopping malls, and real estate developers embracing microturbine technology and setting up single or stacked units in buildings, on roofs, in parking lots, in basements, and along new streets. Banks of such turbines could be stacked in key locations, ensuring reliability because any turbine that fails is rapidly replaced with a new one or electrically switched to an idle one. A new turbine repair industry can be expected to emerge, much like the independent photocopier, fax machine, and computer repair businesses that emerged to complement those technologies. Such developments could displace utility and distribution lines.

Areas that lack distribution lines are also likely to lack natural-gas lines, but the microturbines can be modified to run on diesel, gasoline, propane, kerosene, and other fuels that can transported by truck or railroad as well as pipeline. Thus, gensets can easily adapt to installations beyond either the electricity grid or the gas main.

Recently, gas turbines derived from commercial aviation propulsion engines (turbojets and turbofans) have been adapted to industrial shaft power drives. These "aero-derivative" engines have spurred the development of a new class of very high output, highly mobile gensets useful for peaking service. Such engines, operating on natural gas, are beginning to compete with diesels in the 10- to 60-mW range. While they consume somewhat more energy per unit of electricity output, they are lightweight and compact enough to be integrated into highly mobile intermodal containers easily sited in most neighborhoods.

Living Proofs of the Genset Alternative

Generators and controls are available for local domestic and isolated building service as well as for paralleling on the grid. Most of the on-site applications are for standby or emergency power units but are capable of continuous operation under load. Such units are installed in numbers at nearly every major hotel, hospital, and high-rise building in the country, in conformance with prudence, fire insurance policies, and numerous, complex layers of governmental codes and permits. Even if they run only occasionally, they pay for themselves in terms of fewer interruptible utility rates and lower insurance premiums. Some such installations that operate continuously generate both heat and air conditioning.

The response of the genset industry to Hurricane Hugo in 1989 illustrates the robust capability and potential of this technology and industry. At this time, major genset manufacturers such as Stewart and Stevenson Services of Houston (www.ssss.com) and Penske Power of Hoboken, New Jersey (www.penske.com), had stocked various types and sizes of gensets for short- and long-term lease as well as sale. When the hurricane struck, the Carolina utility system went down because substations were flooded; generating furnaces were extinguished; and power poles were toppled. Emergency service agencies and private companies expedited the delivery of thousands of gensets from Stewart and Stevenson, Penske, and other suppliers by truck, rail, and barge. With competent field support from the suppliers, they succeeded in powering up isolated buildings and serviceable parts of the grid well before central service was restored. By the time the interstate power intertie system was ready to resume service, the dispersed power units on temporary loan were providing about 500 mW of electricity, or almost 10 percent of the normal utility load (Fox 1992).[1]

Recent Technological Developments in Gensets

Although dispersed generation by independent gensets has been technically feasible for many years, recent technological advancements have considerably enhanced the economic viability of dispersed generation. Significant improvements have been made in engines, combustion, materials, microprocessors, instrumentation, controls, automation, and electronics by which gensets can produce power, either inside or outside the grid, and compete with central stations on the basis of reliability, unit cost of power, and cost of contracting. Accordingly, the market for gensets now is huge (see www.dieselpub.com).

Significant technology developments in the community electricity supply field include the following:

Technological Advancements in Internal Combustion Engines:

Lean-burn natural gas. This is a technique for using natural gas in a homogeneous charge spark ignition engine with an excess of air over chemical correctness in order to improve fuel efficiency.

Low-emission diesel. Regenerative particulate traps and selective catalytic reduction units have been developed to permit stationary diesel engines to operate at low emission levels of carbon soot and nitrogen oxides.

Dual-fueled diesel-natural gas. This is a technique for substituting a major fraction of the fuel energy in a compression ignition diesel engine by fumigating cheaper, cleaner-burning natural gas. Besides lowering the cost of fuel, the process reduces the emissions of particulates, carbon, and nitric oxide as well as noise.

Ebullient cooling for steam cogeneration. Engine cooling can be a source of heat for other uses. When heat from the engine oil and structure is removed by conventional liquid cooling, it is dissipated via radiators and the like. New technology has been developed to generate low-pressure steam within the engine as a consequence of controlling the engine's temperature. The steam produced is a valuable commodity for heating purposes, and the engine is cooled more efficiently.

Exhaust heat recovery. Improved materials and heat exchanger technology permit the development of more effective means for recovering useful heat from otherwise wasted engine exhaust. This heat can be delivered at somewhat higher temperatures than that recoverable from engine cooling jackets. However, exhaust heat recovery requires sophisticated design measures using highly durable materials.

Induction alternators. Most electric motors used nowadays for industrial purposes are polyphase "squirrel-cage" induction types. This machinery is rugged, inexpensive, and free of the sliding electrical contacts that account for most of the maintenance cost for electrical machinery. With certain advances in electrical engineering know-how, induction machines are being used as asynchronous alternators. These machines must be operated on the grid to be loaded synchronously with other generators, but they provide power-factor correction to the grid. In an alternating-current distribution system, inductive reaction in certain loads causes the current to lag the voltage in phase, resulting in a loss of available electrical power. Induction generators deliver their current at leading phase, which tends to correct the power factor. Many small such generators dispersed about the grid could recover some of the nearly 10 percent of the otherwise unavailable reactive power in the grid.

This technology is not only useful for building economic capacity, but it should also be considered an important conservation technique.

Emission controls. Automotive emission control technology developments can be economically transferred to stationary engines of the spark ignition type. These are the genset engines that run on natural gas, propane, or gasoline. The most important and valuable of these technologies are the closed-loop electronic engine controls, exhaust gas–oxygen sensors, electronic fuel injectors, nonselective three-way catalysts, and exhaust gas recirculation controls. Turbochargers, wastegates, and intercoolers developed for heavy-duty on-highway truck application are important and economical emission-control features of stationary diesel engines.

Noise control. Advancements in acoustic controls and materials now enable the construction of genset enclosures for stationary engines to run in virtual silence. Sound and vibration absorption as well as acoustic wave cancellation by electronic means are being used to eliminate noise objections in most neighborhood installations.

Technological Advancements in External Combustion Turbine Engines

Recuperation. In their simplest form, external combustion gas turbine engines cannot compete with internal combustion engines for fuel economy. However, recent developments in materials and heat exchanger technology recover internal heat during the cycle to significantly improve the engine's thermal efficiency. Such thermal recuperation consists of cooling the underexpanded combustion gases leaving the turbine and transferring the heat recovered to the cooler air leaving the compressor before entering the combustor. Less fuel is thereby required to maintain the turbine's inlet temperature and power output.

Foil bearings. Lubrication is a high-maintenance item in all machinery because wear determines the useful life of the equipment. The invention and development of foil bearings for gas turbine application have extended the equipment's service life and lowered its maintenance cost. Such bearings permit the lightweight, very high speed shaft to be supported by a film of air that reduces friction, wear, and maintenance. This achievement enables an otherwise prohibitively expensive machine to compete on the basis of its life-cycle cost.

High-speed brushless permanent magnet alternators. The development of new high-coercive-strength magnetic materials and high-speed microprocessor-based electronic controls has yielded a new generation of synchronous generators that can be driven at very high shaft speeds. This permits direct turbine drive and eliminates gear reductions and attendant machinery costs and lubrication problems. In addition, the generator is small and lightweight. These generators can be run at any speed with synchronization with the grid provided by external rectification and inversion using solid-state controls.

Emission controls. Although emissions standards are more easily met by gas turbines than by internal combustion engines, control measures are often required to meet local codes. Water and steam injection has been perfected to minimize the emission of nitric oxides. In addition, selective catalytic reduction processes have been developed to reduce these ozone-forming emissions even further.

NOISE CONTROL. Advancements in acoustic controls and materials also apply to the soundproofing of gas turbine engine enclosures. However, additional acoustic controls are required for these engines to deal with high-frequency emissions from their intakes and exhaust stacks. Control of such noise is now routine using a combination of materials, baffles, and electronic acoustic wave cancellation.

Does Dispersed Generation Forsake Scale Economies?

Central plants can capitalize on the so-called six-tenths power law (Chilton et al. 1967). Originating in the chemical industry, this loose maxim describes the relationship between the cost of production and plant capacity. It maintains that the cost of producing a quantity of plant output is proportional to the plant capacity raised to the 0.6 power. Thus, if plant 2 has twice the capacity of plant 1, the larger plant's output (say, 200 units) should cost only 1.52 times as much as that of the smaller plant (100 units). Thus, plant 2's average cost would be only about 75 percent of plant 1's average cost. This maxim applies to raw materials, labor, and capital.

For small-scale producers, however, scale economies apply to the mass-produced capital component only. The heat engine prime mover for a genset may be sourced from automotive or aviation production volume. The genset assembly itself may well justify volume production to serve a multitude of applications. Thus, genset production itself exhibits economies of scale.

An outstanding bargain in engine power is the 350-horsepower Chevrolet Mark V ("Big Block") truck engine that can be purchased complete in boxcar lots from the factory in Tonawanda, New York, for less than \$1,500 per engine (1990 dollars). (The current automobile dealer price complete is about \$2,000, depending on accessories.) Once the truck engine is prepared and equipped to run on natural gas and drive a 200-kW generator at constant speed, this engine costs about \$5,000, or \$25 per kW (Lowi 1991).

Technological developments are making small-scale generation even better at producing power closer to the customer and transporting it over shorter distances at lower voltages.

Improvements in engine performance and durability are reducing the costs of on-site generation to such an extent that small plants can now compete with large central stations on the basis of energy consumption and direct operating cost. Small-scale electricity production on site eliminates the costs of the grid and power transmission. Those costs include organization, land use, amortization of capital, maintenance, and voltage dissipation in transmission lines and substations.

In addition, on-site production facilitates the cogeneration of heat from a single source of fuel energy for such processes as laundry and climate conditioning. Such heat is necessarily wasted by remote central plants.

These developments favor a competing model of "subgrids" or self-contained loops. Although these subgrids might make deals with incumbents to connect themselves to the main grid, on-site generation could bypass the grid altogether. Just as mainframe computing technology has given way to "desktop" computing, with suitable liberalization we could see a flourishing of dispersed power generation.

Portability and the Reversibility of Investment

The traditional power plant is site specific and largely nonsalvageable, so the investment that it represents is largely irreversible, or "sunk." But advances in generator design are changing the situation significantly, even for generators that are quite large. The capability has long existed for water-transportable power plants designed to float atop barges. Used to serve places lacking adequate infrastructure, such plants eliminate a great deal of default risk. On land or water, gensets and microturbines can often be installed, uninstalled, transported, and reinstalled. Such portable stations will, according to Donald Smith, president of the Smith Corporation, "be liquid assets like a tanker or a 747" (quoted in Bulkeley 1996, B1). Thus, in a liberal regime, electricity delivery would enjoy not only a large measure of free entry but also what has been called *free exit*, meaning the ability to recover the costs of market forays that don't pan out or that have run their course. The ability to recover makes the foray more appealing and more likely in the first place. Markets would be more competitive and more "contestable" (Baumol, Panzar, and Willig 1982).

Obstacles to On-Site Power

The operation of local gensets is not as common as their economics would presume, because of the administrative hurdles facing a small power producer in contracting with a regulated utility company to connect to the grid for either base load or peaking service. However, since the early 1980s, a growing number of cogenerators and small power producers have been so connected. A few have managed to secure arrangements under the rules of the Federal Energy Regulatory Commission (FERC) and the 1978 Public Utility Regulatory Policies Act (PURPA), according to which they are permitted to sell their excess power to major utility companies for retail distribution.

Many regulatory barriers stand in the way of dispersed generation (whether or not they are grid connected). Regulators do not like to see a multiplication of regulatees with whom they must interact. In other words, they much prefer a system in which they regulate a small number of large sites, rather than a large number of small sites. Thus, they tend to drag their feet and throw roadblocks in the way of small-scale permitting.

The following list of difficulties is based on the situation in California, but the description may be generalized to the rest of the country.

Permit to Construct

In seeking to install a small-scale plant on site, a business must apply for a construction permit from the local government. The construction-permit process delves into the health, safety, environmental, and economic impacts of the proposed project. Deposits on fees are not refunded if the application is withdrawn or the permit is denied.

Permit to Operate

After the plant is permitted, constructed, and approved again by the relevant building and safety agencies, a separate permit to operate must be obtained from state and local government agencies. All this must be done in the proper sequence before the plant can be used for its intended purpose. Further costs in time, expenses, and fees are then incurred while EPA, OSHA, state and district air-quality authorities, and local housing and safety agencies inspect facilities, observe operations, and look over the test data. At any point along the way, a single bureaucratic office can kill the project, making the entire effort for naught. Thus, aside from the delays involved, the process entails enormous uncertainties.

Grid Connection Difficulties

If the small-scale producer wishes to connect its on-site system to the grid, it must meet the utility's connection specifications. It must obtain certain "utility grade" relays, switches, and circuit breakers that must be procured at grossly inflated prices from the utility company and installed under the supervision of the utility company's engineers. The utility company's charges for these special parts and services are not known in advance (somewhat like military specifications). Accordingly, allowing competition at the local level by ending the franchise would make utilities more inclined to make a deal.

Moreover, if the grid-connected enterprise wishes to obtain lower rates in exchange for its willingness to disconnect when ordered (during which time it would rely on its own generating facilities), it would face extraordinary charges in the event that it did not disconnect when ordered. Among the reasons that it might not be able to disconnect when ordered are the following: (1) its generator is down for maintenance or repair; (2) it is out of fuel (possibly owing to gas service interruption); or (3) the enterprise may have run out of emission credits to operate, in which case it would face heavy emission fines. These connection difficulties discourage those who need to maintain a grid connection from developing on-site generation.

Avoided-Cost Contract with the Franchised Utility

Small-scale producers who want to use the grid to sell their excess power and capacity must obtain a contract with the local franchised utility. Under federal law (PURPA), the sales price schedule for the power sold is based on the so-called avoided cost of the franchised utility receiving the power. This "avoided cost" is to be determined and approved by the state's public utility commission. For the small-scale producer, the bureaucratic framework means a loss of time, huge uncertainties, and back-and-forth bargaining in the "avoided-cost" determination—and the PUC bureaucrats, who usually protect the franchised monopoly, have the final word. PURPA also contain bureaucratic rules regarding "energy utilization" to qualify for such a contract. Even if a contract is secured, if spot-check inspectors (from FERC, the state PUC, or the utility company) find that a contracted producer is cogenerating electricity and heat year-round at rates less than 50 percent of the fuel burned, the utility can claim an "energy utilization" disqualification and refuse payment or rescind the contract. Thus, bureaucratic uncertainties and transaction costs suffuse any such agreement with the franchised local monopoly. To make matters worse, when the franchised utilities became insolvent at the onset of the electricity crisis in early 2000, the PUC bureaucrats allowed their clients to renege on avoided-cost contracts with small-power producers (Tamaki 2001).

Tribute Extracted by the Franchised Utility

In California, if a customer with its own on-site generators wishes to exit the grid to generate its own electricity independently or to buy electricity through the grid from a supplier other than the franchised utility company, it must pay tribute of up to $6.40 per kW of its own generating capacity per month (even after it has left the system). Backed up by the PUC, the utilities rationalize this tribute as continued payment for historic investments to serve the customer—never mind that the customer may not want the service (Hirsch 2001). The arrangement is rather like a restaurant extracting monthly tribute from local residents on the grounds that it had to invest in building the restaurant and that it incurs current costs in continuing to provide residences with the option of going to the restaurant.

The existing bureaucratic conditions can make it very difficult for hospitals, hotels, factories, and homeowners' associations to generate power on-site, especially if they wish to connect to the external grid as a backup or an avenue to the retail electricity market. In a freer market, many more would do so because of favorable terms and reliability. In a free market, the dispersed-power option competing with the electricity-generation establishment would quickly deliver more generating capacity in response to demand, shave peaks, reduce costs, and enhance reliability and price stability. In a setting of secure and certain property rights and freedom of contract, users would have many options—connecting to competing loops (not a monolithic grid), buying power from a neighbor, and self-generating. Entrepreneurship would be the prime mover.

Free-Enterprise Dispersed Generation Would Increase Stability

The stability of the alternating-current electrical utility grid is reckoned in terms of constancy in voltage and frequency at whatever location within the rating of the service connection. The frequency must be maintained at given level (60 hzÅ1/8 wavelength in the United States). Otherwise, generators would not synchronize and share the load, and many clocks would not keep time. Voltage surges cause appliance failures. Low voltage (a brownout) damages loaded-induction motors such as those in refrigerators. Obviously, blackouts—whether of the deliberate load-shirking rolling type or inadvertent breakdowns—are the ultimate instability.

Grid instabilities may be local or general. Local instabilities occur when local power demand exceeds the current carrying capacity of the grid conductors, causing a drop in the local voltage. In that case, no amount of excess generating capacity at a distance can stabilize the grid; only additional conductors or locally generated current will suffice.

General instabilities of the grid are attributable to deficiencies in the overall generating capacity connected to the grid. When the connected load exceeds the generating capacity—as when some of that capacity is impaired by equipment problems, fuel shortages, or emission quotas—there is a risk of overload. In that case, distributed or dispersed generation can stabilize the grid not only locally but also generally.

New technology in computer controls and automation enables dispersed generators to operate unattended on the grid in perfect harmony with established central utility stations. The necessary voltage and frequency regulation performance of PC-based computer controls are well within the state of the art.

Heightened Complexity, or Other Reasons to Be Humble

Besides the technological advancements that make dispersed generation more viable, other technological developments enhance the viability of grid competition, including parallel transmission and distribution, and cogeneration. All told, technology is making electricity experts and regulators aware of the vast diversity of options and opportunities. Because of their extreme complexity, the results of alternative policies are unknowable. But these technologies can be reduced to decentralized practice at the hands of private owners and entrepreneurs with predictable results.

Aggressive Cogeneration

An additional incentive for adopting dispersed generation is the recovery of heat. Heat recovery is valuable only if it can be used locally before it dissipates into the environment. Central plants offer no reasonable access to such heat. If electricity is its only useful product, the typical heat engine–powered generating plant squanders 60 to 70 percent of the fuel's energy.

Companies like Trigen Energy Corporation (www.trigen.com) produce standardized, mass-produced modular "trigeneration" systems (hence the name Trigen), which burn fuel once to make three energy products: heating, cooling, and electricity. How's that for energy conservation?

This process serves offices, universities, and hospitals. Through such a system, the utilization of the fuel energy rises from approximately 30 percent to 85 percent. In Trigen's case, a key is an assembly line–produced gas-fired cogenerator that can be trucked to a site from order to operation in two months. The cogeneration factor makes it more complex and exacerbates the regulator's unknowability problem.

The Potential for Parallel Transmission and Distribution

In 1997, America was crisscrossed by about 600,000 miles of high-voltage transmission lines and about 2.5 million miles of distribution wire (Collins 1997). Ending franchises would allow at least the right to build one's own infrastructure alone or in alliance with other network industries such as telecommunications firms, pipeline companies, and railroads. Potential partners in private infrastructure development would include competition-minded utilities, real estate developers, long-distance and local telephone companies, cable companies, water utilities, natural-gas companies, railroads, private landowners, and authorities governing interstate highways and Amtrak corridors.

Contrary to natural-monopoly doctrine, it is common to have duplication, overlap, and active competition in distribution services. Network industries other than power utilities are spending billions of dollars to expand their systems. During the Internet boom, fiber-optic cable was being deployed at the rate of 4,000 miles per day. Even though some of today's most sophisticated fiber optics can carry all the calls on Mother's Day on a single strand, numerous firms are building overlapping networks. The research company KMI predicted that by 2001 the amount of fiber-optic cable deployed would be equivalent to 82 round trips between the earth and the moon (GaAs Net). Installing fiber-optic line is much simpler than installing power distribution line. Nonetheless, the fiber-optic bonanza may suggest that the dreaded inefficiencies of "duplication" are vastly overstated. Eighty percent or more of fiber optics' costs are incurred before any customers are signed up (Gilder 1997, 2). If the telecommunications industry can manage both the costs and the coordination of investors and customers, so can electric power entrepreneurs. Working together, the two industries could be even more successful.

In a free market, hungry electricity entrepreneurs would make good partners with those intent on wiring America for voice, data, and video. Distribution line installation could piggyback on the installation of cable modem wiring and other home-wiring options. Most fiber-optic cables come to an end a few yards or a few hundred yards from homes, but the current layout cannot sustain growth, since none are fast enough. For example, to download the film *Titanic* (about 4.7 gigabytes), it would take a 28,800 bps modem sixteen days, an ISDN line (128,000 bps) about three and a half days, and a cable modem about one hour. The demand for greater bandwidth will be without limit as people become increasingly accustomed to live interactive video conferencing. The demand is likely to be such that even homeowners' associations might pay to dig up their own streets to "fiberize" if real estate developers have not already done so. Clearly, cross-industry alliances are critical here.

Another promising avenue that may induce new electric firms to justify the expense of adding to or modifying wire networks is the development of techniques for allowing phone calls and high-speed Internet access to be offered through electricity lines. Access is obtained through the standard electric outlet. Electricity and information travel through the same wires. As the capability matures and engineering problems are worked out, electricity entrepreneurs will look anew at the value of their wire networks.

Horizontal Directional Drilling

Computer-controlled technology called *horizontal directional drilling* allows oil and gas companies to drill sideways, flexibly snaking under streets and buildings with no disturbance aboveground, while sensors read surrounding conditions and allow lines to be installed (www.directionaldrilling.com/). High-tech drilling can also be used to bury low-voltage electric distribution lines in towns, and using it in that way could eventually bring down the costs of all applications. Burying lines in this way may be highly attractive compared with digging up a crowded city or residential street or stringing more unsightly wire overhead on poles.

One can envision fiber-optic installers such as Qwest and cable TV and fiber-to-the-home innovators being invited in to run their lines down the conduit in exchange for shouldering some of the costs. They could buy a guaranteed slot for future generations of higher-speed fiber, much as Qwest has done in leaving an empty conduit for itself along railroad tracks (Diamond 1998).

Integrating Centralization and Dispersion

Several technologies, not discussed here, raise the value of central generation and transmission by enhancing efficiency, capacity, reliability, and stability. Such developments make central-station generation and long-range transmission more valuable relative to dispersed generation. But regulation cannot determine the proper balance and integration of the two approaches. Voluntary processes based on property and contract would best discover balance in a competitive environment. Private control would permit prices to fluctuate to reflect relative scarcities. Free-enterprise forces would send the signals to upgrade the grid at key bottlenecks and avoid the possible stagnation of new-generation technologies. As noted, electricity and information can flow along the same wire, leading to potentially interesting and unpredictable alliances between power producers and telecommunications, Internet, and software firms. It is important for analysts to recognize the richness of potential relationships and consumer benefits.

Other developments are just starting to change the nature of power transport. A newly developed superconductive film can carry many times the electricity of current wire technology. Such innovations combined with silicon switching technology change the nature of the grid and undermine utopian visions of its being managed efficiently by regulators. Modular flywheel energy storage devices targeted at cable and telephone markets provide power during outages and can provide backup power at hospitals and schools (*Electricity Daily* 1996b, 2). These portend new alliances with independent generators that lessen dependence on the power company for reliability. And although solar power is currently above market prices at its cheapest, photovoltaic cells do provide "a competitive peaking power option" (*Electricity Daily* 1996a, 1).

Intellectuals cannot know the local undulations of opportunity, just as they cannot chart and predict the specific patterns of skating in a roller rink. The skaters carry on, nonetheless, profitably and without difficulty. The regulator who would direct and control activities is like the perambulator who would accompany the skater.

Conclusion

Dispersed generation has long been economically viable, with technology making it even more so. Natural monopoly is a myth. Furthermore, the continuum between central generation and dispersed generation must be mediated in each particular context by parties with appropriate authority and local knowledge. Not all the answers about the shape of tomorrow's power markets are locked in some imagined set of initial conditions, as planners assume. Knowledge and opportunity are created as we go along. Technology has delivered conditions and alternatives that recommend a system whose success no longer depends on regulators making the right decisions.

NOTE

1. The best corroborative references available for the 500 mW statement are verbal communications with Eric Gozer, president, Certified Electric Distributors, York, SC (802) 684-0058; and Herbert Whittall, technical adviser, Electrical Generating Systems Association, Boca Raton, FL (561) 564-2641. The exact numbers were originally obtained by phone from Corporate Marketing (Barbara), Stewart and Stevenson Services, Inc., Houston, TX (713) 898-7700.

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